DESIGN AND OPERATIONS MANUAL PRESSURIZED IRRIGATION SYSTEMS VOLUME I

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VOLUME I

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PREFACE

This manual covers the technical design and operational aspects of high efficiency (pressurized) irrigation system in a brief and comprehensive way. The first volume covers a detail discussion of pressurized irrigation systems including their classifications, selection criteria and components followed by basics of design. Design proforma for design of drip and sprinkler irrigation system has been discussed in detail covering the procedure for collection of necessary field data required for proper system design. Hydraulic principles have also been covered in detail for proper selection of pipe network and pumping unit. Design procedure has been elaborated with solved examples. Second volume of this manual covers the operational part of pressurized irrigation systems, which includes general maintenance and tips for durability and sustainability of high efficiency irrigation system equipments. It also covers the vigilance and checking during system operation, care after completing a crop season, care of prime movers, system re-adjustments, clogging and its remedies, chemigation including acid treatment and chlorination, maintenance tips of water storage tanks, general trouble shooting and remedies. A list of tables and diagrams is also provided for the ease of users. This manual will provide a general guideline to project technical staff and contractors for proper design and smooth field operations of high efficiency irrigation system sites and it will also be helpful for effective post installation services and getting the desired results from high efficiency irrigation systems.

**DESIGN OPERATION AND MAINTENANCE MANUAL
FOR
HIGH EFFICIENCY IRRIGATION SYSTEMS**

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5. BASICS OF HEIS DESIGN

The basic information required for design of micro irrigation system is described in following sections.

5.1 GENERAL INFORMATION

5.1.1 Water Source

It is very essential to confirm the source and quantum of water available before designing of any irrigation system. There are mainly three types of water sources used for irrigation in Pakistan namely Canal water, Tube wells and Dug wells. The location of the water source on the layout map should be demarcated which ultimately helps to locate the best possible location for head unit installation.

Using different methods as given below, the volume of available water can be determined for three types of available water sources.

5.1.1.1 Canal Water

Volume of water available can be calculated as under:

$$V = (B \times C \times K)$$

V	=	Volume of water available (litres)
B	=	Time of water availability (hrs)
C	=	Discharge of canal outlet (LPS)
K	=	Constant, 3600

Example: Determine volume of available water for 1.5 cfs (42.5 lps) canal outlet discharge. Total time of water availability is 5 hours.

B = 5 hrs

C = 42.5 lps

Volume of available water = (5 x 42.5 x 3600) = 765450 liters (765.450 M³)

If the discharge of the canal outlet is not known, then rough estimation can be made using the float method.

5.1.1.2 Tubewell Water

The discharge of the tubewell water can be estimated by the trajectory method as follows:

The Discharge in LPS can be found as

$$Q = 0.0174 X (D)^2 / \sqrt{Y}$$

D = Diameter of delivery pipe, cm

X = X value of trajectory, cm

Y = Y value of trajectory, cm

Fig. 5.1 Trajectory of Water Flow from the Tubewell

Example:

Determine the discharge of a tubewell with pipe diameter 11 cm, X & Y values of trajectory are 55 cm & 25 cm, respectively

Solution:

By using equation 3.5 the discharge of tubewell can be calculated as:

$$Q = 0.0174 X (D)^2 / \sqrt{Y}$$

$$Q = 0.0174 X (11)^2 X 55 / \sqrt{25}$$

$$= 23.2 \text{ LPS}$$

5.1.1.3 Dug Well

The volume of water in a dugwell can be determined using following relationship.

Available volume of water in m³ can be found as:

$$V = 3.14 (D)^2 (B) / 4$$

V = Volume of water, m³
 D = Diameter of Well, m
 B = Depth of water column, m

Example:

Calculate water availability for 5 meter diameter dug well, the depth of water column in the dug well is 2m.

Using equation 3.4, volume of available water in the dug well can be calculated as:

$$V = 3.14 \times (5 \times 5) \times 2 / 4 = 39.25 \text{ m}^3$$

5.2 FIELD LAYOUT AND TOPOGRAPHY

The first step to proceed for the design is to determine the area of the field layout for which the system is to be designed. This may be done measuring directly the lengths and the widths of the field. A particular farmer field will be of specific geometrical shape such as square and rectangular. Sometimes it may be of irregular shape. Measurements for such area will not be easy with conventional systems using measuring tapes; it may require use of Global Positioning System (GPS) for establishing plot boundaries and directly measuring the area. Particular geometrical shapes and formulae for calculating area are given below:

Where;

L₁, L₂ = Length, m (ft)
 W₁, W₂ = Width, m (ft)

$$A = \frac{1}{2} \times b \times h$$

A = Area, m² (ft²)
 b = Width, m (ft)
 h = Height of triangle, m (ft)

In case the area to be irrigated is fairly large and visibly having topography uneven, a topographic survey of the area is carried out in order to determine the general slope and contours are drawn. If practically possible, the main line is laid along contours and sub-mains are laid along the slope. Accordingly, a field layout is drawn showing the dimensions (length and width) of the area, location of water source/pump-set, location and lengths of main, sub-mains, laterals according to the plant or row spacing

5.3 CROPS

Information regarding crops should be entered in “crop information” section of the design proforma as given in **Table 5.1**

Table 5.1 Crop Information Proforma

Parameters			Crop	Area (acres)	Plant spacing (m)	Row spacing (m)	Age of crop (years)	Sowing Date	Harvesting Date
Block-I	Row crops	Proposed							
		Rotation							
Sub-Total: I									
Block-II	Orchards	Type-I							
		Type-II							
Sub-Total: II									
Block-III	Annual Crops								
Sub-Total: III									
Block-IV	Field Crops	Type-I							
		Type-II							
Sub-Total: IV									
Total / Design Value									

5.3.1 Row Crops

Line source drip systems are generally suitable for row crops such as cotton, maize, cucumber, chilli, capsicum, melons, tomatoes, onions, sunflower and sugarcane etc. Sprinklers can also be used on most of these crops with certain care. Generally distance between two plant rows is kept 0.76 m (2.5 ft) under conventional planting practice (Furrow), whereas under drip irrigation system it will cost more. An appropriate technique may be to place on drip line at 1.52 m (5 ft) spacing (depending upon soil characteristics) and planting two plant rows on each side of the lateral. A single drip line may be provided for two or more crop rows or for a single crop row depending upon growth behavior. The information needed for designing a system includes distance between rows of crop and the time of sowing and harvesting etc. Similar information regarding rotational crop is very important for selecting and designing a suitable system that will be suitable for both the crops.

5.3.2 Orchards

Orchards comprise of fruits or nut producing trees grown for commercial production. Point source drip line, mini sprinklers, spray jets or bubblers can be used for irrigation of orchard depending upon plant stage. Most of the orchard crops grown in Pakistan include Banana, Coconut, Guava, Mango, Citrus, Date Palm, Lychee, Apple, Apricot, Chikku, Ber, Peach and Plum. The information regarding time of sowing, age of crop, canopy diameter and spacing between plants and rows of matured/new orchard is required to be collected for designing purpose. It is also important to note whether farmer plans to go for intercultural practices in the orchard or not. This should be decided at the planning stage and will effect the selection of particular emitting devices/high efficiency irrigation system.

5.3.3 Annual Crops

This category particularly covers sugarcane which remains standing for whole of the year.

5.3.4 Field Crops

It comprises a particular group of crops which are not cultivated in geometrical shapes (beds, furrow) but are broadcasted like wheat, fodders, oilseeds etc. sprinkler system is suited for such kind of crops.

5.4 IRRIGATION SYSTEM EFFICIENCY

Irrigation system efficiency is that part of the water pumped or diverted through the conveyance system which is used effectively by the plants. It is the product of two types of efficiencies i.e., conveyance efficiency and field application efficiency. Conveyance efficiency represents the efficiency of water transported in canals, watercourses and field application efficiency represents the efficiency of water application in the field. For pressurized irrigation systems, conveyance efficiency is almost 100% and thus design engineers are only concerned with field application efficiency. Conventional irrigation system is the lowest efficient method. Among pressurized irrigation systems, drip is the most efficient irrigation method as shown in **Fig. 5.2**

Fig. 5.2 Least to Most Efficient Irrigation Systems

Field application efficiency mainly depends on the irrigation method and the level of farmer discipline. Some indicative values of the average field application efficiency are given in following **Table 3.4**.

Table 5.2 Values of Field Application Efficiency

Water Application Method	Water Use Efficiency (%)
Surface	40-70
Sprinkler (Center Pivot)	85-90
Sprinkler (Linear Move)	80-88
Fixed Sprinkler (Solid set)	60-85
Trickle/ Drip (Point Source)	65-92
Trickle/ Drip (Line Source)	60-85

5.5 WATER QUALITY

Quality of water is very important for prevention of clogging in micro irrigation system especially for drip irrigation system. Potential contributors towards emitter clogging are shown in **Table 5.3**

Table 5.3 Major Contributors of Emitter Clogging

PHYSICAL (Suspended Solids)	CHEMICAL (Precipitation)	BIOLOGICAL (Bacteria and algae)
1. Sand	1. Calcium or magnesium carbonate	1. Filaments
2. Silt	2. Calcium sulphate	2. Slimes
3. Clay	3. Heavy metal hydroxides, oxides, carbonates, silicates and sulphides	3. Microbial depositions:
		(a) Iron
		(b) Sulphur
		(c) Manganese
4. Organic matter	4. Fertilizers	4. Bacteria
	(a) Phosphate	
	(b) Aqueous ammonia	
	(c) Iron, zinc, copper, manganese	
		5. Small aquatic organisms
		(a) Snail eggs
		(b) Larva

(Source: FAO, 1994)

Prevention requires an understanding of the potential problems associated with a particular water source. Water quality information should be obtained and made available to the designer and irrigation manager in the early stages of the planning so that suitable system components especially the filtration system and management and maintenance plans can be selected. Water quality refers to the characteristics of a water supply that will influence its suitability for a specific use, i.e. how well the quality meets the needs of the user. Quality is defined by certain physical, chemical and biological characteristics (FAO) and may impose long term impacts on soil as well as result in clogging of micro irrigation system. Type and quantity of dissolved salts will determine the severity of water quality. Standard water quality tests are shown in **Table 5.4**.

Table 5.4 Standard quality tests for Micro Irrigation System

Major Inorganic Salts	Micro-organisms
Hardness ¹	Iron
Suspended Solids	Dissolved Oxygen
Total Dissolved Solids (TDS) ¹	Hydrogen Sulphide
BOD (Biological Oxygen Demand)	Iron Bacteria
COD (Chemical Oxygen Demand)	Sulphate Reducing Bacteria
Organics and Organic Matter	

(Source: FAO, 1994)

The analysis needed will vary with each situation. It is to keep in mind that cost of the micro irrigation system is very high and it is advisable to bear some additional cost which is very nominal to perform these tests so as the system can be run effectively. The presence of elements (**Table 5.6**) in irrigation water will determine the degree of clogging and restriction of water use.

Table 5.6 Influence of water quality on emitter clogging

Potential Problem	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Physical				
Suspended Solids	mg/l	< 50	50 – 100	> 100
Chemical				
pH		< 7.0	7.0 – 8.0	> 8.0
Dissolved Solids	mg/l	< 500	500 – 2000	> 2000
Manganese ²	mg/l	< 0.1	0.1 – 1.5	> 1.5
Iron ³	mg/l	< 0.1	0.1 – 1.5	> 1.5
Hydrogen Sulphide	mg/l	< 0.5	0.5 – 2.0	> 2.0
Biological				
Bacterial populations	maximum number/ml	<10 000	10 000 – 50 000	>50 000

(Source: FAO, 1994)

5.6 LEACHING REQUIREMENT

Presence of salts in irrigation water and in the soil affects the crop yield. Under micro irrigation system, salts are usually repelled away from the wetting front of the emitter; therefore, marginally saline water can be used efficiently for crop production. For sprinkler irrigation system, irrigation frequency may be more than one day especially under rain-guns; there is a need to account for leaching requirements to leach the salts down from root zone of the plant. It is important to keep the salinity level within permissible limits by applying additional quantity of water to soil/plants so that yield may not be reduced more than 10%.

Leaching requirement (LR) can be estimated using following equation (Rhoades and Merrill 1976):

$$LR = \frac{EC_w}{5 (EC_e) - EC_w}$$

LR = minimum leaching requirement (Fraction) needed to control salts within the tolerance (EC_e)

EC_w = salinity of the applied irrigation water in dS/m which can be determined by laboratory analysis

EC_e = Average soil salinity tolerated by the crop as measured on a soil saturation extract which is depicted in **Table 5.7**

Table 5.7 Values of E_{Ce} with 10% yield reduction

Crop	E _{Ce} – dS/m
Cotton	9.6
Sorghum	5.1
Wheat	7.4
Corn (maize)	2.5
Tomato	3.5
Cucumber	3.3
Spinach	3.3
Potato	2.5
Onion	1.8
Date palm	6.8
Orange	2.3
Apple	2.3
Peach	2.2
Apricot	2.0
Grape	2.5
Almond	2.0

Example: Calculate Leaching Requirement for sprinkler system

Given data:

Crop: Wheat

EC_w: 2.1 dS/m

Solution: Select E_{Ce} of wheat from Table 3.8. E_{Ce} = 7.4 and solving equation 3.8.

$$LR = \frac{EC_w}{5 (EC_e) - EC_w}$$

$$LR = 2.1/(5 \times 7.4 - 2.1) = 0.06 \text{ (fraction)}$$

5.7 WETTED AREA

Wetted area is important for micro irrigation system as only portion of the plant's area is wetted as shown in **Fig. 5.2**. The first criterion, wetting a sufficient portion of the plant's root volume, must be achieved for a plant to efficiently utilize the water that is delivered.

When drip devices are used, the area or volume of the soil that is wetted depends on the soil type and emitter flow rate. At least 33 percent and up to 67 percent of the plant root zone should be wetted to get the maximum benefit from micro-irrigation. On sandy soils, micro-spray or sprinkler emitters rather than drip emitters may be needed to wet sufficient root volume.

Fig. 5.2 Partial wetting of soil under micro irrigation system (Source: FAO,)

While published guidelines for drip emitter wetted diameters on typical sand, loam and clay soils can be used, it is much better to field test by actually wetting one or more selected typical locations in the field. This can be done easily by setting up a small portable pump (or connecting to a house or barn water system) and running a suitable line with drip emitters attached to the selected sites (adjust pressure according to emitters used). The wetting patterns which develop from dripping water onto the soil depend on discharge and soil type. **Fig. 5.5 & 5.6** shows the effect of changes in discharge on two different soil types, namely sand and clay.

Fig. 5.3 Wetting patterns for Sandy soils with high and low discharge (Source: FAO,)

Fig. 5.4 Wetting patterns for Clay soils with high and low discharge rates

On sandy soils, the maximum wetted width may be reached in as little as two hours, but on clay soils this may take 12 to 15 hours (caution: do not allow surface runoff to occur). For safety, the emitter should be operated the same number of hours that is planned for the zone set time, according to soil type. Measurement of wetted diameter is done by trenching across the visible wetted edge to see how far from the emitter water has moved. The wetted area will be wider beneath the soil surface, but it is impossible to know how far it extends without digging. Estimated wetted area by 4LPH dripper is given in **Table 5.7a**.

Table 5.7a Estimated area wetted by 4 L/hr emitter (m x m)

Soil depth (m)	Soil Texture	Degree of soil stratification		
		Homogeneous	Stratified	Layered
0.75	Coarse	0.4 x 0.5	0.6 x 0.8	0.9 x 1.1
	Medium	0.7 x 0.9	1.0 x 1.2	1.2 x 1.5
	Fine	0.9 x 1.1	1.2 x 1.5	1.5 x 1.8
1.5	Coarse	0.6 x 0.8	1.1 x 1.4	1.4 x 1.8
	Medium	1.0 x 1.2	1.7 x 2.1	2.2 x 2.7
	Fine	1.2 x 1.5	1.6 x 2.0	2.0 x 2.4

(Source: Jack Keller and Ron D. Bliesner- 1990)

Table 5.8 can also be used if none of the information regarding wetted diameter or area of soil available. To be on safer side lower values may preferably be used.

Table 5.8 Estimated area wetted

Soil Type	Diameter (m)			Area (m ²)		
	Min	Max	Average	min	max	Average
Sandy (coarse soil)	0.8	1.5	1.1	0.46	1.82	1.14
Loam (medium soil)	1.5	2.7	2.1	1.82	5.91	3.87
Clay (fine soil)	2.7	4.3	3.5	5.91	14.30	10.11

5.8 POWER SOURCE

All sprinkler and drip irrigation systems require energy to move water through pipe distribution network and deliver it through the emitting devices. In some instances, this energy is provided by gravity as water flows downhill through the delivery system which is most likely possible in Balochistan, NWFP and Northern areas of Pakistan. However, in most irrigation systems, energy is provided by a pump that in turn receives its energy from either an electric motor or an internal combustion engine. The combination of pump and engine is central to the performance of most irrigation systems. The most common power source/drive units for pumps are electric motors, diesel or petrol engines and PTO of tractors.

5.8.1 Electric Motors

Electric motors are more efficient, cheaper to maintain and where they needed to be run continuously, the fuel costs are lower than for other types of power source. On drip irrigation system, mostly Three Phase Motors are installed. Before designing a system, a transformer of required capacity must be ensured to operate the system. The electricity supply in Pakistan is 50 cycles and the standard motor operating speeds are 2900 rpm, 1450 rpm and 960 rpm. Ideally the pump unit should couple direct to the motor shaft so the speeds of the two units are identical. However, where a different pump speed is required, V-belts and pulleys will be required. Efforts should be made to select an efficient electric motor to keep the operational cost low.

5.8.2 Petrol Engines

Petrol engines can be used for intermittent operation such as supplementary irrigation, where the operating time per day does not exceed two or three hours. The use of CNG fuel is becoming more widespread in Pakistan which can be a good replacement of petrol to be used.

5.8.3 3. Diesel Engines

Compact high speed diesel engines should be used as energy source where electricity is not available. Diesel engines offer the most efficient form of drive for

pumps. They are particularly suited for use on portable installations. Care should be taken to select a suitable drive unit otherwise operational cost will become much higher as compared to the electricity.

5.8.4 Tractors

Tractor can also be used as power source for high pressure system such as Rain Gun sprinkler system which requires high energy or to drive pumps as a stand-by measure in the event of the primary unit breaking down or where the scheme is primarily for supplementary irrigation and is only operated for a few hours every day.

6. DRIP DESIGN STEPS

The main objective of an irrigation system design is to supply adequate and timely water to plants and to help farmer to get best out of his fields. The following considerations may help achieve this objective:

1. Planning proper irrigation zones and system layout
2. Properly engineered system components

Properly engineered system components are secondary to a good system layout and it has a little value if the system has not been properly zoned and planned. It may include the following objectives:

- Optimum selection of the system components
- Ease in operation and maintenance of the system
- Low system cost with high efficiency

6.1 OBJECTIVE OF DESIGN

- Selection of Optimum Components
- Easy Management and Maintenance of System Parts
- Low System Cost Vs High Efficiency
- To help farmer get best out of his field
- To maintain higher system and irrigation efficiency by means of higher emission uniformity.
- To maintain optimum moisture level in soil for optimization of crop yield.
- To maintain both initial investment and annual cost at minimum level.
- To design suitable type of system which last and perform well.
- To design a manageable system which can be easily operated and maintained.
- To satisfy and fulfill the requirements of crops and farmers.

6.2 DRIP DESIGN PROCEDURE-STEP BY STEP (ORCHARD)

Under the on-going project, drip systems are being installed on orchard and at row crops/vegetables. In this section, steps for designing a drip system for orchard will be discussed. The following are the design steps.

1. Collection of Basic Information
2. Estimation of Peak Water Requirement PWR
3. Drawing of project area, selection of zone area and No. of Operations
4. Selection of emitter/dripper, and flow rate
5. No. of emitters per plant, No. of drip lines per row, optimal distance between two laterals
6. Calculation of plant area, total number of plants and minimum number of emitters per plant
7. Calculation of total length of lateral and total No. of emitters
8. Calculation of Total Flow rate requirement (Q)
9. Calculation of Application Rate
10. Total Operational Time
11. Pipe Hydraulics
12. Selection and Design of Lateral Line
13. Design of Sub-mainline
14. Design of Mainline
15. Selection of Filters and other equipment and head loss
16. Calculation of total dynamic head (H)
17. Calculation of required horsepower (HP)
18. Selection of Pumps and Motor
19. Preparation of Drawing
20. Preparation of Bill of Quantities

Step 1. Collection of Basic Information

The following basic information be available before designing a drip irrigation system.

- General information: Name of farmer, village/chak No., tehsil, district, phone No.
- Land holding and Area spared for the project
- Engineering survey: GPS coordinates, Field measurement, Elevation difference/slope. After field measurement, a map showing all dimensions and location of water source be drawn
- Agricultural details: crops (orchard, row/field crop), spacing, type, age, reference evapotranspiration of the area and water requirement of crop
- Crop Spacing (Row to Row, Plant to Plant), sowing and harvesting date
- Soil Type/texture
- Soil and water analysis reports: water quality, presence of iron, pH, suspended particles, soil type, Ec, pH
- Water Source, quantity, availability, location
- Power Source: Electric motor, diesel engine, tractor, solar system
- Climatologically data: temperature, humidity, rainfall, wind speed
- Peak Water Requirement: (ET_o, K_c, C_f)
- Water source and Total Available Time of water
- System capacity: The system should have capacity adequate to fulfill daily crop water requirements of the area within a stipulated time or not more than 12 hours of operation per day (only for Pakistan circumferences, otherwise may be 22 hrs).

The basic information can be categorized as under.

6.2.1 General Information

Name of beneficiary		Town/Village/City	
Tehsil		District	
Province		Phone No.	
Land holding (Acre)		Scheme area (acres)	
Topography (Flat/Undulated)			

6.2.2 Crop Information

Parameters			Crop	Area (acres)	Plant spaci g (m)	Row spacin g (m)	Age of crop(year s)	Sowin g date	Harvestin g date
Block-I	Orchard	Propose d	Citrus	7.04	3.10	6.1	2		
		Rotation							
Sub total: I									
Block-I	Orchard	Propose d	Citrus	6.07	4.57	4.57	New		
		Rotation							
Sub total: II									
Block-I	Orchard	Propose d	Mang o	1.2	6.10	6.1	1		
		Rotation							
Sub total: III									
Block-I									
Sub total: IV									

6.2.3 Soil Type/Soil Test/Water Supply/Water Quality

Soil type/Texture			
Soil limitation (soil analysis report attached)			
Soil EC , PH , N , P , K , SAR			
WATER SUPPLY			
Available water sources			
1) Canal			
Sanctioned discharge (LPS)			
Perennial/non-perennial			
		Warabandi Days	
		Hours per Warabandi	
		Total Volume (m3) of water for 7 days	
2) Groundwater			
a) Dug well			
Depth of well			
Diameter of well			
Recharge rate			
b) Tube well/bore well			
Discharge capacity (LPS)			
Diameter of bore (inches)			
Depth of water table from ground (m)			
3) Storage/reservoir capacity (m3)			
Water quality (detailed report attached)			
		Iron	
		Ph	
		EC(mmoHs/cm)	
Distance of water source from field (m)			

6.2.4 POWER SOURCE AND PUMP

POWER SOURCE	
Type of power to be used	
For electric Motor, Type of connection (single/3-phase) Make/model HP of Motor RPM of Motor	ELECTRICITY NOT AVAILABLE
For diesel engine Make HP Condition)	
For Tractor Make/model HP Condition	
Any other power source, if any	
PUMP SET	
Type Make/Model Pressure (ft/psi/bar) Flow(lps) Inlet/outlet size RPM Pulley size	

6.2.5 Water Analysis Report

Farmer Name : Abbass Qureshi			Water Source		Tube Well
Address :Muzaffar garh			Sampling Date		10/5/2010
Ph :0345-8644888			Sp Receive Date :		13/05/2010
Agronomist: Ather Mehmood Khursheed			Report Date :		31/05/2010
			Ref.Sample	#	372
Parameters	Degree of Presence / Problem				Lab Result
	Unit	Noma l	Higher	Extrem e	
pH		7	<7 Acidic	>7 A	7.37
Electrical Conductivity (Salinity)	microsemens/cm	-	-	-	2240
Total dissolved solids	ppm	<500	500 - 600	>600	1290
Hardness	ppm	<200	200 - 300	>300	312
Calcium	ppm	<60	60 - 100	>100	78.4
Magnesium	Ppm	<25	25 - 40	>40	28.21
Carbonate	Ppm	<200	200 - 600	>600	72
Bicarbonate	Ppm	<200	200 - 600	>600	176
Chloride (Toxic)	Ppm	<140	140 - 350	>350	198.5
Sulphates	Ppm	<20	20 - 50	>50	23.4
Sodium	Ppm	<100	100 - 200	>200	235
SAR	-	<3	3-9	>9	2
Potassium	Ppm	<10	10 - 20	>20	12
Sulphides	Ppm	<15	15-25	>25	-
Iron	Ppm	<0.1	0.1 - 0.4	>0.4	0.1
Manganese	Ppm	<0.2	0.2 - 0.4	>0.4	-
Suspended solids	Ppm	<10	10 - 100	>100	7.1
Boron	Ppm	<0.5	0.5 - 2.0	>2.0	-

Ag 16/2/15

SOIL AND WATER TESTING LABORATORY FOR RESEARCH
AGRICULTURE DEPARTMENT, GOVERNMENT OF THE PUNJAB

Thokar Niaz baig Lahore. Ph # 042-99260319, Fax # 042-99260321 E-mail: swtl_lhr@yahoo.com

SOIL ANALYSIS REPORT

Name of Customer: ذہیر کپور Report No: 309/167 Date: 23-2-15

Address: _____ Mob # _____

Sample No.	Detail		EC mScm ⁻¹	pH	Organic Matter (%)	Available Phosphorus (mg kg ⁻¹)	Available Potassium (mg kg ⁻¹)	Saturation (%)	Texture	Gypsum Required (Ton/acre 6")
	Acre No.	Depth								
381	1-	6	1.0	8.4	0.95	4.3	196	42	loam	
382	2-	6	0.9	8.2	0.91	3.8	212	44		
383	3-	6	1.0	8.3	0.85	3.8	204	44		
384	1-	12	0.9	8.4	0.81	2.6	126	40		
385	2-	12	1.0	8.5	0.85	3.1	134	40		
386	3-	12	0.8	8.4	0.81	3.4	161	42		
387	41	24	0.9	8.3	0.49	2.1	145	42		
388	2	24	0.8	8.4	0.49	2.8	169	44		
389	3	24	0.9	8.4	0.49	1.7	122	42		
390	1	36	0.8	8.3	0.35	1.4	106	42		
391	2	36	0.8	8.4	0.35	1.3	82	44		
392	3	36	0.9	8.2	0.35	1.8	96	42		

REMARKS _____

Method(s) Used: Conductance ☐ pH meter ☐ Walkly & Black ☐ Olsen Bicarbonate ☐ Amm. Acetate ☐ Hydrometer ☐ Calcium basis ☐

Note 1: For assessment of analytical report and for site specification recommendation please consult back side of the page.

Note 2: in case sample (s) is/are provided by the customer, the responsibility about the integrity of sample(s) lie(s) with the customer.

Note 3: The results are reported with a confidence level of 95 %; i.e. [K=2] and pertaining to analyzed sample (s) only.

Note 4: This test report cannot be reproduced except in full, without written approval of laboratory authority.

Analysis Fee Rs. 3500/- Vide Receipt No. _____

Signature of AA C _____ f Agricultural Chemist (Sodic) Lahore.

Figure 6.1. Sample Report

XXXXXXXXXXXXXXXXXXXX

6.2.6 Soil Analysis Report

Farmer Name : Abbas Qureshi				Block Size :							
Address : Muzaffargarh				Sampling Date :		11/5/2010					
Ph : 345864488				Sp Receive Date :		13/05/2010					
Agronomist : Ather Mehmood Sheikh				Report Date :		26/04/2010					
				Code :		AMK-S001					
Ref.Soil Sample #	Block #	Depth (inches)	Texture	Organic Matter %	pH	Electrical conductivity (mic/cm)	Available Phosphorus(P) (ppm)	Available Potassium(K) (ppm)	Soluble & Exch. Na (meq/L)	Soluble & Ca +Mg (meq/L)	SAR
						Neutral 6.5- 7.5 Alkaline >8.5	Poor <7.0 Medium 7-13 Satisfactory >13	Poor <125 Medium 125-250 Satisfactory >250			
2835	1	0 - 6"	Sand,Clay	0.245	8.44	411	-	110	6.52	3.2	4
2836		6 - 12"	Sand,Clay	0.582	7.74	468	-	120	6.95	3.2	4.3
2837	2	0 - 6"	Sand,Clay	0.827	8.15	572	-	110	11.73	3.1	7.5
2838		6 - 12"	Sand,Clay	0.612	8.26	550	-	110	10.43	2.7	7.7
2839	3	0 - 6"	Sand,Clay	0.612	8.29	316	-	90	6.52	3.4	3.8
2840		6 - 12"	Sand,Clay	0.735	8.39	304	-	90	6.95	3.7	3.7
2841	4	0 - 6"	Sand,Clay	0.821	8.21	384	-	100	6.08	3.2	3.8
2842		6 - 12"	Sand,Clay	0.735	8.25	358	-	100	6.52	3.2	4
2843		0 - 6"	Sand,Clay	1.01	8.02	506	-	150	4.34	5.1	1.7
2844		6 - 12"	Sand,Clay	0.98	8.02	494	-	160	4.34	4.2	2
2845	6	0 - 6"	Sand,Clay	1.041	8.05	412	-	120	4.34	4.2	2
2846		6 - 12"	Sand,Clay	0.919	8.11	356	-	100	4.34	4.2	2
2847	7	0 - 6"	Sand,Clay	0.919	7.97	1080	-	80	10.86	6.6	3.2
2848		6 - 12"	Sand,Clay	0.549	8.02	1123	-	80	11.73	5.8	4

It is advisable to make rough map of the area and mark salient features, divide the drawn map into different blocks and number the same for soil and water sampling. This map will be finalized during designing of drip irrigation system and will show all necessary details including drippers, dia, length and location of laterals, submain and main, location of water source, power source etc.,

6.2.7 Estimation of Peak Crop Water Requirement

Estimating the reference crop evapotranspiration (**ET_o**), using the Penman-Monteith method, and the crop evapotranspiration (**ET_c**), through the use of the appropriate crop factor **K_c**, have been covered in Chapter-4 of this Manual. Evapo-transpiration is composed of the evaporation from the soil and the transpiration of the plant. Since under localized irrigation only a portion of the soil is wetted, the evaporation component of evapotranspiration can be reduced accordingly, using the appropriate ground cover reduction factor K_r.

For the design of surface and sprinkler irrigation systems:

$$ET_c = ET_o \times K_c$$

For the design of Drip irrigation systems:

Water Requirements for Orchard $ET_c = ET_o \times K_c \times \text{Canopy Factor} / \text{Efficiency Percent area wetted}$, 100% for closely spaced crops with rows and emitter lines less than 1.8m.

Peak Crop Water Requirement can be tabulated as under.

Month	J	F	M	A	M	J	J	A	S	O	N	D
E _{to} (mm/d)	2.1	2.7	4.2	5.6	7	7.9	7.3	6.8	5.9	4.8	3.3	2.3
K _c (citrus)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Crop factor at mat.	0.57	0.57	0.57	0.57	0.57	0.6	0.57	0.57	0.57	0.57	0.6	0.57
Efficiency	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
PCWR (citrus)	0.93	1.20	1.86	2.48	3.10	3.50	3.24	3.01	2.62	2.13	1.46	1.02
K _c (mango)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Crop factor at mat.	0.55	0.55	0.55	0.55	0.55	0.6	0.55	0.55	0.55	0.55	0.6	0.55
PCWR (mango)	1.41	1.82	2.82	3.76	4.71	5.31	4.91	4.57	3.97	3.23	2.22	1.55
K _c (field crops)												
CWR (field crops)												

6.2.8 Drawing of Project Area, Selection of zone area and No. of Operations

A map of the scheme area be drawn and tentative number of zones having equal area of the project be selected to estimate number of operations. It is advisable that area of each of each zone must be equal so that all the discharge coming out from the pump be fully utilized in each zone area. In case all zones are not equal, some additional water has to be sent back to the water storage tank through bypass valve during irrigation of small area zones.

6.2.9 Step 4. SELECTION OF EMITTER/DRIPPER AND FLOW RATE

Varieties of drippers/drip tubing are available with different discharge rates, dripper spacing, characteristics and suitability for different crops. The emitter selected for the drip system:

- Should be Inexpensive, durable and serviceable
- Should have relatively low discharge rate to keep the system cost low
- Should have higher emission uniformity (90%) and low coefficient of variation (CV 5%)
- Should have emission discharge exponent in the range of 0.4-0.7.
- Should have relatively large cross sectional area and flow path to avoid clogging
- Should have turbulent flow path and pressure compensation action
- Should not create runoff within the immediate application area

Drippers are available for 2, 4, 8 and 12 LPH discharge. Emitter operating pressure is usually 10m.

The shape of the wetted zone of the emitter depends on the physical properties

In sandy and light soil , the water will tend to go straight down, and there will be less lateral movement as compared to downward movement. In light soils, the distribution of the water will be narrow and deeper	(close spaced low discharged emitters/Closer emitter spacing)
In loamy soil , the water will move slowly and will spread evenly	(average discharged emitter &/or Spacing)
In clay soil , the water will be absorbed very slowly and there will be more lateral movement as compared to downward movement. In heavy soil, the distribution of the water will be relatively spherical shape, wider and less depth.	wider emitter spacing

Recommended emitter spacing (cm) for various Discharge Rates (LPH) in different soils

Soil Type	Discharge Rates (LPH)		
	2 LPH	4 LPH	8 LPH
Light	40	80	120
Medium	80	120	160
Heavy	120	160	200

- Heavy soil recommended distance: 0.50 to 1.00 meter*
- Medium soil recommended distance: 0.40 to 0.75 meter*
- Light soil recommended distance: 0.20 to 0.50 meter*
- *The spacing between drippers depend on the root depth of the crop.

Emitter spacing should be maximum 0.5m, 0.4-0.6 and 0.5-0.8m in light, medium and heavy soil respectively.

Emitter Discharge Exponent

The flow or discharge from most trickle irrigation emitters or sprayers with fixed or flexible cross sections can be expressed by:

$$q = K_d H^x \quad (17.1)$$

in which

q = emitter flow rate or discharge, L/hr (gph)

K_d = discharge coefficient, which is a constant of proportionality that characterizes each emitter

H = working pressure head at the emitter or sprayer, m (ft)

x = emitter discharge exponent

The value of x characterizes the flow regime and discharge versus pressure relationship of the emitter. The lower the value of x , the less discharge will be affected by variations in pressure (see Fig. 17.1). Noncompensating simple orifice and nozzle emitters and sprayers are typically fully turbulent and $x = 0.5$. For fully compensating emitters, $x = 0.0$. The exponent of long-path emitters is usually between 0.7 and 0.8. For vortex sprayers or emitters, x is about 0.4. The exponent of tortuous path emitters usually falls between 0.5 and 0.7.

FIG. 17.1. Discharge Variation Resulting from Pressure Changes for Emitter Having Different Discharge Exponents (Adapted from: Karmeli and Keller, 1975 (Fig. 2.7)).

Calculation of X value for a 4 LPH discharge emitter

Performance Graph-J-Turbo Line® 16mm OD

S. No.	Q (lph)	P (m)	%ΔQ	%ΔP
1	4	10	--	--
2	5	15	25%	50%
3	6	20	50%	100%

Emitter Discharge Exponent (x):				
$x = \text{Log } (q_1/q_2) / \text{Log } (P_1/P_2)$				
with aforementioned data, X = 0.584				

Most of the water emitter flow regime is fully turbulent with an exponent value equal to 0.5. In order to ensure a high uniformity of water application over the field, the differences in the discharge of the emitters should be kept to the minimum possible and in no case exceed 10 percent. These criteria were established by J. Christiansen for sprinklers and are now applied in all pressurized systems. As a general rule, the maximum permissible difference in pressure between any two emitters in operation should be no more than 20 percent. **The lateral lines with emitters must be of a size that does not allow a loss of head (pressure) due to friction of more than 20 percent. In case emitter operating pressure is 01 bar or 10 meter, the head loss in the selected lateral must not be more than 02 meter.**

Coefficient of Variation (Cv) of Emitter

Coefficient of Variation is a measure of consistency in the flow. If we randomly select several emitters and measure the discharge of each at nominal pressure, the consistency in the results will reveal Cv of the product.

$$Cv = \frac{\text{Standard Deviation of Discharge Rate}}{\text{Average Discharge Rate of Sample}}$$

Cv %	Classification
< 5%	Excellent
5% - 7%	Good
7% - 11%	Marginal
> 11%	Poor

6.2.10 No. of Emitters per Plant, No. of Drip Lines per Row and optimal Distance between two Laterals

No. of emitters/drippers per plant can be 2, 4 or 6. No. of drip lines per row can be 02.

Optimal distance between two laterals can be 20 feet (6.1 m)

6.2.11 Step 6. Calculation of Plant Area and Total Number of Plants and Minimum No. of Emitters per plant

Plant Area

Individual plant such as orchards will be irrigated by individual emitters. Area of each plant will be required for estimation of number of plants in scheme as well as for calculation of water requirements. Area for individual plant can be determined by using following relationship.

$$A_p = S_p \times S_R$$

Where

$$\begin{aligned} A_p &= \text{Plant area (m}^2\text{)} \\ S_p &= \text{Plant spacing (m)} \\ S_R &= \text{Row spacing (m)} \end{aligned}$$

No. of Plants

$$N_p = A / A_p$$

Where

$$\begin{aligned} N_p &= \text{Number of plants} \\ A &= \text{Scheme area (m}^2\text{)} \end{aligned}$$

Example:

Scheme area	=	8.1 ha (20 acre)
Plant spacing	=	5 m
Row Spacing	=	5 m
Plant area	=	5 x 5 = 25 m ²
No. of plants	=	20 x 4047 m ² ÷ (25 m ²)
	=	3,238 Nos.

For row crops, almost entire field will be covered by the crops and hence number of plants is not important as their water requirements will be calculated based on the shaded area which is usually taken as 100%.

Note: Number of plant is not important for sprinkler system

6.2.12 Emitter Placement Geometry

In drip irrigation systems, the lateral lines are the pipes on which the emitters are attached. Water flows from the manifold into the laterals, which are usually made of plastic tubing ranging from 10 mm to 25 mm in diameter. Continuous-size tubing provides better flushing. The layout of lateral lines should be such that it provides the required emission points for the crop to be irrigated. Sometimes two laterals per row of trees are needed. Other methods of obtaining more emission points per tree are zigzag and "snake" layouts and use of pigtail lines looped around or between the trees. **Figs 6.1 to 6.4** show various lateral layouts for widely spaced permanent crops.

Single line for each row of tree

For a drip system with straight laterals of single drip emitters and emitter spacing (S_e) equal to or less than optimum emitter spacing (S_e') then percent area wetted P_w , can be computed by following equation

$$P_w = \frac{e S_e S_w}{S_p S_r} \times 100$$

Where:

P_w = Percent area wetted

e = number of emission points per plant.

S_e = spacing between emitters on a lateral, m or feet.

S_w = width of the strip that would be wetted by emitters on a lateral at S_e' : or closer, m/feet.

S_p = plant spacing in the row, m/feet.

S_r = plant row spacing, m/feet.

Fig. 4.1 Single lateral line for each row of plants

Double line for each row of tree

For drip systems with double laterals or zigzag, pigtail, or multi exit layout, wetted area P_w , can be computed by following equation.

$$P_w = \frac{eS_e'(S_e' + S_w)}{2(S_p S_r)} \times 100$$

For double laterals, the two laterals should be placed apart at a distance equal to S_e' . This spacing gives the greatest A_w , and leaves no extensive dry areas between the double lateral lines. For the greatest A_w , with zigzag, pigtail, and multi exit layouts, the emission points should be placed at a distance equal to S_e' in each direction.

Fig. 6.2 Two lateral lines for each row of plants

Spray System

For a drip system with spray emitters, P_w , can be computed by following equation.

$$P_w = \frac{e[A_s + (\frac{1}{2}S_e' \times PS)]}{(S_p S_r)} \times 100$$

Where;

A_s = estimate of the soil surface area wetted per sprayer from field tests with a few sprayers, square meters/ square feet/.

PS = perimeter of the area directly wetted by the test sprayers, feet/m.

$1/2S_e'$ = one-half the S_e' values for homogeneous soils, m/feet

Minimum No. of Emitters

For micro irrigation system (drip, bubbler, micro jets) type and numbers of emitters are selected based on the soil, crop and area to be wetted. The number of emitters is based on the volume of wetting for each plant. The number of emitters required at each plant or tree to wet sufficient root zone can be calculated by the formula:

$$e = S_p \times S_r \times P_w / A_w$$

e = Minimum number of emitters

S_p = Plant spacing

S_r = Row spacing

P_w = % area to be wetted area wetted by each emitter

A_w = Area wetted by a single emitter

This will give the number of emitters per plant. If the number is a fraction, the next larger number should be used.

Example:

Number of emitters = (5 m X 5 m X 40% wetted area) ÷ (1.8 m² wetted by each emitter)

= 5.5 say 6 Emitters.

Six emitters must be used to wet sufficient root zone. No. of drip lines can be selected as 02.

6.2.13 Calculation Of Total Length Of Lateral, Number Of Emitters In One Zone And Total Number Of Emitters

The length of lateral required for the scheme area under micro irrigation system can be calculated as follows:

Orchard/Row Crops: Double Lateral or Single Lateral per plant row

$$L = K \cdot A \cdot NI / Ls$$

K = 4047

A = Area (acres)

L = Lateral length (m)

NI = Number of laterals per plant row

Ls = Lateral spacing, m

Orchard: Pigtail/ Loop with single Lateral per plant row

$$L = A \times K / [Ls + (Np \times Lr)]$$

L = Lateral length, m

A = Area (acres)

K = 4047

Ls = Lateral spacing, m

Np = Number of plants

Lr = Length of loop (m)

Similarly, lateral length for sprinkler system can be calculated as

$$L = A \times K / Ls$$

TOTAL NUMBER OF EMITTERS

Total no. of emitters in a scheme area or in a zone, can be calculated using following relationship.

Orchard:

$$N = Np \times e$$

N = Total number of emitters

e = Number of emitters per plant

Np = Total no. of plants

Example: Determine total number of emitters required in 5 hectares for 5 m x 5 m plant spacing. Assume 6 numbers of emitters per plant.

Solution:

Number of plants = Area/ (plant spacing x row spacing)

$$= 5 \times 10000 \text{ m}^2 / (5 \text{ m} \times 5 \text{ m})$$

$$= 2000 \text{ plants}$$

No. of emitters = 2000 plants x 6 emitters per plant

$$= 12,000 \text{ Emitters}$$

Row crops:

$$\text{Total number of emitters} = \text{Total lateral length} / \text{Emitter spacing}$$

Similarly, the numbers of sprinklers are calculated based on the following pattern using relationship:

$$\text{Number of sprinklers} = A / (S \times L)$$

A = Area, Acres (hectares)

L = Sprinkler spacing between lateral or Lateral spacing

S = Sprinkler spacing at lateral or sprinkler spacing

6.2.14 Calculation of Total Flow Rate Requirements (lph)

For micro irrigation system, total flow rate required for the hydro-zone and/or scheme area can be calculated using the following relationships.

For Orchard:

$$Q = N_p \times e \times q$$

Q = Total Flow Rate, lph

q = emitter flow rate, lph

Example: Orchard

$$\begin{aligned} \text{Total flow rate} &= 3238 \times 6 \times 8 \text{ lph} &= 155,424 \text{ LPH} \\ & &= 43.2 \text{ LPS} \\ & &= 155.424 \text{ m}^3/\text{hr} \end{aligned}$$

For Row Crops:

$$Q = e \times q$$

$$Q = L \times q \times S_e$$

Where,

S_e = Emitter spacing

Similarly for sprinkler irrigation system, total flow will be calculated based on the following relationship.

$$Q = N_s \times Q_s$$

Ns = Number of sprinklers operating in a zone
 Qs = Sprinkler flow rate, lph

6.2.15 Calculation of Application Rate (Mm/Hr)

Application rate is the depth of water uniformly distributed over the entire scheme area and can be estimated using following relationship.

$$I = Q / A$$

I = Application Rate (mm/hr)
 Q = Total flow rate, Lph
 A = Area, m²

For Orchard:

Application rate = 155.424 m³/hr x 1000 / (20 * 4047 m²)
 = 1.92 mm/hr

For Row crops:

Application rate = m³/hr x 1000 / (20 * 4047 m²)
 = mm/hr

Application rate for sprinkler system can be calculated using above relationship. Average application rate can also be calculated as:

$$I = K \times q / (S \times L)$$

I = Application rate, mm/hr (in/hr)
 K = Conversion constant, 60 for metric unit (96.3 for English unit)
 Q = Sprinkler discharge, L/min (gpm)
 S = Sprinkler spacing along lateral, m (ft)
 L = Lateral spacing, m (ft)

6.2.16 Total Operation Time (Hrs)

Operation time required to provide irrigation depth to meet daily consumptive use can be estimated using following relationship. The same relationship can be applied for both the Micro Irrigation system and sprinkler irrigation system.

$$T = Cu / I$$

T = Daily Operation time, hrs

Example: Orchard

$$\begin{aligned} \text{Daily operation hours} &= 2.4 \div 1.92 \\ &= 1.25 \text{ hrs} \end{aligned}$$

Operation time can also be calculated using following equation.

$$Ta = IR / (Np \times q)$$

Where

Ta = Daily Operation Time, hrs
 IR = Gross irrigation requirement, mm
 Np = No. of emitters per plant
 q = Emitter flow rate, LPH

Example orchard:

Total area under HEIS : 4.5 Acres
 ETo mm/day : 7.9
 Kc : 0.7
 Plant spacing m : 6.1
 Row Spacing m : 6.1
 Canopy Diameter : 5.18
 Emitter Flow Rate : 8 LPH

Calculate Design Steps from 1-10

Solution:

Calculation of Design Parameters of HEIS Design

Sr. No	Parameters	Formula Description	Units	Zone I
1	Total area under HEIS	A	Acres	4.5
2	Reference Evapotranspiration (ET)		mm/d	7.9
3	Crop Factor (Kc)			0.70
4	Plant spacing		m	6.10
5	Row spacing/ Lateral spacing		m	6.10
6	Canopy Diameter	Cd	m	5.18
7	Canopy Area	$Ca = 3.1416 \times \text{Canopy diameter}^2/4$	m ²	21.1
8	Canopy factor at maturity	$Cf = \text{Canopy Area} / (\text{Plant Spacing} \times \text{Lateral Spacing})$	Fraction	0.57
9	Irrigation system efficiency		%	90
10				8.0
11	Emitter flow rate		LPH	8.0
12	Optimal wetted width of each emitter (30 cm below soil surface at peak water demand)			
13	No. of emitter/dripper per plant		Nos.	6.0
14	Emitter spacing along plant canopy			
15	No. of drip lines per row		Nos.	2.0
16	Optimal distance between two Laterals		m	6.10
17	Irrigation cycle (assume one day)		Days	1.0
18	Peak daily consumptive use per day	$\text{Reference ET} \times \text{crop factor} \times \text{Canopy factor} / \text{Efficiency}$	mm/d	3.50
19	Total no. of plants	$\text{Area} \times 4047 / (\text{Plant Spacing} \times \text{Lateral Spacing})$	Nos.	489
20	Total drip line length	$\text{Area} \times 4047 / (\text{Lateral Spacing} \times \text{No. of drip lines per row})$	m	5971
21	Total no. of emitters/drippers	$\text{Total no. of plants} \times \text{drippers per plant}$	Nos.	2937
22	Average emitter spacing	$\text{Total drip line length} / \text{Total no. of emitters}$	m	2.03
23	Total flow rate	$\text{Total no. of emitters} \times \text{emitter flow rate}$	LPH	23492
24	Application rate	$(\text{Total flow rate} / 1000) / (\text{Area} \times 4047) \times 1000$	mm/hr	1.29
25	Operation time*	$\text{Peak daily consumptive use per day} / \text{Application rate}$	Hrs	2.72

6.3 PIPES

As a rule, pressurized irrigation schemes are composed of water lifting devices, piped networks, water delivery devices, and pressure and water control devices. Sometimes water gravitates in the system and no water lifting devices required in the system.

Some of the systems require less pressure for operation and other require more to operate. Keeping in view all the limitations which may technical, economical and on ground demand, the type and size of the pipe is decided for the irrigation schemes to be installed.

In case where water is lifted at higher elevations the material and equipment used in the start of the schemes withstands higher pressure. The reverse is true when water is flowing from higher elevation to lower elevation the material used at the end of the scheme withstand higher pressure. The design engineers must be careful in selection of materials for such types of schemes.

6.3.1 Selection of Pipes

The most common pipes used for pressurized irrigations systems are;

- Fiber- cements pipes known as Asbestos cement pipes
- Un plasticized polyvinyl chloride pipes (uPvc)
- Polyethylene pipes
- Hoses
- Aluminum pipes
- Steel pipes

Very often design engineer is confronted with the question of which type of pipe should be used for what diameter, their life expectancy and the installation cost.

For the sizing of economic pipe diameter the Smit (1993) proposed the following combination of pipe sizes and types of pipes for south African conditions.

- For size up to 50 mm = Polyethylene pipes
- For size from 50 mm- 110 mm = u Pvc Pipes
- For Sizes from 110 mm- 350 mm = Fiber cement pipes
- For sizes larger than 350mm = steel pipes

However, these norms vary from country to country because of combined effect of pipes prices, transportation and installation cost.

There is large fluctuation in rates of pipes as derivative of petroleum product.

In our conditions sizing and selection of pipes for pressurized irrigations schemes is based on pressurized non bursting velocity, financial limits and water demands.

$$D = 63.25 (Q / 3.141 \times v)^{1/2}$$

Where D = Dia of pipe in inches

Q = Discharge in lps

V = velocity in m/sec (assumed 1.0-1.5m)

6.3.2 Fiber Cement Pipes

Fiber cement pipes or Asbestos pipes are made from port land cement reinforced by fibers, the formulation of which contains chrysotile Asbestos. The pipe is very smooth internally and thus friction coefficient is very low. It can easily be damaged if poorly handled. At times, cracks occurring during transports and installation only become noticeable later on during testing. The yet another disadvantage of this pipe is its poor fitting. Diverse kind of specials is used for jointing of pipes.

The standards available for AC pipe are;

ISO 160:1980, ISO 390, ISO 7337, SAZS 113:2000

NOMINAL AND OUT SIDE DIAMETER AT FINISHED ENDS OF FIBER- CEMENTS PRESSURE PIPES SAZS -113: 2000

Nominal dia (mm)	Class	Outside dia (mm)	Tolerance at outside dia (+/-)
50	A II	69.1	0.6
75	A II	95.6	0.6
100	A II	121.9	0.6
125	A II	149.9	0.6
150	A II	177.3	0.6

CLASSIFICATION OF FIBER CEMENT PRESSURE PIPES ISO-160: 1980

CLASS	Work hydraulic test pressure	
	Bar	Mpa
5	5	0.5
6	6	0.6
10	10	1.0
12	12	1.2

6.3.3 Un-plasticized Polyvinyl Chloride Pipes (UPVC)

uPVC pipes and fittings are made by PVC- U polymer, to which some additives are incorporated in order to facilitate manufacture. ISO – 1620 provides for the testing of this polymer. These pipes are cheaper, light in weight, resistant to corrosion, long life and offer less resistance to flow. The only limitation is that these are to be protected from sunlight and always laid underground.

In Pakistan these are manufactured according to BS 3505,1991 standard for PVC pipes.

The class of pipe is selected according to the total head (pressure) which pipe has to withstand.

6.3.4 CLASSIFICATION OF PIPES

CLASS	WORKING PRESSURE				TEST PRESSURE		
	Bar	Kgf/ cm ²	Lbf / in ²		Bar	Kgf/ cm ²	Lbf / in ²
B	6	6.12	87		9	9.18	130
C	9	9.18	130		14	13.77	195
D	12	12.25	173		18	18.38	259
E	15	15.3	217		23	22.95	325

Normal Size	Outside Diameter (mm)	Class B pipe		Class C pipe		Class D pipe		Class E Pipe	
		Minimum thickness (mm) 6 Bar	Weight Kgs/ M	Minimum thickness (mm) 9 Bar	Weight Kgs/ M	Minimum thickness (mm) 12 Bar	Weight Kgs/ M	Minimum thickness (mm) 15 Bar	Weight Kgs/ M
3"	88.7	2.9	1.17	3.5	4.14	4.6	1.82	-	-
4"	114.1	3.4	1.78	4.5	2.32	6.0	3.03	-	-
5"	140.0	3.8	2.44	5.5	3.49	-	-	-	-
6"	188.0	4.5	3.46	6.6	5.01	-	-	-	-
8"	218.8	5.3	5.30	7.8	7.72	-	-	-	-
10"	272.6	6.6	8.26	-	-	-	-	-	-
12"	323.4	7.8	11.55	-	-	-	-	-	-

TESTS

Physical and chemical characteristics

Appearance

The pipe should be reasonably round. The external and internal surface of the pipe should be smooth, clean, and reasonably free from grooving and other effects that would impair its performance in service. The ends should be cleanly cut and square with the axis of the pipe.

Heat Revision Test

Pipe should be tested at the temperature of 150°C for at least 15 minutes. After testing, the pipe shall show no faults, for example cracks, cavities, or blisters and pipe length should not change more than 5%.

Acetone Test:

A short length of pipe shall be immersed vertically to depth of at least 25 mm in acetone complying with BS 509 at room temperature. The effect of the acetone on the pipe surface shall be noted after 2 hours.

After testing, sample should not show any delaminating or disintegration. Flattering and/or swelling of the pipe shall not be deemed to constitute failure.

Test for resistance to sulphuric acid

The test specimen should be cut from the pipe and must have a surface area of 45 ± 3 sq.cm or (7 ± 0.5 sq inches). The test specimen should be cleaned, wiped and weighed then totally immersed in $93 \pm 0.5\%$ sulphuric acid for 14 days at $55 (\pm 2)^{\circ}\text{C}$. Care should be taken to avoid gradual connection of the acid during the test due to evaporation losses etc. After the specified time the specimen should be removed, washed in running water for 5 minutes, wiped dry with clean cloth and re-weighed immediately.

When tested by the method, the mass of the specimen shall neither increase more than 0.32 grams nor decrease by more than 0.013g. The effect of the acid on the surface appearance of the specimen should be ignored.

Test for opacity:

The following apparatus will be used in this test

- a) Source of light
- b) Photoelectric cell
- c) Spot light galvanometer

The light source and photoelectric cell shall be set up at convenient distance of daylight. The galvanometer shall be connected to the photoelectric cell and the maximum deflection registered shall be noted. A piece of pipe shall then be placed over the photoelectric cell so that one wall is interposed between the light source and cell being kept constant. The maximum deflection of the galvanometer shall again be noted. The second deflection expressed as percentage of the first shall give a measure of the visible light transmitted. When tested by this method the wall of the pipe should not transmit more than 0.2% of the visible light falling on to it.

6.3.5 MECHANICAL CHARACTERISTICS

Short term hydrostatic test

A sample pipe collected from the field is checked in the laboratory at 20° c. The sample pipe is fitted in the apparatus and appropriate internal pressure is applied within 30-40 seconds. The pipe should withstand the appropriate internal pressure for at least one hour without failure.

MINIMUM ONE HOUR INTERNAL PRESSURE

CLASS OF PIPE	Minimum one hour internal hydrostatic pressure	
	Bar	Psi
B all sizes	21.8	310
C all sizes	32.4	470
D all sizes	43.2	620
E all sizes	54.0	780

Long term hydrostatic test

The specimen collected as explained under procedure for short term and fitted in the same way is admitted to maintain a pressure within accuracy of (+/-) 2 % throughout the test at 20° c. For each test specimen stress shall be so chosen that first piece of pipe should be expected to burst with in period of 1-10 hours and the second piece of pipe should be expected to burst with in period of 100-1000 hours. Both pieces of pipes should be tested to failure.

Stress limits

Size of pipe	Minimum one hour stress		Minimum 50 years stress	
	Bar	Psi	Bar	Psi
Below 1"	353	5124	206	2988
1"- 7"	366	5700	230	3340
8" and above	443	6430	360	3770

After testing, the extrapolated 1 hour and 50 year circumferential stress levels should not be less than the appropriate values given above.

Falling weight or impact test

Falling weight or impact test is conducted at 20°c (room temperature). Test pieces are placed in the apparatus to sustain particular number of strokes with respective weights from height of 2 meters.

Dia Size	No of strokes	Size of test piece	Falling weight
3"	4	0.75 inch	2.25 kg
4"	6	1 inch	2.75 kg
5"	8	1.25 inch	3.25 kg

6.3.6 GALVANIZED IRON PIPES (G.I Pipes)

Galvanized pipes are made from steel sheets and coated through chemical process of galvanization. These pipes are very costly, shorter in life. Susceptible to corrosion, heavy in weight and offer more resistance to flow.

These pipes are only used in specific conditions where pvc pipes cannot buried or where higher pressures are to be sustained and liable to be kept on the surface.

The GI pipes are prepared according to the international standards BS and ASTM. The PSI has developed PS 1851/1987 standard for GI pipes in Pakistan.

The GI pipes are generally classified as light, medium and heavy according to BS 1387/1967 standards.

Dimensions of Pipes (Light) BSS 1387/1967

SIZE (INCHES)	OUT SIDE DIAMETER (in)		WALL THICKNESS (inches)	WEIGHT Kg/ft
	Maximum	Minimum		
2	2.370	2.347	0.116	1.25
2.5	2.991	2.960	0.128	1.77
3	3.491	3.460	0.128	2.08
4	4.481	4.450	0.144	3.01

Dimensions of pipes (Medium) BSS 1387/1967

SIZE (INCHES)	OUT SIDE DIAMETER (inches)		WALL THICKNESS (inches)	WEIGHT Kg/ft
	Maximum	Minimum		
2	2.394	2.354	0.144	1.55
2.5	3.014	2.969	0.144	1.99
3	3.524	3.469	0.160	2.58
4	4.525	4.459	0.176	3.69
5	5.534	5.459	0.192	4.94
6	6.539	6.459	0.192	5.85

SIZE (INCHES)	OUT SIDE DIAMETER (in)		WALL THICKNESS (inches)	WEIGHT Kg/ft
	Maximum	Minimum		
2	2.394	2.354	0.176	1.89
2.5	3.014	2.969	0.176	2.41
3	3.524	3.469	0.192	3.07
4	4.525	4.459	0.212	4.40
5	5.534	5.459	0.212	5.44
6	6.539	6.459	0.212	6.49

Pipes should be physically checked for appearance, smoothness, seeming line, and galvanization by making abrasions on the surface.

Light Quality - 8 %
+ no limit

Light Quality - 10 %
+ no limit

Light Quality - 10 %
+ no limit

Single tube 20 ft - 8 % + 10 %

Lot of 1000 ft & over - 4 % + 4 %

Light 700 Psi

Medium 700 psi

Heavy 700 Psi

6.3.7 POLYETHYLENE PIPES

The extrusion compound used for the PE pipe is manufactured from mixture of polyethylene which may include copolymers of ethylene and higher olefins. It also includes antioxidants and carbon black uniformly dispersed.

There are several ISO standards defining the material and are as given below.

ISO 12162 / 1995, ISO 8779/ 2001 and ISO 8796/ 1989

Two types of polyethylene pipes are available in the market the low density polyethylene pipe (LDPE) and high density polyethylene pipe (HDPE). The LDPE pipe is used for drip irrigation schemes and is specified by SABS 533 Part 1:1982. It is used both on ground and underground installations. In some countries, HDPE pipe is used as secondary and manifold lines for drip irrigation systems.

There are several types of LDPE and HDPE pipes confirming the SABS standards.

6.3.8 DRIP TAPE

One of the most interesting development with localized irrigation is the introduction of what is commonly known as drip tape. The ANSI/ASAE S553 MAROI standard provide the specifications.

6.4 PIPE HYDRAULICS

6.4.1 Friction Loss

Head loss results from friction between the pipe walls and water as it flows through the system. Various fittings such as turns, bends, expansions and contractions, etc. along the way, will increase the head loss.

Head loss in a pipe system is affected by the following:

Length

Type of material

Inside diameter

Flow rate through pipe

Type of liquid flowing through the pipe

There are two types of friction losses that will occur while water will be flowing through the pipe system of the pressurized irrigation system namely major losses and minor losses. Major head losses result as water moves through straight pipes. Minor losses are created when water flows through bends and transitions.

6.4.2 Calculation of Friction Loss

Different methods and equations developed i.e., Hazen-Williams, Darcy-Weisbach, and Watters & Keller can be used for the calculation of head losses through the pipes and fittings. This manual will cover only two of these methods namely; Hazen-Williams and Watters & Kellers due to their simplicity.

6.4.3 Hazen-Williams Equation

Empirical formulae are sometimes used to calculate the approximate head loss in a pipe when water is flowing and the flow is turbulent. Prior to the availability of personal computers, Hazen-Williams formula was very popular with engineers because of the relatively simple calculations required. Unfortunately, the results depend upon the value of the Friction Factor “C” which must be used with the formula and this can vary from around 80 up to 130 and higher, depending on the pipe type, pipe size and the water velocity. The empirical form of the Hazen Williams formula is:

$$J = hf / L/100 = K (Q/C)^{1.852} \times D^{-4.8655}$$

Where:

- hf = Head loss due to pipe friction, m (ft)
- J = Head loss gradient, m/100 m (ft/100 ft)
- K = Conversion constant, 1.212×10^{12} for metric units (1050 for English units)
- L = Length of pipe, m (ft)
- C = Friction coefficient, which is a function of pipe material characteristics
- Q = Flow rate in the pipe, L/s (gpm)
- D = Inside diameter of the pipe, mm (in)

The empirical nature of the friction factor C makes the ‘Hazen-Williams’ formula unsuitable for accurate prediction of head loss. The results are only valid for fluids which have a kinematics viscosity of 1.13 centistokes, where the fluid velocity is less than 10 feet per sec and the pipe size is greater than 2” diameter. Water at 60° F (15.5° C) has a kinematics viscosity of 1.13 centistokes.

Table 5.1 Typical values of C for various types of pipe

Asbestos Cement	140
Plastic pipe	140
PVC pipe	150
General smooth pipes	140
Galvanized Steel pipe	135
Aluminum	130

Hazen-Williams formula provides more accurate results for pipe diameters 75mm (3 inches) or larger, however, for small diameter pipes this equation underestimates the results.

Example: Determine head loss through 100 mm (inside diameter 99 mm) Aluminum pipe, 396 m long pipe with 990 litre/minute (16.5 L/s).

Select C value from **Table 6.1** and enter values in the equation.

$$J = 1.21 \times 10^{12} (16.5/130)^{1.852} \times (99)^{-4.8655}$$

$$J = 5.06 \text{ m/100 m}$$

$$H_f = 5.06/100 \times 396 = 20 \text{ m}$$

6.4.4 Watters & Keller Equation

Watters & Kellers developed a simplified equation for use with smooth plastic pipes and hoses less than 125 mm (5 inches).

$$J = 100 \text{ hf/ L} = K Q^{1.75} / D^{1.75}$$

Where

$$K = \text{Conversion constant, } 7.89 \times 10^7 \text{ for metric units (0.133 for English units)}$$

For large plastic pipe, where diameter is greater than 125 mm (5 in), the friction head loss gradient can be approximated by:

$$J = 100 \text{ hf/ L} = K Q^{1.83} / D^{4.83}$$

Where

$$K = \text{Conversion constant, } 9.58 \times 10^7 \text{ for metric units (0.133 for English units)}$$

6.4.5 VELOCITY OF FLOW

Velocity of water flowing through pipes can be calculated using the following equation

$$V = K Q / (D^2)$$

Where

$$V = \text{velocity of flow in pipe, m/s (ft/s)}$$

$$Q = \text{Flow rate, L/s (gpm)}$$

$$K = \text{Conversion factor, 1273 for metric unit (0.4085 for English units)}$$

$$D = \text{Inside diameter of pipe, mm (in)}$$

Example: Determine velocity of water through pipe (inside diameter 10.226 in) flowing at 1200 gpm

Using Equation No. 5.4

$$V = 0.4085 \times 1200 / (10.226)^2]$$

$$V = 4.7 \text{ ft/s}$$

Velocity in sub-mainlines may be kept under 2.5 m/s.

Nominal Size	Mean Outside Diameter		Wall Thickness (S)							
			Class B 6 Bar (200 ft head)		Class C 9 Bar (300 ft head)		Class D 12 Bar (400 ft head)		Class E 15 Bar (500 ft head)	
Inches	min	max	min	max	min	max	min	max	min	max
½	21.2	21.5							1.7	2.1
¾	26.6	26.9							1.9	2.5
1	33.4	33.7							2.2	2.7
1 ¼	42.1	42.4					2.2	2.7	2.7	3.2
1 ½	48.1	48.4					2.5	3.0	3.1	3.7
2	60.2	60.5			2.5	3.0	3.1	3.7	3.9	4.5
2 ½	75.0	75.3			3.0	3.5	3.9	4.5	4.8	5.5
3	88.7	89.1	2.9	3.4	3.5	4.1	4.6	5.3	5.7	6.6
4	114.1	114.5	3.4	4.0	4.5	5.2	6.0	6.9	7.3	8.4
5	140.0	140.4	3.8	4.4	5.5	6.4	7.3	8.4	9.0	10.4
6	168.0	168.5	4.5	5.2	6.6	7.6	8.8	10.2	10.8	12.5
8	218.8	219.4	5.3	6.1	7.8	9.0	10.3	11.9	12.4	14.5
10	272.6	272.4	6.6	7.6	9.7	11.2	12.8	14.8	15.7	18.1
12	323.4	324.3	7.8	9.0	11.5	13.3	15.2	17.5	18.7	21.6
14	355.0	356.0	8.5	9.8	12.6	14.5	16.7	19.2	20.5	23.6
16	405.9	406.9	9.7	11.2	14.5	16.7	19.0	21.9	23.4	27.0
18	456.7	457.7	11.0	12.7	16.3	18.8	21.4	24.6	-	-
20	507.5	508.5	12.2	14.1	18.1	20.9	-	-	-	-
24	609.1	610.1	14.6	16.8	21.7	25.0	-	-	-	-

6.4.6 Selection and Design of Lateral Line

Laterals are available in different sizes i.e. 12 mm, 16 mm and 20 mm. Head loss in the lateral length between the first and last emitter should not exceed by 20% of the head available at the first emitter to keep flow variation within 10% so as 90% of application uniformity can be achieved.

The design of lateral pipe involves selection of required pipe size for a given length which can require quantity of water to the plant. This is the most important component of the system as large amount of pipe per unit of land is required and the pipe cost is such that system is economically viable.

In designing the lateral, the discharge and operating pressure at emitters are required to be known and accordingly, the allowable pressure drop can be determined by the same formula as the main line. The total friction head loss in lateral can be calculated by multiplying the head loss over the total length by a factor F given in **Table 6.2**.

$$\text{Lateral Head loss} = hf \times F$$

Criteria: Allowable pressure drop in sub-mainline and laterals depends upon the operating pressure required at emitters. The pressure difference between the proximate and distant point along the supply line should not exceed 20% which will keep the variation of discharge within 10% of its value at the first emitter. The emitter operating pressure is usually 10 m, therefore, the maximum allowable head loss in a lateral should be less than 20% of emitter operating pressure i.e. 2m.

Table 6.2 Reduction Coefficient 'F' for Multiple Outlet Pipeline Friction Loss

No. of outlets	F	No. of outlets	F
1	1	8	0.42
2	0.65	10 to 11	0.41
3	0.55	12 to 15	0.40
4	0.50	16 to 20	0.39
5	0.47	21 to 30	0.38
6	0.45	31 to 37	0.37
7	0.44	38 to 70	0.36

Example Lateral Design:

Assume:

Flow per dripper = 8 LPH

Dripper to dripper spacing (average) = 2.30 m

Lateral diameter = 16mm (inside diameter= 14.2m)

What should be maximum permissible length of lateral to have a head loss of 2m= ?

Solution:

Particulars	Unit	H.Zone1
Lateral Length	m	56
Inside diameter	mm	10.2
Pipe material		PE
Pipe friction coefficient		150
Emitter spacing	m	2.0
No. of emitters	Nos.	27
Emitter flow rate	LPH	8
Lateral flow rate	LPH	216
Factor for multiple outlet	-	0.36
Fittings loss for emitters	m	0
Head loss (Watter & Keller)	m/100m	3.3
Head loss (Hazen Willam)	m/100m	2.7
Total lateral head loss, h_f	m	1.87
Velocity	m/sec	0.73

Emitter operating pressure=	10
Required lateral head loss (20%)=	2
Calculated lateral head loss =	1.87
	OK

Lateral is selected

Example Lateral Design:

Assume:

Flow per dripper = 8 LPH

Dripper to dripper spacing (average) = 2.30 m

Lateral diameter = 16mm (inside diameter= 14.2m)

What should be maximum permissible length of lateral to have a head loss of 2m= ?

Solution:

Lateral Length	M	109
Inside diameter	Mm	14.2
Pipe material		PE
Pipe friction coefficient		150
Emitter spacing	M	2.3
No. of emitters	Nos.	47
Emitter flow rate	LPH	8
Lateral flow rate	LPH	376
Factor for multiple outlet	-	0.36
Fittings loss for emitters	M	0
Head loss (Watter & Keller)	m/100m	1.8
Head loss (Hazzen Willam)	m/100m	1.5
Total lateral head loss, h_f	M	2.00
Velocity	m/sec	0.66

Emitter operating pressure=	10
Required lateral head loss (20%)=	2
Calculated lateral head loss =	2.00
	OK

Lateral is selected

6.4.7 DESIGN OF SUB-MAIN LINE

On the manifolds, whether these pipelines are the sub-main or the mains as well, a number of laterals are fed simultaneously. The flow of the line is distributed en route, as in the laterals with the emitters. Consequently, when computing the friction losses.

The mains, sub-main and all hydrants are selected in such sizes that the friction losses do not exceed approximately 15 percent of the total dynamic head required at the beginning of the system's piped network. On level ground, these friction losses amount to about 20 percent of the emitter's fixed operating pressure. This is a practical rule for all pressurized systems to achieve uniform pressure conditions and water distribution at any point of the systems. The above figure

should not be confused with or related in any way to the maximum permissible friction losses along the laterals.

Criteria:

- Maximum Water Velocity in sub-main and mainline= 1.5 m/s
- Maximum Frictional Losses in sub-main = 2m
- Maximum Frictional Losses in mainline = 20m per 1000m length
- Hazen Williams Equation for Frictional Losses

Assume:

Flow per dripper = 4 LPH

Dripper to dripper spacing= 0.5 m

Lateral to lateral spacing = 1.5 m

Sub-main diameter = 2 inch= 63 mm (inside diameter= 59.8 mm)

What should be sub-main maximum permissible length to have a head loss of 2m= ?

Particulars	Unit	H.Zone1
Sub-Mainline Length	m	41
Inside diameter	mm	75
Pipe material		PVC
Pipe friction coefficient		150
Lateral spacing	m	0.75
No. of laterals operating	Nos.	55
Lateral flow rate	LPH	368
Sub-mainline flow rate	LPH	20117
Factor for multiple outlet	-	0.36
Head loss gradient (Watter & Keller)	m/100m	0.72
Head loss gradient (Hazen Willam)	m/100m	0.73
Total head loss, h_f	m	0.3
Velocity	m/s	1.27

Sub-main is selected

Assume:

Flow per dripper = 8 LPH

Dripper to dripper spacing= 0.5 m

Lateral to lateral spacing = 1.5 m

Sub-main diameter = 2 inch= 63 mm (inside diameter= 59.8 mm)

What should be sub-main maximum permissible length to have a head loss of 2m= ?

Particulars	Unit	H.Zone1
Sub-Mainline Length	m	95
Inside diameter	mm	71.4
Pipe material		PVC
Pipe friction coefficient		150
Lateral spacing	m	2.29
No. of laterals operating	Nos.	83
Lateral flow rate	LPH	256
Sub-mainline flow rate	LPH	21240
Factor for multiple outlet	-	0.36
Head loss gradient (Watter & Keller)	m/100m	0.99
Head loss gradient (Hazzen Willam)	m/100m	1.02
Total head loss, h_f	m	1.0
Velocity	m/s	1.47

6.4.8 Selection and Design of mainline

Criteria:

- Should be selected based on the quantity of water, length, elevation of ground, velocity, cost etc.
- Permissible velocity : Less than 1.5 m/s
- Frictional losses : Less than 2 m/100 m
- Economics: Less initial and annual operating cost
- Elevation and Class of Pipe: Pipe class affects the system cost, use appropriate pressure class pipe and try to lay the pipe at same elevation
- Control measures: Pressure relief valves at appropriate location i.e., where elevation changes

Example

Assume

Mainline length = 156 m

Diameter = 4 inch= 150 mm (inside diameter= 85.6 mm)

Designed discharge= 23492 lps

Material is PVC (C=150)

Calculate friction loss and check velocity

Particular	Unit	Section
		1
Length	m	156
Inside diameter	mm	85.6
Pipe material		PVC
Pipe friction coefficient		150
Design capacity	LPH	23492
Head loss gradient (Watter & Keller)	m/100 m	1.39
Head loss gradient (Hazen Willam)	m/100m	1.42
Mainline fittings losses	m	0
Flow velocity	m/s	1.13
Total mainline head loss	m	2.21

Main line is selected

Example 2

Particular	Unit	Section
		1
Length	m	213
Inside diameter	mm	84.4
Pipe material		PVC
Pipe friction coefficient		150
Design capacity	LPH	23253
Head loss gradient (Watter & Keller)	m/100 m	1.46
Head loss gradient (Hazen Willam)	m/100m	1.49
Mainline fittings losses	m	0
Flow velocity	m/s	1.16
Total mainline head loss	m	3.17

6.4.9 HEAD LOSS THROUGH FITTINGS

The three conventional methods for computing the additional pressure-head losses from special equipment, valves, pipe and fittings are: (1) graphing friction loss vs. flow rate, (2) expressing the added pressure head loss as the length of pipe (of the same diameter) that would give the same loss, and (3) expressing the loss in terms of a velocity head coefficient. Following **Equation 5.5** can be used for computing friction head loss caused by a specific fitting (h_e), feet.

$$h_e = K_f \frac{V^2}{2g}$$

Where;

K_f = friction head-loss coefficient for a specific fitting.

$V^2/2g$ = velocity head, which is the energy head from the velocity of flow, feet or m.

K_f values should be supplied by manufacturers or taken from handbooks on hydraulics. Usually the losses attributed to standard pipe fittings are small and can be grouped in a miscellaneous friction-loss or safety factor.

6.4.10 SELECTION OF FILTERS AND THEIR HEAD LOSS

There are four kinds of filters used in different combination depending upon source of water

- Hydrocyclone Filter (H)
- Sand Media (S)
- Disc Filter (D)
- Screen filters

Application:

- H+S+D = When Water quality is very bad, contains silt particles
- S+D = Open Well, Tank, Pond, Reservoir, Canal
- H+D = Borewell
- D (only) = When water is very clean

To prevent solid particles in the water from penetrating the irrigation system and clogging the drippers

- Source of water
- Type, size and concentration of physical impurities
- Type of irrigation system
- Ease of handling, cleaning, maintenance and repairing
- Filtration media and frictional losses
- Economical investment, maintenance and power cost

Sand Media Filter

Hydrocyclone Filter

Disc Filter

WATER QUALITY

(Factor for drip irrigation)

Physical (Suspended solids)	Chemical (Precipitation)	Biological (Bacteria & Algae)
Inorganic particles Sand Silt Clay Plastics	Calcium or Magnesium carbonates, Calcium Sulphates	Filaments Slime
Organic Particles Aquatic plants Aquatic animals Bacteria	Heavy metals, oxides, hydrocides, carobonates, silicates and sulphides	Microbial decomposition Iron Sulphur Manganese
	Oil or other lubricant fertilizers Phosphate Aqueous Ammonia Iron, Copper, Zinc, Manganese	

WATER QUALITY CRITERIA FOR EMITTER CLOGGING

Type of Problem	Clogging Hazard		
	Minor	Moderate	Severe
Physical (Suspended solids ^a)	50	50 - 100	➤ 100
Chemical pH	7.0	7.0 – 8.0	➤ 8.0
Dissolved Solids ^a	500	500 – 2000	➤ 2000
Manganese ^a	0.1	0.1 – 1.5	➤ 1.5
Total Iron ^a	0.2	0.2 – 1.5	➤ 1.5
Hydrogen Sulphides ^a	0.2	0.2 – 2.0	➤ 2.0
Biological Bacterial Population ^b	10,000	10,000 – 50,000	➤ 50, 000

(a: ppm

b: number/mL)

Selection of Valves

- The Valve can take upto 40% more flow than the pipe flow rate. Hence the Valve size can be one size less than the Pipeline Size
- The Friction loss in the Valve will be upto 2m approx.

6.4.11 Total Dynamic Head

Total Dynamic head is the total pressure required to provide the required pressure at the end of the last emitter. It is calculated as follows

$$\text{Total Dynamic Head} = \text{suction head} + \text{delivery head} + \text{filter losses} + \text{mainline losses} + \text{sub-mainline losses} + \text{lateral loss} + \text{Fertigation system loss} + \text{fitting loss} + \text{- elevation difference} + \text{operating pressure}$$

Emitter operating pressure	m	10
Elevation difference	m	0
Total Head Loss (Pipe network)	m	4.18
Fitting loss Lateral	m	0.1
Fitting loss Mainline	m	0.6
Fitting loss Sub-mainline	m	0.6
Fitting loss Head unit	m	0.7
Head loss in filters	m	12
Head loss in fertigation system	m	4
Head loss in flow meter	m	1
Field fitting losses	m	0
Miscellaneous head loss	m	2
Pumping lift	m	2
Total Dynamic Head	m	37.18

Total pipe network HL < 25% of Total Dynamic Head

Main line and sub mainline head loss may be less than 1m/100m

Emitter operating pressure	M	10	
Elevation difference	M	0	
Headloss in lateral	M	0.7	
Headloss in Submain	M	1.1	1.1
Head Loss (Main)	M	3.17	3.17
Headloss in valves	M	2	2
Fitting loss Lateral	M	1.1	1.1
Fitting loss Mainline	M	2	2
Fitting loss Sub-mainline	M	0	
Fitting loss Head unit	M	0	
Head loss in filters(Primary)	M	4	
Head loss in filters(secondry)	M	4	
Head loss in fertigation system	M	5	
Head loss in flow meter	M	0	
Field fitting losses	M	0	
Safty equipment headloss	M	2	
Miscellaneous head loss	M	0	
Suction head	M	1	
Delivery head	M	1	
Pumping lift	M	0	
Total Dynamic Head	M	37.07	9.37

Total pipe network headloss/Total Dynamic Head (%)=**25 %****Total pipe network HL < 25% of Total Dynamic Head**

Lateral head loss may be less than 20% of the emitter operating pressure

Flow velocity less than 1.5 m/sec

Main line and sub mainline head loss may be less than 1m/100m

6.4.12 Calculation of Required Horsepower

Pumps and lifting/propelling devices are often classified on the basis of the mechanical principle used to lift the water: direct lift, displacement, creating a velocity head, using the buoyancy of a gas or gravity. Most categories sub-divide into further classifications “reciprocating/cyclic” and “rotary”. Virtually all water lifting devices can best be characterized for practical purposes by measuring their output at different heads and speeds. Normally the performance of a pump is presented on a graph of head versus flow (an H-Q graph) and in most cases curves can be defined for the relationship between H and Q at different speeds of operation. Invariably there is a certain head, flow and speed of operation that represents the optimum efficiency of the device, i.e. where the output is maximized in relation to the power input. Some devices and pumps are more sensitive to variations in these factors than others; i.e. some only function well close to a certain design condition of speed, flow and head, while others can tolerate a wide range of operating conditions with little loss of efficiency.

- Selection of Pump and Motor depends on Flow and pressure required for system.
- Pressure is calculated after adding all the losses of the system and pressure required at emitters.
- An approximate HP for motor is calculated as follows:

$$HP = \frac{Q \times H}{75 \times E1 \times E2}$$

where:

Q is discharge, LPS

H is the total head, m;

E1 is the pump efficiency (fraction in the order of 0.5-0.8); and

E2 is the driving efficiency (fraction of 0.7-0.9 for electric motors and 0.5-0.75 for diesel engines).

The overall pumping efficiency under field conditions ranges accordingly from 0.35 in engine driven units to 0.50 in motor driven pumps. Higher efficiencies are not realistic.

(Always rely on manufacturer chart to know the actual horse power)

PUMP REQUIREMENT	Unit	
Capacity	(LPS)	6.46
Head	(m)	37.1
Motor efficiency	(%)	0.9
Pump Efficiency	(%)	0.65
Pump H.P required	H.P	5

6.4.13 Selection of Pump and Motor

Curves for pump selection KSB - ETA 65-200

6.4.14 Preparation of Drawing

6.4.15 Preparation of Bill of Quantities BOQ

Bill of Quantities is divided into following subsets:

- Pump Set, Head Unit, Valves, PVC Pipes and Fittings, Emitting System
- Safety and Monitoring Equipments

S.No	Description	Specification	Unit	Quantity	Rate	Cost
	Pump set-	5 HP	Pcs	01	50,000	50,000
	Elect. Motor	23-93 m ³ /hr	"	"	10,000	10,000
	Pressure gauge	3-bar	"	06	12.00	72.00
	AR-V	3"	"	01	12.00	12.00
	NR-V	"	"	01	4800	4800
	Foot-V	"	"	01	1500	1500
	S. Media-F	30 m ³ /hr	"	01	50,000	50,000
	Disc Filt	"	"	01	20,000	20,000
	H-Cycl-F	35 m ³ /hr	"	01	24,000	24,000
	Drip line	13 mm	m	26566	17	451,622
	Dripper	8 LPH	No.	11628	05	58,140
	Submain	Pvc 76 mm	m	400	175	70,000
	Main	Pvc 90 mm	m	233	250	58,250
	Control val.	3"	Pcs	4	2500	10,000
	Flange	95 mm Dia	"	8	300	2,400
						<u>882,459</u>

= 765,112.00

Trench, Back filling 633m x 60 = 37980-w

Head unit Plate Farm = 14000

Services charges 8% = 65367-w

= 882,459-w

Farmer Share 40% = 352,983-w

Tot. Govt. Share. 60% = 529,475-w

Name of beneficiary:			GHULAM ABBAS QURESHI		Designer Name:		Arif ul Rehman	
Address:			ABBAS PLAZA MUZAFERGARH		Agronomist Name:		M. Saqib	
Contact Number:			-		Area (ac):		20	
Proposed at Design / BOQ-Memoona Sultana-AH931							Date:	11/2/2010
	MAKE	MODEL	SPECIFICATION	UNIT	QTY	UNIT PRICE	TOTAL PRICE	
Pump Set and Prime Mover								
1	KSB	KSB 65/20	KSB PUMP 65/20 3" X 2.5" 2900RPM(IMPELLER DIA 200MM)	NOS	1	TO BE PROVIDED BY FARMER		
2	GOLDEN	DE 32HP	GOLDEN DIESEL ENGINE 32HP 2900RPM	NOS	1			
3	GOLDEN	BFDE	BASE FRAME AND COUPLING FOR DIESEL ENGINE	NOS	1			
4			SUCTION ACCESSORIES (TO BE PROVIDED BY FARMER)	NOS	1			
Filtration System+Fertigation								
5	JAIN	DCYM60	JAIN DISC CLEAN FILTER 60M³HR. 1F 4" DELUXE	NO.	1	37,075.18	37,075	
6	JAIN	JHFM080	JAIN HYDROCYCLONE SEPARATOR 80 M³HR. 4"	NO.	1	67,725.04	67,725	
7	JAIN	FM060SMM	JAIN FILTER MASTER 3"/36" 60M³HR.-M SINGLE WITH MMF	SET	1	125,395.79	125,396	
8	JAIN	VA34	VENTURY ASSEMBLY COMPLETE 34"	SET	1	2,326.94	2,327	
9	JAIN	Fte090	FERTILIZER TANK - 90 LITER ECONOMY	NO.	1	17,440.42	17,440	
10	Local	MFT090	MESH FOR FERTILIZER TANK	NO.	1	3,333.33	3,333	
11	LOCAL	GMV40	G. M. VALVE 1 - 1/2"	NO.	1	2,107.14	2,107	
12	LOCAL	HU3	HEAD UNIT FITTINGS 3	LUMPSUM	1	27,928.57	27,929	
VALVES								
13	Audco	BVN100	BUTTERFLY VALVE 100 MM (4")	NO.	7	7,775.59	54,429	
14	JAIN	ARVC100	DOUBLE ACTION AIR/VACUUM RELEASE VALVE 1"	NO.	5	1,417.03	7,085	
15	JAIN	SFV63	FLUSH VALVE 63 MM	NO.	12	202.03	2,424	
16	JAIN	SFV50	FLUSH VALVE 50 MM	NO.	1	172.49	172	
17	JAIN	SFV40	FLUSH VALVE 40 MM	NO.	5	141.07	705	
PVC Pipes								
18	JAIN	RPA140063SGS0060	PVC PIPE 140MM X 6.3KG/CM2 ISO-4422	MTR.	516	425.71	219,667	
19	JAIN	RPA110063SGS0060	PVC PIPE 110MM X 6.3KG/CM2 ISO-4422	MTR.	66	264.32	17,445	
20	JAIN	RPA090050SGS0060	PVC PIPE 90MM X 5KG/CM2 ISO-4422	MTR.	72	183.60	13,219	
21	JAIN	RPA075050SGS0060	PVC PIPE 75MM X 5KG/CM2 ISO-4422	MTR.	684	129.77	88,764	
22	JAIN	RPA063050SGS0060	PVC PIPE 63MM X 5KG/CM2 ISO-4422	MTR.	696	94.32	65,647	
23	JAIN	RPA050063SGS0060	PVC PIPE 50MM X 6.3KG/CM2 ISO-4422	MTR.	84	81.92	6,882	
24	JAIN	RPA040063SGS0060	PVC PIPE 40MM X 6.3KG/CM2 ISO-4422	MTR.	192	53.76	10,322	
25	JAIN	F&A	FITTINGS AND ACCESSORIES	LUMPSUM	1		42,195	
EMITTING SYSTEM (INLINE LATERALS)								
26	JAIN	PT122	12MM OD/10.2MM ID, MINIMUM 0.9MM W.T.	MTR.	2000	11.08	22,170	
27	JAIN	JTA1204502	12MM, MINIMUM 0.6MM W.T., 4LPH, 50CMS SPACING	MTR.	53500	10.86	580,794	
28	JAIN	GTO01213	POLY GROMMET TAKE OFF 12 X 13 MM	SET	1700	8.95	15,223	
29	JAIN	TLJ12	J-TURBO AQUILA / J TURBO LINE JOINER 12 MM	NO.	1800	6.13	11,028	
30	JAIN	ES0812	LATERAL END STOP "8" SHAPE 12 MM	NO.	1700	5.03	8,546	
31	JAIN	PG6FLC	PRESSURE GAUGE GLYCERIN FILLED LATERAL CHECK	SET	2	967.73	1,935	
ADDITIONAL SAFETY AND MONITORING EQUIPMENT								
32	Capstan	CWM4ET	CAPSTAN WATER METER 4" ENC. TYPE 100 MM	NO.	1	25,663.56	25,664	
33	LOCAL	NRV25	C. I. NON RETURN VALVE 2.5"	NO.	1	10,086.54	10,087	
OTHER CHARGES								
34			TRENCHING AND BACKFILLING	RFT	6500	14.29	92,885	
TOTAL PRICE IN PAK RUPEES							1,580,622	
			SERVICE CHARGES			9.00%	142,256	
Spare Parts								
1	JAIN	JTA1204502	12MM, MINIMUM 0.6MM W.T., 4LPH, 50CMS SPACING	MTR.	1000	11	10,856	
2	JAIN	TLJ12	J-TURBO AQUILA / J TURBO LINE JOINER 12 MM	NO.	400	6	2,451	
3	JAIN	PG6FLC	PRESSURE GAUGE GLYCERIN FILLED LATERAL CHECK	SET	1	967.73	968	
4	JAIN	ES0812	LATERAL END STOP "8" SHAPE 12 MM	NO.	300	5	1,508	
TOTAL PROJECT PRICE							1,738,660	

Note:

The above quotation does not include cost of construction of Pond/Bore well and pumpset with prime mover along with the suction accessories. This will be provided by beneficiary as per specification provided by SSC.

Example Orchard - 1

Design a drip irrigation system for citrus using following data:

Size of the field	=	1 ha
Shape	=	assume square plot of 100m X 100m
Type of drippers	=	on-line
Plant spacing	=	6.09 m
Row spacing (Lateral spacing)	=	6.09 m
Discharge of dripper	=	8 LPH at 1 Kg/cm ²
Maximum ETo	=	8 mm/day
Kc for citrus	=	0.70
Area to be wetted as a		
Percentage of total area	=	60 %
Soil type	=	clay loam
Availability of electricity per day	=	12 hours
Topography of field	=	level
Application efficiency	=	90 %
Hazen-William constant	=	150 for PVC pipe and 140 for LDPE pipes

Assume water source is at the corner of the field.

Solution:

A) Computation of water requirement of the area

Consumptive use can be calculated using equation - 4.6

$$\begin{aligned}
 CU &= E_{to} \times K_c \times K_f \div \text{efficiency} \\
 &= 8 \times 0.70 \times 0.60 / (90 / 100) \\
 &= 3.73 \text{ mm/day}
 \end{aligned}$$

B) Calculation of number of plants

Total no. of plants can be calculated by using equation

$$\begin{aligned}
 N_p &= A / A_p \\
 &= 10000 / (6.09 \times 6.09) \\
 &= 269 \text{ plants}
 \end{aligned}$$

C) Selection of emitters

Numbers of emitters are selected based on the equation.

$$e = S_P \times S_R \times P_w / A_w$$

The value of A_w is selected from Table-3.10 for loam (medium) soil and is used in the above equation to find the no. of emitters per plant.

$$\begin{aligned}
 e &= 6.09 \times 6.09 \times 0.60 / 3.87 \\
 &= 5.8 \\
 &= 6 \text{ (Approx.)}
 \end{aligned}$$

Total no. of drippers required for the area can be calculated using equation

$$\begin{aligned}
 N &= N_p \times e \\
 &= 269 \times 6 \\
 &= 1614
 \end{aligned}$$

D) Computation of Flow Rate

Total flow rate can be calculated by using equation

$$\begin{aligned}
 Q &= N_p \times e \times q \\
 &= 269 \times 6 \times 8 \\
 &= 12912 \text{ LPH}
 \end{aligned}$$

E) Lateral Requirement

Two no. of drip line for one row of plants is suggested and the total drip line length for the area can be calculated by using equation

$$\begin{aligned}
 L &= K. A. N_l / L_s \\
 &= 4047 \times 2.471 \times 2 / 6.09 \\
 &= 3284 \text{ m}
 \end{aligned}$$

F) Application Rate

Application rate can be calculated using equation – 4.29

$$\begin{aligned}
 I &= Q / A \\
 &= 12912 / 10000 \\
 &= 1.29 \text{ mm/hr}
 \end{aligned}$$

G) Total Operation Time

Operation time can be calculated using equation – 4.31

$$\begin{aligned}
 T &= C_u / I \\
 &= 3.73 / 1.29 \\
 &= 2.89 \text{ hrs}
 \end{aligned}$$

Here it comes the decisive moment to prepare layout for pipe network. The entire system can be irrigated in one operation requiring larger sized head unit components and pipe networks resulting higher initial investments but less operation hours. The same system can further be economized by dividing the area into zones (may be four) that will result in approximately 12 hours of operations but smaller sized head unit components and pipe diameters. To make design calculations easier, the entire system is to irrigate in a single operation.

H) Selection and Design of Lateral

For economy, divide the flow into two sections and give the submain at the center of plot.

- i) Length of lateral on one side of sub-main = 50 m
 No. of plants on one lateral = Lateral length / plant spacing
 = 50/6.09
 = 8
- ii) Two no. of laterals for one crop row are suggested @ 3 no. of drippers on each lateral per plant, so the total no. of drippers on each lateral can be calculated as:
 = No. of plants on each lateral X no. of dripper per plant per lateral
 = 8 X 3
 = 24 no.
- iii) Flow rate of the lateral can be calculated by using equation as:
 = Total no. of dripper on each lateral X Flow rate of each emitter
 = 24 X 8
 = 192 LPH

Select 12 mm diameter lateral (thickness of the lateral is 1.1 mm), inside diameter of lateral =
 $12 - (1.1 + 1.1)$
 = 9.8 mm

Using equation – 5.2 (Watter and Keller)

$$\begin{aligned}
 J &= 100 \text{ hf/ L} &= K Q^{1.75} / D^{4.75} \\
 &= 100 \text{ hf/ (50 m)} = 7.89 \times 10^7 \times (192/3600)^{1.75} / 9.8^{1.75} \\
 & &= 9.14 \text{ m} \\
 H_f &= 9.14 \times 50/100 = 4.57 \text{ m}
 \end{aligned}$$

Multiplying by outlet factor for multiple outlets i.e., 0.36 taken from Table 6.2.

$$\text{Total head loss in lateral} = 4.57 \times 0.36 = 1.65 \text{ m}$$

Head loss due to friction for 50m lateral length = 1.65 m

Emitter operating pressure is 10 m and calculated head loss 1.65 m is less than 20%, which means flow variation is less than 10%. Lateral of 12 mm size is sufficient to carry the flow.

I) Selection and Design of Sub-main

- i) Length of sub-main = 100 m
- ii) No. of lateral on one side of submain
 = 2 X (Submain length / Lateral spacing)
 = 2 X (100 / 6.09)
 = 33

$$\begin{aligned} \text{iii) No. of laterals on submain} &= 33 \times 2 \\ &= 66 \end{aligned}$$

$$\begin{aligned} \text{iv) Flow rate in submain} &= \text{flow rate in one lateral} \times \text{No. of laterals on submain} \\ &= 192 \times 66 \\ &= 12672 \text{ LPH} \end{aligned}$$

Which is approximately the same as calculated total flow of area considering total plants in the area i.e 12912 LPH

$$\text{v) Outlet factor (66 outlet) for sub main} = 0.36$$

Select 60.5 mm diameter of sub main, inside diameter of sub main = 55.5 mm

Using equation – 5.2 (Water and Keller) as described in lateral size calculation

$$\text{Head loss due to friction for 100m sub main length} = 1.53 \text{ m}$$

J) Calculation of Flow Velocity

Flow velocity can be calculated using equation 5.4.

$$\begin{aligned} V &= K Q / D^2 \\ &= 1273 (12912/3600) / (55.5)^2 \\ &= 1.48 \text{ m/s} \end{aligned}$$

As the calculated head loss is less than 2 m, also the velocity is also less than the maximum permissible limit of 2.5 m/s, the sub-main of 60.5 mm size is sufficient to carry the flow. Therefore, the design of sub-main is acceptable.

K) Selection and design of mainline

$$\begin{aligned} \text{i) Length of main line} &= 50 \text{ m} \\ \text{ii) Flow rate of main line} &= \text{Flow rate of submain} \\ &= 12912 \text{ LPH} \end{aligned}$$

Select 60.5 mm diameter of submain, inside diameter of submain = 55.5 mm

Using equation – 6.2 (Watter and Keller)

$$\begin{aligned} \text{Head loss due to friction for 100m lateral length} &= 3.82 \text{ m} \\ \text{Head loss due to friction for 50m main line length} &= 1.91 \text{ m} \end{aligned}$$

$$\text{Velocity} = 1.48 \text{ m/s}$$

The calculated velocity for mainline is less than the maximum permissible limit of 1.5 m/s, the mainline of 60.5 mm size is sufficient to carry the flow. Therefore, the design of mainline is acceptable.

The head loss for suction and delivery pipe for pump be calculated using the same equation (Water & Keller)

$$\text{Suction and delivery head loss} = 0.09 \text{ m}$$

$$\begin{aligned} \text{Total head losses in piping network} &= 1.65 + 1.53 + 0.09 \\ &= 5.18 \text{ m} \end{aligned}$$

Fitting losses

$$(\text{may be taken 20\% of the pipe losses}) = 1.04 \text{ m}$$

$$\text{Emitter operating pressure in form of water head} = 10 \text{ m}$$

Head losses for fittings, filters, fertigation system and other flow control and monitoring devices shall be added as given by the vendors.

Assume,

$$\text{Head loss in fertigation} = 5 \text{ m}$$

$$\text{Head losses in filters} = 8 \text{ m}$$

$$\text{Head loss in flow meter} = 1 \text{ m}$$

$$\text{Misc. head losses} = 2 \text{ m}$$

The total dynamic head can be calculated by adding all the head losses occurring in the system and can be presented as follow:

$$\begin{aligned} \text{Total Dynamic Head} &= 30.22 \text{ m} \\ \text{Pump flow rate} &= 12912 \text{ (LPH)} / 3600 \text{ (Sec.)} \\ &= 3.59 \text{ LPS} \end{aligned}$$

L) Horse Power Requirement

Horse Power Requirement can be calculated using equation

$$\text{H.P} = \frac{Q \cdot H}{75 \times E_m \times E_p}$$

The efficiencies for pump and electric motor are assumed as 60% and 80% respectively.

$$= \frac{3.59 \times 30.22}{75 \times 0.6 \times 0.8}$$

$$\text{Required Horse Power} = 3.0 \text{ (appx.)}$$

Fig. 6.2 Design layout for drip irrigation system

Example Orchard - 2

LATERAL LAYOUT PATTERNS FOR ORCHARDS

- A. Single lateral for each tree row. S_p = plant spacing; S_r = row spacing; S_w = width of wetted strip; S_e = emitter spacing; S_l = lateral spacing.

2

Cont

B. Double laterals for each tree row.

C. Zigzag lateral for each tree row.

Cont

D. Pigtail with four emitters per tree.

E. Multiexit six-outlet emitter with distribution tubing.

AREA WETTED BY ONE EMITTER

Soil Type	Area wetted by one emitter (m ²)
Sandy soils	0.5-2
Loamy soils	2-6
Clay	6-15

Rain Bird, 1980

Percent Wetted Area

- The percentage area wetted P_w is the average horizontal area wetted within the top 30cm of the crop root zone depth in relation to the total cropped area.
- For largely spaced crops such as orchards is to wet at least one third and as much as two third (33%-66%) of potential horizontal area of the plant root system.
- In closely spaced crops with rows and emitter laterals spaced less than 1.8 m apart often reaches 100%.

Example

Percentage Wetted Area P_w =

no. of emitters x area wetted by single emitter

Row to Row x Plant-Plant distance

No. of emitters	= 4
Area wetted by single emitter	= 4 m ²
Row to Row distance	= 4.57 m
Plant-Plant distance	= 4.57 m

$P_w = 4 \times 4 / 4.57 \times 4.57 = 77\%$

Design a drip irrigation system for Citrus Orchard in Okara District.

Crop Information

Parameters			Crop	Area (acres)	Plant spacing (m)	Row spacing (m)	Age of crop (years)	Sowing Date	Harvesting Date
Block-I	Row crops	Proposed	Citrus	15	4.57	4.57	1 year		
		Rotation							
Sub-Total: I									
Block-II	Orchards	Type-I							
		Type-II							
Sub-Total: II									
Block-III	Annual Crops								
Sub-Total: III									
Block-IV	Field Crops	Type-I							
		Type-II							
Sub-Total: IV									
Total / Design Value				15	4.57	4.57			

1

Water Sources

Soil type		Loamy Sand
Water Sources		
1) Canal		
Sanctioned Discharge (LPS)		56
Perennial / Non Perennial		Perennial
Warabandi (Days)		7
Water Availability	Hrs/Warabandi	8
	Volume (m3)	1612

13

EVAPOTRANSPIRATION AND CROP COEFFICIENTS (Eto & Kc)

Month	J	F	M	A	M	J	J	A	S	O	N	D
Eto (mm/d)	1.4	2.2	3.6	5.0	6.3	6.5	5.2	4.7	4.5	3.2	1.8	1.3
Kc (row crop)	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
CWR (row crop)	0.9	1.4	2.3	3.3	4.1	4.2	3.4	3.1	2.9	2.1	1.2	0.8
Kc (orchards)												
CWR (orchards)												
Kc (annual crop)												
CWR (annual crop)												
Kc (field crops)												
CWR (field crops)												

12

1.	Total area under HEIS	Acres	15
2.	Design reference evapotranspiration, ETo	mm/day	6.5
3.	Design Crop factor at maturity, Kc	-	0.65
4.	Plant spacing	m	4.57
5.	Row spacing	m	4.57
	Canopy Area	m ²	14.62
6.	Canopy Factor	%	70
7.	Irrigation system efficiency	%	90
	Optimum wetted width of each emitter	m	
8.	Emitter flow rate	LPH	8
	No. of emitters per plant	Nos.	4
10.	No. of drip lines per plant rows	Nos.	2
11.	Irrigation cycle (assume one day)	Days	1

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S.N	Parameters	Unit	Calculations
13	Peak daily consumptive use per day	Mm	= ETo * Kc * canopy factor/ efficiency = 6.5 * 0.65 * 0.7/0.9 = 3.29 mm
14	Total no. of plants	Nos	= Area x 4047 / (R-R * P-P) = 15*4047/(4.57*4.57) = 2,908
15	Total drip line length	M	= Area*4047x no of lines per plant row/L-L = 15*4047x2/(4.57) = 26,566
16	Total no. of emitters	Nos	= Total no. of plants x no. of emitters per plant = 2908x4 = 11,632
17	Average emitter spacing	M	2.3
18	Total flow rate	Lph	= total no. of emitters x emitter flow rate = 11632 * 8 = 93,056
19	Application rate	Mm/hr	Total flow rate / area = (93,056/1000)/(15*4047*1000) = 1.53
20	Operation time*	hrs	= Peak daily consumptive use/ Application rate = 3.29/1.53 = 2.15 hrs

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Drip design sheet-orchard

Sr. No	Parameters	Formula Description	Units	Zone I	Total
1	Total area under HEIS	A	Acres	3.75	15.00
2	Reference Evapotranspiration (ET)		Mm/d	6.50	
3	Crop Factor (Kc)			0.65	
4	Plant spacing		M	4.57	
5	Row spacing/ Lateral spacing		M	4.57	
6	Canopy Diameter	Cd	M	4.31	
7	Canopy Area	$Ca = 3.1416 \times \text{Canopy diameter}^2 / 4$	m ²	14.6	
8	Canopy factor at maturity	$Cf = \text{Canopy Area} / \text{Plant Spacing} \times \text{Lateral Spacing}$	Fraction	0.70	
9	Irrigation system efficiency		%	0.9	
10	Emitter flow rate		LPH	8	
11	Optimal wetted width of each emitter (30 cm) below soil surface at peak water demand)				
12	No. of emitter/dripper per plant		Nos.	4	
13	Emitter spacing along plant canopy				
14	No. of drip lines per plant row		Nos.	2	
15	Optimal distance between two Laterals		M		
16	Irrigation cycle (assume one day)		Days	1.0	
17	Peak daily consumptive use per day	$\text{Reference ET} \times \text{crop factor} \times \text{Canopy factor} / \text{Efficiency}$	Mm/d	3.28	
18	Total no. of plants	$\text{Area} \times 4047 / \text{Plant Spacing} \times \text{Lateral Spacing}$	Nos.	727	2907
19	Total drip line length	$\text{Area} \times 4047 \times \text{No. of drip lines per plant row} / \text{Lateral Spacing}$	M	6642	26,567
20	Total no. of emitters/drippers	$\text{Total no. of plants} \times \text{drippers per plant}$	Nos.	2907	11,627
21	Average emitter spacing	$\text{Total drip line length} / \text{Total no. of emitters}$	M	2.29	
22	Total flow rate	$\text{Total no. of emitters} \times \text{emitter flow rate}$	LPH	23,253	93,013
23			LPS	6.46	25.84
24			m ³ /hr	23.25	93.01
25	Application rate	$(\text{Total flow rate} / 1000) / (\text{Area} \times 4047) \times 1000$	Mm/hr	1.53	0.00
26	Operation time*	$\text{Peak daily consumptive use per day} / \text{Application rate}$	Hrs	2.14	8.56
27	Vol. of water req./operation/day	$\text{Flow} \times \text{operational time}$	m ³	50	199

Darcy- Weisbach and Blasius Equation can be combined to give accurate prediction of friction head loss for smooth plastic pipes of less than 125 mm (5 in.) diameter.

$$J = 100 \text{ hf/L} = k * [(Q^{1.75})/(D^{4.75})] * F$$

J = Head loss gradient, m/100 m

Hf = pipe friction head loss, m

K = Constant, $7.89 * 10^7$ for metric units

Q = Flow Rate, LPS

L = Pipe length, m

D = Inside Diameter of Pipe, mm

Lateral Design:

Lateral length = 73 m

No. of emitters = $73/2.3 = 32$

Lateral flow rate = $32 * 8 = 256$ lph

Assume 16 mm lateral line

Inside diameter = 14.2 mm

$$J = 7.89 * 10^7 * [(256/3600)^{1.75} / (14.2^{4.75})] * 0.36$$

$$J = 0.93 \text{ m/100 m}$$

For 73 m length

$$\text{Hf} = 0.68 \text{ m}$$

Particulars	Unit	H.Zone1
Lateral Length	m	73
Inside diameter	mm	14.2
Pipe material		PE
Pipe friction coefficient		150
Emitter spacing	m	2.29
No. of emitters	Nos.	32.00
Emitter flow rate	LPH	8
Lateral flow rate	LPH	256
Factor for multiple outlet	-	0.36
Fittings loss for emitters	m	0
Head loss (Watter & Keller)	m/100m	0.9
Head loss (Hazzen Willam)	m/100m	0.7
Total lateral head loss, h_f	m	0.68
Velocity	m/sec	0.45

Sub-Mainline Design:

Length = 100 m

Sub-main flow rate = 93056/4

=23,264 lph

Assume 71.4 mm ID

Sub-Mainline

$$J = 7.89 \times 10^{-7} \times [(23264/3600)^{1.75} / (71.4^{4.75})] \times 0.36$$

$$J = 1.21 \text{ m/100 m}$$

For 100 m length

$$H_f = 1.21 \text{ m}$$

Darcy- Weisbach and Blasius Equation can be combined to give accurate prediction of friction head loss for smooth plastic pipes of less than 125 mm (5 in.) diameter.

$$J = 100 h_f / L = k \times [(Q^{1.75}) / (D^{4.75})]$$

J = Head loss gradient, m/100 m

H_f = pipe friction head loss, m

K = Constant, 7.89×10^{-7} for metric units

Q = Flow Rate, LPS

L = Pipe length, m

D = Inside Diameter of Pipe, mm

Particulars	Unit	H.Zone1
Sub-Mainline Length	m	100
Inside diameter	mm	71.4
Pipe material		PVC
Pipe friction coefficient		150
Lateral spacing	m	2.29
No. of laterals operating	Nos.	91
Lateral flow rate	LPH	256
Sub-mainline flow rate	LPH	23296
Factor for multiple outlet	-	0.36
Head loss gradient (Watter & Keller)	m/100m	1.17
Head loss gradient (Hazen Willam)	m/100m	1.21
Total head loss, h_f	m	1.21
Velocity	m/s	1.62

Mainline Design:

Length = 213 m

Main-line flow rate = 23264 LPH

Assume 84.4 ID Mainline

$$J = 7.89 \times 10^{-7} \times [(23264/3600)^{1.75} / (84.4^{4.75})]$$

$$J = 1.46 \text{ m/100 m}$$

For 213 m length

$$H_f = 3.17 \text{ m}$$

$$V = 1.274 \times [(23264 / (1000 \times 3600))] / [(84.4 / 1000)^{2}] = 1.16 \text{ m/s}$$

Particular	Unit	Section
		1
Length	m	213
Inside diameter	mm	84.4
Pipe material		PVC
Pipe friction coefficient		150
Design capacity	LPH	23253
Head loss gradient (Watter & Keller)	m/100 m	1.46
Head loss gradient (Hazen Willam)	m/100m	1.49
Mainline fittings losses	M	0
Flow velocity	m/s	1.16
Total mainline head loss	M	3.17

TOTAL DYNAMIC HEAD

- Emitter operating pressure = 10 m
- Head loss in lateral = 0.68 m
- Lateral Elevation = 0 m
- Head loss in submains = 1.16 m

- Head loss in Valve (assume 2 m) = 2.0 m
- Field fitting head loss = 2.0 m
- Head Loss in Main line = 3.12 m
- Primary filter head loss (Gravel 20 m³) = 1.5 m
- Secondary filter head loss (Disc 20 m³) = 1.3 m
- Fertigation equipment head loss (5 m for ventury) = 5 m
- Water source depth = 0 m
- Suction head = 1 m
- Delivery head = 1 m
- Safety equipment head loss = 2 m
- Elevation difference = 0 m
- Other losses = 0 m
- Total Head Required = 30.76 m

Say 31 m

Total Flow Required = 23,264 m³/hr = 6.46 lps

$$\begin{aligned} \text{Pump H.P} &= Q \text{ (LPS)} * H \text{ (m)} / (75 * \text{pump efficiency} * \text{motor efficiency}) \\ &= 6.46 * 30.76 / (75 * 0.65 * 0.9) \\ &= 4.56 \end{aligned}$$

Say 5 H.P

Sample Bill Of Quantities						
S.N	Description	Standard/ specification	Unit	Quantity	Rate (Rs.)	Cost (Rs.)
1	Pump set (20 HP)	KSB/MECO/X	No	01	80,000	80,000
2	Gravel Filter 40 M ³ /Hr	40 M ³ /hr, Jain		02	40,000	80,000
3	Disc filters	40 M ³ /hr, Netafim		02	25,000	50,000
4	Ventury with assembly			01	7,500	7,500
5	Flow Meter	80 M ³ /hr , Kitz		01	65,000	65,000
6	Pressure Gauges			05	1,100	5,500
7	Air Release valves			02	1500	3,000
8	NRV			01	15,000	1,500
9	Foot valve			01	10,000	10,000
10	Flush valves (sub-main)			02	3,000	6,000
11	GI Pipe	110 mm	m	5	2,000	10,000
12	GI Fittings	110 mm	L/s	1	10,000	10,000
13	PVC Pipe , B Class	160 mm	m	60	700	42,000
14	PVC Pipe, B Class	110 mm	m	225	370	83,250
15	Plain Lateral	16mm	m	500	20	10,000
16	Lateral line 2lph x 0.4 m spacing, wt 1.5 mm	16 mm	m	18,000	25	450,000
17	GTO		Nos.	290	15	4,350
18	Lateral End Stop		Nos.	290	10	2,900
	Sub-Total					921,000
	Service charges (Design, Installation, Service)	8% of total				73,680
	Grand Total					994,680

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Example Orchard-3

Given Information

Crop	Citrus
Spacing	6m x 6m
Area	20 Ac
Eto	7 mm/d
Kc	0.7
Time available	12 Hours
Water available	18m3/hr
Open well	6m dia x 8m deep
Soil	Loam

Limitations

Button Dripper	8 lph X 4 per Plant
Lateral	12mm
Plot size	180m x 450m

Total Area = $450 \times 180 = 81000 \text{ m}^2$

PWR = Eto x Kc x canopy factor / efficiency

$$= 6 \times 0.7 \times 0.6 / 0.9 = 2.8 \text{ mm/d}$$

Total drip line length = Area x no. of drip lines per plant row / (lateral spacing)

$$= 81000 \times 1 / 6 = 13500 \text{ m}$$

Total number of plants = Area / (plant spacing x row spacing)

$$= (81000 / (6 \times 6)) = 2250$$

Total number of emitters = No. of plants x Dripper per plant

$$= 2250 \times 4 = 9000$$

Total number of emitters = No. of plants x Dripper per plant

$$= 2250 \times 4 = 9000$$

Average emitter spacing = $13500 / 9000 = 1.5 \text{ m}$

Total flow rate = no. of emitters x emitter flow rate

$$= 9000 \times 8 \text{ lph} = 72,000 \text{ lph}$$

Application Rate = Flow rate/ area

$$= 72000 / 81000 = 0.89 \text{ mm/h}$$

Operation time per day = PWR/ Application Rate

$$= 2.8 / 0.89 = 3.15 \text{ hours}$$

Capacity of the water source is 18000 lph, we will divide the area into shifts

No. of shifts/hydro-zone = $72000 \text{ lph} / 18000 \text{ lph} = 4$

Wetted percentage =

no. of emitters x Area wetterd by single emitter/plant Area

$$= 4 \times 4 / (6 \times 6)$$

$$= 44\%$$

If we go with 6 drippers per plant, then percent wetted area will result about 66%.

A) Lateral Selection

(12 mm OD WT = 0.9 mm)

Length, m = 90 m

Inside diameter, mm = 10.2 mm

Flow rate, lph = $(90/1.5) * 8 = 480$ lph

Head loss using Hazzen-William Equation: $(6.1 \text{ m}/100 \text{ m} = 3.4 \text{ meters})$

PLZ CHECK CALCULATION

B) Sub-Mainline Selection

Length, m = 112.5 m

Inside diameter, mm = 60.0 mm

Flow rate, lph = 18,000 lph

Head loss using Hazzen-William Equation: $2.1 \text{ m}/100 \text{ m} = 2.34 \text{ meters}$

C. Mainline Selection

Length, m = 517.5 m

Inside diameter, mm = 68.0 mm

Flow rate, lph = 18,000 lph

Head loss using Hazzen-William Equation: $2.61 \text{ m}/100 \text{ m} = 11.72 \text{ meters}$

Velocity = 1.38 m/seconds

A) Lateral Selection

(12 mm OD WT = 0.9 mm)

Length, m = 45 m

Inside diameter, mm = 10.2 mm

Flow rate, lph = $(45/1.5) * 8 = 240$ lph

Head loss using Hazzen-William Equation: 3.1 m/100 m = 1.4 meters

B) Sub-Mainline Selection

Length, m = 112.5 m

Inside diameter, mm = 60.0 mm

Flow rate, lph = 18,000 lph

Head loss using Hazzen-William Equation: 2.1 m/100 m = 2.34 meters

C. Mainline Selection

Length, m = 337.5 m

Inside diameter, mm = 68.0 mm

Flow rate, lph = 18,000 lph

Head loss using Hazzen-William Equation: 2.61 m/100 m = 11.72 meters

Velocity = 1.38 m/seconds

TDH = 45 m

Q = 18000 lph

H.P ?

6.5 DRIP DESIGN PROCEDURE-STEP BY STEP (ROW CROP)

Under the on-going project, drip systems are being installed on orchard and at row crops/vegetables. In this section, steps for designing a drip system for row crop will be discussed. The following are the design steps.

1. Collection of Basic Information
2. Estimation of Peak Water Requirement PWR
3. Drawing of project area, selection of zone area and No. of Operations
4. Selection of emitter/dripper, and flow rate
5. Calculation of total length of lateral No. of emitters in one zone and total No. of emitters
6. Calculation of Total Flow rate requirement (Q)
7. Calculation of Application Rate
8. Total Operational Time
9. Selection and Design of Lateral Line
10. Design of Sub-mainline
11. Design of Mainline
12. Head Loss through fittings
13. Selection of Filters and other equipment and head loss
14. Calculation of total dynamic head (H)
15. Calculation of required horsepower (HP)
16. Selection of Pumps and Motor
17. Preparation of Drawing
18. Preparation of Bill of Quantities

Step 1. Collection of Basic Information

The following basic information be available before designing a drip irrigation system.

- General information: Name of farmer, village/chak No., tehsil, district, phone No.
- Land holding and Area spared for the project
- Engineering survey: GPS coordinates, Field measurement, Elevation difference/slope. After field measurement, a map showing all dimensions and location of water source be drawn
- Agricultural details: crops (orchard, row/field crop), spacing, type, age, reference evapotranspiration of the area and water requirement of crop
- Crop Spacing (Row to Row, Plant to Plant), sowing and harvesting date
- Soil Type/texture
- Soil and water analysis reports water quality, presence of iron, pH, suspended particles, soil type, Ec, pH
- Water Source, quantity, availability, location
- Power Source: Electric motor, diesel engine, tractor, solar system
- Climatologically data: temperature, humidity, rainfall, wind speed
- Peak Water Requirement: (ET_o, K_c, C_f)
- Water source and Total Available Time of water
- System capacity: The system should have capacity adequate to fulfill daily crop water requirements of the area within a stipulated time or not more than 12 hours of operation per day (only for Pakistan circumferences, otherwise may be 22 hrs).

The basic information can be categorized as under.

I. GENERAL INFORMATION

Name of beneficiary		Town/Village/City	
Tehsil		District	
Province		Phone No.	
Land holding (Acre)		Scheme area (acres)	
Topography (Flat/Undulated)			

II. CROP INFORMATION

Parameters			Crop	Area (acres)	Plant spacing (m)	Row spacing (m)	Age of crop (years)	Sowing date	Harvesting date
Block-I	Row Crop	Proposed	COTTON	20	0.5	1.52		MARCH	NOV.

III. EVAPOTRANSPIRATION AND CROP COEFFICIENTS (Etc & Kc)

Month	J	F	M	A	M	J	J	A	S	O	N	D
Eto (mm/d)	1.8	2.7	4	6.4	8.6	9.2	7.6	6.5	5.8	4.5	2.7	1.9
Kc (cotton)				0.5	0.8	1	1.29	1.2	0.9	0.7	0.7	
Crop factor at mat.				0.4	0.7	1	1	1.1	1	1	0.7	
Efficiency				0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
PCWR (cotton)				1.42	5.35	10.2	10.89	9.53	5.80	3.50	1.37	
Kc ()												
Crop factor at mat.												
PCWR ()												
Kc (field crops)												
CWR (field crops)												

IV. SOIL TYPE/SOIL TEST/WATER SUPPLY/WATER QUALITY**SOIL TEST**

Soil type/Texture				LOAMY
Soil limitation (soil analysis report attached)				
Soil EC , PH , N , P , K , SAR				
WATER SUPPLY				
Available water sources				
1) Canal				WATER SOURCE IS CANAL AND TUBEWELL
Sanctioned discharge (LPS)				42.46 LPS
Perennial/non-perennial				NON-PERENNIAL
Warabandi (days)			Hrs/Warabandi	48 HOURS PER WEEK
Water availability			Volume (m3)	7337 (1048 CUBIC METERS PER DAY)
2) Groundwater				
a) Dug well				
Depth of well				
Diameter of well				
Recharge rate				
b) Tube well/bore well				
Discharge capacity (LPS)				42.46
Diameter of bore (inches)				8
Depth of water table from ground (m)				9.15
3) Storage/reservoir capacity (m3)				827(20.3x20.3x2m) for 1 day
Water quality (detailed report attached)				
			Iron	
			Ph	
			EC(mmohs/cm)	
Distance of water source from field (m)				

V. POWER SOURCE AND PUMP

POWER SOURCE	
Type of power to be used	
For electric Motor, Type of connection (single/3-phase) Make/model HP of Motor RPM of Motor	ELECTRICITY NOT AVAILABLE
For diesel engine Make HP Condition)	
For Tractor Make/model HP Condition	
Any other power source, if any	
PUMP SET	
Type Make/Model Pressure (ft/psi/bar) Flow(lps) Inlet/outlet size RPM Pulley size	

Water Analysis Report

Farmer Name : Abbass Qureshi			Water Source		Tube Well
Address : Muzaffar garh			Sampling Date		10/5/2010
Ph :0345-8644888			Sp Receive Date :		13/05/2010
Agronomist: Ather Mehmood Khursheed			Report Date :		31/05/2010
			Ref. Sample	#	372
Parameters	Degree of Presence / Problem				Lab Result
	Unit	Nominal	Higher	Extreme	
pH		7	<7 Acidic	>7 A	7.37
Electrical Conductivity (Salinity)	microsemens/cm	-	-	-	2240
Total dissolved solids	ppm	<500	500 - 600	>600	1290
Hardness	ppm	<200	200 - 300	>300	312
Calcium	ppm	<60	60 - 100	>100	78.4
Magnesium	ppm	<25	25 - 40	>40	28.21
Carbonate	ppm	<200	200 - 600	>600	72
Bicarbonate	ppm	<200	200 - 600	>600	176
Chloride (Toxic)	ppm	<140	140 - 350	>350	198.5
Sulphates	ppm	<20	20 - 50	>50	23.4
Sodium	ppm	<100	100 - 200	>200	235
SAR	-	<3	3-9	>9	2
Potassium	ppm	<10	10 - 20	>20	12
Sulphides	ppm	<15	15-25	>25	-
Iron	ppm	<0.1	0.1 - 0.4	>0.4	0.1
Manganese	ppm	<0.2	0.2 - 0.4	>0.4	-
Suspended solids	ppm	<10	10 - 100	>100	7.1
Boron	ppm	<0.5	0.5 - 2.0	>2.0	-

Soil Analysis Report

Farmer Name :		Abbas Qureshi		Block Size :							
Address :		Muzaffargarh		Sampling Date :		11/5/2010					
Ph :		345864488		Sp Receive Date :		13/05/2010					
Agronomist :		Ather Mehmood Sheikh		Report Date :		26/04/2010					
				Code :		AMK-S001					
Ref.S oil Sample #	Block #	Depth (inches)	Texture	Organic Matter %	pH	Electrical Conductivity (mic/cm)	Phosphorus (P) (ppm)	Potassium (K) (ppm)	Soluble & Exch . Na (meq /L)	Soluble & Ca +Mg (meq /L)	SAR
					Neutral 6.5-7.5 Alkaline >8.5		Poor <7.0 Medium 7-13 Satisfactory >13	Poor <125 Medium 125-250 Satisfactory >250			Normal <10.0 Sodic >10.0
2835	1	0 - 6"	Sand, Clay	0.245	8.44	411	-	110	6.52	3.2	4
2836		6 - 12"	Sand, Clay	0.582	7.74	468	-	120	6.95	3.2	4.3
2837	2	0 - 6"	Sand, Clay	0.827	8.15	572	-	110	11.73	3.1	7.5
2838		6 - 12"	Sand, Clay	0.612	8.26	550	-	110	10.43	2.7	7.7
2839	3	0 - 6"	Sand, Clay	0.612	8.29	316	-	90	6.52	3.4	3.8
2840		6 - 12"	Sand, Clay	0.735	8.39	304	-	90	6.95	3.7	3.7
2841	4	0 - 6"	Sand, Clay	0.821	8.21	384	-	100	6.08	3.2	3.8
2842		6 - 12"	Sand, Clay	0.735	8.25	358	-	100	6.52	3.2	4
2843		0 - 6"	Sand, Clay	1.01	8.02	506	-	150	4.34	5.1	1.7
2844		6 - 12"	Sand, Clay	0.98	8.02	494	-	160	4.34	4.2	2

2845	6	0 - 6"	Sand, Clay	1.041	8.05	41 2	-	120	4.34	4.2	2
2846		6 - 12"	Sand, Clay	0.919	8.11	35 6	-	100	4.34	4.2	2
2847	7	0 - 6"	Sand, Clay	0.919	7.97	10 80	-	80	10.8 6	6.6	3.2
2848		6 - 12"	Sand, Clay	0.549	8.02	11 23	-	80	11.7 3	5.8	4

It is advisable to make rough map of the area and mark salient features, divide the drawn map into different blocks and number the same for soil and water sampling. This map will be finalized during designing of drip irrigation system and will show all necessary details including drippers, dia, length and location of laterals, submain and main, location of water source, power source etc.,

Step 2. Estimation of Peak Crop Water Requirement

Estimating the reference crop evapotranspiration (**ET_o**), using the Penman-Monteith method, and the crop evapotranspiration (**ET_c**), through the use of the appropriate crop factor **K_c**, have been covered in Module 4 Chapter_____ of this Manual. Evapo-transpiration is composed of the evaporation from the soil and the transpiration of the plant. Since under localized irrigation only a portion of the soil is wetted, the evaporation component of evapotranspiration can be reduced accordingly, using the appropriate ground cover reduction factor K_r.

For the design of surface and sprinkler irrigation systems:

$$ET_c = ET_o \times K_c$$

For the design of Drip irrigation systems:

Water Requirements for Orchard $ET_c = ET_o \times K_c \times \text{Canopy Factor} / \text{Efficiency}$

Percent area wetted, 100% for closely spaced crops with rows and emitter lines less than 1.8m.

Peak Crop Water Requirement can be tabulated as under.

Month	J	F	M	A	M	J	J	A	S	O	N	D
Eto (mm/d)	2.1	2.7	4.2	5.6	7	7.9	7.3	6.8	5.9	4.8	3.3	2.3
Kc (citrus)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
		0.5	0.5	0.5	0.5		0.5	0.5	0.5	0.5		
Crop factor at mat.	0.57	7	7	7	7	0.6	7	7	7	7	0.6	0.57
Efficiency	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
PCWR (citrus)	0.93	1.2 0	1.8 6	2.4 8	3.1 0	3.5 0	3.2 4	3.0 1	2.6 2	2.1 3	1.4 6	1.02
Kc (mango)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
		0.5	0.5	0.5	0.5		0.5	0.5	0.5	0.5		
Crop factor at mat.	0.55	5	5	5	5	0.6	5	5	5	5	0.6	0.55
PCWR (mango)	1.41	1.8 2	2.8 2	3.7 6	4.7 1	5.3 1	4.9 1	4.5 7	3.9 7	3.2 3	2.2 2	1.55
Kc (field crops)												
CWR (field crops)												

Step 3. Drawing of Project Area, Selection of zone area and No. of Operations

A map of the scheme area be drawn and tentative number of zones having equal area of the project be selected to estimate number of operations. It is advisable that area of each of each zone must be equal so that all the discharge coming out from the pump be fully utilized in each zone area. In case all zones are not equal, some additional water has to be sent back to the water storage tank through bypass valve during irrigation of small area zones.

Zone # 1 to 7
 12mm lateral; Spacing 5ft
 4lph, 50cm emitter spacing
 Crop: Cotton
 Area: 20Acre
 Flow: 16.86lps
 Irrigation Time: 1hrs 45min

Ghulam Abbas Qureshi Farm			
Area:	20 Acre	Crop:	Cotton
Designed By:	Arif ul Rehman	Scale:	1:2500
Date:	09/02/2010	Code:	AI-011
JAFFER BROTHERS (PRIVATE) LTD Citi Towers, 33-A, Block-6, P.E.C.H.S Shahrah-e-Faisal, Karachi-75400 (Pakistan) UAN: 111-527-527			

Step 4. Selection of Emitter/Dripper and Flow Rate

Varieties of drippers/drip tubing are available with different discharge rates, dripper spacing, characteristics and suitability for different crops. The emitter selected for the drip system:

- Should be Inexpensive, durable and serviceable
- Should have relatively low discharge rate to keep the system cost low
- Should have higher emission uniformity (90%) and low coefficient of variation (CV 5%)
- Should have emission discharge exponent in the range of 0.4-0.7.
- Should have relatively large cross sectional area and flow path to avoid clogging
- Should have turbulent flow path and pressure compensation action
- Should not create runoff within the immediate application area

Drippers are available for 2, 4, 8 and 12 LPH discharge. Emitter operating pressure is usually 10m. The shape of the wetted zone of the emitter depends on the physical properties

In sandy and light soil , the water will tend to go straight down, and there will be less lateral movement as compared to downward movement. In light soils, the distribution of the water will be narrow and deeper	(close spaced low discharged emitters/Closer emitter spacing)
In loamy soil , the water will move slowly and will spread evenly	(average discharged emitter &/or Spacing)
In clay soil , the water will be absorbed very slowly and there will be more lateral movement as compared to downward movement. In heavy soil, the distribution of the water will be relatively spherical shape, wider and less depth.	wider emitter spacing

- Heavy soil recommended distance: 0.50 to 1.00 meter*
- Medium soil recommended distance: 0.40 to 0.75 meter*
- Light soil recommended distance:
- 0.20 to 0.50 meter*
- *The spacing between drippers depend on the root depth of the crop.

Emitter spacing should be maximum 0.5m, 0.4-0.6 and 0.5-0.8m in light, medium and heavy soil respectively.

Most of the water emitter flow regime is fully turbulent with an exponent value equal to 0.5. In order to ensure a high uniformity of water application over the field, the differences in the discharge of the emitters should be kept to the minimum possible and in no case exceed 10 percent. These criteria were established by J. Christiansen for sprinklers and are now applied in all pressurized systems. As a general rule, the maximum permissible difference in pressure between any two emitters in operation should be no more than 20 percent. **The lateral lines with emitters must be of a size that does not allow a loss of head (pressure) due to friction of more than 20 percent. In case emitter operating pressure is 01 bar or 10 meter, the head loss in the selected lateral must not be more than 02 meter.**

Step 7. Calculation Of Total Length Of Lateral, Number Of Emitters In One Zone And Total Number Of Emitters

The length of lateral required for the scheme area under micro irrigation system can be calculated as follows:

Row Crops: Single Lateral per plant row

$$L = K \cdot A / L_s \quad (4.19)$$

$$K = 4047$$

$$A = \text{Area (acres)}$$

$$L = \text{Lateral length (m)}$$

$$L_s = \text{Lateral spacing, m}$$

Similarly, lateral length for sprinkler system can be calculated as

$$L = A \times K / L_s \quad (4.21)$$

TOTAL NUMBER OF EMITTERS

Total no. of emitters in a scheme area or in a zone, can be calculated using following relationship.

Row crops:

$$\text{Total number of emitters } e = \text{Total lateral length} / \text{Emitter spacing} \quad (4.23)$$

Step 8. Calculation of total flow rate requirements (lph)

For micro irrigation system, total flow rate required for the hydro-zone and/or scheme area can be calculated using the following relationships.

For Row Crops:

$$Q = e \times q \quad (4.26)$$

$$Q = L \times q \times S_e \quad (4.27)$$

Where,

e = Total number of emitters

q = Emitter flow rate

L = Lateral length

S_e = Emitter spacing

Q = Total flow rate

Step 9. Calculation of application rate (mm/hr)

Application rate is the depth of water uniformly distributed over the entire scheme area and can be estimated using following relationship.

$$I = Q / A$$

I = Application Rate (mm/hr)

Q = Total flow rate, Lph

A = Area, m²

Step 10. Total operation time (hrs)

Operation time required to provide irrigation depth to meet daily consumptive use can be estimated using following relationship. The same relationship can be applied for both the Micro Irrigation system and sprinkler irrigation system.

$$T = Cu / I$$

T = Daily Operation time, hrs

EXAMPLE ROW CROP:

Total area under HEIS : 20 Acres

ET_o mm/day : 7.6

K_c : 1.29

Canopy factor : 1

Plant spacing m : 0.5

Row Spacing m : 0.5

Emitter Flow Rate : 4 LPH

Calculate Design Steps from 1-8

Solution:

Table _____ indicates calculation of all parameters.

Sr. No.	Description	Formulas		Unit	Zone I to VII	Total
1	Area		A	m ²	80940	80940
2	Total Area under HEIS			ac	20.00	20.00
3	Avg. Sectional Area			ac	2.86	
	Avg. Sectional Area			m ²	11563	
	No. of zones			Nos.	7	7.00
4	Lateral dia		B	mm	12	12
5	Emitter flow rate		C	lph	4	4
6	Emitter Spacing		D	m	0.5	0.5
7	Lat-Lat Spacing		H	m	1.52	1.52
	No. of crop rows per drip line				2	
	Irrigation cycle				1	
	Allowable HL in Lateral			m	2	2
	Internal Diameter of lateral			mm	10.7	10.7
	Max. Permissible Length			m	38	38
8	Design reference evapo-transpiration (Eto)		Eo	mm/day	7.6	
9	Design crop factor at maturity (Kc)		F	ratio	1.29	
10	Canopy factor Cf		G	ratio	1	1
	Shaded area				100%	
11	Irrigation Efficiency		Ef	%	90%	90%
12	Peak Water Requirement PWR(peak daily consumptive use per day)	$I = E_o * K_c * C_f / E_f$	$I = E_o * F * G / E_f$	mm/day	10.89	

Sr. No.	Description	Formulas		Unit	Zone I to VII	Total
14	Total No. of Emitters	=Area/lat-lateral spacing*Emitter spacing	M=L/D	Nos.	15214	106500
15	Total Flow	=Area*emitter flow rate/lat-lateral spacing*Emitter spacing	N=M*C	lph	60857	
				lps	16.90	
	Application Rate(method-1)	Total flow/total area		mm/hr	5.26	
16	Application Rate(method-2)	=Emitter flow rate/(lat-lat spacing * emitter spacing)	O=C/(H*D)	mm/hr	5.26	5.26
17	Duration per operation	=Peak water requirement/application rate)	P=I/O	hrs	2.07	0.00
	No. of zones/operations			Nos.	7	7
18	Total Irrigation Time		Q=P*J	hrs	14.49	0.00
19	Flow Per Operation	=Total flow/# of zones	R=N/J	m3/hr	8.69	60.86
20	Flow Per Operation			lps	2.41	16.90
21	Flow Per Operation			IGPM	31.92	223.41
22	Vol. of water req./operation/day			m3	125.96	882

Questions: 1. Is total irrigation time per day is less than 12 hours

2. Do we have required volume of water per day

If yes OK

If no

Reduce area and repeat the design process

6.6 Selection and Design of Lateral Line

Laterals are available in different sizes i.e. 12 mm, 16 mm and 20 mm. Head loss in the lateral length between the first and last emitter should not exceed by 20% of the head available at the first emitter to keep flow variation within 10% so as 90% of application uniformity can be achieved.

The design of lateral pipe involves selection of required pipe size for a given length which can require quantity of water to the plant. This is the most important component of the system as large amount of pipe per unit of land is required and the pipe cost is such that system is economically viable.

In designing the lateral, the discharge and operating pressure at emitters are required to be known and accordingly, the allowable pressure drop can be determined by the same formula as the main line. The total friction head loss in lateral can be calculated by multiplying the head loss over the total length by a factor F given in **Table 5.2**.

$$\text{Lateral Head loss} = h_f \times F$$

Criteria: Allowable pressure drop in sub-mainline and laterals depends upon the operating pressure required at emitters. The pressure difference between the proximate and distant point along the supply line should not exceed 20% which will keep the variation of discharge within 10% of its value at the first emitter. The emitter operating pressure is usually 10 m, therefore, the maximum allowable head loss in a lateral should be less than 20% of emitter operating pressure i.e. 2m.

Table 5.2 Reduction Coefficient 'F' for Multiple Outlet Pipeline Friction Loss

No. of outlets	F	No. of outlets	F
1	1	8	0.42
2	0.65	10 to 11	0.41
3	0.55	12 to 15	0.40
4	0.50	16 to 20	0.39
5	0.47	21 to 30	0.38
6	0.45	31 to 37	0.37
7	0.44	38 to 70	0.36

EXAMPLE LATERAL DESIGN:

Assume:

Flow per dripper = 4 LPH

Dripper to dripper spacing = 0.5 m

Lateral diameter = 12mm (inside diameter= 10.7 m)

What should be maximum permissible length of lateral to have a head loss of 2m= ?

Solution:

Particulars	Unit	H.Zone1
Lateral Length	m	29
Inside diameter	mm	10.8
Pipe material		PE
Pipe friction coefficient		150
Emitter spacing	m	0.5
No. of emitters	Nos.	58
Emitter flow rate	LPH	4
Lateral flow rate	LPH	232
Factor for multiple outlet	-	0.36
Fittings loss for emitters	m	0
Head loss (Watter & Keller)	m/100m	2.9
Head loss (Hazen Willam)	m/100m	2.4
Total lateral head loss, h_f	m	0.84
Velocity	m/sec	0.70

Emitter operating pressure=	10
Required lateral head loss (20%)=	2
Calculated lateral head loss =	0.84
	OK

Lateral is Selected

Step 13. Design of sub-main line

On the manifolds, whether these pipelines are the sub-main or the mains as well, a number of laterals are fed simultaneously. The flow of the line is distributed en route, as in the laterals with the emitters. Consequently, when computing the friction losses.

The mains, sub-main and all hydrants are selected in such sizes that the friction losses do not exceed approximately 15 percent of the total dynamic head required at the beginning of the system's piped network. On level ground, these friction losses amount to about 20 percent of the emitter's fixed operating pressure. This is a practical rule for all pressurized systems to achieve uniform pressure conditions and water distribution at any point of the systems. The above figure should not be confused with or related in any way to the maximum permissible friction losses along the laterals.

Criteria

- Maximum Water Velocity in sub-main and mainline= 1.5 m/s
- Maximum Frictional Losses in sub-main = 2m
- Maximum Frictional Losses in mainline = 20m per 1000m length
- Hazen Williams Equation for Frictional Losses

Assume:

Flow per dripper = 4 LPH

Dripper to dripper spacing= 0.5 m

Lateral to lateral spacing = 1.52 m

Sub-main diameter = 3 inch= 75 mm (inside diameter= 71.2 mm)

What should be sub-main maximum permissible length to have a head loss of 2m= ?

Particulars	Unit	H.Zone1
Sub-Mainline Length	m	50
Inside diameter	mm	71.2
Pipe material		PVC
Pipe friction coefficient		150
Lateral spacing	m	1.52
No. of laterals operating	Nos.	
Lateral flow rate	LPH	
Sub-mainline flow rate	LPH	30000
Factor for multiple outlet	-	0.36
Head loss gradient (Watter & Keller)	m/100m	1.84
Head loss gradient (Hazen Willam)	m/100m	1.97
Total head loss, h_f	m	1.0
Velocity	m/s	2.09

Sub-main is selected

STEP 14: Selection and Design of Mainline

CRITERIA:

- Should be selected based on the quantity of water, length, elevation of ground, velocity, cost etc.
- Permissible velocity : Less than 1.5 m/s
- Frictional losses : Less than 2 m/100 m
- Economics: Less initial and annual operating cost
- Elevation and Class of Pipe: Pipe class affects the system cost, use appropriate pressure class pipe and try to lay the pipe at same elevation
- Control measures: Pressure relief valves at appropriate location i.e., where elevation changes

EXAMPLE

Assume

Mainline length = 418 m

Diameter = 6 inch= 150 mm (inside diameter= 133 mm)

Designed discharge= 60700 lps

Material is PVC (C=150)

Calculate friction loss and check velocity

Particular	Unit	Section
		1
Length	m	418
Inside diameter	mm	133
Pipe material		PVC
Pipe friction coefficient		150
Design capacity	LPH	60700
Head loss gradient (Watter & Keller)	m/100 m	0.90
Head loss gradient (Hazen Willam)	m/100m	0.96
Mainline fittings losses	m	0
Flow velocity	m/s	1.21
Total mainline head loss	m	4.01

Main line is selected

6.7 Head Loss Through Fittings

The three conventional methods for computing the additional pressure-head losses from special equipment, valves, pipe and fittings are: (1) graphing friction loss vs. flow rate, (2) expressing the added pressure head loss as the length of pipe (of the same diameter) that would give the same loss, and (3) expressing the loss in terms of a velocity head coefficient. Following **Equation 5.5** can be used for computing friction head loss caused by a specific fitting (h_e), feet.

$$h_e = K_f \frac{V^2}{2g}$$

Where;

K_f = friction head-loss coefficient for a specific fitting.

$V^2/2g$ = velocity head, which is the energy head from the velocity of flow, feet or m.

K_f values should be supplied by manufacturers or taken from handbooks on hydraulics. Usually the losses attributed to standard pipe fittings are small and can be grouped in a miscellaneous friction-loss or safety factor.

Step 15. Selection of Filters and their Head Loss

There are four kinds of filters used in different combination depending upon source of water

- Hydrocyclone Filter (H)
- Sand Media (S)
- Disc Filter (D)
- Screen filters

Application:

- H+S+D = When Water quality is very bad, contains silt particles
- S+D = Open Well, Tank, Pond, Reservoir, Canal
- H+D = Borewell
- D (only) = When water is very clean

To prevent solid particles in the water from penetrating the irrigation system and clogging the drippers

- Source of water
- Type, size and concentration of physical impurities
- Type of irrigation system
- Ease of handling, cleaning, maintenance and repairing
- Filtration media and frictional losses
- Economical investment, maintenance and power cost

Sand Media Filter

Hydrocyclone Filter

Selection of Valves

- The Valve can take upto 40% more flow than the pipe flow rate. Hence the Valve size can be one size less than the Pipeline Size
- The Friction loss in the Valve will be upto 2m approx.

6.8 TOTAL DYNAMIC HEAD

Total Dynamic head is the total pressure required to provide the required pressure at the end of the last emitter. It is calculated as follows

Total Dynamic Head = suction head + delivery head + filter losses + mainline losses + sub-mainline losses + lateral loss + Fertigation system loss + fitting loss + - elevation difference + operating pressure

Emitter operating pressure	m	10
Elevation difference	m	0
Total Head Loss (Pipe network)	m	9
Fitting loss Lateral	m	0.1
Fitting loss Mainline	m	0.6
Fitting loss Sub-mainline	m	0.6
Fitting loss Head unit	m	0.7
Head loss in filters	m	12
Head loss in fertigation system	m	4
Head loss in flow meter	m	1
Field fitting losses	m	0
Miscellaneous head loss	m	2
Pumping lift	m	2
Total Dynamic Head	m	42

Total pipe network headloss/Total Dynamic Head (%)= 25 %

Total pipe network HL < 25% of Total Dynamic Head

Lateral head loss may be less than 20% of the emitter operating pressure

Flow velocity less than 1.5 m/sec

Main line and submainline head loss may be less than 1m/100m

Step 17. Calculation of Required Horse Power

Pumps and lifting/propelling devices are often classified on the basis of the mechanical principle used to lift the water: direct lift, displacement, creating a velocity head, using the buoyancy of a gas or gravity. Most categories sub-divide into further classifications “reciprocating/cyclic” and “rotary”. Virtually all water lifting devices can best be characterized for practical purposes by measuring their output at different heads and speeds. Normally the performance of a pump is presented on a graph of head versus flow (an H-Q graph) and in most cases curves can be defined for the relationship between H and Q at different speeds of operation. Invariably there is a certain head, flow and speed of operation that represents the optimum efficiency of the device, i.e. where the output is maximized in relation to the power input. Some devices and pumps are more sensitive to variations in these factors than others; i.e. some only function well close to a certain design condition of speed, flow and head, while others can tolerate a wide range of operating conditions with little loss of efficiency.

- Selection of Pump and Motor depends on Flow and pressure required for system.
- Pressure is calculated after adding all the losses of the system and pressure required at emitters.
- An approximate HP for motor is calculated as follows:
-

$$HP = \frac{Q \times H}{75 \times E1 \times E2}$$

where:

Q is discharge, LPS

H is the total head, m;

E1 is the pump efficiency (fraction in the order of 0.5-0.8); and

E2 is the driving efficiency (fraction of 0.7-0.9 for electric motors and 0.5-0.75 for diesel engines).

The overall pumping efficiency under field conditions ranges accordingly from 0.35 in engine driven units to 0.50 in motor driven pumps. Higher efficiencies are not realistic.

(Always rely on manufacturer chart to know the actual horse power)

VIII) Pump & Motor Requirement

PUMP REQUIREMENT	Unit	
Capacity	(LPH)	60840
Head	(m)	42.0
Motor efficiency	(%)	0.5
Pump Efficiency (%)	(%)	0.6
Pump H.P required	H.P	32

Step 18. Selection of Pump and Motor

Curves for pump selection KSB - ETA 65-200

Impeller outlet width/Largeur à la sortie de la roue
17.0 mm
17.0 mm

Step 19. Preparation of drawing

Zone # 1 to 7
 12mm lateral; Spacing 5ft
 4lph, 50cm emitter spacing
 Crop: Cotton
 Area: 20Acre
 Flow: 16.86lps
 Irrigation Time: 1hrs 45min

Ghulam Abbas Qureshi Farm			
Area:	20 Acre	Crop:	Cotton
Designed By:	Arif ul Rehman	Scale	1:2500
Date:	09/02/2010	Code:	AI-011
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Step 20. Preparation of bill of quantities BOQ

Bill of Quantities is divided into following subsets:

- Pump Set, Head Unit, Valves, PVC Pipes and Fittings, Emitting System

Name of beneficiary:		GHULAM ABBAS QURESHI		Designer Name:		Anif ul Rehman	
Address:		ABBAS PLAZA MUZAFERGARH		Agronomist Name:		M. Saqib	
Contact Number:				Area (ac):		20	
Proposed at Design / BOQ-Memoona Sultana-AH931						Date:	11/2/2010
	MAKE	MODEL	SPECIFICATION	UNIT	QTY	UNIT PRICE	TOTAL PRICE
Pump Set and Prime Mover							
1	KSB	KSB 65/20	KSB PUMP 65/20 3" X 2.5" 2900RPM(IMPELLER DIA 200MM)	NOS	1	TO BE PROVIDED BY FARMER	
2	GOLDEN	DE 32HP	GOLDEN DIESEL ENGINE 32HP 2900RPM	NOS	1		
3	GOLDEN	BFDE	BASE FRAME AND COUPLING FOR DIESEL ENGINE	NOS	1		
4			SUCTION ACCESSORIES (TO BE PROVIDED BY FARMER.)	NOS	1		
Filtration System+Fertigation							
5	JAIN	DCYM60	JAIN DISC CLEAN FILTER 60M ³ /HR. YF 4" DELUXE	NO.	1	37,075.18	37,075
6	JAIN	JHFM000	JAIN HYDROCYCLONE SEPARATOR 80 M ³ /HR. 4"	NO.	1	67,725.04	67,725
7	JAIN	FM060SMM	JAIN FILTER MASTER 3736" 60M ³ /HR-M SINGLE WITH MMF	SET	1	125,395.79	125,396
8	JAIN	VA34	VENTURY ASSEMBLY COMPLETE 34"	SET	1	2,326.94	2,327
9	JAIN	F16090	FERTILIZER TANK - 90 LITER ECONOMY	NO.	1	17,440.42	17,440
10	Local	MFT090	MESH FOR FERTILIZER TANK	NO.	1	3,333.33	3,333
11	LOCAL	GMV40	G.M. VALVE 1 - 1/2"	NO.	1	2,107.14	2,107
12	LOCAL	HU3	HEAD UNIT FITTINGS 3	LUMPSUM	1	27,926.57	27,929
VALVES							
13	Audco	BVN100	BUTTERFLY VALVE 100 MM (4")	NO.	7	7,775.59	54,429
14	JAIN	ARVC100	DOUBLE ACTION AIR/VACUUM RELEASE VALVE 1"	NO.	5	1,417.03	7,085
15	JAIN	SFV63	FLUSH VALVE 63 MM	NO.	12	202.03	2,424
16	JAIN	SFV50	FLUSH VALVE 50 MM	NO.	1	172.49	172
17	JAIN	SFV40	FLUSH VALVE 40 MM	NO.	5	141.07	705
PVC Pipes							
18	JAIN	PPA140063SG00060	PVC PIPE 40MM X 6.3KG/CM2 ISO-4422	MTR.	516	425.71	219,667
19	JAIN	PPA110063SG00060	PVC PIPE 110MM X 6.3KG/CM2 ISO-4422	MTR.	66	264.32	17,445
20	JAIN	PPA090063SG00060	PVC PIPE 90MM X 5KG/CM2 ISO-4422	MTR.	72	183.60	13,219
21	JAIN	PPA075063SG00060	PVC PIPE 75MM X 5KG/CM2 ISO-4422	MTR.	684	129.77	88,764
22	JAIN	PPA063063SG00060	PVC PIPE 63MM X 5KG/CM2 ISO-4422	MTR.	696	94.32	65,647
23	JAIN	PPA050063SG00060	PVC PIPE 50MM X 6.3KG/CM2 ISO-4422	MTR.	84	81.92	6,882
24	JAIN	PPA040063SG00060	PVC PIPE 40MM X 6.3KG/CM2 ISO-4422	MTR.	192	53.76	10,322
25	JAIN	F&A	FITTINGS AND ACCESSORIES	LUMPSUM	1		42,195
EMITTING SYSTEM (INLINE LATERALS)							
26	JAIN	PT122	12MM OD/10.2MM ID, MINIMUM 0.9MM W.T.	MTR.	2000	11.08	22,170
27	JAIN	JTA1204502	12MM, MINIMUM 0.6MM W.T., 4LPH/50CMS SPACING	MTR.	53500	10.86	580,794
28	JAIN	GTO01213	POLY GROMMET TAKE OFF 12 X 13 MM	SET	1700	8.95	15,223
29	JAIN	TLJ12	J-TURBO AQUILA / J TURBO LINE JOINER 12 MM	NO.	1800	6.13	11,028
30	JAIN	ES0812	LATERAL END STOP "B" SHAPE 12 MM	NO.	1700	5.03	8,546
31	JAIN	PGGFLC	PRESSURE GAUGE GLYCERIN FILLED LATERAL CHECK	SET	2	967.73	1,935
ADDITIONAL SAFETY AND MONITORING EQUIPMENT							
32	Capstan	CWM4ET	CAPSTAN WATER METER, 4" ENC. TYPE 100 MM	NO.	1	25,683.66	25,684
33	LOCAL	NRV25	C.I. NON RETURN VALVE 2.5"	NO.	1	10,086.64	10,087
OTHER CHARGES							
34			TRENCHING AND BACKFILLING	RFT	6500	14.29	92,885
TOTAL PRICE IN PAK RUPEES							1,580,622
			SERVICE CHARGES			9.00%	142,256
Spare Parts							
1	JAIN	JTA1204502	12MM, MINIMUM 0.6MM W.T., 4LPH/50CMS SPACING	MTR.	1000	11	10,856
2	JAIN	TLJ12	J-TURBO AQUILA / J TURBO LINE JOINER 12 MM	NO.	400	6	2,451
3	JAIN	PGGFLC	PRESSURE GAUGE GLYCERIN FILLED LATERAL CHECK	SET	1	967.73	968
4	JAIN	ES0812	LATERAL END STOP "B" SHAPE 12 MM	NO.	300	5	1,508
TOTAL PROJECT PRICE							1,738,660

Note: The above quotation does not include cost of construction of Pond/Bore well and pumpset with prime mover along with the suction accessories. This will be provided by beneficiary as per specification provided by SSC.

- Safety and Monitoring Equipments

6.9 DESIGN OF DRIP IRRIGATION SYSTEM (ROW CROP)

To design a drip irrigation system for 6.5 acres of cotton crop in Bhakkar. Soil is sandy loam. System should be farmer friendly.

Canal water is available for 2 hours and discharge is 28 lps. Farmer is interested to use canal water only but he can manage, ground water also.

3

Crop Information

Parameters			Crop	Area (acres)	Plant spacing (m)	Row spacing (m)	Age of crop (years)	Sowing Date	Harvesting Date
Block-I	Row crops	Proposed	Cotton	6.5	0.3	1.52	new	15 May	15 Nov
		Rotation							
Sub-Total: I									
Block-II	Orchards	Type-I							
		Type-II							
Sub-Total: II									
Block-III	Annual Crops								
Sub-Total: III									
Block-IV	Field Crops	Type-I							
		Type-II							
Sub-Total: IV									
Total / Design Value				6.5	0.3	1.52		15 May	15 Nov

4

EVAPOTRANSPIRATION AND CROP COEFFICIENTS (ET_o & K_c)

Month	J	F	M	A	M	J	J	A	S	O	N	D
Eto (mm/d)	1.8	2.7	4.0	6.4	8.6	9.2	7.6	6.5	5.8	4.5	2.7	1.9
Kc (row crop)					0.4	0.6	0.8	1.2	1.1	0.4	0.4	
CWR (row crop)					3.4	5.5	6.1	7.8	6.4	2.1	1.1	
Kc (orchards)												
CWR (orchards)												
Kc (annual crop)												
CWR (annual crop)												
Kc (field crops)												
CWR (field crops)												

5

Water Sources

Soil type	Loamy Sand	
Water Sources		
1) Canal		
Sanctioned Discharge (LPS)	28	
Perennial / Non Perennial	Non-Perennial	
Warabandi (Days)	7	
Water Availability	Hrs/Warabandi	2
	Volume (m3)	

6

1.	Total area under HEIS	Acres	6.5
2.	Design reference evapotranspiration, ETo	mm/day	6.5
3.	Design Crop factor at maturity, Kc	-	1.2
4.	Plant spacing	m	0.3
5.	Lateral spacing	m	1.52
6.	Shaded area	%	100
7.	Irrigation system efficiency	%	90
8.	Emitter flow rate	LPH	2
9.	Emitter spacing	m	0.4
10.	No. of crop rows per drip line	Nos.	1.0
11.	Irrigation cycle (assume one day)	Days	1

S.N	Parameters	Unit	Calculations
13	Peak daily consumptive use per day	Mm	= $ETo * Kc * \text{shaded area} / \text{efficiency}$ = $6.5 * 1.2 * 1 / 0.9 = 8.7 \text{ mm}$
14	Total no. of plants	Nos	= $\text{Area} * 4047 / (R-R * P-P)$ = $6.5 * 4047 / (1.52 * 0.3) = 57,688$
15	Total drip line length	M	= $\text{Area} * 4047 / L-L$ = $6.5 * 4047 / (1.52) = 17,306$
16	Total no. of emitters	Nos	= $\text{Total drip length} / \text{emitter spacing}$ = $17306 / 0.4 = 43,266$
17	Average emitter spacing	M	0.4
18	Total flow rate	Lph	= $\text{total no. of emitters} * \text{emitter flow rate}$ = $43266 * 2 = 86,531$
19	Application rate	Mm/hr	$\text{Total flow rate} / \text{area}$ = $(86,531 / 1000) / (6.5 * 4047) * 1000$ = 3.29
20	Operation time*	hrs	= $\text{Peak daily consumptive use} / \text{Application rate}$ = $8.7 / 3.29$ = 2.64 hrs

10

Do We Have Sufficient Water?

Peak Water Requirement = 8.7 mm/day (calculated previously)

Volume of water required (m³/d)

$$\begin{aligned}
 &= \text{PWR} \times \text{Area (m}^2\text{)} \\
 &= 8.7 / 1000 * 6.5 * 4047 \\
 &= 229 \text{ cubic meters per day}
 \end{aligned}$$

Water Availability

a) For Canal Water

Outlet discharge = 28 lps

Warabandi period = 2 hrs

Total water availability = $28 / 1000 * 3600 * 2 = 202$ cubic meters for seven days

NO

Water is not sufficient to design a drip irrigation system for 6.5 acres.

Options:

a) Reduce area

Or

b) Arrange alternate water source

Go for option b) as farmer has arranged water source i.e., tubewell water:

Proceed further

Darcy- Weisbach and Blasius Equation can be combined to give accurate prediction of friction head loss for smooth plastic pipes of less than 125 mm (5 in.) diameter.

$$J = 100 \text{ hf/L} = k * [(Q^{1.75})/(D^{4.75})]$$

- J = Head loss gradient, m/100 m
- Hf = pipe friction head loss, m
- K = Constant, $7.89 * 10^7$ for metric units
- Q = Flow Rate, LPS
- L = Pipe length, m
- D = Inside Diameter of Pipe, mm

Darcy- Weisbach and Blasius Equation can be combined to give accurate prediction of friction head loss for smooth plastic pipes of less than 125 mm (5 in.) diameter.

$$J = 100 \text{ hf/L} = k * [(Q^{1.75})/(D^{4.75})] * F$$

- J = Head loss gradient, m/100 m
- Hf = pipe friction head loss, m
- K = Constant, $7.89 * 10^7$ for metric units
- Q = Flow Rate, LPS
- L = Pipe length, m
- D = Inside Diameter of Pipe, mm

Lateral Design:

Lateral length = 60 m

No. of emitters = $60/0.4 = 150$

Lateral flow rate = 300 lph

Assume 13 mm lateral line

Inside diameter = 10 mm

$$J = 7.89 \times 10^{-7} \times [(300/3600)^{1.75} / (10^{4.75})] \times 0.36$$

$$J = 6.53 \text{ m/100 m}$$

For 60 m length

$$H_f = 3.92 \text{ m}$$

Lateral Design:

Lateral length = 60 m

No. of emitters = $60/0.4 = 150$

Lateral flow rate = 300 lph

Assume 16 mm lateral line

Inside diameter = 13 mm

$$J = 7.89 \times 10^{-7} \times [(300/3600)^{1.75} / (13^{4.75})] \times 0.36$$

$$J = 1.9 \text{ m/100 m}$$

For 60 m length

$$H_f = 1.1 \text{ m}$$

Sub-Mainline Design:

Length = 120 m

No. of laterals = $120/1.52 = 79$ Sub-main flow rate = $86531/2$

= 43265 lph

Assume 70 mm lateral line

Inside diameter = 63 mm

$$J = 7.89 \times 10^{-7} \times [(43265/3600)^{1.75} / (63^{4.75})] \times 0.36$$

$$J = 6.3 \text{ m/100 m}$$

For 120 m length

$$H_f = 7.5 \text{ m}$$

Sub-Mainline Design:

Length = 120 m

No. of laterals = $120/1.52 = 79$ Sub-main flow rate = $86531/2$

= 43265 lph

Assume 110 mm Sub-Mainline

Inside diameter = 104 mm

$$J = 7.89 \times 10^{-7} \times [(43265/3600)^{1.75}/(104^{4.75})] \times 0.36$$

$$J = 0.6 \text{ m/100 m}$$

For 120 m length

$$H_f = 0.7 \text{ m}$$

Darcy- Weisbach and Blasius Equation can be combined to give accurate prediction of friction head loss for smooth plastic pipes of less than 125 mm (5 in.) diameter.

$$J = 100 \text{ hf/L} = k \times [(Q^{1.75})/(D^{4.75})]$$

J = Head loss gradient, m/100 m

Hf = pipe friction head loss, m

K = Constant, 7.89×10^{-7} for metric units

Q = Flow Rate, LPS

L = Pipe length, m

D = Inside Diameter of Pipe, mm

Mainline Design:

Length = 60 m

Sub-main flow rate = 86531 LPH

Assume 110 mm Sub-Mainline

Inside diameter = 104 mm

$$J = 7.89 \times 10^{-7} \times [(86531/3600)^{1.75}/(104^{4.75})]$$

$$J = 5.4 \text{ m/100 m}$$

For 60 m length

$$H_f = 3.2 \text{ m}$$

$$V = 1.274 \text{ q} / d^2$$

Where

V = velocity (m/s)

Q = volume flow (m^3/s)

D = pipe inside diameter (m)

$$V = 1.274 \times [(86531/(1000 \times 3600))]/ [(104/1000)^2]$$

$$= 3.68 \text{ m/s}$$

Darcy- Weisbach and Blasius Equation can be combined to give accurate prediction of friction head loss for smooth plastic pipes of less than 125 mm (5 in.) diameter.

$$J = 100 \text{ hf/L} = k * [(Q^{1.75})/(D^{4.75})]$$

J = Head loss gradient, m/100 m
 Hf = pipe friction head loss, m
 K = Constant, $7.89 * 10^7$ for metric units
 Q = Flow Rate, LPS
 L = Pipe length, m
 D = Inside Diameter of Pipe, mm

Mainline Design:

Length = 60 m

Sub-main flow rate = 86531 LPH

Assume 170 mm Sub-Mainline

Inside diameter = 160 mm

$$J = 7.89 * 10^7 * [(86531/3600)^{1.75} / (160^{4.75})]$$

$$J = 0.7 \text{ m/100 m}$$

For 60 m length

$$H_f = 0.4 \text{ m}$$

Velocity of Mainline

$$v = 1.274 \, q / d^2$$

where

v = velocity (m/s)

q = volume flow (m³/s)

d = pipe inside diameter (m)

$$\begin{aligned}
 V &= 1.274 \times [(86531 / (1000 * 3600)) / [(104 / 1000)^2]] \\
 &= 1.20 \text{ m/s}
 \end{aligned}$$

OK

23

Velocity Formula to Determine Pipe Size for Mainline

$$v = 1.274 q / d^2$$

$$d^2 = V / (1.274 q)$$

$$d = \text{SQRT} [V / (1.274 q)]$$

v = velocity (m/s)

q = volume flow (m³/s)

d = pipe inside diameter (m)

24

Filters: Head Loss

Source: Jain Disc Filter

25

Filters: Head Loss

Source: Jain Hydro-cyclone Filter

26

Filters: Head Loss

Source: Jain Media Filter

27

TOTAL DYNAMIC HEAD

- Emitter operating pressure = 10 m
- Head loss in lateral = 1.1 m
- Lateral Elevation = 0 m
- Head loss in submains = 0.7 m
- Head loss in Valve (assume 2 m) = 2.0 m

- Field fitting head loss = 2.0 m
- Head Loss in Main line = 0.4 m
- Primary filter head loss (Gravel 2 x40 M3) .2x2 =4m = 4 m
- Secondary filter head loss (Disc 2 x 40 M3) .2x2 = 4m = 4 m
- Fertigation equipment head loss (5 m for ventury) = 5 m
- Water source depth = 0 m
- Suction head = 1 m
- Delivery head = 1 m
- Safety equipment head loss = 2 m
- Elevation difference = 0 m
- Other losses = m
- **Total Head Required = 33.2 m**

Say 35 m

PUMP REQUIREMENT

Total Flow Required = 85.531m³/hr = 23.8 lps

$$\begin{aligned} \text{Pump H.P} &= Q \text{ (LPS)} * H \text{ (m)} / (75 * \text{pump efficiency} * \text{motor efficiency}) \\ &= 23.8 * 35 / (75 * 0.65 * 0.9) \\ &= 19 \end{aligned}$$

Say 20 H.P

Option-II (Irrigate area into Zones: Say 2 Zones)

30

Option-III (Irrigate area into Zones: Say 4 Zones)

31

Parameters	Unit	HZ-1	HZ-2	HZ-3	HZ-4	Total
Area	Acres	1.625	1.625	1.625	1.625	6.5
Peak daily consumptive use per day	Mm	8.7	8.7	8.7	8.7	8.7
Total no. of plants	Nos	14,422	14,422	14,422	14,422	57,688
Total drip line length	M	4,327	4,327	4,327	4,327	17,306
Total no. of emitters	Nos	10,816	10,816	10,816	10,816	43,266
Average emitter spacing	M	0.4	0.4	0.4	0.4	0.4
Total flow rate	Lph	21,633	21,633	21,633	21,633	21,633
Application rate	Mm/hr	3.3	3.3	3.3	3.3	0.8
Operation time*	hrs	2.6	2.6	2.6	2.6	10.5

Darcy- Weisbach and Blasius Equation can be combined to give accurate prediction of friction head loss for smooth plastic pipes of less than 125 mm (5 in.) diameter.

$$J = 100 \text{ hf/L} = k * [(Q^{1.75})/(D^{4.75})]$$

J = Head loss gradient, m/100 m
 Hf = pipe friction head loss, m
 K = Constant, $7.89 * 10^7$ for metric units
 Q = Flow Rate, LPS
 L = Pipe length, m
 D = Inside Diameter of Pipe, mm

Darcy- Weisbach and Blasius Equation can be combined to give accurate prediction of friction head loss for smooth plastic pipes of less than 125 mm (5 in.) diameter.

$$J = 100 \text{ hf/L} = k * [(Q^{1.75})/(D^{4.75})] * F$$

J = Head loss gradient, m/100 m
 Hf = pipe friction head loss, m
 K = Constant, $7.89 * 10^7$ for metric units
 Q = Flow Rate, LPS
 L = Pipe length, m
 D = Inside Diameter of Pipe, mm

Lateral Design:

Lateral length = 60 m

No. of emitters = $60/0.4 = 150$

Lateral flow rate = 300 lph

Assume 13 mm lateral line

Inside diameter = 10 mm

$$J = 7.89 \times 10^7 \times [(300/3600)^{1.75}/(10^{4.75})] \times 0.36$$

$$J = 6.53 \text{ m/100 m}$$

For 60 m length

$$H_f = 3.92 \text{ m}$$

Lateral Design:

Lateral length = 60 m

No. of emitters = $60/0.4 = 150$

Lateral flow rate = 300 lph

Assume 16 mm lateral line

Inside diameter = 13 mm

$$J = 7.89 \times 10^7 \times [(300/3600)^{1.75}/(13^{4.75})] \times 0.36$$

$$J = 1.9 \text{ m/100 m}$$

For 60 m length

$$H_f = 1.1 \text{ m}$$

Sub-Mainline Design:

Length = 120 m

No. of laterals = $120/1.52 = 79$

Sub-main flow rate = 86531/4

$$= 21,633 \text{ lph}$$

Assume 70 mm lateral line

Inside diameter = 63 mm

$$J = 7.89 \times 10^7 \times [(21,633/3600)^{1.75}/(63^{4.75})] \times 0.36$$

$$J = 1.9 \text{ m/100 m}$$

For 120 m length

$$H_f = 2.2 \text{ m}$$

Darcy- Weisbach and Blasius Equation can be combined to give accurate prediction of friction head loss for smooth plastic pipes of less than 125 mm (5 in.) diameter.

$$J = 100 \text{ hf/L} = k \times [(Q^{1.75})/(D^{4.75})]$$

J = Head loss gradient, m/100 m

Hf = pipe friction head loss, m

K = Constant, 7.89×10^7 for metric units

Q = Flow Rate, LPS

L = Pipe length, m

D = Inside Diameter of Pipe, mm

Mainline Design:

Length = 60 m

Sub-main flow rate = 86531 LPH

Assume 90 mm Sub-Mainline

Inside diameter = 87 mm

$$J = 7.89 \times 10^{-7} \times [(21633/3600)^{1.75} / (87^{4.75})]$$

$$J = 1.1 \text{ m/100 m}$$

For 60 m length

$$H_f = 0.7 \text{ m}$$

Velocity of Mainline

$$v = 1.274 \, q / d^2$$

where

v = velocity (m/s)

q = volume flow (m^3/s)

d = pipe inside diameter (m)

$$\begin{aligned} V &= 1.274 \times [(21633/(1000 \times 3600))] / [(87/1000)^2] \\ &= 1.01 \text{ m/s} \end{aligned}$$

38

Filters: Head Loss

Source: Jain Hydro-cyclone Filter

40

Filters: Head Loss

Source: Jain Media Filter

41

Filters: Head Loss

Source: Jain Media Filter

41

- Emitter operating pressure = 10 m
- Head loss in lateral = 1.1 m
- Lateral Elevation = 0 m
- Head loss in submains = 2.2 m
- Head loss in Valve (assume 2 m) = 2.0 m
- Field fitting head loss = 2.0 m
- Head Loss in Main line = 0.7 m
- Primary filter head loss (Gravel 20 m3) = 1.5 m
- Secondary filter head loss (Disc 20 m3) = 1.3 m
- Fertigation equipment head loss (5 m for ventury) = 5 m
- Water source depth = 0 m
- Suction head = 1 m
- Delivery head = 1 m
- Safety equipment head loss = 2 m
- Elevation difference = 0 m
- Other losses = m
- **Total Head Required = 29.8 m**

Say 30 m

Total Flow Required = 21.382 m3/hr = 5.94 lps

$$\begin{aligned}
 \text{Pump H.P} &= Q \text{ (LPS)} * H \text{ (m)} / (75 * \text{pump efficiency} * \text{motor efficiency}) \\
 &= 5.94 * 30 / (75 * 0.65 * 0.9) \\
 &= 4.1
 \end{aligned}$$

Say 5 H.P

6.10 DESIGN OF SPRINKLER IRRIGATION SYSTEM

A pressurized irrigation system is a network of installation consisting of pipes, fittings and other devices properly designed and installed to supply water under pressure from the source of the water to the irrigable area.

Two main classification:

- Sprinkler Irrigation
- Micro/Drip Irrigation

Typical Sprinkler Irrigation System Layout

Piped irrigation systems are classified according to the pressure required for operation, the method of delivering water to plants, and the type of installation

PRESSURE: it is the maximum water pressure required for normal system operation

- Low Pressure System: 2.0 to 3.5 bars
- Medium Pressure System: 3.5 to 5.0 bars
- High Pressure System: > 5.0 bars

TYPE OF INSTALLATION

- Solid Installation (all components are installed at fixed positions)
- Semi- solid installation (Main and submain are permanent, lateral are portable, hand move or mechanical move)
- Portable (all component parts are portable)

WATER DELIVERY METHOD

- Sprinkler (Over head irrigation)
- Micro-irrigation (Localized irrigation) by dripper, bubblers, micro jets etc

Sprinkler irrigation is the method where water is sprayed through the air and it falls to the ground like rain. The spray is obtained by the flow of water under pressure through small orifices or nozzles known as sprinklers. Water is conveyed from the pump and distributed through a network of pipes called mainline, sub-mainlines, laterals and sprinklers.

Advantages

- ☐ Sprinkler irrigation is suitable for all crops except rice as it requires standing water.
- ☐ Water can be spread over row crops and under canopy of tree crops.
- ☐ Large sprinklers are not suitable for delicate flowering and fruiting plants because larger water drops may damage the crop.
- Suitable to complete range of topography
- Land leveling not required
- Light textured soil which cannot be irrigated properly by surface irrigation can be effectively irrigated.
- Higher irrigation efficiency can be achieved through proper designing
- Soluble fertilizers can be applied through foliar application
- Easy to operate
- Less sensitive to clogging.
- High efficiency can be achieved with a proper design

Disadvantages

- ☐ Very sensitive to wind conditions
- ☐ Higher evaporation rate
- ☐ Fine textured soil having very low infiltration rates cannot be irrigated efficiently
- ☐ Few crops with delicate flowering cannot be irrigated with sprinkler system
- ☐ Use of low quality water may cause leaf burn
- ☐ Must work under pressure, according to the manufacturer's recommendations to obtain good results

- Two Basic Groups
 - Set System
 - Periodic move systems
 - Hand move lateral, End-Tow Lateral, Rain Gun system, Boom sprinklers etc.
 - Fixed system
 - Lateral lines and sprinkler heads are fixed
 - Continuous move systems
 - Center Pivot system
 - Linear Move system

CLASSIFICATION OF SPRINKLERS AND APPLICABILITY

Classification of sprinkler heads based on operating pressure

Agriculture sprinklers	Operating pressure (bars)	Flow rate (m ³ /h)	Diameter coverage (m)
Low pressure	1.5-2.5	0.3-1.5	12-21
Medium pressure	2.5-3.5	1.5-3.0	24.35
High pressure	4.0-9.0	5.0-45.0	60-80

The initial cost and the labor required are both directly related to the portability of a sprinkler system. The more portable a system, the lower the initial cost and the higher the labor requirements to operate it. Conversely, the permanent system has the highest initial cost and lowest labor requirements. Each person selecting a sprinkler system has his own set of circumstances and economic conditions to consider.

The selection of a system is an economic compromise of these individual conditions. and no two may be exactly alike. However, after the type of system has been selected, there is a basic common guideline to follow in developing the details of the system.

6.10.1 Components of Sprinkler System

A. PUMP SET

- ▣ Centrifugal/deep-well turbine pumps may be used.
- ▣ May be powered by electric motors or internal combustion engines using diesel, gasoline or natural gas.

B. Main pipeline, Sub-mains & Laterals

- ▣ To convey water from the pumping unit to the laterals.
- ▣ Laterals may be directly connected to the main line without any sub-main line.
- ▣ Generally made of uPVC and HDPE
- ▣ Generally made of uPVC and HDPE

C. Laterals

- receive water from the main pipeline *or* sub-main to the sprinklers.
- Usually made of uPVC, HDPE

D. Riser/Hydrants

- ▣ To connect sprinkler head to the lateral pipe.
- ▣ Height of riser pipe depends upon the height of crop to be irrigated and sprinkler flow rate..

- ▣ Generally made of Aluminum, GI

E. Valves & Safety Equipment

- ▣ Flow control valve: To divert flow from mainline to sub-mainline
- ▣ Check/NRV valves: on the discharge side of the pump so that if the pump is shut off it should maintain water in the pipeline above the pump.
- ▣ Foot-valve: on the bottom of the suction pipe
- ▣ Pressure Gauges: To monitor system pressure
- ▣ Flow Meter: to record amount of water passing

6.11 SPRINKLER SYSTEM TECHNICAL ASPECT

i. Discharge from Sprinkler Nozzle

Theoretical discharge from sprinkler nozzle can be computed from orifice flow equation:

$$q = cda\sqrt{2gh}$$

- q = nozzle discharge, m³/sec
 a = x- sectional area of sprinkler nozzle, m²
 h = pressure head at the nozzle, m
 Cd = coefficient of discharge as a function of friction and contraction (ranges from 0.8 to 0.98: larger the nozzle, lower the coefficient)
 g = acceleration due to gravity, m/sec²

ii. Wetted Area of Sprinkler

$$A = \lambda R$$

$$R = 1.35\sqrt{dh}$$

- A = Area covered by the sprinkler, m²
 R = Radius of water area, m
 d = Diameter of sprinkler nozzle, mm
 h = Pressure head at nozzle, m

iii. Distribution Uniformity

$$Ed = \left(1 - \frac{y}{d}\right) \cdot 100$$

Indicates the extent to which water is uniformly distributed.

Ed = Water distribution efficiency, %
 d = Average depth of water stored
 y = Average numerical deviation from d

iv. Application Rate of Sprinkler

The rate at which sprinkler apply water on soil surface. Application rate depends on:

- Size of sprinkler nozzle
- Operating pressure
- Spacing between sprinklers

$$I = \frac{q}{Sl \times Sm}$$

I = Application rate, mm/hr
 q = Discharge, lph
 Sm = Sprinkler spacing along sub-mainline, m
 Sl = Sprinkler spacing on lateral, m

v. Capacity Requirement

$$Q = \frac{2.78Ad}{fT}$$

Q = System Discharge Capacity, lps
 A = design area (ha)
 D = gross depth of application (mm)
 f = Time allowed for completion of irrigation (days)
 T = Actual operating time (hrs/day)

vi. Minimum Number of Sprinklers Operating

$$Nn = \frac{Q}{q}$$

Nn = Minimum average number of sprinkler operating
 q = average sprinkler discharge

vii. Wind Effect on the Diameter of Throw

For 0-3 mph wind:

reduce manufacturer's listed diameter of throw by 10% for an effective value (i.e. the diameter where the application of water is significant)
 over 3 mph wind:

reduce manufacturer's listed diameter of throw by an additional 2.5% for every 1 mph above 3 mph (5.6% for every 1 m/s over 1.34 m/s)

viii. Wind Effect on The Diameter of Throw

For 0-3 mph (0-1.34 m/s):

$$\text{diam} = 0.9\text{diammanuf}$$

For > 3 mph (> 1.34 m/s):

$$\text{diam} = \text{diammanuf} [0.9 - 0.025 (\text{windmph} - 3)]$$

Example: a manufacturer gives an 80-ft diameter of throw for a certain sprinkler and operating pressure. For a 5 mph wind, what is the effective diameter?

$$80 \text{ ft} - (0.10)(0.80) = 72 \text{ ft}$$

$$\text{diam} = 80(0.9 - 0.025(5 - 3)) = 68 \text{ ft}$$

ix. Overlapping

Distribution pattern of a single sprinkler is not uniform throughout the radius and also affects drastically by wind. To minimize the effect of wind and provide uniform depth of water on the area under sprinkler irrigation system, distance between the sprinklers is reduced in such a way that water from one sprinkler reaches approximately to the adjacent sprinkler.

SPRINKLER OVERLAPPING

SPRAY PATTERN AS A RESULT OF OVERLAPPING

SPRAY PATTERN AS A RESULT OF OVERLAPPING

DIFFERENT PATTERN OF SPRINKLER PLACEMENT

1. RECTANGULAR SPACING

Sprinkler spacing at lateral

40% of effective diameter

Lateral Spacing

67% of the effective diameter

(For big volume Rain Gun lateral spacing should not exceed 65% of effective diameter and sprinkler spacing at lateral should be 50% of effective wetted diameter)

2. SQUARE SPACING

Sprinkler spacing at lateral

50% of effective diameter

Lateral Spacing

50% of the effective diameter

3. TRIANGULAR SPACING

Sprinkler spacing at lateral

62% of effective diameter

Lateral Spacing

54% of the effective diameter

OVERLAPPING PATTERNS

DIFFERENT SPACING OF LATERALS

Rectangular: 40% x 67%

Square: 50% x 50%

Triangular: 62% x 54%

HYDRANT/RISER HEIGHT

Riser pipes elevate and support the sprinklers above the crop
Provide connecting link to the lateral.

Sprinkler Discharge (lps)	Minimum Riser height (cm)
< 0.6	15
0.6 to 1.6	23
1.6 to 3.2	30
3.2 to 7.6	45
>7.6	90

SUGGESTED MAXIMUM SPRINKLER APPLICATION RATE

Soil texture	Maximum application rate (mm/hr)			
	0 to 5%	5 to 8%	8 to 12%	12 to 16%
Coarse sandy soil	50	38	25	13
Light sandy loam	25	20	15	10
Silty loam	13	10	8	5
Heavy textured clay	4	2.5	2	1.5

PERFORMANCE CHART FOR MEDIUM VOLUME RAIN GUN

Performance Chart for Model 162 & 163

Trajectory - for 162 - 30°, for 163 - 23°

*Pressure kg/cm ²	Nozzle Ø 8 mm			Nozzle Ø 10 mm			Nozzle Ø 12 mm			Nozzle Ø 14 mm			Nozzle Ø 16 mm		
	Radius	Discharge	ppt. rate	Radius	Discharge	ppt. rate	Radius	Discharge	ppt. rate	Radius	Discharge	ppt. rate	Radius	Discharge	ppt. rate
	m	l/s	inch/hr	m	l/s	inch/hr	m	l/s	inch/hr	m	l/s	inch/hr	m	l/s	inch/hr
2.00	19.50	1.37	0.17	21.50	1.89	0.19	23.00	2.52	0.23	24.00	3.27	0.27	24.50	4.14	0.32
3.00	22.00	1.67	0.16	24.00	2.31	0.19	26.00	3.09	0.22	27.50	4.01	0.25	28.50	5.07	0.29
4.00	24.00	1.93	0.15	26.50	2.67	0.18	28.50	3.57	0.21	30.00	4.63	0.24	31.50	5.86	0.27
5.00	25.50	2.16	0.15	28.50	2.98	0.17	30.50	3.99	0.20	32.00	5.18	0.24	33.50	6.55	0.27
6.00	-	-	-	-	-	-	32.50	4.37	0.19	33.50	5.67	0.23	34.50	7.17	0.28

Note: The Performance data are based on ideal test conditions and may be adversely affected by wind, poor hydraulic entrance. * The pressure refers to pressure at nozzle

Performance Data - Metric Units

BARS @ Nozzle	NOZZLE SIZE											
	14 mm		16 mm		18 mm		20 mm		22 mm		24 mm	
	(m)	(m ³ /hr)	(m)	(m ³ /hr)	(m)	(m ³ /hr)	(m)	(m ³ /hr)	(m)	(m ³ /hr)	(m)	(m ³ /hr)
	Rad.	Flow	Rad.	Flow	Rad.	Flow	Rad.	Flow	Rad.	Flow	Rad.	Flow
2.8	31,4	12,5	32,0	16,4	34,4	20,9	39,9	25,9	38,4	30,4	38,4	36,8
3.4	33,2	13,9	33,8	17,9	37,8	22,9	41,8	28,2	41,5	33,6	41,8	40,2
4.1	35,1	15,0	36,6	19,5	40,5	25,0	43,0	30,9	42,7	36,8	43,3	43,9
4.8	36,9	16,4	38,4	21,1	42,7	26,8	44,5	33,4	45,4	39,8	46,0	47,5
5.5	39,0	17,5	39,0	22,5	44,5	28,9	46,6	35,7	49,1	42,7	50,6	50,9
6.2	40,8	18,6	41,1	24,1	46,0	30,9	48,5	38,2	51,2	45,7	53,3	54,5
6.9	42,7	20,0	43,0	25,7	46,9	32,7	50,0	40,4	53,6	48,6	56,1	57,9

PERFORMANCE CHART FOR BIG VOLUME RAIN GUN

Twin 101														Taper bore nozzle Trajectory 24°														
Pressure	Nozzle 12 mm - 0.47"				Nozzle 14 mm - 0.55"				Nozzle 16 mm - 0.63"				Nozzle 18 mm - 0.71"				Nozzle 20 mm - 0.79"				Nozzle 22 mm - 0.87"				Nozzle 24 mm - 0.94"			
	Flow		Radius		Flow		Radius		Flow		Radius		Flow		Radius		Flow		Radius		Flow		Radius		Flow		Radius	
bar	m³/s	l/s	m		m³/s	l/s	m		m³/s	l/s	m		m³/s	l/s	m		m³/s	l/s	m		m³/s	l/s	m		m³/s	l/s	m	
2.0					10.6	2.96	26.0		13.9	3.86	27.9		17.6	4.89	29.7		21.7	6.04	31.5		26.3	7.30	33.1		31.3	8.69	34.7	
2.5					11.9	3.31	28.3		15.5	4.32	30.4		19.7	5.47	32.4		24.3	6.75	34.3		29.4	8.17	36.1		35.0	9.72	37.8	
3.0	9.6	2.66	27.9		13.0	3.62	30.3		17.0	4.73	32.6		21.6	5.99	34.7		25.6	7.39	36.7		32.2	8.95	38.7		38.3	10.65	40.5	
3.5	10.4	2.87	29.5		14.1	3.91	32.1		18.4	5.11	34.5		23.3	6.47	36.8		28.7	7.99	38.9		34.8	9.66	41.0		41.4	11.50	43.0	
4.0	11.1	3.07	31.1		15.1	4.18	33.8		19.7	5.46	36.3		24.9	6.91	38.7		30.7	8.54	41.0		37.2	10.33	43.1		44.3	12.29	45.2	
4.5	11.7	3.26	32.5		16.0	4.44	35.3		20.9	5.80	38.0		26.4	7.33	40.5		32.6	9.05	42.8		39.4	10.96	45.1		46.9	13.04	47.3	
5.0	12.4	3.44	33.8		16.8	4.68	36.8		22.0	6.11	39.5		27.8	7.73	42.1		34.4	9.54	44.6		41.6	11.55	46.9		49.5	13.74	49.2	
5.5	13.0	3.60	35.1		17.7	4.91	38.1		23.1	6.41	41.0		29.2	8.11	43.7		36.0	10.01	46.2		43.6	12.11	48.7		51.9	14.42	51.0	
6.0	13.6	3.76	36.3		18.4	5.12	39.4		24.1	6.69	42.4		30.5	8.47	45.1		37.6	10.46	47.8		45.5	12.65	50.3		54.2	15.06	52.7	
6.5	14.1	3.92	37.4		19.2	5.33	40.6		25.1	6.96	43.6		31.7	8.81	46.5		39.2	10.88	49.3		47.4	13.17	51.9		56.4	15.67	54.4	

N.B. The performance data were obtained under ideal testing conditions and may be adversely affected by wind and other factors. Pressure refers to pressure at nozzle. A lowered trajectory angle improves the irrigation efficiency in windy conditions. For every 3° drop of the trajectory angle the throw is reduced by approximately 3 to 4%.

ECE VALUES FOR DIFFERENT CROPS THAT WILL GIVE 10% REDUCTION IN YIELD

S.No	Crop	Ece (dS/m)
1	Cotton	9.6
2	Sorghum	5.1
3	Wheat	7.4
4	Maize	2.5

The criteria for selection of sprinkler spacing are based on uniformity of water distribution within the limitation of wind velocity. Higher the wind velocity will result in lower spacing between the sprinklers and vice versa. **Fig 6.5** below shows water distribution pattern of a particular sprinkler system. This depicts that area under the first 60% of the sprinkler's radius is generally sufficiently irrigated for growing crop without any overlapping. Beyond this, quantum of water will be reducing and thus will not be sufficient to grow crop. To overcome this problem, overlapping between the sprinklers is suggested with following recommendations.

Fig. 6.5 Wetting Pattern Without and with Overlapping

At the same time wind badly affects the distribution pattern of a sprinkler system. **Fig. 6.6** shows the effect of wind over the distribution pattern of a particular sprinkler system.

Fig 6.6 Distribution Pattern Distorted by Wind (10.7 MPH)

Volume of water delivered from the sprinkler varies from sprinkler to the edge of the wetted radius as shown in Fig. below. More water will be available near the sprinkler and will be reduced gradually as we move away from sprinkler. Finally, where the sprinkler radius came to an end there will be no water. Sprinkler water distribution graph is shown in **Fig 6.7**.

Fig 6.7 Sprinkler water distribution graph (Courtesy: Rain Bird)

It is noted that 60% radius of the sprinkler will be well irrigated to meet the crop water demands and remaining 40% will be under irrigated. To overcome this problem, the flow from other sprinkler should fall in this 40% radius of the first sprinkler so as sum of flows from both sprinklers in this area would approximately match the flow depth in the 60% radius of the first sprinkler as shown in the **Fig 6.8**.

Fig 6.8 60% of diameter sprinkler spacing (Courtesy: Rain Bird)

Another layout showing head-to-head sprinkler spacing is shown in following **Fig 4.9** to match the flow in each part of the area under sprinkler system.

Fig 6.9 Head To Head Sprinkler Spacing For Uniform Water Distribution

6.11.1.1 Effect of pressure on Sprinkler

Sprinkler wetting pattern is affected by pressure and nozzle size. For a particular combination of nozzle size and at manufacturer's recommended operating pressure, precipitation profile seems like **Fig 6.10-b**. When pressure is much lower than the manufacturer's recommended pressure, large sized drops fall near the sprinkler in a ring as shown in **Fig. 6.10-a**. When pressure is much higher than manufacturers recommended pressure, then very small sized drops results and can be distorted easily and precipitation profile results like **Fig. 6.10-c**.

Fig 6.10-a. Pressure is too low

Fig 6.10-b. Pressure is satisfactory

Fig 6.10-c. Pressure is too high

6.11.1.2 Sprinkler Pattern

There are three different ways for placing sprinklers to achieve uniform application of water namely square, triangle and rectangular pattern.

The detail of sprinkler patterns is explained in the following sections.

Square Spacing

The distance between sprinkler along the laterals and between the lateral is kept same under square pattern of sprinkler spacing as shown in **Fig.6.11**. This pattern is suitable to sites which are square in geometry. The spacing between sprinklers is decided based on the wind conditions as given below:

- For wind velocity 0 to 3 mph (0 to 5 km/h), the spacing should be 55% of diameter
- For wind velocity 4 to 7 mph (6 to 11 km/h), the spacing should be 50% of diameter
- For wind velocity 8 to 12 mph (13 to 19 km/h), the spacing should be 45% of diameter

Fig 6.11 Square sprinkler pattern

The limitation of square pattern is that diagonal distance increases to approximately 70% of wetted diameter (for 50% sprinkler spacing).

Triangular Spacing

Triangular spacing is generally adopted for irregular field boundaries, over spray is permitted and no part circle sprinklers are needed. The geometrical view of triangular spacing is shown in **Fig 6.12**. The recommended spacing for this pattern as suggested by Rain Bird is given below:

Fig 6.12 Triangular Sprinkler Pattern

The distance between sprinklers is usually labeled S, and the distance between rows is labeled L.

Sprinkler spacing should be selected based on the following relationship.

$$L = S \times 0.866$$

Where;

L = sprinkler spacing between lateral

S = sprinkler spacing at lateral

Recommends triangular spacing (Source Rain Bird):

60% if wind velocities are 0-3 mph on site.

55% if wind velocities are 4-7 mph on site.

50% if wind velocities are 8-12 mph on site.

Rectangular Spacing

The spacing between lateral (L) is usually kept more than the sprinkler spacing (S) forming a rectangular pattern. The recommended spacing for rectangular pattern is given below.

Recommended triangular spacing (Source Rain Bird):

L=60% of wetted diameter, S=50% wetted diameter if wind velocities are 0-3 mph on site.

L=60% of wetted diameter, S=45% wetted diameter if wind velocities are 4-7 mph on site.

L=60% of wetted diameter, S=40% wetted diameter if wind velocities are 8-12 mph on site.

CONSUMPTIVE USE

For the design of surface and sprinkler irrigation systems:

$$ET_{crop} = ET_o \times K_c / (1 - LR)$$

$$\text{Potential Water Requirement} = ET_{crop} / (\text{Efficiency})$$

LEACHING REQUIREMENT

$$LR = \frac{EC_w}{5(EC_e) - EC_w}$$

LR = leaching requirement (Fraction)

EC_w = Salinity of applied irrigation water in dS/m

EC_e = Average soil salinity tolerated by crop taken from literature

IRRIGATION DEPTH

$$dx = \text{MAD} (W_a \cdot Z) / 100$$

dx = Maximum depth of water to be applied per irrigation (mm)

MAD =Management Allowed Deficit (%)
 Wa =Water holding capacity of soil, mm/m
 Z =Effective root depth, m

IRRIGATION INTERVAL

$F_x = dx/C_u = \text{MAD} (W_a \cdot Z)/(c_u \cdot 100)$
 F_x = Irrigation interval, days
 dx = Maximum depth of water to be applied per irrigation (mm)
 MAD =Management Allowed Deficit (%)
 W_a =Water holding capacity of soil, mm/m
 Z =Effective root depth, mm
 C_u = Consumptive use, mm

OPERATIONAL TIME

Operation time depends upon various factors including;

- Weather conditions
- Crop stage,
- Root depth etc.

Daily operation time =
 Daily consumptive use/ Application Rate

SYSTEM HYDRAULICS

- Determining the pressure distribution in the system
- Selection of pipe sizes and fittings to convey and regulate water delivery
- Determining the power and energy requirements

WAYS OF CALCULATING FRICTION LOSS

- Equations
- Hazen-Williams
- Darcy-Weisbach
- Watters and Keller
- Tables/Charts
- for any given pipe material, pipe diameter, and flow rate, look up values for friction loss in meter per hundred meters of pipe
- Software:
- Based on equations

FACTORS AFFECTING FRICTION LOSS

- Flow rate
- Pipe diameter
- Pipe length
- Pipe roughness
- Type of fluid

HAZEN- WILLIAM EQUATION

$$J = hf / (L/100) = K (Q/C)^{1.852} * D^{-4.87}$$

- J = head loss gradient, m/100m
 K = Conversion constant, $1.212 * 10^{12}$ for metric units
 Hf = Head loss due to pipe friction, m
 L = Length of pipe, m
 Q = Flow rate in pipe, L/S
 C = Friction Factor, for PVC pipe C=150
 D = Inside diameter of pipe, mm

Typical values of C for use in the Hazen-Williams equation are:

Pipe Material	C
Plastic	150
Epoxy-coated steel	145
Cement asbestos	140
Galvanized steel	135
Aluminum (with couplers every 30 ft)	130
Steel (new)	130
Steel (15 years old) or concrete	100

Source: (Keller and Blisner, 1988, page 135)

For smooth plastic pipes, Watters and Keller (1978) proposed the following equations as discussed by Keller and Bliesner (1988, page 138):

WATERS AND KELLER FORMULA

For small Pipe less than 125 mm

$$J = 100 * hf / L = K (Q)^{1.852} * D^{-4.75}$$

- J = head loss gradient, m/100m
 K = Conversion constant, $7.89 * 10^7$ for metric units
 Hf = Head loss due to pipe friction, m
 L = Length of pipe, m
 Q = Flow rate in pipe, L/S
 D = Inside diameter of pipe, mm

WATERS AND KELLER FORMULA

For Pipe Greater than 125 mm

$$J = 100 * hf / L = K (Q)^{1.83} / D^{4.83}$$

- J = head loss gradient, m/100m
 K = Conversion constant, $9.58 * 10^7$ for metric units
 Hf = Head loss due to pipe friction, m
 L = Length of pipe in, m
 Q = Flow rate in pipe, L/S
 D = Inside diameter of pipe, mm

DARCY- WEISBACH AND BLASIUS EQ.

Darcy- Weisbach and Blasius Equation can be combined to give accurate prediction of friction head loss for smooth plastic pipes of less than 125 mm (5 in.) diameter.

$$J = 100 \text{ hf/L} = k * [(Q^{1.75})/(D^{4.75})]$$

J = Head loss gradient, m/100 m

Hf = pipe friction head loss, m

K = Constant, $7.89 * 10^7$ for metric units

Q = Flow Rate, LPS

L = Pipe length, m

D = Inside Diameter of Pipe, mm

VELOCITY FORMULA TO DETERMINE PIPE SIZE FOR MAINLINE

$$v = 1.274 q / d^2$$

$$d^2 = V / (1.274 q)$$

$$d = \text{SQRT}[V / (1.274 q)]$$

v = velocity (m/s)

q = volume flow (m^3/s)

d = pipe inside diameter (m)

LATERAL DESIGN

$$\text{hf} = J * F * L / 100$$

F is the reduction coefficient to compensate for the discharge along the pipe.

$$\text{hf} = J * F * L / 100$$

F is the reduction coefficient to compensate for the discharge along the pipe.

Average Lateral Flow Rate, Ql

$$Ql = N * qa$$

$$Ql = L/Se * qa$$

Ql

N

qa

Se

m

= Average lateral flow rate, L/h

= No. of emitters along the lateral

= Average emitter discharge, L/hr

= Spacing of emitters along the Lateral,

No. of Outlets	F
1	1.00
2	0.52
3	0.44
4	0.41
5	0.40
6	0.39
7	0.38
8	0.38
9	0.37
10 -11	0.37
12 -15	0.37
16 – 20	0.36
21 – 30	0.36
>_ 31	0.36

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MINOR LOSSES

(Fittings and Valve Losses)

$H_f = K_r [V^2 / 2g]$
 H_f = Friction head loss due to pipe fittings, m (ft)
 K_r = Resistance coefficient for the fitting or valve
 $V^2/2g$ = Velocity head for given discharge, m (ft)
 g = Acceleration due to gravity, 9.81 m/s (32.2 ft/sec)

$$V^2/2g = K Q^2/D^4$$

K is constant 8.26×10^4 for metric unit, 2.59×10^{-3} for English unit)

Table 8.4. Resistance coefficient K for use determining head losses in fittings and valves.

STANDARD PIPE							
Nominal diameter							
Fitting or valve	3 in. (76.2 mm)	4 in. (101.6 mm)	5 in. (127.0 mm)	6 in. (152.4 mm)	7 in. (177.8 mm)	8 in. (203.2 mm)	10 in. (254 mm)
Bends:							
Return flanged	0.33	0.30	0.29	0.28	0.27	0.25	0.24
Return screwed	.80	.70					
Elbows:							
Regular flanged 90°	0.34	0.31	0.30	0.28	0.27	0.26	0.25
Long radius flanged 90°	.25	.22	.20	.18	.17	.15	.14
Long radius flanged 45°	.19	.18	.18	.17	.17	.17	.16
Regular screwed 90°	.80	.70					
Long radius screwed 90°	.30	.23					
Regular screwed 45°	.30	.28					
Tees:							
Flanged line flow	.16	.14	.13	.12	.11	.10	.09
Flanged branch flow	.73	.68	.65	.60	.58	.56	.52
Screwed line flow	.90	.90					
Screwed branch flow	1.20	1.10					
Valves:							
Globe flanged	7.0	6.3	6.0	5.8	5.7	5.6	5.5
Globe screwed	6.0	5.7					
Gate flanged	.21	.16	.13	.11	.09	.075	.06
Gate screwed	.14	.12					
Swing check flanged	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Swing check screwed	2.1	2.0					
Angle flanged	2.2	2.1	2.0	2.0	2.0	2.0	2.0
Angle screwed	1.3	1.0					
Foot	.80	.80	.80	.80	.80	.80	.80
Strainers-basket type	1.25	1.05	.95	.85	.80	.75	.67

*SCS National Engineering Handbook, Section 15, Chapter 11

Charts

Example

Size	1"		1 1/2"		2"	
OD	1.315		1.9		2.375	
ID	1.211		1.784		2.229	
Wall Thk	0.052		0.058		0.073	
Flow GPM	Velocit y FPS	PSI Loss	Velocit y FPS	PSI Loss	Velocit y FPS	PSI Loss
2	0.56	0.06	0.26	0.01	0.16	0
4	1.11	0.22	0.51	0.03	0.33	0.02
6	1.67	0.46	0.77	0.07	0.49	0.03
8	2.23	0.79	1.03	0.12	0.66	0.05
10	2.78	1.19	1.28	0.18	0.82	0.07
12	3.34	1.67	1.54	0.25	0.99	0.11
16	4.45	2.85	2.05	0.43	1.31	0.18
18	5.01	3.54	2.31	0.54	1.48	0.22
20	5.56	4.31	2.56	0.65	1.64	0.26
22	6.12	5.14	2.82	0.78	1.81	0.31
24	6.68	6.03	3.08	0.92	1.97	0.36
26	7.23	7	3.33	1.06	2.14	0.41
28	7.79	8.03	3.59	1.22	2.3	0.47
30	8.35	9.12	3.85	1.38	2.46	0.62
35	9.74	12.14	4.49	1.84	2.87	0.8
40	11.13	15.54	5.13	2.36	3.28	0.99
45	12.52	19.33	5.77	2.93	3.7	1.21
50	13.91	23.49	6.41	3.57	4.11	1.44
55	15.3	28.03	7.05	4.26	4.52	1.69
60	16.69	32.93	7.69	5	4.93	1.96
65	18.08	38.19	8.33	6.65	5.34	2.25
70	19.47	43.81	8.97	7.56	5.75	2.56
75	-	-	9.61	8.52	6.16	2.88

Total head required (H)

Total dynamic head should be capable of supplying required pressure and discharge for efficient functioning of the system.

Total head required (H) = suction head + Delivery head + Filtration losses+ Fertigation system losses+ Friction loss in pipes (main, sub-main and lateral) + Emitter operating pressure+ Fitting losses + Elevation (if any)

Suction = Vertical distance between water level to center of pump

Delivery = Vertical distance between center of pump to ground level

Filtration losses = Filtration head losses in different types of filters

Fertigation losses = Certain pressure is required to operate fertigation system, generally 5 m for manually operated ventury.

Friction losses in pipe = sum of pressure loss calculated for main, sub-main and lateral lines

Emitter operating pressure = Recommended emitter operating pressure given by the manufacturer

Fitting Losses = Generally 20% of pipe network lossess

Elevation = Vertical distance b/w ground level near to water source to the highest or lowest level

HORSE POWER REQUIRED

$$H.P = \frac{Q \times H}{75 \times e1 \times e2}$$

where:

Q is discharge, l/s

H is the total head, m;

e1 is the pump efficiency (fraction in the order of 0.5-0.8); and

e2 is the driving efficiency (fraction of 0.7-0.9 for electric motors and 0.5-0.75 for diesel engines).

The overall pumping efficiency under field conditions ranges accordingly from 0.35 in engine driven units to 0.50 in motor driven pumps. Higher efficiencies are not realistic. (Always rely on manufacturer chart to know the actual horse power)

6.12 Design Process Sprinkler

6.12.1 Factors Affecting the Layout of Sprinkler System

- Availability of water, quality, and source of power
- Soil factors
- Crop factors and uniformity required
- Purpose of the system and amount and frequency of water application

- Sprinkler spacing, nozzle size, and operating pressure
- Relative land elevations and pressure requirements.
- Layout of main and lateral lines
- Sizing of main and lateral lines for proper operation.
- Plans for proper operation of system
- Economic analysis

6.12.2 Design Procedure-Step by Step (Sprinkler)

Under the on-going project, sprinkler systems are being installed on field crops. In this section, steps for designing a sprinkler irrigation system will be discussed. The following are the design steps.

- Collection of Basic Information
- Selection of Sprinkler Heads
- Place sprinkler heads
- Design map
- Calculation of total flow
- Estimation of PWR
- Calculation of Application rate
- Running time per operation
- No. of operations
- Calculation of sectional flow
- Calculation of total dynamic head (H)
- Calculation of required horsepower (HP)
- Selection of Pumps and Motor
- Preparation of Drawing
- Preparation of Bill of Quantities

Step 1. Collection of Basic Information

The following basic information be available before designing a sprinkler irrigation system.

- General information: Name of farmer, village/chak No., tehsil, district, phone No.
- Land holding and **Area of the project**
- Engineering survey: GPS coordinates, Field measurement, Elevation difference/slope. After field measurement, a map showing all dimensions and location of water source be drawn
- Agricultural details: crops (orchard, row/field crop), spacing, type, age, **Effective Crop Root Depth**, **Reference Evapo-transpiration of the area (ET_o)**, and water requirement of crop, **Management Allowable Deficit (MAD)**
- Crop Spacing (Row to Row, Plant to Plant), sowing and harvesting date
- Soil Type/texture, **Water Holding Capacity**
- Soil and water analysis reports: water quality, presence of iron, pH, suspended particles, soil type, **Electrical Conductivity of Irrigation water (E_{ciw})**, pH
- Water Source, quantity, availability, location
- Power Source: Electric motor, diesel engine, tractor, solar system
- Climatologically data: temperature, humidity, rainfall, wind speed
- Peak Water Requirement: (ET_o, K_c, C_f)
- Water source and Total Available Time of water
- System capacity: The system should have capacity adequate to fulfill daily crop water requirements of the area within a stipulated time or not more than 12 hours of operation per day (only for Pakistan circumferences, otherwise may be 22 hrs).

The basic information can be categorized as under.

I. GENERAL INFORMATION

Name of beneficiary		Town/Village/City	
Tehsil		District	
Province		Phone No.	
Land holding (Acre)		Scheme area (acres)	16.06
Topography (Flat/Undulated)			

II. CROP INFORMATION

Parameters			Crop	Area (acres)	Plant spacig (m)	Row spacing (m)	Age of crop(years)	Sowing date	Harvesting date
Block-I	Orchard	Proposed	Citrus	7.04	3.10	6.1	2		
		Rotation							
Sub total: I									
Block-I	Orchard	Proposed	Citrus	6.07	4.57	4.57	New		
		Rotation							
Sub total: II									
Block-I	Orchard	Proposed	Mango	1.2	6.10	6.1	1		
		Rotation							
Sub total: III									
Block-I									
Sub total: IV									

III. SOIL TYPE/SOIL TEST/WATER SUPPLY/WATER QUALITY

Soil type/Texture			
Soil limitation (soil analysis report attached)			
Soil EC , PH , N , P , K , SAR			
WATER SUPPLY			
Available water sources			
1) Canal			
Sanctioned discharge (LPS)			
Perennial/non-perennial			
		Warabandi Days	
		Hours per Warabandi	
		Total Volume (m3) of water for 7 days	
2) Groundwater			
a) Dug well			
Depth of well			
Diameter of well			
Recharge rate			
b) Tube well/bore well			
Discharge capacity (LPS)			
Diameter of bore (inches)			
Depth of water table from ground (m)			
3) Storage/reservoir capacity (m3)			
Water quality (detailed report attached)			
		Iron	
		Ph	
		EC(mmohs/cm)	
Distance of water source from field (m)			

IV. POWER SOURCE AND PUMP**POWER SOURCE**

Type of power to be used

For electric Motor,

Type of connection (single/3-phase)

Make/model

HP of Motor

RPM of Motor

For diesel engine

Make

HP

Condition)

For Tractor

Make/model

HP

Condition

Any other power source, if any

PUMP SET

Type

Make/Model

Pressure (ft/psi/bar)

Flow(lps)

Inlet/outlet size

RPM

Pulley size

Water Analysis Report

Farmer Name : Abbass Qureshi		Water Source		
Address :Muzaffar garh		Sampling Date		
Ph :0345-8644888		Sp Receive Date :		
Agronomist: Ather Mehmood Khursheed		Report Date :		
		Ref.Sample		#

Parameters	Degree of Presence / Problem			
	Unit	Nomal	Higher	Extreme
pH		7	<7 Acidic	>7 A
Electrical Conductivity (Salinity)	microsemens/cm	-	-	-
Total dissolved solids	ppm	<500	500 - 600	>600
Hardness	ppm	<200	200 - 300	>300
Calcium	ppm	<60	60 - 100	>100
Magnesium	Ppm	<25	25 - 40	>40
Carbonate	Ppm	<200	200 - 600	>600
Bicarbonate	Ppm	<200	200 - 600	>600
Chloride (Toxic)	Ppm	<140	140 - 350	>350
Sulphates	Ppm	<20	20 - 50	>50
Sodium	Ppm	<100	100 - 200	>200
SAR	-	<3	3-9	>9
Potassium	Ppm	<10	10 - 20	>20
Sulphides	Ppm	<15	15-25	>25
Iron	Ppm	<0.1	0.1 - 0.4	>0.4
Manganese	Ppm	<0.2	0.2 - 0.4	>0.4
Suspended solids	Ppm	<10	10 - 100	>100
Boron	Ppm	<0.5	0.5 - 2.0	>2.0

Soil Analysis Report

Farmer Name :		Abbas Qureshi		Block Size :							
Address :		Muzaffargarh		Sampling Date :		11/5/2010					
Ph :		345864488		Sp Receive Date :		13/05/2010					
Agronomist :		Ather Mehmood Sheikh		Report Date :		26/04/2010					
				Code :		AMK-S001					
Ref. Soil Sample #	Block #	Depth (inches)	Texture	Organic Matter %	pH	Electrical conductivity (mic/cm)	Available Phosphorus(P) (ppm)	Available Potassium(K) (ppm)	Soluble & Exch. Na (meq/L)	Soluble & Ca +Mg (meq/L)	SAR
					Neutral 6.5- 7.5 Alkaline >8.5						Normal <10.0 Sodic >10.0
2835	1	0 - 6"	Sand,Clay	0.245	8.44	411	-	110	6.52	3.2	4
2836		6 - 12"	Sand,Clay	0.582	7.74	468	-	120	6.95	3.2	4.3
2837	2	0 - 6"	Sand,Clay	0.827	8.15	572	-	110	11.73	3.1	7.5
2838		6 - 12"	Sand,Clay	0.612	8.26	550	-	110	10.43	2.7	7.7
2839	3	0 - 6"	Sand,Clay	0.612	8.29	316	-	90	6.52	3.4	3.8
2840		6 - 12"	Sand,Clay	0.735	8.39	304	-	90	6.95	3.7	3.7
2841	4	0 - 6"	Sand,Clay	0.821	8.21	384	-	100	6.08	3.2	3.8
2842		6 - 12"	Sand,Clay	0.735	8.25	358	-	100	6.52	3.2	4
2843		0 - 6"	Sand,Clay	1.01	8.02	506	-	150	4.34	5.1	1.7
2844		6 - 12"	Sand,Clay	0.98	8.02	494	-	160	4.34	4.2	2
2845	6	0 - 6"	Sand,Clay	1.041	8.05	412	-	120	4.34	4.2	2
2846		6 - 12"	Sand,Clay	0.919	8.11	356	-	100	4.34	4.2	2
2847	7	0 - 6"	Sand,Clay	0.919	7.97	1080	-	80	10.86	6.6	3.2
2848		6 - 12"	Sand,Clay	0.549	8.02	1123	-	80	11.73	5.8	4

It is advisable to make rough map of the area and mark salient features, divide the drawn map into different blocks and number the same for soil and water sampling. This map will be finalized during designing of drip irrigation system and will show all necessary details including drippers, dia, length and location of laterals, submain and main, location of water source, power source etc.,

Step 2. Estimation of Leaching Requirement

All irrigation water contains some dissolved salts that are pushed downward by sprinkling and rainfall. By applying more water than the plants consume, most of the salts can be pushed or leached below the root zone. The first step in computing the additional water required for leaching is to determine the leaching requirement by:

$$LR = \frac{EC_w}{5EC_e - EC_w}$$

Where

LR = leaching requirement ratio for sprinkle or surface irrigation

EC_w = electrical conductivity of the irrigation water, Ds/M (MMHOS/CM)

EC_e = estimated electrical conductivity of the average saturation extract of the soil root zone profile for an appropriate yield reduction, ds/m (mmhos /cm)

It is recommended that the EC_e values presented in Table 3.5 be used in Eq. 3.3. These are values that will give an approximate 10% yield reduction, as

Table 3.5. Values of EC_e that will give 10% yield reduction for various crops¹

Crop	EC _e – dS/m	Crop	EC _e – dS/m
<i>Field crops</i>			
Barley	10.0	Rice	3.8
Cotton	9.6	Corn	2.5
Sugar beets	8.7	Flax	2.5
Wheat	7.4	Broadbeans	2.6
Soybean	5.5	Cowpeas	2.2
Sorghum	5.1	Beans	1.5
Groundnut	3.5		
<i>Fruit and nut crops</i>			
Date palm	6.8	Apricot	2.0
Fig, olive	3.8	Grape	2.5
Pomegranate	3.8	Almond	2.0
Grapefruit	2.4	Plum	2.1
Orange	2.3	Blackberry	2.0
Lemon	2.3	Boysenberry	2.0
Apple, pear	2.3	Avocado	1.8
Walnut	2.3	Raspberry	1.4
Peach	2.2	Strawberry	1.3
<i>Vegetable crops</i>			
Beets	5.1	Sweet corn	2.5
Broccoli	3.9	Sweet potato	2.4
Tomato	3.5	Pepper	2.2
Cucumber	3.3	Lettuce	2.1
Cantaloupe	3.6	Radish	2.0
Spinach	3.3	Onion	1.8
Cabbage	2.8	Carrot	1.7
Potato	2.5	Beans	1.5
<i>Forage crops</i>			
Tall wheat grass	9.9	Wild rye grass	4.4
Bermuda grass	8.5	Vetch	3.9
Barley (hay)	7.4	Alfalfa	3.4
Rye grass	6.9	Corn (forage)	3.2
Crested wheat grass	6.0	Berseem clover	3.2
Tall fescue	5.8	Orchard grass	3.1
Sudan grass	5.1	Clover	2.3

¹Adapted from Ayers and Westcott (1985).

presented by Ayers and Westcott (1985). (For conversion purposes: 1.0 ppm $\approx 640 \times EC$ in dS/cm.)

Under full irrigation, where $LR < 0.1$, the annual deep percolation losses, even in most of the least watered areas, will normally be sufficient to provide the necessary leaching. However, under deficit irrigation or when $LR \geq 0.1$, water in addition to the consumptive use should be applied or available at some time during the year to satisfy leaching requirements. The ratio of the total depth of irrigation water required with and without leaching is equal to $1/(1 - LR)$.

Sample Calculation 3.3 *Computing leaching requirement for a sprinkle irrigation system.*

GIVEN: Corn irrigated by a traveling sprinkler with water having an electrical conductivity of $EC_w = 2.1$ dS/m.

FIND: The leaching requirement.

CALCULATIONS: From Table 3.5, the electrical conductivity of the average saturation extract of the soil root zone profile that would give a 10% yield reduction, $EC_e = 2.5$ dS/m, and by Eq. 3.3:

$$LR = \frac{2.1}{5(2.5) - 2.1} = 0.20$$

Step 2. Estimation of Peak Crop Water

Requirement

Estimating the reference crop evapo-transpiration (**ET_o**), using the Penman-Monteith method, and the crop evapo-transpiration (**ET_c**), through the use of the appropriate crop factor **K_c**, have been covered in Module 4 Chapter_____ of this Manual. Evapo-transpiration is composed of the evaporation from the soil and the transpiration of the plant. Since under localized irrigation only a portion of the soil is wetted, the evaporation component of evapotranspiration can be reduced accordingly, using the appropriate ground cover reduction factor **K_r**.

For the design of sprinkler irrigation systems:

$$ET_c = ET_o \times K_c$$

III. CROP WATER REQUIREMENT

Month	J	F	M	A	M	J	J	A	S	O	N	D
Eto (mm/d)	1.4	2.2	3.6	5	6.3	6.5	5.2	4.7	4.5	3.2	1.8	1.3
Kc Carrot	1.0 5	1.0 5	1.0 5	1.0 5	1.0 5	1.05 5	1.0 5	1.0 5	1.0 5	1.0 5	1.0 5	1.0 5
Crop factor cp				1	1	1	1	1	1	1	1	1
CWR (row crop)	1.4 7	2.31	3.78	5.25	6.62	6.8 3	5.46	4.94	4.73	3.36	1.89	1.37
Kc (annual crop)												
CWR (annual crop)												
Kc (field crops)												
CWR (field crops)												

Step 3. Drawing of Project Area, Selection of zone area and No. of Operations

A map of the scheme area be drawn and tentative number of zones having equal area of the project be selected to estimate number of operations. It is advisable that area of each of each zone must be equal so that all the discharge coming out from the pump be fully utilized in each zone area. In case all zones are not equal, some additional water has to be sent back to the water storage tank through bypass valve during irrigation of small area zones.

Example:

Crop = carrot
 Area = 0.67 acre
 ETo = 6.5 mm/day
 kc = 1.05
 Irrigation system efficiency = 0.75
 ECiw = 0.2
 ECe = 7.4

Calculate leaching requirement.

Calculate peak daily consumptive use

Solution

Calculated data can be tabulated as under.

No.	Parameters	Notation/Formula	Zone 1	Units
1	Total area under HEIS	A	0.67	Acres
2	Reference Evapo-transpiration	ET_o	6.5	mm/d
3	Crop Factor	K_c	1.05	
5	Irrigation system efficiency	N	75.0	%
6	Quality of Irrigation Water	EC_{iw}	0.2	dS/m
7	Estimated water quality of root zone that will cause 10% yield reduction	EC_e	7.4	dS/m
8	Leaching Requirements	LR=EC_{iw}/(5EC_e-EC_{iw})	0.01	Fraction
9	Peak daily consumptive use per day	E_{tc}=ET_o x k_c/(n) x (1-LR)	9.15	mm/day

Step 4. SELECTION OF SPRINKLER HEAD

As an example, select a sprinkler rain gun Twin 101 with operating pressure of 60 psi, 24 mm (0.94 inch) nozzle diameter with a discharge of 198 gpm and sprinkler wetted diameter of 315 feet. Assume a sprinkler overlapping along lateral 100% and sprinkler overlapping between laterals 65%. Lateral spacing and sprinkler spacing at lateral can be calculated as under.

System is to be designed with KOMET Rain-Gun 101

Selection of Rain-Gun

Radius = 41.6 m at 4.0 bars with 24 mm Nozzle

Wetted Diameter of sprinkler = 96 m
 Effective diameter = 96- 10/100 (96)
 = 96-9.6= 86.4 m

Effect of wind = Nil as wind velocity is taken as zero

For Rectangular Pattern:

Sprinkler spacing between lateral/sub-mainline=0.65 x 86.4 = 56 m

Sprinkler spacing at lateral/sub-mainline = 0.5 x 86.4 = 43 m

No.	Parameters	Zone 1	Units		
1	Sprinkler flow rate	198.0	gpm		
2	Sprinkler Flow Rate	44906	LPH	12.474	lps
3	Nozzle size	24	mm	0.94	Inch
4	Nozzle operating pressure PSI	41.60	m	60	psi
5	Nozzle operating pressure Bars			4	bar
6	Wetted diameter of sprinkler	96.0	m	315.0	ft
7	Wetted radius of sprinkler	48.0	m	157.5	ft
8	Maximum wind velocity	6.0	km/hr		
9	Sprinkler overlapping along lateral	100.0	%		
10	Sprinkler overlapping between lateral	65.0	%		
11	Lateral spacing	56	m		
12	Sprinkler spacing at lateral	43			
13	Irrigation cycle (assume one day)	1.0	Days		
14	Total No. of Sprinkler	1	Nos.		

PERFORMANCE DATA - US. UNITS

Twin max taper bore nozzle, 24° trajectory

PSI	Nozzle 0.39"		Nozzle 0.43"		Nozzle 0.47"		Nozzle 0.51"		Nozzle 0.55"		Nozzle 0.59"		Nozzle 0.63"		Nozzle 0.67"		Nozzle 0.71"		Nozzle 0.79"		Nozzle 0.87"		Nozzle 0.94"	
	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.
25	-	-	-	-	32	148'	37	156'	43	163'	50	170'	57	177'	64	185'	72	191'	89	202'	107	213'	128	223'
30	24	148'	29	156'	35	162'	41	171'	48	180'	55	187'	62	193'	70	201'	79	207'	97	221'	118	231'	140	243'
35	26	156'	32	165'	38	173'	44	183'	51	191'	59	199'	67	205'	76	214'	85	221'	105	237'	127	244'	151	256'
40	28	163'	34	174'	40	182'	47	193'	55	201'	63	209'	72	216'	81	225'	91	233'	112	247'	135	255'	162	268'
45	30	170'	36	180'	43	190'	50	200'	58	208'	67	218'	76	225'	86	233'	96	242'	119	257'	144	265'	171	279'
50	31	177'	38	188'	45	197'	53	207'	62	213'	71	225'	80	232'	91	242'	102	250'	126	266'	152	274'	181	290'
55	33	183'	40	195'	47	204'	56	214'	65	221'	74	232'	84	240'	95	249'	107	258'	132	274'	159	285'	190	300'
60	34	191'	42	202'	50	212'	58	221'	67	229'	77	240'	88	247'	99	256'	111	266'	138	282'	166	292'	198	309'
65	36	198'	43	208'	52	218'	60	228'	70	236'	81	247'	92	254'	103	264'	116	273'	143	290'	173	300'	206	318'
70	37	205'	45	215'	53	225'	63	235'	73	244'	84	254'	95	262'	107	271'	120	280'	148	297'	180	307'	214	323'
80	40	216'	48	227'	57	237'	67	248'	78	257'	89	266'	102	276'	115	285'	129	294'	159	309'	192	318'	229	343'
90	42	227'	51	238'	61	248'	71	259'	83	269'	95	278'	108	289'	122	296'	136	308'	168	319'	204	331'	242	355'
100	44	235'	54	246'	64	257'	75	269'	87	280'	100	289'	114	300'	128	309'	144	320'	178	330'	215	341'	256	364'
110	47	243'	56	255'	67	265'	79	279'	91	290'	105	300'	119	310'	135	319'	151	331'	186	338'	225	350'	268	371'

Twin 101 taper bore nozzle, 24° trajectory

PSI	Nozzle 0.47"		Nozzle 0.55"		Nozzle 0.63"		Nozzle 0.71"		Nozzle 0.79"		Nozzle 0.87"		Nozzle 0.94"	
	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.	GPM	DIA.
30	-	-	48	187'	62	201'	79	217'	97	232'	118	247'	140	260'
40	40	183'	55	203'	72	220'	91	234'	112	250'	136	265'	162	279'
50	45	197'	62	215'	80	232'	102	250'	125	267'	152	283'	181	300'
60	50	212'	67	230'	88	247'	111	266'	138	282'	167	298'	198	315'
70	54	225'	73	244'	95	262'	120	280'	149	297'	180	314'	214	323'
80	57	237'	78	257'	102	276'	129	294'	159	312'	192	329'	229	344'
90	61	248'	83	269'	108	289'	137	308'	169	326'	204	343'	243	359'
100	64	257'	87	280'	114	300'	144	320'	178	339'	215	357'	256	374'
110	67	265'	91	290'	119	310'	151	331'	186	351'	225	369'	268	388'

Step 4. Calculation of maximum irrigation interval

As an example, Water holding capacity = 167 mm/m
MAD = 50%
Effective crop root depth = 0.9 m
Peak daily consumptive use = 9.15 mm/day

Calculate maximum irrigation interval

Solution

The same is given in following table

No.	Parameters	Notation/Formula	Zone 1 to 24	Units
1	No. of zones		24	
2	Effective crop Root depth	D	0.9	M
3	Management Allowed Deficit	MAD	50.0	%
4	Water holding capacity of soil	WHC	167.0	mm/m
5	Peak daily consumptive use per day	Etc=ET_o x kc/(n) x (1-LR)	9.15	mm/d
6	Max. depth of irrigation water that can be applied	Dmax=D x MAD x WHC/100	75	Mm
7	Max. irrigation interval	li=Dmax/ETc	8.2	Days

Step 4. Calculation of Lateral Length and number of sprinklers

As an example, Area = 0.67 acre

Lateral spacing = 56 m

Sprinkler spacing 45 meter = 45 m

Calculate length of lateral and No. of sprinklers

Length of Lateral and No. of Sprinklers/hydrants

Length of laterals can be calculated using Equation (4.21) as follows

$$L = A \times K / L_s$$

$$\begin{aligned} \text{Total lateral line length} &= \text{Area in acres} \times 4047 / \text{Lateral spacing} \\ &= 0.67 \times 4047 / 56 \\ &= 48 \text{ m} \end{aligned}$$

Total number of sprinklers/ hydrants required can be calculated using Equation (4.24)

$$\begin{aligned} \text{Number of sprinklers} &= A / (S \times L) \\ &= 0.67 \times 4047 / (56 \times 45) \\ &= 1 \text{ No.} \end{aligned}$$

A) Total Flow Rate

Total flow rate for sprinkler system depends upon the number of sprinkler to be operated simultaneously and can be calculated using Equation (4.28).

$$\begin{aligned}
 \text{Total flow rate} &= \text{No. of sprinkler} \times \text{Sprinkler flow rate} \\
 &= 1 \times 44906 \\
 &= 44906 \text{ LPH} \\
 &= 12.47 \text{ lps}
 \end{aligned}$$

B) Application Rate

Using equation (4.29) application rate can be calculated as:

$$\begin{aligned}
 \text{Application rate} &= \text{Total flow rate} / (\text{Area in acres} \times 4047) \\
 &= 44906 / (0.67 \times 4047) \\
 &= 16.56 \text{ mm/hr}
 \end{aligned}$$

C) Operation Time (hr)**D)**

Total operation time can be calculated using Equation (4.31)

$$\begin{aligned}
 \text{Operation time} &= \text{DCU} / \text{Application rate} \\
 &= 9.15 / 16.56 \\
 &= 0.55 \text{ hrs}
 \end{aligned}$$

In case the area is 16 acres, 26 no. of sprinklers will be required for which the total flow rate to irrigate 16 acres is 1167556 LPH (324 lps) which is much higher. To deliver this flow rate to the system, larger diameter pipe is required accordingly; high energy will be required, which is economically not feasible. Depending upon the farmer's ease and economics and available power source for the system it is suggested to operate only one rain gun at a time, such that the total area of 16 acres is irrigated in 26 shifts.

$$\begin{aligned}
 \text{Area irrigated in one shift/zone} &= \text{total area} / \text{No. of shifts} \\
 &= 16 / 26 \\
 &= 0.62 \text{ acres}
 \end{aligned}$$

Sprinkler Design Example

Design a rain-gun sprinkler system for 43 acres to provide supplemental Irrigation.

Crop: Wheat
 Soil type : Sandy
 Water source: canal + Tubewell
 Energy source: Tractor Engine

Important: System is to be designed with KOMET Rain-Gun 101

Selection of Rain-Gun

Radius = 45 m at 4.0 bars with 24 mm Nozzle

Wetted Diameter of sprinkler = 90 m

Effective diameter = $90 - \frac{10}{100} (90)$
 = $90 - 9 = 81$ m

Effect of wind = Nil as wind velocity is taken as zero

For Rectangular Pattern:

Sprinkler spacing between lateral/sub-mainline = $0.65 \times 81 = 53$ m

Sprinkler spacing at lateral/sub-mainline = $0.5 \times 81 = 41$ m

SPECIFICATIONS OF TWIN 101

Twin 101												Taper bore nozzle Trajectory 24°											
Pressure	Nozzle 12 mm - 0.47"			Nozzle 14 mm - 0.55"			Nozzle 16 mm - 0.63"			Nozzle 18 mm - 0.71"			Nozzle 20 mm - 0.79"			Nozzle 22 mm - 0.87"			Nozzle 24 mm - 0.94"				
	Flow	Radius		Flow	Radius		Flow	Radius		Flow	Radius		Flow	Radius		Flow	Radius		Flow	Radius			
	m ³ /h	l/s	m	m ³ /h	l/s	m	m ³ /h	l/s	m	m ³ /h	l/s	m	m ³ /h	l/s	m	m ³ /h	l/s	m	m ³ /h	l/s	m		
2.0				10.6	2.96	26.0	13.9	3.86	27.9	17.6	4.89	29.7	21.7	6.04	31.5	26.3	7.30	33.1	31.3	8.69	34.7		
2.5				11.9	3.31	28.3	15.5	4.32	30.4	19.7	5.47	32.4	24.3	6.75	34.3	29.4	8.17	36.1	35.0	9.72	37.8		
3.0	9.6	2.66	27.9	13.0	3.62	30.3	17.0	4.73	32.6	21.6	5.99	34.7	25.6	7.39	36.7	32.2	8.95	38.7	38.3	10.65	40.5		
3.5	10.4	2.87	29.5	14.1	3.91	32.1	18.4	5.11	34.5	23.3	6.47	36.8	28.7	7.99	38.9	34.8	9.66	41.0	41.4	11.50	43.0		
4.0	11.1	3.07	31.1	15.1	4.18	33.8	19.7	5.46	36.3	24.9	6.91	38.7	30.7	8.54	41.0	37.2	10.33	43.1	44.3	12.29	45.2		
4.5	11.7	3.26	32.5	16.0	4.44	35.3	20.9	5.80	38.0	26.4	7.33	40.5	32.6	9.05	42.8	39.4	10.96	45.1	46.9	13.04	47.3		
5.0	12.4	3.44	33.8	16.8	4.68	36.8	22.0	6.11	39.5	27.8	7.73	42.1	34.4	9.54	44.6	41.6	11.55	46.9	49.5	13.74	49.2		
5.5	13.0	3.60	35.1	17.7	4.91	38.1	23.1	6.41	41.0	29.2	8.11	43.7	36.0	10.01	46.2	43.6	12.11	48.7	51.9	14.42	51.0		
6.0	13.6	3.76	36.3	18.4	5.12	39.4	24.1	6.69	42.4	30.5	8.47	45.1	37.6	10.46	47.8	45.5	12.65	50.3	54.2	15.06	52.7		
6.5	14.1	3.92	37.4	19.2	5.33	40.6	25.1	6.96	43.6	31.7	8.81	46.5	39.2	10.88	49.3	47.4	13.17	51.9	56.4	15.67	54.4		

N.B. The performance data were obtained under ideal testing conditions and may be adversely affected by wind and other factors. Pressure refers to pressure at nozzle. A lowered trajectory angle improves the irrigation efficiency in windy conditions. For every 3° drop of the trajectory angle the throw is reduced by approximately 3 to 4%.

DATA INPUT

Total area under HEIS	,	43.0	Acres
Design reference evapotranspiration, ETo	,	4.2	mm/day
Design Crop factor at maturity, Kc	,	0.75	-
Plant spacing	,	0.1	m
Row spacing	,	0.1	m
Irrigation system efficiency	,	75	%
Quality of irrigation water	,	4.5	dS/m
Estimated water quality of root zone that will cause 10% yield reduction	,	7.5	dS/m
Effective crop root depth	,	1.0	m
Management allowed deficit	,	50.0	%
Water holding capacity of soil	,	83.0	mm/m
Sprinkler flow rate	,	44300	lph
Nozzle size	,	24	mm
Nozzle operating pressure	,	40	m
Wetted diameter of sprinkler/nozzle	,	81	m
Maximum wind velocity	,	0.0	km/hr

Leaching requirement

$$\begin{aligned}
 &= E_{cw} / [5 E_{ce} - E_{cw}] \\
 &= 4.5 / [5 \times 7.5 - 4.5] \\
 &= 0.136
 \end{aligned}$$

Peak Daily Consumptive use per day

$$\begin{aligned}
 &= E_{to} \times K_c / [(1-LR) \times \text{efficiency}] \\
 &= 4.2 \times 0.75 / [(1- 0.136) \times 0.75] \\
 &= 4.86 \text{ mm}
 \end{aligned}$$

Lateral Length

$$= \text{Area} \times 4047 / \text{Lateral spacing}$$

$$= 43 \times 4047 / 53 = 3283 \text{ m}$$

Minimum Sprinkler/Hydrants

$$= \text{Area} \times 4047 / [\text{lateral spacing} \times \text{sprinkler spacing}]$$

$$= 43 \times 4047 / [53 \times 41]$$

$$= 80$$

Total Flow Rate, LPH

$$= \text{No. of sprinklers} \times \text{sprinkler flow rate}$$

$$= 80 \times 44300$$

$$= 3,544,000 \text{ lph}$$

Application Rate, mm/hr

$$= \text{Total flow rate} / \text{total area}$$

$$= 3,544,000 / [43 \times 4047]$$

$$= 20.36$$

$$= \text{SPRINKLER FLOW RATE} / (\text{SL} \times \text{Sm})$$

$$= 44300 / (53 \times 41) = 20.38 \text{ mm/hr}$$

Operation Time (when all sprinklers operating together)

$$= \text{Peak daily consumptive use} / \text{Application Rate}$$

$$= 4.86 / 20.38$$

$$= 0.24 \text{ hrs}$$

$$\text{No. of operations/hydro-zones}$$

$$= \text{total no. of sprinklers or hydrants} / \text{no. of sprinklers operating}$$

$$= 80 / 2$$

$$= 40$$

$$\text{Total operation time}$$

$$= \text{No. of operation} \times \text{operation time for one setting}$$

$$= 40 \times 0.24$$

$$= 9.60 \text{ hours}$$

WATERS AND KELLER FORMULA

For small Pipe less than 125 mm

$$J = 100 * hf / L = K (Q)^{1.852} \times D^{-4.75}$$

J = head loss gradient, m/100m

K = Conversion constant, 7.89×10^7 for metric units

Hf = Head loss due to pipe friction, m

L = Length of pipe, m

Q = Flow rate in pipe, L/S

D = Inside diameter of pipe, mm

For Pipe Greater than 125 mm

$$J = 100 * hf / L = K (Q)^{1.83} / D^{4.83}$$

J = head loss gradient, m/100m

K = Conversion constant, 9.58×10^7 for metric units

Hf = Head loss due to pipe friction, m

L = Length of pipe in, m

Q = Flow rate in pipe, L/S

D = Inside diameter of pipe, mm

Velocity Formula to Determine Pipe Size for Mainline

$$v = 1.274 q / d^2$$

$$d^2 = V / (1.274 q)$$

$$d = \text{SQRT} [V / (1.274 q)]$$

v = velocity (m/s)

q = volume flow (m^3/s)

d = pipe inside diameter (m)

Hydraulic Calculation

Mainline Head Loss (6" pipe, ID = 154 mm, L= 530 m, Q= 88600 lph)

Using Watters and Keller Eq.

$$J = 9.58 \times 10^7 \times Q^{1.83} / D^{4.83}$$

$$J = 9.58 \times 10^7 \times (24.6)^{1.83} / (154)^{4.83}$$

$$= 0.91 \text{ m/100m}$$

$$= 0.91 / 100 \times 530 = 4.823 \text{ m}$$

$$v = 1.274 q / d^2 = 1.274 \times (0.0246) / (0.154 \times 0.154)$$

v = velocity (m/s)

q = volume flow (m^3/s)

d = pipe inside diameter (m)

$$\text{Velocity} = 1.32 \text{ m/s}$$

Using Watters and Keller Eq.

Sub-Mainline Head Loss (4", ID = 105 mm, L= 328m, Q= 44300 lph)

$$J = 7.89 \times 10^7 \times Q^{1.852}/D^{4.75}$$

$$J = 7.89 \times 10^7 \times (12.3)^{1.852}/(105)^{4.75}$$

$$= 2.06 \text{ m/100m}$$

$$= 2.0/100 \times 328 = 6.56 \text{ m}$$

$$\text{Velocity} = 1.42 \text{ m/s}$$

TOTAL DYNAMIC HEAD	
Sprinkler operating pressure	40.0
Elevation difference	0.0
Head loss in lateral	0.0
Head loss in sub-mainline	3.3
Head loss in mainline	6.6
Head loss in filter	0.0
Head loss in hydrant	1.0
Head loss in fertigation system	0.0
Head loss in flow meter	1
Field fitting losses	2.0
Miscellaneous head loss, if any	
Pumping lift	0
Total Head Requirement (Approximately)	53.0

Pump Requirement

$$Q = 88600 \text{ lph}$$

$$= 24.6 \text{ lps}$$

$$H = 53 \text{ m}$$

$$\text{HP} = 24.6 \times 53 / (75 \times 0.7 \times 0.5)$$

$$50$$

BILL OF QUANTITIES

S.N	Description	Standard/ specification	Unit	Quantity	Rate (Rs.)	Cost (Rs.)
1	Pump set	25 LPS , 51 M	No	01		
2	Flow Meter	100 M3/hr		01		
3	Pressure Gauges			03		
4	Air Release valves			02		
5	NRV			01		
6	Foot valve			01		
7	GI Hydrants with brass valves	2 inches, 2m	Nos.	80		
8	Flow control valves	4 inches	Nos.	11		
9	GI Fittings	160 mm	L/s	1		
10	PVC Pipe , B Class	160 mm	m	530		
11	PVC Pipe, B Class	110 mm	m	3280		
12	Rain Guns	Twin 10l	Nos.	03		
13	Trenching					
14	Civil works for head unit & Hydrants reinforcement		L.S.			
	Sub-Total					
	Service charges (Design, Installation, Service)	8% of total				
Grand Total						

6.13 SELECTION OF PUMP

Pump is selected based on the discharge and total dynamic head. The selection process involves finding an economic pumping plant that will provide required discharge and head and also operate at high efficiency. Pump characteristic curves developed by the manufacturers provide the ready reference for selection of most efficient pumping unit.

Horse power requirement can be calculated as

$$\text{H.P} = \frac{\text{Q. H}}{75 \times \text{Em} \times \text{Ep}} \quad (5.6)$$

Q = Flow rate, lps
H = Total dynamic head, m
Em = Motor efficiency (fraction)
Ep = Pump efficiency (fraction)

Electric motor efficiency is generally taken as 80%.

Diesel engine efficiency is generally take as 40-50%

Pump efficiency is generally taken as 50-75%.

6.14 Design of Sprinkler Irrigation System – Example 2

Design a Rain Gun sprinkler system for wheat crop on a rectangular area of dimensions 880 ft X 795 ft with the following available data:

Given Data:

Growing season	-	November to May
Soil Type	-	Loam
Ec of water	-	0.20 dS/m
Max. Wind velocity	-	6 Km/hr
Komet Twin-101 rain gun is selected having following specifications:		
Nozzle diameter	-	24mm
Flow rate	-	44244 LPH (Liter per Hour)
Nozzle operating pressure	-	4.0 bar
Wetted radius	-	45.2 m

Design Calculations:

A) Leaching Requirement

LR can be calculated using equation 3.8 as given below

$$LR = \frac{EC_w}{5 (EC_e) - EC_w}$$

Estimated water quality of root zone that will cause 10% yield reduction for wheat crop is taken from the Table-3.8, which is 7.4 dS/m.

$$= 0.2 / 5 [7.4 - 0.2] = 0.01$$

B) Crop Water Requirement

Crop water requirement is calculated by multiplying ETo and Kc values for each month of the growing season of the wheat crop. ETo values in mm per day for each month of the year and Kc values of the growing season of the selected area can be selected from Tables given in Crop Water Requirement Manual. For designing purpose select the maximum crop water requirement (CWR) value. For wheat the maximum CWR value comes in the month of February so the ETo and Kc values of this month are incorporated in the design sheet.

Peak daily consumptive use (CU) per day is calculated using equation as follows:

$$\begin{aligned} \text{CU} &= \text{ETo} \times \text{Kc} \times \text{Kf} / [\text{efficiency} \times (1 - \text{LR})] \\ &= 2.2 \times 1.2 \times 1 / (0.75 \times (1 - 0.01)) \\ &= 3.56 \text{ mm/day} \end{aligned}$$

Irrigation system efficiency for sprinkler system is taken from the Table-3.4 giving range (60-85%) the average value 75% is generally used for high pressure sprinkler system such as Rain-Gun.

C) Sprinkler Pattern/ Spacing

100% of sprinkler overlapping is selected along lateral while 65% overlapping is selected between laterals. Using this type of overlapping the sprinkler to sprinkler and lateral to lateral spacing is calculated as below:

$$\begin{aligned} \text{Sprinkler Spacing} &= 0.50 \times \text{Wetted dia. of sprinkler} \\ &= 0.50 \times (2 \times 45.2) \\ &= 45.2 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{Lateral Spacing} &= 0.65 \times \text{Wetted dia. of sprinkler} \\ &= 0.65 \times (2 \times 45.2) \\ &= 58.76 \text{ m} \end{aligned}$$

D) Length of Lateral and No. of Sprinklers/hydrants

Length of laterals can be calculated using Equation (4.21) as follows

$$L = A \times K / L_s$$

$$\begin{aligned} \text{Total lateral line length} &= \text{Area in acres} \times 4047 / \text{Lateral spacing} \\ &= 16 \times 4047 / 58.76 \\ &= 1102 \text{ m} \end{aligned}$$

Total number of sprinklers/ hydrants required can be calculated using Equation (4.24)

$$\begin{aligned}
 \text{Number of sprinklers} &= A / (S \times L) \\
 &= 16 \times 4047 / (58.76 \times 45.2) \\
 &= 24.4 \text{ say } 25 \text{ Nos.}
 \end{aligned}$$

E) Total Flow Rate

Total flow rate for sprinkler system depends upon the number of sprinkler to be operated simultaneously and can be calculated using Equation.

$$\begin{aligned}
 \text{Total flow rate} &= \text{No. of sprinkler} \times \text{Sprinkler flow rate} \\
 &= 25 \times 44244 \\
 &= 1106100 \text{ LPH}
 \end{aligned}$$

F) Application Rate

Using equation application rate can be calculated as:

$$\begin{aligned}
 \text{Application rate} &= \text{Total flow rate} / (\text{Area in acres} \times 4047) \\
 &= 1106100 / (16 \times 4047) \\
 &= 17.08 \text{ mm/hr}
 \end{aligned}$$

G) Operation Time (hr)

Total operation time can be calculated using Equation.

$$\begin{aligned}
 \text{Operation time} &= \text{DCU} / \text{Application rate} \\
 &= 3.56 / 17.08 \\
 &= 0.21 \text{ hrs}
 \end{aligned}$$

As 25 no. of sprinklers are required for which the total flow rate to irrigate 16 acres is 1106100 LPH which is much higher. To deliver this flow rate to the system, larger diameter pipe is required accordingly; high energy will be required, which is economically not feasible. Depending upon the farmer's ease and economics and available power source for the system it is suggested to operate only one rain gun at a time, such that the total area of 16 acres is irrigated in 25 shifts.

$$\begin{aligned}
 \text{Area irrigated in one shift/zone} &= \text{total area} / \text{No. of shifts} \\
 &= 16 / 25 \\
 &= 0.64 \text{ acres}
 \end{aligned}$$

H) Maximum irrigation Depth

Maximum irrigation depth (dx) can be calculated using Equation (4.12)

$$dx = \text{MAD} (W_a \times Z) / 100$$

Effective rooting depth of wheat crop is taken from Table-4.4 which is 1.2 m.

Management Allowed Deficit is taken from the Table-3.2 which is 25%

Water holding capacity for loam soil is taken from Table-3.1 which is 170 mm/m

$$= 25 \times (170 \times 1.2) / 100$$

$$= 51 \text{ mm}$$

I) Maximum Irrigation Interval

Maximum irrigation interval can be calculated using Equation 4.13.

$$F_x = dx / Cu$$

$$F_x = 51 / 3.56 = 14 \text{ days}$$

Design layout for sprinkler irrigation system

All the above calculated values are arranged in the form of table for design as flows:

Sr. No.	Parameters	Units	Zone (1 to 24)	Total
1	Total Area	Acres	0.64	16
2	Design Reference Evapotranspiration, ETo	mm/day	2.2	
3	Design crop factor at maturity, Kc	-	1.2	
4	Irrigation system efficiency	%	75	
5	Quality of irrigation water	dS/m	0.20	
6	Estimated water quality of root zone that will cause 10% yield reduction	dS/m	7.4	
7	Effective crop root depth	m	1.2	
8	Management Allowed Deficit	%	25	
9	Water holding capacity of soil	mm/m	170	
10	Leaching requirement	fraction	0.01	
11	Maximum wind velocity	Km/hr	6	
12	Sprinkler flow rate	LPH	44244	44244
13	Nozzle size	mm	24	
14	Nozzle operating pressure	m	40	
15	Wetted radius of sprinkler	m	45.2	
16	Sprinkler overlapping along lateral	%	100	
17	Sprinkler overlapping between lateral	%	65	
18	Sprinkler spacing at lateral	m	45.2	
19	Lateral spacing	m	58.76	
20	Irrigation Cycle	days	1	
21	Peak daily consumptive use per day	mm/day	3.52	
22	Total no. of sprinklers	No.	1	
23	Total flow rate	LPH	44244	
24	Application rate	mm/hr	17.08	
25	Operation time	hrs	0.21	5.04

J) Head Loss Calculations

The maximum lateral line length to be laid at site is 180 m (see layout) while only one number of sprinkler is to be operate on a lateral for which the flow rate is 44244 LPH. The diameter of pipe required to deliver this amount of water shall be selected such that the head loss may be less than 20% of the sprinkler operating pressure or the velocity shall not exceed 1.5 m/s. A 4" pipe diameter is selected for which the head loss can be calculated by using equations as illustrated in Exapmle-1.

Lateral Head Loss for 100m length using Watter & Keller's equation	=	1.42 m
Lateral Head Loss for 180m length using Watter & Keller's equation	=	2.56 m

Lateral Head Loss for 100m length using Hazzen William's equation= 1.49 m
 Lateral Head Loss for 180m length using Hazzen William's equation= 2.68 m

Average lateral head loss for 180 m of length = 2.62 m

The total length of main line pipe to deliver water to the remotest lateral is 325m (see layout) which will also be used to carry water flow rate of 44244 LPH to each outlet point in the pipe network, so similar sized pipe can be used for lateral and mainline.

As the flow rate and diameter of pipe is same and only the length is changed so that the head loss for 325 m of length can be given as:

Main line head loss for 325 m of length = 4.90 m

The head loss for suction and delivery pipe for pump be calculated using the same equation.

Suction and delivery head loss = 0.09 m
 Total head losses in piping network = 2.62 + 4.90 + 0.09
 = 7.61m
 Fitting losses
 (may be taken 20% of the pipe losses) = 1.52 m
 Sprinkler operating pressure in form of water head = 40 m

Head losses for fittings, filters, fertigation system and other flow control and monitoring devices shall be included as given by the manufacturers. For example

Head loss in fertigation = 5 m
 Head loss in flow meter = 1 m
 Misc. head losses = 2 m

The total dynamic head can be calculated by adding all the head losses occurring in the system and can be presented as follow:

Total Dynamic Head = 57.13 m

K) Power requirements

Horse Power Requirement can be calculated using equation – 5.6

Pump flow rate = 44244 (LPH) / 3600 (Sec.)
 = 12.29 LPS

The efficiencies for pump and electric motor are assumed as 60% and 80% respectively.

H.P = $Q \cdot H / [75 \times E_m \times E_p]$
 = $12.29 \times 57.13 / [75 \times 0.55 \times 0.8]$
 Required Horse Power = 20 (appx.)

References

Consultants will furnish references on request.