Citrus Orchard Foreman Occupational Learning

P.O. Box 461, Hillcrest, 3650
(031) 765-3410

Work Scenario Guide

B4:
Irrigation Installation

Qualification:	110667 – Occupational Certificate: Orchard and Vineyard Foreman
Work Scenario:	**B4: Irrigation Installation**
Learning Area:	B: Lead the establishment of new citrus orchard
Scenario Description:	Your orchard needs an irrigation system. You need to plan and oversee the installation of the entire system, and ensure that the system is optimally placed and correctly installed.

1st edition (06/2026)

Content originator:
Citrus Academy

Occupational alignment:
Ukudla Namanzi (Pty) Ltd

Contents

Alignment Information

Qualification

The content of this learner guide is aligned to the following occupational qualification:

SAQA QUAL ID	**Qualification Title**			
110667	Occupational Certificate: Orchard and Vineyard Foreman			
Originator				
Development Quality Partner – AgriSETA				
Primary Or Delegated Quality Assurance Functionary		**NQF Sub-Framework**		
-		OQSF - Occupational Qualifications Sub-Framework		
QUALIFICATION TYPE	**FIELD**		**SUBFIELD**	
Occupational Certificate	Field 01 - Agriculture and Nature Conservation		Primary Agriculture	
Abet Band	**Minimum Credits**	**Pre-2009 NQF Level**	**NQF Level**	**Qual Class**
Undefined	147	Not Applicable	NQF Level 04	Regular-ELOAC

Modules

The content of this learner guide is aligned to the following modules of the occupational qualification above.

Module Code	Module Title	Level	Credits
Knowledge Modules			
611202-001-00-KM-01	Plant Structure and Physiology	4	5
611202-001-00-KM-02	Vineyard or Orchard Establishment	3	2
611202-001-00-KM-03	Vineyard or Orchard Manipulation Processes	3	8
611202-001-00-KM-04	Harvesting	3	4
611202-001-00-KM-05	Basic Principles of Plant Nutrition	4	4
611202-001-00-KM-06	Crop Protection	3	3
611202-001-00-KM-07	Assets in Horticultural Production	3	2
611202-001-00-KM-08	Farm Business Management and Farming Process Management	4	8
611202-001-00-KM-09	Human Resource Management and Processes	4	8
611202-001-00-KM-10	Overseeing Farming Resource Utilisation	4	8
Practical Skill Modules			
611202-001-00-PM-01	Organise, Allocate and Monitor Availability and Productive Use of Resources	4	5
611202-001-00-PM-2a	Set Team and Individual Performance Goals to Enhancing Team Performance	4	10
611202-001-00-PM-2b	Control Vineyard or Orchard Practices	4	10

611202-001-00-PM-03	Supply Accurate Daily Orchard or Vineyard and Production Information	4	10
Work Experience Modules			
611202-001-00-WM-01	Vineyard or Orchard Resource Optimisation	4	20
611202-001-00-WM-02	Skilled and Motivated Work Team Output	4	20
611202-001-00-WM-03	Daily Orchard or Vineyard and Production Information Availability	4	20

Learning Outcomes

The content of this learner guide is aligned to the following learning outcomes of the modules above.

Knowledge Topics	
Outcome Code	**Module Title**
KM-02-KT03	**Block establishment**
IAC0309	An irrigation plan and diagram is interpreted
IAC0310	The importance of correct installation of an irrigation system for planting area is explained
KM-08-KT06	**Farm renewal strategy**
IAC0604	Methods and operations to be applied in the establishment of new orchards/vineyards are discussed
IAC0607	Methods and operations to be applied in the replacement of orchards/vineyards are discussed
Practical Skills	

Chapter 1
Irrigation Systems

learning outcomes

The content of this chapter is aimed at helping you to:

- Select an appropriate irrigation system.

1. Introduction

Irrigation systems come in many shapes and sizes, and not all of them are suitable for citrus production. In this chapter, we will give a brief overview of the types of systems, followed by a discussion on the factors that play an important role in the decision on the type and specifications of irrigation system to be installed. These factors include:

- Water availability
- Water quality
- Crop type
- Soil water holding capacity
- Cost
- Management
- Maintenance

When selecting an irrigation system, or if you have any questions about your irrigation systems, it is helpful to contact a SABI (South African Irrigation Institute) accredited irrigation designer. They will be competent in selecting the correct irrigation system for a specific situation, and are also available to assist with the evaluation of irrigation systems.

Irrigation systems can be classified as shown below:

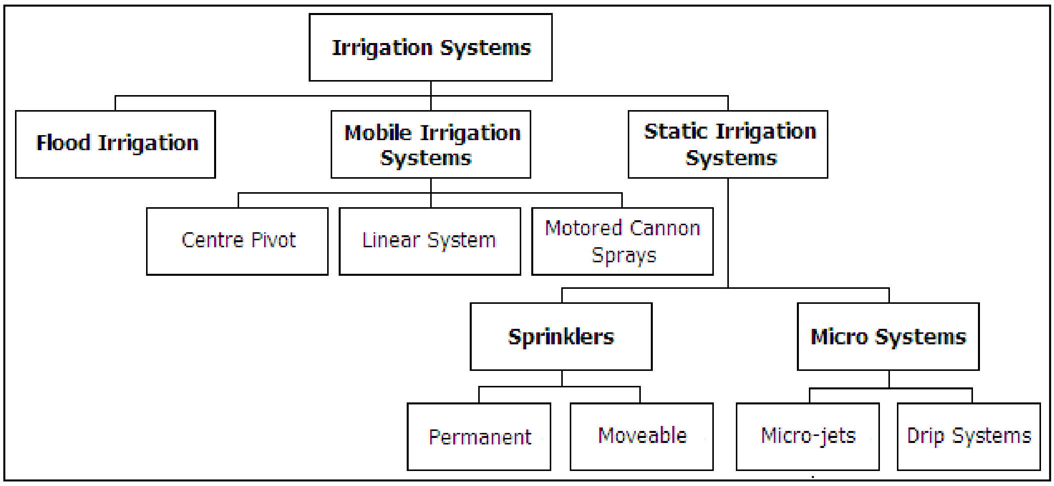


Diagram of Basic Irrigation System Classification

1.1. Flood Irrigation

In flood irrigation water is channelled to the crop by furrows in the ground. This means that the area that is irrigated must have a constant slope that is not too steep. In some instances, basins that can be filled with water are made around the crop plants.

1.2. Mobile Irrigation Systems

Mobile, or moving, irrigation systems irrigate while the system is moving and includes systems such as centre pivots, linear systems and motored cannon sprays.

The centre pivot consists of sections that are supported by wheels and rotates around a fixed point called a tower. The linear system is similar to the centre pivot in the sense that it is also steel sections supported on wheels, however the linear system moves in a linear motion across a field. Motored cannon sprays are water cannons, or large sprinklers, mounted on trailers. A mechanism is provided, usually a water powered winch, which propels the trailer through the field.

1.3. Static Systems

Static systems are systems that stand still while they irrigate. These include systems such as permanent and non-permanent sprinkler systems and micro-jet and drip systems.

2. Water Availability

Before you begin to install or even decide on a specific system, you need to assess the availability and quality of the available irrigation water. To assess whether the quantity of water is sufficient, a two-tiered approach is used. Firstly, the crop water requirements must be established and secondly, the available water sources must be assessed.

Water on the farm can be from a number of sources such as:

- The enlisted water allocation from an irrigation scheme
- Storage and holding dams
- Free streams and fountains
- Boreholes

The enlisted water allocation is the easiest source to quantify. The farm can either be enlisted for a total volume of water per annum, for instance 200,000m³, or for a number of hectares. When hectares are used, a volume of water is allocated per hectare per annum. To calculate the total water quota the number of enlisted hectares is multiplied by the allocation per hectare.

example

Calculation of Total Water Quota

A farm has 35ha enlisted in an irrigation scheme and the allocation is 11,000m³/annum/ha. The total allocation per annum is calculated as follows:

= Enlisted ha x allocation

= 35ha x 11,000m³/annum/ha

= 385,000 m³/annum

Water sources like dams, streams, fountains and boreholes are dependent on rain to be sustainable. It is recommended that a proper hydrological study or at least an assessment of historical weather data is done to determine the annual water yield from these sources. A hydrological study is used to determine the catchments area, after which the amount of runoff water per annum is estimated. These figures are used to derive an average annual runoff figure. This process is however complex and should be undertaken by a hydrologist.

Keep in mind that most of South Africa suffers from erratic rainfall and periods of drought. There is no set formula to determine the effect of drought on the available water sources. The best approach is to determine a reserve amount of water with the aid of historical rainfall figures and the help of neighbouring farmers.

This reserve is the amount of water that is required to continue sufficient irrigation even if water allocations are cut. The reserve can be used to irrigate annual crops in good years and in dry years the reserve can be used to irrigate the tree crops.

Once the available water is estimated, it must be determined whether it is sufficient for sustainable irrigation of the crop. To do this, the crop water requirement must be known and weighed against the available water. If the available water resources are inadequate, you may need to consider cultivating a smaller area, or other crops. If the available water is sufficient, you need to consider pumping and storage constraints.

Water resources such as channels and boreholes deliver water over 24 hours, so when the water is not pumped it is "lost". Other resources such as rivers and channels may only allow water extraction at specific times that may be outside irrigation hours. These constraints are overcome by using holding dams or reservoirs that have sufficient capacity to store water for a few days. Water from rivers, canals and boreholes is stored in these reservoirs and pumped from the reservoir to the various irrigation blocks.

Another pumping constraint is the physical location of the pump and river installations, which can become a problem when there is a big variance in water levels. River pumps are usually prone to flood damage during the rainy season, and it is advised to consult a pump specialist in this regard. Possible solutions include using watertight pump houses or submersible pumps, placing the pump on a pontoon, and a pump installation that enable fast extraction to form the river.

Irrigation system efficiency is another factor that determines whether sufficient water is available. Every irrigation system has a system efficiency that can range from 50% to 90% depending on the type of system. Drip and micro-jet irrigation are used most often for citrus because of high system efficiencies.

definition

Irrigation Efficiency

Irrigation efficiency refers to the percentage of the water displaced by the irrigation system that is utilised by the crop. If a system has an efficiency of 80%, 80% of the water is utilised by the crop and 20% is lost.

The water loss occurs for the following reasons:

- Evaporation of the water as it is applied from the emitter to the ground.
- Mist drift, when the wind carries mist that is formed during irrigation outside the root-zone area.
- Non-absorption due to the wetted area being larger than the root-zone area, which is usually because of system design.

- Non-absorption due to the wetted depth being deeper than the root depth.

Where the quantity of water is limited, the system with highest efficiency must be used. Apart from more water reaching the plant, it also reduces pumping costs and conserves water. The table below is a list of systems with their estimated efficiencies.

information

System Efficiency of Irrigation Systems

System	*System Efficiency*	*Factors Influencing Efficiency*
Flood	50–60%	A portion of the water penetrates the ground in the furrows and does not reach the root-zone.
Pivot	70–80%	Water is lost because of drifting and evaporation, and areas outside the root-zone are covered.
Cannon	65%	Water is lost because of drifting and evaporation, and areas outside the root-zone are covered.
Linear	70–80%	Water is lost because of drifting and evaporation, and areas outside the root-zone are covered.
Sprinkler	75%	Water is lost because of drifting and evaporation, and areas outside the root-zone are covered.
Micro-jets	80%	Water is lost because of drifting and evaporation. The efficiency is higher because the water application is localised around the tree and hence the root-zone.
Drip	90%	Losses are minimal with this system, because of zero drifting and water being applied directly in the root-zone.

3. Water Quality

Water quality varies from farm to farm and influences aspects such as type of system, filtration and fertigation. Water quality is classified in terms of:

- Physical water quality factors
- Chemical water quality factors
- Biological water quality factors

Poor water quality affects the crop, irrigation system, soil and environment. Physical and biological impurities are detrimental mainly to the irrigation system and lower efficiency and uniformity. Chemical water quality factors affect the crop, soil and environment directly.

Fertigation is also affected by poor water quality. Water of a poor chemical quality complicates fertigation because the water quality must either be improved, or the fertigation practice must be adapted. Fertigation can also lead to the formation of excessive biological slimes and increase the salt content of the water since fertilisers are salts.

3.1 Physical Water Quality Factors

Physical water quality factors refer (generally) to impurities that can be seen with the naked eye, and include particles such as sand, silt and particles that make water turbid. Heavy particles such as sand and silt can be filtered out directly, but some suspended solids such as clay particles need to be flocculated and allowed to settle before filtration.

Physical water quality can be improved through processes such as filtration and sedimentation. Filtration is the most basic and essential water treatment. Filtration removes most physical impurities and other un-dissolved solids in the water. Most irrigation systems require filtration to some degree, depending on the system.

Sedimentation, also referred to as flocculation or sinking, is a process whereby the flow of water is reduced, and the suspended material is allowed to settle to the bottom. This is done by letting the water into a storage dam and extracting it from the other end. During the time the water is in the storage dam, the flow is reduced to zero and solid particles settle. This process is effective at removing solids such as silt, sand, cuttings and some organic debris.

3.2 Chemical Water Quality Factors

Generally, chemical water quality factors mostly refer to the non-visible, dissolved elements and characteristics of water. The impact of the chemical water factors depends on the type and concentration of these elements. Some chemical elements can be detrimental to the soil and plants, such as sodium, chloride, heavy metals and toxins. Chemical water quality factors can also cause blockages of the emitters of the irrigation system.

To determine the chemical water quality, a water sample is taken at the extraction point and sent for analysis. The analysis determines the chemical characteristics of the water, of which the most important are:

- Electrical Conductivity – The ability of water to conduct electricity and is an indication of the total dissolved salts in water.
- Total Dissolved Salts (TDS) – The total amount of dissolved salts in the water. The higher the salt content of the water, the more energy plants need to expend to absorb the water.
- Sodium Absorption Ratio (SAR) – The relation between sodium and calcium plus magnesium in the water. The higher this value, the more sodium is present, and the greater the hazard of degradation of the physical properties of the soil.
- pH – The acidity or alkalinity of water.

With an advanced water analysis, other chemical properties can also be determined, such as carbonates, metals, and other elements. This will only be necessary with more advanced specifications and applications.

Improving chemical water quality factors is usually expensive and, apart from pH, not financially viable. There are certain processes that can be considered, such as oxidation.

When water comes into contact with air, dissolved metals like iron and manganese are oxidised to their insoluble form and settle at the bottom of the water. Oxidation can be accelerated through spraying water through the air into a storage dam or by using an aerator.

3.3 Biological Water Quality Factors

Biological water quality factors refer to the levels of organic colloids, algae and bacteria in the water. Organic impurities tend to cause flakes and slimes that block irrigation systems, especially drippers. Chlorine is used to kill organisms in the water, in this way helping to prevent blockages due to organic compounds. Chlorine can also precipitate iron and manganese.

Chlorine can be injected as a gas or by using sodium or calcium salts which liberate chlorine. Hydrogen peroxide can also be used for this purpose. It is cheaper than chlorine and is more effective in dealing with algae. Irrigation systems are affected differently by water quality. The table below lists the effects of water quality on the types of irrigation systems are summarised.

information

Sensitivity of Irrigation Systems to Water Quality

System	***Sensitivity to Water Quality***
Flood	Not sensitive
Pivot	Not very sensitive, water may require screening, saline water can burn leaves
Cannon	Not sensitive, saline water can burn leaves
Sprinkler system	Not very sensitive, water may require screening, saline water can burn leaves
Micro-jet	Sensitive to blockage but to a lesser degree than drippers, requires filtration
Drippers	Sensitive to blockage, needs good physical water quality or good filtration

4. Crop Type

Your choice of irrigation system will also be affected by the specific crop you are planning to grow. The following crop factors should be considered when planning an irrigation system:

- Crop lifespan and seasonality
- Irrigation frequency
- Application area
- Peak crop water requirement

4.1 Crop Lifespan and Seasonality

Irrigation systems that are used for annual, seasonal crops such as vegetables must be able to be installed and removed annually in order to allow the normal cultivation and harvesting practices. Typically, this includes movable systems and static systems such as sprinklers, which can be moved, and drippers, which can be rolled up and stored.

Long-term crops such as citrus require a permanent system that allows for irrigation throughout the year, including during harvesting. The long lifespan and high-income potential of an orchard also necessitates a permanent system.

4.2 Irrigation Frequency

The frequency at which crops requires to be irrigated impacts on the choice of irrigation system. For crops such as citrus that require frequent and regular irrigation, permanent irrigation systems are most suitable.

Citrus yield and quality are extremely sensitive to water stress. Water availability is critical especially during flowering and fruit set, which is the time with the highest peak water demand for all citruses.

Generally speaking, citrus requires regular irrigation at least two or three times a week, because citrus trees have shallow root systems with an average depth of only about 300mm. This limits the plant available water. The physiological processes of citrus trees, and therefore their production, are very quickly influenced by water stress.

Certain irrigation systems, such as moveable sprinklers, are also extremely labour intensive and time-consuming. Movable systems are more suitable for crops that are less sensitive to water stress.

4.3 Application Area

Certain crop plants can be wetted completely during irrigation, whereas for other crops, such as citrus, you should try not to wet the leaves and fruit of your trees. This is because diseases such as black spot spread and develop more rapidly under wet conditions.

When choosing a system, you must consider the parts of the plant that can be wetted. Certain plants, such as field crops, are also planted very closely together, while orchard crops are planted further apart. For these crops that are planted close together, it makes sense to apply water to an entire field of crops by using overhead systems. For citrus however, such a system would be wasteful because irrigation is only required on the root-zone of each tree.

4.4 Peak Crop Water Requirement

The peak water requirement for citrus is in the summer months, when transpiration is high. The peak water requirement is expressed as mm/day and is the minimum application rate the irrigation system must have. The peak water requirement for citrus is usually between 4mm/day and 6mm/day.

Peak irrigation requirements differ between production areas, with cooler, moist areas having a lower peak requirement than warmer and drier areas. The peak irrigation requirement for a specific area is determined from historical E-pan data and crop factors, or computer models such as SAPWAT.

The irrigation designer determines the peak irrigation requirement for the specific production area before the irrigation design is done. An irrigation system must at least be able to supply the peak irrigation requirement.

example

Daily Application Rate

An irrigation system has an application rate of 3mm/h.

Crop is irrigated for 4 hours every second day, being 3 days a week.

The daily application rate is calculated as follows:

Application per Cycle: 3mm/h x 4h = 12mm

Application per Week: 12mm per day x 3 days per week = 36mm per week

Daily Application Rate: 36mm per week / 7 days = 5.1mm per day

This irrigation system can satisfy a peak water requirement of 5mm a day, assuming that the soil can hold 15mm of water for Friday, Saturday and Sunday.

All types of irrigation systems have application rates high enough to satisfy the crop water requirements of citrus. The design of the specific irrigation system will determine if the system as a whole can satisfy the peak irrigation requirement. The most commonly used irrigation systems for citrus production are permanent micro-jet and drip irrigation systems.

Both systems are suitable for citrus as permanent systems that can irrigate a block at any time and that can be scheduled according to the requirements of the crop and water holding capacity of the soil; as well as irrigating under the tree, wetting only the root-zone

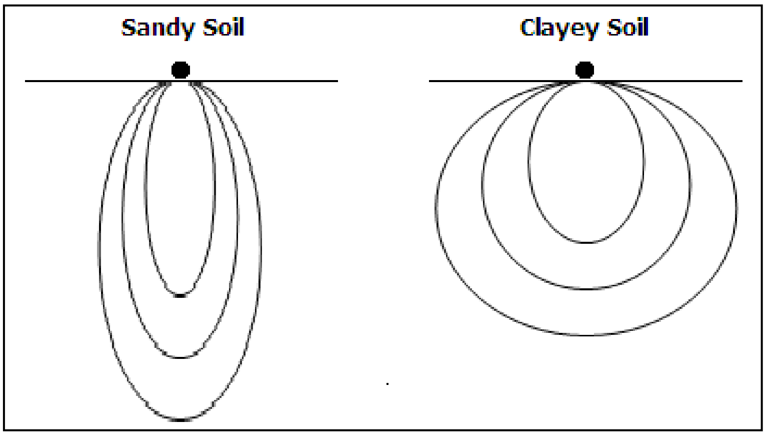
5. Soil Water Holding Capacity

The water holding capacity of soil depends on the soil texture, which influences the water content at field capacity, the wilting point, and therefore available water. Sandy soils have a low water holding capacity, because water does not adhere well to sand particles. When irrigating sandy soils, the soil fills quickly to field capacity and all free water immediately starts to drain away.

Sandy soils also have a lower water content at field capacity and because of this the volume of available water is quickly depleted. Sandy soils must be irrigated with short stand-times at regular intervals. Lateral distribution of the water in sandy soils is also poor, meaning that water tends to move straight down into the soil. An irrigation system that spreads the water over a wider area, such as micro-jets and double or triple drip lines, is more suited to sandy soils.

The drainage capacity of sandy soil is an advantage in that it prevents the soil from becoming waterlogged. This works well with fertigation as excess salts can be leached from time to time. Clayey soils have a high water holding capacity because the water adheres well to the clay particles. This translates to a high water content at field capacity but also a higher water content at wilting point, and sometimes more plant available water.

The higher plant available water means that stand-times can be longer and irrigation intervals spaced further apart. Good lateral movement of water in clayey soil also helps to get a wider distribution pattern, which means that it is suited to either drip or micro-jet irrigation. Because clayey soil does not drain well, the soil can however become waterlogged.



Water Distribution Patterns in Sandy and Clayey Soils

Non-permanent and movable irrigation systems are not compatible with sandy soils, as the plants would dry out between irrigations. Flood irrigation is also not compatible with sandy soils. On clayey soils, pretty much any irrigation system can be used as long as it does not cause over-irrigated and waterlogged soil.

Micro-jet and drip systems, which are widely used in citrus production, are compatible with both sandy and clayey soils, provided the irrigation scheduling is correct. With sandy soils, drip irrigation can irrigate regularly in small quantities, with some drip systems irrigating a block up to six times a day.

On clay soils, the lateral movement of the water in the soil can improve the poor distribution pattern associated with drippers. Micros-jets with a good distribution pattern are not negatively affected by sandy soils. Some clay soils cannot absorb and utilise the higher water application of micro-jets effectively.

The ideal soil for citrus production is soil with clay content of between 7% and 30%. Such soil offers better water holding capacity and lateral movement associated with clay, while having the drainage capabilities of sand.

6. Cost

The cost of an irrigation system is calculated by adding the items listed below. This is referred to as the combined cost of the system.

- Capital
- Labour
- Maintenance
- Energy
- Cost of failure

6.1 Capital

Capital cost refers to the amount of initial money needed to purchase and install the system. Drip and micro-jet systems are generally more expensive than many other types of systems.

6.2 Labour

Labour is the cost of the workforce required to operate the system. Drip and micro-jet systems are fairly inexpensive since only a little labour is required to open and close valves and, in some cases, the whole system is automated. Movable systems require far more labour to move the system between blocks, except for centre pivot and motored cannon spray systems, which move on their own power.

6.3 Maintenance

Maintenance costs are the direct costs of maintaining the system. This includes the regular maintenance and incidental repairs to the whole system, including the pumps, filters, pipes, valves and in-field system. Drip and micro-jet systems generally have higher maintenance costs than other systems.

6.4 Energy

Energy refers to the cost of electricity to operate the system. Drip and micro-jet systems have lower energy costs since the operating pressure is lower at only 2 bar and the system efficiency is higher. A higher efficiency means less irrigation is required, and therefore less energy is used. Sprinkler and pivot systems need about 5 bars of pressure to operate effectively. The lower system efficiency also means more pumping.

6.5 Cost of Failure

The cost of failure is not easily quantifiable, but it is a cost factor none the less. It is best explained by using an example.

example

The Cost of Failure

A farmer with a 60ha citrus farm chooses a moveable irrigation system to irrigate his citrus because the initial capital outlay and maintenance cost is lower. During fruit set there is a labour shortage on the farm, and he cannot move the system fast enough to provide in all the trees' water needs.

As a direct result of water stress, he incurs a 20% loss in yield and only realises 32t/ha from an expected yield of 40t/ha. His total loss in yield is 480 tons. The price he receives at the farm gate is R1,500/ton, meaning his loss in income is R720,000, which is the cost of the failure of the irrigation system. The use of a permanent drip or micro-jet irrigation system would have prevented such a scenario.

As this example shows, it is often better to spend more initially to get the best system for your needs, otherwise the cost of failure due to choosing a less suitable system may cost more than any savings you had.

7. Management

Even with the best irrigation system, poor management can cause losses in yield and quality. It is important to take into account the management resources and capabilities on the farm when selecting an irrigation system. For example, a centre pivot system is fairly easy to manage because it is automated. Irrigation scheduling may be more cumbersome because only full, half or quarter circles can be irrigated.

The management of moveable systems is focused on ensuring that irrigation and rotation schedules are met, and that labourers dismantle and erect the system correctly. Permanent sprinklers systems also require little management. Drip and micro-jet systems are easy to manage in terms of scheduling since individual blocks can be opened and closed as required but managing the system maintenance is more intense.

Special attention must be given to water quality and filtration, preventive and ongoing maintenance, and the assessment of irrigation effectiveness and uniformity. Effective management goes a long way in ensuring tree health, yield and quality.

8. Maintenance

Irrigation systems require ongoing maintenance and drip and micro-jet systems generally require more maintenance than most other systems. Flood irrigation systems require virtually no maintenance apart from keeping the furrows open.

Pivots and other moveable systems have mechanical components and hoses that need regular servicing. Blockages do not occur in these systems since the orifice size is large. These systems also require no filters, with only strainers used in some cases to catch large impurities.

Drip and micro-jet systems are prone to blocking and most maintenance is focussed on cleaning the irrigation and filtration system. The disadvantage of higher maintenance is however offset by the other advantages of drip and micro-jet irrigation.

summary

Chapter 1 – Irrigation Systems

- Factors that play an important role in the decision on the type and specifications of irrigation system to be installed are water availability, water quality, crop type, soil water holding capacity, cost, management, and maintenance.
- The main types of irrigation systems are flood irrigation, mobile irrigation systems, and static irrigation systems.
- In flood irrigation water is channelled to the crop by furrows in the ground.
- Mobile, or moving, irrigation systems irrigate while the system is moving and includes systems such as centre pivots, linear systems and motored cannon sprays.
- Static systems stand still while it irrigates and includes systems such as permanent and non-permanent sprinkler, micro-jet and drip systems.
- To assess whether the quantity of available water is sufficient the crop water requirements must be established, and the available water sources must be quantified.
- Pumping and storage constraints can be overcome by using holding dams or reservoirs.
- Irrigation efficiency refers to the percentage of the water displaced by the irrigation system that is utilised by the crop and varies between different types of systems.
- The water loss occurs because of evaporation, mist drift and a wetted area larger and deeper than the root-zone area.
- Physical and biological impurities are detrimental mainly to the irrigation system and lower efficiency and uniformity.
- Water of a poor chemical quality complicates fertigation because the water quality must either be improved, or the fertigation practice must be adapted.
- Physical water quality can be improved through processes such as filtration and sedimentation.
- Chemical water quality factors can be improved by various processes, for instance through oxidation.
- Chlorine is used to kill organisms in the water, in this way helping to prevent blockages due to organic compounds.
- The decision on which irrigation system to use is based on the crop type depends on the crop lifespan and seasonality, irrigation frequency, application area, and peak crop irrigation requirement.
- The most commonly used irrigation systems for citrus production are permanent micro-jet and drip irrigation systems, because both systems are permanent systems that can irrigate a block at any time and only irrigate under the tree, wetting only the root-zone.
- The water holding capacity of soil depends on the soil texture, which influences the field capacity, wilting point and the available water.
- Sandy soils have a low water holding capacity and clayey soils have a high water holding capacity because the water adheres well to the clay particles and not well to sand particles.
- Lateral water distribution is better in clay soils than in sandy soils.

- The ideal soil for citrus production is soil with clay content of between 7% and 30%, because it offers better water holding capacity and lateral movement associated with clay, while having the drainage capabilities of sand.

assessment activities

- ✓ **Activity P1**: Complete this activity to test your knowledge of irrigation systems.

Chapter 2
Irrigation System Installation

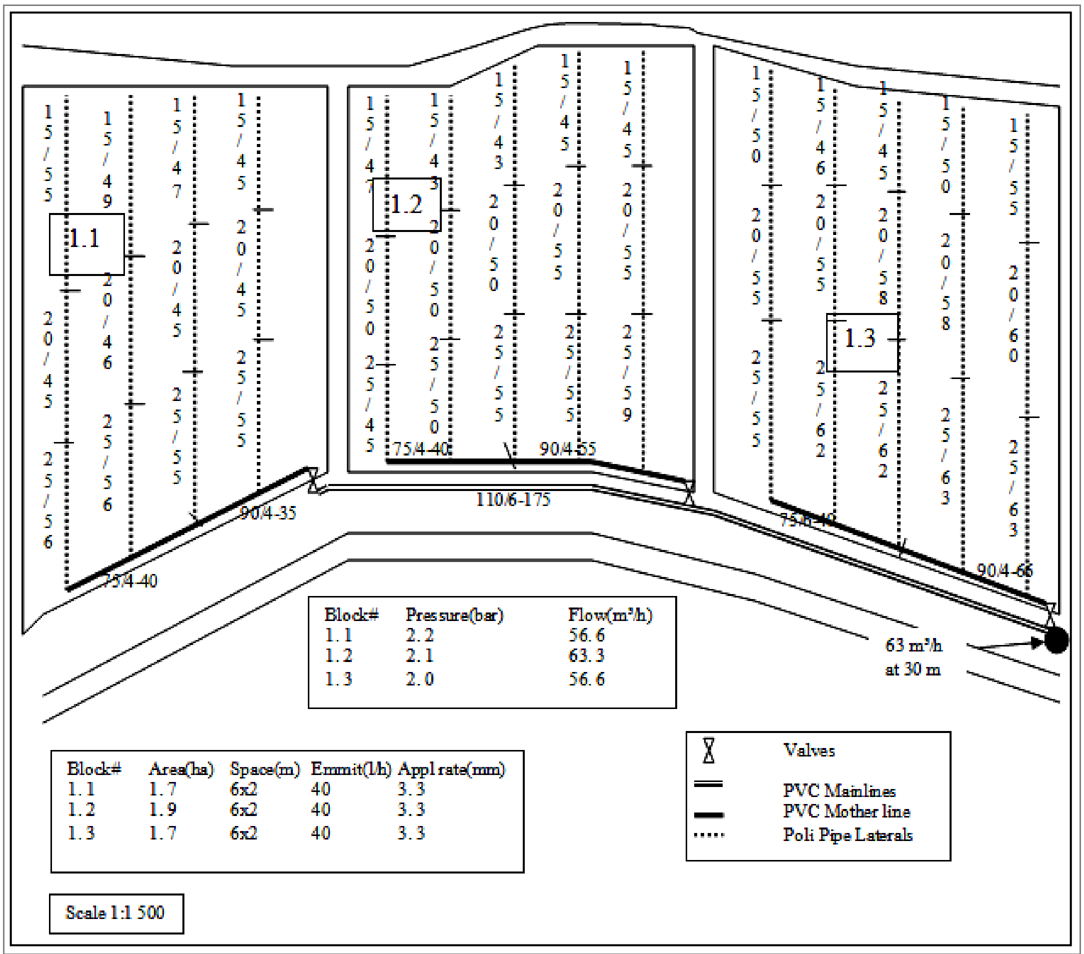
learning outcomes

The content of this chapter is aimed at helping you to:

- Install an irrigation system.

1. Interpreting an Irrigation Design Plan

The first step in installing an irrigation system is the interpretation of a design plan. This plan is a guide on where and how to install the system. This plan, along with reliable data on your crop, soil and root system, form the basis of a successful installation. It is recommended that you have the irrigation system (and the plan) designed by a qualified irrigation consultant. Below is an example of an irrigation design plan for three adjacent blocks.



Irrigation Design Plan

2. Orientation

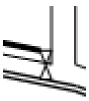
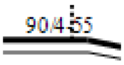
When reading an irrigation design plan, the first step is to get the orientation right. The plan must be turned so that landmarks on the plan agree with the actual landmarks, such as dams, canals, koppies, or any other distinguishable feature that is shown on the map. Familiarise yourself then with the block and pipe layout on the plan and compare it with the actual block and pipe layout.

3. Symbols

On an irrigation design plan symbols or different colours are used to depict the various pipes, valves and other features. Usually, a key is provided with the symbols and their meaning. In the table below, the symbols and keys that are used on the irrigation design plan above are explained.

information

Symbols and Keys Used on Irrigation Design Plan

Symbol	*Description*	*Example of Use*	*Details*
●	Pump		The best place to start on an irrigation plan is at the pump station or the beginning of the mainline. The pump station is marked on the plan with a dot and the pump duty point is noted ($63m^3/h$ at 30m in this case).
═	Mainline		The mainline can be traced from the pump station. On some plans there may also be sub-mainlines, which are pipes that branch off the mainline to take water to blocks that are further off the mainline.
⧗	Valve		On the mainline and sub-mainlines are the valves for the blocks. Valves feed directly into the mother lines.
▬	Mother Line		There is a mother line for each block. The lateral lines branch off from the mother lines.
······	Lateral line		Lateral lines run from the mother line along the tree rows. The emitters are located on the laterals.

4. Pipe Notations

The notations next to the different sections of pipes indicate the pipe size and class for that particular section of pipe, and the length of the pipe.

For example, let us look at the notation of 110/6-175 for the mainline in the table above. The 110/6 indicates the pipe size and class, meaning the pipe will have a nominal diameter of 110mm and will be PVC class 6 pipe. The second part of the notation indicates the length of the pipe in meters, meaning that this pipe will be 175m long. Note this is the total length and includes the bends in the pipe.

Pipe sections are indicated by a short line (/ or -). In the example above, the different sections of the lateral lines are marked in this way. The first lateral for block 1.3 has the numbers 25-63, 20-60 and 15-55. This means that in the first section, 25mm poly-pipe is laid for 63m. In the second section, 60m of 20mm poly-pipe is laid, and 15mm poly-pipe is laid for 55m in the third section.

Classes are usually not specified for the laterals, because class 3 poly-pipe is used as a rule. If drippers are used, the drip line would be specified. The class of the pipe indicates, for plastic, PVC and poly-pipe, how much pressure in Bar the pipe can withstand. The class notations for asbestos and cement pipes are more complicated and have to be verified with the supplier. On the following page is information on the commonly used pipe sizes and classes.

information

Popular Pipe Sizes and Classes for Irrigation Pipes

Pipe	*Number*	*Nominal Diameter (mm)*	*Class*	*Working Pressure (bar)*
Poly-pipe	15/3	15	3	3
Poly-pipe	20/3	20	3	3
Poly-pipe	25/3	25	3	3
Poly-pipe	32/3	32	3	3
Poly-pipe	40/3	40	3	3
Poly-pipe	50/3	50	3	3
Poly-pipe	32/6	32	6	6
Poly-pipe	40/6	40	6	6
Poly-pipe	50/6	50	6	6
Poly-pipe is available in sizes 65mm, 80mm, 100mm and in classes 3, 6, 9. Note that this for LDPE (low density pipe).				
PVC	50/4	50	4	4
PVC	50/6	50	6	6
PVC	63/4	63	4	4
PVC	63/6	63	6	6
PVC	75/4	75	4	4
PVC	75/6	75	6	6
PVC	90/4	90	4	4
PVC	90/6	90	6	6
PVC	110/4	110	4	4
PVC	110/6	110	6	6
PVC	140/4	140	4	4
PVC	140/6	140	6	6
PVC	160/4	160	4	4

PVC	160/6	160	6	6
PVC	200/4	200	4	4
PVC	200/6	200	6	6
PVC pipe is available in sizes up to 500mm and up to class 20.				
Asbestos Cement	150/6	150	6	3
Asbestos Cement	150/12	150	12	6
Asbestos Cement	150/18	150	18	9
Asbestos Cement	200/6	200	6	3
Asbestos Cement	200/12	200	12	6
Asbestos Cement	200/18	200	18	9
Asbestos Cement	250/6	250	6	3
Asbestos Cement	250/12	250	12	6
Asbestos Cement	250/18	250	18	9

5. Irrigation Block Information

On the irrigation design plan information with regard to each block is given in a table that shows the block number, area, spacing, emitter delivery and application rate.

Block#	Area(ha)	Space(m)	Emmit(l/h)	Appl rate(mm)
1.1	1.7	6x2	40	3.3
1.2	1.9	6x2	40	3.3
1.3	1.7	6x2	40	3.3

Block Information on Irrigation Design Plan

The area of each block is indicated in hectares (ha). In the Space column, the plant spacing is indicated. In the example the spacing is 6x2, meaning that the plant rows are 6m apart and the trees are planted 2m apart in the rows. Remember that plant spacing varies according to the cultivar and the production area.

The plant spacing is used to calculate the number of plants per hectare, and therefore the number of emitters that is required. The plant spacing is multiplied to calculate the area per plant, and area in hectare is divided by the area per plant, which will give the plant population per hectare. Remember that 1 hectare equals 10,000m^2.

example

Calculating Area per Plant

Plant spacing: 6m x 2m

6m x 2m

=12m^2 per plant

Calculating Plant Population per Hectare

Area of a hectare / Area per plant

10,000m^2 / 12m^2

=833 plants per hectare

Calculating Plants per Block

Plants per hectare x Block Area

833 plants x 1.7ha

=1,416 plants in block number 1.1

This is useful when plants are ordered or when the plants are allocated per block.

The emitter delivery in the table is used to calculate the precipitation and to check the emitters. The precipitation is used in the scheduling of the irrigation. The irrigation design plan also contains a table with the pressure and flow per block. This information is used in the irrigation scheduling.

6. Bill of Quantities

When a system is designed from scratch or if new blocks are designed, a bill of quantities is supplied along with the irrigation design plan. This bill of quantities is almost like a shopping list of everything needed for the system. If the company that designed the system is delivering the materials as well, the bill of quantities is used to check and verify all the materials that are delivered. If the designer is not delivering the materials, the bill of quantities is used to obtain quotations for the materials and for budgeting.

example

Bill of Quantities

Item	*Unit*	*Quantity*
Poly-pipe 15/3	m	1,200
Poly-pipe 20/3	m	1,300
Poly-pipe 25/3	m	900
25 mm nylon couplings	Each	90
20 mm nylon couplings	Each	130
15 mm nylon couplings	Each	120

Reducer 25x20 mm	Each	80
Reducer 20x15	Each	85
Grommet fitting and rubber	Each	85
Micro 40 l/h, spreader, peg, tube, barb	Each	8,250
PVC 50/4	m	300
PVC 63/4	m	200
PVC 75/4	m	180
PVC 90/4	m	150
Reducer boseng 63x50	Each	6
RO bend 80x90	Each	6
Valve cluster 80mm hydraulic valve, pilot	Each	6
Saddle 110x50	Each	6
Reducing socket 50x80	Each	6
Nipple 50 mm nylon	Each	6
Glue on bend 50mm	Each	12
Glue on ball valve	Each	6
End cap 110	Each	1
Air valves 25 mm	Each	6
Risermatic short 25 mm	Each	6
Bend boseng 110mm	Each	2
PVC 110/6	m	800
Pipet	Each	1
Pressure gauge 0 – 4 bar	Each	1
Pipe punch	Each	2
Hole saw	Each	1
Pipe lubricant	Bucket	1

7. Laying Out the Irrigation System

Now that we have developed an understanding of the irrigation design plan, the blocks can be pegged out in the field. The assumption is made that the land has been cleared and soil preparation has been done, and that other infrastructure items, such as roads and waterways, have already been demarcated.

You should be very careful when laying out the irrigation blocks that it is done correctly and precisely. It may take a day or two longer to get it right but remember that the result will be visible for the lifespan of the orchard.

The following tools and equipment are required for pegging out the blocks:

- Pegs (one per tree in the block)

- Hammer
- Dumpy level or other surveying instrument
- Measuring tape
- Wire or rope

Blocks are laid out as follows:

- Marking the corners of the blocks
- Marking the rows
- Marking the plant positions

7.1. Marking Block Corners

The corners of the blocks are first pegged out roughly to see the relation of the blocks to one another. The lengths of the sides of the blocks are now measured on the irrigation design plan, and the scale of the plan is used to calculate the actual length.

The scale is a ratio that shows the relation between the measurement on the plan and the actual distance on the ground. The scale of the plan in our example is 1:1500, meaning that for every centimetre on the plan, the distance on the ground would be 1,500cm or 15m. If the side of a block measures 10cm on the plan, it equals a distance of 15,000cm or 150m on the ground.

The corners of the blocks can now be marked precisely. Make sure the corners are in the right spot and that the pegs are hammered in well. These corners will be the markers used to lay out the rest of the block, so if they are wrong, the rest of the layout will also be wrong.

7.2. Marking Rows

Start by measuring the rows on the side of the block with the mother line, using a measuring tape. Remember that poor-quality measuring tapes can stretch and expand. Use a good quality measuring tape made of fibre. If the plant spacing on the irrigation design plan is, for example, 6x2, it means that there must be a 6m space between rows, and a 2m space between the plants in the rows. The row spacing is the bigger number.

Set the dumpy level up at one of the corners of the block. To set up the dumpy, the legs of the tripod are extended and secured. The base of the dumpy is fastened to the tripod by means of the attachment screw on the base the tripod.

On the dumpy is a spirit level, located on the eyepiece or the base of the dumpy. By moving one leg of the tripod at a time in or out, adjust the level of the dumpy until it is almost in the middle. On each of the three corners of the base of the dumpy is an adjusting screw.

Adjust these screws until the spirit level shows dead centre. In the case of the spirit level being located on the eyepiece, the dumpy has to be turned to face the leg that is being adjusted. Rotate the dumpy through all three legs after it is levelled to check the levelling.

When you look into the dumpy level you will note crosshairs on the inside. Turn the dumpy towards the other corner of the block. If the other corner is out of sight due to elevation, have an assistant hold a long pole or staff at the other corner. Plant pegs between the corners at about 20m to 30m intervals.

Make sure the pegs are in the vertical crosshair and therefore in line with the other corner. These preliminary pegs give a straight line along the side of the block for the measuring of the rows.

Use a tape measure to mark the end of each row with a peg. Make sure the straight line is followed. Check the pegs with the dumpy. They should all be in one straight line from the dumpy to the other corner. Move the pegs perfectly into line, and check the row spacing again with the measuring tape.

Keep the dumpy at the corner it is and swivel it to mark a line perpendicular to the one on which the rows have been marked. Apply the same method as above and put down two marking pegs at about 50m to 100m intervals on this line. Move the dumpy to the first peg and level as set out above.

Turn the dumpy back to the first corner and zero the degree scale, by adjusting the degree plate on the dumpy so that 0 degrees shows to the first corner. Now swivel the dumpy through 90° and lock.

Peg out a line to the opposite end of the block and use the same method as above to mark the rows at six-meter intervals on this line as well. Repeat the procedure for the remaining pegs that run parallel to the rows. When the rows are marked the pegs in the rows must be checked to see that they are in line.

Citrus orchards are ridged in many cases. This means that the ground is cropped up into the row to improve the soil depth and drainage. Once the rows are marked, the ridges must be made. Once the rows have been ridged, the rest of the land can be pegged.

After ridging the row markers must be checked again as the grader could have moved the pegs. Check the rows by using the same method that was used to lay them out.

7.3. Marking Plant Positions

Set up the dumpy at the end of a row and look at the other end. Use the tape measure to measure the inter-plant spaces. If the plant spacing is 6x2m, this would be 2m. Plant pegs at every spot where a tree must be planted.

Check the pegs visually to see that they are in line. Check them also at an angle, meaning from one corner to the corner diagonally opposite, to see if they are aligned.

8. Conveyance System Trenches

Conveyance system trenches are the trenches into which the pipelines are buried. Before the trenches are dug, they must first be pegged out. The centre of the trench can be pegged with pegs about 50m to 100m apart. Tie a wire or a rope to the pegs to mark out line between them and use ordinary lime (chalk) to mark out the line of the trench. When the trenches are dug, the chalk line must be in the centre of the trench.

Trenches are dug about 400mm to 600mm wide, depending on the size of the pipe. Trenches are usually about 600mm deep. Trenches for pipes that go through lands and roads, such as mainlines and sub-mainlines, should be 1,000mm deep. Trenches for mother lines can be a bit shallower, at about 400mm. Trenches must be free of protruding rocks on the bed since these rocks can break the pipes.

Trenches can be dug by either using manual labour or a back-end loader, also called an excavator. Manual labour may be cheaper, but will take longer, while using a back-end loader will be faster but more expensive. Keep in mind that back-end loaders are also more suited for rocky terrain. The choice will depend on the budget.

9. Installing Irrigation Equipment

In the table below, various items of irrigation equipment are discussed in greater detail.

information

Irrigation Equipment

Pipes	
Asbestos Cement (AC) Pipes	Asbestos cement pipes are not manufactured any longer due to health concerns regarding the manufacturing process. It is however not uncommon for these pipes to be used second-hand. Many older systems also use these pipes for mainlines and sub-mainlines. AC pipes are hard but very brittle, so care must be taken when they are handled and transported. The trench must be free of protruding stones and the pipe must be laid on a bed of clean sand. AC pipes are joined by collars. Triplex couplings are made out of asbestos cement and have three seal rings. The pipe slides into this socketed joint. The other method of joining AC pipes is with the short collar, which is a coupling with two iron rings that are tightened around an iron collar. Each ring contains a rubber ring that is compressed around the pipe when the collar is tightened, preventing the collar from leaking. AC pipes come in COD (constant outside diameter) and CID (constant inside diameter).
PVC Pipes	This is the most commonly used pipe for irrigation. PVC is a plastic material, and these pipes are more flexible and tolerant to movement. The one end of the pipe is chamfered, and the other end is socketed. The chamfered end slides into the socketed end. Trenches must be free of stones, but do not need to be lined with sand for smaller pipe sizes of 200mm and smaller. Fittings are either steel or PVC and are also socketed. Inside the sockets are lip-seals that seal the pipe.
Steel Pipes	Steel pipe is very expensive but very reliable and durable. Steel pipes are used more often for suction pipes, delivery pipes, risers, and filter manifolds, where the line must go through or over unsuitable terrain. Steel pipes can be threaded at the end (up to 150mm) or flanged (from 50mm and bigger). Threaded pipes are connected using screwed sockets. Flanged pipes are bolted together with a packing in the middle. Steel pipes rust, so they must be coated with a rust-proof coating such as paint, coupon, galvanizing or powder coating.
Poly-pipe	Poly-pipe is used for the lateral lines. Class 3 LDPE pipe (low density pipe) is used most often, but HDPE (high density pipe) is also available. HDPE pipe is used more often in boreholes and shade houses.
General Fittings	
Reducers	A reducer is used to connect pipes of different sizes.
Bend	A bend is used to allow a pipe to change direction. Bends are available in 90° and 45°.
End Cap	An end cap is used to plug the end of a pipe.
Air Valve	An air valve expels air from the system, preventing air locks. Some air valves have a vacuum function (see below).

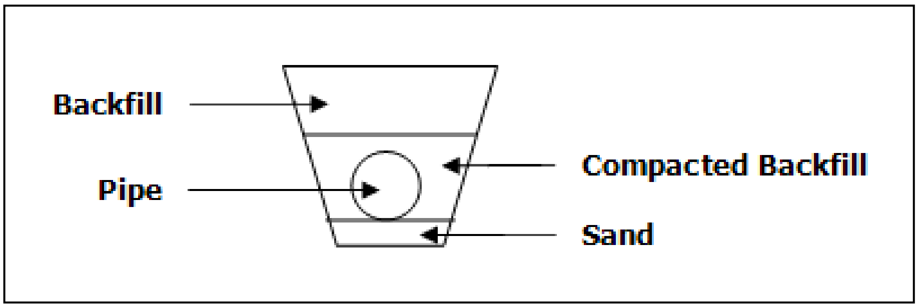
Vacuum Valve	A vacuum valve prevents the formation of a vacuum when the pump system is switched off.
Non-return Valve	A non-return valve prevents the backflow of water.
Gate and Butterfly Valve	Gate and butterfly valves open and close the pipeline, thereby decreasing and increasing the water flow. They are used to regulate the water pressure in a block manually.
Hydraulic Valves	Hydraulic valves are also used to decrease or increase the water-flow, thereby regulating the water pressure in a block.
Infield Fittings	
Grommets	A grommet is a fitting that is used to connect lateral lines to the mother line.
Nylon Couplings	Nylon couplings and reducers are used to connect poly-pipe.
Micro-jets and Drippers	Micro-jets and drippers are the emitters that supply water to each individual tree. They are installed on the lateral lines.

9.1. Installing Pipes

Where bends or end caps are fitted there is always the possibility that the joints can kick out, except in the case of steel joints. Bends and end caps must be anchored either by driving Y-standards in and tying them down, or by casting trust blocks. Trust blocks can be 600x600x300 and cast in ordinary concrete.

It is good practice to flush the pipes as the work continues. First flush the mainline before the valves are fitted. Then flush the mother lines before the laterals are fitted. Next, the laterals can be flushed before emitters are fitted.

After the system has been tested the trenches can be backfilled. The backfilling around and above the pipe for about 100mm must be stone free and compacted. The rest of the backfill does not need to be compacted.



Cross Section of a Backfilled Trench

9.2. Installing Filters and Valve Clusters

Pump and filter bank installation is a specialised job that should be carried out by a competent contractor. Inline filters can however be installed very easily. The filter is attached to risers so that it is above ground. At the bottom end of the risers are riser outlet bends, which are spigoted to slide over the pipe. At the back of each riser leg, a Y-standard is hammered in and tied down to the riser to keep the leg from popping out. The valve clusters are installed in the same way.

9.3. Installing Infield Fittings

Grommets are installed by sawing a hole in the mother line and inserting a rubber ring into the hole. The ring has a groove that fits into the sides of the pipe. The coupling is inserted into the lateral and then pushed into the rubber ring. There is also another type of grommet that is pushed into the hole and the retaining nut on the grommet is tightened.

Nylon couplings and reducers are pushed into the poly-pipe. No clamps are needed as long as the working pressure is within limits. Micros have a tube that is fitted with a barb and drippers have the barb moulded onto them. A hole is punched into the poly-pipe and the barb inserted into the hole.

10. Testing the Irrigation System

The various components of the irrigation system are tested as they are installed, and the performance of the entire system is tested once the installation is complete.

As the pipes are laid and flushed, joints are inspected for leaks. Once the pipes are partially backfilled with the joints exposed, the system is brought up to working pressure. The blocks that are grouped in operations are opened. Pressure readings are taken before and after the valves, and these are compared with the values noted on the irrigation design plan in the Pressure and Flow at Nodes table. If the readings are not correct, it may be an indication of wrong pipe size, incorrect hydraulic valve settings, or pump or filter malfunction.

Hydraulic valves are calibrated at this time. The pressure gauge is inserted downstream after the valve and the valve is opened. Note the pressure reading. Once the block is filled, the valve is switched to automatic. If the pressure reading drops, the screw on the pilot is turned slowly in a clockwise direction. If the pressure rises, the screw on the pilot is turned anticlockwise. The process is repeated by adjusting the pilot, checking the pressure again after a while, and adjusting the pilot again if necessary.

Once the hydraulic valves have been calibrated, the pressures in the lateral lines can be checked. Check the pressure at the end of each lateral, which should be close to the pressure that the valve is set at. Alternatively, each lateral can be assessed visually, and the pressure of the laterals measured that appears to have a different distribution pattern than the other lines.

Emitter delivery can also be checked to see if it corresponds with the irrigation plan. Place the emitter in a suitable container. After 15 or 30 minutes, remove the container and measure the volume of water. Multiply the volume of water by four for 15 minutes and two for 30 minutes to calculate the emitter delivery per hour. When this test is done with a representative sample for the whole block, it is called a CU (Coefficient of Uniformity) test.

After this test is done and the system has been operating for a couple of days, inspect joints for leaks. If no leaks are found, the trenches can be backfilled completely.

summary

Chapter 2 – Irrigation System Installation

- The combined cost of an irrigation system is calculated by adding the capital, labour, maintenance, and energy costs to the cost of failure.
- Drip and micro-jet systems are easy to manage in terms of scheduling but managing system maintenance is more intense.
- Irrigation systems require ongoing maintenance and drip, and micro-jet systems generally require more maintenance than most other systems.
- The foundation of a reliable irrigation system is converting soil, tree and rooting data into a good irrigation design plan.
- The first step in reading an installation plan is to orientate the plan according to landmarks.
- Symbols are used on the irrigation design plan to indicate positions of pipes and other components of the irrigation system.
- Notations next to pipes indicate their size, class and length.
- A table on the irrigation design plan provides information on the individual irrigation blocks, including the size, tree spacing, emitter delivery and the application rate.
- A bill of quantities indicates the equipment that is required to install the irrigation system.
- Blocks are laid out by first marking out the corners of the blocks, then marking the rows, and lastly marking the position of each tree.
- The lengths of the blocks on the irrigation design plan are used in conjunction with the scale of the plan to determine the position of the corners of the blocks.
- A dumpy level is used to ensure that rows are straight, starting at the row closest to the mother line of the block.
- A measuring tape is used to determine the positions of trees in each row.
- Conveyance system trenches are dug for all pipelines, and the width and depth of the trenches depend on the size of the pipe.
- The manner in which irrigation equipment is installed depends on the type of equipment.
- Components of the irrigation system, such as pipes, are tested while being installed, and the entire system is tested once the installation has been completed.

assessment activities

- ✓ **Activity P2**: Complete this activity to test your knowledge of irrigation system installation.
- ✓ **Activity F1**: Complete this activity to test your knowledge of the entire module.