LEARNER GUIDE

Irrigation

Level 5

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Title:	**Develop Suitable Irrigation Systems**						
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Table of Contents

Directions **5**

Introduction **6**
1. Purpose 6
2. Learning Assumed to Be in Place 6

Revision of Level 4 ..... **7**
1. Installing an Irrigation System 7
2. Maintaining and Evaluating an Irrigation System 7
3. Efficiently Operate an Irrigation System 8
4. Collate Irrigation System Data 8

Chapter 1 ..... **9**
1. Introduction 9
2. Types of Irrigation Systems 9
   2.1. Flood Irrigation 9
   2.2. Mobile Irrigation Systems 10
   2.3. Static Systems 10
3. Water Availability 10
4. Water Quality 12
   4.1. Physical Water Quality Factors 12
   4.2. Chemical Water Quality Factors 12
   4.3. Biological Water Quality Factors 13
5. Crop Type 14
   5.1. Crop Lifespan and Seasonality 14
   5.2. Irrigation Frequency 14
   5.3. Application Area 14
   5.4. Peak Crop Water Requirement 14
6. Soil Water Holding Capacity 15
7. Cost 16
   7.1. Capital 16
   7.2. Labour 16
   7.3. Maintenance 17
   7.4. Energy 17
   7.5. Cost of Failure 17
8. Management 17
9. Maintenance 18

Chapter 2 ..... **20**
1. Adapting Irrigation Schedules to the Water Requirements of Crops 20
2. Water Loss Detection Programs 20
   2.1. Leaking Valves 21
   2.2. Leaking and Broken Pipes 21
   2.3. Opening and Closing of Valves 21
3. Recordkeeping 21
   3.1. Water Usage Records 21
   3.2. Water Quality Records 23
   3.3. Fertigation Records 23
4. Irrigation System Operational Manual 24
5. Staff Training 28
6. Alternative Approaches to Problem Solving 28
   6.1. Problem Definition 29
   6.2. Idea Generation 29

6.3. Evaluation ... 29
6.4. Solution Implementation ... 29

Chapter 3 ... 32
1. Crop Water Usage Estimation ... 32
2. Optimising Irrigation Scheduling ... 33
3. Evaluating Irrigation Scheduling Equipment ... 34
4. Improving the Performance of Irrigation Scheduling Devices ... 34
5. Water Use Efficiency Technology ... 36

Chapter 4 ... 38
1. Optimising Seasonal Fertigation Programs ... 38
2. Fertigation Safety Procedures ... 41
3. Micro-Jet and Drippers Sanitation Programs ... 42
3.1. Chlorination ... 43
3.2. Acid Treatments ... 43
4. Filter Operation and Maintenance Programs ... 44
5. Irrigation System Operational Efficiency ... 45

Chapter 5 ... 47
1. Evaluating the Efficiency of Operational Equipment ... 47
1.1. Pumps and Motors ... 47
1.2. Filters ... 47
1.3. Valves ... 47
1.4. Gauges ... 48
1.5. Control Panels ... 48
1.6. Water Meters ... 48
1.7. Pipes ... 48
1.8. Emitters ... 48
2. Emitter Performance ... 48
3. Pump and Motor Performance ... 48
4. Pressure and Flow Checks of Control Valves ... 50
5. Replacement Equipment and Spares ... 50
6. Plant Safety and Evacuation Plan for Floods ... 52

Chapter 6 ... 54
1. Information Database ... 54
2. Possible Points of Pollution ... 54
2.1. Pollutants ... 54
2.2. Points of Pollution ... 55
2.3. Preventative Action ... 55
2.4. Developing a Remedial Plan ... 55
3. Chemical Spills ... 56
3.1. Containment and Clean-Up ... 56
3.2. Medical Emergencies ... 57
4. Environmental and Health and Safety Legislation ... 57
4.1. Occupational Health and Safety Act ... 57
4.1.1. Responsibilities of the Employer ... 57
4.1.2. Responsibilities of the Employee ... 58
4.2. Environmental Management Act ... 59

Bibliography ... 60

Directions

This learning material has been developed to assist the learner wishing to complete this unit standard. The guide contains all necessary learning to ensure that the learner will attain the competencies required by the unit standard.

The learner guide is accompanied by a Learner Assessment Guide. Please ensure that you have access to this guide as well.

The learner guide was designed to be used by a learner during the presentation of a skills program based on the unit standard, and to be kept afterwards by the learner for reference purposes. The learner assessment guide was designed to be completed during and after the presentation of the skills program, and forms part of the assessment process.

Although this learner guide contains all the information required for attaining competency in this unit standard, references to additional resources, both printed and electronic, are provided for further study by the learner.

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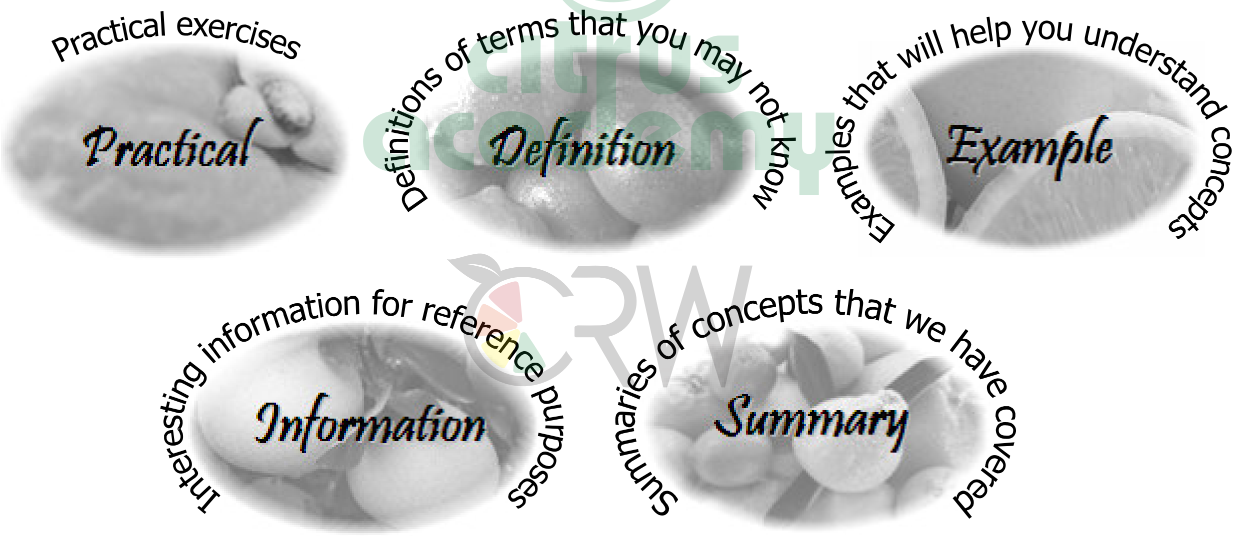


Introduction

1. Purpose

A learner achieving this unit standard will be able to manage and control irrigation infrastructure and related resources, including equipment, technology and infrastructure, in a sustainable manner and explain the importance of sound utilisation and maintenance practices. The learner will also be able to incorporate this understanding into an optimisation program and policy. The learner will be able to optimise seasonal (year) work programs with reference to water availability, irrigated area, crop water requirements, irrigation scheduling and related technology and infrastructure. The learner will be in a position to prescribe strategies with respect to irrigation practice in situations of water shortage (risk seeking vs. risk adverse).

Learners will gain specific knowledge and skills in irrigation and will be able to operate in a plant production environment implementing sustainable and economically viable production principles. They will be capacitated to gain access to the mainstream agricultural sector, in plant production, impacting directly on the sustainability of the sub-sector. The improvement in production technology will also have a direct impact on the improvement of agricultural productivity of the sector.

2. Learning Assumed to Be in Place

It is assumed that the learner has successfully completed the unit standards listed below:

NQF Level	***Unit Standard Number***	***Unit Standard Description***
NQF4	Literacy and Numeracy	
4	116317	Schedule the operation and maintenance of irrigation systems
5	116369	Optimise water quality
5	116384	Manage and control resources in a sustainable manner

Revision of Level 4

1. Installing an Irrigation System

- 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 irrigation design 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 is 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.

2. Maintaining and Evaluating an Irrigation System

- A preventative maintenance plan ensures that minor problems do not turn into major problems.
- Constant evaluation and monitoring of the system ensures that the system operates within the required parameters and that problems are picked up and dealt with when they occur.
- In citrus production irrigation is used all year round, but during the winter the water requirement is lower and therefore major maintenance is done during the winter.
- Physical water quality impacts on the frequency with which certain maintenance actions will be performed.
- A maintenance plan include actions that has to be performed on a daily, weekly, monthly, annual and two- to ten-yearly basis.

- The coefficient of uniformity (CU) test is used to determine the variance in the performance of equipment.

- The irrigation system is evaluated by opening the blocks as per the list of operations, checking and correcting, if necessary, the block pressures, noting the pump operating parameters and the pressures at nodes, performing a CU test, repeating the procedure for all the operations, and evaluating the data.

3. Efficiently Operate an Irrigation System

- Irrigation scheduling should ensure that the soil-water balance is maintained at optimum levels, being FWC (or full point) and -50kPa (or refill point) for micro-jets and a constant water potential for drippers.

- An irrigation operations schedule consists of a table of operations, the irrigation schedule and a list of pressures and flows.

- Various types of equipment are used to monitor the effectiveness of the irrigation schedule by monitoring the soil-water balance.

- The effectiveness of irrigation is assessed by taking a holistic approach and taking into account CU test, scheduling equipment data, visual inspection of profile pits, tree health and crop yield.

- The CU test indicates the uniformity of the irrigation system and measures the actual delivery of and pressure at the emitters.

- Scheduling equipment data indicates the soil water balance.

- Profile pits are used to visually assess the water balance throughout the profile, especially in the subsoil-levels.

- Tree health and crop yield data is subjective methods to measure the effectiveness of irrigation, as it can be influenced by many other production factors.

4. Collate Irrigation System Data

- Data collection and recording is essential for proper management.

- Records that are kept for irrigation management include daily records, weather station and scheduling equipment data, yield data and labour records.

- Data is mostly first recorded by hand and then transferred to a computerised recordkeeping system.

- Databases or spreadsheets are used to collect data and convert it into information.

- Data must be evaluated as equipment can be incorrect or measurements can be taken incorrectly.

- The best way to evaluated data is through reasonability tests.

- Reports are developed for specific purposes from data that has been collected.

Chapter 1

After completing this chapter, the learner will be able to:

Select an appropriate irrigation system

1. Introduction

Various types of irrigation systems are available, but not all of them are suitable for citrus production. In this chapter, a brief overview is given 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, being:

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

A SABI (South African Irrigation Institute) accredited irrigation designer is competent in selecting the correct irrigation system for a specific situation. They are also available to assist with the evaluation of irrigation systems.

2. Types of Irrigation Systems

Irrigation systems can be classified as below.

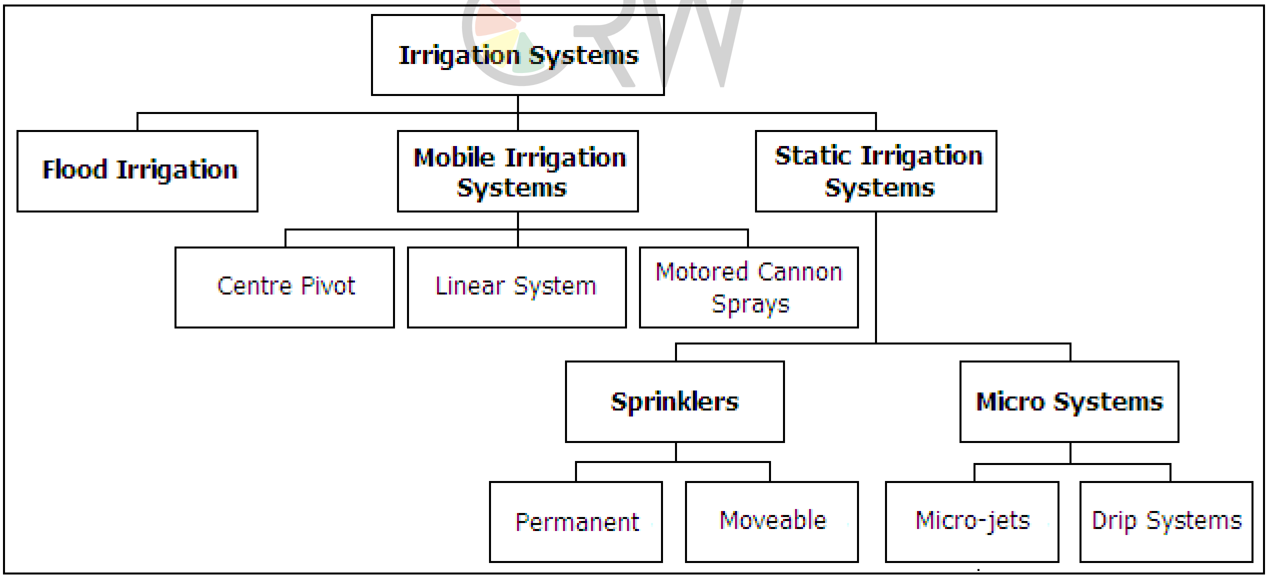


Figure 1.1: Diagram of Basic Irrigation System Classification

2.1. 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.

2.2. 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. The linear system however moves in 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 trough the field.

2.3. Static Systems

Static systems are systems that stand still, or are static, while it irrigates. It includes systems such as permanent and non-permanent sprinkler systems and micro-jet and drip systems.

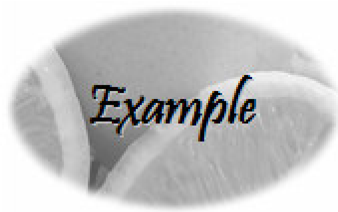
3. Water Availability

To asses whether the quantity of water is sufficient, a two tiered approach is used. Firstly, the crop water requirements must be established (see section 5.4 of this chapter) and secondly, the available water sources must be quantified.

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.



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 in essence determines 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 (see section 5.4 of this chapter) must be known and weighed against the available water. If the available water resources are inadequate, consideration must be given to cultivating a smaller area, or to other crops or farming enterprises.

If the available water is sufficient, possible pumping and storage constraints must be investigated. 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. If new plantings are considered and no such infrastructure exists, it must be included in the budget and business plan for the new planting.

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 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 is used most often for citrus because of high system efficiencies.

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.
- The wetted area is larger than the root-zone area, which is usually because of system design.
- The wetted depth is greater 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. In table 1.1 below is a list of systems with their estimated efficiencies.

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.

System	System Efficiency	Factors Influencing Efficiency
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.

Table 1.1: System Efficiency of Irrigation Systems

4. 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.

4.1. Physical Water Quality Factors

Physical water quality factors in general terms refer to impurities that can be seen, 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.

4.2. 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*** – Refers to the ability of water to conduct electricity, and is an indication of the total dissolved salts in water.

- ***Total Dissolved Salts (TDS)*** – Refers to 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)*** – Is a measurement of 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*** – Is a measurement of 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 settles to the bottom of the water. Oxidation can be accelerated through spraying water through the air into a storage dam or by using an aerator.

4.3. Biological Water Quality Factors

Biological water quality factors refer to 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. In table 1.2 below the effects of water quality on the types of irrigation systems are summarised.

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

Table 1.2: Sensitivity of Irrigation Systems to Water Quality

5. Crop Type

Factors related to the crop that impacts on the decision of which irrigation system to use are the following:

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

5.1. Crop Lifespan and Seasonality

Irrigation system that are used for annual, seasonal crops such as vegetables must be of such a type that it can 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.

5.2. 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 citrus. 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 suitable for crops that are less sensitive to water stress.

5.3. Application Area

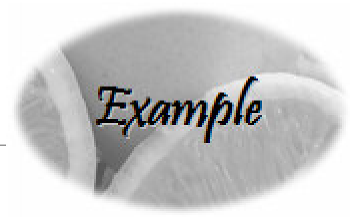
Certain crop plants can be wetted completely during irrigation, while cultural practises of other crops, such as citrus, prohibit wetting of leaves and fruit. Diseases such as black spot spread and develop more rapidly under wet conditions. A decision on the irrigation system to use must take into account 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. It would therefore make sense to apply water to an entire field of crops by using overhead systems, while it would not make sense using such a system for citrus because irrigation is only required on the root-zone of each tree.

5.4. 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.



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 the 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 satisfy the criteria for the crop type by:

- Being a permanent system 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
- Irrigating under the tree, wetting only the root-zone

6. Soil Water Holding Capacity

On previous levels the concepts of water holding capacity, field water capacity, wilting point and plant available water were discussed in detail. 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.

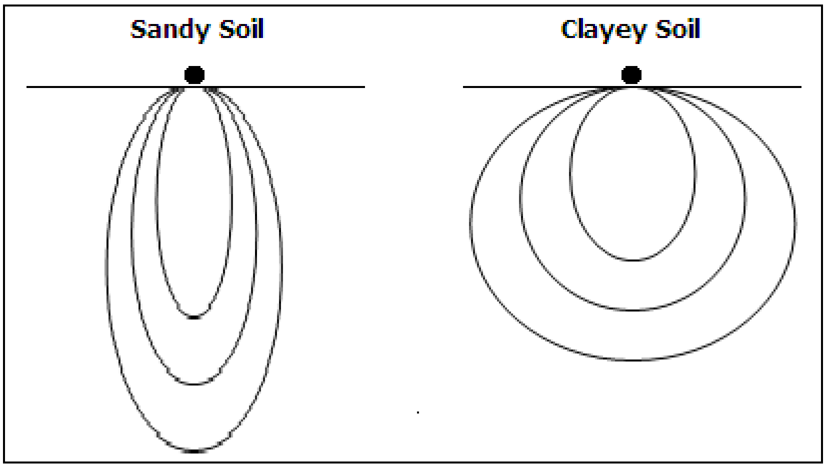


Figure 1.2: Water Distribution Patterns in Sandy and Clayey Soils

Non-permanent and movable irrigation systems are not compatible with the 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.

7. 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

7.1. Capital

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

7.2. Labour

Labour is the cost of the labour 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. Exceptions are centre pivot and motored cannon spray systems, which move on its own power.

7.3. Maintenance

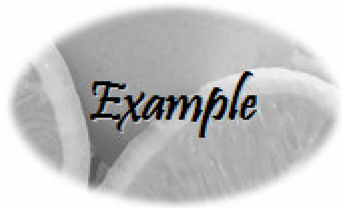
Maintenance costs are the direct cost of maintaining the system. This includes the regular maintenance and incidental repairs to the whole system, including the pumps, filters, pipes, valves and in-field system. Drip and micro-jet systems generally have higher maintenance costs than other systems. The impact of maintenance on the choice of irrigation system is discussed in more detail in section 8 below.

7.4. Energy

Energy refers to the cost of energy 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 bar of pressure to operate effectively. The lower system efficiency also means more pumping.

7.5. 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.



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 labour unrest 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 permanent a drip or micro-jet irrigation system would have prevented such a scenario.

8. 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.

A centre pivot system for example 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.

9. 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.

Chapter 1

- 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 asses 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.

- 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.

Complete activities 1 and 2 in the **Learner Workbook**.

Chapter 2

After completing this chapter, the learner will be able to:

Manage an extended irrigation operation efficiently and cost-effectively

1. Adapting Irrigation Schedules to the Water Requirements of Crops

At previous levels the development and implementation of irrigation schedules for citrus production were discussed in detail. The same principles are used when adapting irrigation schedules for different crops.

Different crops have different water requirements and to meet these requirements, irrigation scheduling must be adapted for according to the crop. In addition, in the same way that citrus have different water requirements for different tree ages and physiological stages, so do other crops have different water requirements depending on age and season.

A soil analysis is done to determine field water capacity and the permanent wilting point for the soil type. These indicate the upper and lower limits of the soil water reservoir. After this a profile hole is made to determine the effective root depth of the plants. On crops that are replanted annually, one can use existing crop data to determine root depth. Using the above data the plant available water and the easily available water can be calculated.

The operations table, pressure and flows table and the irrigation schedule must be known or obtained from the irrigation design. Using the available scheduling equipment, the irrigation stand-time and cycles must be adapted to suit the crop water requirements. In the table below the process is summarised.

Step	***Item***	***Method***
1	Field water capacity (FWC)	Determine through lab tests or with scheduling equipment such as tensiometers and probes
2	Permanent wilting point (PWP)	Determine through lab tests or with scheduling equipment
3	Effective root depth (ERD)	Determine by digging a profile hole
4	Plant available water (PAW)	Estimate using formula **PAW = FWC – PWP**
5	Easily available water (EAW)	Estimate using formula **EAW = PAW x ERD x 50%**
6	Crop water requirement	Calculate from soil water balance or use industry information
7	Operations table, pressure and flow table, irrigation schedule	Obtain from irrigation design
8	Optimise scheduling	Use scheduling equipment such as E-pans, probes and tensiometers to optimise the stand time

Table 2.1: Adapting Irrigation Scheduling

2. Water Loss Detection Programs

The water that is lost in an irrigation system is the water that enters the system but does not reach the emitters. Water is lost for a number of reasons such as:

- Leaking valves
- Leaking and broken pipes
- Valves that are opened or closed at the wrong time

The easiest way to detect water loss is by closely inspecting and surveying the problem areas mentioned above. A water loss detection program should concentrate on these problem areas.

2.1. Leaking Valves

Gate and butterfly valves are likely to leak at glands and hydraulic valves at the hydraulic tubing and diaphragms. Leaks can also occur if valves do not close properly. This kind of leak is usually accompanied by a hissing sound or the sound of water flowing.

A valve that is suspected of leaking is loosened at the downstream side and visually inspected to see if it is leaking. Hydraulic valves are prone to leaking as worn tubes and diaphragms prevent the valve from closing properly.

2.2. Leaking and Broken Pipes

Leaking pipes are difficult to detect, especially if they are underground. A sign of a possible leaking pipe is if wet spots or surface water are detected along the pipeline. The easiest way to locate underground leaking pipes is to follow the pipeline according to the map and look out for wet spots and areas with exceptionally lush vegetation. It is easier to detect underground leaks during the dry season than during the wet season. If a leak is suspected, the pipe must be dug open and inspected. Pay special attention to risers and hydrants as these are prone to damage by people and tractors. Some farms are equipped with water meters at the pump and at the irrigation blocks. In such cases excessive variance between the meter readings can indicate water loss in the main lines.

Broken pipes, as opposed to leaking pipes, are easy to detect as the water gushes out and the severe pressure drop makes irrigation impossible.

2.3. Opening and Closing of Valves

Water can be lost trough incorrect opening and closing of valves. Make a habit of visiting sections that are not irrigated or operational on a regular basis, and ensure that the valves are closed properly. The same applies to unattended hose pipes and reservoirs.

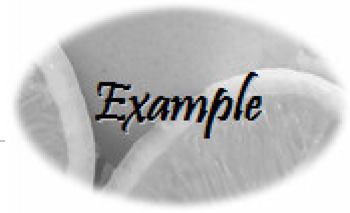
3. Recordkeeping

Good recordkeeping of water use, water quality and fertigation data is essential to enable effective management of the irrigation system on a farm. Recordkeeping is also becoming important in terms of export accreditation requirements, an example of which is GlobalGAP. Records must be up-to-date and accurate, and the system must be such that data can be converted into useful information with the minimum of effort.

3.1. Water Usage Records

Water usage records must be kept of total farm usage, usage per section, and usage per block. The most accurate data can be collected by using a water meter, which records the total amount of water used at a certain point to date, much as the electricity meter in a house records the total amount of electricity used. The difference between the water meter readings from one day to the next is the usage for that day.

Water meters are expensive and are usually found only at pump stations. Installing a water meter at each block is usually not cost effective. A water meter is therefore effective in determining usage per section served by a particular pump station, and water usage for the entire farm. Water usage per irrigation block can be determined by the number of irrigation hours per block. During irrigation, the infield pressure is constant, and the flow-rate in that block is therefore also constant. When the system application rate and block area is known, the flow-rate can be calculated, from which the water usage for a specific period can then be calculated.



Calculating the Flow-Rate and Water Usage per Block

System Application Rate: 4mm/h
Block Area: 2.5ha

Flow rate per hour = Application rate per hour x Area
= 4mm/h x 2.5ha
= 0.004m/h x 25,000m²
= 100m³/h

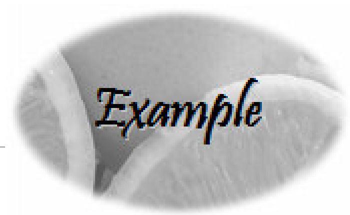
If the flow rate is 100m³/h for the block and the block is irrigated 6 hours per week, the total water usage for the block is 600m³ per week.

Another quicker method that can be used to calculate the flow-rate is as follows:

An application rate of 1mm/h means that 10m³/ha/h is used. (0.001m/h x 10,000m²)
An application rate of 4mm/h therefore means that 40m³/ha/h is used.
40m³/ha/h x 2.5ha = 100 m³/h is the flow-rate for this block

For the water usage per block, only the number of irrigation hours needs to be recorded. Note that the irrigation hours should be in line with the irrigation schedule, but that the irrigation schedule must not be used to complete these records. Actual hours must be recorded. There should be a correlation between the total block usage and the total farm usage.

The extent to which water usage is recorded depends on the farm and the manager. On some farms recording the total farm usage is sufficient. On other more intensive operations, the water use per block is required as this can be used to determine the efficiency of the irrigation operation and irrigation scheduling, and water loss. Below is an example of a table that collects data and also determines the system efficiency.



Water Usage Data

Date	*Pump Meter Reading (m³)*	*Water Use at Pump (m³)*	*Meter Reading Section 1 (m³)*	*Water Use Section 1 (m³)*	*Hours Irrigated Section 1*			*Meter Reading Section 2 (m³)*	*Water Use Section 2 (m³)*	*Hours Irrigated Section 2*		
					1.1	*1.2*	*1.3*			*2.1*	*2.2*	*2.3*
03/05	3,500	160	1,500	100	2		2	2,000	60	2		
04/05	3,360	170	1,600	50		2		2,060	120		2	2
05/05	3,830	160	1,650	100	2		2	2,180	60	2		
06/05	3,990		1,750					2,240				

Assumptions:

- Meter readings are taken before start up.
- Blocks in section 1 use 25 m³/h and blocks in section 2 uses 30 m³/h.

3.2. Water Quality Records

The collection of data pertaining to water quality varies between farms and depends on the available water source. Where the water source is stable with little or no upstream pollution, the water quality can be assessed annually or biannually. Where the water resource is more erratic or if pollution is more imminent, such as if the farm is downstream from a factory, the frequency of sampling must be higher, and more regular records must be kept.

Water quality can be monitored by taking the following factors in account:

- The number of filter flushes per week
- Presence of algae
- Presence of smells
- Water clarity

As long as the above factors remain stable, it can be assumed that the water quality is stable. If the above factors are worsening, it is an indication that water quality is deteriorating and that a water sample should be analysed. It is advisable to determine at this time which type of water quality factor (physical, chemical or organic) is deteriorating as this will help to decide on the best remedial action.

Keep in mind however that water quality changes with seasons, and it is therefore important to compare present observations to previous observations during the same season. As a general rule the different types of water quality factors are affected as follows by the different seasons:

- **Physical water quality** deteriorate during periods of low rainfall, when water levels are low and the pumps tend to suck up extra sand and silt from extraction points. During and just after heavy rains it will also be worse as soil and silt are washed down.

- **Chemical water quality** tends to deteriorate during periods of lower rainfall, when the concentration of salts is higher because of low water levels. Water sources are also supplemented in such times with borehole water that may contain high salt concentrations.

- **Biological water quality** is negatively affected during summer months when there is a higher growth of algae and slimes.

Water quality records can be in the form of weekly or monthly reports of observations, and laboratory reports of water analyses.

3.3. Fertigation Records

Fertigation is becoming part of modern farming more and more. In its simplest form, seasonal fertiliser is introduced for a short period. In this instance, it is important to record the amount of fertiliser, the type of fertiliser, the blocks fertilised at the same time, and the stand-time.

More advanced systems introduce fertilisers on a continuous basis to irrigation water. These systems have different storage tanks for different types of fertilisers. The fertigation process can be controlled manually or by computer. Recordkeeping must cover the following fields:

- Concentration, volume and type of fertiliser in each tank
- Daily tank levels
- Daily flow meter readings where applicable
- EC and pH readings where applicable
- The blocks irrigated and the stand-time
- Hardcopies of computer downloads

Record of Seasonal Fertigation

Date	***Block Numbers***	***Type of Fertiliser***	***Concentration (kg/1000l)***	***Volume Applied***	***Stand Time***
03/05	1, 3	Urea	400	200	3 hours
04/05	2, 5	Urea	400	400	3 hours
05/05	4, 6	Urea	400	300	3 hours

Please Note: The above is only for illustration purposes and **does not** represent a fertigation program.

4. Irrigation System Operational Manual

An operational manual for the irrigation system is useful in ensuring that all staff members that play a role in its operation are aware of what is required from them. An operation manual must include the following:

- The operational parameters for the irrigation system that is included on the irrigation design, including:
  - The list of operations
  - The pressures and flows at valves and at nodes
  - The plant spacing and precipitation for each block
- The pre-start-up inspection
- Start-up and shut-down procedures
- The irrigation schedule
- Procedures to be implemented when crop is irrigated
- Procedures for the maintenance of the irrigation system

Irrigation System Operational Manual

The following example is compiled by the various examples given in levels 2 to 5.

1. Tables with Operations, Blocks, Pressures and Flows and Irrigation Schedule

List of Operations

Operation	Block	Block	Block	Block	Block	Block
1	1.1	2.3	3.2	4.4	5.1	6.2
2	1.2	2.1	3.4	4.3	5.2	6.1
3	1.4	2.4	3.1	4.1	5.3	6.4
4	1.3	2.2	3.3	4.2	5.4	6.3

List of Pressures per Block

Block	*Pressure*	*Block*	*Pressure*	*Block*	*Pressure*	*Block*	*Pressure*
1.1	2.0	1.2	2.2	1.3	2.2	1.4	2.0
2.1	2.0	2.2	2.0	2.3	2.2	2.4	2.0
3.1	2.2	3.2	2.0	3.3	2.0	3.4	2.0
4.1	2.0	4.2	2.2	4.3	2.0	4.4	2.2
5.1	2.2	5.2	2.0	5.3	2.2	5.4	2.0
6.1	2.0	6.2	2.0	6.3	2.2	6.4	2.2

Block Area, Flow and Plant Spacing

Block	*Area*	*Flow*	*Block*	*Area*	*Flow*	*Block*	*Area*	*Flow*	*Block*	*Area*	*Flow*
1.1	2	40	1.2	2.5	50	1.3	2	40	1.4	2	40
2.1	2.5	50	2.2	2	40	2.3	3	60	2.4	2.5	50
3.1	2	40	3.2	2	40	3.3	2.5	50	3.4	2	40
4.1	2.5	50	4.2	2	40	4.3	2	40	4.4	2	40
5.1	2	40	5.2	3	60	5.3	2	40	5.4	2	40
6.1	2	40	6.2	2	40	6.3	3	60	6.4	2	40

Area in ha and flow in m³/h

Irrigation Schedule

Day	*Operation 07h00 – 11h00*	*Operation 11h00 – 14h00*
1	1	2
2	3	4
3	1	2
4	3	4
5	1	2
6	3	4
7	-	-

Plant spacing for all blocks 6m x 3m
Precipitation per ha = 2mm
Effective precipitation = 4mm

Total Flow per Operation to be measured at Pump plus Operating Pressure

Operation	Block	Block	Block	Block	Block	Block	Total Flow	Pressure
1	1.1	2.3	3.2	4.4	5.1	6.2	260	6.2
2	1.2	2.1	3.4	4.3	5.2	6.1	280	6
3	1.4	2.4	3.1	4.1	5.3	6.4	260	6.2
4	1.3	2.2	3.3	4.2	5.4	6.3	270	6

Flow in m³/h and pressure in kPa

Note that the pressure at the pump is specific to the irrigation system

2. Pre-Start-Up and Start-Up Procedure

The following form must be completed daily before start-up.

Pre-Start-Up Checklist

Pre-Start-Up Checklist		
Pump Station:		**Date:**
Item	***Checked***	***Comments***
Water Level		
Pump		
Excessive Water		
Oil Levels		
Flanges		
Gland Packaging		
Couplings		
Mountings		
Free Rotation		
Motor/Starter Panel Dry		
Other Comments:		
Filters		
Valves		
Lids		
Seals		
Flanges		
Inline Filter (Hydraulic Valves)		
Other Comments:		
Valves (Manual)		
Manual Open/Close		
Spindle		
Leaks		
Other Comments		
Valves (Hydraulics)		
Settings		
Other Damage		
Other Comments		
Checked By:		**Signed:**

The following start-up and shut-down procedure must be followed

Starting Up

1. Perform the pre-start-up inspection
2. Check that the pump is properly primed
3. Close the delivery valve
4. Start the pump by pushing the start button and remain at the panel until the pump runs smoothly (10-20 seconds), if any unusual noise or vibration occurs, immediately press the stop button
5. If the pump runs normally, open the delivery valve slowly

Shutting Down

1. Close the delivery valve slowly, preventing water hammer
2. As soon as the valve is closed, switch off the pump
3. Note that just before shutting down the pump pressure readings must be taken and noted and the filters back flushed

Pump Operating Parameters

Operation	Amps	Total Flow	Pressure
1	220	260	6.2
2	230	280	6
3	220	260	6.2
4	225	270	6

3. Irrigation Procedures

1. Open and close valves as dictated by the irrigation schedule
2. Check block pressure twice a week
3. Notice and report over and under irrigation

4. Scheduling Procedures

1. Take probe readings twice a week
2. Update scheduling program daily with relevant data such as rain meter readings, irrigated block data and probe data when available
3. Download weather forecasts on Monday, Wednesday and Friday and report on rain and heat waves

5. System Maintenance Procedures

Daily	• Repair leaks and malfunctioning micros • Check automated filter flushing twice a day
Monthly	• Grease pump motors • Clean discs on disc-filters • Open and inspect sand-filters • Check pilot valve settings
Yearly	• Replace filter sand • Have electrical panel inspected by electrician • Check pump alignment • Replace oil inside the pump • Inspect and, if possible, repair suction pipe

5 Yearly	• Overhaul pump by replacing bearings, seals, wear rings and impeller, if necessary • Replace diaphragms on hydraulic valves
5–7 Yearly	• Replace micro-jets, drippers and poli-pipe, depending on the type

5. Staff Training

For staff to optimise the pressures and flow rates, they need to have a thorough understanding of:

- Control valves;
- Taking pressure readings; and
- The correlation between pressure and flow
- The effect of under- and over-irrigation

Infield valves can be hydraulic, gate or butterfly valves. Staff must be able to open and close the various types of valves. They must also be able to operate hydraulic valves that are equipped with a pilot valve and a three-way valve, and know how to set the valve on open, close and auto.

Controlling pressure and flow rate necessitates taking pressure readings. Pressure readings can be taken from hydromatics or pressure points. Staff must be familiar with the different types and the correct equipment to take pressure readings. They must also be able to take infield pressure readings on the downstream side of valves and filters.

Staff must also be able to regulate the infield pressure by opening or closing gate valves and butterfly valves and control the working of hydraulic valves.

Staff must understand the relationship between pressure and flow, being the higher the infield pressure, the higher the flow in the irrigation block, and vice versa. In the irrigation design plan the optimum pressure for each block is stated in the list with the operating pressures. When irrigating, the infield pressure must be as close as possible to the recommended operating pressure.

When optimising the pressure and flow rates the effects of over- and under-irrigation must be understood. Too low pressure settings will reduce the flow rate and cause:

- Under-irrigation and water stress because of the lower application rate
- Poor hydraulic performance because pressure is lower than operating pressure

Too high pressure settings will increase the flow rate and cause the following:

- Over irrigation and water logging
- Increased water wastage because water percolates outside the root zone
- Increased misting that lowers the system efficiency
- Increased soil erosion because of excessive run-off

Staff members must be attentive to the points mentioned above. They must also be encouraged to report faults and problems even if it seems that other parameters are fine, as this can indicate other problems. An example of this is where misting occurs, but the block pressure is according to prescriptions. It might be that the pressure gauge is faulty and needs replacement.

6. Alternative Approaches to Problem Solving

Not all problems that are encountered needs to be addressed in the traditional way. The solution to some problems lies in an alternative or new approach. Often this type of solution is more effective and simpler. A great aid to help with the alternative approach to problem solving is to be informed about the latest technology and trends.

Acquiring creative problem solving skills assists a manager with finding alternative solutions to problems. The steps and guidelines below will help explain the process.

The steps of creative problem solving:

- Problem definition
- Idea generation
- Evaluation
- Solution implementation

6.1. Problem Definition

This step involves identifying and analysing the real source of the problem, and includes gathering all data relevant to the problem. This step culminates in a problem definition statement. During problem definition, think and act like a detective. Explore and seek out clues and facts. Ask questions such as: is this the real problem, is there an underlying problem, etc.

6.2. Idea Generation

This step involves brainstorming and teamwork. Brainstorming is the process where many relevant ideas and possible solutions are noted. These ideas do not need to be the best, or economical or practical. The objective is to gather as many ideas as possible. Teamwork is where you consult with other co-workers, specialists or any other person and get their ideas and possible solutions.

During idea generation think like an artist, and be creative. Do not prejudge ideas at this time, but leave it for the next step when ideas will be judged. Gather as many ideas and possible solutions as possible.

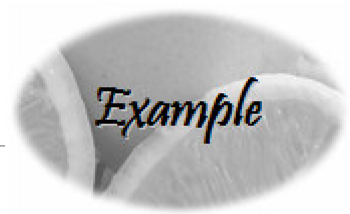
6.3. Evaluation

In this step all the ideas and possible solutions are evaluated. A set of evaluation criteria must be developed and can cover aspects such as cost, practicality, efficiency, time, etc. Solutions are ranked in order of their suitability according to the criteria and the best solution is selected.

Evaluation is the task of the engineer and judge. Firstly, the ideas must be evaluated for their suitability to addressing the problem. Now the judge must make a decision on which solution is the best suited to the problem.

6.4. Solution Implementation

A plan must now be made of how the solution to the problem can be implemented. Think like a producer to generate a plan for implementation. Cover aspects such as timeframe, budget, alterations, assessment of the solution, etc.



Problem Solving

This is a true story that happened in the drought during the nineties. A farmer had to cut the water consumption on his farm.

Problem Definition: The farmer investigated the situation and found that the low irrigation system efficiency was the underlying cause of the high water consumption.

Idea Generation: The farmer was using micro-jets at that time. He explored various options such as different emitters, spreaders, tune cans to limit the radius, pieces of pipe acting as shrouds, and drippers. A product specialist suggested using a bubbler, which is a dripper with a very high flow-rate and is used for stadiums and sport fields.

Evaluation: The farmer took into account cost, efficiency, flow-rate and ease of installation. He decided on the bubbler, which posed advantages such as low cost, high efficiency, similar flow rates to micros (this ease the management and scheduling) and ease of installation (the bubbler fits on the existing tube).

Implementation: The required number of bubblers were calculated and ordered, the staff was trained in the installation of the bubblers and they were installed.

Information

As an additional resource, read **Creative Problem Solving** by Edward and Monika Lumsdaine.

Summary

<u>Chapter 2</u>

- The same principles that are used for the development and implementation of irrigation schedules for citrus production are used when adapting irrigation schedules for different types of crops.
- A soil analysis is done to determine field water capacity and the permanent wilting point for the soil type.
- The operations table, pressure and flows table and the irrigation schedule must be known or obtained from the irrigation design.
- Scheduling equipment is used to adapt the irrigation stand-time and cycles to suit the crop water requirements.
- The water that is lost in an irrigation system is the water that enters the system but does not reach the emitters, which can happen because of leaking valves, leaking and broken pipes, and valves that are opened or closed at the wrong time.
- Good recordkeeping of water use, water quality and fertigation data is essential to enable effective management of the irrigation system on a farm.
- Water usage records must be kept of total farm usage, usage per section, and usage per block.
- The collection of data pertaining to water quality varies between farms and depends on the available water source.
- Fertigation records must at least contain information on the concentration and volume of fertiliser, the type of fertiliser, the blocks fertilised at the same time, and the stand-time.
- An irrigation system operation manual must include the operational parameters for the irrigation system, pre-start-up inspection, start-up and shut-down procedures, the irrigation schedule, procedures to be implemented when crop is irrigated, and procedures for the maintenance of the irrigation system.
- For staff to optimise the pressures and flow rates, they need to have a thorough understanding of control valves, taking pressure readings, the correlation between pressure and flow, and the effect of under- and over-irrigation.

Practical

Complete activities 3, 4, 5, 6 and 7 in the **Learner Workbook**.

Chapter 3

After completing this chapter, the learner will be able to:

Implement appropriate task related technology in the irrigated agricultural environment in variable water availability scenarios

1. Crop Water Usage Estimation

The crop water usage estimation is necessary to manage the available water sources. This is especially true for situations where water is scarce such as during droughts. In this time water management is more critical.

Water use estimation records comprise the water usage data and data collected from scheduling equipment. Water usage data relates to the amount of water used for the irrigation, while scheduling equipment quantifies the amount of water used during transpiration.

Most of this data is recorded, because it is required for other aspects of irrigation. The data needs only to be captured on a spreadsheet to determine the water use estimation. The spreadsheet should cover aspects such as water use, cycle and stand time, and data from scheduling equipment. In the example, below the system efficiency is also derived from the data. This is not necessary, but is a handy tool to evaluate the overall system performance.

In the example:

- **Area** is the size of the block in ha.
- **System Application Rate** is the application rate of the irrigation system in mm/h.
- **Irrigation Hours** are the total number of hours that the block is irrigated for during the week. This is the product of the cycle time times the stand-time.
- **Evapotranspiration** is the evaporation multiplied by the crop factor for the week. The scheduling equipment used in this example is an evaporation pan. Where probes and tensiometers are used, the data can be entered here. Remember that the format would be different.
- **Water Meter Reading Usage** is the volume of water used according to the water meter readings. In this example each block is equipped with a water meter.
- **Water Use Estimate** is the calculation of the water usage based on the system application rate, the block area and the number of irrigation hours.
- **Water Use Based on E-Pan Data** is the water usage derived from information from scheduling equipment.
- **System Efficiency** is the water used based on e-pan divided by water used according to the water meter and expressed as a percentage. The e-pan expresses the amount of water used by the plant and the water meter reading quantifies the amount of water used to irrigate the block.
- The **Total Water Use** figures are the sums for the week.
- **Average System Efficiency** is the average for all the blocks.

Example

Water Use Data and System Efficiency

2. Optimising Irrigation Scheduling

The optimisation of irrigation scheduling relies on the correct working of scheduling equipment. At times when more water is available, the irrigation schedule must be managed to prevent over-irrigation. This is especially true during rainy seasons or when long rainy spells occur. The soil water content must be managed so that it does not exceed field water capacity, otherwise water logging will occur.

Adapting irrigation schedules during a drought is however more complex, as the available water sources is under pressure. During droughts, the following guidelines can be followed.

- Determine the available water from the existing sources and the estimated crop water use. It is important to determine if all the blocks can be irrigated or if irrigation must be stopped on some of the blocks because there is simply not enough water.

- Prioritise the blocks for irrigation, to decide on which blocks irrigation will be stopped first. Consider table 3.1 that lists factors that influence block prioritisation.

Factors Favourable To Lower Prioritisation	***Factors Favourable To Higher Prioritisation***
Old trees that are near the replanting date.	New and young trees with a high yield potential.
Old trees use more water because of the large leaf area.	Young trees use less water because of the smaller leaf area and likely newer efficient irrigation systems.

Factors Favourable To Lower Prioritisation	*Factors Favourable To Higher Prioritisation*
Trees with micro-jets tend to have better developed root systems that can utilise under ground reserves better.	Trees with drippers have generally smaller and more localised root-zones.
Low value crops or cultivars pose lower economic risk.	High value crops pose a bigger economic risk.
Annual crops and crops that are drought tolerant, such as mangos and prickly pears.	Long term plantations and crops that are not drought resistant, such as citrus.

Table 3.1: Factors that Influence Block Prioritisation

- Optimise irrigation efficiency by implementing the following:
  - Irrigate at night when evaporation losses are at a minimum.
  - Limit irrigation during windy days and nights.
  - Lower the block pressure to reduce the misting of micro-jets.

- Decrease the wetted area to decrease water application. With drippers the wetted area is already limited, but with micro-jets the area can be decreased. Options are using a swivel with a smaller wetting radius, which is new technology, using traditional concave spreaders that also have a smaller wetting radius, placing a cap over the micro to prevent the water from spreading, or replacing micro-jets with drippers. A basin around the tree will also prevent water from running off the ridge. Be careful of over irrigating and wetting the soil beneath the roots, this is a waste of water.

- Reduce the number of cycles to limit water losses at start-up and shut-down. It is better to wet trees well once or twice a week than a number of small half irrigations. Be careful not to wet the area below the root-zone.

- Pay special attention to pumps and filters. Water levels are low during dry spells, so pumps can suck air or muck more easily. Ensure that the water extraction point is wide and deep enough with a non-turbulent inflow. During dry spells, chemical and physical water quality is also more likely to be poor, and the workload on filters will increase. Make sure that filters operate properly and that they are back-flushed often enough. Back-flushed water can be recycled, provided the dirt settles out of the water before entering the pump again.

- Adapt the fertigation program. Water also tends to have a higher salt content during dry periods. Added to the salts of the fertiliser, it can be detrimental to the soil and plants.

3. Evaluating Irrigation Scheduling Equipment

To ensure that irrigation equipment remains accurate and efficient, the proper maintenance must be performed as required for the different types of equipment. The calibration of the equipment must be checked regularly, and it must be recalibrated if necessary. To evaluate the efficiency and accuracy of scheduling devises, do not depend on one device, but compare data from at least two devices to ensure accurate readings. In addition, evaluate the accuracy of the data with visual inspections in orchards. If trees are stressed or water-logged, investigate if it is in line with the scheduling equipment data. These evaluations can be noted in weekly reports or as part of the irrigation schedule.

4. Improving the Performance of Irrigation Scheduling Devices

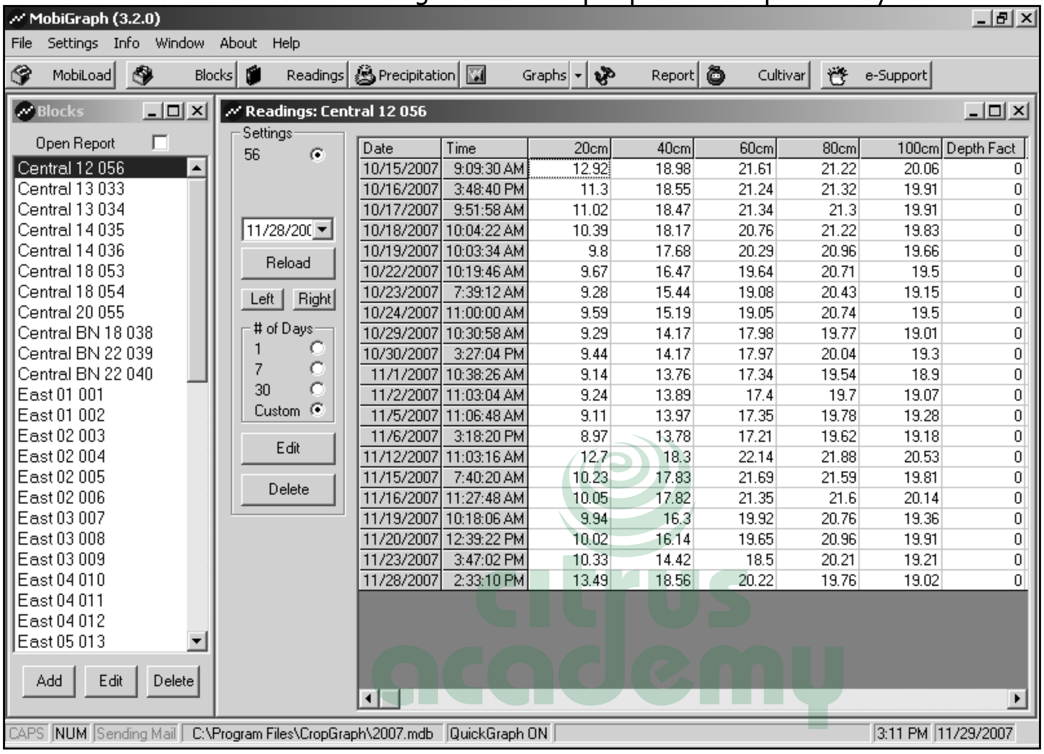
Most modern scheduling equipment is compatible with computers. Data from equipment can be downloaded using data loggers, such as the data logger on probe, or directly, such as telemetric data loggers sending data directly as is the case with weather stations.

This kind of equipment is expensive but has advantages such as higher accuracy, real time measurements, reduced labour cost, and improved management. This kind of adoptions should be done with the help of a consultant in order to optimise the information system.

Example

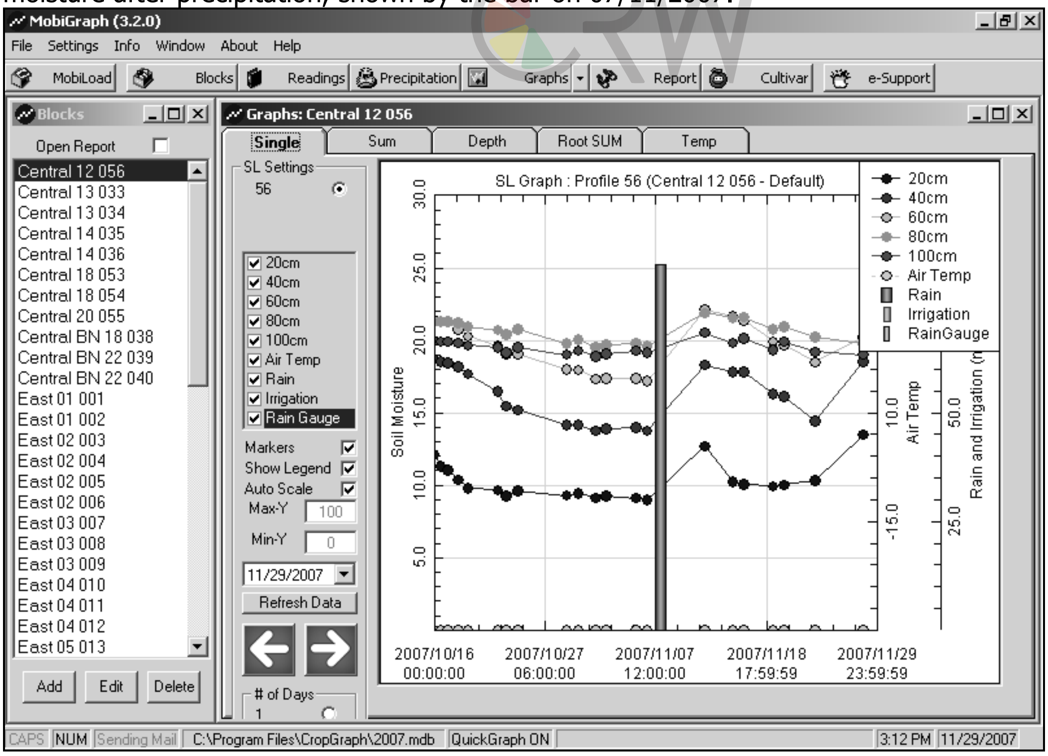
Data and Graphs from the Cropsystem MobiProbe

The table below shows data readings for each depth profile for specific days.

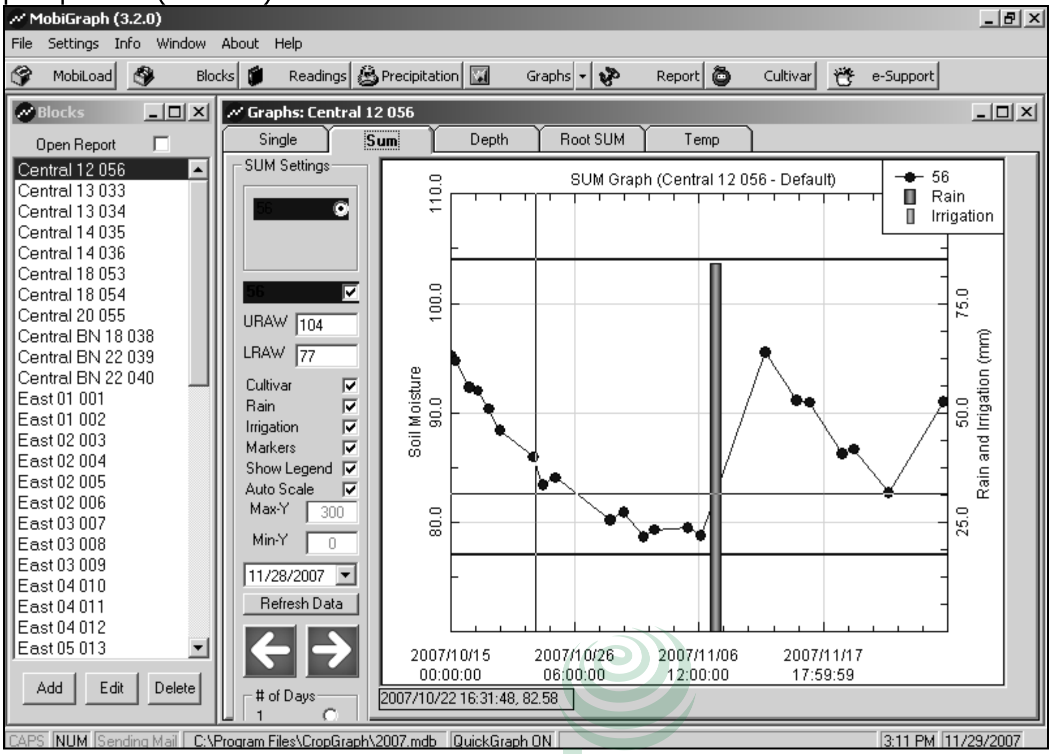


Date	Time	20cm	40cm	60cm	80cm	100cm	Depth Fact
10/15/2007	9:09:30 AM	12.92	18.98	21.61	21.22	20.06	0
10/16/2007	3:48:40 PM	11.3	18.55	21.24	21.32	19.91	0
10/17/2007	9:51:58 AM	11.02	18.47	21.34	21.3	19.91	0
10/18/2007	10:04:22 AM	10.39	18.17	20.76	21.22	19.83	0
10/19/2007	10:03:34 AM	9.8	17.68	20.29	20.96	19.66	0
10/22/2007	10:19:46 AM	9.67	16.47	19.64	20.71	19.5	0
10/23/2007	7:39:12 AM	9.28	15.44	19.08	20.43	19.15	0
10/24/2007	11:00:00 AM	9.59	15.19	19.05	20.74	19.5	0
10/29/2007	10:30:58 AM	9.29	14.17	17.98	19.77	19.01	0
10/30/2007	3:27:04 PM	9.44	14.17	17.97	20.04	19.3	0
11/1/2007	10:38:26 AM	9.14	13.76	17.34	19.54	18.9	0
11/2/2007	11:03:04 AM	9.24	13.89	17.4	19.7	19.07	0
11/5/2007	11:06:48 AM	9.11	13.97	17.35	19.78	19.28	0
11/6/2007	3:18:20 PM	8.97	13.78	17.21	19.62	19.18	0
11/12/2007	11:03:16 AM	12.7	18.3	22.14	21.88	20.53	0
11/15/2007	7:40:20 AM	10.23	17.83	21.69	21.59	19.81	0
11/16/2007	11:27:48 AM	10.05	17.82	21.35	21.6	20.14	0
11/19/2007	10:18:06 AM	9.94	16.3	19.92	20.76	19.36	0
11/20/2007	12:39:22 PM	10.02	16.14	19.65	20.96	19.91	0
11/23/2007	3:47:02 PM	10.33	14.42	18.5	20.21	19.21	0
11/28/2007	2:33:10 PM	13.49	18.56	20.22	19.76	19.02	0

The table below shows soil moisture graphs for each individual depth profile. Note the rise in soil moisture after precipitation, shown by the bar on 07/11/2007.



The table below shows the combined soil moisture in the soil profile. Note the effect of precipitation (blue bar) on soil moisture.



5. Water Use Efficiency Technology

With new technological development, improvements and innovations are constantly made to irrigation systems and equipment, including the development of new practices and trends. It is beneficial to stay informed about these advances as some of them can benefit the production environment you work in. Information can be gathered from:

- Relevant workshops, including short courses, workshops and seminars. The lecturers are usually specialists in their key areas and bring a wealth of information and experience.

- Visiting farmer days, expos and shows. These tend to be a platform for suppliers to showcase the latest developments.

- The Internet holds a wealth of information and provides easy access to information such as production practises in other countries, new trends and ideas, and international research material. The home pages of various suppliers and institutes can be accessed through the internet.

- Local irrigation consultants and suppliers are knowledgeable or have access to individuals that are aware of new irrigation technologies.

- Join your local study group or growers association, which is a channel through which you can get exposure to new technologies.

The following links, companies and institutes can be researched on the internet to get information:

- DWAF - www.dwaf.gov.za
- SABI - www.sabi.co.za
- GULF - www.agriplas.co.za
- AgriPlas - www.agriplas.co.za
- Netafim - www.netafim.co.za
- Dripin - www.toroag.com
- DAN - www.naandan.com

When you encounter new irrigation technology, take the time to thoroughly research and evaluate it. Discuss it with persons that are knowledgeable in that area.

Chapter 3

- The crop water usage estimation is necessary to manage the available water sources.
- Water use estimation records comprise the water usage data and data collected from scheduling equipment.
- At times when more water is available, the irrigation schedule must be managed to prevent over-irrigation.
- During droughts, determine the available water from the existing sources and the estimated crop water use, prioritise the blocks for irrigation, optimise irrigation efficiency, decrease the wetted area to decrease water application, reduce the number of cycles to limit water losses at start-up and shut-down, pay special attention to pumps and filters, and adapt the fertigation program.
- To evaluate the efficiency and accuracy of scheduling devises, do not depend on one device, but try to compare data from at least two devices to ensure accurate readings, and evaluate data with visual inspections in orchards.
- Most modern scheduling equipment is compatible with computers and data from equipment can be downloaded and analysed with specialised software.
- Information on new technological developments can be gathered from short courses, workshops, seminars, farmer days, expos, shows, the Internet, local irrigation consultants and suppliers, and local study group or growers associations.

Complete activities 8, 9 and 10 in the **Learner Workbook**.

Chapter 4

After completing this chapter, the learner will be able to:

Manage appropriate seasonal (year) irrigation related work programs with reference to crop water requirement, crop value, area irrigated, water availability and water quality

1. Optimising Seasonal Fertigation Programs

Fertigation is the application of fertiliser through the irrigation system using the water as carrier and spreader. It can be in the form of seasonal fertiliser on a weekly or monthly basis, or it can be in the form of a continuous injection of a balanced fertiliser mix during each irrigation cycle. Continuous injection is called a hydroponics approach, and is almost exclusively used with drippers and pressure compensated drippers.

An irrigation system must be designed for fertigation. The main criterion is that the system must have a good coefficient of uniformity. Micro-jets and drippers that are well maintained usually have a good coefficient of uniformity. These systems also consist largely of PVC, poly-ethylene and plastic components that are resistant to the corrosive nature of fertiliser. Where components and pipes are made of steel or asbestos cement, fertigation should not be attempted without consulting an expert.

Fertilisers that are used for fertigation are in a liquid or water-soluble powder form. The fertiliser must be able to dissolve completely in water, and not all fertilisers can therefore be used for fertigation. Some fertilisers cause precipitate that can block pipes and emitters. Some of the fertilisers suitable for fertigation are:

- Ammonium phosphate
- Ammonium sulphate
- Magnesium sulphate
- Magnesium nitrate
- Calcium nitrate.
- Potassium nitrate
- Urea

Micro-elements can also be added to the fertigation water by using water soluble forms.

The simplest fertigation systems have one tank where one type of fertiliser, or compatible fertilisers, is added. Compatible fertilisers are different types of fertilisers that can be mixed in the same tank in a concentrated form.

Certain types of fertilisers cannot be mixed, as the chemical reaction that will take place in the tank will cause precipitation during which insoluble salts are formed. Such fertilisers are incompatible. An example of incompatible fertilisers is sulphate products which are incompatible with calcium products. Calcium and sulphate form calcium sulphate (gypsum) which is insoluble.

More advanced systems have two or three tanks, depending on the compatibility of the fertilisers and whether acids are introduced.

Figure 4.1: Fertigation Tanks at Crookes Brothers (Nkwalini)

The setting up of a fertigation system requires the help of a fertigation expert. Such an expert is able to advise a producer on aspects such as:

- The type of system
- The dosage technique
- Fertigation programs
- Tank mixes
- Management aids
- Skills transfer

Getting the correct product and tank mix requires a fertigation schedule. This can be obtained from an expert in fertigation, as the schedule needs to be chemically balanced as well as catering for the physiological needs of the specific crop. The product is mixed in the different tanks according to the schedule.

The fertiliser can be introduced to the irrigation water by the following means:

- Direct feeding from the tank to the suction side of the pump. This is the simplest and cheapest option, but it is not recommended. The fertiliser mix can corrode the inside of the pump and the risk of the pump sucking air increases.

- By using a venturi (see figure 4.3), which is a devise that lowers the pressure in a pipeline to below atmospheric pressure, thus sucking fertilisers from the mix tanks. The venturi is fairly inexpensive, but creates a large pressure drop in the system.

- By using an electric pump, which can be of the diaphragm, plunger or centrifugal type. The pump injects the fertiliser mix into the high pressure side of the system, being after the water pump, at a pressure greater than the system pressure. Pumps work very well and can be regulated accurately, but they are expensive and use electricity.

- By using water powered dosing pumps, which use the system pressure to dose the fertiliser mix into the irrigation water. Dosing pumps are accurate but expensive. A small amount of pressure or water loss occurs to power the dosing pump.

- By using a pressurised tank that allows for the use of soluble solids. The small stream of water is used to dissolve the fertiliser and carries the solution into the system.

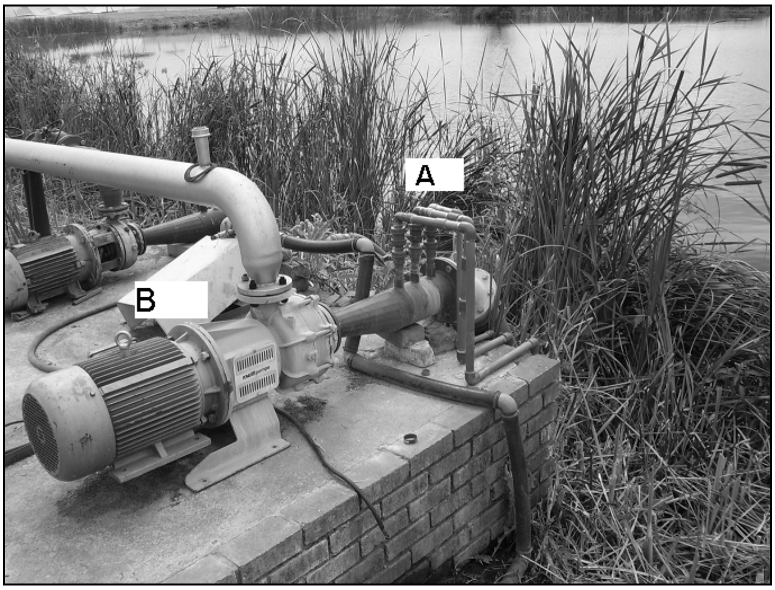


Figure 4.2: Injection on Pump Suction

A - Chemical injection on the suction side of pump
B - Pump

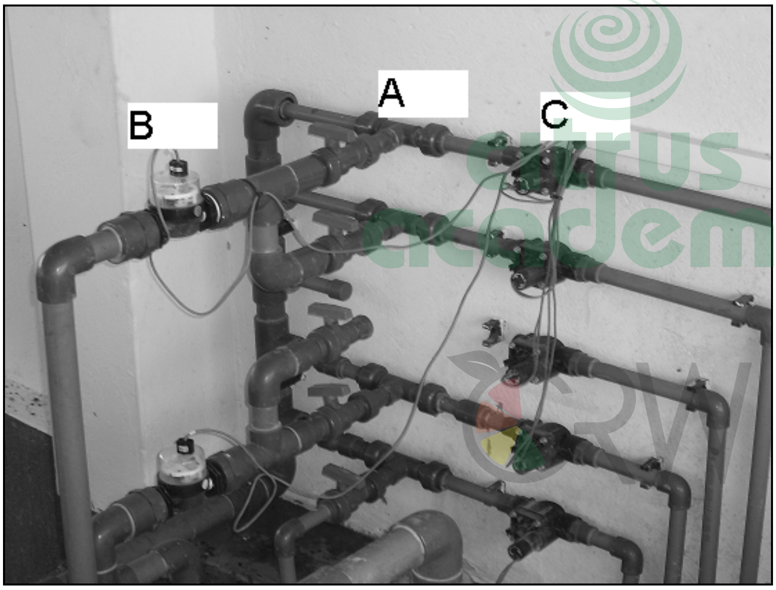


Figure 4.3: Venturi System

A - Bank of Venturi's
B - Flow meter to measure the amount of fertiliser applied
C - Solenoid valve that controls the injection of the fertiliser

More advanced fertigation systems, such as open hydroponics, are monitored and controlled by computers. Usually these systems incorporate pH and EC meters. pH meters are used to ensure that the water is in the optimum pH range of 5.6 to 6.2. The EC (electrical conductivity) meter is used to measure the concentration of fertiliser in the water.

Fertigation systems require intensive management and aids like computers, pH and EC meters to simplify the task. It is also very important to keep records of all tank mixes, the types of fertilisers used, flow-rates, and operations.

The following maintenance is required on fertigation systems:

- Regularly inspect the inline filters and valves for blockages and correct operation
- Regularly inspect flow, pH, EC meters and computer for correct operation
- Annually open and clean pumps, tanks, valves and equipment

Remember that fertiliser is corrosive, so if equipment is stored for a long time, it should be rinsed and filled with clean water.

Fertigation programs must be adapted when the water quality changes. The adaptation of fertigation programs should always be done in consultation with a fertigation expert. In droughts the following must be kept in mind:

- During droughts water tend to be more saline. If the water becomes too saline fertigation should be suspended.

- When irrigation is reduced, fertigation should be lowered or stopped. The reduced irrigation can increase the concentration of salts in the soil. The increase in salts can be harmful to plants. It can burn the plant roots and inhibit water absorption.

During periods of prolonged rain leaching of nutrients can occur. In some instances, this can be desirable, but in other instances the nutrient levels must be boosted. Again this must be done in conjunction with an expert.

2. Fertigation Safety Procedures

Fertigation systems use corrosive and concentrated chemicals. Proper care and safety should be observed when working with these chemicals or near them. Chemicals can cause the following conditions in humans:

- Acid burns
- Affixation from vapours and odours
- Poisoning

When working with chemicals always wear the following protective clothing:

- Rubber gloves to protect hands and arms
- A clean pair of overalls
- Rubber boots
- A respirator or dust mask
- Goggles or a full face mask

When mixing or handling chemicals observe the following precautions:

- Treat all chemicals with respect.

- Transport chemicals separately so that they do not mix.

- Avoid using the same container for different chemicals.

- Store different types of chemicals separately and never in the same area as poisons as it may break down the poison, in the workshop as it will cause corrosion, or close to fuel, as it could cause an explosion.

- Always add chemicals to water and not water to chemicals.

- Know the safety plan and procedures.

A chemicals safety plan and procedures must be developed in the form of a written document. This document must be made available to all staff members, and they should be made well aware of its requirements. Drills and mock emergencies can be practised to familiarise staff with the safety plan. The safety plan can also be incorporated into the other safety plans on the farm, such as the fire drill and the poison safety plan.

The chemicals safety plan and procedures must cover the following areas:

- Recordkeeping of all chemical handling, including the name of the person working with the chemicals, the purpose, and the time and date. These records can be integrated with the existing recordkeeping system.

- Proper safety procedures as set out above.

- Emergency drill in case of injury, such as:
    - Remove the injured person from the area;
    - Wash the area on the skin that came in contact with the chemicals with water;
    - If chemicals came into the eyes or face, wash with water or milk;
    - If the person inhaled chemicals and stopped breathing, perform CPR;
    - If any chemicals were swallowed, do not induce vomiting but seek medical assistance;
    - Seek medical advice as soon as possible.

- Emergency drill in case of a chemical spill or fire, such as:
    - Contain the spill by means of a dam or sand.
    - Use protective clothing such as gloves, overalls and gumboots.
    - Use a fire extinguisher suitable for chemical fires.

3. Micro-Jet and Drippers Sanitation Programs

Present in irrigation water are physical, chemical and organic impurities that can cause blockages. These impurities are removed from the water by using filters, chlorination, airing, sedimentation and acid treatments. These processes are part of the sanitation of micro-jets and drippers, and can be a continuous or a periodic process.

The sanitation process is more critical on drippers, as blocked drippers are useless and must be thrown away. Micro-jets on the other hand can be cleaned when blocked.

In the continuous process, chemicals are continuously added to improve the water quality to a point where no or very little effects are noticed on the irrigation system. Periodic processes can also be done regularly, or in the form of shock treatments that are applied periodically to clean or sanitise the irrigation system.

In table 4.1 is a list of problems that can be caused by poor water quality and recommended remedies:

Problem	***Remedy***
Blockages due to physical impurities	Physical impurities are mainly filtered out, but flakes or granules formed by chemical and organic impurities can physically block emitters. It is important to flush lateral lines frequently after treatments.
Blockage due to chemicals Chemical impurities tend to precipitate due to chemical reactions in the water.	Acid treatment will dissolve the precipitations and also condition the water by lowering the pH to a point where precipitation is limited. Chlorine will precipitate the chemicals, and must be added before the filters so that precipitated chemicals can be filtered out.
Blockages due to organic material Organic slimes are organisms that grow inside the irrigation system. These slimes are usually associated with chemical impurities such as iron, manganese and sulphur.	Chlorine can be used to combat the slimes.

Table 4.1: Problems Caused by Poor Water Quality and Recommended Remedies

3.1. Chlorination

The purpose of chlorination is to prevent sedimentation of organic compounds. Chlorine is also used to precipitate iron and manganese out of the water, and it must be added before the filter in this instance. Various sources of chlorine can be used such as calcium hypo-chloride, sodium hypo-chloride and chlorine gas. The concentrations should be as follows:

Chlorination Purpose	***Application Method***	***Desired Concentration (ppm)***	
		At Start of System	***At End of System***
Prevention of Sedimentation	Continuous	3 – 5	0.5
	Periodic	5 – 10	1 – 2
Cleaning of system with shock treatment		10 – 15	2 – 3

Table 4.2: Chlorine Concentrations

Periodic applications of chlorine can be done on a monthly or weekly basis, depending on the water quality. Chlorine shock treatments can be applied once or twice a year, and preferably not during a period of active root growth. Chlorine works for organic material, and hydrogen peroxide (H_2O_2) is cheaper and more effective as a treatment of algae.

The chlorine must be injected at the irrigation block. Chlorine injection must continue for 20 minutes after the active chlorine is tested at 0.5 to 3ppm (parts per million) at the last dripper.The mother-lines must then be flushed, followed by the lateral lines. When flushing laterals, the flow speed inside the lateral should not be reduced to under 0.5m/s.

When chlorine is injected centrally, mainlines must first be treated and flushed before the blocks are opened. This is to prevent debris from mainlines to block the drippers. The pH of the irrigation water can be lowered to between 6 and 7 to improve the effectiveness of the chlorine.

Fertilisers, pesticides and herbicides lower the efficiency of chlorine, and chlorination should therefore be done separately in the case of periodic or shock treatments.

When working with chlorine observe the following safety measures:

- Avoid eye and skin contact, and do not inhale the gasses
- Avoid the direct contact between chlorine and fertiliser, as this can cause an explosion
- Chlorine and acid injection must be done at separate points, as the direct mixing of chlorine and acid forms a poisonous gas
- Always mix chlorine with water and not water with chlorine

3.2. Acid Treatments

Acid treatments are used to loosen and dissolve the scales formed by the precipitation of chemical impurities. Acid treatments must be done before chlorine treatments where organic slimes and deposits occur.

Table 4.3 shows the concentrations for treatments with different types of acid.

Recommended Concentration of Acid in Treated Water (%)	***Type of Acid***	***Concentration of Acid (%)***	***Dosage (ml acid per 100 l of water)***
0.6	Hydrochloric Acid	33-35	1818 – 1714
0.6	Sulphuric Acid	65	923
0.6	Nitric Acid	60	1000
0.6	Phosphoric Acid	85	706

Table 4.3: Concentrations for Acid Treatments

When an acid is used with a different concentration, the concentration in the treated water must be adapted. The acid treatment will reduce the pH to between 2 to 3, and must therefore not be applied during active root growth. Remember that acid is corrosive and that steel, asbestos cement, and aluminium products are affected by acids. The acid treatment can be done in the following steps:

- Start the irrigation system at working pressure and flush the lines.
- Irrigate for an hour with clean water to wet the root system.
- Connect the injection pump to the block that is being treated. Determine the application rate of the pump and do the calculations to determine the amount of acid that must be injected for an hour to achieve a concentration of 0.6%.
- Inject the required amount of acid.
- After the injection, flush the injection equipment with clean water.
- Irrigate for another hour to normalise the pH in the root-zone.
- Flush the system. Do not flush more than two laterals at a time to ensure a decent flow speed in the lateral.

Apply the following safety precautions:

- Add acid to water and not water to acid.
- Wear protective clothing when handling acids. Acids can cause burns and blindness.
- Do not drink or inhale acids.
- Follow the manufacturer's instructions.
- Do not store acid and chlorine together.
- Use clean water with acid treatments.

Poor water quality necessitates more vigorous sanitation programs. This means that concentrations be increased and the treatment intervals can be shortened.

The best course of action is to evaluate the current sanitation procedures by cutting open some of the drippers to see the effect of cleaning on the inside. When it is suspected that the sanitation process is inadequate, it is recommended to seek expert advice on adapting the sanitation process, especially on the aspect of types of chemicals to use, the correct concentrations, and application time.

4. <u>Filter Operation and Maintenance Programs</u>

Efficient filtering is an essential component of an effective irrigation system. When water quality changes, the filter system must be monitored more closely by paying attention to:

- Up- and down-stream pressure differentiation, which is an indication of the load on the filter and the number of back-flushes that is required per day.

- Up- and down-stream pressure of secondary filters and visual inspection, which will give an indication of the efficiency of the primary filters. If the load on the secondary filters increases dramatically, it means that the primary filter should be inspected.

- Inspection of primary filters should be done more often. In sand filters check for holes in the sand and in disc filters check for worn or broken disks. If mesh filters are used, check for perforations in the mesh.

5. Irrigation System Operational Efficiency

Various aspects of irrigation operations parameters have been discussed such as:

- Adaptation of fertigation during scenarios of varying water availability
- Filter operation under various water availability scenarios
- The adaptation of scheduling programs during various water availability scenarios

During periods of low water availability, water quality tends to be worse because:

- Bottom water is extracted from dams and rivers, which has higher silt content and is murkier
- Bottom water is released from supply dams and weirs
- Irrigation water is supplemented with borehole water which has a high salt content
- Most of the time low water availability is due to dry spells with hot weather, which is when organic impurities in water increase

It must be added that heavy rains can raise the sand and silt content of water resources. Usually irrigation is stopped during such rain spells. If irrigation needs to be continued, filter operation must be monitored as the sand and silt can increase the filter load.

When water availability is low, the effect on scheduling fertigation and the irrigation operation should be considered.

Scheduling is the most important aspect. Proper scheduling ensures that the right trees get the right volume of water at the right time. Fertigation should be closely monitored. Caution should be taken to prevent salinisation of the soil. To prevent salinisation, factors such as soil properties, the EC and TDS of the water, and irrigation schedule should be considered. Fertigation expert must be consulted.

Check and control the proper operation of pumps, filters, valves and infield irrigation. Pay attention to aspects such as water extraction points, filter flushing and cleaning pressure and flow regulating, blockage of emitters and line flushing.

Chapter 4

- ➢ Fertigation is the application of fertiliser through the irrigation system using the water as carrier and spreader.
- ➢ The simplest fertigation systems have one tank where one type of fertiliser, or compatible fertilisers, is added. More advanced systems have two or three tanks, depending on the compatibility of the fertilisers and whether acids are introduced.
- ➢ Fertigation systems require regular inspection of inline filters and valves for blockages and correct operation, regular inspection of flow, pH, EC meters and computer for correct operation, and annual opening and cleaning of pumps, tanks, valves and equipment.
- ➢ Fertigation programs must be adapted when the water quality changes.

- Fertigation systems use corrosive and concentrated chemicals and these should be handled with respect and care.
- Impurities are removed from the water by using filters, chlorination, airing, sedimentation and acid treatments.
- The purpose of chlorination is to prevent sedimentation of organic compounds, and periodic applications of chlorine can be done on a monthly or weekly basis, depending on the water quality.
- Acid treatments are used to loosen and dissolve the scales formed by the precipitation of chemical impurities.
- The best way to evaluate the efficacy of current sanitation procedures is to cut open some of the drippers to see the effect of cleaning on the inside.
- The filter system is monitored by paying attention to up- and down-stream pressure differentiation, up- and down-stream pressure of secondary filters and visual inspections, regular inspection of primary filters.

Practical

Complete activities 11, 12, and 13 in the **Learner Workbook**.

Chapter 5

After completing this chapter, the learner will be able to:

Recommend a safety, servicing and replacement policy with reference to expenditure implications

1. Evaluating the Efficiency of Operational Equipment

The efficiency of the irrigation system as a whole is assessed by determining the system efficiency as described in chapter 3. The efficiency of the components of the irrigation system is assessed and evaluated separately.

The operational components of an irrigation system consist of:

- Pumps and motors
- Filters
- Valves
- Gauges
- Control panels
- Water meters
- Pipes
- Emitters
- System as a whole
- Fertigation

1.1. Pumps and Motors

The operational parameters for the pumps, motors, or pump-motor combinations can be obtained from the irrigation design plan. Pay special attention to aspects such as operating flow, operating pressure, operating amps and closed valve pressure. Deviations, such as lower flow pressure, lower or higher amps, or lower closed valve pressure, can indicate lower pump efficiency.

1.2. Filters

The efficiency of filters can be assessed by:

- The number of back-flushes that are required, which may indicate worn filter material

- A visual inspection of the filter material during which holes in sand or worn or broken rings and discs can be detected.

- Assessing the load on the secondary filters, which if increasing may indicate a loss of efficiency of the primary filter.

It is important to keep to a maintenance schedule. Proper cleaning and inspection of filters keep filters performing as they should.

1.3. Valves

Valves are assessed by their ability to open, close and regulate pressure in the case of hydraulic valves. Valves should also be inspected for leaks.

1.4. Gauges

Gauges should be maintained properly. Gauges can be evaluated for accuracy by comparing pressure readings with a second gauge.

1.5. Control Panels

Control panels can be inspected for correct operation, including proper working of motors, fertigation and valves that are operated by the control panel. On most panels there are displays that indicate correct operation or error codes. Error codes should be noted and referenced to the user manual for corrective action.

1.6. Water Meters

Water meters should be inspected for proper working order, consisting of a visual inspection to see if the dials are rotating while the pump is running, as well as a check to compare flow rates derived from current meter readings with previous meter readings.

1.7. Pipes

Pipes are checked for leaks during the water loss detection process. The general condition of the pipes can be inspected visually for instance quarterly to assess pipes for exposure due to soil erosion and PVC and poli-pipe for perishing.

1.8. Emitters

Emitters are evaluated by performing a coefficient of uniformity test as explained below.

2. Emitter Performance

The water flowing through emitters causes emitters to wear out. The presence of sand, silt or other impurities in the water can accelerate the wear and tear on emitters. A coefficient of uniformity (CU) test is performed to assess wear and tear.

The CU test determines the delivery rate of a sample of emitters in a block. The deviation between the average and the lowest or highest delivery rate is expressed as a coefficient of uniformity. When measuring the delivery rate of the emitters, the design delivery must also be noted.

When the CU test is complete, the results are compared with those of previous CU tests to see if the CU is deteriorating. When the CU is below the SABI (South African Irrigation Institute) norms of 90%, being a 10% deviation, the emitters on the specific block must be inspected.

It is important to determine the cause of the poor CU, which may be leakages, blockages, or worn emitters. Blockages are detected by doing a visual inspection. Worn emitters are identified by evaluating the delivery rate against the design specifications. Worn emitters will deliver consistently more than the design specifications. Drippers are more likely to be blocked than to wear out. The blocked drippers will affect the CU test adversely. When the CU test is below 90%, a decision must be taken on whether the drippers are going to be cleaned or replaced.

The cost of cleaning as opposed to replacing blocked drippers should be weighed against the results. The cleaning of drippers should first be discussed with your irrigation consultant and drip manufacturer to estimate the effectiveness of a cleaning operation. When the effectiveness of cleaning is low it is better to replace the drippers.

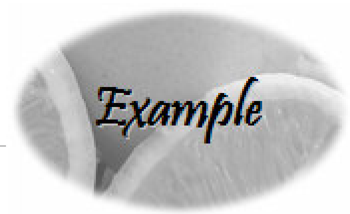
3. Pump and Motor Performance

Pumps and motors are subject to wear when they are operational. Wear is directly proportional to the number of operating hours, provided that no extraordinary circumstances occurs that cause excessive wear, such as cavitation. This is the same principle that applies to motor vehicles, which must be inspected and serviced at regular intervals.

The number of operating hours can be read from the hour meter in the starting panel of it is equipped with one. If not, the number of operational hours can be estimated by multiplying the number of operating hours per day, which can be obtained from the irrigation schedule, with the number of operating days per month. Alternatively, one can multiply the number of operating hours per week with 4.33, which will also result in the number of operating hours per month.

Daily and weekly operating hours, and the number of operating days per week, can be retrieved from the irrigation schedule. Remember that this information will change for various times during the year.

The number of operating hours per annum can be calculated by multiplying the monthly hours by 12. The operating hours can be calculated per semester, quarterly, bimonthly or monthly. The period will depend on pump use during peak and off-peak seasons.



Records of Pump Operating Hours

According to the irrigation schedule the daily operating hours for a pump is as follows:

Period	***January – March***	***April – June***	***July – September***	***October – December***
Daily operating hours	8	8	9	9
Irrigation days in a week	6	4	4	6

In the table below, the weekly, monthly and periodic operating hours is calculated from this information.

Period	***January – March***	***April – June***	***July – September***	***October – December***
Daily Operating Hours	8	8	9	9
Irrigation Days in a Week	6	4	4	6
Weekly Operating Hours	8x6=48	32	36	54
Monthly Operating Hours	48x4.33=207.8	138.6	155.9	233.8
Periodic Operating hours	207.8x3=623.4	415.8	467.7	701.4

The periodic operating hours is added up to determine the annual operating hours:

623.4 + 415.8 + 467.7 + 701.4 = 2,208.3

When the annual operating hours is known, a maintenance program can be implemented based on the hours.

- Motors and pumps must be greased every 200 hours or monthly, whichever is soonest.
- Replace the oil and perform an annual inspection every 2,500 hours or annually.
- Replace the bearings and inspect the impeller and wear rings, and replace if necessary every 5,000 to 10,000 hours or every 2 to 5 years. As a general rule, high speed pumps, being pumps that run at

2,900rpm, will be done every 5,000 hours, while low speed pumps, being pumps that run at 1,450 rpm and lower, will be done every 10,000 hours. The best is to confirm the service interval with the pump manufacturer.

- The impeller must be replaced at every 10,000 to 12,500 hours.

Please note the following:

- The oil, grease and replacement intervals are according to the B10 bearing life principle which is used by most manufacturers of pumps and motors. Confirm that the pumps and motors incorporate these standards. Alternatively, enquire about the specific maintenance schedule for the make of pump and motor.

- Impeller wear is based on cast iron impellers in good operating conditions. Factors such as cavitation, water quality, and impeller material can shorten or extend the impeller life. Impeller replacement should rather be assessed through visual inspection and pump performance evaluation.

- The manufacturer or supplier of pumps such as submersible pumps, borehole pumps and vertical booster pumps should supply the maintenance schedule for these pumps. Generally, these pumps are opened and inspected annually or every 2,500 hours.

4. <u>Pressure and Flow Checks of Control Valves</u>

As part of the maintenance program, the pressure and flow of control valves must be carried out. This forms part of the daily and weekly irrigation process. The procedures that are followed, as well as the maintenance procedures and recordkeeping guidelines, are discussed in detail in earlier unit standards.

5. <u>Replacement Equipment and Spares</u>

To ensure the smooth operation of an irrigation system, it is necessary to keep stock of the most commonly used spares.

The cost of keeping spares on the farm is high, and items that are kept as spares must therefore be selected carefully. Criteria for selecting spares are:

- Frequency of use
- Availability from suppliers
- Importance of component
- The cost of keeping it in stock versus the cost of not keeping it in stock

The cost of not keeping an item in stock is based on possible losses that may occur if the repair to the system is delayed.

If a large inventory of spares cannot be held, it is advisable to develop procedures whereby spares can be on the farm within 48 hours. This can be achieved by having a service agreement with a supplier or by using a courier service to deliver the goods. The proximity of the farm to spares and equipment suppliers must also be taken into account when deciding on the size of the inventory. Large farming operations are more able to carry a large stock of spares and even replacement equipment.

Based on the guidelines above, table 5.1 shows a list of spares and equipment that can be kept on a medium-sized farm with reasonable access to suppliers.

Item	***Number***
Pump Spares and Equipment	
Motor protection relay	1
Star delta timer	1

Item	***Number***
Impeller	
Pump shaft	
Bearings	
Motor coupling	
Filter Spares and Equipment	
Diaphragms for hydraulic valves	1
Hydraulic tubing	2m
3 way valve	1
Connecters	Assorted tees and elbows 5 of each
Filter sand	
Rings	
Complete filter element	1
Filter lids	
Lid seals	2
Delivery Lines Spares and Equipment	
Repair couplings	1 for each size
Repair fittings (e.g. cascade)	
Lengths of the different sizes and classes of pipe	2 lengths of each size in highest class
Saddles	
Generally used items	
IR gaskets	
Bolts and nuts	
Valves	
Pressure gauges	1
Air valves	
Hydromatics	2
Infield Irrigation Spares and Equipment	
Micro peg	25
Tube with barb	25
Complete micro bridge	25
Emitters	25
Spreaders/swivels	25
Drippers	25
Poly pipe	50 m of each size
PVC pipe	2 lengths of each size and class
Nylon fittings	
PVC fittings	
Pilot valve service kit	

Item	*Number*
Pilot valve	
Replacement Spares and Equipment	
Pump set	
Starter panel	
Complete hydraulic valve	1
Complete other valves	1
Generator	

Table 5.1: Spares and Equipment Kept on Farm

6. Plant Safety and Evacuation Plan for Floods

Emergency plans vary from farm to farm, but the basics requirements are the same. Floods can do damage by flooding pump stations or by literally sweeping away pump installations. It is important to be in contact with the local water users association as they issue flood warnings. If heavy rains occur keep in mind that a flood can occur.

Use the following guidelines:

- Stop the pumps and isolate the main electrical circuit, including the transformers and substations. Keep the keys to the main distribution box, transformer or substation in a place that is easily accessible in an emergency. If possible, contact Escom or the local electricity provider to isolate the transformer at the pole, especially if there is a danger of it flooding.
- When the pump is installed in a place that is vulnerable to flooding, such as down the embankment or on a pontoon in the river, try to install the pump in such a way that it can be easily and quickly removed. It can for example be placed on a trolley, rails or sledge. The pump can then be towed, hoisted on a trailer, or pulled to safety. Use couplings and connections that are quick release, for example Bauer couplings at the pipe work and heavy duty welding plugs, to disconnect the cable. If the pump can be removed, the possibility of it being swept away is nil. When the pump is installed, it is best to do the installation in such a way that it eases the extraction of the pump in a crisis situation.
- After the flood, never switch on the main isolator, transformer or substation until the pump and panels have been assessed by a qualified electrician. Wet motors and panels explode and can cause serious injury or death.

It is important that emergency procedures such as this are worked out and practised in advance. The procedures can be formulised in an action plan that explains stepwise what must be done in the correct order. It can also incorporate a plan of action when a flash flood is experienced.

During flash floods not much can be done. The best option is to isolate the electrical supply and then see if the pump can be retracted or anchored.

Chapter 5

- ➢ The efficiency of the irrigation system as a whole is assessed by determining the system efficiency as described before, while the efficiency of the components of the irrigation system is assessed and evaluated separately.
- ➢ The operational parameters for the pumps, motors, or pump-motor combinations can be

obtained from the irrigation design plan, and deviations from the operational parameters can indicate lower pump efficiency.

- The efficiency of filters can be assessed by the number of back-flushes that are required, a visual inspection of the filter material, and assessing the load on the secondary filters.
- Valves are assessed by their ability to open, close and regulate pressure.
- Gauges can be evaluated for accuracy by comparing pressure readings with a second gauge.
- Control panels can be inspected for correct operation, including proper working of motors, fertigation and valves that are operated by the control panel.
- Water meters should be inspected for proper working order, consisting of a visual inspection to see if the dials are rotating while the pump is running.
- Pipes are checked for leaks during the water loss detection process.
- Emitters are evaluated by performing a coefficient of uniformity test which determines the delivery rate of a sample of emitters in a block.
- The wear on pumps and motors is directly proportional to the number of operating hours, provided that no extraordinary circumstances occur.
- As part of the maintenance program, the pressure and flow of control valves must be carried out.
- To ensure the smooth operation of an irrigation system, it is necessary to keep stock of the most commonly used spares.
- Criteria for selecting spares are frequency of use, availability from suppliers, importance of component, and the cost of keeping it in stock versus the cost of not keeping it in stock.
- Emergency plans vary from farm to farm, but the basics requirements are the same.

Complete activities 14, 15, 16, and 17 in the **Learner Workbook**.

Chapter 6

After completing this chapter, the learner will be able to:

Ensure that all irrigation practices are environmentally sensitive specifically in terms of water extractions and return flows

1. Information Database

The new water law and accreditation by standards organisations such as GlobalGAP requires that farms and farm managers keep detailed production records covering all aspects of the farming operation. One such aspect is water use. Water use, water quality, and all other water related information must be kept in a database.

Water use data does not need to be collected, but can be sourced from the water use estimation records and irrigation scheduling records. Data pertaining to the water quality can be gathered from the relevant lab reports and the weekly and monthly farm reports. The fertigation data and spray records can also be added or linked to the database, as these concern water use and are possible pollution points.

The database contains records of all water related records or copies of such records and can include the following:

- Water use records and estimations
- Irrigation scheduling records
- Water quality records
- Fertigation records
- Spray records
- Other records or documents such as water records related to packhouses and on-farm processing, and letters and quotas from the local water users association.

The database can be in hardcopy or electronic format. An electronic format is preferable as relevant records can be linked, sorted or searched electronically. Copies can be printed, thus lowering the chance of original documents being lost.

2. Possible Points of Pollution

The definition for pollution is *to make dirty or impure, especially by adding harmful or offensive substances*. The point source of pollution can be any place or point where pollutants are introduced into the environment.

2.1. Pollutants

Pollutants come in many forms such as:

- Fertiliser used in excess
- Crop protection chemicals if not applied correctly
- Other chemicals such as oil, disinfectants and cleaners that are not disposed of correctly
- Human excrement
- Empty or unused poison and chemical containers
- Old and unused chemicals
- Irrigation water

These untreated pollutants can be introduced into the water system directly or indirectly through the ground water by leaching from the soil.

2.2. Points of Pollution

Points of pollution can be:

- The fertigation plant, where pollution can occur when the tanks are cleaned or during fertiliser spills.
- The chemical water treatment plant, where pollution can occur when tanks are cleaned.
- Spray cart filler points, where poisons can wash down into the soil during filling.
- In irrigation blocks and orchards, if not properly managed, salts and chemicals can build up in the soil and some chemicals can leach through the soil if not applied correctly.
- Packhouses and on-farm processing plants can create effluents that are environmentally harmful.
- Workshops have effluent that is oily and full of chemicals.
- Toilets and the sewerage systems can contaminate water sources with organisms, such as cholera if not operating properly.
- Poor quality water applied to good quality soil.

2.3. Preventative Action

Prevention is better than cure in the case of pollution, and it is advisable to have protocols in place to prevent or limit pollution.

The proper handling and storage of chemicals reduces the likelihood of pollution. Chemicals used for fertilisation should be stored in a dry, lockable area that is well ventilated. It is recommended that fertilisers are stored on pallets that can be used to demarcate areas for specific types of fertilisers, and that will prevent it from getting wet accidentally.

Poisonous and dangerous chemicals, such as chlorine, must be locked in a separate cage inside the store. Plant protection products cannot be kept in the same room as fertilisers. The fertiliser store must have a register where a responsible person keeps record of fertilisers that was received and dispensed.

2.4. Developing a Remedial Plan

A remedial plan should focus on the prevention of pollution and should concentrate on the following:

- Spills must be prevented if at all possible, and contained if they occur.
- Control measures must be in place for all chemicals. Records must be kept of all chemicals on the farm, and chemicals must be stored as prescribed by protocols such as GlobalGAP.
- Suitable waste water systems, such as suitable catchments and septic tanks or French drains must exist where chemicals are washed down or where mixes are disposed of. This includes points such as fertigation and chemical dosing points, packhouse water outlets, and spray cart refill points. A septic tank is recommended, but a French drain can be used in the case of the refill point. Polluted water can also be collected in a tank and disposed of at a central septic tank. Where soil conditions do not permit the use of a septic tank, a reed dam can be used to

break down the chemicals. Regular samples must be taken at the overflow of the reed dam to check the levels of pollutants, especially organophosphates and carbonates.

- Suitable effluent systems where water from the workshop and processing plant can pass through a trap to remove oils and other contaminants. If the water is free of chemicals, it can be returned to the water source, if not, it must be collected in a septic tank or storage facility.

- Proper disposal of used chemical containers and unused chemicals will prevent contamination from these sources. Empty containers must be pierced and locked up until it can be disposed of. The conventional means of disposing of is by incineration. For chemicals, a local waste management company can be contacted to help with the disposal of the chemical.

- Process control and monitoring can entail the evaluation of the remedial plan as well as assessing how well and diligently it is executed by the persons involved.

3. Chemical Spills

Chemical spills must be prevented where at all possible. To ensure that chemical spills are limited, staff that handle chemicals must be well aware of the safe working procedures.

When a chemical spill does occur, the priorities are containment and clean-up, and dealing with medical emergencies. These three actions must take place concurrently and specific staff members should be responsible for performing the necessary tasks.

3.1. Containment and Clean-Up

Where chemicals are stored in bulk, such as 10,000l fertiliser tanks, the tanks must placed on a cement floor that are ringed by a wall that has been sealed watertight. The volume of this "dam" around the tank must be more than the volume of the tanks. The chemical will be contained within the dam around the tank if the tanks should crack or break, or if a leakage occurs.

The contingency plan for chemical spill must include the following procedures:

- Isolate the spill area and keep all unauthorised people away.

- Every person involved in the clean-up operation must wear protective clothing. Raincoats, gumboots and gloves must be kept handy in an emergency locker for the workers who have the responsibility of cleaning the spill.

- Attempt to contain the spill or leakage as far as possible by constructing an absorbent barrier of sand/earth or lime around the spilt material. Sawdust can also be kept handy to soak up the chemical.

- Place leaking containers, if any, into open-top drums and label the drums clearly for future reference and disposal.

- Collect the spilt material and absorbent substance using the shovels and brooms, and place it into open-top drums for disposal.

- Ventilate the building as much as possible by opening all doors and windows.

- If the spillage occurred on soil or gravel, dig up the area and dispose of the soil or gravel.

- Only if an acidic chemical is spilt on concrete, neutralise it with lime or a 10% solution of sodium carbonate (Na_2CO_3) or alternatively, with 5% sodium hydroxide ($NaOH$).

- Clean all equipment used during the clean-up operation thoroughly, including laundering protective clothing.

- Dispose of the collected spill material in the prescribed manner.
- Wash and rinse the open-top drums.

3.2. Medical Emergencies

Arrange for medical attention as soon as possible, or arrange for transporting the affected person to a hospital or clinic. While this is being done, administer the following first aid procedures:

- Determine which chemical caused the poisoning.
- If the product is known, consult the label for the specific first aid procedures.
- Ascertain how the chemical was absorbed (orally, through the skin or by inhalation)
- Make sure that the breathing tract is open.
- If the patient is unconscious, turn him / her onto stomach.
- Start artificial respiration if the person is not breathing.
- If the patient absorbed the chemical via the skin, remove the patient from the contamination point, remove all contaminated clothing and rinse under an emergency shower.
- If the eyes have been affected, wash with clean water for at least 15 minutes.
- If the chemicals have been swallowed do NOT induce vomiting unless specifically stated on the product label.
- Keep the patient warm.

4. Environmental and Health and Safety Legislation

The laws concerned with personal and environmental safety are:

- The Occupational Health and Safety Act
- The Environmental Management Act

4.1. Occupational Health and Safety Act

The Occupational Health and Safety Act (OHSA) aims to ensure the safety and health of employees in the work place. The employer has the responsibility of providing and maintaining, as far as is reasonably practicable, a working environment that is safe and without risk to the health of his employees. Employees on the other hand must comply with the regulations and procedures prescribed by the act and the employer that are aimed at creating a safe working environment.

The act also states that no person shall intentionally or recklessly interfere with, damage, or misuse anything which is provided in the interest of health and safety.

The complete act can be found on the website of the Department of Labour at www.labour.gov.za.

4.1.1. Responsibilities of the Employer

The responsibilities of the employer includes in particular:

- The provision and maintenance of systems of work, plant and machinery that are safe and without risks to health.

- Taking such steps as may be reasonably practicable to eliminate or mitigate any hazard or potential hazard to the safety or health of employees, before resorting to personal protective equipment.

- Making arrangements for ensuring the safety and absence of risks to health in connection with the production, processing, use, handling, storage or transport of articles or substances.

- Establishing what hazards to the health or safety of persons are attached to any work which is performed, any article or substance which is produced, processed, used, handled, stored or transported, and any plant or machinery which is used, establishing what precautionary measures should be taken in order to protect the health and safety of persons, and providing the necessary means to apply such precautionary measures.

- Providing such information, instructions, training and supervision as may be necessary to ensure the health and safety at work of his employees.

- Not permitting any employee to do any work or to produce, process, use, handle, store or transport any article or substance or to operate any plant or machinery, unless the necessary precautionary measures have been taken.

- Taking all necessary measures to ensure that the requirements of the act are complied with by every employee and all other persons on premises.

- Enforcing such measures as may be necessary in the interest of health and safety.

- Ensuring that work is performed and that plant or machinery is used under the general supervision of a person trained to understand the hazards associated with it and who have the authority to ensure that precautionary measures taken by the employer are implemented.

4.1.2. <u>Responsibilities of the Employee</u>

Employees have the obligation to:

- Take reasonable care for their own health and safety and that of other persons who may be affected by their acts or omissions.

- Cooperate with the employer to enable him to comply with his responsibilities under the Act.

- Carry out any lawful order given to him, and obey the health and safety rules and procedures laid down by his employer or by anyone authorised to do so by his employer, in the interest of health or safety.

- If any situation which is unsafe or unhealthy comes to his attention, as soon as practical report such situation to his employer or to the health and safety representative for his workplace or section, who shall report it to the employer.

- If he is involved in any incident which may affect his health or which has caused an injury to himself, report such incident to his employer or to anyone authorised for this purpose by the employer, or to his health and safety representative, as soon as possible, but not later than the end of the particular shift during which the incident occurred, unless the circumstances were such that the reporting of the incident was not possible, in which case he shall report the incident as soon as practical thereafter.

4.2. Environmental Management Act

The Environmental Management Act aims to protect, maintain and improve the environment and to ensure the right to a safe and healthy environment. It also regulates the relationships between government, communities and agriculture.

All institutions that are doing activities that have an impact on the environment are required to do an environmental impact assessment and to develop an environmental management plan. The act also stipulates that specific action must be taken to protect and preserve resources such as soil and water.

This act can be found on the website of the Department of Environmental Affairs at www.environment.gov.za.

Safe Handling of Chemicals

It is essential that chemicals used in and on the irrigation system, are handled, stored and discarded correctly to prevent damage to the system, the persons working with the system, and the environment. For guidelines to the safe use and storage of chemicals, please consult the Crop Protection Application learner guide of the Citrus Academy.

Chapter 6

- Water use, water quality, and all other water related information must be kept in a database.
- The definition for pollution is to make dirty or impure, especially by adding harmful or offensive substances.
- Pollutants include fertiliser used in excess, crop protection chemicals if not applied correctly, other chemicals such as oil, disinfectants and cleaners that are not disposed of correctly, human excrement, empty or unused poison and chemical containers, and old and unused chemicals.
- Points of pollution can be the fertigation plant, the chemical water treatment plant, spray cart filler points, in irrigation blocks and orchards, packhouses, workshops, and toilets and the sewerage systems.
- It is advisable to have protocols in place to prevent or limit pollution.
- When a chemical spill occurs, the priorities are containment and clean-up, and dealing with medical emergencies.
- The laws concerned with personal and environmental safety are the Occupational Health and Safety Act and the Environmental Management Act.
- The Occupational Health and Safety Act (OHSA) aims to ensure the safety and health of employees in the work place.
- The Environmental Management Act aims to protect, maintain and improve the environment and to ensure the right to a safe and healthy environment.

Complete activity 18 in the **Learner Workbook**.

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