5.1 Selecting an irrigation system

This material is summarised from NSW DPI PROwater© Irrigation Training Series Module 2: Selecting an irrigation system.

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Key points

- A number of different surface and pressurised irrigation systems exist, offering a range of advantages and limitations.
- It is important to consider different irrigation system alternatives in light of your overarching enterprise goals.
- The most appropriate irrigation system for a particular situation should consider the topography, soils, crop water requirements, energy, labour and irrigation performance.
- System capacity is a key measure in determining the suitability of an irrigation system to a particular crop type and location.
- The system selection process can be complex.
- Any system should be designed by an appropriately qualified irrigation designer to ensure that it operates to its potential.

Introduction

Selecting an irrigation system requires you to determine which one is most suitable for your situation. In many cases, no single best solution may exist, as each system has their particular advantages and disadvantages and no two situations are exactly the same.

Selecting a suitable system is a process of balancing a number of key parameters that are specific to each irrigation enterprise. These include the enterprise goals, area of land, topography, soils, water supply, climate, crops, finances, regulatory requirements and management style.

Investigating existing systems that are working well in situations similar to yours is usually very helpful.

This chapter provides an overview of the principles and processes and the opportunities and constraints that the various systems allow.

Types of irrigation systems

Irrigation systems can be categorised into two broad groups:

- Surface irrigation systems – where water is applied to the root zone by flow over the soil surface by gravity, e.g., furrow, border check, contour bay.
- Pressurised irrigation systems – where water is applied through a pressurised pipe system and emitters or sprinklers, e.g., centre pivot, lateral move, travelling irrigator, drip.

No system type is inherently better than another; each individual irrigation system should be selected and designed depending on a range of factors specific to each site.

Surface irrigation systems

Border check; consists of a sloping strip of land, level across the strip, bordered by low check banks. Laser-levelled fields are essential for even water distribution. Slopes range from 1:100 to 1:1200, common bay lengths are 300 to 600 metres, and common bay widths are 30 to 100 metres. Bay inlets are usually gates or siphons, and the lower ends of the bays generally drain directly into a shallow tail water channel.

Furrow or bed irrigation (WATERpak Chapters 5.2 and 5.3). Water flows down narrow furrows between crop rows or beds. Laser-levelling of fields is usually required to obtain a consistent slope down the field which is essential for even irrigation along the furrows and good drainage but does not need to be as precise as for Border Check systems. Slopes range from 1:500 to 1:1500, common furrow lengths are 300 to 1000 metres, and furrows are usually V-shaped. For furrow irrigation, furrows are usually 1 or 2 metres apart, and for bed irrigation they can be up to 4 metres apart. Inlets are usually siphons or through-the-bank pipes. The lower end of each furrow generally drains directly into a tail water channel.

Contour irrigation; fields are laid out with banks formed on topographic contours and have slope in the lateral direction (i.e., across the width of the bay) but not in the longitudinal direction (i.e., down the length of the bay). Contour irrigation is usually reserved for ponded crops like rice but is also used to grow rotation crops such as pasture or wheat. Precise laser-levelling of fields is essential to obtain a consistent, small slope.

Figure 5.1.1. Border Check irrigation system (image: G. Giddings)

Figure 5.1.2. Furrow irrigation system

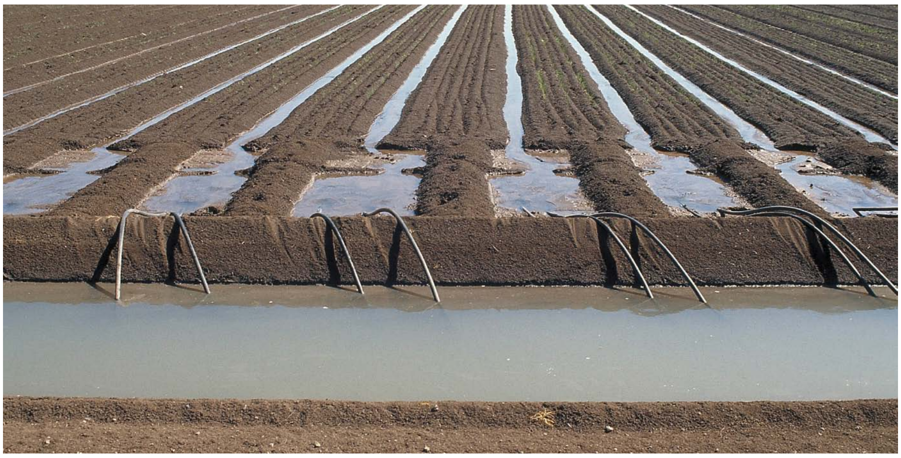


Figure 5.1.3. Bed irrigation system

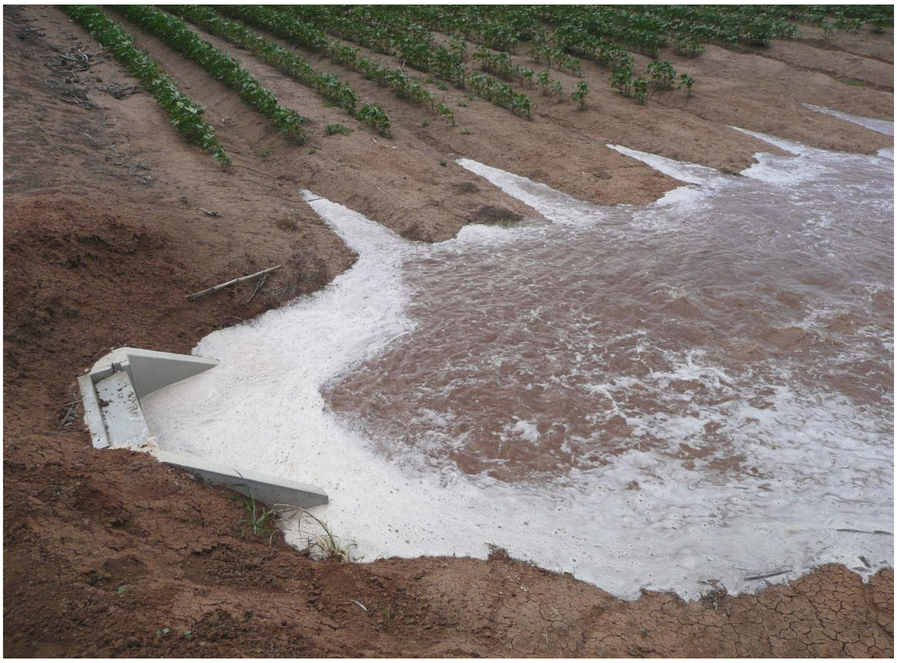
This is necessary to provide an even depth of water when ponded, good drainage when the water is released, and even irrigation for the rotation crops. For rice crops, the soil should be heavy clay that limits deep drainage. Slopes commonly range from 1:1000 to 1:2000. Common bay lengths are 400 to 450 metres with check banks at 50 mm contour intervals. Inlets are usually gates or 'stops'. Each bay may drain into the next with the last bay in a sequence draining into a tail water channel, or each bay may be drained directly into a tail water channel.

Bankless channel or side-ditch delivery (WATERpak Chapter 5.4). Water is applied and drained from the bottom of the slope. These systems have a supply channel running with the slope down one side of the irrigation block without a bank on the inside of the bay. Checks are placed across the supply channel at each contour bank to control flows. The bed of the channel is below the level of the bay and acts as both a supply and drain. Longitudinal slopes range from 1:5000 to level, with 1:10000 a commonly used slope.

These very flat grades provide enough slope to drain water from the field without creating excessive water depths at the inlet. Water moves up the slope when being applied and drains back to the supply channel to augment flow to the next downstream bay. For flat-planted systems a lateral slope is sometimes introduced, whilst in bed or furrow configurations there is zero side slope. This creates a terraced system with a step between the bays of 0.1 to 0.2 m.

Figure 5.1.4. Contour irrigation systems. (Foreground shows a conventional system with check banks formed along the natural contours. Background shows land-formed fields that are rectangular in shape and with check banks formed along the altered contours.)

Figure 5.1.5. Bankless channel system commencing irrigation (Photo: M. Grabham)



Pressurised irrigation systems

Spray lines – fixed. Fixed spraylines are often used for vegetable crops, permanent horticultural plantings and sometimes for pasture irrigation. Water is delivered through a permanent, buried mainline. The irrigation area is usually divided into a number of blocks with a sub-main for each block running off the mainline. Sub-mains are usually permanent (buried) but may be portable (laid on the surface). Water reaches the crop though a grid of surface laterals fitted with sprinklers which are generally of the 'knocker' type and provide from 5 to 20 mm per hour of water and operate between 200 and 450 kPa.

Figure 5.1.6. Fixed Overhead irrigation system

Spray lines – movable. Hand-shift spraylines consist of lengths of aluminium irrigation pipe with quick connect and release couplings at both ends and a sprinkler at one end. These are moved and fitted together by hand and usually supplied from a riser attached to a buried sub-main. The sprinklers also may be mounted on risers to get above a crop. Pressure ranges from 150 to 450 kPa. They are used for irrigating pasture or short crops such as lucerne and vegetables. This system is suitable for regular or irregular shaped fields.

End-tow spraylines are similar to hand-shift except each coupling is fitted with a skid or pair of small wheels. This allows the entire length of connected pipes to be towed by the end from one position to the next, reducing the labour requirement. The couplings have to be more robust than for hand shift. These systems must be moved empty of water, so the couplings have valves for draining the pipes. The direction of tow must be in line with the pipes if fitted with skids, so movement can only be directly to an adjacent field. If wheels are fitted, movement can be straight ahead to another field or at an angle of 45° in the same field in a zigzag pattern, towed alternatively from opposite ends. This system is best suited to rectangular fields with gentle topography.

Side-roll systems are also similar to hand-shift except each length of pipe is mounted through the centre of a large wheel of about 2-metre diameter. The entire length of pipe can then be shifted to the next position in a few minutes by rolling it sideways. A small motor and drive mechanism is usually fitted at the centre of the length of pipes to eliminate all manual effort. The sprinklers are mounted on a swivel so they remain upright. The system must be moved empty of water, so the couplings have spring-loaded valves that open when the pressure has dropped, allowing the water to drain out. This system is best suited to rectangular fields with gentle topography.

Travelling guns and booms. These irrigators come in two forms: with a soft hose and a cable drum, or with a hard hose drum. They can be fitted with a single 'big gun' sprinkler or with a boom which has a number of emitters along it. The booms use sprinklers that are commonly fitted to other sprinkler systems such as centre pivots or spray-lines. 'Big-gun' travellers require high pressure to operate properly, so are high consumers of energy.

Rotary boom irrigators are similar except that the big gun sprinkler is replaced by a galvanised boom fitted with medium to low pressure sprinklers. The boom is rotated by the discharge from the sprinkler nozzles, and the rotation provides the energy to operate the drive mechanism and cable winch. Various sprinkler combinations (big gun, rotating, and low pressure) can be used.

Working pressures for travelling guns and booms range from 70 kPa to 500 kPa.

These systems are commonly used to irrigate pastures and lucerne, but machines with elevated wheels can be used on taller crops.

Figure 5.1.7. Side-roll sprayline system

Figure 5.1.8. 'Big-gun' Travelling irrigator

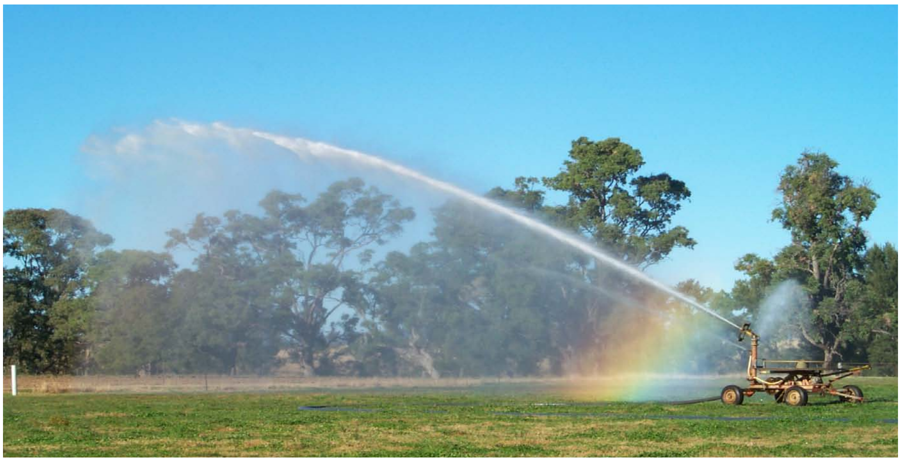
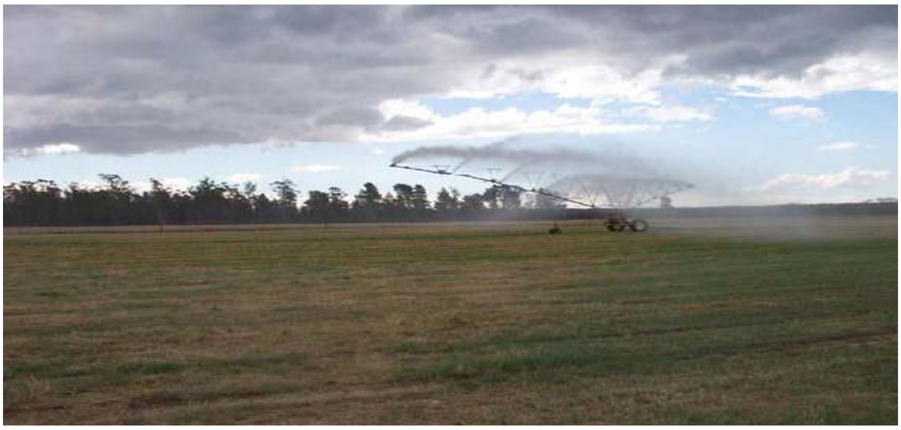
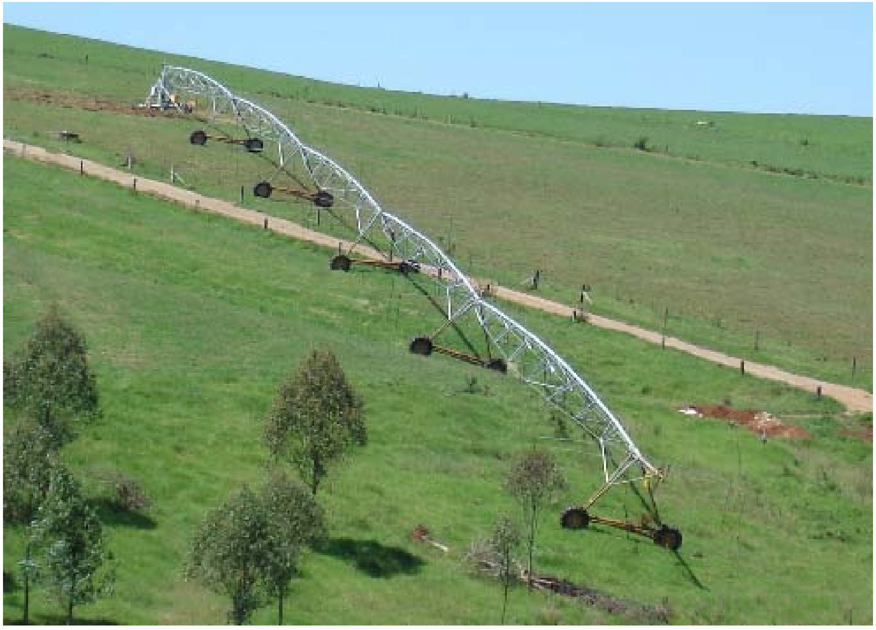


Figure 5.1.9. Rotary Boom Irrigator



Centre pivot & lateral move (WATERpak Chapter 5.5). Centre pivot and Lateral (or Linear) move (CPLM) systems are both a mobile pipeline and a platform for water application devices. A centre pivot is a travelling irrigation line that is fixed at one end and the other end rotates around it. They are often around 400 metres long and commonly have 4 to 12 towers that position the pipeline high above the ground. A centre pivot's main distinction is a fixed centre tower containing a water supply point and power source around which the other spans and towers rotate. A major advantage of centre pivots is that they cover large areas at low operating pressures, thus minimising pumping costs. These systems can operate over undulating country (as shown in figure 5.1.10) as long as pressure regulators are fitted to each sprinkler.

Figure 5.1.10. Centre Pivot irrigation system (Photo: E. Parr)



Lateral move machines are constructed in a manner similar to centre pivots except that they do not have a central fixed supply point. Instead, they have the water supply point located either in the middle (centre-feed) or at one end (end-feed) of the machine on a cart-tower assembly which usually contains a mobile power plant and the pump. Lateral move machines that are supplied from open channels are provided with a large lift pump, while hose-supplied systems are fitted with an attachment point for connection to the water supply pipe line via a hydrant and a flexible water delivery hose. They are commonly 800 to 1000 metres wide with average run lengths greater than 1 kilometre creating an irrigated area of around 165 ha but can be used on areas down to 50 ha or over 300 ha. Lateral Moves require level, rectangular blocks. Run lengths can be several kilometres with separate sections irrigated each season or in rotation.

CPLM machines may be fitted with end-guns to increase the irrigable area for a small extra cost, but careful design is required to ensure acceptable distribution uniformity. End-gun systems typically require on-board booster pumps to provide sufficient nozzle pressure, increasing energy usage.

The direction and speed of CPLM systems is governed by the end towers. With electric machines, the drive points on the intermediate towers start when they get slightly behind and stop when they get slightly ahead. With hydraulic units, the towers are in constant motion but at varying speeds according to oil flow and pressure. The intermediate towers have mechanisms to control the oil flow or pressure, speeding them up when slightly behind and slowing them down when slightly ahead.

Drip irrigation (WATERpak Chapter 5.6). Drip irrigation systems are so named because they use low flow-rate emitters. Above ground drip systems are commonly used in permanent horticulture (vineyards, fruit trees, etc.) while sub-surface drip is installed for pasture or broad acre crops.

Because drip systems apply water at precise rates near or at the root zone, and losses through evaporation runoff or deep drainage are almost nil, irrigation efficiency can be very high.

Drip systems are usually installed permanently so components are not moved to various positions. This means they can be easily automated. Both of these features reduce labour and are often sufficiently appealing in themselves for farmers to choose this system over others, let alone the greater water efficiency and despite the significantly higher cost.

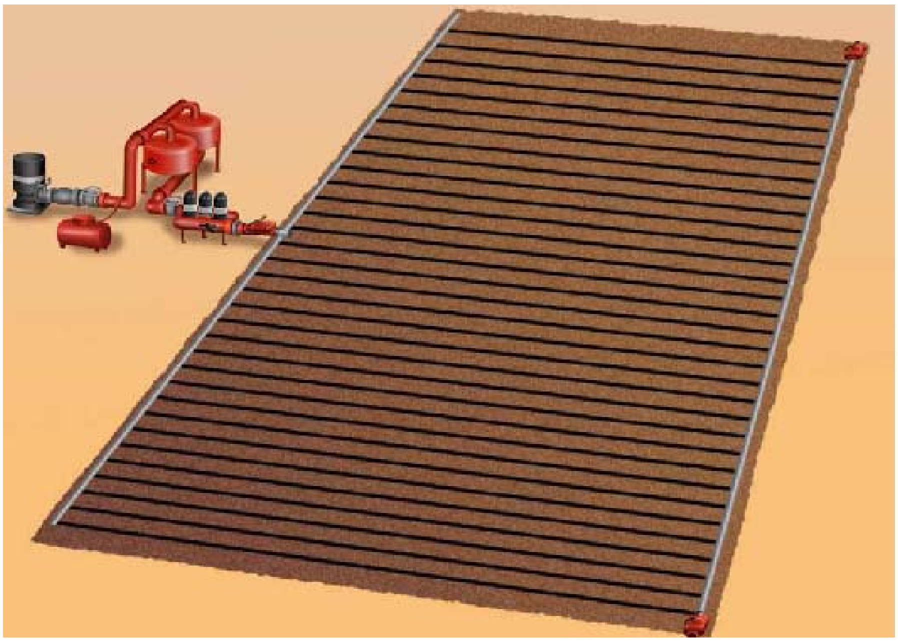
Water filtration is required to remove contaminants and prevent emitters clogging. The equipment required depends on the water quality and may be up to a third of the total cost of the system.

Water delivery to the field is usually achieved through PVC or poly main supply lines and sub-mains. Small diameter plastic lines placed within the crop are called laterals. These are laid parallel to each other and are connected to the sub-mains. The plastic emitters or drippers are typically built into the lines during manufacture, though emitters can be installed afterwards.

For terrain with high slopes, pressure compensating emitters may be necessary to ensure even application.

This animation explains the steps in sub-surface drip irrigation.

Figure 5.1.11. A typical drip layout (Netafim)



Micro-irrigation. These systems are suited to under-tree irrigation and some intensive horticulture enterprises like ornamental flowers and vegetables. Individual emitters are placed adjacent to trees or vines so as to deliver water to the area of the plant rootzone rather than the entire field.

There are two types of emitters: fixed spray head (known as a micro-jet or micro-spray) and small rotating sprinkler (usually called a mini-sprinkler). Micro-jets provide between 20 and 200 litres per hour at operating pressures of 100 to 250 kPa. Their diameter of coverage ranges from 1 to 7 metres. Mini-sprinklers provide up to 600 litres per hour at operating pressures of 150 to 350 kPa. Their diameter of coverage ranges from 2 to 12 metres.

Both types require filtration to avoid blockages due to their small openings and passages. Filter selection is determined by the quality of the water used.

Figure 5.1.12. Micro-spray under a citrus tree

Irrigation System Considerations

Enterprise goals

The goals of enterprises may vary widely. Factors affecting goals can be economic, environmental and social.

- Economic factors may include available capital, cash flow and desired profitability.
- Environmental factors may include biodiversity, vegetation, habitat, soil health, water quality, available water volume, water extraction rate, pollutants and emissions.
- Social factors may include community viability, aesthetic and amenity value or relationships with neighbours.

The following steps do not consider how to set your enterprise goals and assume that your goals remain consistent. It is important that you weigh up each step in light of your goals.

Collect basic information

Selection and design of an effective irrigation system is only as good as the information that goes into it. Time spent carefully considering the intended use of the system and gathering relevant information is essential for a satisfactory result.

The first step is to collect basic farm information.

Physical Location

- current and proposed irrigated areas
- contour lines
- farm and field boundaries
- water source(s)
- earthworks, laser levelling, etc.
- soil types, infiltration rates, problems, etc.
- current agricultural practices
- power lines, roadways, buildings, easements, trees, other features and obstacles

Water Supply

- quantity available, incorporating; the volume of licensed entitlements (river and groundwater), reliability, on-farm storage capacity, overland flow harvest, rainfall, effluent water, etc.
- maximum flow rate
- quality over time
- cost of water

Irrigable Area

- crops intended to be grown, their suitability for the climate, soils, water quality, etc.
- seasonal peak crop water use (peak ETc)
- total irrigation requirements
- maximum depth of water applied per irrigation
- irrigation frequency and cycle
- required irrigation system capacity
- irrigable area to be developed

Topography

The topography is the first factor for deciding whether irrigation is a suitable option. Generally, flat land is best while very steep or highly variable slopes may preclude irrigation.

Surface irrigation requires flat land with small slopes. Flatter slopes are better suited to heavier soil types. Pressurised systems suit a wider range of slopes which can be quite steep.

For furrow, border check and contour layouts the slope should all be in the same direction, otherwise drainage will be a problem.

For centre pivots, slope does not need to be in the same direction. Lateral moves need flat fields or a constant rise or fall in the direction of travel otherwise steering performance will be affected. CPLM systems used to grow row crops must be 'cut to drain' so that rainfall runoff does not run along furrows and pool at low areas. Runoff must have a pathway to escape from crop rows when required.

For surface systems, topography will influence the infiltration opportunity time and thus the uniformity of infiltration. For pressurised systems topography will influence the pressures required to pump the water.

Soils

The soil type(s) and their characteristics are the most important factor in selecting an irrigation system. They have a major impact on whether irrigation is a suitable option in the first place, and they set the main limits on the proposed system.

For surface irrigation, the soil is the main regulator of the water applied to the root zone. The application rate of the system is set by the infiltration rate of the soil. Sandy soils have high infiltration rates. Clay soils usually have low infiltration rates. Loam soils are somewhere in between. Table 5.1.1 shows general infiltration rates of various soil types.

Table 5.1.1. Average infiltration rates for some soil types

Texture group	Application rate (mm/h)		Infiltration rate range (mm/h)
	Average soil structure	Well-structured soil	
Sands	50	-	50 – 700
Sandy loam	30	45	50 – 700
Loam	30	45	5 – 300
Clay loam	10	25	2.5 – 300
Light clay	2.5	5	0.5 – 40
Medium-heavy clay	2.5	5	0.1 – 40

Adapted from Charman, P.E.V. and B. W. Murphy (eds) 2000, Soils: their Properties and Management, in association with the NSW Department of Land and Water Conservation, 2nd ed, Oxford University Press, Melbourne.

Most soils have a somewhat higher infiltration rate when dry, which decreases as the moisture content increases. This is particularly evident with cracking clay soils that are common in most cotton growing areas.. These can have infiltration rates like sand when dry, reducing to very low rates like heavy clay when wet. The degree of this variation is determined by how strongly cracking the clay is; different base minerals and different mixtures of clay, silt and sand create this variation.

Furthermore, variations in soil across the field and below the surface cause variations in the infiltration rate, resulting in variations in the amount of water reaching the root zone.

Surface irrigation is therefore best suited to soils with little variation. The best soils for most surface irrigation systems are deep clays with strong self-mulching and cracking characteristics.

Pressurised irrigation is better for soils with higher infiltration rates and/or fields with a lot of soil variation. The application rate of the irrigation system should be designed to match the infiltration rate of the soil, taking into account the initial and steady-state infiltration rates. For systems that apply water for a short amount of time (e.g., CPLM), the initial rate is most relevant, while for systems that apply water for several hours, the steady-state rate is most relevant.

Crop Water Requirements and System Capacity

Your irrigation system must be designed to meet the maximum or peak water requirements of your crop. For winter crops the peak water requirement will usually be in spring when the crop is flowering. For summer crops it will usually be in the hottest period of the summer.

The amount of water a crop requires is dependent upon:

- Crop type and variety
- Yield goal – generally higher yielding crops will have higher water requirements
- Weather conditions (temperature, solar radiation, wind speed, humidity, rainfall)

For a particular crop and yield goal, the weather is the key factor. Crop water requirements are covered in more detail in WATERpak chapter 3.2 (cotton), WATERpak Section 4 (grains) and WATERpak chapter 5.5 (for CPLM systems).

System Capacity

For an irrigation system to work effectively it must have the capacity to supply water to the crop during the peak periods. 'System Capacity' is a measure of the ability of a system to meet these requirements. It is usually expressed as millimetres per day.

All irrigation systems should be designed to have a minimum capacity equal to the daily peak potential crop water requirement. If it is a multi-crop system, the design should be based on the crop with the highest peak water use. The 'Design' System Capacity is determined from two factors; the mean daily flow of water, and the irrigated area used in the design. It assumes the system can be operated 24 hours a day, 7 days a week in peak water use periods.

$$\text{System Capacity (mm/day)} = \frac{\text{Average daily pump flow rate (L/day)}}{\text{Area Irrigated (m}^2\text{)}}$$

Generally surface systems have ample system capacity and it is rarely a limitation to crop performance. This is because water is supplied in ample amounts at relatively infrequent intervals (e.g., 1 to 3 weeks). The limitation to having enough water available for the crop is the infiltration rate of the soil and the system should be designed to suit this. However, system capacity may be inadequate where water is being sourced from an irrigation scheme or trust where there is prescribed time or rate limitations for extraction, where water is being sourced directly from a low yielding bore, or where supply channel capacities are inadequate.

Pressurised systems have their capacity limited more commonly by the infrastructure; the capacity of the pump, the main supply lines and the field supply pipes. It is easier to end up with a pressurised system of insufficient capacity when compared with surface systems, because it is cheaper to buy and install lower capacity components in pressurised systems but the effect is not obvious until too late.

Insufficient system capacity means the crop may suffer yield and/or quality loss due to inadequate water availability. This may be apparent steadily over time or quite quickly.

Making changes to your irrigation system, such as increasing the irrigated area, diverting some supply flow to something else, or if the supply rate decreases for some reason, your System Capacity is lowered and the risk of suffering loss is increased.

In practice, the risk of crop losses is also increased because most irrigation systems cannot be reliably operated 24 hours a day, 7 days a week, and there are usually some losses of water between the supply point and the field. This is due to things such as:

- The availability and/or flow rate of supply water
- Leaks or seepage out of the system
- Runoff or movement of water off the field
- The number of hours per day that the system can be run
- Time required for shifting the system
- Labour availability and/or skill
- System down time for maintenance, break downs, etc.

These factors are taken into account to give what is termed the **Managed System Capacity** which is the effective or actual system capacity needed to match peak irrigation requirements. The Managed System Capacity is always lower than the

Design System Capacity, and it is this figure that should be equal to the peak crop water demand.

As application efficiency (E_a) takes account of water losses within a system, the managed system capacity can be determined by defining the proportion of system irrigation time as the Pumping Utilisation Ratio (PUR) and calculating thusly:

Managed System Capacity (mm/day) = Design System Capacity (mm/day) x E_a (%) x PUR (%)

As system capacity is a critical consideration for CPLM machines, further explanation is included in WATERpak Chapter 5.5.

Your decision of which system to select will be a balance between budget constraints and the level of risk that you are willing to accept. The key is to ensure that you don't simply opt for a cheaper quote and end up with an under-designed system; it is important to buy value, not cheapness.

Energy and labour requirements

With surface irrigation, little or no energy is required to distribute the water throughout the field, but some energy may be expended in bringing the water to the field, especially when pumped from groundwater. In some instances these energy costs may be substantial, particularly when application efficiency is low. Some energy cost will be incurred for land grading, preparation and field maintenance.

For pressurised systems, energy consumption is primarily determined by the operating pressure of the system, which varies considerably between systems. At the extremes, the Low Energy Precision Application (LEPA) emitters on lateral move and centre pivot systems may require only around 70 kPa (10 psi), while big-gun travelling systems may require 700 kPa (100 psi) or more. Other systems generally operate around 200 to 400 kPa (30 to 60 psi), depending on design of the sprinklers and the nozzles chosen.

Drip irrigation emitters require pressures ranging from 35 to 170 kPa (5 to 25 psi) but additional pressure is required to compensate for losses through the control gear (filters and control valves) and the pipe network. System pressures range from about 200 kPa (small systems on flat terrain) to 400 kPa (larger systems on undulating terrain).

Labour requirements for centre pivot, lateral move and drip systems are usually significantly less than other systems in terms of man-hours but these systems require more skills for efficient and reliable management.

Contour (or basin) irrigation involves the least labour of the surface methods, particularly if the system is automated. Border and furrow systems may also be automated to some degree to reduce labour requirements and pipe through the bank (PTB) systems have been used by some growers (WATERpak Chapter 5.3). The complicated "art" of border irrigation (and to a lesser extent furrow irrigation) requires skilled operators if high efficiencies are to be achieved. The setting of siphons or slide openings to obtain the desired flow rate is a required skill, but one that can be learned. The labour skill needed for setting border or furrow flows can be decreased by using higher cost equipment.

Selection of a system

Consideration of the factors above will narrow the options of irrigation systems to those suitable for you. Table 5.1.2 demonstrates the complexity that can be associated with selecting an irrigation system and is included to provide a quick reference guide to help with this process.

Once you have settled on your options, the next steps require more detailed investigation considering your own lifestyle and management preferences, management capability of the irrigation operators, labour requirements, financial and economic constraints, and how the irrigation system will integrate with operation of the rest of the farm.

It is worthwhile consulting an irrigation adviser to help with working through this process, and once you have made your selection, in order to have efficient system that will operate well for the long term, it is essential to engage a competent irrigation designer.

A calculator is available on the NSW DPI web site to help determine if a change of system is economically viable.

Table 5.1.2. Various factors to be considered when selecting irrigation systems

	OWNERSHIP	WATER SUPPLY	DRAINAGE	WATER SALINITY	WATER SEDIMENT	MAX. SLOPE	WIND EFFECTS	CROP HEIGHT	PHYSICAL LIMITS	BLOCK SHAPE	SOIL TYPE	CROP TYPE	FROST CONTROL	LABOUR INPUT
PERMANENT SOLID SET	Owner operator	Less frequent, long application irrigation can be full cover	Minimal if irrigation system designed and managed correctly. Important for row crops planted on hills or beds.	Leaf burn possible with sensitive crops. Night time irrigations an alternative. LEPA may be used on CPLM to avoid foliage contact.	Minor filtration necessary only. Some nozzle types prone to wear.	Unlimited	Prone to poor distribution in windy conditions	Limited to riser height	No limit	Any	Heavy soils prone to runoff if application rate exceeds infiltration rate.	All crop types	Yes	Low
PORTABLE SOLID SET (HAND MOVE)	Well suited to leased situations as system can be readily moved					Unlimited						Highly suited to annual crops		Medium to high
CENTRE PIVOT		Frequent, short applications required due to high application rate				20%	Adequate with the use of drop tubes	Limited to span height	Must be clear of obstructions with path for towers	Circular (square or irregular possible)			No	Low
LATERAL MOVE						5%				Square or rectangular				Low to med
UNDER CANOPY SPRINKLER	Owner operator	Less frequent application needed as full cover irrigation is possible		Foliage contact can be avoided if angle of throw low enough	Reasonable filtration necessary. Plastic nozzles prone to wear.		Some, but less than solid set systems	Unlimited. Minimum canopy height of greater concern.	None	Any		Permanent plantings	Some	Low
SURFACE DRIP	Generally permanent for perennial plantings. Could be leased if above ground system.	Frequent water application needed as generally 1/3 of profile is wetted		Foliage contact avoided. Higher salt levels tolerated when well managed.	High degree of filtration necessary to avoid blockages	Unlimited. PC and ND emitters advisable.	Unaffected by wind	Unlimited				Perennial or annual crops	No	Low
SUB SURFACE DRIP	Owner operator										Heavier soils give better transverse movement.			Low
BORDER CHECK	Owner operator	Least frequent water application required	Drainage required. Re-use possible.	Foliage contact avoided. Water logging can reduce plant's salinity tolerance and damage soil structure	Filtration not needed	0.1% Landforming required				Square or rectangular preferred	Unsuitable for light soils due to excessive drainage. Clay soils with low infiltration rates are generally best.		Some	Medium
FURROW	Owner operator				Filtration not needed	0.1% Landforming required								High

Further information

FAO (2001) 'Irrigation Manual Planning, Development Monitoring and Evaluation of Irrigated Agriculture with Farmer Participation Volume III, Module 8: Sprinkler Irrigation Systems - Planning, Design, Operation and Maintenance' Harare, 2001

Burt C.M. et al (1999) 'Selection of Irrigation Methods for Agriculture', ASCE, Virginia

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Management' in association with the NSW Department of Land and Water Conservation, 2nd ed, Oxford University Press, Melbourne.

North, S. (2008) 'A review of Basin (Contour) Irrigation Systems I: Current design and management practices in the Southern Murray-Darling Basin, Australia' CRC for Irrigation Futures

NSW Department of Primary Industries (2008) 'Water Efficiency Technologies Module 2: Irrigation System Evaluation – Pressurised Systems Course Notes' NSW

Resources

Victoria DPI Irrigation System Selection and Design Guidelines

NCEA 'EconCalc' decision support tool used to economically evaluate the costs and benefits associated with a new irrigation system