Evaluating your pressurised system: introduction

These materials were developed by NSW Agriculture staff from the water management program.

CONTENTS

INTRODUCTION

The aim of the *Introduction to Irrigation Management* course is to give you the skills to manage your irrigation system more effectively and to improve your water use efficiency.

In this workshop you will evaluate the uniformity and application rate of a pressurised irrigation system.

With the skills you learn you will be able to perform these tests on your own system, and identify if changes to equipment, or how you operate it, are required to improve your irrigation efficiency.

In the scheduling workshop you learn when to irrigate and how much is required, but to use scheduling effectively you must know that your application rate is correct and water is distributed evenly.

Learning outcomes

On completion of this workshop you will be able to:

1 identify the importance of irrigation efficiency

2 measure and record how evenly your irrigation system applies water

3 discuss how the evenness of application interacts with soil infiltration rates

'I learnt about measuring soil moisture requirements and the distribution uniformity percentage (DU%) of my system.

'Previously we had irrigated on a gut feeling: now we are a lot more precise, and, from our newly acquired knowledge on pressure requirements and DU%, we have plans to improve our irrigation system.'

A well-designed, maintained and operated system uniformly delivers the correct amount of water to the crop, at the correct time, with the minimum of losses.

To achieve these outcomes, the workshop activities include:

- discussing irrigation efficiency
- using a checklist to assess your system's efficiency
- interpreting technical data and making comparisons between emitters { NOTE: emitters are sprinklers, drippers, micro and mini-jets, and so on. We use the term 'sprinkler/emitter' in these notes.}*
- measuring the evenness of application of an operating irrigation system
- measuring pressure and flow at various locations in the system
- calculating the uniformity (evenness) of application
- calculating how much water is being applied by the system

Program

	Approximate time in minutes
Revision of soils workshop	60
Scene setting for today's program	10
Irrigation efficiency	30
Calculating MAR and DU using example data	60
Irrigation system measurements and calculations using worksheets	120
Infiltration rates	20
Summary of the day Instructions for scheduling workshop	10
	5 h (+ breaks)

Assessment

Assessment for this workshop is by participation and in completing the workbook activities. These activities are designed to give you experience in measuring and calculating the figures needed to determine your system's mean application rate and distribution uniformity.

HOW EFFICIENT IS YOUR PRESSURISED SYSTEM?

Start by taking a few minutes to answer these questions:

Does your irrigation system:

	YES	NO	DON'T KNOW
Deliver water at a rate that is less than the infiltration rate of the soil?			
Have the capacity to apply enough water to meet peak crop requirements without waterlogging?			
Run for the right amount of time to deliver the amount of water needed by the crop?			
Apply water evenly to the required area of the root zone, or across the paddock?			
Use the emitters (the sprinklers or drippers) that the design and crop requires?			
Use an efficiently operating pump (one that is operating with correct suction and delivery pressures, no blockages, and at the most efficient point on the pump performance curve)?			
Operate within specific design parameters? (That is, was it designed, or just put together?)			
Operate efficiently within the physical and topographic conditions of the area (for example, rock, slope, trees, power poles, water quality)?			
Match the overall management and labour constraints of the farming enterprise?			

This workshop aims to give you the skills to be able to assess an aspect of your system efficiency.

The aim of efficient irrigation

The aim of efficient irrigated agriculture is to get maximum production for the same or less input: for example, growing more crop with the same or less amount of water.

One measure of efficiency relates product to unit of water applied, for example, tonnes of product per megalitre of water applied. (This is **water use efficiency**: it combines system, crop and agronomic aspects.)

Irrigation efficiency is the percentage of water that actually gets into the soil and is used by the crop, compared with the amount pumped into the system.

In an efficiently operating, well-designed and well-managed pressurised sprinkler system, nearly all the water supplied will be used by the plant.

Avoiding waste

Over-irrigating or irrigating inefficiently not only wastes water but also money and adversely affects the environment: consider the cost of unnecessary pumping and or nutrient wastage (particularly with fertigation, applying fertiliser with the water).

Water is lost through run-off, deep drainage and evaporation (both direct evaporation from foliage and the soil surface) Evaporative losses are less with drip systems. losses occur typically through over-watering, system leakage or system drainage.

If the irrigation system used on a property is appropriate for the soil type and crop, and is installed and maintained correctly, it can apply the correct amount of water to the crop without excessive losses.

Applying water evenly

If losses are low, and the volume of water flowing through the sprinkler nozzle is correct, the system can still be inefficient if the water is not applied evenly where it is needed. If the application is not even or uniform, some areas will get over-watered while some won't get enough.

There are many ways of assessing the efficiency of the components of an irrigation system, but in this workshop we are concerned with only one method, measuring the rate and uniformity of water application. (We assume that the pump, pipelines, valves, supply and other associated components are all working at their best.

To determine the evenness of application, we:

- measure the pressure and flow at various points in the system and compare this to the manufacturer's data
- calculate the mean application rate (MAR) and compare this to the soil infiltration rate to make sure it is acceptable
- calculate the evenness of application at various points in the system (that is, the distribution uniformity, DU)

PRESSURES AND FLOWS

Incorrect pressures and flow rates are common causes of system inefficiency. If pressure is restricted then the flow will be reduced. Operating pressure can dramatically affect the sprinkler/emitter pattern and output, and therefore the evenness of application.

A variation in pressure between sprinklers/emitters of more than +/-10% is an indication that the system is not operating efficiently. Pressure compensating sprinklers/emitters are used in many systems to maintain the flow rate across a wide range of pressures along the sprayline or due to differing positions in the paddock of travelling systems.

Similarly, a flow variation of greater than ± 5% is unacceptable.

Reasons for pressure and flow variations include:

- wear and blockages in sprinklers/emitters
- system not designed correctly
- system not being used as designed
- system leakages
- pump not performing. (The pump may be worn or not being operated at best efficiency.)

When evaluating your system you must measure pressures and flows and compare these to the pump and sprinkler/emitter specifications. In table 2 you can compare some typical sprinkler/emitter pressures and flows.

Table 2. Common operating pressures and flows of various irrigation systems

Sprinkler/emitter type	Pressure range	Flow rate range
	(kPa)	(L/h)
Dripper	90–110	1.2–8
Micro-jet	100–150	25–200
Mini-sprinkler	130–200	35–350
Low-throw impact sprinkler	180–300	300–1200
Overhead impact sprinkler	240–400	700–3000
Centre pivot	100–400	100 000–200 000

It is important to run your system at the designed pressure. If a sprinkler/emitter is operated below its correct pressure, large droplets tend to be thrown further than small droplets, resulting in a 'doughnut ring' shaped output. If pressure is too high, more water falls close to the sprinkler/emitter, or fine droplets are caused, creating a fine mist, and excessive wind drift and evaporation.

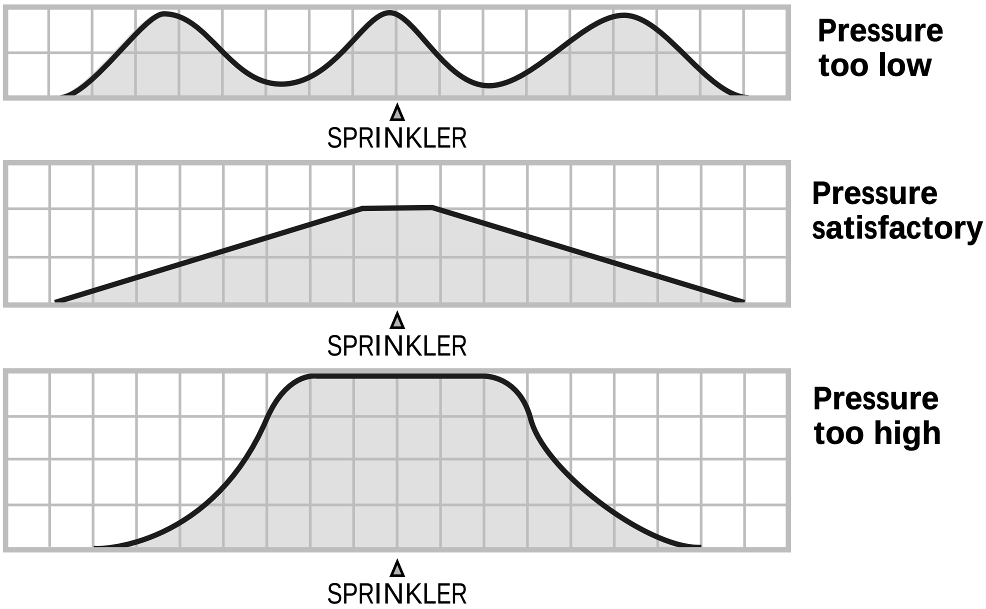
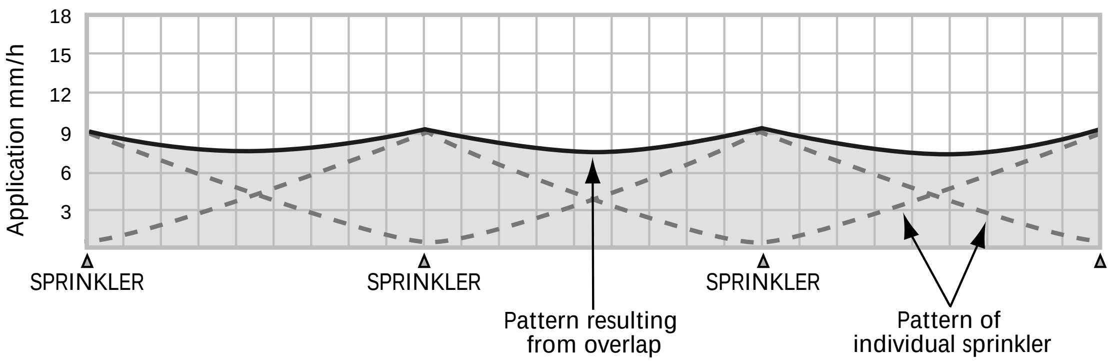


Figure 2 overlap pattern from several sprinklers



EVENNESS OF APPLICATION

The aim of a sprinkler system is to evenly apply water to the application area, while with drippers it is important to apply the water evenly at each point.

Even distribution of water is important. If your system distributes water unevenly, some areas may be over-watered while others are under-watered. This is inefficient.

A common tactic to compensate for uneven watering is to apply the water for longer. While this may mean that all areas get sufficient water (thus increasing yield) there may also be penalties from over-watering:

- increased water use
- increased pumping costs
- excessive run-off and losses to deep drainage
- reduction in the area that can be irrigated
- decrease in yield due to waterlogging roots.

Wetting patterns for sprinklers

Actual application rates over a wetted area often vary greatly. To illustrate this, look at the following typical sprinkler patterns.

Note: The numbers on these charts represent the water falling at that point in millimetres per hour.

Figure 2. Water distribution pattern from a single sprinkler, at 200 kPa (left) and 350 kPa (right).

Each number in the pattern represents the application rate in mm/hour at that point.

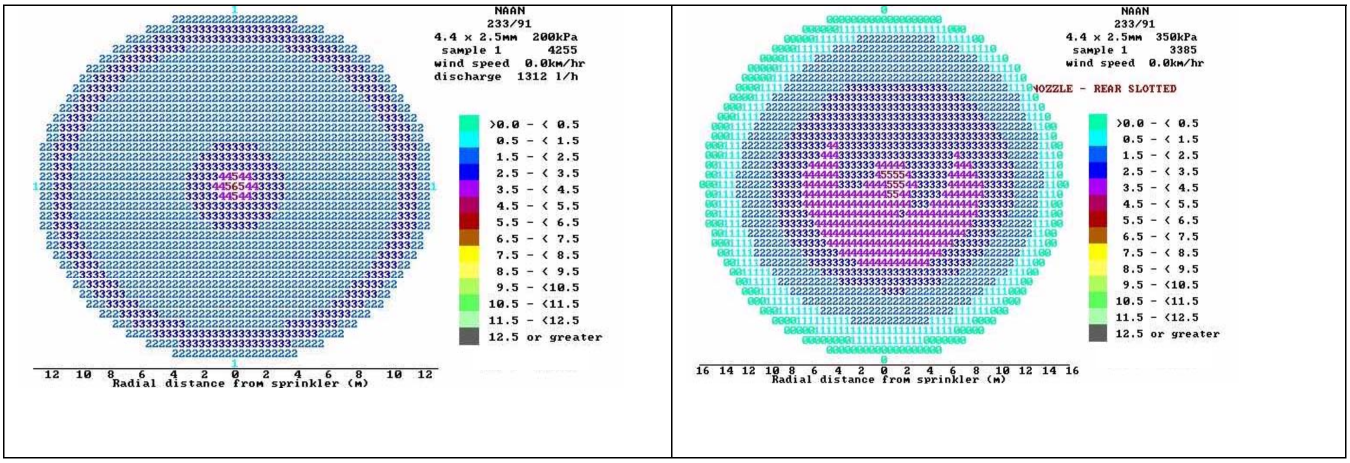


Figure 3. Water distribution profiles at increasing distance from the sprinkler

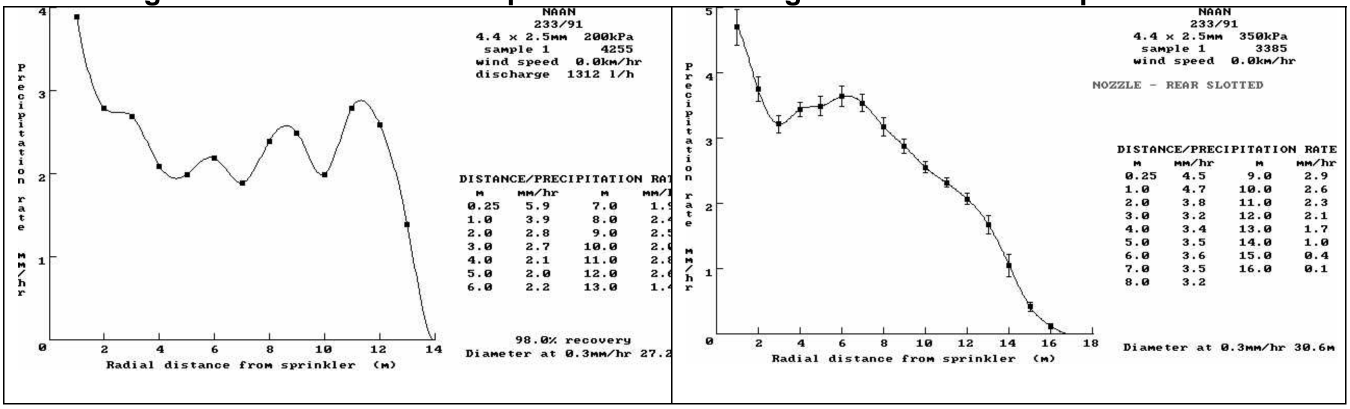
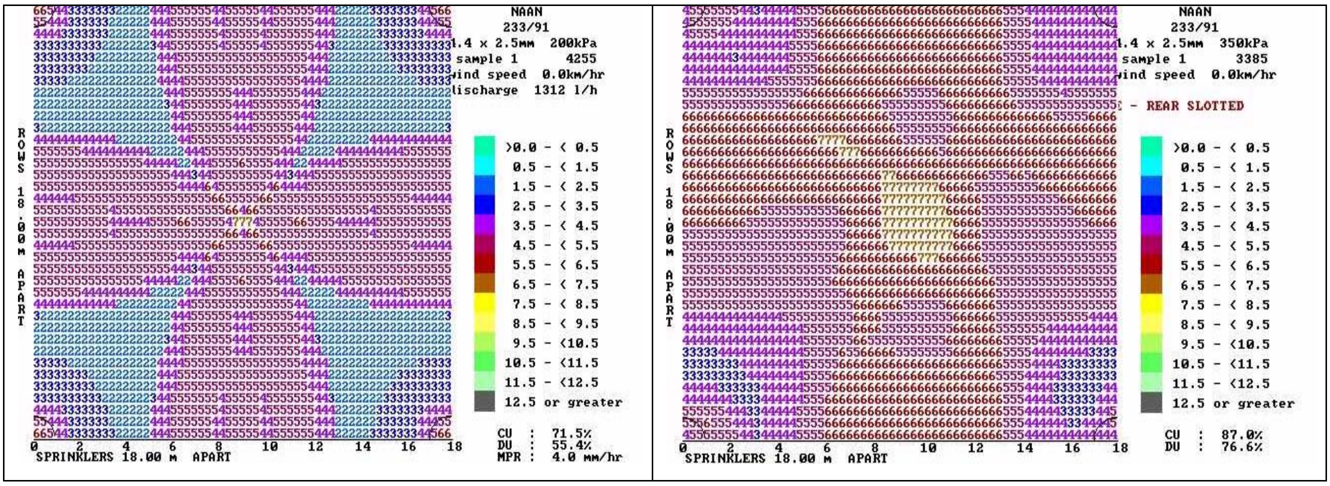


Figure 4. Water distribution pattern with overlapping sprinklers

There is a sprinkler at each corner of the chart. Each number in the pattern represents the application rate in mm/h at that point.



[Figure 4 uses the term MPR (mean precipitation rate) instead of our term MAR.]

Two terms are used to describe the uniformity of application rate and the uniformity of coverage of sprinklers and emitters: these are mean application rate (MAR) and distribution uniformity (DU). When you are able to calculate these for your own system you will be able to evaluate how effectively it is operating.

Mean application rate (MAR)

The mean application rate (MAR) is the average rate (in mm/h) that water is applied to the wetted area of the soil. It is very important that the MAR does not exceed the **infiltration rate** for the soil, otherwise run-off will result.

(With travelling systems the situation is different because the machine moves over the field. In this case it is the instantaneous application rate (not the MAR) that must not exceed the long-term infiltration rate of the soil. Increasing travel speed does ***not*** reduce the instantaneous application rate. Less water is applied (less RAW is replaced) but you may be just filling the cracks between the soil. This is a common occurrence with travellers.)

Distribution uniformity (DU)

The DU, often expressed as a percentage, gives an indication of how evenly your sprinklers/emitters are operating or overlapping.

The higher the DU, the more evenly your water is being distributed. A DU greater than 75% is acceptable for sprinkler systems. New drip systems should have a DU of 95%, while in older drip systems a DU of 85% is acceptable.

DU is affected by pressure variations, sprinkler/emitter wear, and, with overlapping systems, the sprinkler/emitter position. Incorrect spacing of sprinklers in both fixed and travelling systems will result in a low DU.

EVALUATING YOUR SYSTEM

By evaluating your irrigation system you can tell whether it is causing or contributing to any of the problems mentioned earlier. Depending on your exact system and layout, the evaluation procedure will vary. (The worksheets cover evaluation methods in more detail.)

In general there are four steps.

Step 1: Check components

Before you take any measurements, you should conduct a general physical check of all components and make sure the system is operating as correctly as possible. This means checking that there are no leaks or suction problems, and that the number of outlets operating, their size and their pressure match the system design.

Step 2: Measure pressure and flow

If possible you should have the original design figures for the system available. As a minimum you should have the pressure and flow charts for the sprinklers/emitters.

Check pressures and flows at various points within each block and across the whole system. After taking the readings, make any adjustments needed before continuing.

You may find the output and distribution of a system is correct at one point, and not at another. This could be because:

- a different supply main or hydrant is being used (end or high point versus start and low point)
- a hydrant is not set correctly (these can be adjusted to adjust pressure), or
- other sections are being irrigated.

Make sure all testing is done with the system operating in its normal configuration.

Measuring across a whole shift and within a block

One way to check pressures and flow for any system, including drip, is to measure at the ‘near’, ‘far’, ‘high’ and ‘low’ points of the complete system.

After that, each individual block or section should be tested.

With travelling systems, it is important to check the pressure when the traveller is at high and low points.

Step 3: Measuring mean application rate (MAR)

To measure MAR, catch cans are placed in the irrigated area and the amount of water (mL) collected is measured, converted to a depth in mm, and then divided by the number of cans to give a MAR in mm/h.

MAR = total depth (mm) collected in catch cans per hour ÷ no. of catch cans

For drip systems, the procedure varies slightly. The output from a dripper is collected over a measured time, and the amount collected divided by the wetted area.

Dripper MAR = volume collected from the dripper ÷ average wetted area

The result then needs to be converted to an hourly basis.

If the MAR exceeds the infiltration rate of the soil (or half the infiltration rate, with some overlapping sprayline systems), you should make adjustments to reduce the MAR. This is further explained in the worksheets.

Remember it is the instantaneous application rate (rather than the MAR) that must not be exceeded with travelling irrigators.

Step 4: Measuring distribution uniformity (DU)

Distribution uniformity (DU) was defined earlier. When all the volumes have been converted to depths, the lowest 25% are selected. The average of the lowest 25% is divided by the MAR to give the DU figure.

DU = Average depth of lowest 25% of cans ÷ MAR

(For drippers use the volumes of the lowest 25% of the drippers being checked.)

Comparing systems by MAR and DU

To see how distribution uniformity affects water usage, we'll compare the effect of a particular irrigation system operating at two different pressures: 200 kPa, and then 350 kPa. The example system is a bike-shift system operating on 33 hectares of perennial ryegrass and clover pasture.

System details

Sprinklers – Naan 233/91 – 4.4 mm x 2.5 mm jets, spacing 18 m x 18 m with each of 126 sprinklers having 9 shift positions.

This system requires each sprinkler to be moved twice per day for an irrigation interval of 4.5 days in times of peak demand.

	System 1	*System 2*
Operating pressure	200 kPa	350 kPa
Flow rate	1312 L/h	1670 L/h
Mean application rate (MAR)	4 mm/h	5.2 mm/h
Distribution uniformity (DU)	55.4% (0.554)	76.6% (0.766)
Time to apply (say) 20 mm: = application depth ÷ MAR ÷ DU	 = 20 x 4 x 0.554 = 9 hours	 = 20 x 5.2 x 0.766 = 5 hours
Pump flow required: = no. of sprinklers x flow rate	 = 126 x 1312 = 165,312 L/h	 = 126 x 1670 = 210,420 L/h (Note the higher flow rate required.)

	System 1	*System 2*
Total volume per application: = pump flow x time/shift x shifts	= 165,312 x 9 x 9 = 13,390,272 L = 13.39 ML	= 210,420 x 5 x 9 = 9,468,900 L = 9.47 ML
If there are 18 irrigations over the 33 hectares per season, then the yotal water use:	= 13.39 ML x 18 = 241 ML or 7.3 ML/ha	= 9.47 ML x 18 = 170 ML or 5.2 ML/ha

You can see that the system operating at the higher pressure and flow is applying 71 ML less every year. The higher water use of System 1 is the result of its poor (low) distribution uniformity. System 1 uses a lower pressure and flow rate, but takes almost double the time to achieve an irrigation of 20 mm over the area.

Having a higher DU results in savings of water and time. Pumping costs are also reduced - however, higher pressures may not always be the solution. An alternative sprinkler may provide the best option.

Always make sure that the MAR does not exceed the infiltration rate of the soil.

CONCLUSION

When you have completed the evaluation exercises you will know how to measure the pressures and flows within a system and determine the mean application rate and distribution uniformity of a pressurised irrigation system.

You should now work through an evaluation of a system as outlined in the worksheets.

APPENDICES

Mini/micro sprinkler performance chart

Sprinkler colour	Nozzle size (mm)	Pressure (kPa)	Diameter (m)	Flow rate (L/hr)
Black	1.0	100 150	5.4 6.3	29 35
White	1.3	100 150	6.0 7.2	46 56
Green	1.6	100 150	7.1 8.3	72 87
Blue	2.0	100 150 200	7.4 8.6 9.1	104 126 147
Yellow	2.4	100 150 200	8.2 9.6 10.3	140 183 211
Red	2.8	100 150 200	8.3 9.8 10.5	192 240 276

Medium pressure rotating sprinkler performance

Colour	Grey		Green		Orange		Yellow		Blue		Red		Maroon	
Size (mm)	**4.4**		**4.9**		**5.4**		**6.1**		**6.6**		**7.1**		**7.6**	
kPa	Dia. (m)	L/m	Dia. (m)	L/m	Dia. (m)	L/m	Dia. (m)	L/m	Dia. (m)	L/m	Dia. (m)	L/m	Dia. (m)	L/m
200	26.0	17.9	26.3	20.9	25.8	24.2	27.7	30.2	29.2	35.1	28.0	37.8	30.0	43.0
250	26.6	20.1	26.4	23.4	28.2	27.3	28.1	33.9	30.8	39.0	32.0	42.9	31.5	48.1
300	27.1	22.0	29.3	25.8	30.0	30.0	30.0	36.9	32.0	42.5	32.0	47.0	32.4	52.5
350	27.6	23.8	30.0	27.8	30.0	32.4	30.6	39.9	33.7	46.0	33.9	50.8	34.6	56.7
400	28.5	25.4	30.0	29.9	30.3	34.5	30.7	42.6	34.4	49.0	34.1	54.3	35.9	60.7

Jet	4.4 x 3		5.4 x 3		4.9 x 5		6.1 x 3		7.1 x 3		6.6 x 5		7.1 x 5		7.6 x 5	
kPa	Dia. (m)	L/m	Dia. (m)	L/m	Dia. (m)	L/m	Dia. (m)	L/m	Dia. (m)	L/m	Dia. (m)	L/m	Dia. (m)	L/m	Dia. (m)	L/m
200	25.1	24.8	27.6	30.9	24.4	32.1	26.1	36.5	26.7	43.8	26.1	43.9	25.8	46.9	26.2	50.2
250	26.4	28.1	28.2	34.9	27.0	36.0	27.7	40.7	29.4	48.9	28.1	48.9	28.6	52.6	28.8	56.2
300	27.4	30.8	29.3	38.3	27.6	39.7	28.8	44.8	30.6	53.7	29.7	53.2	30.6	57.7	30.5	61.4
350	28.3	33.2	30.3	41.4	28.7	42.8	29.6	48.1	31.7	58.4	30.6	57.8	30.7	62.5	31.8	66.5
400	28.2	35.4	30.5	44.1	29.0	45.4	30.2	51.8	33.3	62.3	31.7	61.5	31.7	66.7	33.5	73.4

Sprayline discharge and application rates

Spacing	Min. dia.	Application rate (mm/hour)			
	of coverage	7 mm	8 mm	9 mm	10 mm
metres	metres	Sprinkler output (L/min)			
14.6 x 7.3	22.7 m	12.5	14.3	16.1	17.8
14.6 x 9.1	22.7 m	15.6	17.8	20.1	22.3
14.6 x 14.6	26.9 m	25.0	28.5	33.2	35.7
18.2 x 9.1	28.3 m	19.5	22.3	25.1	27.9
18.2 x 12.2	26.8 m	26.0	29.7	33.4	37.2
18.2 x 14.6	30.4 m	31.2	35.7	40.1	44.6
21.9 x 14.6	34.3 m	37.5	42.8	48.2	53.5
27.3 x 18.2	42.9 m	58.5	66.9	75.3	83.6

Performance data for travelling irrigators

Sprinkler	Nozzle size	Sprinkler pressure	Output rate	Wetted width	Approx. lane spacing	Average Precipitation rate (Full Circle)	400 metre run				
							Approx. area per run	Gross application			
								7.5 hour run	11 hour run	22 hour run	44 hour run
	mm	kPa	L/sec	m	m	mm/hr	ha	mm	mm	mm	mm
NELSON	32.0	482	18.65	104	62	7.9	2.5	20.3	29.8	59.6	119.1
		551	19.86	106	64	8.1	2.6	21.0	30.7	61.4	122.9
P150R	34.0	482	22.44	108	65	8.8	2.6	23.7	34.2	68.4	136.7
		551	24.03	112	67	8.8	2.7	24.2	35.5	71.0	142.0
21^{o}	35.8	482	26.23	112	67	9.6	2.7	26.4	38.8	77.5	155.0
		551	28.13	117	70	9.4	2.8	27.1	39.8	79.6	159.1
	32.8	551	18.35	107	64	7.3	2.6	19.4	28.4	56.8	113.5
		620	19.56	110	66	7.4	2.6	20.0	29.3	58.7	117.4
NELSON	37.1	551	24.03	116	70	8.2	2.8	23.2	34.0	68.0	135.9
		620	25.55	120	72	8.1	2.9	24.0	35.1	70.3	140.5
P200R	39.6	551	28.13	122	73	8.7	2.9	26.0	38.1	76.3	152.6
		620	30.03	126	76	8.7	3.0	26.7	39.1	78.2	156.5
21^{o}	42.2	551	32.53	127	76	9.2	3.0	28.9	42.4	84.7	169.5
		620	34.42	132	79	9.0	3.2	29.4	43.1	86.3	172.5