Measured Irrigation Manual

A major advance in drip irrigation

Dr Bernie Omodei & Sophie Thomson celebrate the successful installation
of measured irrigation at Sophie's Patch at Mount Barker

Measured irrigation is a radical departure from the current drip irrigation scheduling paradigm and the implications for water-efficiency and energy-efficiency are significant.

Measured irrigation is a drip irrigation scheduling method that satisfies the following two conditions:

1. Variations in the water usage throughout the year are controlled by the prevailing net evaporation rate (evaporation minus rainfall).
2. The volume of water emitted by each dripper during an irrigation event is controlled directly without the need to control the flow rate or the duration of the irrigation event.

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~~February~~ August 2019

Contact Bernie Omodei or go to the website for further information or to place an order.

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Chapter 1. Introduction to measured irrigation

1.1 Introduction

Conventional drip irrigation systems use a timer or controller to control the opening and closing of valves in order to control the duration of the irrigation event and the frequency of irrigation. The volume of water emitted by a dripper during the irrigation event is controlled by using drippers with a specified flow rate and controlling the duration of the irrigation event. The acceptance of this drip irrigation scheduling paradigm has led to the development of pressure compensating drippers whereby the flow rate from the dripper is relatively constant for a range of water pressures. Measured irrigation uses a totally different paradigm for controlling the volume of water emitted by a dripper during the irrigation event.

Definition of measured irrigation

Measured irrigation is a drip irrigation scheduling method that satisfies the following two conditions:

- *Variations in the water usage throughout the year are controlled by the prevailing net evaporation rate (evaporation minus rainfall).*
- *The volume of water emitted by each dripper during an irrigation event is controlled directly without the need to control the flow rate or the duration of the irrigation event.*

Note that the term **water usage** refers to the number of litres per week (or litres per month) used by the irrigation system.

Note that the flow rate and the duration of the irrigation event adjust automatically to ensure that the required volume of water is delivered by each dripper. As the water pressure increases, the flow rate increases. However with measured irrigation, there is a corresponding decrease in the duration of the irrigation event to ensure that volume of water emitted by a dripper does not change.

The conventional volume control paradigm requires the control of two variables, namely, flow rate and time. Measured irrigation requires the control of a single variable, namely, volume. Once the focus of attention changes from flow rate and time to volume, then the design of drip irrigation systems may change significantly.

Measured irrigation is a radical departure from the conventional drip irrigation scheduling paradigm and the implications for water-efficiency and energy-efficiency are significant. Measured irrigation is a new approach to drip irrigation rather than a new irrigation technology. Existing drip irrigation installations may be upgraded to measured irrigation. However, to maximise water-efficiency and energy-efficiency for an irrigation application, it is preferable that the measured irrigation implementation is designed from scratch.

Conventional pressurised drip irrigation systems usually use pressure compensating drippers designed to operate within the pressure range 100 kPa to 300 kPa. A gravity feed drip irrigation system that directly controls the volume of water emitted by the drippers during the irrigation event is a potential threat to multinational irrigation companies that have billions of dollars invested in pressurised irrigation technology

Gravity feed measured irrigation is well suited to smallholders in poorer countries where access to mains power and mains water is unavailable, unreliable or too expensive. In remote locations where mains power and mains water are unavailable, gravity feed measured irrigation can provide an automated irrigation system that delivers a measured volume of water to each plant.

Irrigation zones

An irrigation application is often subdivided into zones, whereby the irrigation in any zone is independent of the irrigation in the other zones. For pressurised irrigation the flow rate from the water supply is often insufficient to allow all plants to be irrigated at the same time. Hence for a pressurised irrigation application zones are needed and each zone is irrigated at a different time.

For gravity feed irrigation the flow rate from the drippers is sensitive to changes in ground level. Hence on uneven or sloping ground it is often important to subdivide the gravity feed irrigation application into a number of zones whereby all the drippers in a zone are at approximately the same level.

1.2 Pressurised drip irrigation versus gravity feed measured irrigation

Think twice before you buy a pump for your rainwater tank.

Suppose you walk into your local irrigation supplier and say that you would like to irrigate your garden using a rainwater tank. One of the first issues raised will the choice a suitable pump.

The downside of pressurised drip irrigation is the cost and maintenance. A pressurised system needs to be checked frequently for blocked drippers and for leaks. Because measured irrigation is very simple, there are fewer things to go wrong. You don't need a pump, you don't need an irrigation controller (or timer), and hose clamps are not needed due to the low pressure. You will save time and money by installing a gravity feed measured irrigation system instead of a pressurised system.

To save water and protect your plants, you would like adjust the irrigation to take account of the prevailing weather conditions. For example, when it is hot and dry you will need a lot more water. And when it rains you don't need to water the garden at all. Pressurised drip irrigation without sensors does not automatically adjust to the prevailing weather conditions, whereas measured irrigation automatically adjusts to the prevailing weather conditions. For example, measured irrigation will stop watering the garden in Adelaide during the months of June, July and August - in these months the rainfall is greater than the evaporation. The water usage is directly proportional to the net evaporation rate (that is, evaporation minus rainfall).

The table below summarises the differences between pressurised drip irrigation and gravity feed measured irrigation.

Pressurised drip irrigation	**Gravity feed measured irrigation**
Requires access to mains water or to mains power (to operate a high pressure pump).	Does not require access to mains water or to mains power, and hence can be installed in remote locations.
Pressure compensating (regulated) drippers are required to control of the volume of water emitted by each dripper.	The volume of water emitted by each dripper is controlled directly and is independent of the flow rate.
Unless sensors are used, the water usage does not respond automatically to the prevailing weather conditions.	The water usage responds automatically to the prevailing weather conditions.
The irrigation is controlled by an irrigation controller or timer.	The irrigation is controlled by evaporation from and rainfall into a container.
Hose clamps are necessary.	Hose clamps are not needed due to very low pressure.
A water tank needs a high pressure pump (for example, 500 watts).	A water tank may need a low pressure pump (for example, 14 watts).
Uses sophisticated technology.	Uses simple technology (fewer things to go wrong).

1.3 Emitters and nozzles for gravity feed measured irrigation

For gravity feed measured irrigation, all the emitters in a zone should have the same emitter discharge exponent (see Appendix 1). Hence, a combination of different emitters can be used in a zone provided that they all have the same emitter discharge exponent. Drippers for gravity feed measured irrigation should be unregulated online drippers or unregulated inline drippers Emitters for gravity feed measured irrigation may be made from short blunt stainless steel needles with different internal diameters.

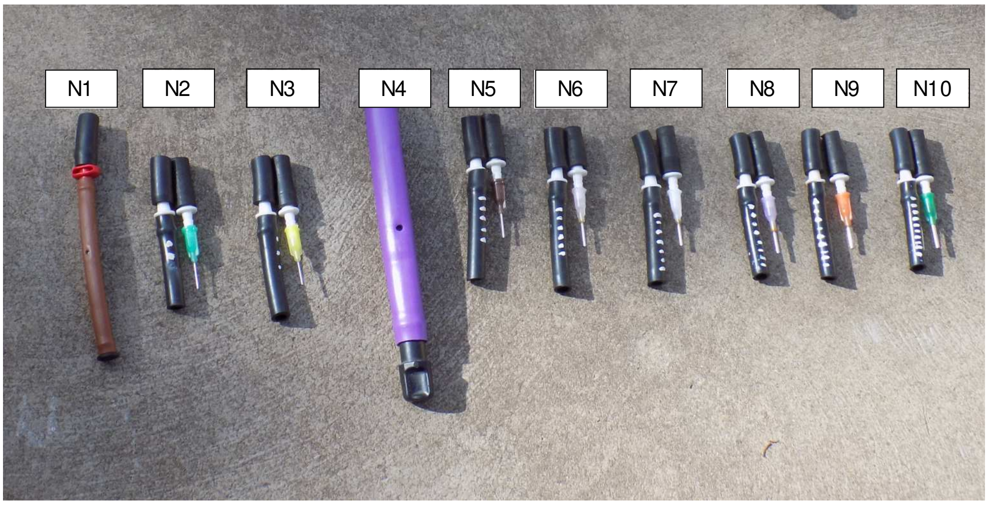
In the context on gravity feed measured irrigation, the term **nozzle** is used to refer to a short cylindrical tube or hole for restricting the flow. A dripper is an example of a nozzle. We will use the term nozzle when we wish to include other emitters as well as drippers.

1.4 Nozzles available from Measured Irrigation

Table 1 provides a list of nozzles available from Measured Irrigation. Contact Bernie Omodei at Measured Irrigation to discuss your nozzle requirements. All of the nozzles have an emitter discharge coefficient of 0.5 (see Appendix 1). The table also provides the flow rate in lph at a pressure of 100 kPa.

Table 1 Nozzles for gravity feed measured irrigation

nozzle number	nozzle name	description	flow rate in at 100 kPa
N1	Miniscape dripper	Netafim Miniscape (Landline 8) dripper in brown drip line 6 mm ID	2.00
N2	Green	stainless steel needle nozzle 0.56 mm ID	4.15
N3	Yellow	stainless steel needle nozzle 0.64 mm ID	6.27
N4	Bioline dripper	Netafim Bioline (Landline Purple) dripper in drip line 13mm ID	8.00
N5	brown	stainless steel needle nozzle 0.79 mm ID	10.6
N6	pink	stainless steel needle nozzle 0.99 mm ID	18.0
N7	White	stainless steel needle nozzle 1.17 mm ID	28.6
N8	Purple	stainless steel needle nozzle 1.35 mm ID	36.0
N9	orange	stainless steel needle nozzle 1.51 mm ID	50.3
N10	olive	stainless steel needle nozzle 1.77 mm ID	65.0



Nozzles available from Measured Irrigation. The needle nozzles are illustrated both with and without the protective black tube.

1.5 Nozzle ratios

For any two nozzles with the same emitter discharge exponent and at the same pressure, the ratio of the volumes of water emitted by the two nozzles is a constant called the **nozzle ratio**. The nozzle ratio is independent of the pressure. For any measured irrigation application there is a special nozzle called the **control nozzle** that drips water into a container (called the evaporator).
The nozzle ratios for the nozzles in Table 1 are listed below in Table 2.

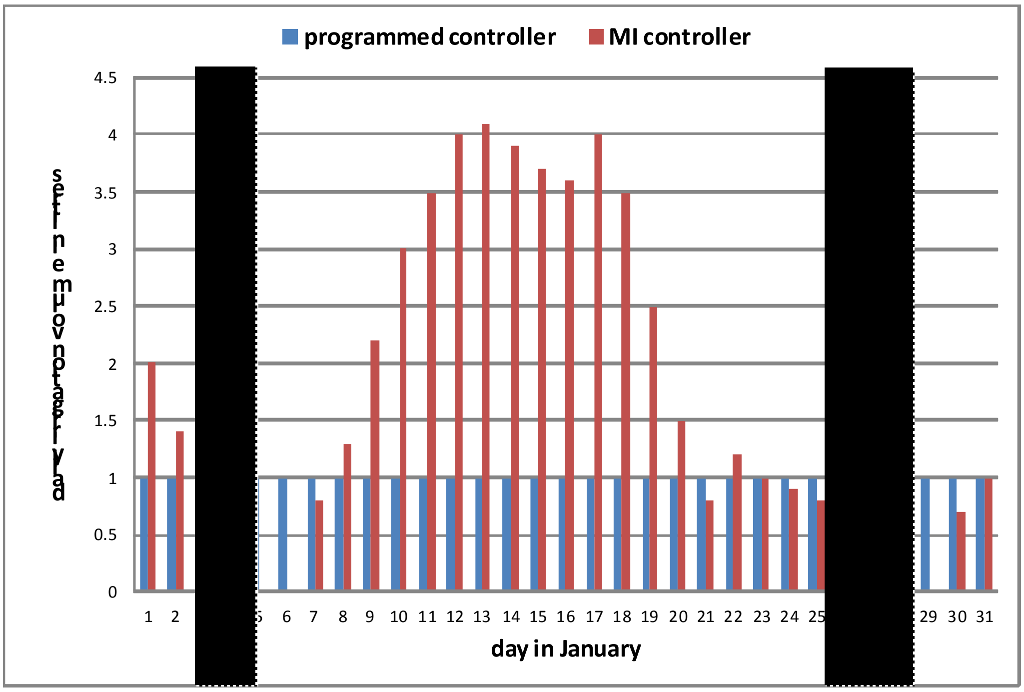
Table 2 Nozzle ratios emitter nozzle to control nozzle

control nozzle

emitter nozzle	Miniscape dripper	green	yellow	Bioline dripper	brown	pink	white	purple	orange	olive
nozzle 1 Miniscape dripper	1.00	0.529	0.351	0.250	0.207	0.122	0.0769	0.0611	0.0436	0.0338
nozzle 2 green	2.08	1.00	0.663	0.519	0.392	0.231	0.145	0.1155	0.0825	0.0639
nozzle 3 yellow	3.13	1.51	1.00	0.783	0.591	0.348	0.219	0.174	0.124	0.0964
nozzle 4 Bioline dripper	4.00	1.93	1.28	1.00	0.755	0.444	0.280	0.222	0.159	0.123
nozzle 5 brown	5.30	2.55	1.69	1.32	1.00	0.589	0.371	0.295	0.210	0.163
nozzle 6 pink	9.00	4.33	2.87	2.25	1.70	1.00	0.630	0.500	0.358	0.277
nozzle 7 white	14.3	6.88	4.56	3.57	2.70	1.59	1.00	0.794	0.568	0.439
nozzle 8 purple	18.0	8.7	5.74	4.50	3.40	2.00	1.26	1.00	0.715	0.553
nozzle 9 orange	25.2	12.1	8.03	6.29	4.75	2.80	1.76	1.40	1.00	0.774
nozzle 10 olive	32.5	15.7	10.4	8.13	6.14	3.61	2.28	1.81	1.29	1.00

1.6 Measured irrigation scheduling

Suppose you have a pressurised drip irrigation system and you are using an irrigation controller (or timer) to schedule the irrigation events. Suppose that you need to go away for the whole of January, and so you program your controller to irrigate for 30 minutes every evening. Hence a 2 lph dripper will emit 1 litre every evening regardless of the weather. The chart below shows typical daily irrigation volumes per dripper in Adelaide in January for MI irrigation scheduling compared with the programmed irrigation scheduling. Notice how the MI controller adapts to the weather conditions.



It rained for 5 days in January, and so the MI controller responded by not irrigating. The programmed controller wasted a lot of water by not responding to the rain.

There was an unexpected heat wave from January 11th till January 18th and the MI controller responded by increasing the irrigation volume per dripper to almost 4 litres. The programmed controller continued to deliver only 1 litre per dripper and so many plants didn't get enough water.

Chapter 2. Unpowered Manual Measured Irrigation

Chapter 2. Unpowered Manual Measured Irrigation

2.1 Introduction to manual measured irrigation

It is assumed that a smallholder is using drip irrigation (either pressurised or gravity feed) on a garden or a small plot of land.

To install manual measured irrigation, all that is needed is an evaporator and an adjustable dripper.

The **evaporator** is any container with vertical sides, with a surface area of at least 0.05 m^2, and a depth of at least 0.1 m.

Examples of suitable evaporators

Any **adjustable dripper** may be used. Examples of an adjustable dripper are Claber 91214 adjustable dripper and Claber 91225 adjustable dripper.

Claber 91214 adjustable dripper

Claber 91225 adjustable dripper

Claber 912014 adjustable dripper can be purchased from the Online Shop at the Measured Irrigation website.

2.2 How to make a precision adjustable dripper

Adjustable drippers do not normally indicate the flow rate when you adjust the dripper. Furthermore, some adjustable drippers to do deliver a consistent flow rate for a particular setting of the adjustable dripper at a particular pressure. You can avoid such problems by making your own precision adjustable dripper using a combination of non-adjustable drippers.

You can make your precision adjustable dripper using three Netafim Miniscape (Landline 8) drippers and three Netafim Bioline (Landline purple) drippers (see Section 1.4). Each dripper should have a separate control valve so that you can adjust the precision adjustable dripper by selectively turning the control valves off or on. The precision adjustable dripper can be adjusted to deliver the following flow rate at 100 kPa:

2 lph, 4 lph, 6 lph, 8 lph, 10 lph, 12 lph, 14 lph, 16 lph. 18 lph, 20 lph, 22 lph, 24 lph, 26 lph, 28 lph, 30 lph

Precision adjustable dripper with 3 Netafin Miniscape drippers and 3 Netafim Bioline drippers.

You can also make your precision adjustable dripper using Netafim Landline 12 drippers. By using three drippers with a flow rate of 1 lph (at 100 kPa) and three drippers with a flow rate of 4 lph (at 100 kPa), the precision adjustable dripper can be adjusted to deliver the following flow rate at 100 kPa:

1 lph, 2 lph, 3 lph, 4 lph, 5 lph, 6 lph, 7 lph, 8 lph, 9 lph, 10 lph, 11 lph, 12 lph, 13 lph, 14 lph, 15 lph

If you have a pressurised irrigation system with pressure compensating drippers, you should make your own precision adjustable dripper using a combination of pressure compensating drippers with different flow rates.

2.3 Instructions for installing manual measured irrigation

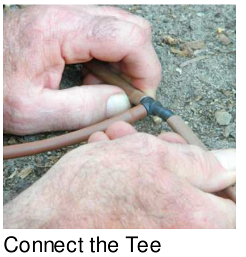
Step 1. Draw a line on the inside of the evaporator about 1.5 cm below the overflow level. This line corresponds to the high level.

Draw a line on the inside of the evaporator about 1.5 cm below the overflow level

Step 2. Connect the adjustable dripper to the irrigation system and position the evaporator so that the adjustable drip drips water into the evaporator during irrigation. The adjustable dripper should be at the same level as the irrigation drippers. The adjustable dripper is called the **control dripper**.

The adjustable dripper can be connected to a drip line using a Tee

Cut the drip line so that you can connect the Tee



Connect the Tee

The adjustable drip drips water into the evaporator during irrigation

Step 3. Place a measuring container under one of the irrigation drippers.

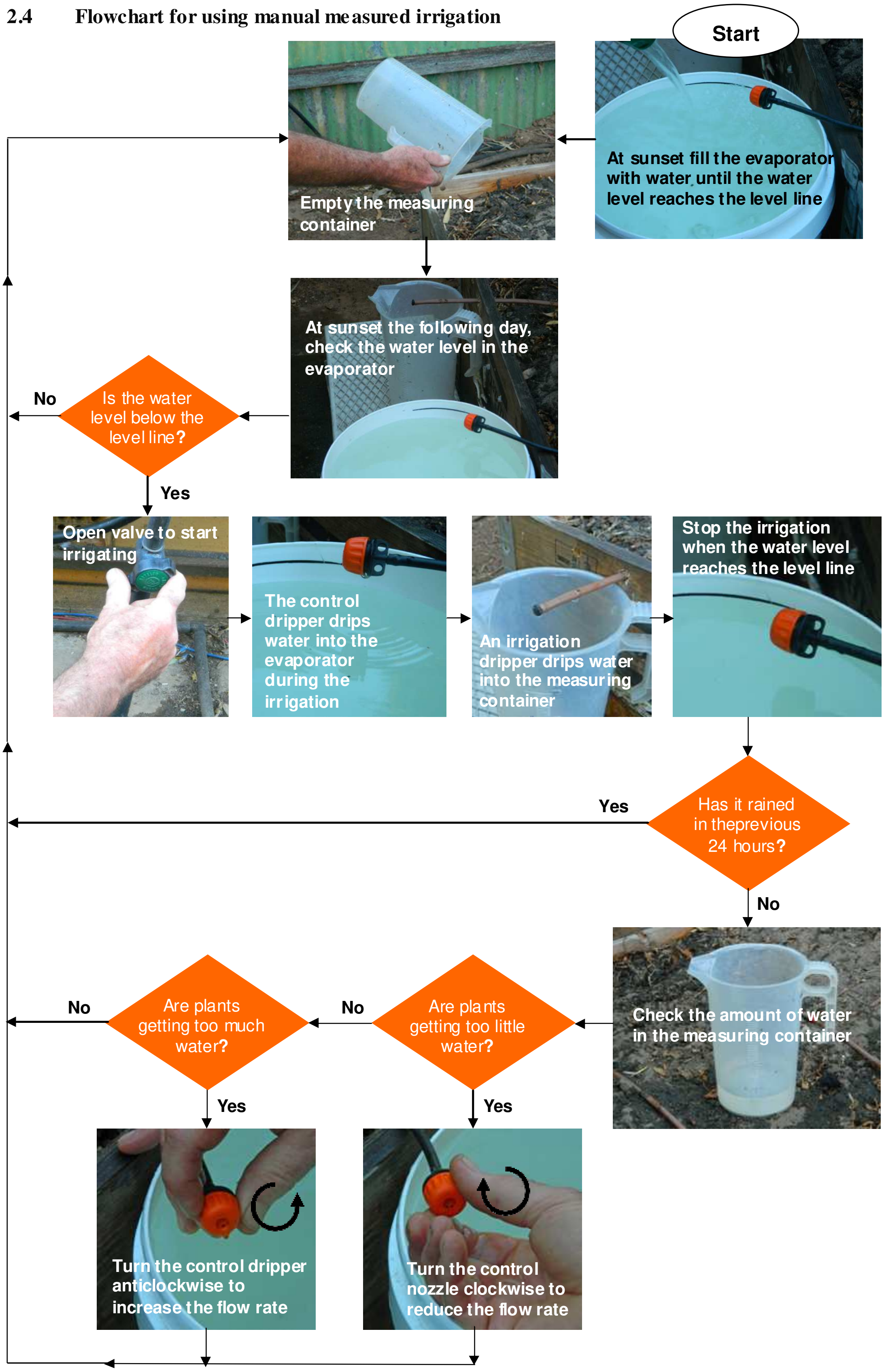
Place a measuring container under one of the irrigation drippers

Step 4. Adjust the control dripper so that flow rate is about the same as the flow rate of the irrigation drippers. Make sure that there is no air in the tube connected to the control dripper.

Adjust the control dripper so that flow rate is about the same as the flow rate of the irrigation drippers

Step 5. You may wish to protect the evaporator to prevent animals drinking the water, but make

2.4 Flowchart for using manual measured irrigation



If you have a pressurised irrigation system with pressure compensating drippers, you should replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2). You can alter the water usage by either adjusting the precision adjustable dripper or changing the surface area of evaporation.

If your plants require less frequent watering, you may choose not to irrigate on certain evenings. For example, at sunset one day the water level is below the high level and you decide not to irrigate. At sunset the following day the water level will have fallen even further, and so when you irrigate the irrigation volume will be the sum of the irrigation volumes for both days. Changing the irrigation frequency does not affect the total amount of water used for irrigation during the growing season.

If the garden requires more frequent watering, you may choose to irrigate at the middle of the day as well as at sunset (for example, if the weather is very hot and dry).

Manual measured irrigation can be used for sprinkler irrigation as well as drip irrigation.

Garden beds being irrigated by manual MI

Chapter 3. Unpowered Measured Irrigation Controller (UMIC)

3.1 Introduction to Unpowered Measured Irrigation Controller (UMIC)

It is assumed that a smallholder is using drip irrigation (either pressurised or gravity feed) on a garden or a small plot of land. Using the Unpowered Measured Irrigation Controller (UMIC), you can upgrade your drip irrigation system so that all your plants are irrigated automatically. The water supply pressure should be at least 10 kPa (1 metre head). Provided you have a continuous water supply to UMIC, you can leave your garden unattended for weeks on end. This will allow you to become involved in other activities away from the garden; for example, travelling to the market to sell your produce.

It is recommended that you watch the YouTube video Unpowered Measured Irrigation Controller.

UMIC can be used for sprinkler irrigation as well as drip irrigation.

The Unpowered Measured Irrigation Controller (UMIC) can be purchased from the Online Shop at the Measured Irrigation website https://www.measuredirrigation.com/shop-1.

Measured irrigation is a new method of irrigation scheduling that responds to the prevailing weather conditions. This means that you use much less water without affecting the yield.

All of the plants in the three photos below are being irrigated automatically by one UMIC.



How large can the plot be?

It is assumed that the smallholder has already established a drip irrigation system. Provided that the drip irrigation system is already working effectively, you can use one or more UMIC's to automate the irrigation system for any size plot. For irrigation systems that require a large flow rate, you can use a Hi-flow Unpowered Measured Irrigation Controller (HUMIC, see Chapter 4) or you can use a Smart Solenoid Irrigation Controller (see Chapters 5 and 6).

3.2 Instructions for installing the Unpowered Measured Irrigation Controller (UMIC)

Installing the Unpowered MI Controller is incredibly simple. Start with any drip irrigation application, either pressurised or gravity feed. Before installing the controller, it is assumed that the irrigation is operated manually by opening and closing the main valve.

Step 1. Position the evaporator in a suitable location so that the evaporation matches the evaporation in your garden.

Step 2. Connect the water supply to the inlet of the UMIC (the inlet is on the opposite side to the adjustable control dripper).

Step 3. Connect the UMIC outlet (next to the adjustable control dripper) to the irrigation zone.

Step 4. Position the float shaft so that it points vertically up. Be very careful when adjusting the float shaft to avoid placing any stress on the fragile plastic float shaft. Position the adjustable control dripper so that it will drip water into the evaporator during the irrigation.

Float shaft must be vertical

Step 5. For gravity feed application you may need to adjust the height of the evaporator so that the control dripper is at the same level as the irrigation drippers. Use a spirit level to ensure that the evaporator is horizontal. Then use the spirit level to ensure that the float shaft is vertical. The float shaft must be vertical so that there is minimal friction between the float and the float shaft.

Step 6. Slide the float over the float shaft so that the clear tube attached to the float is uppermost

Slide the float over the float shaft

Step 7. Turn on the water supply and the irrigation should start. The adjustable control dripper drips water into the evaporator.

Step 8. Adjust the control dripper so that flow rate is about the same as the flow rate of the irrigation drippers.

Adjust the control dripper

Step 9. Fill the evaporator with water until the float jumps up as the magnetic valve closes.

Step 10. The float falls as water slowly evaporates from the evaporator. When the float reaches the low level, the irrigation starts automatically. The float rises as the control dripper drips water into the evaporator. When the float reaches the high level the irrigation stops automatically. The cycle continues indefinitely.

The irrigation starts when the float reaches the low level

The irrigation stops when the float reaches the high level

Step 11. Adjust the control dripper to suit the water requirements of your plants

Step12. You may wish to protect the evaporator to prevent animals drinking the water, but make sure that you do not impede the evaporation (chicken wire is ideal).

UMIC is completely automatic and does not need any electricity. Furthermore, it is a smart controller because the water usage for each dripper is controlled by the prevailing weather conditions. In fact, the water usage (litres per week for example) is directly proportional to the net evaporation rate (that is, evaporation minus rainfall). You can adjust the water usage by adjusting the control dripper. You can adjust the irrigation frequency by adjusting the slides on the float.

Most irrigation controllers need to be programmed and so they cannot respond to an unexpected heat wave. UMIC responds to an unexpected heat wave. If the evaporation rate doubles then so does the water usage.

When it rains water enters the evaporator and delays the start of the next irrigation.

If your plants need more water, rotate the control dripper clockwise.
If your plants need less water, rotate the control dripper anticlockwise.

Replace the water and clean the UMIC regularly to remove algae and other contaminants.

Because UMIC is so simple, there are fewer things to go wrong.

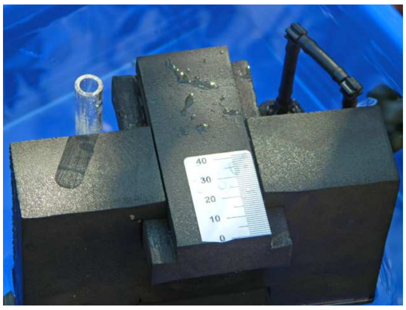
If you have a pressurised irrigation system with pressure compensating drippers, then you should replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2). You can alter the water usage by either adjusting the precision adjustable dripper or changing the surface area of evaporation.

3.3 How to adjust irrigation frequency for UMIC

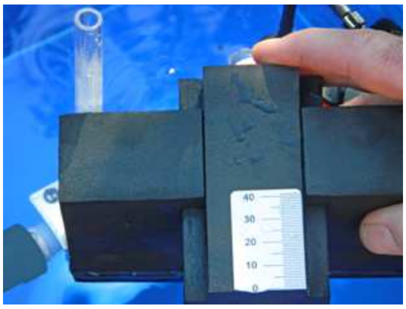
To increase the options for the irrigation frequency, the UMIC is provided with two floats, a large float and a small float.

Large float and small float

The float has two slides that can be moved up or down in order to adjust the irrigation frequency.



20 mm gap between the bottom of the float and the bottom of the slides



40 mm gap between the bottom of the float and the bottom of the slides

The following table shows the irrigation frequency for various positions of the slides for both the large float and the small float. The irrigation frequency is controlled by the net evaporation from the evaporator between irrigation events.

UMIC Table 1. Irrigation frequency

Gap in mm between the bottom of the float and the bottom of the slides	Net evaporation in mm between irrigation events with large float	Net evaporation in mm between irrigation events with small float
Slides removed	8	15
0	7	11
10	7	11
20	7	12
25	8	12
30	8	23
35	8	26
40	26	30
45	30	34
50	35	37
55	40	40
60	45	43

If the gap between the bottom of the large float and the bottom of the slides is 30 mm, then 8 mm of water has to evaporate between irrigation events.

Provided that the water level in the evaporator is between the low level and the high level, you can start the irrigation manually at any time by pressing the float down.

For example, you may wish to irrigate at sunset each day assuming that the water level is between the low level and the high level at sunset. Simply push the float down at sunset to start irrigating.

You can delay the next irrigation or stop the irrigation at any time by removing the float. The irrigation cannot start again until the float is replaced.

It is important to realise that when you adjust the irrigation frequency by adjusting the slides, the water usage (litres per week for example) does not change. Both the irrigation frequency and the water usage are directly proportional to the net evaporation rate.

3.4 How to adjust water usage for UMIC

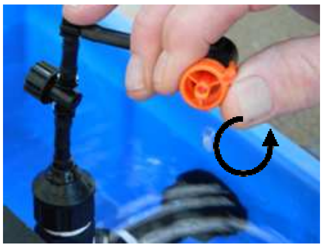
Adjusting water usage by adjusting the control dripper

The term **water usage** refers to the number of litres per week (or litres per month) used by the irrigation system.

1. Position an empty measuring container under one of the irrigation drippers so that water drips into the container during the irrigation event.

2. At the end of the irrigation event check the amount of water in the measuring container. You may also wish to check the moisture in the soil.

3. If your plants are not getting enough water, turn the control dripper clockwise to reduce the flow rate of the control dripper.



4. If your plants are getting too much water, turn the control dripper anticlockwise to increase the flow rate of the control dripper.

changing the water usage does not change the irrigation frequency

changing the irrigation frequency does not change the water usage

This is important because it means that the water usage and the irrigation frequency can be adjusted independently.

Adjusting water usage by adjusting the surface area

You can also adjust the water usage by adjusting the surface area of evaporation.

To increase the water usage, select one or more containers with vertical sides and connect the containers to the UMIC evaporator. One way to connect containers is to drill in hole in the side of each container and to insert a rubber grommet into each hole. Insert a barbed connector into each grommet, and then use a length of flexible tube to connect the containers. The water level will be same in all containers and the surface area of evaporation is increased.

You can decrease the water usage by decreasing the surface area of evaporation (for example, by placing full bottles of water in the evaporator).

Pressure compensating drippers

If you have a pressurised irrigation system with pressure compensating drippers, then you should replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2). You can alter the water usage by either adjusting the precision adjustable dripper or changing the surface area of evaporation.

3.5 UMIC flow rate

UMIC can be used for pressures ranging from 10 kPa to 800 kPa.

The maximum UMIC flow rate is greater than 1500 lph (at 800 kPa).

The maximum UMIC flow rate when the input pressure is 100 kPa is greater than 500 lph.

The following table shows the maximum UMIC flow rate for gravity feed input pressures ranging from 10 kPa (1 metres head) to 20 kPa (2 metres head).

UMIC Table 2. Flow rate

Input pressure in kPa	Maximum UMIC flow rate in lph
10	206
11	221
12	235
13	248
14	260
15	272
16	283
17	293
18	303
19	312
20	321

For some drip irrigation applications you may need more than one UMIC to provide an adequate flow rate from the drippers. Subdivide your irrigation application into the same number of zones as the number of UMIC's so that each zone has approximately the same water requirement. Within each zone the drippers should be at approximately the same level. For each zone install a UMIC as described in Section 3.2.

3.6 Key features of UMIC

1. UMIC is completely automatic
2. No electricity is needed (no batteries, no solar panels, no computers, and no electronics)
3. UMIC is a smart irrigation controller – the irrigation is controlled by the prevailing weather conditions rather than a program
4. You can adjust the water usage by adjusting the control dripper
5. You can adjust the irrigation frequency by adjusting the slides on the float
6. Two floats are provided to increase your options for setting the irrigation frequency
7. Adjusting the control dripper does not change the irrigation frequency
8. Adjusting the float does not change the water usage
9. UMIC can be used for both gravity feed and pressurised irrigation
10. The irrigation frequency and the water usage are directly proportional to the net evaporation rate
11. Respond appropriately when there is an unexpected heat wave
12. When it rains, water enters the evaporator and delays the start of the next irrigation
13. The water usage is independent of the water supply pressure
14. UMIC uses much less water without affecting the yield
15. UMIC is incredibly simple and low tech and so there are fewer things to go wrong
16. Provided you have a continuous water supply, you can leave your irrigation application unattended for weeks on end
17. UMIC is low cost with free delivery to any postal address in the world (see the Online Shop at the Measured Irrigation website https://www.measuredirrigation.com/shop-1)

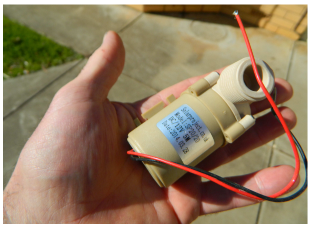
3.7 Using a solar pump to fill a header tank

You can use a solar panel and a small submersible pump to automatically pump water from your farm pond (or from a rainwater tank, lake or river) to a header tank. The pump should be protected by a DC voltage converter (or voltage regulator).

An ideal pump including a DC voltage converter is available from the Online Shop at the Measured Irrigation website https://www.measuredirrigation.com/shop-1

The pump is also available from Solar Project UK http://www.solarproject.co.uk/page2.html

This brilliant submersible baby pump is 12 volt 14 watt.



Submersible baby pump

A 20 watt solar panel is required to operate the pump via the voltage converter without using a battery. You may need more than one pump to fill the header tank. For each additional pump you will require an additional 20 watt solar panel.

There is a major advantage of using multiple baby pumps compared with a single pump of equivalent power. If one of the pumps fails, the remaining pumps can continue to operate while you replace the broken pump.

The pumps will operate whenever there is sufficient direct sunlight on the solar panels. The overflow from the header tank should be returned to the farm pond.

When you submerge the pump (or pumps) in the farm pond, you should attach a filter to the inlet to the pumps. The inlet to the filter should be at least 15cm above the bottom of the pond to avoid clogging the filter with the sediment on the bottom of the pond.

How many pumps do you need?

If the head is less than 3.25 metres, then all the pumps should be connected in parallel. The flow rate with two pumps will be twice the flow rate of one pump. The flow rate with three pumps will be three times the flow rate of one pump, and so forth.

If the head is greater than 3.25 metres and you need a second pump, then the second pump should be connected in series with the first pump to create a **double pump.** If additional pumping is still required, you will need two additional pumps connected in series to create a second double pump. The second double pump should be connected in parallel with the first double pump.

Two pumps connected in series to create a double pump. A filter is connected to the inlet of the first pump.

When the head is at the critical level of 3.25 metres, two pumps connected in parallel have the same flow rate as two pumps connected in series, namely 520 lph

If you want to use fewer solar panels to provide sufficient power for your pumps, you will need to use a suitable battery and solar charge controller. The solar panels will then charge the battery during sunlight hours and the battery will be used to provide the power to the pumps as required.

For solar-unpowered measured irrigation, see the **DIY Solar Measured irrigation Training Manual for Smallholders.**

Chapter 4. Hi-flow Unpowered Measured Irrigation Controller (HUMIC)

4.1 Introduction to Hi-flow Unpowered Measured Irrigation Controller (HUMIC)

The Unpowered Measured Irrigation Controller (UMIC) has a limited flow rate because the magnetic valve is quite small. HUMIC uses a much larger magnetic valve. HUMIC uses an Irritrol 2400 Series solenoid valve with 25mm BSP inlet and outlet. The water supply pressure should be between 69 kPa and 1034 kPa (10 – 150 psi). The maximum flow rate for HUMIC is 6800 lph (at 1034 kPa). Provided you have a continuous water supply to HUMIC, you can leave your irrigation application unattended for weeks on end.

HUMIC can be used for sprinkler irrigation as well as drip irrigation.

The Hi-flow Unpowered Measured Irrigation Controller (HUMIC) can be purchased from the Online Shop at the Measured Irrigation website https://www.measuredirrigation.com/shop-1.

Hi-flow Unpowered Measured Irrigation Controller (HUMIC)

Unpowered Irritrol solenoid valve

How large can the plot be?

It is assumed that you have already established your irrigation system. Provided that the irrigation system is already working effectively, you can use one or more HUMIC's to automate the irrigation system for any size plot. For irrigation systems that require a very large flow rate, you can use a Smart Solenoid Irrigation Controller (see Chapters 5 and 6).

4.2 Instructions for installing the Hi-flow Unpowered Measured Irrigation Controller (HUMIC)

Installing the Hi-flow Unpowered MI Controller is incredibly simple. Start with any pressurised irrigation application. Before installing the controller, it is assumed that the irrigation is operated manually by opening and closing the main valve.

Step 1. Position the evaporator in a suitable location so that the evaporation matches the evaporation in your garden.

Step 2. Connect the water supply to the inlet of the HUMIC (the inlet is on the opposite side to the adjustable control dripper).

Step 3. Connect the HUMIC outlet (next to the adjustable control dripper) to the irrigation zone.

Step 4. Position the float over the solenoid and use the two wing-nuts to secure the aluminium bar that prevents the float from jumping off the solenoid when the irrigation stops.

Position the float over the solenoid

Use the two wing-nuts to secure the aluminium bar

Step 5. Turn on the water supply and the irrigation should start. The adjustable control dripper drips water into the evaporator.

Step 6. Fill the evaporator with water until the float jumps up as the solenoid valve closes.

Fill the evaporator

Step 7. The float falls as water slowly evaporates from the evaporator. When the float reaches the low level, the irrigation starts automatically. The float rises as the control dripper drips water into the evaporator. When the float reaches the high level the irrigation stops automatically. The cycle continues indefinitely.

The irrigation starts when the float reaches the low level

The irrigation stops when the float reaches the high level

Step 8 Adjust the control dripper to suit the water requirements of your plants

Step 9. You may wish to protect the evaporator to prevent animals drinking the water, but make sure that you do not impede the evaporation (chicken wire is ideal).

Replace the water and clean the HUMIC regularly to remove algae and other contaminants.

Because the HUMIC is so simple, there are fewer things to go wrong.

4.3 How to adjust irrigation frequency for UMIC

To increase the options for the irrigation frequency, HUMIC is provided with the following float components:


Float with magnet (1 provided)


Float without magnet (2 provided)


Half float (2 provided)


Full slide (2 provided)


Cut slide (2 provided)


UV resistant rubber bands

The following images show the irrigation frequency for various float assemblies. The irrigation frequency is controlled by the net evaporation from the evaporator between irrigation events.

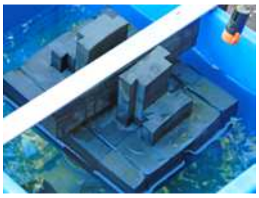

13mm net evaporation between irrigation events (zero gap between magnet and bottom of full slides)

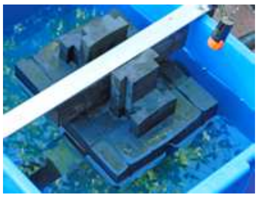

19mm net evaporation between irrigation events (zero gap between magnet and bottom of full slides)

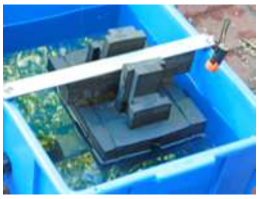

23mm net evaporation between irrigation events (zero gap between magnet and bottom offull slides)


26mm net evaporation between irrigation events (20mm gap between magnet and bottom of full slides)


31mm net evaporation between irrigation events (zero gap between magnet and bottom of cut slides)


37mm net evaporation between irrigation events (10mm gap between magnet and bottom of cut slides)


44mm net evaporation between irrigation events (15mm gap between magnet and bottom of cut slides)


48mm net evaporation between irrigation events (20mm gap between magnet and bottom of cut slides)

Provided that the water level in the evaporator is between the low level and the high level, you can start the irrigation manually at any time by pressing the float down.

For example, you may wish to irrigate at sunset each day assuming that the water level is between the low level and the high level at sunset. Simply push the float down at sunset to start irrigating.

You can delay the next irrigation or stop the irrigation at any time by removing the float. The irrigation cannot start again until the float is replaced.

It is important to realise that when you adjust the irrigation frequency by adjusting the float, the water usage (litres per week for example) does not change. Both the irrigation frequency and the water usage are directly proportional to the net evaporation rate.

4.4 How to adjust water usage for the HUMIC

Adjusting water usage by adjusting the control dripper

If your plants are not getting enough water, turn the control dripper clockwise to reduce the flow rate of the control dripper. If your plants are getting too much water, turn the control dripper anticlockwise to increase the flow rate of the control dripper

changing the water usage does not change the irrigation frequency

changing the irrigation frequency does not change the water usage

This is important because it means that the water usage and the irrigation frequency can be adjusted independently.

Adjusting water usage by adjusting the surface area

You can also adjust the water usage by adjusting the surface area of evaporation.

To increase the water usage, select one or more containers with vertical sides and connect the containers to the HUMIC evaporator. One way to connect containers is to drill in hole in the side of each container and to insert a rubber grommet into each hole. Insert a barbed connector into each grommet, and then use a length of flexible tube to connect the containers. The water level will be same in all containers and the surface area of evaporation is increased.

You can decrease the water usage by decreasing the surface area of evaporation (for example, by placing full bottles of water in the evaporator).

Pressure compensating drippers

If you have a pressurised irrigation system with pressure compensating drippers, then you should replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2). You can alter the water usage by either adjusting the precision adjustable dripper or changing the surface area of evaporation.

4.5 Key features of HUMIC

1. HUMIC is completely automatic
2. No electricity is needed (no batteries, no solar panels, no computers, and no electronics)
3. HUMIC is a smart irrigation controller – the irrigation is controlled by the prevailing weather conditions rather than a program
4. You can adjust the water usage by adjusting the control dripper
5. You can adjust the irrigation frequency by adjusting the float
6. Adjusting the control dripper does not change the irrigation frequency
7. Adjusting the float does not change the water usage
8. The irrigation frequency and the water usage are directly proportional to the net evaporation rate
9. If there is an unexpected heat wave, HUMIC will respond appropriately
10. When it rains, water enters the evaporator and delays the start of the next irrigation
11. The water usage is independent of the water supply pressure
12. HUMIC uses much less water without affecting the yield
13. HUMIC is incredibly simple and low tech and so there are fewer things to go wrong
14. Provided you have a continuous water supply, you can leave your irrigation application unattended for weeks on end

Chapter 5. DIY Smart Irrigation Controller

5.1 Introduction to the DIY Smart Irrigation Controller

I will show you how to convert a solenoid valve into an unpowered smart irrigation controller. An irrigation controller is called smart when the irrigation scheduling is controlled by the prevailing weather conditions. Many solenoid valves have a separate cylindrical solenoid that screws into the valve. Some suitable solenoid valves are shown below. Almost any non-latching solenoid valve used for irrigation can be converted into an unpowered smart irrigation controller. If you have a latching solenoid valve, you will need to replace the latching solenoid with a non-latching solenoid. If you have a large scale irrigation application you will need to use a high flow solenoid valve. For example, the Irritrol 200B Series is available with 1", 1½" or 2" connections.

A cylindrical solenoid screws into the solenoid valve

Toro solenoid valve

Orbit solenoid valve

Irritrol 2500 Series

Irritrol 2400/2600 Series

Irritrol 200B Series with 1", 1½" or 2" connections

This Do It Yourself project may become a time-saving, water-saving, money-saving game changer for poor landholders.

It is recommended that watch the YouTube video DIY Smart Irrigation Controller.

Components of the DIY Smart Irrigation Controller

Components of the DIY Smart Irrigation Controller

To complete the project you will need the following components:
(unless specified, all pipes and pipe fittings are 15mm BSP)

- a non-latching solenoid valve
- an adjustable irrigation dripper
- a galvanised cross
- two galv pipes 500mm long
- two galv pipes 200mm long
- a galv pipe 300mm long
- two galv tees
- two galv nipples
- a poly cap
- a poly cut-off riser, 15mm female x 15mm male
- two galvanised flanges
- eight galvanised nuts and bolts
- a small platform for supporting the counter weights
- a large platform for supporting the evaporator
- one or more evaporators (an evaporator is any container with vertical sides)
- two 20 litre water containers
- a ferrite ring magnet assembly or a rare earth disc magnet assembly

Ferrite ring magnet assembly on the left
Rare earth disc magnet assembly on the right

Ferrite ring magnet option

The ferrite ring magnet assembly has the following components:

- a ferrite ring magnet 32mm ID, 70mm OD, 15mm thick. The OD and thickness can vary provided that the magnet is strong enough to activate the plunger in the solenoid valve.
- a galvanised reducing socket 32mm x 20mm
- a poly or galvanised reducing nipple 20mm x 15mm
- a 75mm length of 13mm straight poly pipe

Components of the ferrite ring magnet assembly

The ferrite ring magnet slides over the solenoid. This option is only appropriate when there is 25mm clearance around the solenoid. When the magnet is in the low position, the magnet lifts the plunger inside the solenoid and opens the valve. When the magnet is in the high position, the plunger is released and the valve closes.

When the magnet is in the low position, the magnet lifts the plunger inside the solenoid and opens the valve

When the magnet is in the high position, the plunger is released and the valve closes

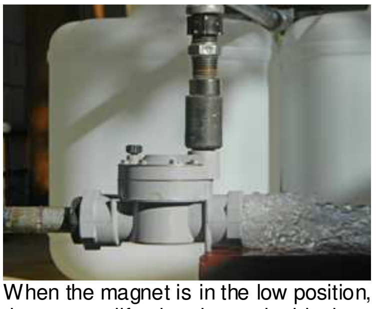
Rare earth disc magnet option

The rare earth disc magnet assembly has the following components:

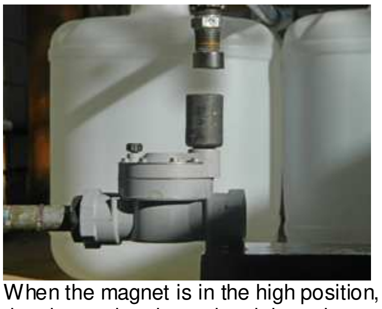
- a rare earth disc magnet 25.4mm (1 inch) diameter, 12.7mm (½ inch) thick
- a galvanised nipple
- a poly cut-off riser, 15mm female x 15mm male

Components of the rare earth disc magnet assembly

The rare earth disc magnet is positioned directly above the solenoid. When the magnet is in the low position, the magnet lifts the plunger inside the solenoid and opens the valve. When the magnet is in the high position, the plunger is released and the valve closes.



When the magnet is in the low position, the magnet lifts the plunger inside the solenoid and opens the valve



When the magnet is in the high position, the plunger is released and the valve closes

5.2 How to assemble the DIY Smart Irrigation Controller

I will now give you step by step instructions for assembling the DIY Smart Irrigation Controller.

Step 1 Assemble the balance bar by screwing the two 500mm pipes and the two 200mm pipes into the cross.

Step 2 Screw the tees onto the ends of the balance bar.

Step 3 Screw the 300mm pipe into one of the tees and then screw the cap onto the pipe.

Step 4 Screw one nipple into the tee connected to the 300mm pipe and screw other nipple into the other tee.

Step 5 Use 4 bolts to connect one flange to the centre of one of the platforms. Connect the other flange to the centre of the other platform.

Step 6 Screw the large platform onto the nipple opposite the 300mm pipe. Screw the small platform onto a nipple at the other end of the balance bar.

Step 7 (ferrite ring magnet assembly)

Screw the reducing nipple into the galvanised reducing socket. Insert the 75mm length of 13mm straight poly pipe into the reducing socket so that the end of the poly pipe is 10mm inside the reducing socket. Use contact adhesive to securely attach the ferrite ring magnet to the reducing socket.

Step 7 (rare earth disc magnet assembly)

Cut the poly cut-off riser so that it is 28mm long. Screw the cut-off riser onto the galvanised nipple. Attach the rare earth disc magnet to the galvanised nipple (no adhesive is required because the rare earth magnet is so strong).

Step 8 Screw the ferrite ring magnet assembly or the rare earth disc magnet assembly onto the nipple opposite the small platform.

Step 8 Use the two water containers to support the balance bar. Stabilise the containers by filling them with water. The height of the balance bar should be about 330mm.

Step 9 Cut off the two electrical wires connected to the solenoid (remember that the irrigation controller is unpowered)

Step 10 Install the solenoid valve and position the balance bar so that when the magnet assembly is in the high position, the balance bar is level and the top of the solenoid is directly below the magnet assembly.

Step 11 Place the evaporator on the large platform and add water until the depth is at least 20mm.

Step 12 Place counter weights on the small platform until the magnet assembly falls from the high position to the low position thus opening the valve.

Step 13 Slowly add water to the evaporator until the magnet assembly rises from the low position to the high position.

Step 14 (ferrite ring magnet assembly)

When the ferrite ring magnet assembly is in the high position, the top of the solenoid should be 10mm inside the ring magnet. Attach a poly cut-off riser to the 300mm pipe to increase the length of the pipe as required. Make fine adjustments by screwing or unscrewing the ring magnet assembly, the 300mm pipe, the cut-off riser, or the cap.

When the ferrite ring magnet assembly is in the high position, the top of the solenoid should be 10mm inside the ring magnet

Step 14 (rare earth disc magnet assembly)

When the rare earth disc magnet assembly is in the high position, the top of the solenoid should be 20mm below the magnet. Attach a poly cut-off riser to the 300mm pipe to increase the length of the pipe as required. Make fine adjustments by screwing or unscrewing the disc magnet assembly, the 300mm pipe, the cut-off riser, or the cap.

When the rare earth disc magnet assembly is in the high position, the top of the solenoid should be 20mm below the magnet

Step 15 Connect the inlet of the solenoid valve to the water supply, and connect the outlet of the solenoid valve to the irrigation application. Turn on the water supply.

Step 16 Position the adjustable dripper so that it will drips water into the evaporator during the irrigation.

Step 17 Water slowly evaporates from the evaporator until the weight of the water in the evaporator is light enough for the magnet assembly to fall and the irrigation starts automatically.

Step 18 Water drips into the evaporator until the weight of the water in the evaporator is heavy enough for the magnet assembly to rise and the irrigation stops automatically. The cycle continues indefinitely.

Step 19 The irrigation controller should be protected from birds and other animals.

Designing the balance bar

Depending on your application and your choice of magnet assembly, you may wish to use different lengths of pipe for the balance bar. To reduce the weight of water required to open and close the valve, you can increase the length of the pipe connected to the large platform, and/or decrease the length of the pipe connected to the small platform.

Buying the components for the DIY Smart Irrigation Controller

The DIY Smart Irrigation Controller is Do-It-Yourself and so you can minimise the cost by using locally sourced components. It will be even cheaper if you can find suitable used complements.

Some of the components are available in kit form from the Online Shop at the Measured Irrigation website https://www.measuredirrigation.com/shop-1

Two kits are available with free delivery to any postal address in the world.

DIY Smart Irrigation Controller Kit with ferrite ring magnet assembly

The components of the kit are:

- an adjustable irrigation dripper
- two galvanised flanges
- a poly cap
- a poly cut-off riser, 15mm female x 15mm male
- a ferrite ring magnet assembly

DIY Smart Irrigation Controller Kit with rare earth disc magnet assembly

The components of the kit are:

- an adjustable irrigation dripper
- two galvanised flanges
- a galvanised cross
- a poly cap
- a poly cut-off riser, 15mm female x 15mm male
- a rare earth disc magnet assembly

5.3 How to adjust the irrigation frequency for the DIY Smart Irrigation Controller

You can adjust the irrigation frequency by using an evaporator with a different surface area for evaporation. In fact the irrigation frequency is directly proportional to the surface area of the evaporator. For example, if you double the surface area you double the irrigation frequency. If you use a smaller evaporator you reduce the irrigation frequency.


Use a smaller evaporator to reduce the irrigation frequency

Another way to adjust the irrigation frequency is to change the ratio of the lengths of the two pipes used to make the balance bar. For example, if you reduce the length of the pipe connecting the tee to the small platform, the irrigation frequency will increase.

If you are using the rare earth disc magnet assembly you can increase the irrigation frequency by inserting spacers (coins for example) between the solenoid and the magnet. The spacers should be made from a material that is not attracted to the magnet. Note that the thickness of the spacers should not prevent the magnet from lifting the plunger when the magnet is in the low position.


Spacer on top of the solenoid

If you are using a particular evaporator, you will find that the irrigation frequency for the rare earth disc magnet assembly is significantly less than the irrigation frequency for the ferrite ring magnet assembly.

You can start the irrigation manually at any time by pressing the counter weights down. For example, if you want the irrigation to start at sunset each day, simply push the counter weights down at sunset.

5.4 How to adjust the water usage for the DIY Smart Irrigation Controller

If you decide that your plants are not getting enough water, then turn the control dripper clockwise to increase the water usage.

If you decide that your plants are getting too much water, then turn the control dripper anticlockwise to decrease the water usage.

If you have a pressurised irrigation system with pressure compensating drippers, you should replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2).

If you adjust the irrigation frequency by changing the lengths of the pipes in the balance bar, the water usage will also change. However, when you adjust the water usage by adjusting the control dripper, the irrigation frequency does not change. It is therefore recommended that you adjust the irrigation frequency before you adjust the water usage.

5.5 Key features of the DIY Smart Irrigation Controller

1. Completely automatic
2. No electricity is needed (no batteries, no solar panels, no computers, and no electronics)
3. You can adjust the water usage by adjusting the control dripper
4. You can adjust the irrigation frequency by changing the evaporator
5. Use for both gravity feed and pressurised irrigation
6. The irrigation frequency and the water usage are directly proportional to the net evaporation rate (that is, evaporation minus rainfall
7. Responds appropriately when there is an unexpected heat wave
8. When it rains, water enters the evaporator and delays the start of the next irrigation
9. Water usage is independent of the water supply pressure
10. Uses much less water without affecting the yield
11. It is incredibly simple and low tech and so there are fewer things to go wrong
12. Provided you have a continuous water supply, you can leave your irrigation application unattended for weeks on end
13. The DIY Smart Irrigation Controller is Do-It-Yourself and so you can minimise the cost by using locally sourced components. It will be even cheaper if you can find suitable used complements.
14. Use for any size irrigation application provided that the solenoid valve has a large enough flow rate.

Chapter 6. Smart Solenoid Irrigation Controller (SSIC)

6.1 Introduction to Smart Solenoid Irrigation Controller

In Chapter 5 we presented a Do-It-Yourself approach to making your own smart irrigation controller. In this chapter we introduce the Smart Solenoid Irrigation Controller, a product can be ordered from the Online Shop at the Measured Irrigation website: https://www.measuredirrigation.com/shop-1

The Smart Solenoid Irrigation Controller enables you to transform any non-latching irrigation solenoid into a smart irrigation controller. The critical component of the SSIC is a rare earth disc magnet 25.4mm (1 inch) diameter and 12.7mm (½ inch) thick. If you have a latching solenoid valve, you will need to replace the latching solenoid with a non-latching solenoid.

SSIC can be used for sprinkler irrigation as well as drip irrigation.

Smart Solenoid Irrigation Controller

6.2 How to assemble and install the SSIC

Step 1 Screw the threaded pipes into the cross.

Step 2 Screw the small platform into the tee above the magnet, and screw the large platform into the other tee.

Step 3 Position the magnet so that it is above the solenoid. The SSIC pivots on the caps on the two pipes below the elbows. Make sure that the caps have a secure footing so that the pivot points are fixed. Use poly cut-off risers and lengths of galvanised pipe to ensure that the magnet is 20mm above the solenoid. Screw or unscrew the connections to make fine adjustments.

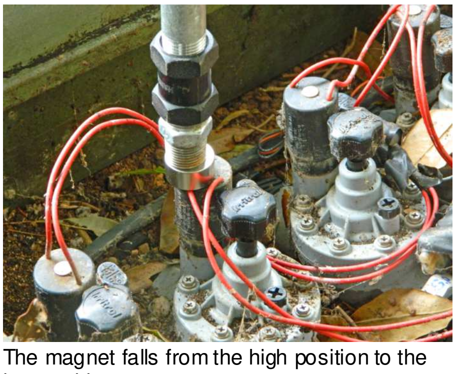
Position the magnet so that it is above the solenoid

Step 4 Place the evaporator on the large platform and add water until the depth is at least 20mm.

Step 5 Turn on the water supply to the solenoid valve.

Add water to the evaporator until the depth is a least 20mm

Step 6 Place counter weights on the small platform until the magnet falls from the high position to the low position. The solenoid valve opens and the irrigation starts. House bricks make good counter weights. If the solenoid valve does dot open you should cut off the two electrical wires connected to the solenoid. This will allow the magnet to get closer to the solenoid.



The magnet falls from the high position to the low position

The solenoid valve opens and the irrigation starts

Step 7 Slowly add water to the evaporator until the magnet rises from the low position to the high position. The solenoid valve closes and the irrigation stops. If the solenoid valve does not close, screw the connections until the magnet is sufficiently far away from the solenoid for the solenoid valve to close.

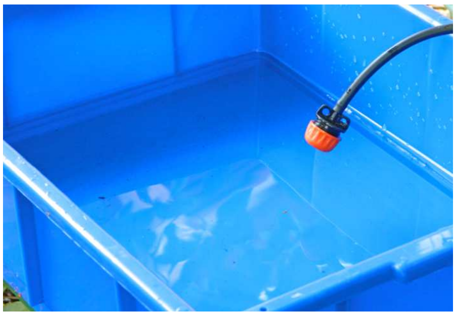
The solenoid valve closes and the irrigation stops

The solenoid valve closes and the irrigation stops

Step 8 Position the adjustable dripper so that it will drips water into the evaporator during the irrigation.

Step 9 Water slowly evaporates from the evaporator until the weight of the water in the evaporator is light enough for the magnet to fall from the high position to the low position and the irrigation starts automatically.

Water slowly evaporates from the evaporator until the weight of the water in the evaporator is light enough for the magnet to fall from the high position to the low position



Position the adjustable dripper so that it will drips water into the evaporator

Step 10 Water drips into the evaporator until the weight of the water in the evaporator is heavy enough for the magnet to rise from the low position to the high position and the irrigation stops automatically. The cycle continues indefinitely.

Water drips into the evaporator

The weight of the water in the evaporator is heavy enough for the magnet to rise from the low position to the high position

Step 11 The evaporator should be protected from birds and other animals. You may need to use somehing to prevent rainwater collecting in the depressions in the platforms

Adjusting the overflow level

When it rains water enter the evaporator and delays the start of the next irrigation. If there is sufficient rain the evaporator will eventually overflow. If the overflow level is too high, the delay before the next irrigation may be unacceptably long. The overflow level can be adjusted as follows:

1. Drill a hole near the bottom of the evaporator.
2. Insert a rubber grommet into the hole.
3. Insert a barbed elbow into the hole.
4. Connect a short length of poly pipe to the barbed elbow.
5. Rotate the elbow so that the end of the poly pipe is set at the desired overflow level.

Rotate the elbow so that the end of the poly pipe is set at the desired overflow level

Securing the pivot points for the balance bar

One way to secure the pivot points for the balance bar is to use two 20 litres water containers. Disconnect the two 150 mm pipes from the balance bar and replace them with the two 300mm pipes. Support the balance bar with the water containers and use two saddle clamps to attach the 300 pipes to the top of the water containers. Fill the containers with water. Depending on the application, you may wish to replace the 200mm pipe connecting the small platform to the cross with a longer pipe.

Secure the pivot points with two 20 litre water containers

6.3 How to adjust the irrigation frequency for SSIC

You can adjust the irrigation frequency by using an evaporator with a different surface area of evaporation. In fact the irrigation frequency is directly proportional to the surface area of the evaporator. For example, if you double the surface area you double the irrigation frequency. If you use a smaller evaporator you reduce the irrigation frequency.

Use a larger evaporator to increase the irrigation frequency

Use a smaller evaporator to reduce the irrigation frequency

You can increase the irrigation frequency by inserting spacers (coins for example) between the solenoid and the magnet. Before inserting the spacers you should cut off the two electrical wires connected to the solenoid. The spacers should be made from a material that is not attracted to the magnet. Note that the thickness of the spacers should not prevent the magnet from lifting the plunger when the magnet is in the low position. See Section 5.3.

You can start the irrigation manually at any time by pressing the counter weights down. For example, if you want the irrigation to start at sunset each day, simply push the counter weights down at sunset.

6.4 How to adjust the water usage for SSIC

If you decide that your plants are not getting enough water, then turn the control dripper clockwise to increase the water usage.

If you decide that your plants are getting too much water, then turn the control dripper anticlockwise to decrease the water usage.

If you have a pressurised irrigation system with pressure compensating drippers, you should replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2).

When you adjust the irrigation frequency by changing the evaporator, the water usage will also change. However, when you adjust the water usage by adjusting the control dripper, the irrigation frequency does not change. Therefore, it is recommended that you adjust the irrigation frequency before you adjust the water usage.

6.5 Key features of SSIC

1. Completely automatic
2. No electricity is needed (no batteries, no solar panels, no computers, and no electronics)
3. You can adjust the water usage by adjusting the control dripper
4. You can adjust the irrigation frequency by changing the evaporator
5. Adjusting the control dripper does not change the irrigation frequency
6. Changing the evaporator does not change the water usage
7. The irrigation frequency and the water usage are directly proportional to the net evaporation rate (that is, evaporation minus rainfall
8. Responds appropriately when there is an unexpected heat wave
9. When it rains, water enters the evaporator and delays the start of the next irrigation
10. Water usage is independent of the water supply pressure
11. Uses much less water without affecting the yield
12. It is incredibly simple and low tech and so there are fewer things to go wrong
13. Provided you have a continuous water supply, you can leave your irrigation application unattended for weeks on end
14. Can be used for any irrigation application that uses a non-latching solenoid valve.

2.1 Introduction to manual measured irrigation

It is assumed that a smallholder is using drip irrigation (either pressurised or gravity feed) on a garden or a small plot of land.

To install manual measured irrigation, all that is needed is an evaporator and an adjustable dripper.

The **evaporator** is any container with vertical sides, with a surface area of at least 0.05 m^2, and a depth of at least 0.1 m.

Examples of suitable evaporators

Any **adjustable dripper** may be used. Examples of an adjustable dripper are Claber 91214 adjustable dripper and Claber 91225 adjustable dripper.

Claber 91214 adjustable dripper

Claber 91225 adjustable dripper

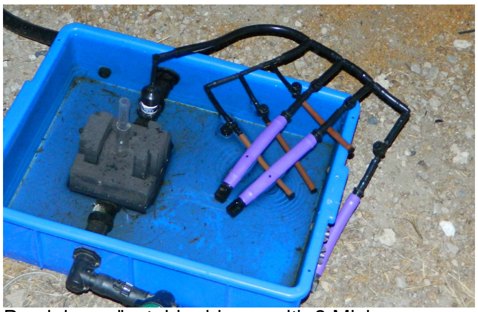
Claber 912014 adjustable dripper can be purchased from the Online Shop at the Measured Irrigation website.

2.2 How to make a precision adjustable dripper

Adjustable drippers do not normally indicate the flow rate when you adjust the dripper. Furthermore, some adjustable drippers do not deliver a consistent flow rate for a particular setting of the adjustable dripper at a particular pressure. You can avoid such problems by making your own precision adjustable dripper using a combination of non adjustable drippers.

You can make your precision adjustable dripper using three Netafim Miniscape (Landline 8) drippers and three Netafim Bioline (Landline purple) drippers (see Section 1.4). Each dripper should have a separate control valve so that you can adjust the precision adjustable dripper by selectively turning the control valves off or on. The precision adjustable dripper can be adjusted to deliver the following flow rate at 100 kPa:

2 lph, 4 lph, 6 lph, 8 lph, 10 lph, 12 lph, 14 lph, 16 lph. 18 lph, 20 lph, 22 lph, 24 lph, 26 lph, 28 lph, 30 lph



Precision adjustable dripper with 3 Miniscape drippers and 3 Bioline drippers.

You can also make your precision adjustable dripper using Netafim Landline 12 drippers. By using three drippers with a flow rate of 1 lph (at 100 kPa) and three drippers with a flow rate of 4 lph (at 100 kPa), the precision adjustable dripper can be adjusted to deliver the following flow rate at 100 kPa:

1 lph, 2 lph, 3 lph, 4 lph, 5 lph, 6 lph, 7 lph, 8 lph, 9 lph, 10 lph, 11 lph, 12 lph, 13 lph, 14 lph, 15 lph

If you have a pressurised irrigation system with pressure compensating drippers, you should make your own precision adjustable dripper using a combination of pressure compensating drippers with different flow rates.

2.3 Instructions for installing manual measured irrigation

Step 1. Draw a line on the inside of the evaporator about 1.5 cm below the overflow level. This line corresponds to the high level.

Draw a line on the inside of the evaporator about 1.5 cm below the overflow level

Step 2. Connect the adjustable dripper to the irrigation system and position the evaporator so that the adjustable drip drips water into the evaporator during irrigation. The adjustable dripper should be at the same level as the irrigation drippers. The adjustable dripper is called the **control dripper**.

The adjustable dripper can be connected to a drip line using a Tee

Cut the drip line so that you can connect the Tee

Connect the Tee

The adjustable drip drips water into the evaporator during irrigation

Step 3. Place a measuring container under one of the irrigation drippers.

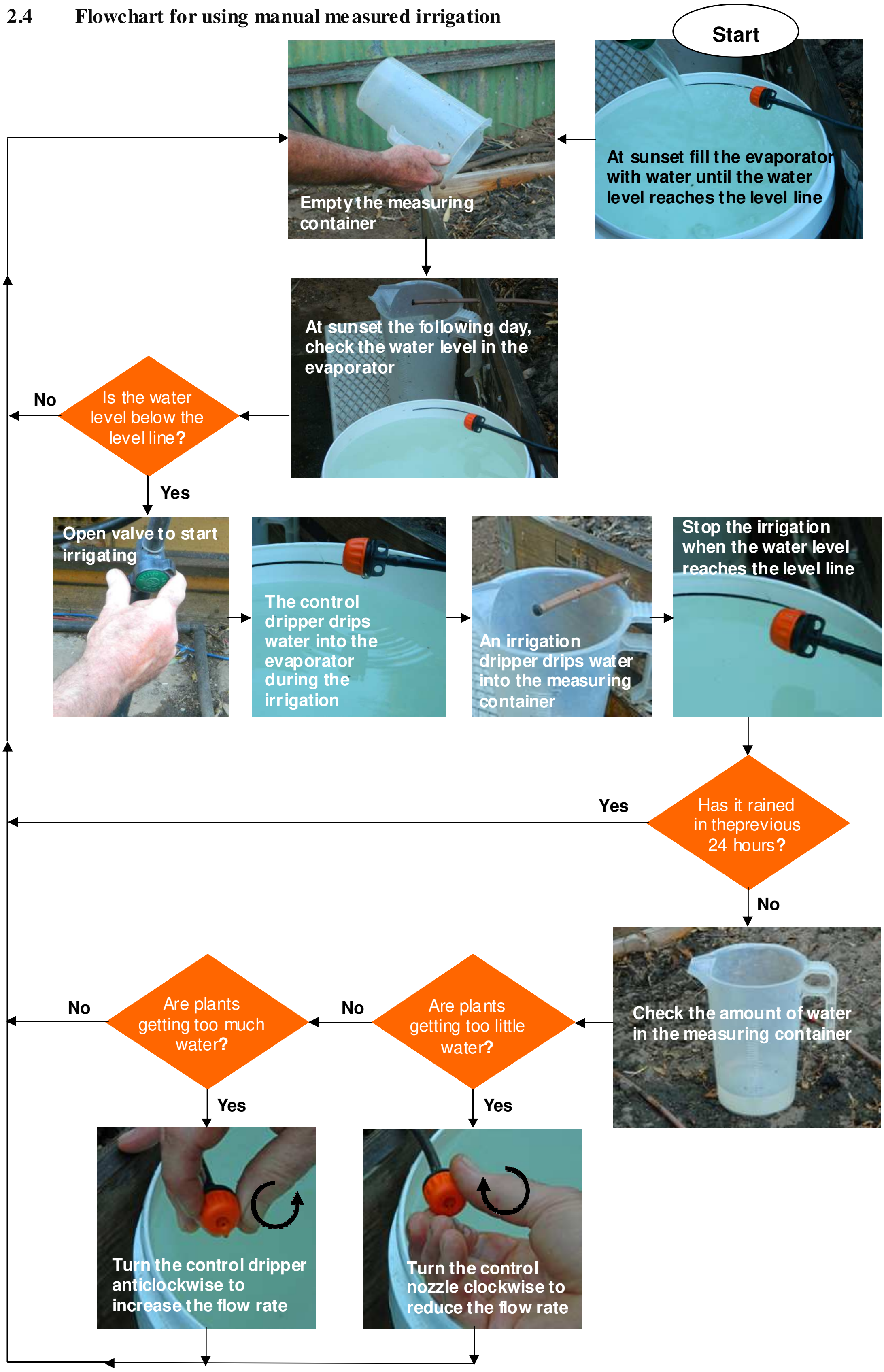
Place a measuring container under one of the irrigation drippers

Step 4. Adjust the control dripper so that flow rate is about the same as the flow rate of the irrigation drippers. Make sure that there is no air in the tube connected to the control dripper.

Adjust the control dripper so that flow rate is about the same as the flow rate of the irrigation drippers

Step 5. You may wish to protect the evaporator to prevent animals drinking the water, but make sure that you do not impede the evaporation (chicken wire is ideal).

2.4 Flowchart for using manual measured irrigation



If you have a pressurised irrigation system with pressure compensating drippers, you should replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2). You can alter the water usage by either adjusting the precision adjustable dripper or changing the surface area of evaporation.

If your plants require less frequent watering, you may choose not to irrigate on certain evenings. For example, at sunset one day the water level is below the high level and you decide not to irrigate. At sunset the following day the water level will have fallen even further, and so when you irrigate the irrigation volume will be the sum of the irrigation volumes for both days. Changing the irrigation frequency does not affect the total amount of water used for irrigation during the growing season.

If the garden requires more frequent watering, you may choose to irrigate at the middle of the day as well as at sunset (for example, if the weather is very hot and dry).

Manual measured irrigation can be used for sprinkler irrigation as well as drip irrigation.

Garden beds being irrigated by manual MI

Chapter 3. Unpowered Measured Irrigation Controller (UMIC)

3.1 Introduction to Unpowered Measured Irrigation Controller (UMIC)

It is assumed that a smallholder is using drip irrigation (either pressurised or gravity feed) on a garden or a small plot of land. Using the Unpowered Measured Irrigation Controller (UMIC), you can upgrade your drip irrigation system so that all your plants are irrigated automatically. The water supply pressure should be at least 10 kPa (1 metre head). Provided you have a continuous water supply to UMIC, you can leave your garden unattended for weeks on end. This will allow you to become involved in other activities away from the garden; for example, travelling to the market to sell your produce.

It is recommended that you watch the YouTube video Unpowered Measured Irrigation Controller.

UMIC can be used for sprinkler irrigation as well as drip irrigation.

The Unpowered Measured Irrigation Controller (UMIC) can be purchased from the Online Shop at the Measured Irrigation website https://www.measuredirrigation.com/shop-1.

Unpowered Measured Irrigation Controller (UMIC)

Measured irrigation is a new method of irrigation scheduling that responds to the prevailing weather conditions. This means that you use much less water without affecting the yield.

All of the plants in the three photos below are being irrigated automatically by one UMIC.

How large can the plot be?

It is assumed that the smallholder has already established a drip irrigation system. Provided that the drip irrigation system is already working effectively, you can use one or more UMIC's to automate the irrigation system for any size plot. For irrigation systems that require a large flow rate, you can use a Hi flow Unpowered Measured Irrigation Controller (HUMIC, see Chapter 4) or you can use a Smart Solenoid Irrigation Controller (see Chapters 5 and 6).

3.2 Instructions for installing the Unpowered Measured Irrigation Controller (UMIC)

Installing the Unpowered MI Controller is incredibly simple. Start with any drip irrigation application, either pressurised or gravity feed. Before installing the controller, it is assumed that the irrigation is operated manually by opening and closing the main valve.

Start with any drip irrigation application

Step 1. Position the evaporator in a suitable location so that the evaporation matches the evaporation in your garden.

Step 2. Connect the water supply to the inlet of the UMIC (the inlet is on the opposite side to the adjustable control dripper).

Step 3. Connect the UMIC outlet (next to the adjustable control dripper) to the irrigation zone.

Step 4. Position the float shaft so that it points vertically up. Be very careful when adjusting the float shaft to avoid placing any stress on the fragile plastic float shaft. Position the adjustable control dripper so that it will drip water into the evaporator during the irrigation.

Float shaft must be vertical

Step 5. For gravity feed application you may need to adjust the height of the evaporator so that the control dripper is at the same level as the irrigation drippers. Use a spirit level to ensure that the evaporator is horizontal. Then use the spirit level to ensure that the float shaft is vertical. The float shaft must be vertical so that there is minimal friction between the float and the float shaft.

Use a spirit level to ensure that the float shaft is vertical

Step 6. Slide the float over the float shaft so that the clear tube attached to the float is uppermost

Slide the float over the float shaft

Step 7. Turn on the water supply and the irrigation should start. The adjustable control dripper drips water into the evaporator.

Step 8. Adjust the control dripper so that flow rate is about the same as the flow rate of the irrigation drippers.

Adjust the control dripper

Step 9. Fill the evaporator with water until the float jumps up as the magnetic valve closes.

Fill the evaporator

Step 10. The float falls as water slowly evaporates from the evaporator. When the float reaches the low level, the irrigation starts automatically. The float rises as the control dripper drips water into the evaporator. When the float reaches the high level the irrigation stops automatically. The cycle continues indefinitely.

The irrigation starts when the float reaches the low level

The irrigation stops when the float reaches the high level

Step 11. Adjust the control dripper to suit the water requirements of your plants

Adjust the control dripper

Step12. You may wish to protect the evaporator to prevent animals drinking the water, but make sure that you do not impede the evaporation (chicken wire is ideal).

UMIC is completely automatic and does not need any electricity. Furthermore, it is a smart controller because the water usage for each dripper is controlled by the prevailing weather conditions. In fact, the water usage (litres per week for example) is directly proportional to the net evaporation rate (that is, evaporation minus rainfall). You can adjust the water usage by adjusting the control dripper. You can adjust the irrigation frequency by adjusting the slides on the float.

Most irrigation controllers need to be programmed and so they cannot respond to an unexpected heat wave. UMIC responds to an unexpected heat wave. If the evaporation rate doubles then so does the water usage.

When it rains water enters the evaporator and delays the start of the next irrigation.

If your plants need more water, rotate the control dripper clockwise.
If your plants need less water, rotate the control dripper anticlockwise.

Replace the water and clean the UMIC regularly to remove algae and other contaminants.

Because UMIC is so simple, there are fewer things to go wrong.

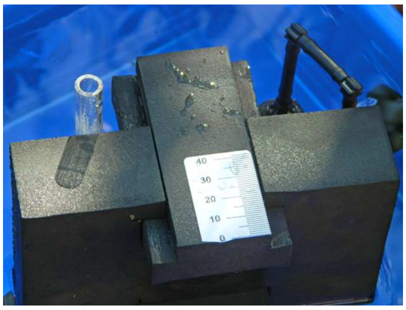
If you have a pressurised irrigation system with pressure compensating drippers, then you should replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2). You can alter the water usage by either adjusting the precision adjustable dripper or changing the surface area of evaporation.

3.3 How to adjust irrigation frequency for UMIC

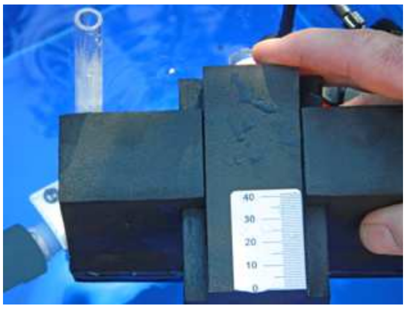
To increase the options for the irrigation frequency, the UMIC is provided with two floats, a large float and a small float.

Large float and small float

The float has two slides that can be moved up or down in order to adjust the irrigation frequency.



20 mm gap between the bottom of the float and the bottom of the slides



40 mm gap between the bottom of the float and the bottom of the slides

The following table shows the irrigation frequency for various positions of the slides for both the large float and the small float. The irrigation frequency is controlled by the net evaporation from the evaporator between irrigation events.

UMIC Table 1. Irrigation frequency

Gap in mm between the bottom of the float and the bottom of the slides	Net evaporation in mm between irrigation events with large float	Net evaporation in mm between irrigation events with small float
Slides removed	8	15
0	7	11
10	7	11
20	7	12
25	8	12
30	8	23
35	8	26
40	26	30
45	30	34
50	35	37
55	40	40
60	45	43

If the gap between the bottom of the large float and the bottom of the slides is 30 mm, then 8 mm of water has to evaporate between irrigation events.

Provided that the water level in the evaporator is between the low level and the high level, you can start the irrigation manually at any time by pressing the float down.

For example, you may wish to irrigate at sunset each day assuming that the water level is between the low level and the high level at sunset. Simply push the float down at sunset to start irrigating.

You can delay the next irrigation or stop the irrigation at any time by removing the float. The irrigation cannot start again until the float is replaced.

It is important to realise that when you adjust the irrigation frequency by adjusting the slides, the water usage (litres per week for example) does not change. Both the irrigation frequency and the water usage are directly proportional to the net evaporation rate.

3.4 How to adjust water usage for UMIC

Adjusting water usage by adjusting the control dripper

The term **water usage** refers to the number of litres per week (or litres per month) used by the irrigation system.

1. Position an empty measuring container under one of the irrigation drippers so that water drips into the container during the irrigation event.

2. At the end of the irrigation event check the amount of water in the measuring container. You may also wish to check the moisture in the soil.

3. If your plants are not getting enough water, turn the control dripper clockwise to reduce the flow rate of the control dripper.

4. If your plants are getting too much water, turn the control dripper anticlockwise to increase the flow rate of the control dripper.

changing the water usage does not change the irrigation frequency

changing the irrigation frequency does not change the water usage

This is important because it means that the water usage and the irrigation frequency can be adjusted independently.

Adjusting water usage by adjusting the surface area

You can also adjust the water usage by adjusting the surface area of evaporation.

To increase the water usage, select one or more containers with vertical sides and connect the containers to the UMIC evaporator. One way to connect containers is to drill in hole in the side of each container and to insert a rubber grommet into each hole. Insert a barbed connector into each grommet, and then use a length of flexible tube to connect the containers. The water level will be same in all containers and the surface area of evaporation is increased.

You can decrease the water usage by decreasing the surface area of evaporation (for example, by placing full bottles of water in the evaporator).

Pressure compensating drippers

If you have a pressurised irrigation system with pressure compensating drippers, then you should replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2). You can alter the water usage by either adjusting the precision adjustable dripper or changing the surface area of evaporation.

3.5 UMIC flow rate

UMIC can be used for pressures ranging from 10 kPa to 800 kPa.

The maximum UMIC flow rate is greater than 1500 lph (at 800 kPa).

The maximum UMIC flow rate when the input pressure is 100 kPa is greater than 500 lph.

The following table shows the maximum UMIC flow rate for gravity feed input pressures ranging from 10 kPa (1 metres head) to 20 kPa (2 metres head).

UMIC Table 2. Flow rate

Input pressure in kPa	Maximum UMIC flow rate in lph
10	206
11	221
12	235
13	248
14	260
15	272
16	283
17	293
18	303
19	312
20	321

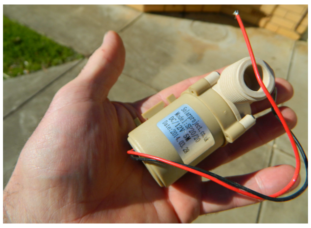
For some drip irrigation applications you may need more than one UMIC to provide an adequate flow rate from the drippers. Subdivide your irrigation application into the same number of zones as the number of UMIC's so that each zone has approximately the same water requirement. Within each zone the drippers should be at approximately the same level. For each zone install a UMIC as described in Section 3.2.

3.6 Key features of UMIC

1. UMIC is completely automatic
2. ~~No electricity is needed (no batteries, no solar panels, no computers, and no electronics)~~
3. UMIC is a smart irrigation controller – the irrigation is controlled by the prevailing weather conditions rather than a program
4. ~~You can adjust the water usage by adjusting the control dripper~~
5. You can adjust the irrigation frequency by adjusting the slides on the float
6. ~~Two floats are provided to increase your options for setting the irrigation frequency~~
7. ~~Adjusting the control dripper does not change the irrigation frequency~~
8. ~~Adjusting the float does not change the water usage~~
9. ~~UMIC can be used for both gravity feed and pressurised irrigation~~
10. ~~The irrigation frequency and the water usage are directly proportional to the net evaporation rate~~
11. ~~Responds appropriately when there is an unexpected heat wave~~
12. ~~When it rains, water enters the evaporator and delays the start of the next irrigation~~
13. ~~The water usage is independent of the water supply pressure~~
14. ~~UMIC uses much less water without affecting the yield~~
15. ~~UMIC is incredibly simple and low tech and so there are fewer things to go wrong~~
16. Provided you have a continuous water supply, you can leave your irrigation application unattended for ~~weeks on end~~
17. ~~UMIC is low cost with free delivery to any postal address in the world (see the Online Shop at the Measured Irrigation website https://www.measuredirrigation.com/shop-1)~~

3.7 Using a solar pump to fill a header tank

You can use a solar panel and a small submersible pump to automatically pump water from your farm pond (or from a rainwater tank, lake or river) to a header tank. The pump should be protected by a DC voltage converter (or voltage regulator).



Submersible baby pump

An ideal pump including a DC voltage converter is available from the Online Shop at the Measured Irrigation website https://www.measuredirrigation.com/shop-1

The pump is also available from Solar Project UK http://www.solarproject.co.uk/page2.html

This brilliant submersible baby pump is 12 volt 14 watt.

A 20 watt solar panel is required to operate the pump via the voltage converter without using a battery. You may need more than one pump to fill the header tank. For each additional pump you will require an additional 20 watt solar panel.

There is a major advantage of using multiple baby pumps compared with a single pump of equivalent power. If one of the pumps fails, the remaining pumps can continue to operate while you replace the broken pump.

The pumps will operate whenever there is sufficient direct sunlight on the solar panels. The overflow from the header tank should be returned to the farm pond.

When you submerge the pump (or pumps) in the farm pond, you should attach a filter to the inlet to the pumps. The inlet to the filter should be at least 15cm above the bottom of the pond to avoid clogging the filter with the sediment on the bottom of the pond.

How many pumps do you need?

If the head is less than 3.25 metres, then all the pumps should be connected in parallel. The flow rate with two pumps will be twice the flow rate of one pump. The flow rate with three pumps will be three times the flow rate of one pump, and so forth.

If the head is greater than 3.25 metres and you need a second pump, then the second pump should be connected in series with the first pump to create a **double pump.** If additional pumping is still required, you will need two additional pumps connected in series to create a second double pump. The second double pump should be connected in parallel with the first double pump.

Two pumps connected in series to create a double pump. A filter is connected to the inlet of the first pump.

When the head is at the critical level of 3.25 metres, two pumps connected in parallel have the same flow rate as two pumps connected in series, namely 520 lph

If you want to use fewer solar panels to provide sufficient power for your pumps, you will need to use a suitable battery and solar charge controller. The solar panels will then charge the battery during sunlight hours and the battery will be used to provide the power to the pumps as required.

For solar unpowered measured irrigation, see the **DIY Solar Measured irrigation Training Manual for Smallholders.**

Chapter 4. Hi-flow Unpowered Measured Irrigation Controller (HUMIC)

4.1 Introduction to Hi-flow Unpowered Measured Irrigation Controller (HUMIC)

The Unpowered Measured Irrigation Controller (UMIC) has a limited flow rate because the magnetic valve is quite small. HUMIC uses a much larger magnetic valve. HUMIC uses an Irritrol 2400 Series solenoid valve with 25mm BSP inlet and outlet. The water supply pressure should be between 69 kPa and 1034 kPa (10 – 150 psi). The maximum flow rate for HUMIC is 6800 lph (at 1034 kPa). Provided you have a continuous water supply to HUMIC, you can leave your irrigation application unattended for weeks on end.

HUMIC can be used for sprinkler irrigation as well as drip irrigation.

The Hi-flow Unpowered Measured Irrigation Controller (HUMIC) can be purchased from the Online Shop at the Measured Irrigation website https://www.measuredirrigation.com/shop-1 .

Hi-flow Unpowered Measured Irrigation Controller (HUMIC)

Unpowered Irritrol solenoid valve

How large can the plot be?

It is assumed that you have already established your irrigation system. Provided that the irrigation system is already working effectively, you can use one or more HUMIC's to automate the irrigation system for any size plot. For irrigation systems that require a very large flow rate, you can use a Smart Solenoid Irrigation Controller (see Chapters 5 and 6).

4.2 Instructions for installing the Hi-flow Unpowered Measured Irrigation Controller (HUMIC)

Installing the Hi-flow Unpowered MI Controller is incredibly simple. Start with any pressurised irrigation application. Before installing the controller, it is assumed that the irrigation is operated manually by opening and closing the main valve.

Step 1. Position the evaporator in a suitable location so that the evaporation matches the evaporation in your garden.

Step 2. Connect the water supply to the inlet of the HUMIC (the inlet is on the opposite side to the adjustable control dripper).

Step 3. Connect the HUMIC outlet (next to the adjustable control dripper) to the irrigation zone.

Step 4. Position the float over the solenoid and use the two wing nuts to secure the aluminium bar that prevents the float from jumping off the solenoid when the irrigation stops.


Position the float over the solenoid


Use the two wing-nuts to secure the aluminium bar

Step 5. Turn on the water supply and the irrigation should start. The adjustable control dripper drips water into the evaporator.

Step 6. Fill the evaporator with water until the float jumps up as the solenoid valve closes.


Fill the evaporator

Step 7. The float falls as water slowly evaporates from the evaporator. When the float reaches the low level, the irrigation starts automatically. The float rises as the control dripper drips water into the evaporator. When the float reaches the high level the irrigation stops automatically. The cycle continues indefinitely.


The irrigation starts when the float reaches the low level


The irrigation stops when the float reaches the high level

Step 8 Adjust the control dripper to suit the water requirements of your plants

Step 9. You may wish to protect the evaporator to prevent animals drinking the water, but make sure that you do not impede the evaporation (chicken wire is ideal).

Replace the water and clean the HUMIC regularly to remove algae and other contaminants.

Because the HUMIC is so simple, there are fewer things to go wrong.

~~4.3 How to adjust irrigation frequency for UMIC~~

~~To increase the options for the irrigation frequency, HUMIC is provided with the following float components:~~

Float with magnet (1 provided)

Float without magnet (2 provided)

Half float (2 provided)

Full slide (2 provided)

Cut slide (2 provided)

UV resistant rubber bands

The following images show the irrigation frequency for various float assemblies. The irrigation frequency is controlled by the net evaporation from the evaporator between irrigation events.

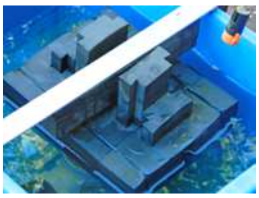
13mm net evaporation between irrigation events (zero gap between magnet and bottom of full slides)

19mm net evaporation between irrigation events (zero gap between magnet and bottom of full slides)

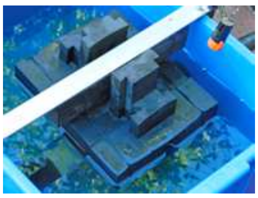
23mm net evaporation between irrigation events (zero gap between magnet and bottom of full slides)

26mm net evaporation between irrigation events (20mm gap between magnet and bottom of full slides)

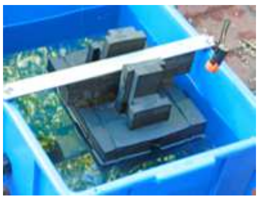
31mm net evaporation between irrigation events (zero gap between magnet and bottom of cut slides)



37mm net evaporation between irrigation events (10mm gap between magnet and bottom of cut slides)



44mm net evaporation between irrigation events (15mm gap between magnet and bottom of cut slides)



48mm net evaporation between irrigation events (20mm gap between magnet and bottom of cut slides)

Provided that the water level in the evaporator is between the low level and the high level, you can start the irrigation manually at any time by pressing the float down.

For example, you may wish to irrigate at sunset each day assuming that the water level is between the low level and the high level at sunset. Simply push the float down at sunset to start irrigating.

You can delay the next irrigation or stop the irrigation at any time by removing the float. The irrigation cannot start again until the float is replaced.

It is important to realise that when you adjust the irrigation frequency by adjusting the float, the water usage (litres per week for example) does not change. Both the irrigation frequency and the water usage are directly proportional to the net evaporation rate.

4.4 How to adjust water usage for the HUMIC

Adjusting water usage by adjusting the control dripper

If your plants are not getting enough water, turn the control dripper clockwise to reduce the flow rate of the control dripper. If your plants are getting too much water, turn the control dripper anticlockwise to increase the flow rate of the control dripper

changing the water usage does not change the irrigation frequency

changing the irrigation frequency does not change the water usage

This is important because it means that the water usage and the irrigation frequency can be adjusted independently.

Adjusting water usage by adjusting the surface area

You can also adjust the water usage by adjusting the surface area of evaporation.

To increase the water usage, select one or more containers with vertical sides and connect the containers to the HUMIC evaporator. One way to connect containers is to drill in hole in the side of each container and to insert a rubber grommet into each hole. Insert a barbed connector into each grommet, and then use a length of flexible tube to connect the containers. The water level will be same in all containers and the surface area of evaporation is increased.

You can decrease the water usage by decreasing the surface area of evaporation (for example, by placing full bottles of water in the evaporator).

Pressure compensating drippers

If you have a pressurised irrigation system with pressure compensating drippers, then you should replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2). You can alter the water usage by either adjusting the precision adjustable dripper or changing the surface area of evaporation.

4.5 Key features of HUMIC

1. HUMIC is completely automatic
2. No electricity is needed (no batteries, no solar panels, no computers, and no electronics)
3. HUMIC is a smart irrigation controller – the irrigation is controlled by the prevailing weather conditions rather than a program
4. You can adjust the water usage by adjusting the control dripper
5. You can adjust the irrigation frequency by adjusting the float
6. Adjusting the control dripper does not change the irrigation frequency
7. Adjusting the float does not change the water usage
8. The irrigation frequency and the water usage are directly proportional to the net evaporation rate
9. If there is an unexpected heat wave, HUMIC will respond appropriately
10. When it rains, water enters the evaporator and delays the start of the next irrigation
11. The water usage is independent of the water supply pressure
12. HUMIC uses much less water without affecting the yield
13. HUMIC is incredibly simple and low tech and so there are fewer things to go wrong
14. Provided you have a continuous water supply, you can leave your irrigation application unattended for weeks on end

Chapter 5. DIY Smart Irrigation Controller

5.1 Introduction to THE DIY Smart Irrigation Controller

I will show you how to convert a solenoid valve into an unpowered smart irrigation controller. An irrigation controller is called smart when the irrigation scheduling is controlled by the prevailing weather conditions. Many solenoid valves have a separate cylindrical solenoid that screws into the valve. Some suitable solenoid valves are shown below. Almost any non-latching solenoid valve used for irrigation can be converted into an unpowered smart irrigation controller. If you have a latching solenoid valve, you will need to replace the latching solenoid with a non-latching solenoid. If you have a large scale irrigation application you will need to use a high flow solenoid valve. For example, the Irritrol 200B Series is available with 1", 1½" or 2" connections.

A cylindrical solenoid screws into the solenoid valve

Toro solenoid valve

Orbit solenoid valve

Irritrol 2500 Series

Irritrol 2400/2600 Series

Irritrol 200B Series with 1", 1½" or 2" connections

This Do It Yourself project may become a time saving, water saving, money saving game changer for poor landholders.

It is recommended that watch the YouTube video DIY Smart Irrigation Controller.

Components of the DIY Smart Irrigation Controller

Components of the DIY Smart Irrigation Controller

~~To complete the project you will need the following components:~~
~~(unless specified, all pipes and pipe fittings are 15mm BSP)~~

Ferrite ring magnet assembly on the left
Rare earth disc magnet assembly on the right

- ~~a non latching solenoid valve~~
- ~~an adjustable irrigation dripper~~
- a galvanised cross
- ~~two galv pipes 500mm long~~
- ~~two galv pipes 200mm long~~
- ~~a galv pipe 300mm long~~
- ~~two galv tees~~
- ~~two galv nipples~~
- ~~a poly cap~~
- ~~a poly cut-off riser, 15mm female x 15mm male~~
- two galvanised flanges
- ~~eight galvanised nuts and bolts~~
- ~~a small platform for supporting the counter weights~~
- ~~a large platform for supporting the evaporator~~
- one or more evaporators (an evaporator is any container with vertical sides)
- ~~two 20 litre water containers~~
- ~~a ferrite ring magnet assembly or a rare earth disc magnet assembly~~

~~Ferrite ring magnet option~~

~~The ferrite ring magnet assembly has the following components:~~

- ~~a ferrite ring magnet 32mm ID, 70mm OD, 15mm thick. The OD and thickness can vary provided that the magnet is strong enough to activate the plunger in the solenoid valve.~~
- ~~a galvanised reducing socket 32mm x 20mm~~
- a poly or galvanised reducing nipple 20mm x 15mm
- ~~a 75mm length of 13mm straight poly pipe~~

Components of the ferrite ring magnet assembly

The ferrite ring magnet slides over the solenoid. This option is only appropriate when there is 25mm clearance around the solenoid. When the magnet is in the low position, the magnet lifts the plunger inside the solenoid and opens the valve. When the magnet is in the high position, the plunger is released and the valve closes.

When the magnet is in the low position, the magnet lifts the plunger inside the solenoid and opens the valve

When the magnet is in the high position, the plunger is released and the valve closes

Rare earth disc magnet option

The rare earth disc magnet assembly has the following components:

- a rare earth disc magnet 25.4mm (1 inch) diameter, 12.7mm (½ inch) thick
- a galvanised nipple
- a poly cut off riser, 15mm female x 15mm male

Components of the rare earth disc magnet assembly

The rare earth disc magnet is positioned directly above the solenoid. When the magnet is in the low position, the magnet lifts the plunger inside the solenoid and opens the valve. When the magnet is in the high position, the plunger is released and the valve closes.

When the magnet is in the low position, the magnet lifts the plunger inside the solenoid and opens the valve

When the magnet is in the high position, the plunger is released and the valve closes

Smart Solenoid Irrigation Controller

If you are not interested in the DIY project, you can purchase the Smart Solenoid Irrigation Controller from the Online Shop at the Measured Irrigation website.

5.2 How to assemble the DIY Smart Irrigation Controller

I will now give you step by step instructions for assembling the DIY Smart Irrigation Controller.

~~Step 1 Assemble the balance bar by screwing the two 500mm pipes and the two 200mm pipes into the cross.~~

Step 2 Screw the tees onto the ends of the balance bar.

~~Step 3 Screw the 300mm pipe into one of the tees and then screw the cap onto the pipe.~~

Step 4 Screw one nipple into the tee connected to the 300mm pipe and screw other nipple into the other tee.

~~Step 5 Use 4 bolts to connect one flange to the centre of one of the platforms. Connect the other flange to the centre of the other platform.~~

~~Step 6 Screw the large platform onto the nipple opposite the 300mm pipe. Screw the small platform onto a nipple at the other end of the balance bar.~~

Step 7 (ferrite ring magnet assembly)

Screw the reducing nipple into the galvanised reducing socket. Insert the 75mm length of 13mm straight poly pipe into the reducing socket so that the end of the poly pipe is 10mm inside the reducing socket. Use contact adhesive to securely attach the ferrite ring magnet to the reducing socket.

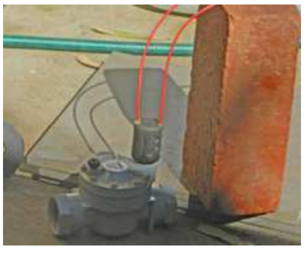
Step 7 (rare earth disc magnet assembly)

Cut the poly cut-off riser so that it is 28mm long. Screw the cut-off riser onto the galvanised nipple. Attach the rare earth disc magnet to the galvanised nipple (no adhesive is required because the rare earth magnet is so strong).

Step 8 Screw the ferrite ring magnet assembly or the rare earth disc magnet assembly onto the nipple opposite the small platform.

Step 8 Use the two water containers to support the balance bar. Stabilise the containers by filling them with water. The height of the balance bar should be about 330mm.

Step 9 Cut off the two electrical wires connected to the solenoid (remember that the irrigation controller is unpowered)



Step 10 Install the solenoid valve and position the balance bar so that when the magnet assembly is in the high position, the balance bar is level and the top of the solenoid is directly below the magnet assembly

Step 11 Place the evaporator on the large platform and add water until the depth is at least 20mm.

Step 12 Place counter weights on the small platform until the magnet assembly falls from the high position to the low position thus opening the valve.

Step 13 Slowly add water to the evaporator until the magnet assembly rises from the low position to the high position.

Step 14 (ferrite ring magnet assembly)

When the ferrite ring magnet assembly is in the high position, the top of the solenoid should be 10mm inside the ring magnet. Attach a poly cut off riser to the 300mm pipe to increase the length of the pipe as required. Make fine adjustments by screwing or unscrewing the ring magnet assembly, the 300mm pipe, the cut-off riser, or the cap.

When the ferrite ring magnet assembly is in the high position, the top of the solenoid should be 10mm inside the ring magnet

Step 14 (rare earth disc magnet assembly)

When the rare earth disc magnet assembly is in the high position, the top of the solenoid should be 20mm below the magnet. Attach a poly cut off riser to the 300mm pipe to increase the length of the pipe as required. Make fine adjustments by screwing or unscrewing the disc magnet assembly, the 300mm pipe, the cut-off riser, or the cap.

When the rare earth disc magnet assembly is in the high position, the top of the solenoid should be 20mm below the magnet

Step 15 Connect the inlet of the solenoid valve to the water supply, and connect the outlet of the solenoid valve to the irrigation application. Turn on the water supply.

Connect the inlet of the solenoid valve to the water supply

Connect the outlet of the solenoid valve to the irrigation application

Step 16 Position the adjustable dripper so that it will drips water into the evaporator during the irrigation.

Step 17 Water slowly evaporates from the evaporator until the weight of the water in the evaporator is light enough for the magnet assembly to fall and the irrigation starts automatically.

Step 18 Water drips into the evaporator until the weight of the water in the evaporator is heavy enough for the magnet assembly to rise and the irrigation stops automatically. The cycle continues indefinitely.

Step 19 The irrigation controller should be protected from birds and other animals.

Designing the balance bar

Depending on your application and your choice of magnet assembly, you may wish to use different lengths of pipe for the balance bar. To reduce the weight of water required to open and close the valve, you can increase the length of the pipe connected to the large platform, and/or decrease the length of the pipe connected to the small platform.

Buying the components for the DIY Smart Irrigation Controller

The DIY Smart Irrigation Controller is Do-It-Yourself and so you can minimise the cost by using locally sourced components. It will be even cheaper if you can find suitable used complements.

Some of the components are available in kit form from the Online Shop at the Measured Irrigation website https://www.measuredirrigation.com/shop-1

Two kits are available with free delivery to any postal address in the world.

DIY Smart Irrigation Controller Kit with ferrite ring magnet assembly

The components of the kit are:

- an adjustable irrigation dripper
- two galvanised flanges
- a poly cap
- a poly cut off riser, 15mm female x 15mm male
- a ferrite ring magnet assembly

DIY Smart Irrigation Controller Kit with rare earth disc magnet assembly

The components of the kit are:

- an adjustable irrigation dripper
- two galvanised flanges
- a galvanised cross
- a poly cap
- a poly cut off riser, 15mm female x 15mm male
- a rare earth disc magnet assembly

5.3 How to adjust the irrigation frequency for the DIY Smart Irrigation Controller

You can adjust the irrigation frequency by using an evaporator with a different surface area of evaporation. In fact the irrigation frequency is directly proportional to the surface area of the evaporator. For example, if you double the surface area you double the irrigation frequency. If you use a smaller evaporator you reduce the irrigation frequency.

Use a smaller evaporator to reduce the irrigation frequency

Another way to adjust the irrigation frequency is to change the ratio of the lengths of the two pipes used to make the balance bar. For example, if you reduce the length of the pipe connecting the tee to the small platform, the irrigation frequency will increase.

If you are using the rare earth disc magnet assembly, you can increase the irrigation frequency by inserting spacers (coins for example) between the solenoid and the magnet. The spacers should be made from a material that is not attracted to the magnet. Note that the thickness of the spacers should not prevent the magnet from lifting the plunger when the magnet is in the low position.

Spacer on top of the solenoid

If you are using a particular evaporator, you will find that the irrigation frequency for the rare earth disc magnet assembly is significantly less than the irrigation frequency for the ferrite ring magnet assembly.

You can start the irrigation manually at any time by pressing the counter weights down. For example, if you want the irrigation to start at sunset each day, simply push the counter weights down at sunset.

5.4 How to adjust the water usage for the DIY Smart Irrigation Controller

If you decide that your plants are not getting enough water, then turn the control dripper clockwise to increase the water usage.

If you decide that your plants are getting too much water, then turn the control dripper anticlockwise to decrease the water usage.

If you have a pressurised irrigation system with pressure compensating drippers, you should replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2).

If you adjust the irrigation frequency by changing the lengths of the pipes in the balance bar, the water usage will also change. However, when you adjust the water usage by adjusting the control dripper, the irrigation frequency does not change. It is therefore recommended that you adjust the irrigation frequency before you adjust the water usage.

5.5 Key features of the DIY Smart Irrigation Controller

1. Completely automatic
2. No electricity is needed (no batteries, no solar panels, no computers, and no electronics)
3. You can adjust the water usage by adjusting the control dripper
4. You can adjust the irrigation frequency by changing the evaporator
5. Use for both gravity feed and pressurised irrigation
6. The irrigation frequency and the water usage are directly proportional to the net evaporation rate (that is, evaporation minus rainfall
7. Responds appropriately when there is an unexpected heat wave
8. When it rains, water enters the evaporator and delays the start of the next irrigation
9. Water usage is independent of the water supply pressure
10. Uses much less water without affecting the yield
11. It is incredibly simple and low tech and so there are fewer things to go wrong
12. Provided you have a continuous water supply, you can leave your irrigation application unattended for weeks on end
13. The DIY Smart Irrigation Controller is Do It Yourself and so you can minimise the cost by using locally sourced components. It will be even cheaper if you can find suitable used complements.
14. Use for any size irrigation application provided that the solenoid valve has a large enough flow rate.

Chapter 6. Smart Solenoid Irrigation Controller (SSIC)

6.1 Introduction to Smart Solenoid Irrigation Controller

In Chapter 5 we presented a Do-It-Yourself approach to making your own smart irrigation controller. In this chapter we introduce the Smart Solenoid Irrigation Controller, a product can be ordered from the Online Shop at the Measured Irrigation website: https://www.measuredirrigation.com/shop-1

The Smart Solenoid Irrigation Controller enables you to transform any non-latching irrigation solenoid into a smart irrigation controller. The critical component of the SSIC is a rare earth disc magnet 25.4mm (1 inch) diameter and 12.7mm (½ inch) thick. If you have a latching solenoid valve, you will need to replace the latching solenoid with a non-latching solenoid.

SSIC can be used for sprinkler irrigation as well as drip irrigation.

Smart Solenoid Irrigation Controller

6.2 How to assemble and install the SSIC

Step 1 Screw the two threaded pipes into the cross.

~~Step 2 Screw the small platform into the tee above the magnet, and screw the large platform into the other tee.~~

Step 3 Position the magnet so that it is above the solenoid. ~~The SSIC pivots on the caps on the two pipes below the elbows. Make sure that the caps have a secure footing so that the pivot points are fixed. Use poly cut-off risers and lengths of galvanised pipe to ensure that the magnet is 20mm above the solenoid. Screw or unscrew the connections to make fine adjustments.~~

Position the magnet so that it is above the solenoid

~~Step 4 Place the evaporator on the large platform and add water until the depth is at least 20mm.~~

~~Step 5 Turn on the water supply to the solenoid valve.~~

Add water to the evaporator until the depth is a least 20mm

~~Step 6 Place counter weights on the small platform until the magnet falls from the high position to the low position. The solenoid valve opens and the irrigation starts. House bricks make good counter weights. If the solenoid valve does dot open you should cut off the two electrical wires connected to the solenoid. This will allow the magnet to get closer to the solenoid.~~

The magnet falls from the high position to the low position

The solenoid valve opens and the irrigation starts

Step 7 Slowly add water to the evaporator until the magnet rises from the low position to the high position. The solenoid valve closes and the irrigation stops. If the solenoid valve does not close, screw the connections until the magnet is sufficiently far away from the solenoid for the solenoid valve to close.

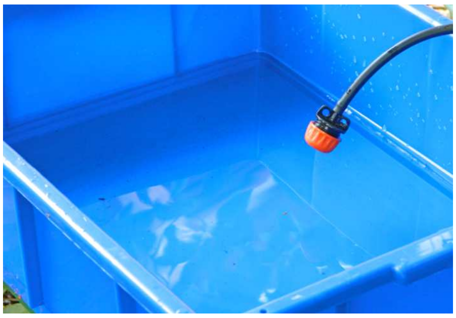
The solenoid valve closes and the irrigation stops

The solenoid valve closes and the irrigation stops

Step 8 Position the adjustable dripper so that it will drips water into the evaporator during the irrigation.

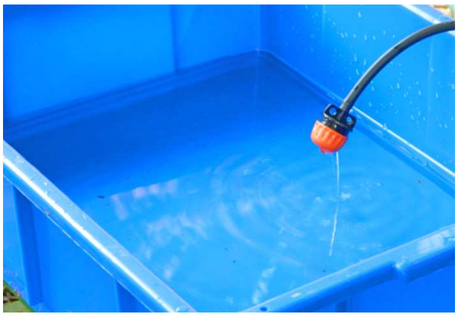
Step 9 Water slowly evaporates from the evaporator until the weight of the water in the evaporator is light enough for the magnet to fall from the high position to the low position and the irrigation starts automatically.

Water slowly evaporates from the evaporator until the weight of the water in the evaporator is light enough for the magnet to fall from the high position to the low position



Position the adjustable dripper so that it will drips water into the evaporator

Step 10 Water drips into the evaporator until the weight of the water in the evaporator is heavy enough for the magnet to rise from the low position to the high position and the irrigation stops automatically. The cycle continues indefinitely.



Water drips into the evaporator

The weight of the water in the evaporator is heavy enough for the magnet to rise from the low position to the high position

Step 11 The evaporator should be protected from birds and other animals. You may need to use something to prevent rainwater collecting in the depressions in the platforms.

Adjusting the overflow level

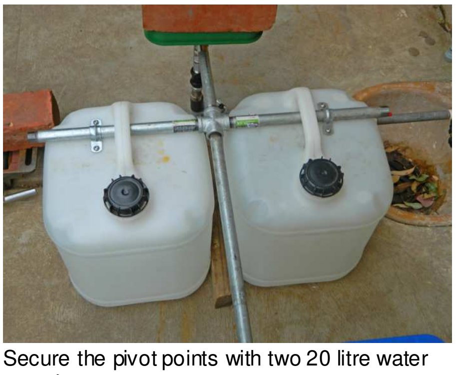
When it rains water enter the evaporator and delays the start of the next irrigation. If there is sufficient rain the evaporator will eventually overflow. If the overflow level is too high, the delay before the next irrigation may be unacceptably long. The overflow level can be adjusted as follows:

1. Drill a hole near the bottom of the evaporator.
2. Insert a rubber grommet into the hole.
3. Insert a barbed elbow into the hole.
4. Connect a short length of poly pipe to the barbed elbow.
5. Rotate the elbow so that the end of the poly pipe is set at the desired overflow level.

Rotate the elbow so that the end of the poly pipe is set at the desired overflow level

Securing the pivot points for the balance bar

One way to secure the pivot points for the balance bar is to use two 20 litres water containers. Disconnect the two 150 mm pipes from the balance bar and replace them with the two 300mm pipes. Support the balance bar with the water containers and use two saddle clamps to attach the 300 pipes to the top of the water containers. Fill the containers with water. Depending on the application, you may wish to replace the 200mm pipe connecting the small platform to the cross with a longer pipe.



Secure the pivot points with two 20 litre water containers

6.3 How to adjust the irrigation frequency for SSIC

You can adjust the irrigation frequency by using an evaporator with a different surface area for evaporation. In fact the irrigation frequency is directly proportional to the surface area of the evaporator. For example, if you double the surface area you double the irrigation frequency. If you use a smaller evaporator you reduce the irrigation frequency.

Use a larger evaporator to increase the irrigation frequency

Use a smaller evaporator to reduce the irrigation frequency

You can increase the irrigation frequency by inserting spacers (coins for example) between the solenoid and the magnet. Before inserting the spacers you should cut off the two electrical wires connected to the solenoid. The spacers should be made from a material that is not attracted to the magnet. Note that the thickness of the spacers should not prevent the magnet from lifting the plunger when the magnet is in the low position. See Section 5.3.

You can start the irrigation manually at any time by pressing the counter weights down. For example, if you want the irrigation to start at sunset each day, simply push the counter weights down at sunset.

6.4 How to adjust the water usage for SSIC

If you decide that your plants are not getting enough water, then turn the control dripper clockwise to increase the water usage.

If you decide that your plants are getting too much water, then turn the control dripper anticlockwise to decrease the water usage.

If you have a pressurised irrigation system with pressure compensating drippers, you should replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2).

6.5 Key features of SSIC

1. Completely automatic
2. No electricity is needed (no batteries, no solar panels, no computers, and no electronics)
3. You can adjust the water usage by adjusting the control dripper
4. You can adjust the irrigation frequency by changing the evaporator
5. Adjusting the control dripper does not change the irrigation frequency
6. Changing the evaporator does not change the water usage
7. The irrigation frequency and the water usage are directly proportional to the net evaporation rate (that is, evaporation minus rainfall
8. Responds appropriately when there is an unexpected heat wave
9. When it rains, water enters the evaporator and delays the start of the next irrigation
10. Water usage is independent of the water supply pressure
11. Uses much less water without affecting the yield
12. It is incredibly simple and low tech and so there are fewer things to go wrong
13. Provided you have a continuous water supply, you can leave your irrigation application unattended for weeks on end
14. Can be used for any irrigation application that uses a non latching solenoid valve.

Chapter 7. DIY solar measured irrigation

7.1 Introduction to the DIY Solar Drip Irrigation Kit

This chapter is for smallholders using gravity feed drip irrigation on a garden or a small plot of land. You can automate your drip irrigation system so that water is pumped automatically from your farm pond (or from a rainwater tank, lake or river) to the header tank. All your plants are irrigated automatically so you can leave your plot unattended for weeks on end. This will allow you to become involved in other activities away from the plot; for example, travelling to the market to sell your produce.

I recommend that you watch the YouTube video with the title DIY Solar Drip Irrigation Kit.

The DIY Solar Drip Irrigation Kit can be purchased online from the Measured Irrigation website: www.measuredirrigation.com.au. All the other parts required may be purchased locally (for example, a solar panel and a battery).

It is assumed that the depth of the farm pond is no more than 4 metres. The water supply pressure from the header tank should be at least 10 kPa (1 metre head).

Farm pond in Kenya for gravity feed drip irrigation

How large can the plot be?

This chapter assumes that the smallholder has already established a gravity feed drip irrigation system. Provided that the drip irrigation system is already working effectively, you can use the DIY Solar Drip Irrigation Kit and the MI Six Zone Adaptor to automate the irrigation system. Additional solenoid valves connected in parallel may be needed to provide adequate flow for your irrigation application. For irrigation systems that require a larger flow rate, the solenoid valve can be replaced by a solenoid valve with a higher flow rate. For example, check out this solenoid valve with a flow rate of 4500 lph at 20 kPa, and 10000 lph at 100 kPa:

https://www.aliexpress.com/item/1-NPT-12v-Solenoid-Water-Valve-2-Way-2-Position-Electric-Solenoid-Valve-Water-Air-Gas/579769104.html

This solenoid valve is also available from the Measured Irrigation website.

Depending of the duration of the irrigation event and the power requirements of the pump and the solenoid valves, you may need to upgrade the battery to a larger battery, and you may need to upgrade the solar panel to a larger solar panel. As the plot becomes larger (400 m^2, for example) you may need more than one DIY Solar Drip Irrigation Kit.

No-pump DIY Solar Drip Irrigation Kit

For some applications the water supply is higher than land to be irrigated, and so the land can be irrigated directly from the water supply. For such applications, a header tank and a pump are not needed. The kit contains only one float switch, and the irrigation controller is quite different to the one used for the kit with the pump.

The No-pump DIY Solar Drip Irrigation Kit can be purchased online from the Measured Irrigation website: www.measuredirrigation.com.au.

The No-pump DIY Solar Drip Irrigation Kit can also be used to upgrade pressurised irrigation systems to fully automated measured irrigation.

7.2 Contents of the DIY Solar Drip Irrigation Kit

As well as the User Manual, the kit includes the following components:

waterproof irrigation controller

light sensor

two float switches

solenoid valve with fittings to connect to19 mm poly pipe, and 2.5 metres of waterproof electrical cable

double pump (two pumps connected in series) with an inlet filter, fittings to connect to 19 mm poly pipe, and 9 metres of waterproof electrical cable

16 waterproof connectors for electrical wire

adjustable dripper

The kit does not include:

evaporator
battery
solar panel
extra 2-strand electrical cable.

7.3 Instructions for installing the DIY Solar Drip Irrigation Kit

Step 1. Connect the pump.

Remove the header tank inlet pipe from the farm pond and connect it to the outlet from the pump (note that the outlet from the pump is perpendicular to the shaft of the pump.

WARNING: The inlet and outlet of the pump are fragile, so be careful not to apply force to the inlet or outlet at any time.

Step 2. Install a float switch on the header tank.

Drill a 13 mm (half inch) hole in the side of the header tank so that the hole is about 1 cm lower than the inlet to the header tank. Install one of the float switches on the inside of the header tank so that the float shaft points down.

Float switch on the header tank is lower that the inlet

Float switch on the inside of the header tank with the float shaft pointing down

Step 3. Choose a suitable evaporator.

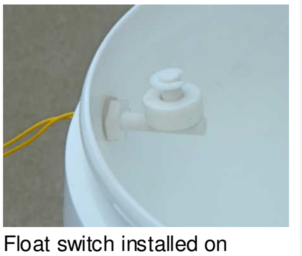
The **evaporator** is any container with vertical sides, with a surface area of at least 0.05 m^2, and a depth of at least 0.1 m. To adjust the water usage with higher precision it is recommended that you use an evaporator with a large surface area.

Evaporator

Step 4. Install the other float switch on the evaporator.

Drill a half inch (13 mm) hole in the side of the evaporator so that the centre of the hole is 3.5 cm lower than the overflow level for the evaporator. Install the other float switch so that the float shaft points up.

Drill a hole in the side of the evaporator



Float switch installed on evaporator with float shaft pointing up

Step 5. Install the solenoid valve.

Connect the solenoid valve at ground level to 19 mm poly pipe at both ends. Check the arrow on the bottom of the solenoid valve to ensure that the flow is in the correct direction. Position the solenoid valve so that the cover protects the solenoid from the weather.

Solenoid valve installed at ground level

Step 6. Purchase and install a solar panel (not in kit).

A 12 volt 20 watt solar panel should provide all the power required. You may purchase the solar panel either locally or online. You need to find a low cost method of mounting the solar panel. In the southern hemisphere the solar panel should face the sun when the sun is in the north. In the northern hemisphere the solar panel should face the sun when the sun is in the south. The ideal angle of the solar panel changes throughout the year. It is easy to adjust the orientation of the solar panel if it is mounted on a pole as shown.

Solar panel mounted on a pole

Step 7. Purchase a battery (not in kit).

A rechargeable 12 volt lead acid battery is required. You may be able to find a used car battery in good condition. If you buy a new battery then I recommend a sealed lead acid battery with a capacity of at least 7 amp hours and a standby voltage of at least 13.5 volts.

Note that the solar panel and the battery may be replaced by a 12V 5A power adaptor.

7 amp hour battery

Step 8. Connect the adjustable dripper.

Connect the adjustable dripper to the irrigation system and position the evaporator so that the adjustable dripper drips water into the evaporator during irrigation. The adjustable dripper should be at the same level as the irrigation drippers. The adjustable dripper is called the **control dripper**.

The adjustable dripper can be connected to a drip line using a Tee

Cut the drip line so that you can connect the Tee

Connect the Tee

The adjustable drip drips water into the evaporator during irrigation

Step 9. Measuring container

Place a measuring container under one of the irrigation drippers.

Measuring container under one of the irrigation drippers

Step 10. Adjust the control dripper.

Adjust the control dripper so that flow rate is about the same as the flow rate of the irrigation drippers. Make sure that there is no air in the tube connected to the control dripper.

Adjust the control dripper so that flow rate is about the same as the flow rate of the irrigation drippers

Step 11. You may wish to protect the evaporator to prevent animals drinking the water, but make sure that you do not impede the evaporation (chicken wire is ideal).

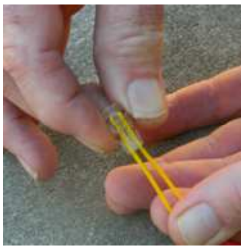
Step 12. Connect the irrigation controller.

The irrigation controller has 10 colour-coded wires which need to be connected to the various components as follows:

Connect the **red** wire to the positive terminal on the battery.
Connect the **black** wire to the negative terminal on the battery.
Connect the **dark blue** wire to the positive wire form the solar panel.
Connect the **dark green** wire to the negative wire form the solar panel.
Connect the **purple** wire to one of the wires from the float switch on the evaporator.
Connect the **pink** wire to the other wire from the float switch on the evaporator.
Connect the **grey** wire to one of the wires from the float switch on the header tank.
Connect the **brown** wire to the other wire from the float switch on the header tank.
Connect the **orange** wire to the yellow wire from the pump.
Connect the **light pink** wire to the white wire from the pump.

16 waterproof connectors for electrical wire are provided. There is no need to strip the wires before inserting them into the connector. The connection is made by using a pair of pliers (for example) to push down the red cap so that the gel is squeezed out of the connector.

Wires are not stripped before insertion



Insert wires (2 or 3) into connector

Use pliers to push down the red cap

Gel is squeezed out of connector

If you are using a power adaptor instead of a battery, connect the **red** wire to the positive wire from the power adaptor, and connect the **black** wire to the negative wire from the power adaptor. It is recommended that you disconnect the red, black, light yellow, and light green wires from the solar charge controller inside the irrigation controller. Then connect the red wire to the light yellow wire, and the black wire to the light green wire.

Step 13. Fill the evaporator.

Fill the evaporator with water until the water level is just below the float switch. (Replace the water and clean the evaporator regularly to remove algae and other contaminants).

Fill the evaporator with water until the water level is just below the float switch

Water level just below the float switch

Step 14. Submerge the pump in the farm pond

The pump inlet should be at least 15cm above the bottom of the pond to avoid pumping sediment from the bottom of the pond and clogging the inlet filter. If clogging of the filter becomes a problem, you may wish to install a larger filter.

The inlet/outlet manifold on each pump may break if too much force is applied to the pump. If you break the inlet/outlet manifold, a replacement manifold (or a replacement pump) can be purchased online from the Solar Project UK: www.solarproject.co.uk.

The pump is also available from the Measured Irrigation website: www.measuredirrigation.com.au.

The two pumps provided in the kit are connected in series. If the water level in the header tank is less than 3.25 metres higher than the water level in the farm pond, rainwater tank, lake or river, then the two pumps should be connected in parallel rather than in series.

7.4 How to use the DIY Solar Drip Irrigation Kit

The switch on the irrigation controller is a three position switch with UP (ON), CENTRE (OFF), and DOWN (ON night only).

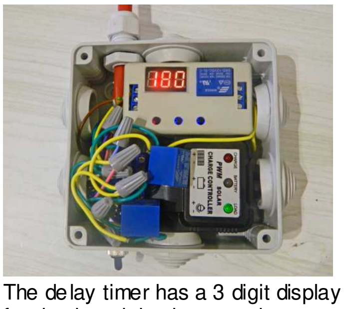
The switch on the irrigation controller has 3 positions: ON, OFF, ON night only

Turn the switch to the ON position (switch up) and the irrigation will start provided that the water level in the evaporator is below the float switch. The irrigation stops automatically when the water level raises the float on the float switch. With the switch in the ON position, the irrigation will start automatically as soon as the water level in the evaporator has fallen below the float switch.

With the switch in the ON night only position (switch down), the irrigation is restricted to dark hours only. If you do not wish to irrigate during the heat of the day, turn the switch to the ON night only position (switch down) so that the irrigation starts automatically at sunset (provided that the water level has fallen below the float switch).

To stop the irrigation at any time, turn the switch to the OFF position.

When the water level in the header tank falls below the float switch, the float switch activates a delay timer inside the irrigation controller and 3 minutes later the pump starts working. When the water level reaches the float switch the pump stops automatically.



The delay timer has a 3 digit display for the time delay in seconds

The operation of the pump is independent of the position of the switch on the irrigation controller.

The delay timer is inside the irrigation controller. You can access the delay timer by removing the four screws and removing the cover. The time delay can be adjusted by pressing the buttons on the delay timer. The delay timer has a 3 digit display for the time delay in seconds (preset to 180 seconds).

To change the time delay, press the middle button to select the digit you wish to change. The digit will flash to indicate that it is ready to be changed. Then press the right hand button to change the digit. When the time delay has been reset press the middle button until no digits are flashing.

Do not press the left hand button.

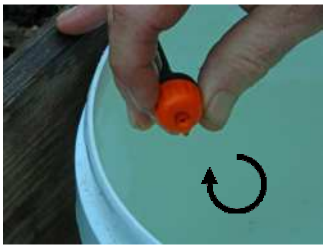
A solar charge controller is located inside the irrigation controller. One of the functions of the solar charge controller is to protect the battery from over-discharge. When the battery voltage is less than 10.8 volts, the solar charge controller isolates the battery so that the pump and solenoid valve stop operating. The over-discharge recovery voltage needs to be greater than 12.8 volts to allow the system to start working again.

7.5 How to use the control dripper to adjust water usage


1. Empty the measuring container before irrigation commences at sunset.


2. Position the measuring container under one of the irrigation drippers so that water drips into the container during the irrigation.


3. After sunrise the following morning, check the amount of water in the measuring container. You may also wish to check the moisture in the soil (see Irrigation scheduling for the DIY Solar Drip Irrigation Kit).


4. If your plants are not getting enough water, turn the control dripper clockwise to reduce the flow rate of the control dripper.


5. If your plants are getting too much water, turn the control dripper anticlockwise to increase the flow rate of the control dripper.

An alternative way to adjust the water usage is to change the surface area of the evaporator.


Garden beds being irrigated by the DIY Solar Drip Irrigation Kit

7.6 Additional Irrigation Zones

In some applications you may wish to use more than one irrigation zone. For example, different crops may require separate zones. On sloping ground it is preferable to have a number of irrigation zones where each zone is at a different level. For each additional zone you will need an evaporator and an adjustable control dripper.

If you are using a DIY Solar Drip Irrigation Kit you will need to purchase a **MI Six Zone Adaptor**. You will also need a solenoid valve, a float switch and an adjustable dripper for each additional zone.


MI Six Zone Adaptor


MI Six Zone Adaptor close-up

The MI Six Zone Adaptor allows you to irrigate up to six additional zones. The MI Six Zone Adaptor, additional solenoids valves, additional float switches and additional adjustable drippers are available from the Measured Irrigation website. www.measuredirrigation.com.au

The MI Six Zone Adaptor has 3 colour-coded wires (inside the red cable) which need to be connected to the irrigation controller as follows:

Connect the **yellow** wire to the purple wire from the irrigation controller.
Connect the **white** wire to the white wire from the irrigation controller.
Connect the **black** wire to the grey wire from the irrigation controller.

For each additional zone, the MI Six Zone Adaptor has 4 colour-coded wires (inside a blue cable) which need to be connected to the various components as follows:

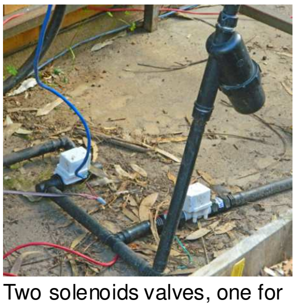
Connect the **blue** wire with the spade connection to one of the terminals on the solenoid valve for the zone.
Connect the **green** wire with the spade connection to the other terminal on the solenoid valve for the zone.
Connect the **red** wire to one of the wires from the float switch for the zone.
Connect the **black** wire to one of the other wire from the float switch for the zone.

For each additional zone, you will need to adjust the control dripper for the zone to adjust water usage for the zone (see Section 3.4).

If you are using the MI Six Zone Adaptor, an extra solar panel or an extra battery may be required.


Evaporator, float switch and control dripper for zone 1


Evaporator, float switch and control dripper for zone 2


Two solenoids valves, one for each zone


Garden beds in zone 2 being irrigated by the MI Six Zone Adaptor in conjunction with the DIY Solar Drip Irrigation Kit

7.7 Contents of the MI Upgrade Kit with Level Sensor

The MI Upgrade Kit with Level Sensor may be purchased from the Measured Irrigation website: www.measuredirrigation.com.au

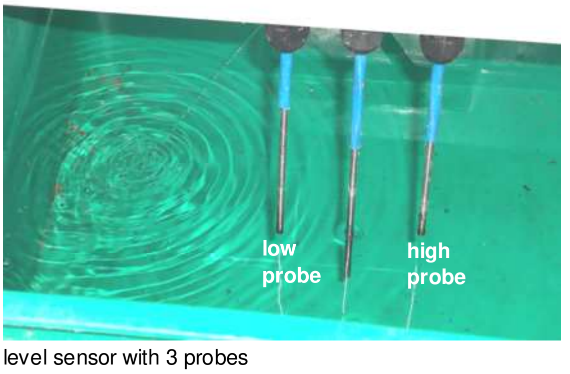
As well as this User Manual, the kit consists of the following components:

level sensor with 3 probes

MI upgrade kit adaptor

9 metres of 3-strand waterproof electrical irrigation cable

The level sensor has three probes as shown. During the irrigation event the water level rises as water slowly drips into the evaporator from the control dripper. When the water level reaches the high probe on the right the solenoid valve closes and the irrigation stops. The water level then falls due to evaporation until the water level is below the low probe on the left at which point the solenoid valve opens and the irrigation recommences. The middle probe is a reference probe. This cycle continues indefinitely.



level sensor with 3 probes

The volume of water required to raise the water level from the low probe level to the high probe level is called the **control volume**. It is also the volume of water that must evaporate between irrigation events. The control volume is determined by the surface area of evaporation and the gap between the high probe and the low probe. The length of the low probe and high probe are adjustable.

As well as being completely automatic, the irrigation frequency responds to the prevailing weather conditions. During very hot weather the evaporation rate will be much greater and so the irrigation frequency increases. On cool overcast days, the evaporation rate will be quite small and so the irrigation frequency decreases. The irrigation frequency can be changed by adjusting the gap between the low probe and the high probe.

7.8 Instructions for installing the MI Upgrade Kit with Level Sensor

Step 1. You may need to replace the evaporator if the level sensor does not rest on the evaporator with the probes clear of the bottom of the evaporator.

Step 2 The MI upgrade kit adaptor has 7 colour-coded wires which need to be connected as follows:

Connect the **red** wire to the grey wire from the irrigation controller.

Connect the **black** wire to the white wire from the irrigation controller.

Connect the **blue** wire to the purple wire from the irrigation controller (or to one of the red wire from the four-zone adaptor to upgrade a zone connected to the four-zone adaptor).

Connect the **green** wire to the pink wire from the irrigation controller (or to the corresponding black wire from the four-zone adaptor to upgrade a zone connected to the four-zone adaptor).

Connect the **white** wire to the white wire from the level sensor (reference probe).

Connect the **yellow** wire to the yellow wire from the level sensor (high probe).

Connect the **brown** wire to the black wire from the level sensor (low probe).

Step 3 Fill the evaporator with water until the water level is just below the low probe

Step 4. Start irrigating

Turn the switch the side if the irrigation controller to the ON position (switch up) and the irrigation will start. The irrigation stops automatically when the water level reaches the high probe. During the day the water level in the evaporator falls due to evaporation. The switch is a three position switch with UP (ON), CENTRE (OFF), DOWN (ON night only).

The switch on the irrigation controller has 3 positions

With the switch in the up position (ON), the irrigation will start automatically as soon as the water level in the evaporator has fallen below the low probe.

With the switch in the down position (ON night only), the irrigation is restricted to dark hours only. If you do not wish to irrigate during the heat of the day, turn the switch to the ON night only position (switch down) so that the irrigation starts automatically at sunset (provided that the water level is below the low probe).

To stop the irrigation at any time, turn the switch to the OFF position.

7.9 Troubleshooting

Problem	Possible cause	Solution
Pump is not working	The time delay has not elapsed yet (time delay preset to 3 minutes)	Wait for the time delay to elapse or reset the time delay on the delay timer inside the irrigation controller.
	Low voltage on the battery (the solar charge controller protects the battery from over-discharge, see * below)	Recharge the battery with a battery charger or the solar panel. Use a multimeter to check the standby voltage on the fully charged battery. If the standby voltage is less than 13 volts replace the battery. Turn the switch on the irrigation controller to the OFF position before reconnecting the battery.
	Float switch on the header tank is mounted incorrectly	Make sure that the float shaft is pointing down.
	Float switch on the header tank is faulty	Replace the float switch on the header tank.
Pump has lost power	One of the pumps in the double pump has become faulty	Replace the faulty pump.
	The pump inlet filter has become clogged	Clean the pump filter or replace the filter with a larger filter.
Header tank is overflowing	Float switch on the header tank is mounted incorrectly	Make sure that the float shaft is pointing down.
	Float switch on the header tank is faulty	Replace the float switch on the header tank.
Irrigation not starting when the switch is ON (switch up)	Water level in the evaporator is above the float switch	Wait for water to evaporate or manually remove some water from the evaporator.
	Low voltage on the battery (the solar charge controller protects the battery from over-discharge, see * below)	Recharge the battery with a battery charger or the solar panel. Use a multimeter to check the standby voltage on the fully charged battery. If the standby voltage is less than 13 volts replace the battery. Turn the switch on the irrigation controller to the OFF position before reconnecting the battery.
	Float switch on the evaporator is not mounted correctly	Make sure that the float shaft is pointing up.
	Float switch on the evaporator is faulty	Replace the float switch on the evaporator.
	Solenoid valve is faulty	Replace the solenoid valve.

Irrigation not starting when the switch is ON night only (switch down)	Too much light on the light sensor	Wait until it is dark or cover the light sensor to exclude light.
	Water level in the evaporator is above the float switch	Wait for water to evaporate or manually remove some water from the evaporator.
	Low voltage on the battery (the solar charge controller protects the battery from over-discharge, see * below)	Recharge the battery with a battery charger or the solar panel. Use a multimeter to check the standby voltage on the fully charged battery. If the standby voltage is less than 13 volts replace the battery. Turn the switch on the irrigation controller to the OFF position before reconnecting the battery.
	Light sensor is faulty	Replace the light sensor.
	Float switch on the evaporator is faulty	Replace the float switch on the evaporator.
	Solenoid valve is faulty	Replace the solenoid valve.
Irrigation not stopping when the water level reaches the float switch	Float switch on the evaporator is not mounted correctly	Make sure that the float shaft is pointing up.
	Float switch on the evaporator is faulty	Replace the float switch on the evaporator.
Irrigation stopping before the water level in the evaporator reaches the float switch	Low voltage on the battery (the solar charge controller protects the battery from over-discharge, see * below)	Recharge the battery with a battery charger or the solar panel. Use a multimeter to check the standby voltage on the fully charged battery. If the standby voltage is less than 13 volts replace the battery. Turn the switch on the irrigation controller to the OFF position before reconnecting the battery.
	Solar panel has not fully charged the battery between irrigation events	If this is a regular problem, you may need a bigger solar panel.
	A fully charged battery cannot meet the demands of your irrigation system	If this is a regular problem, you may need a bigger battery.
Insufficient flow from the solenoid valve	Air in the pipe connected to the inlet of the solenoid valve	Disconnect the pipe from the inlet of the solenoid valve and run water through the pipe to remove any air. Reconnect the solenoid valve while the water is running.
	Solenoid valve is not adequate for your irrigation application	Add an extra solenoid valve (or valves) in parallel with the existing solenoid valve. Alternatively, replace the solenoid valve with a solenoid valve with higher flow rate. For example, check out this link: [https://www.aliexpress.com/item/1-NPT-12v-Solenoid-Water-Valve-2-Way-2-Position-Electric-Solenoid-Valve-Water-Air-Gas/57976910 4.html](https://www.aliexpress.com/item/1-NPT-12v-Solenoid-Water-Valve-2-Way-2-Position-Electric-Solenoid-Valve-Water-Air-Gas/579769104.html) This solenoid valve is also available from the Measured Irrigation website

Pump stopping before the water level in the header tank reaches the float switch	Low voltage on the battery (the solar charge controller protects the battery from over-discharge, see * below)	Recharge the battery with a battery charger or the solar panel. Use a multimeter to check the standby voltage on the fully charged battery. If the standby voltage is less than 13 volts replace the battery. Turn the switch on the irrigation controller to the OFF position before reconnecting the battery.
	Solar panel has not fully charged the battery between irrigation events	If this is a regular problem, you may need a bigger solar panel.
	A fully charged battery cannot meet the demands of your irrigation system	If this is a regular problem, you may need a bigger battery.
Problems with the control dripper	Air in the tube connected to the control dripper	Disconnect the control dripper and run water through the tube to remove any air. Reconnect the control dripper while the water is running.
Variable depth of the wetting front (root zone scheduling)	Non-uniform soil composition	Perform multiple trials with a soil moisture probe and choose the wetting front depth that is deep enough to ensure that almost all your plants get enough water

* One of the functions of the solar charge controller is to protect the battery from over-discharge. When the battery voltage is less than 10.8 volts, the solar charge controller isolates the battery so that the pump and solenoid valve stop operating. The over-discharge recovery voltage needs to be greater than 12.8 volts to allow the system to start working again.

Chapter 8. Measured irrigation using pressurised compensating drippers

The current trend in drip irrigation applications is to use pressure compensating drippers whereby the flow rate from the drippers is relatively constant for water pressure in the range 100 kPa to 300 kPa. If you are designing a measured irrigation system from scratch, it is preferable to use non pressure compensating drippers rather than pressure compensating drippers. If your drip irrigation system already uses pressure compensating drippers, it will be expensive to replace all the pressure compensating drippers with non pressure compensating drippers. There are, however, some situations where you can upgrade the irrigation system to measured irrigation without replacing the pressure compensating drippers.

Option 1. Replace the control dripper with a pressure compensating dripper (or a combination of pressure compensating drippers)

You can alter the water usage by changing the combination of pressure compensating drippers. You can replace the adjustable control dripper with a precision adjustable dripper made from a combination of pressure compensating drippers (see Section 2.2).

After you have replaced the control dripper with a combination of pressure compensating drippers, you can adjust the water usage by changing the surface area of evaporation (this method should not be used for the DIY Smart Irrigation Controller or the Smart Solenoid Irrigation Controller). You can increase the water usage by increasing the surface area of evaporation by using a larger container for the evaporator. In the case of UMIC (or HUMIC), select one or more containers with vertical sides and connect the containers to the UMIC evaporator. One way to connect containers is to drill in hole in the side of each container and to insert a rubber grommet into each hole. Insert a barbed connector into each grommet, and then use a length of flexible tube to connect the containers. The water level will be same in all containers and the surface area of evaporation is increased.

You can decrease the water usage by decreasing the surface area of evaporation (for example, by using a smaller container for the evaporator or by placing full bottles of water in the evaporator).

Option 2. Connect a pressure regulator to the water supply

Pressure compensating drippers require a minimum pressure of 100 kPa. The pressure regulator should ensure that all the pressure compensating drippers have a minimum pressure of 100 kPa. You may wish to check the flow rate of the dripper that is likely to have the lowest flow rate.

Chapter 9~~10~~. Unpowered manual gravity feed measured irrigation from scratch

97.1 Introduction to unpowered manual gravity feed measured irrigation from scratch

In Chapters 2, 3, 4and 5 it was assumed that the drip irrigation system was already established. We will now consider the design of an unpowered manual gravity feed measured irrigation system, starting from scratch.

You can use a water tank to supply water to a simple low-cost irrigation system by attaching the outlet valve on the tank to a network of poly pipe with online emitters, drip line, or drip tape attached to the poly pipe. The drippers should be unregulated (non pressure compensating). All emitters should be at the same level and lower than the outlet on the tank.

A container with vertical sides is placed at a location in your garden so that one of the emitters drips water into the container during the irrigation. This emitter is called the control nozzle. A level line is marked on the inside of the container about 1.5 cm below the overflow level.

When the water level is below the level line and the garden needs watering, open the valve on the tank. When the water level reaches the level line, close the valve. Due to evaporation the water level will fall and so the cycle continues indefinitely. The container is called the evaporator. When it is very hot the water evaporates more quickly and so you will open the valve sooner. And when it rains extra water enters the evaporator and so you will delay the start of the next watering.

Miniscape control nozzle and evaporator

19 mm poly pipe with a brown nozzle (nozzle 5) watering a plant

A thirsty fruit tree is being watered by a loop of Bioline and a pink nozzle (nozzle 6)

Pressure monitor tubes

For gravity feed measured irrigation the pressure should be the same at all the ders, and hence it is a good idea to install a number of clear vertical tubes (pressure monitor tubes) to measure the pressure at various locations. If the variations in pressure are unacceptable, the diameter of the poly pipe within the zone can be increased.

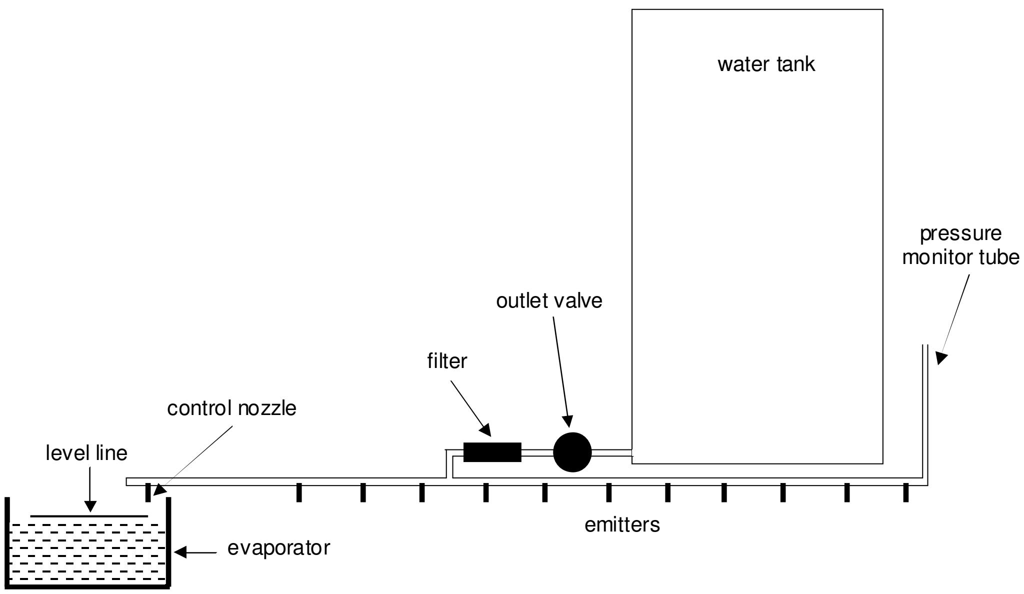
Pressure monitor tubes may be purchased from the Measured Irrigation website: www.measuredirrigation.com.au

Pressure monitor tube indicating the water pressure in the zone

Using mains pressure

Unpowered gravity feed measured irrigation can be connected to mains pressure. Adjust the inlet valve so that the head of water in the pressure monitor tube is approximately 1 metre.

7.9.22 Schematic diagram of unpowered manual gravity feed measured irrigation



97.3 Water usage (litres per week) for measured irrigation

By using irrigation to maintain the water level in the evaporator at the level line, the volume of water entering the evaporator must match the volume of water that evaporates, assuming that there is no overflow.

Monthly statistics for evaporation and rainfall in Australia are available from the Bureau of Meteorology (BOM). Provided you have access to historical data for the mean monthly evaporation and the mean monthly rainfall in your locality, this information can be used to predict the water usage (litres per week) for each of the nozzles in Table 1 (see Section 1.4).

$$w_i = N_E * A * max(0, e_i - r_i) * 7 / n_i \qquad i = 1, 2, 3, \ldots , 12 \qquad (2)$$

where

w_i is an estimate of the weekly water usage for the nozzle in month *i,*

N_E is the nozzle ratio of the emitter nozzle to the control nozzle,

A is the surface area of evaporation,

e_i is the mean monthly evaporation in month *i,*

r_i is the mean monthly rainfall in month *i,* and

n_i is the number of days in month *i.*

Formula (2) is referred to as the **measured irrigation formula** and it is derived in Appendix 2.

Note that these estimates of the water usage for the emitter nozzle depend only on the nozzle ratio, the surface area of evaporation, and the monthly evaporation and rainfall data. The estimates are independent of pressure, flow rate, irrigation frequency, and the duration of the irrigation event. Note that the estimate is zero whenever r_i is greater than e_i.

97.4 Installing unpowered manual gravity feed measured irrigation from scratch

It is recommended that you watch the YouTube video entitled *Think twice before you buy a pump for your rainwater tank:* https://www.youtube.com/watch?v=oN53adj_3sk

It is recommended that you also watch the YouTube video entitled *Irrigation innovation uses the weather to control litres per week per dripper* https://www.youtube.com/watch?v=7qK1Rwzlsko

Unpowered manual gravity feed measured irrigation is installed in 5 simple steps:

Step 1. Attach a 120 mesh filter after the outlet valve on the water tank. The irrigation is gravity feed and so you can only water plants that are lower than the outlet valve.

Step 2. Connect a network of poly pipe to the filter so that all the plants to be watered are close to the nearest poly pipe. Do not use hose clamps, they are not needed. To minimise head loss, 19 mm poly pipe is recommended.

Step 3. For each plant, punch a hole in the nearest poly pipe and insert a 5 mm take-off adaptor into the hole. Cut a suitable length of 6 mm flexible tube to deliver water to the plant. Attach one end of the tube to the take-off adaptor and the other end to an emitter nozzle, a non pressure compensating dripper, drip line, or drip tape. For example, Miniscape (Landline 8) or Bioline (Landline Purple) drip line. Don't worry if you don't know what nozzle to use - you can change a nozzle at any time if a plant is getting too much or too little water. The Measured Irrigation Nozzle Selector Tool will help you to select a suitable emitter nozzle (see Chapter 11). If you are using drip line it may be connected directly to the poly pipe without using flexible tube.

Step 4. Following the procedure in Step 3, attach the control nozzle to a length of flexible tube so that it delivers water to the evaporator. You may need to dig a hole for the evaporator so that control nozzle is at the same level as the other nozzles.

Step 5. Connect a pressure monitor tube to the poly pipe. A pressure monitor tube is used to check the pressure at any point to be confident that everything is working according to your expectations.

Table 1 (see Section 1.4) provides a list of nozzles available from Measured Irrigation. Contact Bernie Omodei at Measured Irrigation to discuss your nozzle requirements.

Sloping ground

If the plants to be watered are at different levels, position a length of poly pipe so that it follows a contour line higher than all the plants to be watered. Attach a nozzle directly to the poly pipe. A length of 6 mm flexible tube delivers the water from the nozzle to the plant at a lower level. Note that there is a small breather hole in the black tube protecting a needle nozzle to ensure that the nozzle remains at atmospheric pressure. If you are using drip line, place a short length of poly pipe over the drip line to collect the water to be delivered to the plant at a lower level.

97.5 Unpowered multi-zone gravity feed measured irrigation

Unpowered multi-zone gravity feed measured irrigation is a simple extension of unpowered single-zone gravity feed measured irrigation whereby the plants are grouped into zones. Each zone is connected to the water tank and has its own inlet valve, evaporator, control nozzle and pressure monitor tube. The emitters in each zone should be at the same level and lower than the outlet on the tank.

When each zone needs watering, open the inlet valve for the zone. When the water level in the zone's evaporator reaches the level line, close the inlet valve.

97.6 Design principles for gravity feed drip irrigation

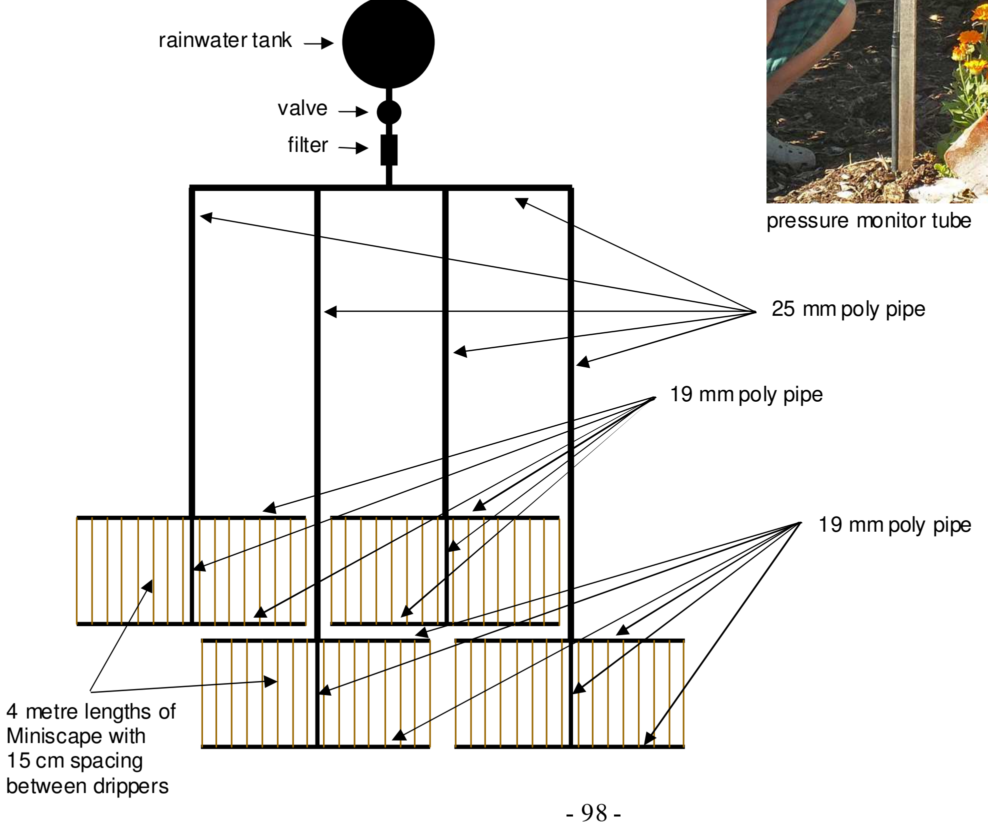
Many smallholders use gravity feed drip irrigation to irrigate a small garden (less than an acre). When the water source is a rainwater tank or a pond, gravity feed irrigation is preferable to pressurised irrigation because you don't need to buy an expensive pump and you don't have the ongoing cost of electricity to run the pump.

Gravity feed drip irrigation is easy to install on level or sloping ground provided you understand some important gravity feed principles:

1. Always use unregulated (non pressure compensating) drippers or drip line. For example, Netafim Miniscape (Landline 8) or Netafim Biolline (Landline Purple).
2. The water source should be at least half a metre higher than all the drippers in the garden.
3. Frictional head loss can be accommodated by designing your irrigation system appropriately. For example, if you are using Miniscape with 15cm spacing between the drippers, each dripper should be no more than 3 metres away from its water supply from the poly pipe. For Bioline each dripper should be no more than 6 metres away from its water supply from the poly pipe. Frictional head loss in the poly pipe can be reduced by either increasing the diameter of the poly pipe or by replacing a single line of poly pipe with multiple parallel line of poly pipe (see the plan view below).
4. On sloping ground you need to use multiple irrigation zones such that the drippers in each zone are at approximately the same level. Each zone should have its own valve so that the irrigation of any zone is independent of the irrigation of the other zones.
5. The water pressure should be approximately the same for all the drippers in a zone. The pressure variation between any 2 drippers in a zone can be monitored by connecting a pressure monitor tube near each dripper. A pressure monitor tube is clear vertical tube open at the top so that you to monitor the water level in the tube. Pressure monitor tubes may be purchased from the Measured Irrigation website www.measuredirrigation.com.au

pressure monitor tube

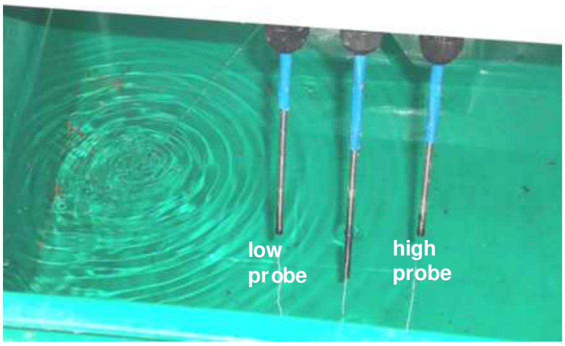
Plan view of a single zone gravity feed drip irrigation system.



Chapter 101. Solar-powered gravity feed measured irrigation with level sensor

108.1 Introduction to solar-powered gravity feed measured irrigation with level sensor

Conventional irrigation systems use an irrigation controller to control the opening and closing of solenoids valves in order to control the duration of the irrigation event and the frequency of irrigation. Solar-powered measured irrigation with level sensor uses an evaporator and level sensor to control the duration of the irrigation event and the frequency of irrigation.



The level sensor has three probes as shown. During the irrigation event the water level rises as water slowly drips into the evaporator from the control nozzle. When the water level reaches the high probe on the right the solenoid valve closes and the irrigation stops. The water level then falls due to evaporation until the water level is below the low probe on the left at which point the solenoid valve opens and the irrigation recommences. The middle probe is a reference probe. This cycle continues indefinitely.

The volume of water required to raise the water level from the low probe level to the high probe level is called the **gap volume**. It is also the volume of water that must evaporate between irrigation events.

The volume of water that is emitted by the control nozzle during an irrigation event is called the **control volume**. It is also the volume of water that has evaporated between the end of the previous irrigation event and the end of the current irrigation event.

The control volume is slightly greater than the gap volume. In fact the control volume equals the gap volume plus the volume of water that evaporates from the evaporator during the irrigation event. The duration of the irrigation event is much less than the time interval between irrigation events, and so the evaporation during the irrigation event is much less than the evaporation between irrigation events. Hence the gap volume can be used as a reasonably accurate estimate of the control volume.

By choosing appropriate nozzles, every nozzle in your garden can emit the desired volume of water during the irrigation event. The volume of water each nozzle emits during the irrigation event is the control volume multiplied by the relevant nozzle ratio (see Table 2 in Section 1.5).

As well as being completely automatic, the irrigation frequency responds to the prevailing weather conditions. During very hot weather the evaporation rate will be much greater and so the irrigation down time will be shorter. On cool overcast days, the evaporation rate will be quite small and so the irrigation down time will be longer.

10

8.2 Irrigation volumes for solar-powered gravity feed measured irrigation with level sensor

The volume of water emitted by a nozzle during the irrigation event is determined by the relationship between the nozzle and the control nozzle. You can ignore the flow rate and you can ignore the duration of the irrigation event, both will adjust automatically to ensure that the desired volume of water is emitted.

For solar-powered gravity feed measured irrigation with a level sensor, you know in advance the volume of water emitted by each nozzle during the irrigation event. Hence you know in advance the total volume of water that will be used during the irrigation event.

Nozzle formula

The **nozzle formula** states that

measured volume = control volume * nozzle ratio

where the control volume is the volume of water emitted by the control nozzle during the irrigation event, and the nozzle ratio is the ratio of the flow rate of the nozzle to the flow rate of the control nozzle when both nozzles are at the same pressure. All measured irrigation volumes can be predicted by the nozzle formula.

For single-zone gravity feed measured irrigation with nozzles at the same level (and hence the same pressure), one can apply the nozzle formula.

The number of litres of water emitted by a nozzle during the irrigation event can be estimated by multiplying the gap volume by the nozzle ratio (see Table 2 in Section 1.5).

Nozzle ratio calibration

For any combination of nozzle and control nozzle, there is a simple method to work out the nozzle ratio. Over the same period of time collect the water from the nozzle in one container and the water from the control nozzle in another container. Then the nozzle ratio is simply the ratio of the water volumes in the two containers. Using this method, it is very easy to make and calibrate your own nozzles suited to your particular irrigation requirements.

Chapter 112. Solar-powered multi-zone measured irrigation with flow-splitter

11.1 9.1 Introduction to solar-powered multi-zone measured irrigation with flow-splitter

This implementation of measured irrigation is suitable for much larger applications that require many separate irrigation zones. This implementation is ideally suited to irrigation on sloping or uneven land where each contour level will require a separate zone. In order to deliver water to all the zones simultaneously, you will need a **flow-splitter**.

The flow-splitter accurately divides a single inflow of water into multiple outflows with one outflow for each irrigation zone. The proportion of water delivered to each outlet is determined by the relative flow rates of the nozzles attached to the outlet.

A control nozzle is connected to one of the outlets on the flow-splitter. In the pictures below the control nozzle is on the right.

The inlet valve and the solenoid valve on the right

Flow-splitter mounted on star pickets

Valve nozzles and the control nozzle on the right

In the photo on the left a tube is connected to the control nozzle. This tube delivers water to the evaporator. The irrigation event will stop when the control volume of water has been delivered to the evaporator. The other tubes are delivering water to the various irrigation zones

The volume of water delivered to an irrigation zone during an irrigation event depends on the control volume and the ratio of the flow rate of the valve nozzle for the zone to the flow rate of the control nozzle. For example, if the control volume is 2 litres and the valve nozzle has 50 times the flow rate of the control nozzle, then 100 litres of water is delivered to the zone.

In the above photo the water level in the flow-splitter has stabilized so that the outflow rate matches the inflow rate. Suppose that the inflow is increased by adjusting the inlet valve. The water level in the flow-splitter will rise until the outflow rate matches the increased inflow rate. However, the volume of water delivered to the evaporator (namely, the control volume) does not change, and so the volume of water delivered to any zone does not change.

Note that a flow-splitter can be any shape or size provided that all the outlets on the flow-splitter are at the same level and hence the same pressure. The water supply for the flow-splitter may be from a solar-powered pump or from main water pressure.

119.2 Water usage for solar-powered multi-zone measured irrigation with flow-splitter

Measured irrigation formula

Monthly statistics for evaporation and rainfall in Australia are available from the Bureau of Meteorology (BOM). Provided you have access to historical data for the mean monthly evaporation and the mean monthly rainfall in your locality, this information can be used to predict the water usage (litres per week) for each of the nozzles in Table 1.

$$w_i = N_E * A * max(0, e_i - r_i) * 7 / n_i \qquad i = 1, 2, 3, \dots, 12 \qquad (2)$$

where

w_i is an estimate of the weekly water usage for the nozzle in month i,

N_E is the nozzle ratio of the emitter nozzle to the control nozzle,

A is the surface area of evaporation,

e_i is the mean monthly evaporation in month i,

r_i is the mean monthly rainfall in month i, and

n_i is the number of days in month i.

The measured irrigation formula (2) is derived in Appendix 2 and it assumes that the pressure at the control nozzle is the same as the pressure at the emitter nozzle. Hence, the measured irrigation formula can only be used for a particular zone after the valve nozzle on the flow-splitter has been adjusted so the head of water in the pressure monitor tube for the zone is the same as the head of water in the flow-splitter.

Measured irrigation slope formula

When the emitter nozzle and the control nozzle are not at the same pressure, the emitter flow equation (1) in Appendix 1 can be used to show that

$$w_i = N_E * A * max(0, e_i - r_i) * 7 / n_i * (H_E / H_C)^x \qquad i = 1, 2, 3, \dots, 12 \qquad (3)$$

where

H_E is the head of water at the emitter nozzle,

H_C is the head of water at the control nozzle, and

x is the emitter discharge exponent.

Formula (3) is called the **measured irrigation slope formula**. After measured irrigation has been established in your garden, you can use the above formula with BOM data to estimate the water usage in litres per week for each emitter nozzle for each month.

119.3 Installing solar-powered multi-zone measured irrigation with flow-splitter

Step 1. Position two star pickets so that the support for the flow-splitter fits neatly between them with the holes in the star pickets facing the flow-splitter. Use nylon fishing line to support the flow-splitter. Use a spirit level to ensure that the flow-splitter is horizontal. The flow-splitter should be at least one metre higher than all the irrigation zones. If some of the zones are a long distance from the flow-splitter, then the flow-splitter should be sufficiently high to allow for the frictional head loss between the flow-splitter and the distant zones.

Step 2. Connect the outlet valve on the water tank to the flow-splitter via the filter, the pump, the inlet valve and the solenoid valve.

Step 3. Connect the irrigation controller to the battery, solar panel, pump, solenoid valve and level sensor. See Notes 2 and 3 for details.

> Step 2 using mains water. Connect the mains water supply to the flow-splitter via the filter, the inlet valve and the solenoid valve.
>
> Step 3 using mains water. Connect the irrigation controller to the battery, solar panel, solenoid valve and level sensor. See Note 2 for details.

Step 4. Position the evaporator so that it is exposed to full sun. Position the level sensor on the evaporator. It is recommended that you secure the level sensor to the evaporator (using cable ties for example) to prevent the level sensor accidentally falling into the water.

Step 5. The Measured Irrigation Nozzle Selector Tool will help you to select the control nozzle (see Chapter 11). Attach the control nozzle to an outlet on the flow-splitter and use a length of 6 mm flexible tube to connect the control nozzle to the evaporator. Ensure that the control nozzle outlet is open to the atmosphere.

Step 6. The control volume is the volume of water that is delivered to the evaporator during the irrigation event. See Note 4 for details on how to estimate the control volume.

Step 7. The irrigation down time is the time it takes for the water level in the evaporator to fall (due to evaporation) from the high level at the end of the irrigation event to the low level (low probe). One can increase or decrease the irrigation down time by increasing or decreasing the number of millimetres between the high probe and the low probe (the probe lengths are adjustable). The Measured Irrigation Nozzle Selector Tool will help you to choose a control volume that will generate an appropriate irrigation frequency for your garden (see Chapter 11).

Step 8. For each zone, connect a network of poly pipe from the flow-splitter so that all the plants to be watered are close to the nearest poly pipe. Do not use hose clamps, they are not needed. To minimise head loss, 19 mm poly pipe is recommended. As the distance from the water tank to the zone increases, you may need to increase the diameter of the poly pipe to compensate for head loss.

Step 9. For each plant in each zone, punch a hole in the nearest poly pipe and insert a 5 mm take-off adaptor into the hole. Cut a suitable length of 6 mm flexible tube to deliver water to the plant. Attach one end of the tube to the take-off adaptor and the other end to an emitter nozzle or a length of Miniscape or Bioline drip line. Don't worry if you don't know what nozzle to use - you can change a nozzle at any time if a plant is getting too much or too little water. The Measured Irrigation Nozzle Selector Tool will help you to select a suitable emitter nozzle (see Chapter 11). If you are using drip line it may be connected directly to the poly pipe without using flexible tube.

Step 10. For each zone, connect a pressure monitor tube to the poly pipe in the zone. A pressure monitor tube can be used to check the pressure at any point in the zone to be confident that everything is working according to your expectations.

Step 11. For each zone, connect an adjustable valve nozzle (9mm or 2mm) to a flow-splitter outlet. Adjust the inlet valve until the water level in the flow-splitter stabilises at the desired level. Adjust the valve on the valve nozzle until the head of water in the flow-splitter is the same as the head of water in the pressure monitor tube. The head of water in the flow splitter is measured from the control nozzle outlet. Note that all nozzles should be open to the atmosphere.

Step 12. For normal operation (assuming a solar panel is used) the switch on the irrigation controller should be set to **ON night only** so that irrigation starts after sunset. Set the switch to **ON** for testing or demonstration purposes or when the garden urgently needs to be watered. To start the irrigation manually, simply raise one side of the level sensor so that the low probe is out of the water. If you decide that you garden needs an extra watering, remove some water from the evaporator to start watering.

Step 13. You should cover the flow-splitter with a light-proof cover to prevent the formation of algae.

Zones on level ground

To ensure that the pressure is the same at all emitter nozzles in the zone, the nozzles should be at the same level and you need to minimise any head loss between the nozzles. You can use pressure monitor tubes to check the pressure at any emitter nozzle and if variations in pressure are unacceptable you can increase the diameter of the poly pipe.

Zones on sloping ground

Position a length of poly pipe so that it follows a contour line higher than all the plants in the zone. Attach each emitter nozzle the poly pipe. A length of 6 mm tube delivers the water from the nozzle to a plant at a lower level. Note that there is a small breather hole in the black tube protecting a needle nozzle to ensure that the nozzle remains at atmospheric pressure.

Note 1

If water is overflowing at a valve nozzle attached to the flow-splitter, there may be pockets of air trapped at high points in the poly pipe. If you can't remedy the situation by physically removing the high points, you may need to insert an air relief valve at one or more of the high points. To insert an air relief valve, simply cut the poly pipe at the high point and insert a tee and a vertical piece of poly pipe higher than the outlet on the flow-splitter.

If there is still a problem after you have attempted to remove trapped air, you can either

- Use poly pipe of greater diameter (for example, change from 13 mm poly pipe to 19 mm poly pipe) or
- Raise the level of the flow-splitter

Note 2

There are 12 colour-coded wires coming from the irrigation controller. The wires should be connected as follows:
red wire connects to the positive lead from the battery.
black wire connects to the negative lead from the battery.
dark blue wire connects to the positive lead from the solar panel.
dark green wire connects to the negative lead from the solar panel.
purple connects to the white wire from the level sensor (reference probe).
orange connects to the yellow (or red) wire from the level sensor (high probe).
brown wire connects to the black wire from the level sensor (low probe).
yellow wire connects to the solenoid valve and the positive lead from the pump.
white wire connects to the solenoid valve and the negative lead from the pump.
grey wire connects to the black lead from the light sensor.
light pink wire connects to the white lead from the light sensor.
light blue wire connects to the red lead from the light sensor.

If you ever need to replace the circuit board inside the irrigation controller, follow the instructions below:
Connect the **Lo** terminal on the board to the brown wire.
Connect the **Ref** terminal on the board to the purple wire.
Connect the **Hi** terminal on the board to the orange wire.
Connect the **Bat +** terminal on the board to the Load positive terminal on the charge controller.
Connect the **Bat –** terminal on the board to the Load negative terminal on the charge controller.
Connect the **Com** terminal on the board to the middle terminal of the 3-way switch
Connect the **NO** terminal on the board to the yellow wire from the solenoid valve and the pump.

Note 3

A 20 watt solar panel provides enough power to automatically irrigate 200 m^2 at 10 litres per m^2 using a 14 watt pump connected to a water tank at ground level.
A 40 watt solar panel provides enough power to automatically irrigate 400 m^2 at 10 litres per m^2 using two 14 watt pumps connected to a water tank at ground level.
A 60 watt solar panel provides enough power to automatically irrigate 600 m^2 at 10 litres per m^2 using three 14 watt pumps connected to a water tank at ground level.
An 80 watt solar panel provides enough power to automatically irrigate 800 m^2 at 10 litres per m^2 using four 14 watt pumps connected to a water tank at ground level.

As you increase the wattage of the solar panel, is recommended that you increase the storage capacity of the battery. If the irrigation stops before the water level has reached the high probe, it indicates that you may have insufficient storage capacity in the battery.

Note 4

In order for measured irrigation to accurately predict the volume of water emitted by each nozzle within each zone, you need to accurately measure the gap volume. The following method is recommended. At the end of the irrigation event slowly take water from the evaporator and transfer it to another container. As the water level gets close to the low level, carefully remove the water with a syringe until the water level separates from the low probe and the irrigation controller starts the next irrigation event. The volume of water in the container is the gap volume and it provides as estimate for the control volume. You can then use the nozzle formula to predict the volume of water emitted by each nozzle.

Note 5

If you decide that for all zones your plants are getting too much water during the irrigation event, either increase the size of the control nozzle or decrease the surface area of evaporation. On the other hand, if you decide that for all zones your plants are not getting enough water, then either decrease the size of the control nozzle or increase the surface area of evaporation. An easy way to adjust water usage is to use an adjustable dripper for the control nozzle.

119.4 Multi-zone MI Kit with Flow-splitter

The kit consists of the following components and is available in Australia only from the measured irrigation website.

Measured Irrigation Manual	1
waterproof solenoid valve 12V 5W	1
irrigation controller with light sensor	1
level sensor with 3 probes	1
evaporator	1
filter – 120 mesh	1
inlet valve	1
pump 12V 14W	1
control nozzles (one of each type)	10
9mm adjustable valve nozzles	8
2mm adjustable valve nozzles	4
Netafim Miniscape drip line with 0.15m dripper spacing (metres)	4
Netafim Bioline drip line with 0.3m dripper spacing (metres)	4
flow-splitter with 25 outlets	1
pressure monitor tubes	4
electrical irrigation cable - 3 strand (metres)	10
waterproof connectors for electrical wire	9
screw connectors for electrical wire	10
light-proof cover for flow-splitter	1

The kit does not include the solar panel and the battery.

Note that the solar panel and the battery may be replaced by a 12V 5A power adaptor.

Pump 12V 14W

Evaporator and level sensor with 3 probes

Light-proof cover protecting the flow-splitter

Chapter 123. Solar-powered single-zone gravity feed measured irrigation with nozzles at different levels

120.1 Introduction to solar-powered single-zone gravity feed measured irrigation with nozzles at different levels

This chapter is only relevant if you have access to historical data for mean monthly evaporation and mean monthly rainfall.

So far it has been required that all the nozzles within a zone be at the same level. For this implementation of measured irrigation the nozzles are allowed to be at different levels (for example, on sloping ground). In order to control the water usage for nozzles at different levels, this implementation assumes the head of water at the control nozzle is maintained at a constant level.

When an emitter nozzle and the control nozzle are at the same pressure, estimates of the water usage are obtained from the measured irrigation formula (2) in Section 6.3, namely,

$$w_i = N_E * A * max(0, e_i - r_i) * 7 / n_i \qquad i = 1, 2, 3, \dots , 12 \qquad (2)$$

where

w_i is an estimate of the weekly water usage for the nozzle in month *i,*

N_E is the nozzle ratio of the emitter nozzle to the control nozzle,

A is the surface area of evaporation,

e_i is the BOM mean monthly evaporation in month *i,*

r_i is the BOM mean monthly rainfall in month *i, and*

n_i is the number of days in month *i.*

When the emitter nozzle and the control nozzle are not at the same level, the emitter flow equation (1) in Appendix 1 can be used to show that

$$w_i = N_E * A * max(0, e_i - r_i) * 7 / n_i * (H_E / H_C)^x \qquad i = 1, 2, 3, \dots , 12 \qquad (3)$$

where

H_E is the head of water at the emitter nozzle,

H_C is the head of water at the control nozzle, and

x is the emitter discharge exponent.

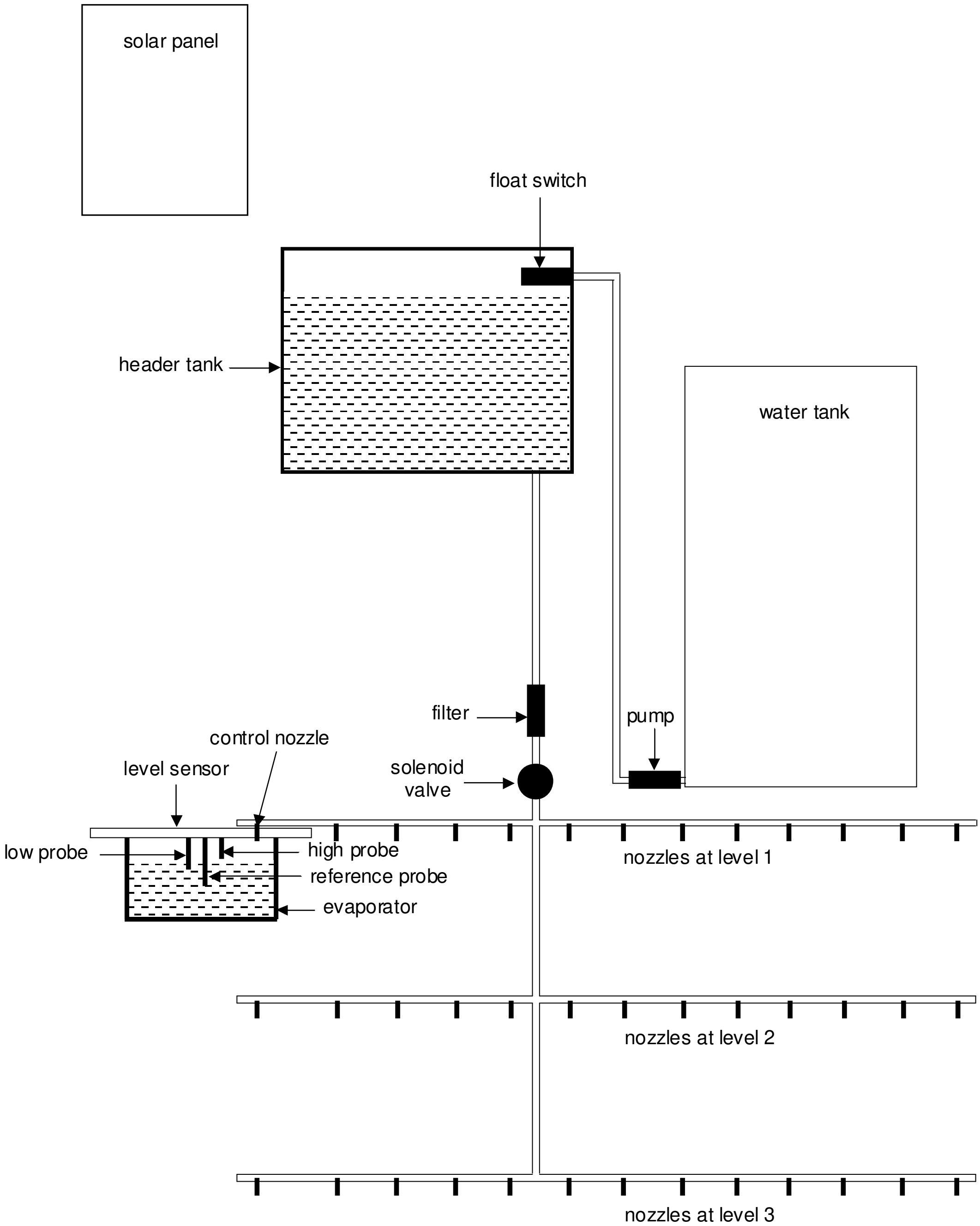
Formula (3) is called the **measured irrigation slope formula**. After measured irrigation has been established in your garden, you can use the above formula to estimate the water usage in litres per week for each emitter for each month.

To apply the measured irrigation slope formula, the head of water at the control nozzle needs to remain constant for the duration of the irrigation event. If the water supply is a dam or reservoir at a higher level, then the head of water at the control nozzle is relatively constant during the irrigation event. However, if the water supply is a tank then the water level in the tank will fall during the irrigation event. One solution is to use a header tank with a float switch (or a float valve) to ensure that the water level in the header tank remains constant. A solar panel may provide the power for a pump to fill the header tank. Alternatively, the header tank may be filled using mains water pressure.

The irrigation may be operated manually, or automatically with a level sensor.

The Measured Irrigation Nozzle Selector Tool implements the measured irrigation slope formula (see Chapter 11).

120.2 Schematic diagram of solar-powered single-zone measured irrigation with nozzles at different levels



Chapter 134. Measured Irrigation Nozzle Selector Tool

131.1 Introduction to Measured Irrigation Nozzle Selector Tool

The Measured Irrigation Nozzle Selector Tool is a powerful interactive spreadsheet used to select the appropriate nozzles for a broad range of measured irrigation applications.

The Measured Irrigation Nozzle Selector Tool can only be used if you have access to historical data for the mean monthly evaporation and the mean monthly rainfall. Historical data from the Australian Bureau of Meteorology (BOM) is included in the spreadsheet.

If you decide to use the Measured Irrigation Nozzle Selector Tool, it is preferable that the evaporator be exposed to full sun.

The nozzle selector tool is the implementation of measured irrigation formula (2) and the measured irrigation slope formula (3) (see Section 9.1).

Instructions for using the Measured Irrigation Nozzle Selector Tool are within the spreadsheet.

131.2 Example worksheets from the nozzle selector tool

Litres per week worksheet

Measured irrigation nozzle selector

The irrigation volumes and application rates in this worksheet are based on monthly evaporation and rainfall data.

enter control nozzle number	1
enter control volume in litres	1.000
enter surface area of evaporation in m^2	0.109
enter number of identical control nozzles	2
head ratio emitter nozzle to control nozzle	1.000
emitter discharge exponent	0.500

	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	
copy and paste the average monthly evaporation in mm (in Australia use the BOM evaporation data worksheet)	284.7	239.8	203.2	130.9	82.4	57.7	61.1	85.2	120.6	175.0	220.3	257.1	Adelaide Airport
copy and paste the average monthly rainfall in mm	17.5	19.2	22.1	35	54.1	56.9	59.7	50.5	45.1	36.6	24.8	23.4	Adelaide Airport
nett evaporation in mm	267.2	220.6	181.1	95.9	28.3	0.8	1.4	34.7	75.5	138.4	195.5	233.7	

In Australia, monthly rainfall data is available from the Bureau of Meteorology website: http://www.bom.gov.au/climate/data/index.shtml

Note that Miniscape refers to a Netafim Miniscape (Landline 8) dripper, Bioline refers to a Netafim Bioline dripper

	waterings per week Jan	waterings per week Feb	waterings per week March	waterings per week April	waterings per week May	waterings per week June	waterings per week June	waterings per week Aug	waterings per week Sept	waterings per week Oct	waterings per week Nov	waterings per week Dec
	6.6	6.0	4.5	2.4	0.7	0.0	0.0	0.9	1.9	3.4	4.8	5.8

nozzle	irrigation litres	L/week Jan	L/week Feb	L/week March	L/week April	L/week May	L/week June	L/week July	L/week Aug	L/week Sept	L/week Oct	L/week Nov	L/week Dec		L/year	average L/week
Miniscape (nozzle N1)	0.50	3.29	3.01	2.23	1.22	0.35	0.01	0.02	0.43	0.96	1.70	2.41	2.88	MS	80	1.54
green (nozzle N2)	1.04	6.83	6.24	4.63	2.53	0.72	0.02	0.04	0.89	1.99	3.54	5.00	5.97	green	167	3.21
yellow (nozzle N3)	1.57	10.30	9.42	6.98	3.82	1.09	0.03	0.05	1.34	3.01	5.34	7.54	9.01	yellow	252	4.84
Bioline (nozzle N4)	2.00	13.15	12.02	8.91	4.88	1.39	0.04	0.07	1.71	3.84	6.81	9.62	11.50	Bioline	321	6.18
brown (nozzle N5)	2.65	17.42	15.92	11.81	6.46	1.84	0.05	0.09	2.26	5.09	9.02	12.74	15.23	brown	425	8.18
pink (nozzle N6)	4.50	29.59	27.05	20.06	10.98	3.13	0.09	0.16	3.84	8.64	15.33	21.65	25.88	pink	723	13.90
white (nozzle N7)	7.14	46.98	42.94	31.84	17.42	4.98	0.15	0.25	6.10	13.72	24.33	34.37	41.09	white	1147	22.06
purple (nozzle N8)	8.99	59.14	54.06	40.08	21.93	6.26	0.18	0.31	7.68	17.27	30.63	43.27	51.73	purple	1444	27.77
orange (nozzle N9)	12.59	82.77	75.66	56.10	30.70	8.77	0.26	0.43	10.75	24.17	42.87	60.56	72.39	orange	2021	38.86
olive (nozzle N10)	16.26	106.92	97.73	72.46	39.65	11.32	0.33	0.56	13.88	31.22	55.38	78.23	93.51	olive	2610	50.20

Drip line worksheet

Gravity feed measured irrigation on sloping ground using non pressure compensating dripline (drip tube or drip tape)

It is assumed that the control dripper is a single dripper from the dripline.

The number of drippers required in this worksheet is based on monthly evaporation and rainfall data.

surface area of evaporation in m^2	0.1090
spacing between drippers in metres	0.300
L/hr for control nozzle at 100 kPa	4.000
L/hr for dripper at 100 kPa	8.000
head of water in metres above control nozzle	1.500
preferred L/wk in hottest month for a particular plant	100
preferred L/wk/m^2 in hottest month	150

Note that the hottest month is the month that has the maximum nett evaporation (evaporation minus rainfall)

	Jan	**Feb**	**March**	**April**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**	
copy and paste the average monthly evaporation in mm (in Australia use the BOM evaporation data worksheet)	284.7	239.8	203.2	130.9	82.4	57.7	61.1	85.2	120.6	175.0	220.3	257.1	Adelaide Airport
copy and paste the average monthly rainfall in mm	17.5	19.2	22.1	35	54.1	56.9	59.7	50.5	45.1	36.6	24.8	23.4	Adelaide Airport
nett evaporation in mm	267.2	220.6	181.1	95.9	28.3	0.8	1.4	34.7	75.5	138.4	195.5	233.7	

In Australia, monthly rainfall data is available from the Bureau of Meteorology website: http://www.bom.gov.au/climate/data/index.shtml

height in metres of control nozzle above dripper	**number of drippers required for the particular plant in the hottest month**	**spacing in metres between driplines to deliver the preferred L/wk/m^2 in the hottest month**
0.0	**7.6**	**0.292**
0.1	7.4	0.302
0.2	7.1	0.311
0.3	6.9	0.320
0.4	6.8	0.329
0.5	**6.6**	**0.338**
0.6	6.4	0.346
0.7	6.3	0.354
0.8	6.1	0.362
0.9	6.0	0.370
1.0	**5.9**	**0.377**
1.1	5.8	0.385
1.2	5.7	0.392

Pressurised irrigation worksheet

Pressurised drip irrigation upgrade to pressurised measured irrigation

It is assumed that the control dripper is a single dripper from the dripline.

Dripper application rates in this worksheet are based on monthly evaporation and rainfall data.

enter surface area of evaporation in m^2	0.109													
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec		
copy and paste the average monthly evaporation in mm (in Australia use the BOM evaporation data worksheet)	284.7	239.8	203.2	130.9	82.4	57.7	61.1	85.2	120.6	175.0	220.3	257.1	Adelaide Airport	
copy and paste the average monthly rainfall in mm	17.5	19.2	22.1	35	54.1	56.9	59.7	50.5	45.1	36.6	24.8	23.4	Adelaide Airport	
nett evaporation in mm	267.2	220.6	181.1	95.9	28.3	0.8	1.4	34.7	75.5	138.4	195.5	233.7		
	L/week Jan	L/week Feb	L/week March	L/week April	L/week May	L/week June	L/week July	L/week Aug	L/week Sept	L/week Oct	L/week Nov	L/week Dec	L/year	av L
Dripper application rate in litres per week	6.58	6.01	4.46	2.44	0.70	0.02	0.03	0.85	1.92	3.41	4.81	5.75	161	

In Australia, monthly rainfall data is available from the Bureau of Meteorology website: http://www.bom.gov.au/climate/data/index.shtml

Chapter 14~~9~~. Soil moisture~~Measured~~ and irrigation scheduling

14.1 Soil moisture probe

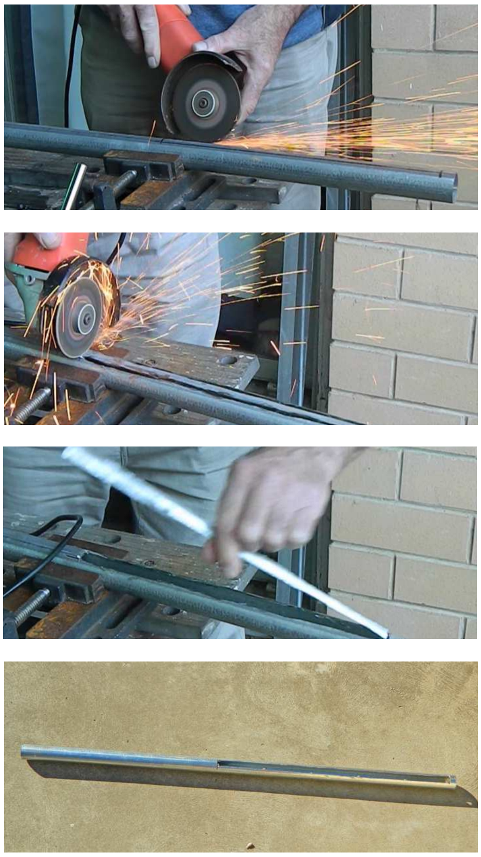
The amount of water that your plants need will depend on many factors in addition to the weather. For example, as the plants grow and become bigger they will need more water. Plants growing in sandy soil will need more water than plants growing in heavy soil.

To take account of all these additional factors, you may need a soil moisture probe is to check the moisture level in the soil at various depths. A very simple soil moisture probe is a length of steel pipe with a long slot. I suggest that the diameter of the pipe be between 30 and 40 mm. An angle grinder can be used to cut a long slot in the steel pipe to that you can inspect the soil inside the pipe. I suggest that the width of the slot be about 15 mm. You can also use the angle grinder to sharpen the edge of the end of the soil moisture probe.

A suitable soil moisture probe may be purchased online from the Measured Irrigation website www.measuredirrigation.com.au

By checking the moisture level in the soil through the slot in the steel pipe, you can decide whether your plants have been irrigated with too much or not enough water. A control dripper may be used to adjust the water usage.

Hammer the steel pipe into the soil near a dripper so that the slot faces the dripper. Remove the steel pipe from the soil and use the slot to inspect the moisture level in the soil and the position of the wetting front. You may wish to use the slot to remove some soil from the pipe and to squeeze the soil sample between your fingers.



An angle grinder can be used to make a long slot in a length of steel pipe

Hammer the steel pipe into the soil near a dripper so that the slot faces the dripper.

Remove the steel pipe from the soil and use the slot to inspect the moisture level in the soil and the position of the wetting front.

14.2 Introduction to measured irrigation scheduling

Irrigation scheduling should take account of soil type and the depth of the root zone.

When you use manual measured irrigation, you check the water level in the evaporator at sunset each day, and if the water level is below the high level, you start irrigating. You stop irrigating when the water level reaches the high level. This method of irrigation scheduling is called **sunset scheduling**. The major advantage of irrigating at sunset is that there are less evaporative losses compared with irrigating during the heat of the day.

For plants with deep roots or for plants in clay soils, it is preferable to irrigate with more water less frequently to enable the water to reach the bottom of the root zone. Between irrigation events the soil near the surface is allowed to dry out, but there should still me moisture in the root zone. If you decide that your plants need irrigating less frequently than daily (for example, once a week), then **root zone scheduling** is recommended.

There are two ways to implement root zone scheduling. The first way is to use an adjustable dripper as the control dripper (see Section 8.3). The second way is to use an irrigation dripper as the control dripper and to select an evaporator with the correct surface area (see Section 8.4).

14.3 Root zone scheduling using an adjustable dripper

The following steps can be applied to any irrigation zone, regardless of the size of the zone.

Step 1. How much water is needed?

Allow the soil to dry out over several days until the soil is dry between the surface and the bottom of the root zone.

Place a measuring container under one of the drippers to collect the water and start irrigating just before sunset.

While irrigating, check the moisture level in the soil by hammering the steel pipe into the soil near a dripper. Stop irrigating when the position of the wetting front is near the bottom of the root zone.

The volume of water in the measuring container is the amount of water that each dripper should deliver during the irrigation event. It is called the **dripper control volume** and it is the volume of water required to moisten the soil from the surface to the bottom of the root zone.

Place a measuring container under one of the irrigation drippers

Dripper control volume for root zone scheduling

Step 2. How much evaporation is required between irrigation events?

You need to know the evaporation in mm before the soil is dry between the surface and the middle of the root zone.

Position any container with vertical sides at a suitable location so that the evaporation from the container matches the evaporation near your plants. Fill the container with water and weigh it.

At sunset each day, check the moisture in the soil until the soil is dry between the surface and the middle of the root zone. If you wish to water your plants less frequently, you could wait until the soil is dry between the surface and the bottom of the root zone.

Reweigh the container to determine the volume of water that has evaporated. The number of mm that has evaporated is the volume of water divided by the surface area of the container. This is called the **root zone evaporation** and it is the evaporation required to dry out the soil from the surface to the middle of the root zone.

Reweigh the container to determine the volume of water that has evaporated

For automated measured irrigation where you can adjust the irrigation frequency, make adjustments to the irrigation frequency so that the net evaporation between irrigation events corresponds to the root zone evaporation. In the case of the DIY Smart Irrigation Controller (Chapter 5) and the SSIC (Chapter 6), adjust the irrigation frequency by changing the evaporator.

Step 3. Run the irrigation

Empty the measuring container and place it below one of the irrigation drippers.

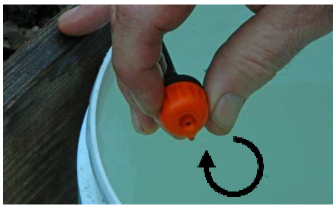
For manual measured irrigation, adjust the water level in the evaporator at sunset until it is at the low level and start irrigating. For automated measured irrigation, the irrigation starts automatically when the water level reaches the low level.

For manual measured irrigation, stop irrigating (turn off the water supply) when the water level in the evaporator reaches the high level. For automated measured irrigation, the irrigation stops automatically when the water level reaches the high level.

Step 4 Adjusting the control dripper

Check the volume of water in the measuring container at the end of the irrigation event. If the volume in the measuring container is less than the dripper control volume, then the moisture below a dripper is unlikely to have reached the bottom of the root zone. So reduce the flow rate of the control dripper (to increase the duration of the irrigation event) in preparation for the next irrigation. If the volume in the measuring container is more than the dripper control volume, then the moisture below a dripper may extend beyond the bottom of the root zone. So increase the flow rate of the control dripper (to decrease the duration of the irrigation event) in preparation for the next irrigation.

Check the volume of water in the measuring container.



If volume in the measuring container is less than the dripper control volume, turn the control dripper clockwise to reduce the flow rate of the control dripper.

If the volume in the measuring container is more than the dripper control volume, turn the control dripper anticlockwise to increase the flow rate of the control dripper.

Repeat Steps 3 and 4 until the volume of water in the measuring container matches the dripper control volume. It is preferable that the above steps are done in a period when there is no rain.

If you have a pressurised irrigation system with pressure compensating drippers, you should replace the adjustable control dripper with a combination of pressure compensating drippers such as a precision adjustable dripper (see Section 2.2).

14.4 Root zone scheduling using an evaporator with the correct surface area

It is recommended that you watch the YouTube video DIY smart irrigation.

The video is for smallholders using manual drip irrigation. The Do-It-Yourself technology is extremely simple. All that is need is a steel pipe and a storage container.

The volume of water emitted by each dripper is controlled by the prevailing weather conditions affecting your plants.

The water level in the storage container tells you when to start irrigating and when to stop irrigating. For crops with a shallow root zone or on sandy soil, you will need to irrigate more frequently with less water. For crops with a deep root zone or on heavy soil, you will need to irrigate less frequently with more water. Root zone scheduling (also called DIY smart irrigation) takes account of evapotranspiration, the soil type and the depth of the root zone.

The following steps can be applied to any irrigation zone, regardless of the size of the zone.

Step 1. How much water is needed? (see Section 8.3)

Step 2. How much evaporation is required between irrigation events? (see Section 8.3)

Step 4. How to choose a suitable evaporator?

You need to know the correct surface area for the evaporator so that root zone evaporation occurs between irrigation events and the dripper control volume is delivered during the irrigation event. Calculate the correct surface area by dividing the dripper control volume by the root zone evaporation. Then choose an evaporator with vertical sides and with the correct surface area.

An evaporator with a surface area of 370 square cm

Step 5. How to set-up the evaporator?

Position the evaporator at a suitable location so that the evaporation matches the evaporation near your plants. Mark a high level on the inside of the evaporator about 2 cm below the overflow level. Mark a low level so that the gap between the high level and the low level is the same as the root zone evaporation.

Position an irrigation dripper so that it will drip water into the evaporator during the irrigation.

Start irrigating when the water level is at the low level

Step 6. How to use the evaporator?

At sunset, fill the evaporator with water until the water level is at the low level and start irrigating.

Stop irrigating when the water level reaches the high level.

Check the water level at sunset each day, and start irrigating again when the water level has fallen below the low level.

As your crop grows and the water requirement of the crop changes, you may wish to repeat the process of root zone scheduling.

Most weather-based irrigation controllers use data from a weather station to control the irrigation scheduling. Despite the fact that DIY smart irrigation very low cost, it performs better than weather-based irrigation controllers. DIY smart irrigation responds to the prevailing weather conditions in your garden rather than the weather at a weather station. For example, DIY smart irrigation responds to the actual ET of your plants, rather than the theoretical ET at a weather station. This is particularly important if you are using a greenhouse.

14.5 Irrigation scheduling for the DIY Solar Drip Irrigation Kit

When you use a DIY Solar Drip Irrigation Kit the irrigation starts at sunset provided that the water level has fallen below the float switch. This method or irrigation scheduling is called **sunset scheduling**.

For plants with deep roots or for plants in clay soils, it is preferable to irrigate with more water less frequently to enable the water to reach the bottom of the root zone. Between irrigation events the soil near the surface is allowed to dry out, but there should still me moisture in the root zone. If you decide that your plants need irrigating less frequently than daily (for example, once a week), then **root zone scheduling** is recommended.

Step by step instructions for root zone scheduling

Step 1. How much water is needed?

Allow the soil to dry out over several days until the soil is dry between the surface and the bottom of the root zone.

Place a measuring container under one of the drippers to collect the water and start irrigating just before sunset.

While irrigating, check the moisture level in the soil by hammering the steel pipe into the soil near a dripper. Stop irrigating when the position of the wetting front is near the bottom of the root zone.

The volume of water in the measuring container is the amount of water that each dripper should deliver during the irrigation event. It is called the **dripper control volume** and it is the volume of water required to moisten the soil from the surface to the bottom of the root zone.

Place a measuring container under one of the irrigation drippers

Dripper control volume for root zone scheduling

Step 2. How much evaporation is required between irrigation events?

You need to know the evaporation in mm before the soil is dry between the surface and the middle of the root zone.

Turn the switch on the irrigation controller to the ON position (switch up) and the irrigation will start. Fill the evaporator with water until the water level raises the float on the float switch and the irrigation stops. Turn the switch on the irrigation controller to the OFF position

At sunset each day, check the moisture in the soil until the soil is dry between the surface and the middle of the root zone. If you wish to water your plants less frequently, you could wait until the soil is dry between the surface and the bottom of the root zone. The number of mm that has evaporated is called the **root zone evaporation** and it is the evaporation required to dry out the soil from the surface to the middle of the root zone.

Mark a line on the inside of the evaporator corresponding to the water level. This line is called the **low level line**. The gap between the float switch and the low level line corresponds to the root zone evaporation.

While the soil is drying, the water level is the evaporator is falling due to evaporation

Mark the low level line

Low level line and float switch

Step 3. Run the irrigation

Empty the measuring container and place it below one of the irrigation drippers.
When the water level in the evaporator has fallen below the low level line, turn the switch on the irrigation controller to the ON night only position (switch down) so that the irrigation starts automatically at sunset and stops when the water level reaches the float switch. Turn the switch to the OFF position after the irrigation has stopped.

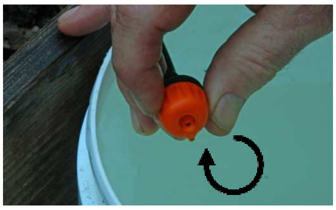
Irrigation starts at sunset

Irrigation stops when the water level reaches the float switch,

Step 4 Adjusting the control dripper

Check the volume of water in the measuring container at the end of the irrigation event. If the volume in the measuring container is less than the dripper control volume, then the moisture below a dripper is unlikely to have reached the bottom of the root zone. So reduce the flow rate of the control dripper (to increase the duration of the irrigation event) in preparation for the next irrigation. If the volume in the measuring container is more than the dripper control volume, then the moisture below a dripper may extend beyond the bottom of the root zone. So increase the flow rate of the control dripper (to decrease the duration of the irrigation event) in preparation for the next irrigation.

Check the volume of water in the measuring container.



If volume in the measuring container is less than the dripper control volume, turn the control dripper clockwise to reduce the flow rate of the control dripper.

If the volume in the measuring container is more than the dripper control volume, turn the control dripper anticlockwise to increase the flow rate of the control dripper.

Repeat Steps 3 and 4 until the volume of water in the measuring container matches the dripper control volume. It is preferable that the above steps are done in a period when there is no rain.

After a few adjustments to the control dripper, the water usage should stabilise at an appropriate level for the plants at their current stage of growth and no further adjustments of the control dripper are required. The volume of water in the measuring container after each irrigation event should be approximately the same as the dripper control volume recorded in Step 2. It is preferable that the above steps are done in a period when there is no rain.

As your crop grows and the water requirement of the crop changes, you may wish to repeat the above steps for root zone scheduling.

Root zone scheduling for the DIY Solar Drip Irrigation Kit is not completely automatic. However, root zone scheduling can be made completely automatic by replacing the float switch with a three probe level sensor that allows you to set both a high level and a low level. The MI Upgrade Kit with Level Sensor is discussed in another section of this document.

~~9.1 Soil moisture probe~~

~~The amount of water that your plants need will depend on many factors in addition to the weather. For example, as the plants grow and become bigger they will need more water. Plants growing in sandy soil will need more water than plants growing in heavy soil.~~

To take account of all these additional factors, you may need a soil moisture probe is to check the moisture level in the soil at various depths. A very simple soil moisture probe is a length of steel pipe with a long slot. I suggest that the diameter of the pipe be between 30 and 40 mm. An angle grinder can be used to cut a long slot in the steel pipe to that you can inspect the soil inside the pipe. I suggest that the width of the slot be about 13 mm. You can also use the angle grinder to sharpen the edge of the end of the soil moisture probe.

An angle grinder can be used to make a long slot in a length of steel pipe

A suitable soil moisture probe may be purchased online from the Measured Irrigation website www.measuredirrigation.com.au

By checking the moisture level in the soil through the slot in the steel pipe, you can decide whether your plants have been irrigated with too much or not enough water. A control dripper may be used to adjust the water usage.

Hammer the steel pipe into the soil near a dripper so that the slot faces the dripper. Remove the steel pipe from the soil and use the slot to inspect the moisture level in the soil and the position of the wetting front. You may wish to use the slot to remove some soil from the pipe and to squeeze the soil sample between your fingers.

Hammer the steel pipe into the soil near a dripper so that the slot faces the dripper.

Remove the steel pipe from the soil and use the slot to inspect the moisture level in the soil and the position of the wetting front.

9.2 Introduction to measured irrigation scheduling

Irrigation scheduling should take account of soil type and the depth of the root zone.

When you use manual MI, you check the water level in the evaporator at sunset each day, and if the water level is below the high level, you start irrigating. You stop irrigating when the water level reaches the high level. This method of irrigation scheduling is called **sunset scheduling**. The major advantage of irrigating at sunset is that there are less evaporative losses compared with irrigating during the heat of the day.

For plants with deep roots or for plants in clay soils, it is preferable to irrigate with more water less frequently to enable the water to reach the bottom of the root zone. Between irrigation events the soil near the surface is allowed to dry out, but there should still me moisture in the root zone. If you decide that your plants need irrigating less frequently than daily (for example, once a week), then **root zone scheduling** is recommended.

9.3 Root zone scheduling

The following steps define root zone scheduling.

Step 1. Allow the soil to dry out over several days until the soil is dry between the surface and the bottom of the root zone (use a soil moisture probe).

Step 2. Place a measuring container under one of the irrigation drippers to collect the water and start irrigating at sunset. At sunset each day check the depth of the moisture below various drippers (use a soil moisture probe). Stop the irrigation when the moisture is close to the bottom of the root zone. Record the volume of water in the measuring container for future reference. This is called the **dripper control volume for root zone scheduling** and it is the volume of water required to moisten dry soil below a dripper from the surface to the bottom of the root zone.

Place a measuring container under one of the irrigation drippers

Dripper control volume for root zone scheduling

Step 3. Fill the evaporator with water until the water level reaches the high level. For manual measured irrigation, the high level is already marked by a horizontal line on the inside of the evaporator. For automated measured irrigation, the high level is the level at which the irrigation stops automatically. At the high level, mark a horizontal line on the inside of the evaporator or measure the depth of the water.

High level for manual measured irrigation

Step 4. Turn off the water supply and allow the soil to dry out over several days until the soil is dry between the surface and the bottom of the root zone (use a soil moisture probe). While the soil is drying, the water level is the evaporator is falling due to evaporation. At sunset each day check the moisture in the soil. When the soil is dry between the surface and the bottom of the root zone, mark the low level by a horizontal line on the inside of the evaporator or measure the depth of the water. The low level is referred to as the **low level for root zone scheduling**. The gap between the high level and the low level is the **root zone scheduling evaporation** and it is the evaporation required to dry out the soil from the surface to the bottom of the root zone. Record the root zone scheduling evaporation for future reference.

Measuring the depth of water in the evaporator at the low level for UMIC

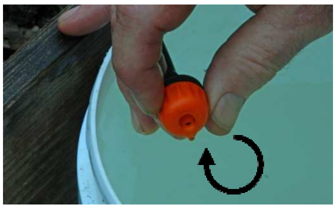
For automated measured irrigation where you can adjust the irrigation frequency, make adjustments to the irrigation frequency so that the net evaporation between irrigation events corresponds to the root zone scheduling evaporation. In the case of the DIY Smart Irrigation Controller (Chapter 5) and the SSIC (Chapter 6), adjust the irrigation frequency by changing the evaporator.

Step 5. Empty the measuring container and place it below one of the irrigation drippers. Turn on the water supply at sunset so that the irrigation starts.

Step 6 For manual measured irrigation, stop irrigating (turn off the water supply) when the water level in the evaporator reaches the high level. For automated measured irrigation, the irrigation stops automatically when the water level reaches the high level.

Step 7. Check the volume of water in the measuring container. If the volume in the measuring container is less than the dripper control volume for root zone scheduling, then the moisture below a dripper is unlikely to have reached the bottom of the root zone. So reduce the flow rate of the control dripper (to increase the duration of the irrigation event) in preparation for the next irrigation. If the volume in the measuring container is more than the dripper control volume for root zone scheduling, then the moisture below a dripper is likely to extend beyond the bottom of the root zone. So increase the flow rate of the control dripper (to decrease the duration of the irrigation event) in preparation for the next irrigation.

Check the volume of water in the measuring container.



If volume in the measuring container is less than the dripper control volume, turn the control dripper clockwise to reduce the flow rate of the control dripper.

If the volume in the measuring container is more than the dripper control volume, turn the control dripper anticlockwise to increase the flow rate of the control dripper.

If you have a pressurised irrigation system with pressure compensating drippers, you should replace the adjustable control dripper with a combination of pressure compensating drippers such as a precision adjustable dripper (see Section 2.2).

Step 8. For manual measured irrigation check the water level in the evaporator at sunset each day, and when the water level is below the low level, repeat Steps 5, 6, 7 and 8. For automated measured irrigation empty the measuring container and place it below one of the irrigation drippers; the irrigation will start automatically after the water level reaches the low level; repeat Steps 6, 7 and 8. If you are using unpowered measured irrigation (UMIC, HUMIC, DIY Smart Irrigation Controller, or SSIC), the irrigation starts automatically when the water level reaches the low level and does not wait until sunset. If you are using solar powered measured irrigation, the irrigation starts automatically at sunset after the water level reaches the low level.

After a few adjustments to the control dripper, the water usage should stabilise at an appropriate level for the plants at their current stage of growth and no further adjustments of the control dripper are required. The volume of water in the measuring container after each irrigation event should be approximately the same as the dripper control volume for root zone scheduling recorded in Step 2. It is preferable that the above steps are done in a period when there is no rain.

Chapter 150. Evapotranspiration and measured irrigation

Evapotranspiration-based controllers have become increasingly popular in recent years with rapid advances in information technology and decreasing prices.

The United States Environmental Protection Agency has developed criteria for the WaterSense labelling of weather-based irrigation controllers. The criteria require the water usage of the irrigation controller to be compared with the local evapotranspiration.

For all implementations of measured irrigation the water usage is directly proportional to the net evaporation from the evaporator. In this Section the water usage is compared to the local evapotranspiration.

A series of research trials were organised at the Bureau of Meteorology Weather Station at Adelaide Airport.

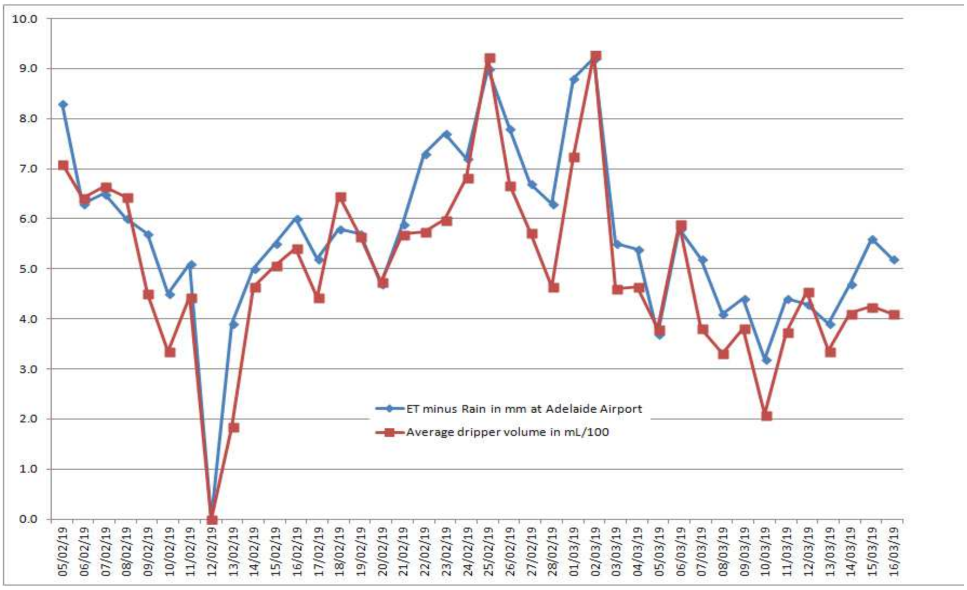
Research trials at Adelaide Airport with gravity fed water supply

An Unpowered Measured Irrigation Controller UMIC delivered water to 5 irrigation drippers and the water from each dripper was collected in a catch can. The adjustable control dripper was a precision adjustable dripper (see Section 2.2) with three Landline Purple drippers and three Landline 8 drippers. For all trials, two Landline Purple drippers were turned on and the remaining drippers in the precision adjustable dripper were turned off. For all trials, the 5 irrigation drippers were Landline Purple drippers.

The Bureau of Meteorology Weather Station at Adelaide Airport publishes daily evapotranspiration and rainfall data for the 24 hour period midnight to midnight. Daily reference evapotranspiration (ET_0) is derived from automatic weather station records and satellite measurements. The research trials were conducted for 40 consecutive days. Before midnight each night, the catch cans were emptied and the float on the UMIC was pressed down to start the irrigation event. The irrigation event stopped automatically when the water reached the high level. The quantity of water in each catch cans was measured and corrected for any evaporation that had occurred during the irrigation event. The irrigation event was started at a time that would ensure that the irrigation event stopped at about midnight.

Results

Here is a graph of ET minus rainfall, and mean irrigation volume at Adelaide Airport from 5 February 2019 to 16 March 2019.



Daily ET minus rainfall, and mean irrigation volume at Adelaide Airport from 5 February 2019 to 16 March 2019.

The table below show the correlation between the daily evapotranspiration minus rainfall data (for 40 days) and the daily mean irrigation volumes for the 5 catch cans (for 40 days). The table also show the correlation between the daily evapotranspiration minus rainfall data and the daily irrigation volumes for each of the catch cans.

Correlation coefficient for dripper 1 volume and ET_0 minus rainfall	0.931
Correlation coefficient for dripper 2 volume and ET_0 minus rainfall	0.928
Correlation coefficient for dripper 3 volume and ET_0 minus rainfall	0.929
Correlation coefficient for dripper 4 volume and ET_0 minus rainfall	0.928
Correlation coefficient for dripper 5 volume and ET_0 minus rainfall	0.925
Correlation coefficient for mean dripper volume and ET_0 minus rainfall	0.929

Our results demonstrate a strong correlation between measured irrigation discharge volumes and the prevailing evapotranspiration minus rainfall. With measured irrigation, the discharge volumes are directly proportional to the net evaporation from the evaporator. Thus we conclude that there is a strong correlation between net evaporation from the evaporator and the prevailing evapotranspiration minus rainfall.

Low cost smart irrigation controllers use evapotranspiration and rainfall data from the nearest weather station**.** Such weather-based irrigation controllers are less effective when the evaportranspiration and rainfall at the weather station differ significantly from the evapotranspiration and rainfall experienced by the plants being irrigated. For example, such smart irrigation controllers are inappropriate for plants in greenhouses.

Measured irrigation controllers use the evaporation and rainfall at the evaporator which can be positioned to reflect the weather conditions experienced by the plants. In the case of a greenhouse, the evaporator would be positioned inside the greenhouse.

Chapter 16. Sophie's Patch

Sophie's Patch uses solar-powered multi-zone measured irrigation with a flow-splitter.

Sophie's Patch is a beautiful demonstration garden near Mount Barker in the Adelaide Hills. The garden has been designed by Sophie Thompson, the South Australian presenter for Gardening Australia on ABC TV. The garden is often featured in Gardening Australia programs. The garden includes a large vegetable growing area and prior to the installation of measured irrigation the garden was watered by overhead spray. Every plant in the vegetable garden is now irrigated by measured irrigation and so every plant receives the desired weekly application rate throughout the year, automatically responding to changes in the weather conditions.

Because the vegetable garden is on sloping land, it was decided to use 11 irrigation zones and each zone follows a contour. The water supply is from a bore and the water has a high salt content of approximately 2000 parts per million.

An important step in designing the irrigation system is to decide the weekly application rate for each plant in the garden for the hottest month of the year and to use the Measured Irrigation Nozzle Selector Tool to select the appropriate nozzle or nozzles. More than half the vegetable garden has rows of low growing vegetables and it was decided to apply 130 litres per square metre per week during the month of January. This weekly application rate in January is achieved with Netafim Miniscape drip line with 15 cm spacing between the drippers and 25 cm spacing between the rows of drip line. Most of the tomato plants are watered with yellow nozzles delivering 16 litres per week in January and the pumpkin plants are watered with brown nozzles delivering 27 litres per week in January. Note that the control nozzle consists of a single Miniscape dripper. The predicted weekly application rates in the Measured Irrigation Nozzle Selector Tool are based on the Bureau of Meteorology average monthly evaporation and rainfall for Mount Barker.

Bernie Omodei & Sophie Thomson celebrate the successful installation of measured irrigation at Sophie's Patch at Mount Barker

Evaporator and level sensor


Sophie's son Beau adjusts the angle of the 20 watt solar panel


Flow-splitter delivering water to each of the eleven irrigation zones


You can see from this picture how the land slopes down towards the old railway carriage. Measured irrigation manages the slope by making the zones follow the contours.


Zone 4 is irrigated by 5 rows of Miniscape drip line 25cm apart and the drippers are 15 cm apart. This arrangement delivers130 litres per square metre per week during January.


Each zone has a clear pressure monitor tube indicating the water pressure in the zone. Beau is pointing to the water level in zone 11 and the pressure is about 40 cm head of water.

Chapter 17. Community Gardens

17.1 Camden CG – solar-powered single-zone measured irrigation with level sensor

This community garden in Adelaide has 9 raised beds. Because all the beds are at the same level, solar-powered single-zone measured irrigation with level sensor was the preferred implementation. All beds are irrigated with Netafim Miniscape drip line with 15 cm spacing between the drippers. It was decided that a suitable weekly application rate for all beds in January (the hottest month of the year) should be 2.2 litres per dripper per week. This weekly application rate is generated by a green hobby box as the evaporator and with 3 Miniscape drippers dripping into the evaporator.

All 9 beds use Miniscape drip line

The pressure monitor tube shows a pressure of about a metre head of water

17.2 Henley CG – solar-powered multi-zone measured irrigation with flow-splitter

Henley Community Garden is an organic permaculture designed community garden created by local resident volunteers in 2013 on land administered by the City of Charles Sturt in Adelaide. This demonstration site has 12 Miniscape drip line zones. This site is quite large and requires more than 1500 litres per hour to irrigate the whole garden. Furthermore, the site does not have access to mains power or to mains water and so pressurised drip irrigation is not an option. All the power required is provided by four 20 watt solar panels which power four 14 watt pumps delivering more than 1500 litres per hour to the flow-splitter. The water supply is bore water stored in two large tanks.

17.3 Yarrawonga CG – solar-powered multi-zone measured irrigation with flow-splitter

This site was established by volunteers in the country town of Yarrawonga in Victoria.

Newly constructed raised garden beds

Tom Hutchinson installing measured irrigation

Chapter 18. Private Gardens

18.1 Cambridge Street Garden (Vale Park, Adelaide) – solar-powered multi-zone measured irrigation with flow-splitter

This large garden has 9 zones and the water comes from a 22,000 litre rainwater tank. The water tank is at the lowest point on the property and four 14 watt pumps are required to pump the water uphill to the flow-splitter 75 metres away.

Four 20 watt solar panels provide the power

Four 14 watt pumps provide sufficient flow to the flow-splitter 75 metres away and about 4 metres higher

A banana tree receives 50 L/week in January from a loop of Netafim Bioline, plus an additional 36 L/week in January from a white needle nozzle (nozzle 7)

This zone has 4 fruit trees beside a fish pond, and each tree receives 50 L/week in January plus extra from a needle nozzle

A light-proof cover protects the flow-splitter from algae formation

This zone is a long narrow bed with 3 rows of Miniscape

A citrus tree receives 50 L/week in January from a loop of Bioline, plus an additional 23 L/week in January from a pink needle nozzle (nozzle 6)

18.2 Thorngate Drive Garden (Belair, Adelaide) – solar-powered multi-zone measured irrigation with flow-splitter

All the plants in this very large private garden are watered automatically. Because the block of land slopes steeply from the back yard to the front yard, 11 zones are needed, each zone following a particular contour. The garden uses a combination Netafim Miniscape drip line with 15 cm spacing between the drippers, and Netafim Bioline with 30 cm spacing between the drippers.

Flow-splitter supplying water to 11 zones. Each outlet valve is adjusted so that the head in the pressure monitor tube for the zone matches the head in the flow-splitter.

Zone beside the driveway using Miniscape drip line

Each level is a separate zone

18.3 Harvey St Garden (Woodville Park, Adelaide) – Unpowered Measured Irrigation Controller

This is an Australian native garden consisting of 4 raised garden beds, each 4 square metres, a 30 metre long garden bed beside the driveway, and a 10 square metre garden bed at ground level. The water supply to the UMIC is either gravity feed from an elevated water tank or pressurised from a mains water tap. The emitters used are Miniscape drip line, Bioline drip line, and a range of needle nozzles. All the plants in the garden are irrigated automatically with a single UMIC.

The slides on the large float are positioned so that the bottom of each slide is level with the bottom of the float. With reference to UMIC Table 1, the irrigation frequency corresponds to a net evaporation of 8 mm between irrigation events.

Unpowered Measured Irrigation Controller UMIC with large float

30 metre long garden bed beside the driveway

Chapter 19. Measured irrigation demonstration sites and contacts

South Australia
Sophie's Patch, phone Sophie Thomson on 0415 841619
Prospect Community Garden, phone Alan on 0429 970466
Camden Community Garden, phone Ken on 0439 800882
Fern Avenue Community Garden (Fullarton), phone John on 0487 172475
~~Henley Community Garden, phone John on (08) 82359926~~
Glenelg North Community Garden, phone Michael on (08) 82940709
Trott Park Community Garden, phone Malcolm on 0431 615114
Windsor Gardens Vocational College, phone Peter on 0401 121368
Harvey Street Garden (Woodville Park), phone Bernie on 0403 935277
Colac Street Garden (Greenacres), phone Katie on 0411 312532
Skipper Street Garden (Mount Barker), phone Gunther on 0432 877105
Radstock Street Garden (Woodville Park) phone Bernie on 0403 935277
Bushman Drive Garden (Walkley Heights), phone Grace on (08) 83596495
Argyle Tce Garden (Klemzig), phone Dan on 0437 480745
Cambridge Street Garden (Vale Park), phone Nathan on 0414 902348
Thorngate Drive Garden (Belair), phone Les and Teresa on 0401 125999
Fifth Ave Garden (Ascot Park), phone Roger on 0411 504410

NT
Kiranou Place Garden (Nightcliff), phone Stephanie on 0414 432245

Victoria
Yarrawonga Community Garden, phone Tom on 0438 589149
Napier Crescent Garden (Montmerency), phone Dan on 0402 465027
Gladstone Street Garden (Windsor), phone Chris on 0419 220309
Kingsley Street Garden (Ivanhoe), phone Paul on 0429 943921

ACT
Community Garden, phone Adrian on 0449 837211

Queensland
University of Sunshine Coast Community Garden (Maroochydore), phone Helen on 0401 839506

WA
Property at Bremer Bay, phone Rod on 0429 988733
Water Installations Pty Ltd, Mundaring, phone Ross on 0439 971213

KENYA
Contact Rob Kelly, World Vision Australia, (03) 92872724

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Appendix 1. Emitter flow equation

Measured irrigation principle

With measured irrigation the plants to be irrigated are often grouped into zones (zones) whereby the irrigation of each zone is independent of all the others zones. For each zone, the emitters should satisfy the measured irrigation principle which is defined as follows:

For any two emitters in a zone and at the same pressure, the ratio of the flow rates is independent of the pressure within the operational pressure range for the zone.

To ensure that the measured irrigation principle is satisfied for a particular irrigation application, it is important to introduce the emitter flow equation.

Emitter flow equation

Micro-irrigation emitter flow rates have different responses to pressure variations. The response of a specific emitter depends on its design and construction. The relationship between emitter operating pressure and flow rate is given by:

$$q = K * P^{x} \qquad (1)$$

where

q= emitter flow rate (lph),

K = emitter discharge coefficient,

P= operating pressure (kPa), and

x= emitter discharge exponent.

The measured irrigation principle is satisfied for a particular zone if and only if all the emitters in the zone have the same emitter discharge exponent for the operational pressure range for the zone. Hence, a combination of different emitters can be used in a zone provided that they all have the same emitter discharge exponent. For measured irrigation an emitter may be a dripper, a length of micro tube, or a nozzle. The term nozzle is used to refer to a short cylindrical tube or hole for restricting the flow.

If the measured irrigation principle is satisfied for a zone, then the nozzle ratio for any two emitter nozzles in the zone is the same as the ratio of the emitter discharge coefficients.

Drippers available commercially are either online (attached externally to the irrigation tube or tape) or inline (attached internally to drip line or drip tape). Drippers are either pressure compensating of non pressure compensating (unregulated). Pressure compensating drippers should not be used for measured irrigation unless the operating pressure is within the range recommended by the manufacturer. The emitter discharge exponent for pressure compensating drippers is almost zero within the pressure range recommended by the manufacturer (typically between 100 kPa and 300 kPa). Non pressure compensating drippers (both online and inline) are ideal for gravity feed measured irrigation. The emitter discharge exponent for most nozzles and non pressure compensating drippers is approximately 0.5.

All of the nozzles in Table 1 (see Section 1.4) have an emitter discharge exponent of 0.5.

Appendix 2. Measured irrigation formula

By using irrigation to maintain the water level at the level line, the volume of water entering the evaporator must match the volume of water that evaporates, assuming that there is no overflow.

Hence, at the end of each irrigation event

$C + R = E$

where

C is the volume of water emitted by the control nozzle during the irrigation event

R is the volume of rainwater that has entered the evaporator since the end of the previous irrigation event, and

E is the volume of water that has evaporated from the evaporator since the end of the previous irrigation event.

Therefore

$C = E – R$

At the end of the irrigation event, let e be the local evaporation in mm since the end of the previous irrigation event and let r be the local rainfall in mm since the end of the previous irrigation event. Let A be the surface area of the evaporation. Then provided that the evaporator never overflows or runs dry

$C = A * (e – r)$

This formula says that provided the evaporator never overflows or runs dry, the volume of water emitted by the control nozzle during the irrigation event is directly proportional to the net evaporation $(e – r)$ since the end of the previous irrigation event.

Let V be the volume of water emitted by one of the emitters during the irrigation event. Then from the definition of the nozzle ratio and the fact that all emitters are at the same level (and hence the same pressure)

$V = N_E * C$

where N_E is the nozzle ratio of the emitter to the control nozzle. Hence

$V = N_E * A * (e – r)$ (1)

where

V is the volume of water emitted by one of the emitters during the irrigation event,

N_E is the nozzle ratio of the emitter nozzle to the control nozzle,

A is the surface area of evaporation,

e is the local evaporation in mm since the end of the previous irrigation event, and

r is the local rainfall in mm since the end of the previous irrigation event.

Formula (1) is important because it proves that the second condition is satisfied in the definition of measured irrigation:

> *The volume of water emitted by each dripper during an irrigation event is controlled directly without the need to control the flow rate or the duration of the irrigation event.*

Monthly statistics for evaporation and rainfall in Australia are available from the Bureau of Meteorology (BOM). Provided you have access to historical data for the mean monthly evaporation and the mean monthly rainfall in your locality, this information can be used to predict the weekly application rate (litres per week) for each of the nozzles in Table 1.

$w_i = N_E * A * max(0, e_i - r_i) * 7 / n_i$ $i = 1, 2, 3, \ldots , 12$ (2)

where

w_i is an estimate of the weekly application rate for the nozzle in month,

e_i is the BOM mean monthly evaporation in month i,

r_i is the BOM mean monthly rainfall in month i, and

n_i is the number of days in month i.

Formula (2) is called the **measured irrigation formula.**