Unpowered Measured Irrigation Training Manual for Smallholders

more crop per drop

Unpowered Measured Irrigation Controller

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For solar powered measured irrigation, see the
Solar Powered Measured Irrigation Training Manual for Smallholders
(download from the Measured Irrigation website: www.measuredirrigation.com.au)

CONTENTS

Chapter 1. Introduction to measured irrigation (MI)

Definition of measured irrigation

Measured irrigation is an 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 discharged by each emitter during an irrigation event is controlled directly without the need to control the flow rate or the duration of the irrigation event.*

It is assumed that the smallholder has already established a drip irrigation system (either pressurised or gravity feed) on a garden or a small plot of land.

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.

Research on measured irrigation conducted at the Bureau of Meteorology weather station at Adelaide Airport demonstrated a correlation greater than 90% between the dripper discharge volumes and the prevailing ET (evapotranspiration) minus rainfall. When it rains the start of the next irrigation event is delayed, and when there is a heat wave the measured irrigation responds appropriately. If fact the water usage (litres per week for example) is directly proportional to the prevailing net evaporation rate. The research report *Evapotranspiration and Measured Irrigation - Report for Smart Approved Watermark* can be downloaded from the Measured Irrigation website: https://www.measuredirrigation.com.

Chapter 2. 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

Provided that the drip irrigation system uses non pressure compensating (NPC) drippers, any **adjustable dripper** may be used. For precision and consistency Claber 91214 adjustable dripper is recommended.

Claber 91214 adjustable dripper

Claber 912014 adjustable dripper can be purchased from the Online Shop at the Measured Irrigation website:
https://www.measuredirrigation.com/product-page/adjustable-dripper.

2.2 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 drip drips water into the evaporator during irrigation

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

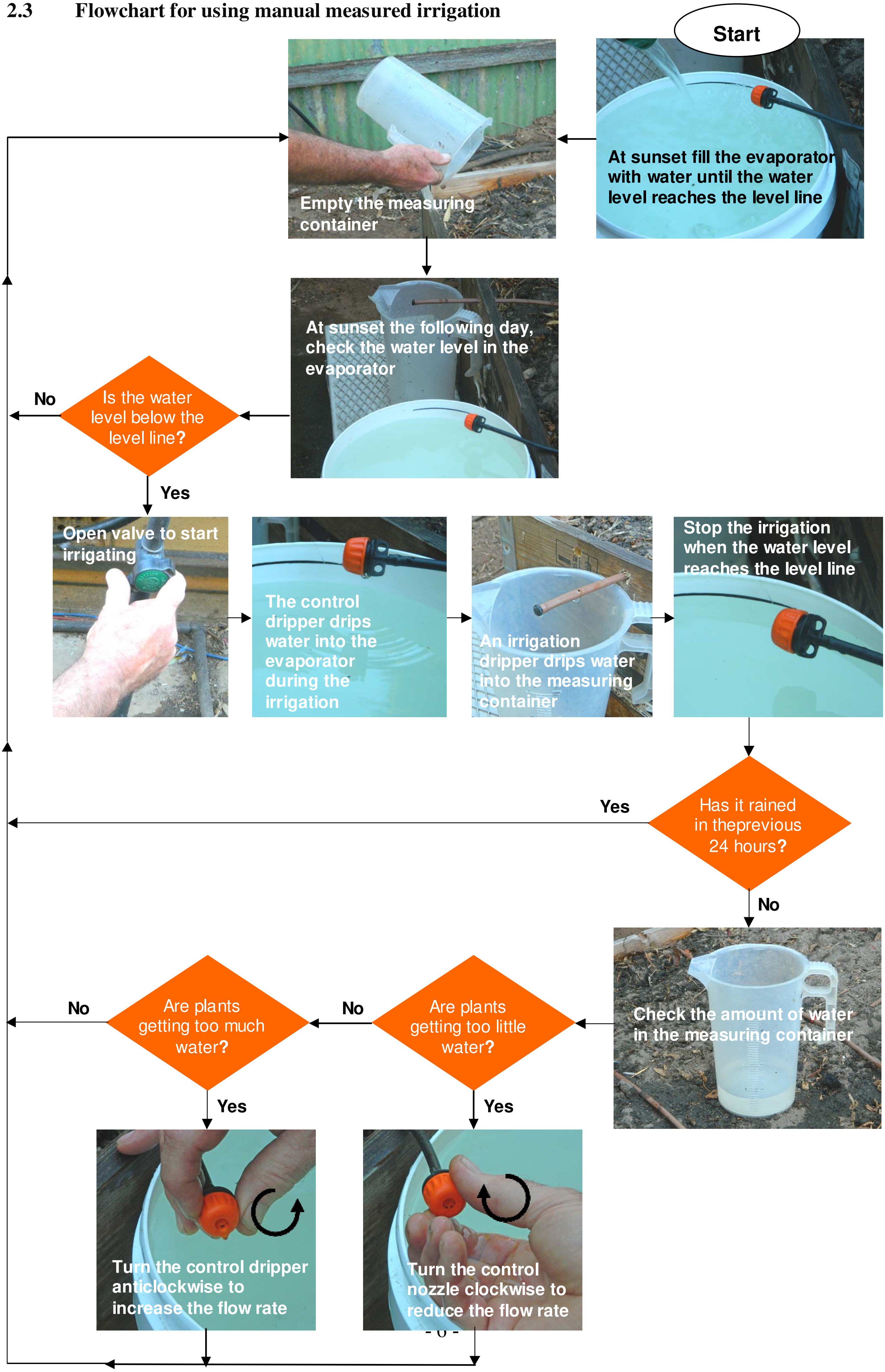
Place a measuring container under one of the irrigation drippers

Step 4. Adjust the control dripper so that flow rate is about the same as the flow rate of the irrigation drippers.

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 you do not impede the evaporation (chicken wire is ideal).

2.3 Flowchart for using manual measured irrigation



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 water usage (litres per week for example).

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 measured irrigation

Chapter 3. Unpowered Measured Irrigation Controller

3.1 Introduction to Unpowered Measured Irrigation Controller

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, 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, 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.

The Unpowered Measured Irrigation Controller can be used for gravity feed or pressurized systems, sprinkler or drip irrigation, porous hose irrigation (weeper hose or soaker hose), pressure compensating drippers or non pressure compensating drippers.

For programmable irrigation controllers, one of the disadvantages of non pressure compensating drippers is that the water usage is affected by variations in the water supply pressure. With the Unpowered MI Controller the water usage is independent of the water supply pressure. If fact the water pressure can change significantly during the irrigation event without affecting the dripper discharge volumes. **This is a unique feature of measured irrigation.**

The water usage for the Unpowered MI Controller is directly proportional to the prevailing net evaporation experienced by your plants. **This is a unique feature of measured irrigation.**

The Unpowered Measured Irrigation Controller can be purchased from the Online Shop at the Measured Irrigation website: https://www.measuredirrigation.com/product-page/unpowered-measured-irrigation-controller.

Unpowered Measured Irrigation Controller

All of the plants in the three photos below are being irrigated automatically by one Unpowered Measured Irrigation Controller.

How large can the plot be?

The valve in the Unpowered Measured Irrigation Controller has a 15mm inlet and outlet and hence the flow rate is limited by the size of the valve. It is assumed that the smallholder has already established a drip irrigation system. Provided that the drip irrigation system is already working effectively, you may need to use a number of Unpowered Measured Irrigation Controllers to automate the irrigation system depending on the size of the plot.

3.2 Instructions for installing the Unpowered Measured Irrigation Controller

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 Unpowered MI Controller (the inlet is on the opposite side to the adjustable control dripper). The water supply pressure should be between 10 kPa and 800 kPa.

Connect the water supply

Step 3. Connect the Unpowered MI Controller 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. If your irrigation drippers are PC (pressure compensating), the control dripper should also be PC. For porous hose irrigation (weeper hose or soaker hose), replace the control dripper by a short length of porous hose.

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.

Step 6. 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.

Slide the float over the float shaft

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 and the irrigation stops.

Fill the evaporator with water until the irrigation stops

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. Adjust the float to control the irrigation frequency (see Section 3.3).

The irrigation starts when the float reaches the low level

The irrigation stops when the float reaches the high level

Step 9. The control dripper can be adjusted to suit the water requirements of your plants (see Section 3.4). If you are using pressure compensating drippers, you can adjust water usage by adjusting the surface area of evaporation.

Step 10. 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 evaporator regularly to remove algae and other contaminants.

The Unpowered Measured Irrigation Controller 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.

Many irrigation controllers are programmed and cannot respond to an unexpected heat wave. The Unpowered Measured Irrigation Controller 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 to reduce the flow rate of the control dripper. If your plants need less water, rotate the control dripper anticlockwise to increase the flow rate of the control dripper.

Because the Unpowered MI Controller is so simple, there are fewer things to go wrong.

3.3 How to adjust irrigation frequency for the Unpowered Measured Irrigation Controller

To increase the options for the irrigation frequency, the Unpowered Measured Irrigation Controller is provided with an adjustable float consisting of a 7 cm diameter cylindrical float and 7 float rings that can slide over the cylinder to increase the outside diameter of the float (the bottom of the float ring should align with the bottom of the cylindrical float).


Cylindrical float and seven float rings


Slide the float ring over the cylindrical float

The following table shows the irrigation frequency for various float rings. The irrigation frequency is determined by the net evaporation from the evaporator between irrigation events.

Table 1. Irrigation frequency for the Unpowered Measured Irrigation Controller

Outside diameter of float	Number of float rings	Net evaporation between irrigation events
7 cm	0	29.3 mm
8 cm	1	24.6 mm
8 cm	2	20.3 mm
9 cm	1	16 mm
10 cm	1	11.6 mm
11 cm	1	9.3 mm
13 cm	1	6 mm
15 cm	1	4 mm

Besides the values of net evaporation in the table, additional values of the net evaporation between irrigation events can be achieved by sliding the float ring up the cylindrical float so that there is small gap between the bottom of the float ring and the bottom of the cylindrical float.

Provided that the water level in the evaporator is below 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 below the high level at sunset. Simply push the float down at sunset to start irrigating.


Push the float down 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.

Remove the float to stop irrigating

It is important to realise that when you adjust the irrigation frequency by adjusting the outside diameter of 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.

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3.4 How to adjust water usage for the Unpowered Measured Irrigation Controller

Adjusting water usage by adjusting the control dripper

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

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.

If your plants are not getting enough water, turn the control dripper clockwise 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.

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If the irrigation drippers are PC (pressure compensating), you can adjust the water usage by replacing the PC control dripper by a different combination of PC drippers.

Adjusting water usage by adjusting the surface area of evaporation

This technique is particularly useful when you are using pressure compensating drippers.

The water usage is directly proportional to the surface area of evaporation. You can increase the surface area of evaporation by choosing a supplementary evaporator with vertical sides. The total surface area of evaporation is the surface area of the supplementary evaporator plus the surface area of the original evaporator minus the surface area of the float. One way to connect the evaporators is to drill in hole in the side of each evaporator and to insert a rubber grommet into each hole. Insert a barbed connector or elbow into each grommet, and then use a length of flexible tube to connect the evaporators. The water level will be same in both evaporators.

You can decrease the surface area of evaporation by placing full bottles of water in the evaporator.

How to connect two evaporators

A full bottle of water decreases the surface area of evaporation

3.5 Unpowered Measured Irrigation Controller flow rate

The Unpowered Measured Irrigation Controller can be used for pressures ranging from 10 kPa to 800 kPa.

The maximum flow rate is greater than 1500 lph when the input pressure is 800 kPa.

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

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

Table 2. Flow rate for the Unpowered Measured Irrigation Controller

Input pressure in kPa	Maximum 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

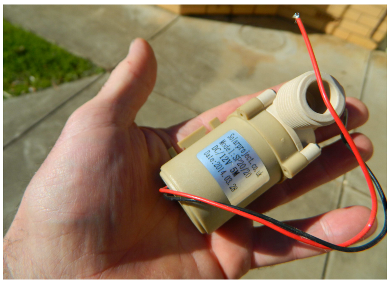
For some drip irrigation applications you may need more than one Unpowered Measured Irrigation Controller to provide an adequate flow rate from the drippers. Subdivide your irrigation application into the same number of zones as the number of controllers so that each zone has approximately the same water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

3.6 Key features of the Unpowered Measured Irrigation Controller

1. Completely automatic
2. No electricity is needed (no batteries, no solar panels, no computers, and no electronics)
3. Smart irrigation controller – the irrigation is controlled by the prevailing weather conditions rather than a program
4. Use for both gravity feed and pressurised irrigation
5. Use for sprinkler or drip irrigation
6. Use for porous hose irrigation (weeper hose or soaker hose)
7. Use for pressure compensating drippers or non pressure compensating drippers
8. You can adjust the water usage by adjusting the control dripper
9. You can adjust the irrigation frequency by adjusting the float
10. Adjusting the control dripper does not change the irrigation frequency
11. Adjusting the float does not change the water usage
12. The water usage is directly proportional to the net evaporation rate
    This is a unique feature of measured irrigation
13. Respond appropriately when there is an unexpected heat wave
14. When it rains, water enters the evaporator and delays the start of the next irrigation
15. The water usage is independent of the water supply pressure
    This is a **unique feature of measured irrigation**
16. Uses much less water without affecting the yield
17. There is no minimum water supply pressure
18. Simple and low tech and so there are fewer things to go wrong
19. Provided you have a continuous water supply, you can leave your irrigation application unattended for weeks on end

3.7 Using a solar pump to fill a header tank

If a header tank provides the water supply for the Unpowered Measured Irrigation Controller, 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/product-page/12-volt-14-watt-submersible-pump.

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 an 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 the broken pump is being replaced.

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 pump 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 pump 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 total 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.

Chapter 4. DIY Smart Irrigation Controller

4.1 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

4.2 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.

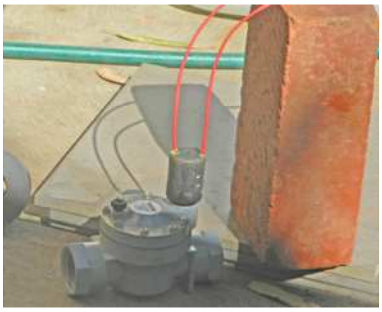
Step 7 (rare earth disc magnet assembly)

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 9 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. You may wish to use 2 saddle clamps to secure the 200mm pipes to the top of the containers.

Step 10 Cut off the two electrical wires connected to the solenoid (remember that the irrigation controller is unpowered)



Step 11 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 12 Place the evaporator on the large platform and add water until the depth is at least 20mm.

Step 13 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 14 Slowly add water to the evaporator until the magnet assembly rises from the low position to the high position.

Step 15 (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.

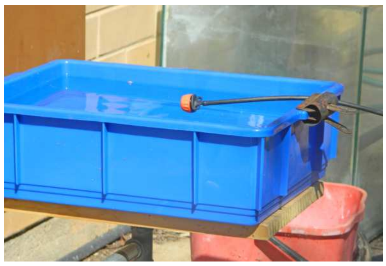

When the ferrite ring magnet assembly is in the high position, the top of the solenoid should be 10mm inside the ring magnet

Step 15 (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 16 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 17 Position the adjustable dripper so that it will drips water into the evaporator during the irrigation.



Step 18 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 19 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 20 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.

4.3 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.

4.4 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 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.

4.5 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 5. Soil moisture and measured irrigation scheduling

5.1 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 from the Online Shop at Measured Irrigation website: https://www.measuredirrigation.com/product-page/soil-moisture-probe.

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.

5.2 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**. One 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 be 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. Root zone scheduling takes account of evapotranspiration, the soil type and the depth of the root zone

There are two ways to implement root zone scheduling. The first way is to use an adjustable dripper as the control dripper (see Section 5.3). The second way is to use one or more irrigation drippers as the control dripper and to select an evaporator with an appropriate surface area (see Section 5.4).

Measured irrigation scheduling can be applied to sprinkler irrigation as well as drip irrigation.

5.3 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 (use the soil moisture probe).

Place a measuring container under one of the drippers to collect the water and start irrigating just before sunset. For sprinkler irrigation, place a measuring container under a non pressure compensating dripper that has been added to the irrigation zone. For porous hose irrigation, connect a small length of porous hose to the irrigation system so that the discharge from the small length of porous hose enters a measuring container.

While irrigating, check the moisture level in the soil by hammering the soil moisture probe into the soil near a dripper. Stop irrigating when the position of the wetting front is near the bottom of the root zone (or when the wetting front has reached an appropriate depth).

The volume of water in the measuring container is the **dripper control volume** and it is the amount of water that each dripper should deliver during the irrigation event 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

By following this procedure the volume of water that each dripper discharges during the irrigation event can be adjusted to match the dripper control volume. Alternatively, your knowledge of your plants requirements at their current stage of growth can be used to adjust the volume the volume of water that each dripper discharges during the irrigation event.

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

You need to estimate the evaporation in mm before the soil is dry between the surface and the bottom 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.

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

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

For manual measured irrigation, mark a low level on the inside of the evaporator so that the gap between the high level and the low level is equal to the root zone evaporation. For the Unpowered Measured Irrigation Controller, make adjustments to the float so that the net evaporation between irrigation events corresponds to the root zone evaporation

Step 3. Run the irrigation

Empty the measuring container and place it below the same dripper used in Step 1. Adjust the control dripper so that the flow rate is roughly the same as the flow rate of the dripper used in Step 1.

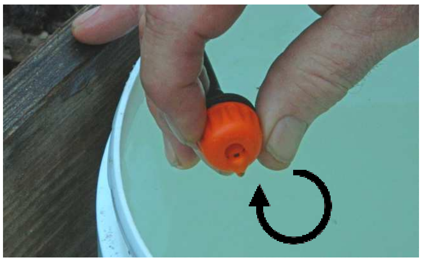
For manual measured irrigation, adjust the water level in the evaporator at sunset until it is at the low level and start irrigating. For the Unpowered Measured Irrigation Controller, the irrigation starts automatically when the water level reaches the low level.

For manual measured irrigation, stop irrigating (turn off the water supply) when the water level in the evaporator reaches the high level. For the Unpowered Measured Irrigation Controller, 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 wetting front 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 wetting front is probably below 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.

5.4 Root zone scheduling using an evaporator with an appropriate 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 following steps can be applied to any irrigation zone, regardless of the size of the zone.

Step 1. How much water is needed (see Step 1 in Section 5.3)

Step 2. How much evaporation is required between irrigation events (See Step 2 in Section 5.3).

Step 3. How to choose a suitable evaporator (Unpowered manual measured irrigation)

You need to choose an evaporator with an appropriate surface area so that the dripper control volume is delivered during the irrigation event. Calculate the **reference surface area** by dividing the dripper control volume by the root zone evaporation. Then choose an evaporator with vertical sides so that the surface area is an integral multiple *m* of the reference surface area. It is preferable that the surface area be at least 0.05 m^2.

Step 3. How to choose a suitable evaporator (Unpowered Measured Irrigation Controller)

You need to increase the surface area of evaporation so that the dripper control volume is delivered during the irrigation event. Calculate the **reference surface area** by dividing the dripper control volume by the root zone evaporation. Then choose a supplementary evaporator with vertical sides so that the total surface area of evaporation is an integral multiple ***m*** of the reference surface area. Note that the total surface area of evaporation is the surface area of the supplementary evaporator plus the surface area of the original evaporator minus the surface area of the float. Connect the two evaporators together. One way to connect the evaporators is to drill in hole in the side of each evaporator 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 both evaporators.

Step 4. How to set-up the evaporator (Unpowered manual measured irrigation)

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 1.5 cm below the overflow level, and 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 ***m*** drippers so that they will drip water into the evaporator during the irrigation event. The drippers should be identical to the dripper used in Step 1.

For example, if the surface area of the evaporator is twice the reference surface area ($m = 2$), then two drippers should be positioned over the evaporator.

Step 4. How to set-up the evaporator (Unpowered Measured Irrigation Controller))

Position the evaporator at a suitable location so that the evaporation matches the evaporation near your plants. Adjust the float so that the net evaporation between irrigation events is as close as possible to the root zone evaporation.

Position ***m*** drippers so that they will drip water into the evaporator during the irrigation event. The drippers should be identical to the dripper used in Step 1.

Step 5. How to use the evaporator (Unpowered manual measured irrigation)

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.

Start irrigating when the water level is at the low level

Step 5. How to use the evaporator (Unpowered Measured Irrigation Controller)

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

Turn on the water supply and the irrigation will start automatically. The irrigation will stop automatically when the water level reaches the high level.

To ensure that irrigation does not occur during the heat of the day, you may wish to use a tap timer set to daily irrigation with a start time of 6:00 pm and a stop time of 6:00 am. The irrigation will only start at 6:00 pm if 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. Root zone scheduling using an evaporator with an appropriate surface area responds to the prevailing weather conditions in your garden rather than the weather at a weather station. For example, it responds to the actual evapotranspiration of your plants, rather than the theoretical evapotranspiration at a weather station. This is particularly important if you are using a greenhouse.