Smart Watering System **20/7/2026**

Intro

This project details the construction of a smart watering system that saves water and a non-trivial amount of money. It uses a combination of parameters such as time of day, soil moisture, forecast rainfall, probability of rainfall, and forecast evapotranspiration rates to decide how much water to give a lawn/garden.

Bill of Materials

1. 1x Wrapit-Solutions Starter Kit which includes a Raspberry Pi hub and an ESP8266 based sensor interface board
2. 1x 12 Volt DC (24 Volt DC would also be fine) Normally Closed Water Solenoid Valve
3. 1x 220VAC/12VDC (or 24VDC) Power adaptor with suitable current capability to drive the solenoid valve
4. 1x Soil Moisture Sensor (Capacitive) e.g. DFRobot SEN0193
5. 2x 10k Ohm ¼ watt resistors
6. 15 ml of a two part epoxy glue (e.g. Araldite)
7. 1x 32mm (1.25”) poly pipe end cap
8. 1x 4 metre length of 32mm poly pipe (or more as required)
9. 2x 32mm 90° poly pipe connectors (or more as required)
10. Suitable data cable, e.g. 3 conductor shielded 22-24 AWG or cat 5 or cat 6
11. 1x Tipping Bucket Rain Gauge (optional)
12. 1x rain gauge mount and poly pipe for rain gauge cabling (optional)

A Word on Sensors

This project uses a capacitive rather than resistive moisture sensor due to the fact that resistive sensors tend to corrode and exhibit unreliable behaviour. The active elements in capacitive sensors are lined with a clear coating that inhibits corrosion. This is not the case for resistive probes as they work on the principle of measuring the changing resistance with moisture and therefore need to be in direct contact with the soil. Unfortunately this leads to unreliable behaviour and makes them unsuitable for long term use.

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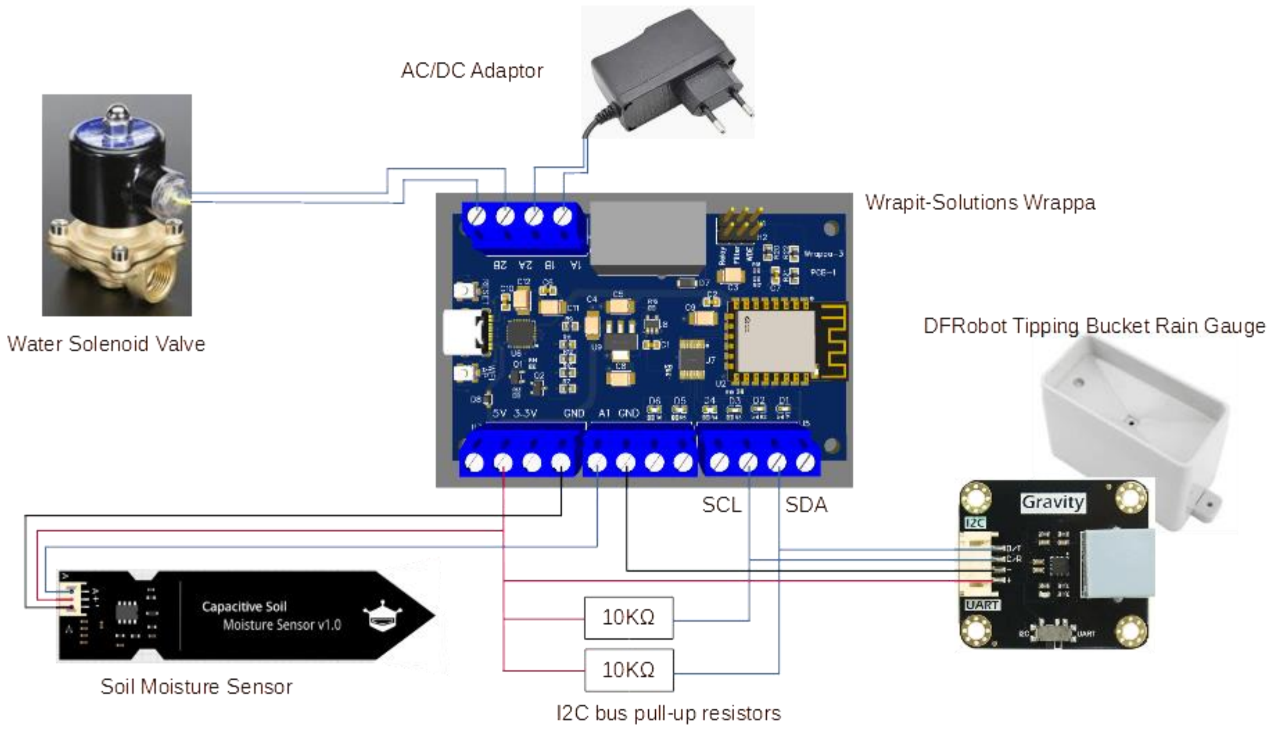
Hardware Connections

The following diagram depicts the interconnections between the various hardware components of the system. Note: The DFRobot tipping bucket rain gauge is an optional extra and is not an essential project component. Include it only in case you are interested in comparing how much rain has actually fallen at your location in the last 24 hours versus Open-Meteo's forecast rainfall.



1. The AC/DC adaptor (12-24VDC) for powering the solenoid connects to Wrappa relay contacts 1A and 1B[Note 1]
2. The water solenoid valve connects to Wrappa relay contacts 2A and 2B[Note 1]
3. The 'D' (SDA) output of the tipping bucket rain gauge connects to the Wrappa terminal D2[Note 2]
4. The 'C' (SCL) output of the tipping bucket rain gauge connects to the Wrappa and D3[Note 2]
5. The '-' output of the tipping bucket rain gauge connects to the Wrappa GND terminals
6. The '+' output of the tipping bucket rain gauge connects to Wrappa 3.3V terminal
7. '+' of the soil moisture sensor connects to the Wrappa 3.3V terminal
8. '-' of the soil moisture sensor connects to a Wrappa GND terminal
9. 'A' of the soil moisture sensor connects to the Wrappa A1 terminal
10. A 10k Ohm I2C bus pull-up resistor is connected between the Wrappa 3.3V terminal and the Wrappa D2 terminal
11. A 10k Ohm I2C bus pull-up resistor is connected between the Wrappa 3.3V terminal and the Wrappa D3 terminal
12. If shielded data cable is used for either the sensor or the rain gauge, terminate the shield on the Wrappa GND terminal. Leave it open at the other end

Note 1: polarity is not important
Note 2: Terminals D2 and D3 need to be configured as the Wrappa's i2c bus using a Wrappa Manager node in the flow

Node-RED flow

The Wrapit Solutions' hub, which is part of the Wrapit-Solutions starter kit, runs an instance of Node-RED, and it is a single Node-RED flow that acts as the logic and coordination engine for this project. Before getting into the Node-Red flow, which is effectively the 'brains' of the watering system, it's worth having a quick look at the factors one might choose to consider in any non-trivial attempt to save on water usage/costs.

Water Use Logic

It's important to recognise that truly optimising water consumption can be a pretty complicated business. Here are just some of the factors to consider for a residential home scenario: forecast sun, wind and rain; forecast reliability (i.e. forecast probabilities); the water requirements and absorption rates of your target plants/trees/grasses; available water pressure; the time of day to water; actual temperature, wind, humidity throughout the day; the characteristics of your chosen water delivery mechanism (drip, sprinkler, soaker hose etc.); soil absorption/drainage characteristics; the garden's exposure to sun/shade/wind; lawn/garden topology and susceptibility to runoff; whether there are requirements for a lawn or garden to be dry at any particular time(s) of the day; yours and your neighbours tolerance for any sounds emitted by your watering system early in the morning; the cost of water, etc. etc.

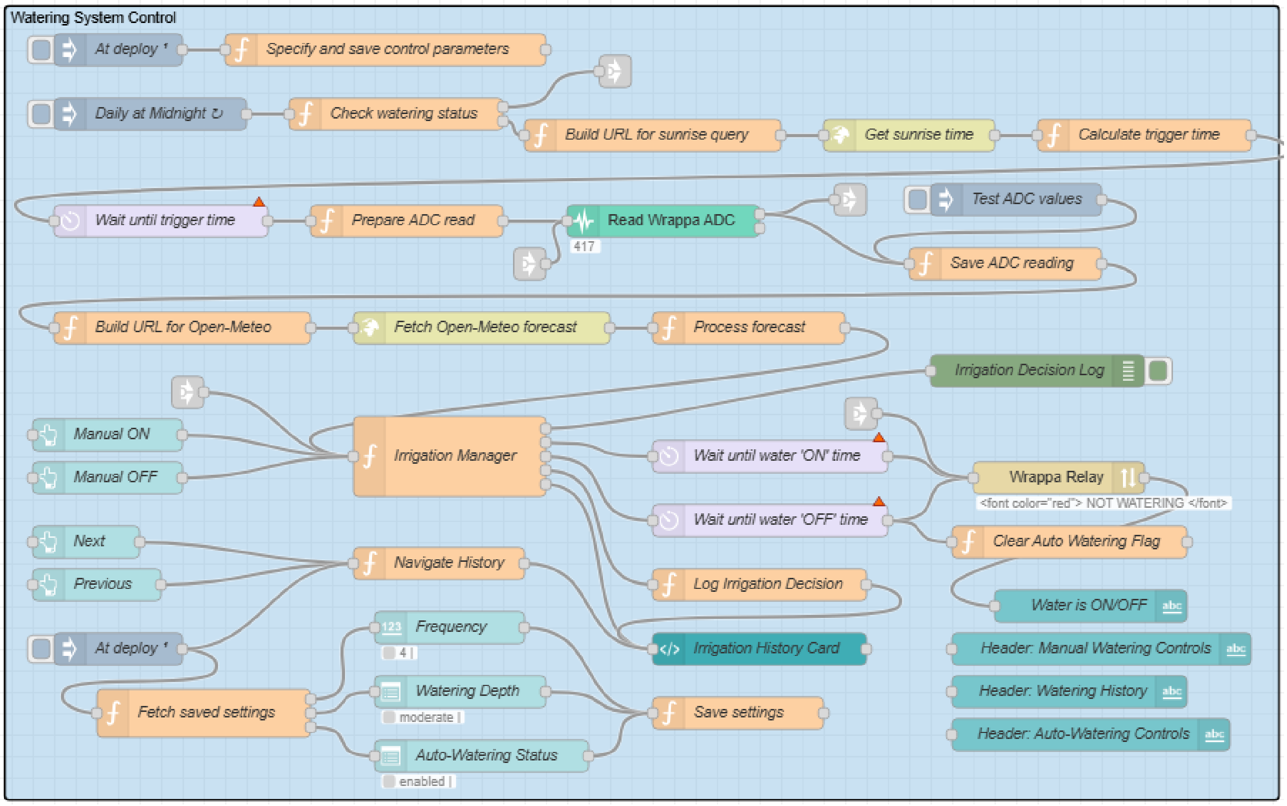
This project doesn't try to 'boil the ocean' by incorporating too many of the above water usage optimisation factors, instead it simply seeks to establish a sensible balance between complexity and efficacy. As such, the following factors were chosen for this project: time of day to water; soil moisture; and a forecast of rainfall, rainfall probability and evapotranspiration rates. With these factors, along with a one-time moisture sensor auto-calibration effort, and by making a small number of parameter settings in a Node-RED flow, this project represents a fairly effective smart watering optimisation solution.

So here's the logic: Every night at just past midnight the system 'wakes up' and determines whether it's a watering day, if not, it goes back to sleep. If watering is scheduled for the current day, a call is made to the website sunrise-sunset.org to obtain a time for sunrise. Once we have time for sunrise, we set a timer to trigger activities at a predefined time before sunrise. Note: watering just before and just after sunrise is generally considered the best time for watering your garden because: it's cooler; there's usually less wind and therefore evaporation; and plants are 'waking up' and absorbing water in preparation to photosynthesise during daylight hours. When the timer triggers, we:

- Take a soil moisture reading
- Obtain an hour by hour forecast of precipitation, precipitation probability, and evapotranspiration rates from the Meteo website
- Use the current soil moisture measurement and the forecast data from Meteo to calculate a watering duration
- Water for half of the calculated duration before sunrise and the other half after sunrise

Implementing the Logic

The figure below is a screenshot of the Node-RED flow that implements the aforementioned logic (click to download). It's worth noting that AI, and more precisely Anthropic's Claude, was used to create the flow for this project from scratch. Claude made some reasonable suggestions and did eventually come up with a pretty decent flow, but in the process it made quite a few errors, often generated overly complex and/or convoluted code, and made a lot of incorrect assumptions, so it took a good number of iterations and more detailed revised prompting and specifying requirements to get it going.



The flow looks a little intimidating but it's actually not too complicated. Here's a short description of how it works: The '*At deploy*' inject node and '*Specify and save control parameters*' function node at the top left of the flow combine to support the specification and saving of system control parameters, including the local timezone and the latitude/longitude of the watering system.

The '*Daily at Midnight*' inject node runs at 1 minute past midnight every night. When it does, it triggers the '*Check watering day*' function node which determines whether or not it's a watering day. Note: the watering frequency is specified using the flow's dashboard (see below). Assuming it's a watering day, the '*Build URL for sunrise query*' function node constructs a request URL which the '*Get sunrise time*' HTTP node sends to the sunrise-sunset.org website. The response from sunrise-sunset.org contains the time for sunrise which the '*Calculate trigger time*' function node converts to a delay period. The delay period is then sent to the '*Wait until trigger time*' delay node.

When the trigger time comes around, the '*Prepare ADC read*' function node triggers a single ADC (analogue in) read by the Wrappa (included in the Wrapit-Solutions start kit). The raw ADC value returned by the Wrappa is saved by the '*Save sample*' function node which also triggers the '*Build URL for Open-Meteo*' function node. That node constructs a forecast query which is sent to the Open-Meteo website by the '*Fetch Open-Meteo forecast*' node. The response from Open-Meteo contains an hour by hour forecast of rain, probability of rain, and evapotranspiration rates which the '*Process forecast*' function node aggregates and sends to the '*Irrigation Manager*'. The irrigation manager node makes an irrigation decision based on: saved calibration data (see below); the recently saved soil moisture reading; and all the forecast information from Open-Meteo. Note:

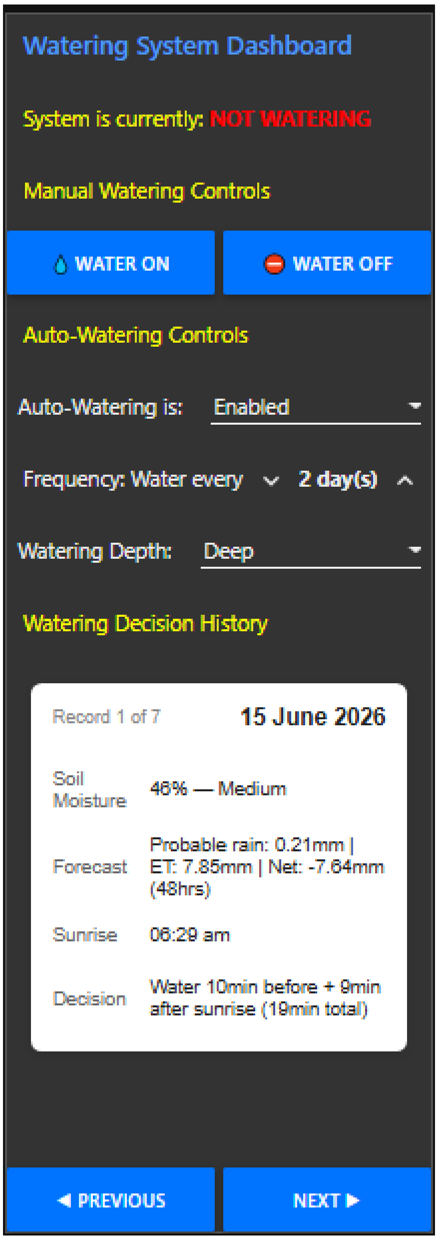
under certain soil moisture and weather forecast conditions the '*Irrigation Manager*' may decide to skip watering altogether.

After the irrigation decision is made for the current day, the irrigation manager node then controls switching the watering system on and off via the '*Wrappa Relay*' node.

The collection of nodes at the bottom of the '*Watering System Control*' flow supports logging irrigation decisions and the construction of the system's user interface or dashboard (see below).

The Dashboard

The Node-Red dashboard produced by this flow offers a variety of options, as shown below.



- The status of the watering system is presented by the '*System is currently*' field at the top of the dashboard, which indicates whether the system is currently watering or not.

- The '*Manual Watering Controls*' buttons act as an over-ride to manually turn the watering system on or off.
- The '*Auto-Watering Controls*' supports:
  - enabling and disabling auto-watering (useful for seasonal control);
  - specifying the number of days between auto-watering attempts; and
  - specifying the auto-watering depth (light, moderate, deep).
- The '*Watering Decision History*' provides visibility into watering decisions for the last 7 days.

Installing the Soil Moisture Sensor

The soil moisture sensor is a critical element in this project so a little effort is necessary to prepare and install it appropriately. The following description is one way to do it (Note: this doesn't mean it's the best or only way to do it, but it does work). Use a 2mm drill to create a line of holes in a 32mm poly pipe end cap. Then use small rat tail and flat files to create a slot in the end cap. Make sure to make the fit between the moisture sensor and the end cap reasonably tight so that when the sensor is 'potted' the epoxy doesn't bleed excessively out of any gaps between the sensor and end cap. The slot also needs to be centred so there's sufficient clearance between both sides of the sensor when the poly pipe is inserted into the cap.

Poly pipe end cap with slot

'Pot' the sensor in the cap using a two part epoxy resin. Make sure not to pot the sensor connector. Note that some epoxy should also be applied to the edges of the sensor to reduce the risk of the printed circuit board delaminating when exposed to a moist environment for a long time.

The finished potted sensor

View inside the end cap

Install the sensor under your lawn/garden bed at a depth of about 10cm (i.e. just beneath grass/plant roots). Note the orientation of the sensor, with the capacitor electrode tracks of the sensor facing upwards. The weight of the soil above the sensor should ensure reasonably good contact between soil and sensor under most, if not all soil moisture conditions.

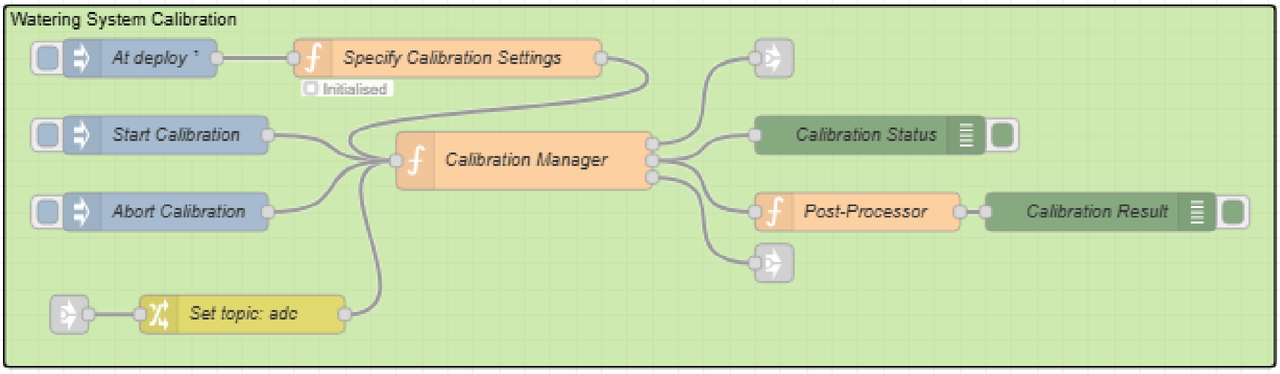
The sensor just before 'reading it its last rites' and burying it

Initial System Verification

Once the probe is installed and connected to the Wrappa, and the solenoid valve is connected in line with your lawn/garden watering system, verify connectivity and proper functioning of the setup before starting the calibration process. Do this by using the manual controls on the dashboard to turn on/off the watering system. Also insert a temporary inject node in the flow and connect its output to the '*Read Wrappa ADC*' node to verify a sensible signal from the moisture probe (obviously the prevailing moisture content in the soil will affect the signal but a value between 500 and 700 is typical. A value less than 10 is likely an indication the sensor is not working correctly).

Calibrating the System

For the system to work effectively in its particular environment, a one-time calibration is required (or more than once if soil/sensor conditions materially change). Here's the calibration process:
1. Install the soil moisture sensor in its intended long term location and ideally leave it for a few days to bed in
2. Allow the target lawn/garden to dry out for several days. The soil needs to be nice and dry before performing the calibration.
3. Make sure the debug panel on the Node-RED design centre is visible
4. Run the 'Watering System Calibration' flow below by clicking on the left of the 'Start Calibration' inject node. Calibration results will start appearing in the debug panel.
5. Wait for the calibration completed message in the debug panel (depending on the permeability of your soil, this could take more than 30 minutes)
4. Tweak calibration parameters in the '*Specify Calibration Settings*' node if the calibration is unsuccessful. How parameters affect calibration is explained in the 'Tuning the System' section below and also in comments in the node's code



Tuning the System

The system parameter settings in the flow will not be suitable in all circumstances, so with this in mind, a number of system control parameters have been exposed and can easily be changed. The key parameters in the ***"Specify and Save Control Parameters"*** node are:

- **Timezone**: Ensures correct conversion from UTC sunrise time to local time. Also takes into account daylight savings where applicable
- **Latitude/Longitude**: Your location for the correct Open-Meteo forecast
- **Light and moderate watering duration percentages**: These parameters specify a watering duration as a percentage of the calibrated deep watering duration.
- **Light, moderate, and deep rainfall in mm**: These specify rainfall equivalent in mm for each watering intensity

The key parameters used in calibration are:

- **BASELINE_SAMPLES**: Count of samples used to establish a stable 'dry' baseline.
- **SAMPLE_INTERVAL_MS**: Interval between ADC samples throughout the various phases of calibration (in milliseconds)
- **BASELINE_DEVIATION_MAX**: Maximum allowable deviation of any baseline sample from the baseline mean. If any sample during the 'dry' baseline phase of calibration exceeds this, calibration aborts with an unstable baseline error.
- **TOO_WET_THRESHOLD**: ADC value at or below which soil is considered too wet to calibrate. Calibration aborts if the baseline mean is at or below this value
- **SATURATION_DELTA**: Used for saturation detection – if ADC values change by less than this for a number of consecutive samples, the soil is deemed saturated.
- **SATURATION_WINDOW**: The number of consecutive samples required to confirm saturation.
- **CALIBRATION_TIMEOUT_MS**: Maximum total calibration duration (milliseconds) before a soft timeout occurs.

These key parameters can be modified in the '*Specify Calibration Settings*' node.