WATER SCOUT™

SMEC 300 Soil Moisture Sensor

PRODUCT MANUAL

Item # 6470-6, 6470-20

Spectrum® Technologies, Inc.

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This manual will familiarize you with the features and operation of your new WaterScout SMEC 300 Soil Moisture Sensor. Please read this manual thoroughly before using your instrument. For customer support, or to place an order, call Spectrum Technologies, Inc. at (800)248-8873 or (815) 436-4440 between 7:30 am and
5:30 p.m. CST, FAX at (815)436-4460, or E-Mail at info@specmeters.com.
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General Overview

Thank you for purchasing a WaterScout SMEC 300 Soil Moisture Sensor. The moisture and nutrient status of your soil or container substrate are key pieces of information. They allow you to tailor your irrigation and fertilization program to suit your crop's needs. They also help identify if it is necessary to leach salts from the profile. The SMEC 300 combines affordability and accuracy into a sensor that is easy to install.

The soil moisture sensor consists of two electrodes that function as a capacitor, with the surrounding soil serving as the dielectric. An 80 MHz oscillator drives the capacitor and a signal proportional to the soil's dielectric permittivity is converted to the output signal. The dielectric permittivity of water is much greater than air, soil minerals and organic matter. So, changes in water content can be detected by the sensor circuitry and correlated to the soil's moisture content.

The salinity of the soil solution, irrigation water or fertilizer solution is an important parameter affecting the root zone environment. Any of these factors can have a significant effect on plant growth and physiology. The easiest way to monitor salinity is by measuring the electrical conductivity (EC). EC is strongly correlated to the salinity of the soil solution. EC measurement is also affected by temperature and, to a lesser degree, by soil moisture content. The SMEC 300 measures EC with a pair of carbon ink electrodes which provide a large contact surface with the soil solution. Temperature is measured with a thermistor potted in the sensor molding.

The SMEC 300 is designed to be compatible with the Watch-Dog® data loggers and weather stations as well as the Field Scout® soil sensor reader. SpecWare™ software enables you to view your data in graphical and tabular form as well as run reports customized to your application.

Specifications

Standard Interfaces	WatchDog weather station, FieldScout Soil Sensor Reader
Connector	2.5mm stereo pin
Range	**VWC** 0% to saturation **EC** 0 to 10 mS/cm **Temp** 33 to 175°F (0.5 to 80°C)
Resolution	**VWC** 0.1% **EC** 0.01 mS/cm **Temp** 0.1°F (0.1°C)
Power	3V @ 6 to 10mA
Output	Analog voltage, time division multiplexed.
Oscillator Frequency	80 MHz
Accuracy	**VWC** 3% **EC** ±2% **Temp** ±1°F (0.6°C)
Sensor Dimensions	2.8in. (7cm) x 1.2in (3cm)
Cable length	6 and 20ft. extendable up to 50ft.

Sensor Placement

The sensors should be located in the effective root zone and at locations that will give a representative picture of the salinity and soil water status of the area being measured. For outdoor applications, consider areas of the field planted to different types of vegetation. This could be fairways vs. greens or landscaped areas planted with trees as well as those planted with flowers. Areas with significant differences in factors such as topography or soil type should be considered unique environments. For greenhouse applications, select one or more representative containers. Selecting a site which receives the least amount of water from the irrigation system will tell you when that area becomes critically dry and is in need of attention. Sites that have the greatest fluctuation in soil moisture will exhibit the greatest level of EC variability as well. Typically, one or two sensors should be installed in the root zone. A single sensor should be placed in the middle of the root zone. When two sensors are installed at a single site, it is recommended to place one sensor at the top of root zone and a second at the bottom. An advantage of installing multiple sensors is it allows you to see how well irrigation and rainwater is moving through the soil profile.

The SMEC 300 is most sensitive to the soil adjacent to the sensor. Therefore, good contact between the soil and sensor is important. Stones and air pockets next to the sensor will affect the accuracy of the readings. Because it is sensitive to differences in dielectric permittivity, care should be taken not to install the sensor in or near metal.

Hardware / Software Compatibility

There are some restrictions on which equipment is compatible with the SMEC 300 and how many sensors can be connected to a single unit. These are outlined below.

Soil moisture sensor reader
• Requires firmware version 4.4 or greater.

Specware software
Weather stations require Specware version 9.04 or greater.

WatchDog weather stations
The table below outlines the compatibility of the sensor with the various WatchDog weather products. All micro-stations and mini-stations with firmware v. 3.8 or greater can read an SMEC 300 on any channel. Full stations and mini-stations with firmware v. 3.5 can only have SMEC 300 sensors connected to ports A or D. Ports B and C (and/or E and F) become "virtual" software ports and are unavailable for other sensors.

Station #	Station Type	Station FW version	Number of Sensors	Compatible Channels	Potentially unavailable channels
1225, 1250	Micro	N/A	0	Incompatible	
1400, 1525, 1650	Micro	2.0	2	A, D	
1200, 1425, 1450	Micro	2.0	1	D	
2475	Mini	3.8	1	A	
2450	Mini	3.8	2	A, B	
2425	Mini	3.8[*]	3	A, B, C	*
2400	Mini	3.8[*]	4	A, B, C, D	*
2550, 2700	Full	6.9	2	A, D	B/C, E/F
2800	Full	3.2	2	A, D	B/C, E/F
2900ET	Full	6.9	1	A	B/C

[*] *Can accommodate 1 SMEC 300 with FW v. 3.5 using port A plus B/C as virtual ports*

Upgrading older weather stations

Older WatchDog mini-stations can be upgraded with a new micro-controller chip (3300WD2). Full weather stations can be upgraded with a replacement micro-controller with integrated clock board (item 3300CBWM). Micro stations can be upgraded through SpecWare software. Contact Spectrum Technologies for details.

Original WatchDog weather stations (models 525, 550, 600, 700, and 900), 200- and 400- series purple loggers, and A-series loggers are incompatible with the SMEC 300.

Calibrating the EC Sensor

The EC sensor can be calibrated with the Soil Sensor Reader or with the EC Calibration Device (item 6470CAL). The calibration procedures are included in the product manuals for each device. With both devices, calibration is done with a 1.41 mS/cm calibration standard. Some important points to remember when calibrating the EC sensor:

1. Be careful not to touch the carbon ink electrodes. Oils from your fingers can affect the accuracy of the sensor. Before calibrating, the electrodes should be cleaned well with alcohol.

2. Immerse the sensor up to the immersion indicator on the sensor molding (indicated by arrow in image to right).

3. Wait until the sensor has come to thermal equilibrium before initiating the calibration routine.
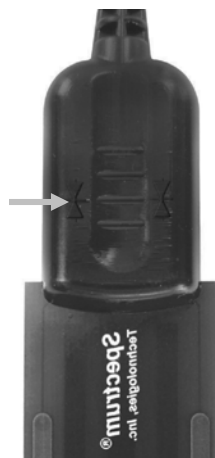
Checking the Sensor

The EC sensor can be checked with the 1.41 mS/cm calibration standard (see Calibrating the EC Sensor p. 9). The soil moisture calibrations were developed using mineral soils and a soilless material (peat moss). Therefore the sensor will not give a value of 100% in water. To check if the soil moisture sensor is still functioning properly, readings can be taken in the following media:

Air
In air, the sensor should read a VWC of 0%.

Water
In distilled water, the sensor should read a VWC of about 55% in Standard mode and about 68% in Soilless mode.

Saturated Playground Sand
Add water to playground sand until the surface glistens and no additional water can permeate the sand. The sensor should read a VWC of about 29% in Standard mode and about 60% in Soilless mode.

Note: WatchDog weather stations display the Standard VWC value. The soilless mode is available on the handheld reader only.

Installation

The most important consideration for installing the sensors is maintaining good contact between the sensor and the soil. This ensures optimum performance. Before any installation, be sure that the EC electrode has been cleaned with alcohol and is recently calibrated (see Calibrating the EC Sensor p. 9)

Important: The sensor can be damaged if it is pushed directly into hard, native soil. Please read installation guidelines before installing the sensors.

<u>Surface Installation</u>
If the sensor is being installed near the surface such that the molding and cable will remain above the soil surface the sensor can sometimes be pushed directly into the soil. Because the sensor board is flexible, care should be taken to avoid snapping it during installation. Do not strike the sensor with a hammer or other blunt instrument as this could damage the sensor electronics. If the soil is very hard, a small slit can be dug into the soil with a knife or shovel to facilitate easier insertion. Subsequently, pushing that same implement into the ground surrounding the sensor will improve the contact between soil and sensor.

<u>**Deep Installation**</u>

Vertical Orientation
To install the sensor in a vertical orientation, dig an access hole to the desired depth. This can be done with an auger or shovel. If a large hole has been dug with a shovel, the sensor can be installed similar to the surface installation and back-filled.

If using an auger, it is recommended that the hole be at a slight angle. This will reduce the effect of water channeling down to the sensor via the sensor cable. A length of

½" Schedule 40 PVC works well as an insertion device because the sensor molding has a width of 7/8". <u>In general, it is not recommended to push the sensor directly into native soil</u>, especially in dry, high-clay or gravel/stone-laden soil. Instead, it is best to return some crumbled native soil from the bottom of the access hole, tamp it sufficiently and use the insertion device to push the SMEC 300 into the packed soil. It is advisable to mark the tamping and insertion tools such that it is possible to determine that the sensor will be completely surrounded by tamped soil
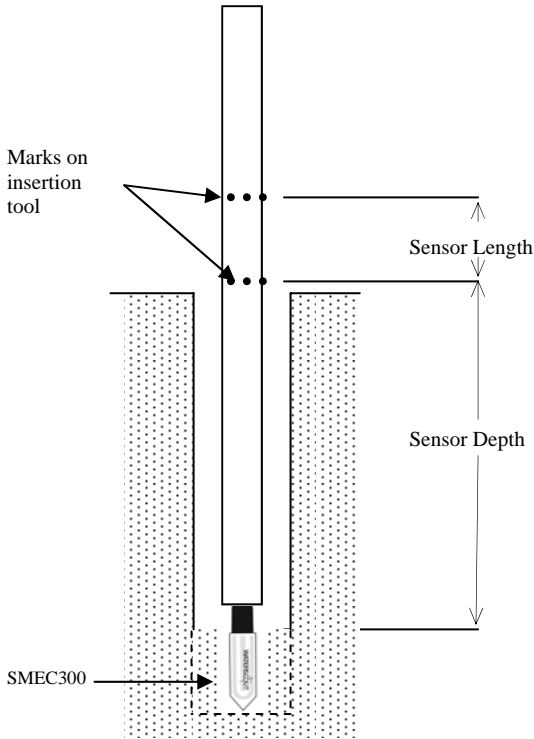
and that the sensor is being installed to the desired depth. The access hole should then be carefully backfilled with native soil and tamped down to eliminate air pockets.

Horizontal Orientation

Digging a small hole or trench in the soil allows the sensors to be installed horizontally. The sensors are pushed directly into the exposed face of undis- turbed soil. Because the sensor board is flexible, care should be taken to avoid snapping it during installation. To limit the effect of water moving vertically through the soil profile, the sensors should be installed so the flat face is perpendicular to the soil sur- face. For the same reason, if sensors are installed at multi- ple depths, they should be offset from one another.
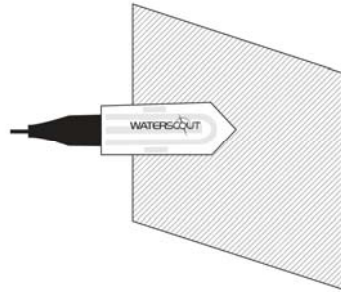
Removal

Care should be taken when removing a sensor that is firmly embedded in soil. Pull on the molding only. Pull- ing on the cable risks damaging the wiring.

Suggestions for protecting sensor cables from rodents

- For vertical installations, run sensor cables through PVC pipe. This can be the same tube used as an installation tool.

- For sensor cable that will be running parallel to the ground, either above or below the soil surface, the sensor cable can be fed through flexible conduit or drip irrigation tubing. When using drip irrigation tubing, it is preferable to use used tubing. This is because the tubing will have the curl taken out of it and will be easier to keep straight. A slit should be cut into the tubing with a box cutter and the cable pushed inside. If the cable and protective cover are not buried, they can be secured to the ground wire with hooks or turf staples.

SOIL MOISTURE Calibrations

In some instances, greater accuracy is desired than can be obtained from a general soil moisture calibration equation. In this case, it is necessary to perform a calibration on your unique soil. Essentially, a relation needs to be developed that relates the meter's electronic reading to the actual volumetric water content (VWC). This will require that some other method be used to measure the VWC.

Mineral Soils

VWC data can be measured in a lab setting by measuring the weight of a perforated soil column of known volume that is saturated, drained and dried. This method is preferred because the soil structure is not altered during the testing procedure. This procedure requires a weighing scale, a soil container with a height slightly greater than the SMEC 300 sensor (2.8 inches) and, depending on the ambient drying conditions, can take several weeks to complete. The procedure is briefly outlined below. Readings of the soil moisture circuit can be taken either with the Soil Sensor Reader or a WatchDog weather station. In either case, the device should be set to Raw AD mode. For the weather stations, when channel A is configured to read **Raw Sensor (raw)**, it will read the soil moisture circuit only. Nothing will be read on channels B or C.

1. Build a small container to hold the soil from a non-metallic material such as PVC. The sensitive volume of the sensor is not large so the container diameter does not have to be very big. In fact, soil-moisture gradients will form in the container as it dries so, unless several sensors will be used in the calibration, a small container will provide the best results. Cap the bottom of the container and drill holes in the cap and in the container's sides. This will allow water to permeate and drain as well as facilitate dry-

ing without allowing soil to spill or leak out. Drilling the holes at a slight downward angle will minimize spillage.

2. Measure the mass of the empty container and the sensor or sensors being used in the calibration.

3. Determine the volume of the container. This can be done geometrically or by measuring the volume of sand needed to completely fill the container.

4. Fill the container with air-dry, sieved soil.

5. Take a reading of the sensor in air, install the sensor in the dry soil, and take the air-dry reading.

6. Place the container (with sensor installed) in a larger receptacle and add distilled water around the OUTSIDE of the container until the water level reaches the top of the container. Allow the container to completely saturate. Take a sensor reading.

7. Transfer the container to the scale and measure the mass. It is advisable to have a tray to hold the container to keep water from spilling on the bench. Be sure to zero out the tare weight of the tray.

At this point, the procedure is to simply allow the container to dry while periodically taking simultaneous weight and sensor readings. Initially, the container will dry rapidly and 2 or 3 readings per day may be appropriate. As the container gets dryer, it will dry more slowly and the frequency of measurements will decrease. When the container returns to its air-dry value, the soil should be removed, oven-dried at 105 ºC for 24 to 48 hours and allowed to cool in a sealed container before measuring the oven dry weight (ODWt).

The volumetric water content at each data point is calculated as follows:

1) $$VWC_i = 100 * \frac{(m_i - m_{dry})}{(\rho_w * V_{tot})}$$

m_i = mass of soil at a given point during drydown (grams)
m_{dry} = mass oven-dry dry soil (grams)
V_{tot} = total soil volume (ml)
ρ_w = density of water (1g/ml)

These calculations can easily be set up in a spreadsheet. The final step is to perform a regression between the raw data and the calculated VWC values. Regression analysis can then be performed on raw sensor data and the calculated VWC values to develop an equation to convert from measured readings to actual VWC.
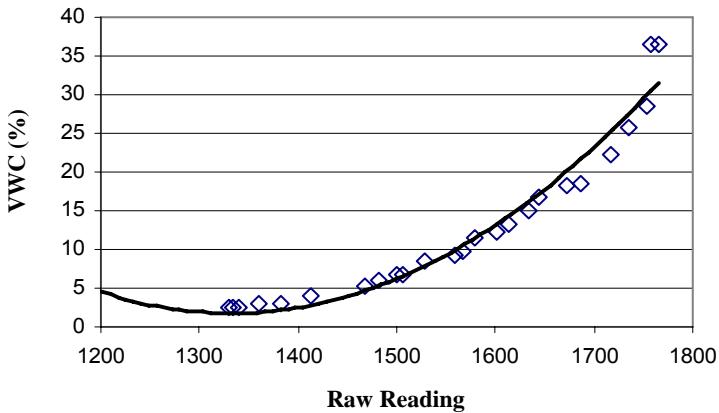
A calibration curve can also be obtained by gradually wetting a pre-measured amount of soil with known increments of water. Care must be taken to return the soil to its original bulk density before a sensor reading is made.

Soilless Media

Because soilless media tend to be hydrophobic and have a tendency to shrink dramatically when very dry, wetting the material and allowing it to dry over time is not the ideal method for collecting data for a media-specific calibration. The recommended procedure is to establish different moisture contents by adding water to a known quantity of material and shaking or tumbling it into the soilless media. This is best done on a mass wetness (MW) basis where mass wetness is defined as:

2)
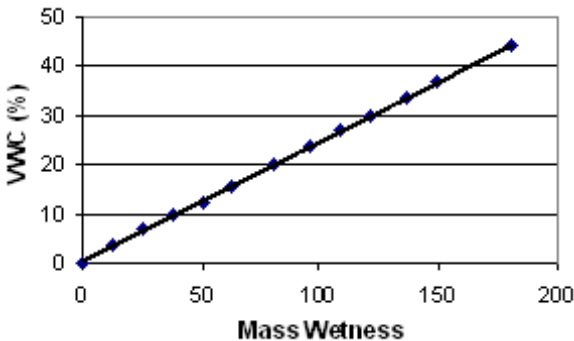$$MW = 100 * \frac{M_{water}}{2 * M_{material}}$$

Where:

MW = target mass wetness (expressed as percent)
M_{water} = mass of water needed
$M_{material}$ = total air-dry mass of sample

We have found that, for sphagnum peat moss, the relationship between volumetric water content (VWC) and MW is on the order of:

$$VWC = 0.243*MW + 0.5008$$

This can be used as a benchmark to determine your target MW values. If later you discover you've selected too narrow a range, this experiment can be repeated.

Calibration procedure

1. Acquire 18 containers with a diameter of 4 to 6 inches and a height slightly greater than SMEC 300 sensor (2.8 inches). This allows for 3 replicates at 6 different water contents. Commercially available pots should suffice. Containers can also be built from PVC.

2. Measure the volume and weight of each container. The volume can be found geometrically or by measuring the volume of sand needed to completely fill the container. Label each container. A convenient naming system would be to use a number to represent a water content and a letter to represent a replicate. For example, container 4B would be the second replicate of water content 4.

3. Starting with air-dry material, measure out 6 samples of soilless media. Each sample should be slightly more than is required to fill 3 containers.

4. Weigh the material and place it into a plastic bag. Establish 6 different water content conditions by mixing water into the air-dry material. Add enough water to bring the material to the desired MW. The needed amount of water can be determined by rearranging equation 2).
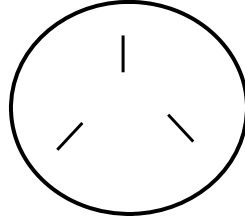
3)
$$M_{water} = 2 * \frac{MW}{100} * M_{material}$$

5. Twist or seal the bag so no material or water can get out. Shake the bag vigorously to incorporate the water into the media. For higher mass wetnesses, the water may be added in increments. After all the water has been added and shaken in, leave the closed bag to sit for, at least, 24 hours to allow the water and material to come to equilibrium.

6. Add wet material to the appropriately labeled containers. It is best to add the material in 3 increments, gently tamping each portion to the proper density.

7. Weigh each of the filled containers.

8. For each container, take three SMEC 300 readings. Take care not to take readings too near the edge of the container. It is recommended to take readings perpendicular to the sides of the container. If using the handheld reader, the reader should be in Raw AD mode. If taking readings with a WatchDog weather station

Suggested sampling locations

or mini-station, the channel the sensor is connected to should be programmed to **Raw Sensor (raw)**.

9. After taking the readings, completely air-dry the material in each container. DO NOT MIX the material from each container. Find the air-dry weight for the material in each container.

10. The volumetric water content for each container is calculated as follows:

$$VWC = \frac{M_{wet-total} - (M_{dry-only} + M_{cont})}{\rho_w * V_{cont}}$$

Where:

> VWC = Volumetric water content
> $M_{wet-total}$ = Total mass of container and wet material
> $M_{dry-only}$ = Mass of air-dry material
> M_{cont} = Mass of container
> ρ_w = Density of water (1g/ml)
> V_{cont} = Volume of container

11. You now have 18 VWC values (one for each container) and 54 raw readings (three for each container). A regression analysis can now be performed to relate raw value to actual water content.

Volumetric Water Content

The SMEC 300 measures volumetric water content. The volumetric water content (VWC) is the ratio of the volume of water in a given volume of soil to the total soil volume. At saturation, the volumetric water content (expressed as a percentage) will equal the percent pore space of the soil.

In-field soil moisture content will range from air-dry to saturation. However, plants cannot extract all the water in a saturated soil and can extract none of the water in an air-dry soil. Instead, two other moisture content levels, **field capacity** and **permanent wilting point** are often used to indicate the upper and lower limit of **plant available water**. Field capacity is defined as the condition that exists after a saturated soil is allowed to drain to the point where the pull of gravity is no longer sufficient to remove any additional water. Water draining from a soil profile cannot, in general, be taken up by plant roots. On the opposite end of the spectrum, permanent wilting point is the highest moisture level at which an indicator plant cannot recover turgor after being placed in a humid environment.

Irrigation should be scheduled somewhere between these two extremes. One rule of thumb is to apply water when half the plant available water has been depleted. However, individual circumstances may dictate a more conservative or liberal approach. Figure 1 illustrates the plant available water range for the 12 USDA-defined soil textures. Keep in mind that these numbers are merely guidelines and will vary for individual soils.
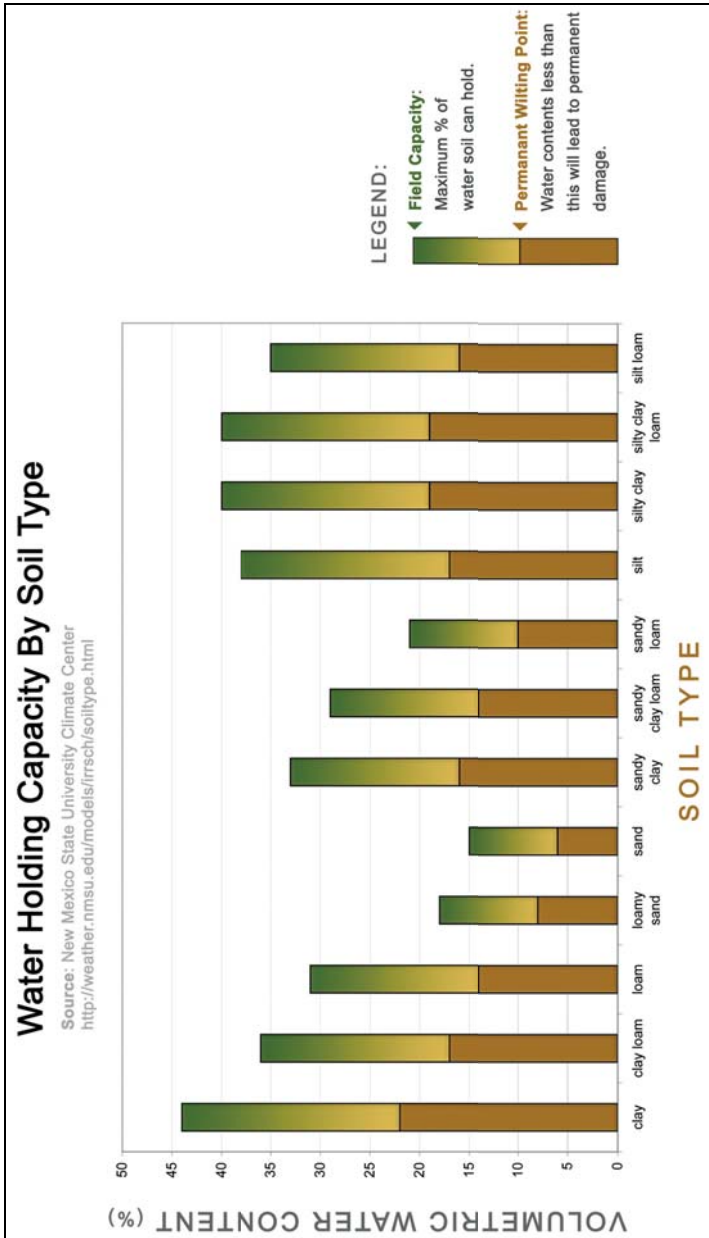
Figure 1.

Electrical Conductivity

Electrical conductivity (EC) is a measure of how well a solution conducts electrons. Pure water does not conduct electricity at all. However, as the concentration of dissolved ions increases, the electrical charged carried by those ions of the solution will increase as well. This is reflected in a higher EC measurement for that solution.

In soil solutions, the sources of these ions are minerals in the soil (such as sodium or calcium) and applied fertilizers. The EC of a liquid at a given temperature is governed mainly by the amount of dissolved salt ions. However, when a direct measurement is being made in a wet soil, the degree of saturation also impacts the measured EC. This is because as water content decreases, the conductive path becomes increasingly tortuous, thus decreasing the EC even though the concentration of salt in the remaining liquid is increasing. Such an EC measurement is sometimes referred to as bulk EC because it reflects how well electrons in the bulk soil are conducted. The SMEC 300 measures bulk EC. An alternative measure of EC is pore EC. This is the value that would be measured if the soil solution alone were extracted from the soil and measured. Pore EC will almost always increase as soil moisture content decreases.

The EC sensor for the SMEC 300 consists of a pair of carbon ink electrodes that are integrated onto the sensor surface. The EC electrodes measure the conductivity of wet soil in contact with the sensor. The carbon ink electrodes provide a large surface area which minimizes the effect of localized dry spots or loss of contact in the soil.

Warranty

This product is warranted to be free from defects in material or workmanship for one year from the date of purchase. During the warranty period Spectrum will, at its option, either repair or replace products that prove to be defective. This warranty does not cover damage due to improper installation or use, lightning, negligence, accident, or unauthorized modifications, or to incidental or consequential damages beyond the Spectrum product. Before returning a failed unit, you must obtain a Returned Materials Authorization (RMA) from Spectrum. Spectrum is not responsible for any package that is returned without a valid RMA number or for the loss of the package by any shipping company.

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