WATERSCOUT™

SM100 Soil Moisture Sensor

PRODUCT MANUAL

Item # 6460

Spectrum® Technologies, Inc.

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This manual will familiarize you with the features and operation of your new WaterScout SM100 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.
www.specmeters.com

Spectrum Technologies, Inc.

General Overview

Thank you for purchasing a WaterScout SM100 Soil Moisture Sensor.

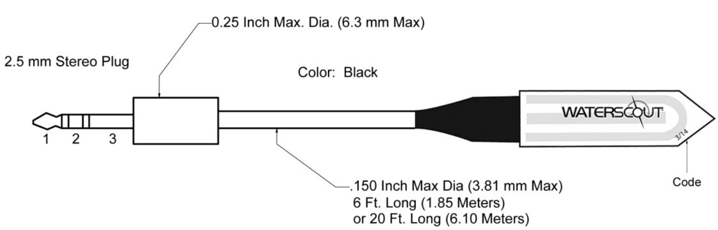
The sensor is made up of two electrodes that function as a capacitor, with the surrounding soil serving as the dielectric. An 80 MHz oscillator drives the capacitor and a signal proportional to the soil's dielectric permittivity is converted to the output signal. The dielectric permittivity of water 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 SM100, in conjunction with a Soil Sensor Reader or a WatchDog weather station, will give you a better idea of how fast soil water is being depleted in different areas of your field. By keeping track of your field's soil moisture status between irrigations, you can better schedule irrigations and evaluate the effectiveness of rain and irrigation water. Regular monitoring will give you an accurate picture of this process over time. Download the accumulated data at your convenience. SpecWare will present data in graphical and tabular form. Use the software to view daily, monthly and yearly reports.

Specifications

Standard Interfaces	WatchDog weather stations, mini stations, and micro stations FieldScout Soil Sensor Reader
Connector	2.5mm stereo pin
Range	0% VWC to saturation
Power	3 to 5V @ 6 to 10mA
Output	Analog voltage proportional to excitation voltage (0.5 to 1.5 V for a 3V excitation)
Oscillator Frequency	80 MHz
Resolution	0.1% VWC
Accuracy	3% VWC @ EC < 8 mS/cm
Sensor Dimensions	2.4in. (6cm) x 0.8in (2cm) x 0.1in (0.3cm)
Cable length	6 and 20ft. extendable up to 50ft.
Temperature Range	33 to 175°F (0.5 to 80°C)

Sensor Wiring Diagram



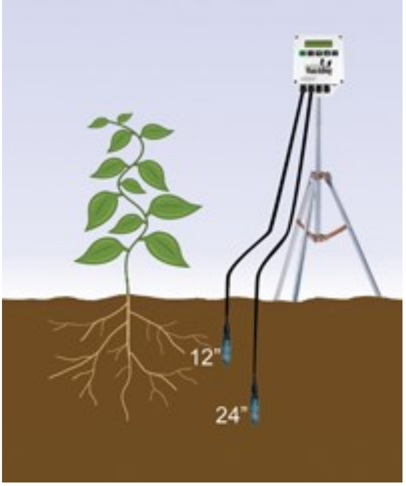
1 - Red Wire (Sensor Output)

2 - White Wire (Sensor V+ Excitation +3.00 to 5.00 regulated)

3 - Black Wire (Ground)

Sensor Placement

The sensors should be located in the effective root zone and at locations that will give a representative picture of the soil water status of the field. Areas of the field planted to different crops or with significant differences in factors such as topography or soil type should be considered unique soil moisture environments. 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. 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 the 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 SM100 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 WaterScout and how many sensors can be connected to a single unit. These are outlined below.

Soil moisture sensor reader
Non data-logger. Reads one sensor at a time. Requires firmware version 3 or greater.

2000-series mini stations (2400, 2425, 2450, 2475)
Require firmware version 1.9 or greater and SpecWare version 9.0 Build 202 or greater. Models with serial number 2310 or greater were manufactured to accommodate the SM100 on all available channels. Compatible stations will have a “W” in the manufacturing code that accompanies the serial number. Stations with earlier serial numbers can accommodate only one SM100.

2000-series weather stations
(models 2550, 2700, 2900)
Require firmware version 6.1 or greater and SpecWare version 9.0 Build 202 or greater. Models with serial number 2310 or greater were manufactured to accommodate the SM100 on all available channels. Compatible meters will have a “W” in the manufacturing code that accompanies the serial number.
(model 2800)
Similar to other weather stations, but requires firmware version 2.4.

1000-series micro stations (models 1200 to 1600)
All firmware versions are compatible with the SM100. Require SpecWare version 9.02 or greater. Any available sensor port can be connected to an SM100 sensor.

Early 2000-series weather stations
2000-series weather stations with serial numbers earlier than 2310 can accommodate only two SM100's. The limitation is that only one sensor can be on ports C through F. The other sensor can be on ports A or B (or G or H in the case of a model 2800 station). Earlier versions of the 2000-series mini stations can accommodate one SM100 sensor. The firmware and software requirements for SM100-compatible stations still apply.

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

CHECKING THE SENSOR

Calibration equations for the SM100 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 sensor electronics are still functioning properly, they may be checked in the following media:

<u>Air</u>
In air, the sensor should read a VWC of 0%.

<u>Water</u>
In distilled water, the sensor should read a VWC of about 55% in Standard mode and about 74% in Soilless mode.

<u>Saturated Playground Sand</u>
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.

Sensor Calibration

Sensors with the “3/14” code printed on the front, (see diagram, p. 4) are capable of being re-calibrated with the soil sensor reader (Item 6466). The purpose of the calibration is to modify the output of the sensor so it gives an expected value in a known standard (distilled water). Basically, it returns it to the factory calibration. It does not make any adjustment that may be necessary to improve accuracy in non-standard soils (see **Soil Specific Calibrations** p. 12).

The calibration is done with the calibration screen of the soil sensor reader. For readers with firmware version 4.5 or higher, the top line of the calibration screen will read “CAL?”. For meters with firmware version 4.4, the top line will read “CAL EC?”.

Installation

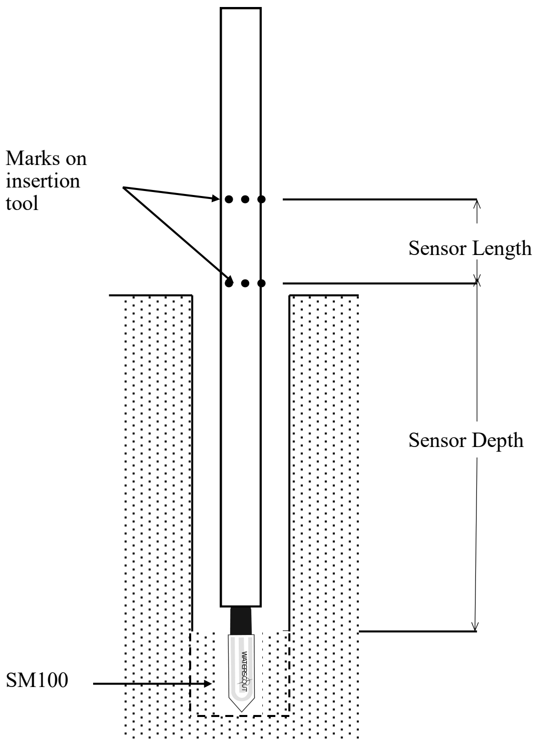
The most important consideration for installing the sensors is maintaining good contact between the sensor and the soil. This ensures optimum performance.
Important: The sensor can be damaged if it is pushed directly into hard, native soil. Please read installation guidelines before installing the sensors.

Surface Installation
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.

Deep Installation

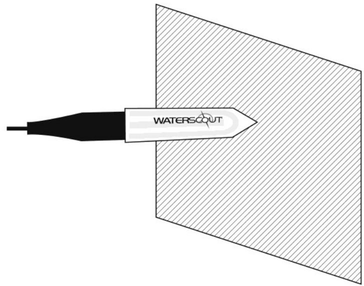
Vertical Orientation
To install the sensor in a vertical orientation, dig an access hole to the desired depth. This can be done with a soil sampler, auger or slide hammer. If possible, it is recommended that the hole be at a slight angle. This will reduce the effect of water channeling down to the sensor via the sensor cable.

The sensor blade is 3/4” while the molding is 5/8”. Therefore, there is a small lip on either side of the molding. This allows the sensor to be installed with a pipe or tube. Any material that fits over the molding and butts up against the base of the sensor may be used. Some options are ½” Class 315 PVC, ½” electrical conduit, or ½” Schedule 40 PVC. If the fit between the sensor molding and the insertion tool is excessively snug, a dowel rod can be used to ensure the sensor is not withdrawn from the access hole along with the insertion tool. In general, it is not recommended to push the sensor directly into native soil, 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 SM100 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 undisturbed 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 surface. For the same reason, if sensors are installed at multiple 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. Pulling 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. If the sensor is attached to the pipe with an epoxy (such as Loctite® Acrylic Epoxy), it can more easily be withdrawn from the soil.

- 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-Specific Calibrations

In some instances, greater accuracy is desired than can be obtained from a general 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 WaterScout sensor (2 inches) and, depending on the ambient drying conditions, can take several weeks to complete. The procedure is briefly outlined below. WaterScout readings 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 or Raw Sensor mode.

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 on the container's sides. This will allow water to permeate and drain as well as facilitate drying 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.

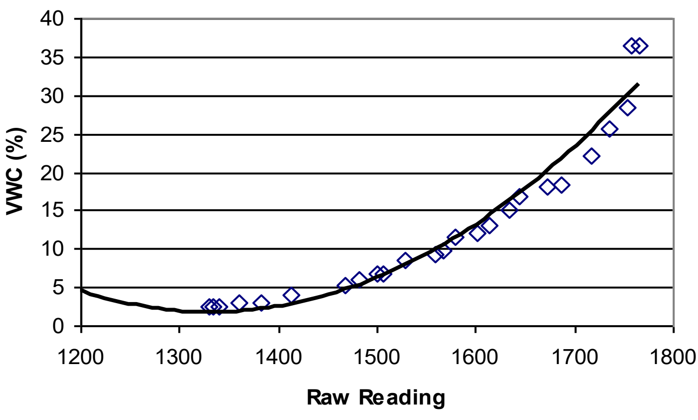
At this point, the procedure is to simply allow the container to dry while periodically taking simultaneous weight and sensor readings. Initially, the container will dry rapidly and 2 or 3 readings per day may be appropriate. As the container gets dryer, it will dry more slowly and the frequency of measurements 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:

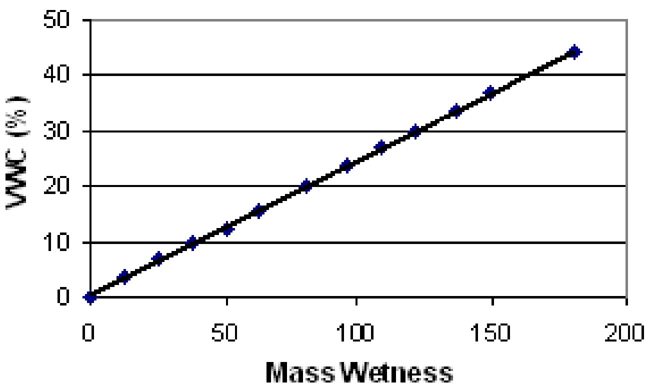
2) $$MW = 100 * \frac{M_{water}}{2 * M_{material}}$$

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 WaterScout sensor (2 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).

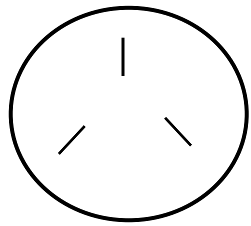
3) $$M_{water} = 2 * \frac{MW}{100} * M_{material}$$

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 SM100 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 or mini-station, the channel the sensor is connected to should be programmed to the Raw Sensor option.



Suggested sampling locations

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 WaterScout SM100 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.

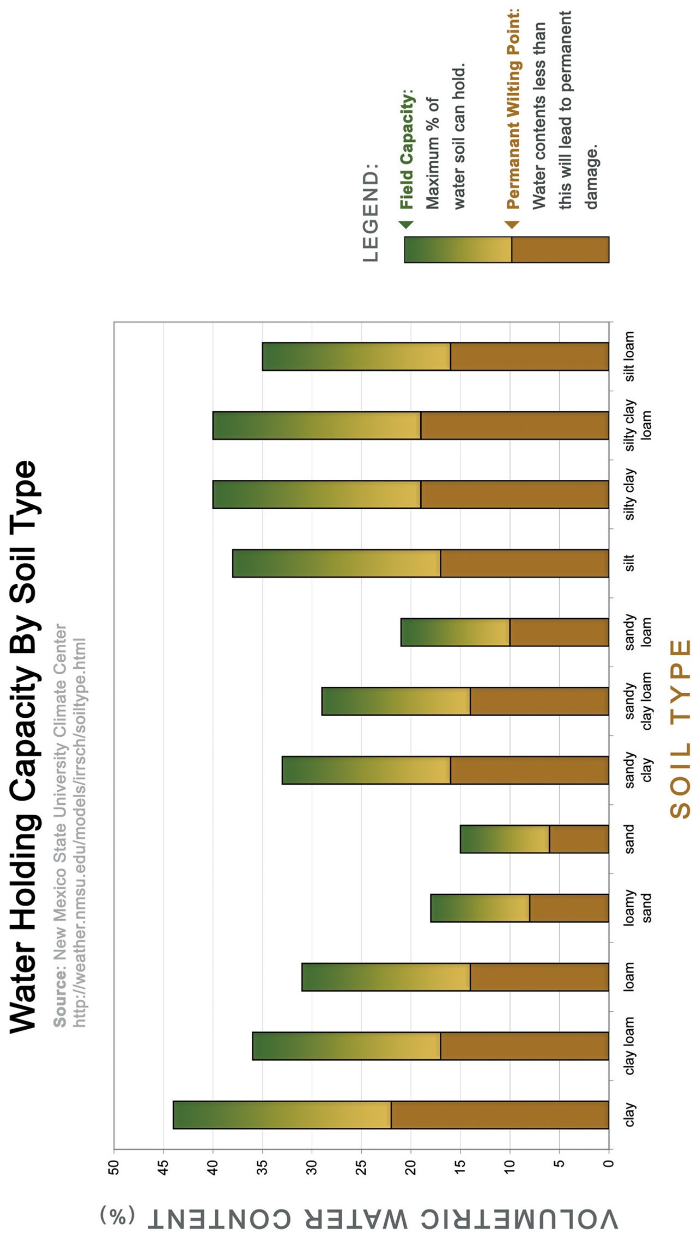

Water Holding Capacity By Soil Type
Source: New Mexico State University Climate Center
http://weather.nmsu.edu/models/irrsch/soiltype.html
VOLUMETRIC WATER CONTENT (%)
50
45
40
35
30
25
20
15
10
5
0
clay
clay loam
loam
loamy sand
sand
sandy clay
sandy clay loam
sandy loam
silt
silty clay
silty clay loam
silt loam
SOIL TYPE
LEGEND:
Field Capacity: Maximum % of water soil can hold.
Permanant Wilting Point: Water contents less than this will lead to permanent damage.

Figure 1.

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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