



Product Manual



Sensor

SoiVUE™ 10

Complete Soil Profiler



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1. Introduction

The SoilVUE™10 is a time-domain reflectometer-based soil profile probe that measures volumetric water content, permittivity, electrical conductivity, and temperature at multiple depths. This probe was designed with environmental researchers and environmental monitoring network operators in mind; it is ideal for long-term outdoor operation and for applications that require highly accurate measurements.

The SoilVUE 10 has two probe length options. The 0.5 m option makes measurements at six depths (5, 10, 20, 30, 40, and 50 cm), and the 1.0 m option makes measurements at nine depths (5, 10, 20, 30, 40, 50, 60, 75, and 100 cm). Waveguides (measurement rods) are embedded in threads and are centered on the measurement depths. The threaded design allows it to screw into a hole created by a standard 5-cm (2-in) hand auger. This simple installation procedure reduces cost, complexity, and disturbance of the soil.

NOTE:

This manual provides information only for CRBasic data loggers. For retired Edlog data logger support, contact Campbell Scientific.

2. Precautions

- READ AND UNDERSTAND the [Safety](#) section at the back of this manual.
- Although the SoilVUE 10 is rugged, it should be handled as a precision instrument.
- The depth of the hole in which the SoilVUE 10 will be installed must match the SoilVUE 10 length. Mark the installation tool to align with the length of the probe to ensure the proper depth is obtained. Gaps between the bottom of the SoilVUE 10 and the bottom of the hole may adversely affect the measurements.
- Water should be used to wet the sides of the hole, reducing the force needed to install the probe.
- This is a robust sensor, but it could break if excessive force is applied during installation.
- Care should be taken to ensure the sides of the hole are even and do not become tapered with repeated removal of soil.



- To prevent damage to the connector pins, the plastic cap should be left on the cable connection during installation.
- External radio frequency (RF) sources can affect probe operation. Therefore, the SoilVUE 10 should be located away from significant RF sources such as ac power lines and motors.

3. Initial inspection

- Upon receipt of the SoilVUE 10, inspect the packaging and contents for damage. File any damage claims with the shipping company.
- The model number and cable length are printed on a label at the connection end of the cable. Check this information against the shipping documents to ensure the expected product and cable length are received.

4. QuickStart

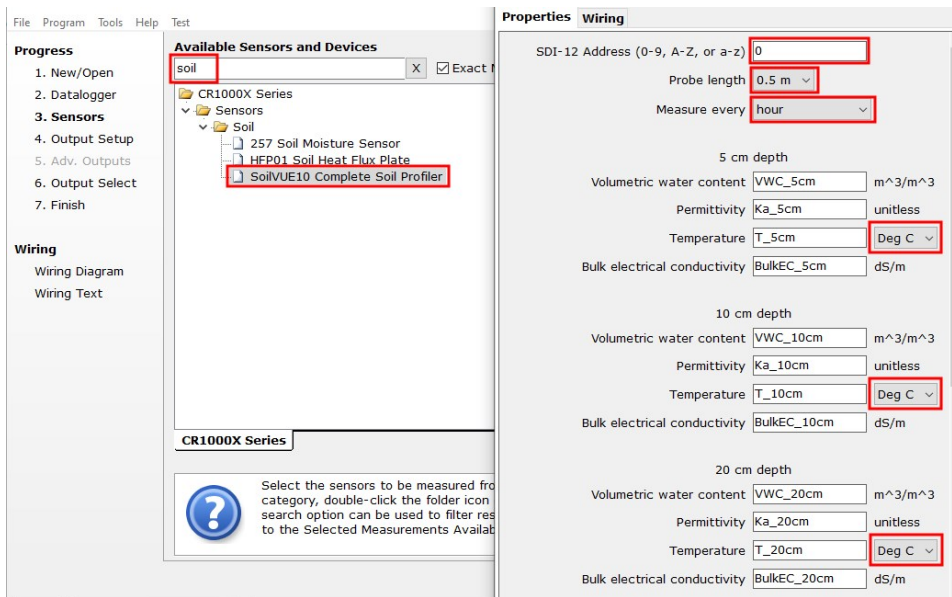
A video that describes data logger programming using *Short Cut* is available at:

www.campbellsci.com/videos/cr1000x-data-logger-getting-started-program-part-3 . *Short Cut* is an easy way to program your data logger to measure the sensor and assign data logger wiring terminals. *Short Cut* is available as a download on www.campbellsci.com . It is included in installations of *LoggerNet*, *RTDAQ*, and *PC400*.

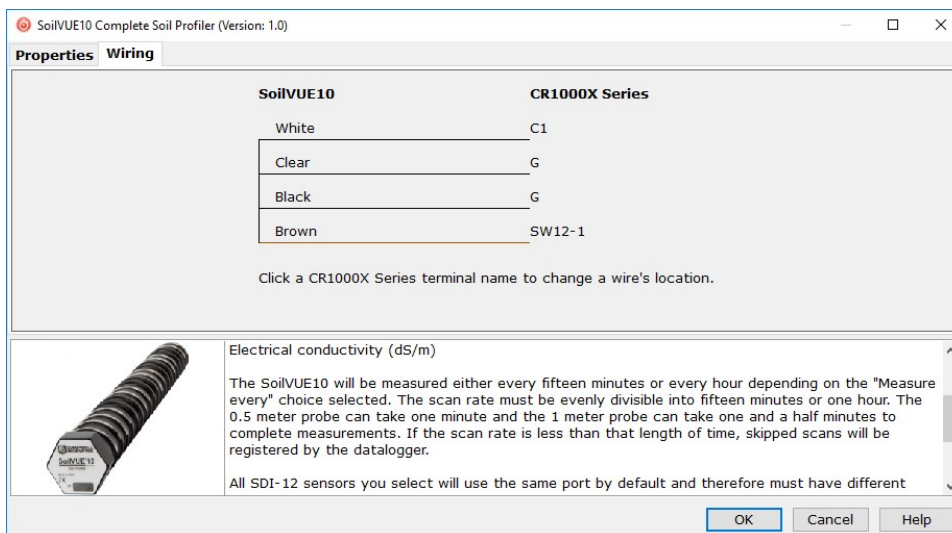
The following procedure also details the use of *Short Cut* in programming the SoilVUE 10.

1. Open *Short Cut* and click **Create New Program**.
2. Double-click the data logger model.

- In the **Available Sensors and Devices** box, type SoilVUE10 or locate the probe in the **Sensors > Soil** folder. Double-click **SoilVUE10 Complete Soil Profiler**. Type the correct **SDI-12 Address**; default address is 0. The **Probe length** defaults to 0.5 m; to change this, click the **Probe length** box and select 1 m. Select whether to **Measure every** hour (default) or every 15 minutes. For each measurement depth, temperature defaults to degrees Celsius. This can be changed by clicking the **Deg C** box and selecting **Deg F** for degrees Fahrenheit or **K** for Kelvin.



- Click the **Wiring** tab to see how the probe is to be wired to the data logger. Click **OK** after wiring the probe.



- Repeat steps three and four for other sensors.

6. In **Output Setup**, type the scan rate, meaningful table names, and **Data Output Storage Interval**.

CAUTION:

The scan rate must be evenly divisible into 15 or 60 minutes (depending on the **Measure every** selected in step 3). The 0.5 m probe can take one minute, and the 1.0 m probe can take one and a half minutes, to complete measurements. If the scan rate is less than that length of time, skipped scans will be registered by the data logger.

Short Cut (CR1000X Series) C:\Campbellsci\SCWin\untitled.scw

File Program Tools Help Test

Progress

1. New/Open
2. Datalogger
3. Sensors
- 4. Output Setup**
5. Adv. Outputs
6. Output Select
7. Finish

Wiring

- Wiring Diagram
- Wiring Text

How often should the CR1000X Series measure its sensor(s)? 60 Seconds

Data is processed by the datalogger and then stored in an output table. Two tables are defined by default; up to 10 tables can be added. Add New Table

1 Hourly 2 Daily

Table Name: Hourly Delete Table

Data Output Storage Interval
Makes 60 measurements per output interval based upon the chosen measurement interval of 60 Seconds. 60 Minutes

Copy to External Storage
☐ SC115 Flash Memory Drive
☒ Memory Card

☐ Advanced Outputs (all tables)

Specify how often measurements are to be made and how often outputs are to be stored. Note that multiple output intervals can be specified, one for each output table. By default, an output table is set up to send data to memory based on time. Select the Advanced Output option to send data to memory based on one or more of the following conditions: time, the state of a flag, or the value of a measurement.

Previous Next Finish Help

7. Select the measurement and its associated output option.

File Program Tools Help Test

Progress

1. New/Open
2. Datalogger
3. Sensors
4. Output Setup
5. Adv. Outputs
- 6. Output Select**
7. Finish

Wiring

- Wiring Diagram
- Wiring Text

Selected Measurements Available for Output

Sensor	Measurement
Default	BattV
SoilVUE10	PTemp_C
SoilVUE10	VWC_5cm
SoilVUE10	Ka_5cm
SoilVUE10	T_5cm
SoilVUE10	BulkEC_5cm
SoilVUE10	VWC_10cm
SoilVUE10	Ka_10cm
SoilVUE10	T_10cm
SoilVUE10	BulkEC_10cm
SoilVUE10	VWC_20cm
SoilVUE10	Ka_20cm
SoilVUE10	T_20cm
SoilVUE10	BulkEC_20cm
SoilVUE10	VWC_30cm
SoilVUE10	Ka_30cm

Selected Measurements for Output

Sensor	Measurement	Processing	Output Label	Units
SoilVUE10	VWC_5cm	Sample	VWC_5cm	m^3/m^3
SoilVUE10	Ka_5cm	Sample	Ka_5cm	unitless
SoilVUE10	T_5cm	Sample	T_5cm	Deg C
SoilVUE10	BulkEC_5cm	Sample	BulkEC_5cm	dS/m
SoilVUE10	VWC_10cm	Sample	VWC_10cm	m^3/m^3
SoilVUE10	Ka_10cm	Sample	Ka_10cm	unitless
SoilVUE10	T_10cm	Sample	T_10cm	Deg C
SoilVUE10	BulkEC_10cm	Sample	BulkEC_10cm	dS/m
SoilVUE10	VWC_20cm	Sample	VWC_20cm	m^3/m^3
SoilVUE10	Ka_20cm	Sample	Ka_20cm	unitless
SoilVUE10	T_20cm	Sample	T_20cm	Deg C
SoilVUE10	BulkEC_20cm	Sample	BulkEC_20cm	dS/m
SoilVUE10	VWC_30cm	Sample	VWC_30cm	m^3/m^3

Select which measurements to store in which tables and how each measurement should be processed. For each value to be stored in the table, choose a measurement from "Selected Measurements Available for Output." Next, select one of the processing functions, such as Average, Sample, etc. Note that the output tables must be set up in order for data to be stored in the datalogger memory.

Previous Next Finish Help

8. Click **Finish** and save the program. Send the program to the data logger if the data logger is connected to the computer.
9. If the sensor is connected to the data logger, check the output of the sensor in the data display in *LoggerNet*, *RTDAQ*, or *PC400* to make sure it is making reasonable measurements.

5. Overview

The SoilVUE 10 uses time-domain reflectometry (TDR) to measure soil volumetric water content (VWC) and electrical conductivity (EC). The waveguides (measurement rods) are embedded in threads and centered on the measurement depths of 5, 10, 20, 30, 40, and 50 cm for the 0.5 m option (Figure 5-1 [p. 5]); depths of 60, 75, and 100 cm are added for the 1.0 m option. The threaded design maximizes soil contact and minimizes preferential flow—two major drawbacks to smooth-sided soil profiling probes. This proprietary implementation of TDR by Campbell Scientific produces a clean, high resolution measurement that provides accuracy and assurance that cannot be found among other commercially available sensors.

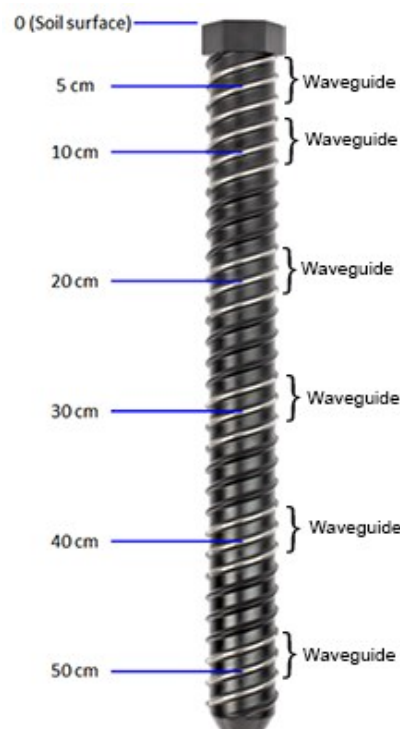


Figure 5-1. SoilVUE 10 waveguides and measurement depths

The SoilVUE 10 should be installed in a hole made by a standard 5-cm (2-in) hand auger tool. Auger the hole to the proper depth and screw the SoilVUE 10 into the hole (see [Field installation](#) [p. 9]). Water should be used to lubricate the sides of the hole to aid in installation and to ensure the probe is not damaged due to excessive force. The threaded design presses the sensing elements into the side of the hole, producing optimal contact with the soil and minimizing air gaps that are common with alternative profile probes.

The SoilVUE 10 also has a detachable cable that allows either the probe or cable to be independently replaced if it gets damaged.

All of these design factors combine to result in a more accurate measurement.

Features:

- Volumetric water content (VWC), electrical conductivity (EC), permittivity, and temperature measurements at six depths over 0.5 m or nine depths over 1.0 m using one probe
- Campbell Scientific proprietary TrueWave™ TDR technology uses advanced waveform analysis to determine the true travel time of a high frequency pulse that provides defensible measurements that can be universally compared with other TDR systems
- Threaded design with individual waveguides built into the threads for optimal contact with soil, which minimizes air-gap errors
- Installation using a standard 5-cm (2-in) hand auger, thus eliminating the need for excavation machinery or expensive proprietary tools
- Quick, low-impact installation
- Detachable cable that facilitates field replacement
- SDI-12 digital output
- Designed for long-term outdoor operation
- Compatible CRBasic data loggers: CR6, CR3000, CR1000X, CR800-series, CR300-series, CR1000

6. Specifications

Operating temperature range: –40 to 60 °C

Volumetric water content range: 0 to 100%

Maximum installation torque: 54 N•m (40 ft•lb)

Diameter without threads:	5.2 cm (2.05 in)
Diameter including threads:	5.8 cm (2.3 in)
Length:	0.55 m/1.05 m (21.5 in/41.2 in)
Weight:	1.9 kg/3.6 kg (4.2 lb/7.9 lb)
Output:	SDI-12 version 1.4 compliant
Operating voltage:	9 to 36 VDC
Current drain at 12 VDC:	~1.5 mA (quiescent), ~64 mA (active)
Measurement depths	
0.5 m option:	5, 10, 20, 30, 40, and 50 cm (2, 4, 8, 12, 16, and 20 in)
1.0 m option:	5, 10, 20, 30, 40, 50, 60, 75, and 100 cm (2, 4, 8, 12, 16, 20, 24, 30, and 40 in)
Permittivity range:	1 to 80
Electrical conductivity range:	0 to 10 dS/m
Accuracy	
Volumetric water content:	±1.5% typical with most soils; soils with high organic matter (>12% soil organic carbon) or high clay content (>45% clay) may need a soil-specific calibration due to the dispersive nature of these materials. For more information, refer to Soil-specific calibration procedure for volumetric water content sensors available on the Campbell Scientific website.
Permittivity:	±1 permittivity unit between 4 and 42 permittivity
Electrical conductivity:	±2% (0 to 2.5 dS/m), ±5% (full range)
Temperature:	±0.15 °C between –30 and 40 °C
Response time:	Up to 1 minute for 0.5 m probe and up to 1.5 minutes for 1.0 m probe
Compliance documents:	View at: www.campbellsci.com/soilvue10



7. Installation

If you are programming your data logger with *Short Cut*, skip [Wiring](#) (p. 8) and [CRBasic programming](#) (p. 8). *Short Cut* does this work for you. See [QuickStart](#) (p. 2) for a tutorial.

7.1 Wiring

[Table 7-1](#) (p. 8) provides the connections for the SoilVUE 10.

Table 7-1: Wire color, function, and data logger connection		
Wire color	Wire function	Data logger connection
White	SDI-12 signal	C or U configured for SDI-12 ¹
Clear	Shield	G
Brown	Power	12V
Black	Power ground	G
¹ U and C terminals are automatically configured by the SDI12Recorder() instruction.		

For the CR6 and CR1000X data loggers, triggering conflicts may occur when a companion terminal is used for a triggering instruction such as [TimerInput\(\)](#), [PulseCount\(\)](#), or [WaitDigTrig\(\)](#). For example, if the SoilVUE 10 is connected to C3 on a CR1000X, C4 cannot be used in the [TimerInput\(\)](#), [PulseCount\(\)](#), or [WaitDigTrig\(\)](#) instructions.

7.2 CRBasic programming


The [SDI12Recorder\(\)](#) instruction is used to measure a SoilVUE 10. This instruction sends a request to the sensor to make a measurement and then retrieves the measurement from the sensor. See [SDI-12 measurements](#) (p. 12) for more information.

For most data loggers, the [SDI12Recorder\(\)](#) instruction has the following syntax:

```
SDI12Recorder(Destination, SDIPort, SDIAddress, "SDICommand", Multiplier, Offset, FillNAN, WaitonTimeout)
```

For the **SDIAddress**, alphabetical characters need to be enclosed in quotation marks (for example, "A"). Also enclose the **SDICommand** in quotation marks as shown. The **Destination** parameter must be an array. The required number of values in the array depends on the command (see [Table 8-1](#) [p. 13]).

FillNAN and **WaitonTimeout** are optional parameters (refer to the *CRBasic Editor* help for more information).

A downloadable example program is available at www.campbellsci.com/downloads/soilvue10-example-program .

7.3 Siting

For more information on installation, watch a video at www.campbellsci.com/videos/soilvue10 .

Proper installation of the SoilVUE 10 is critical. This includes selecting a monitoring site that is representative of the soil of interest, ensuring good contact between the waveguides and the surrounding soil, minimizing disturbance to the soil, and minimizing preferential flow of water along the probe.

Factors that affect the distribution of water in soil include soil properties such as texture, depth, compaction, slope, land usage, vegetation, and disturbance history.

The selected site should be representative of the soil of interest. Certain soil types may present a challenge to properly installing the probe. For instance, sandy soil types are likely to collapse into the augered hole. Pre-wetting the installation location may help to firm up the soil and allow a hole to be created.

Rocky soils may prevent an auger from creating a hole deep enough for the probe or may damage the probe during the installation process. Minor abrasions and dents to the body or threads should not influence the measurements. However, rocky soils may require a different approach to installation. Either create a larger hole and use a slurry method to install the probe, or excavate the soil then backfill the soil around the probe.

7.4 Field installation

Campbell Scientific offers a SoilVUE 10 installation kit ([Figure 7-1](#) [p. 9]).



Figure 7-1. Components of the installation kit

A – Auger extension shaft

B – Hex socket

- C – Hex socket handle
- D – Edelman auger
- E – Auger clean-out tool
- F – Rods to aid in disassembly (insert through holes in extension shaft)
- G – T-handle for auger/extension shaft

The installation kit is not necessary to install the SoilVUE 10. A standard 5-cm (2-in) hand auger may be used instead of the auger supplied in the kit. The SoilVUE 10 can then be inserted into the hole using a standard six-sided 2.25-inch socket.

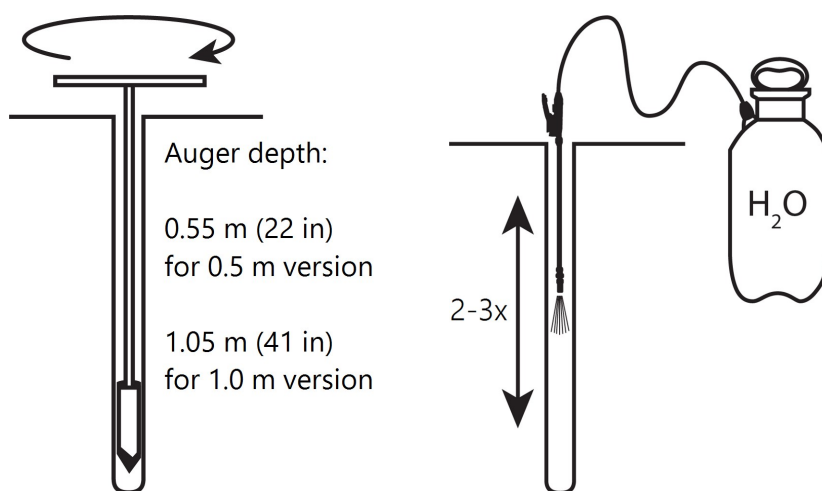
CAUTION:

Do not use a power auger since they may enlarge the hole diameter beyond the desired specification for a properly installed probe. Power augers also tend to bring soil up from lower depths, coating the sides of the hole, which may have adverse effects on the measurements.

1. Connect the T-handle (Figure 7-1 [p. 9], G) to the auger extension shaft (Figure 7-1 [p. 9], A) then connect the shaft to the auger (Figure 7-1 [p. 9], D).
2. Use the auger assembly to create a hole with a 5-cm (2-in) diameter that is approximately 5 cm (2 in) deeper than the SoilVUE 10 length. The auger is narrow at the tip, so making the hole slightly deeper will ensure that the sensor can be fully installed.

CAUTION:

Large gaps between the SoilVUE 10 and the hole bottom can adversely affect the measurements. The following auger depths allow proper installation and avoid large gaps.



- a. Care should be taken to ensure the sides of the hole are even and parallel and do not become tapered with repeated removal of soil.
- b. Wet the sides of the hole to reduce the force needed to install the probe. In most cases, the hole will need to be thoroughly wetted.

CAUTION:

When adding water to the hole, avoid eroding the sides and introducing air gaps. Also avoid standing water at the bottom of the hole.

3. Insert the hex socket handle into the small holes in the hex socket ([Figure 7-2](#) [p. 11]).



Figure 7-2. Hex socket handle and hex socket

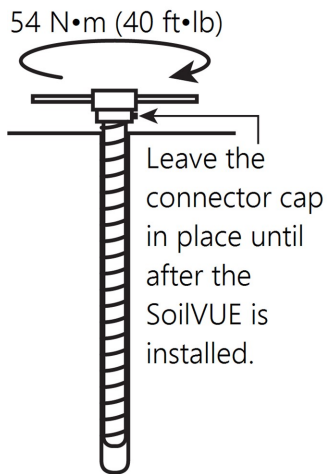
CAUTION:


Leave the plastic cap on the cable connection until the sensor is completely installed and ready to connect the cable.

4. Place the hex socket on top of the probe and use the handle to screw the probe into the augered hole.

CAUTION:

Applying too much force to the sensor during installation can break or crack it. The maximum torque applied during installation should not exceed 54 N•m (40 ft•lb). If significant effort is required to install, remove the sensor, make the hole slightly deeper, add more water, create another hole, or try a combination of these options before trying again.



- a. When the probe is partially installed, remove 5 cm (2 in) of soil around the top of the hole. This will prevent the connector from digging into the soil as the probe is installed and provide room for connecting the cable.
 - b. When the top of the probe is flush with the soil surface, the top sensor is at 5 cm (2 in) depth.
5. Connect the cable to the SoilVUE 10, and hand tighten the cable connector nut to ensure a water-tight seal. Do not over tighten. The cable nut should turn easily. If it does not, check to make sure it is correctly aligned. Also, try gently pushing in on the cable.
- WARNING:**
Do not over tighten. Never use a wrench or spanner on the cable connector nut because it will damage the connector. 
6. After connecting the cable, carefully replace the soil around the top of the probe while adding water and packing well.
 7. Route the cable to the data logger.

8. Operation

8.1 SDI-12 measurements

The SoilVUE 10 responds to the SDI-12 commands shown in [Table 8-1](#) (p. 13). Because of the delays the **M!** command requires, Campbell Scientific recommends measurement scans of at least 10 seconds per sensor. For instance, the recommended scan rate for a 0.5-m probe with six

sensors is at least 60 seconds. A **C!** command does not require the data logger to pause its operation until the values are ready.

Table 8-1: SoilVUE 10 SDI-12 commands		
SDI-12 command ²	Values returned or function	Units
<i>aM!</i>	1. Volumetric water content, 5 cm 2. Volumetric water content, 10 cm 3. Volumetric water content, 20 cm 4. Volumetric water content, 30 cm 5. Volumetric water content, 40 cm 6. Volumetric water content, 50 cm 7. Volumetric water content, 60 cm ¹ 8. Volumetric water content, 75 cm ¹ 9. Volumetric water content, 100 cm ¹	m ³ /m ³ m ³ /m ³ m ³ /m ³ m ³ /m ³ m ³ /m ³ m ³ /m ³ m ³ /m ³ m ³ /m ³ m ³ /m ³
<i>aM1!</i> or <i>aC1!</i>	1. Volumetric water content, 5 cm 2. Relative permittivity (ε), 5 cm 3. Temperature, 5 cm 4. Bulk electrical conductivity, 5 cm	m ³ /m ³ °C dS/m
<i>aM2!</i> or <i>aC2!</i>	1. Volumetric water content, 10 cm 2. Relative permittivity (ε), 10 cm 3. Temperature, 10 cm 4. Bulk electrical conductivity, 10 cm	m ³ /m ³ °C dS/m
<i>aM3!</i> or <i>aC3!</i>	1. Volumetric water content, 20 cm 2. Relative permittivity (ε) 20 cm 3. Temperature, 20 cm 4. Bulk electrical conductivity, 20 cm	m ³ /m ³ °C dS/m
<i>aM4!</i> or <i>aC4!</i>	1. Volumetric water content, 30 cm 2. Relative permittivity (ε), 30 cm 3. Temperature, 30 cm 4. Bulk electrical conductivity, 30 cm	m ³ /m ³ °C dS/m

Table 8-1: SoilVUE 10 SDI-12 commands

SDI-12 command ²	Values returned or function	Units
<i>aM5!</i> or <i>aC5!</i>	1. Volumetric water content, 40 cm 2. Relative permittivity (ϵ), 40 cm 3. Temperature, 40 cm 4. Bulk electrical conductivity, 40 cm	m^3/m^3 $^{\circ}C$ dS/m
<i>aM6!</i> or <i>aC6!</i>	1. Volumetric water content, 50 cm 2. Relative permittivity (ϵ), 50 cm 3. Temperature, 50 cm 4. Bulk electrical conductivity, 50 cm	m^3/m^3 $^{\circ}C$ dS/m
<i>aM7!</i> or <i>aC7!</i> ¹	1. Volumetric water content, 60 cm 2. Relative permittivity (ϵ), 60 cm 3. Temperature, 60 cm 4. Bulk electrical conductivity, 60 cm	m^3/m^3 $^{\circ}C$ dS/m
<i>aM8!</i> or <i>aC8!</i> ¹	1. Volumetric water content, 75 cm 2. Relative permittivity (ϵ), 75 cm 3. Temperature, 75 cm 4. Bulk electrical conductivity, 75 cm	m^3/m^3 $^{\circ}C$ dS/m
<i>aM9!</i> or <i>aC9!</i> ¹	1. Volumetric water content, 100 cm 2. Relative permittivity (ϵ), 100 cm 3. Temperature, 100 cm 4. Bulk electrical conductivity, 100 cm	m^3/m^3 $^{\circ}C$ dS/m
<i>aC!</i>	1. Volumetric water content, 5 cm 2. Relative permittivity (ϵ), 5 cm 3. Temperature, 5 cm 4. Bulk electrical conductivity, 5 cm 5. Volumetric water content, 10 cm 6. Relative permittivity (ϵ), 10 cm 7. Temperature, 10 cm 8. Bulk electrical conductivity, 10 cm 9. Volumetric water content, 20 cm 10. Relative permittivity (ϵ), 20 cm	m^3/m^3 $^{\circ}C$ dS/m m^3/m^3 $^{\circ}C$ dS/m m^3/m^3


Table 8-1: SoilVUE 10 SDI-12 commands

SDI-12 command ²	Values returned or function	Units
	11. Temperature, 20 cm	°C
	12. Bulk electrical conductivity, 20 cm	dS/m
	13. Volumetric water content, 30 cm	m ³ /m ³
	14. Relative permittivity (ε), 30 cm	
	15. Temperature, 30 cm	°C
	16. Bulk electrical conductivity, 30 cm	dS/m
	17. Volumetric water content, 40 cm	m ³ /m ³
	18. Relative permittivity (ε), 40 cm	
	19. Temperature, 40 cm	°C
	20. Bulk electrical conductivity, 40 cm	dS/m
	21. Volumetric water content, 50 cm	m ³ /m ³
	22. Relative permittivity (ε), 50 cm	
	23. Temperature, 50 cm	°C
	24. Bulk electrical conductivity, 50 cm	dS/m
	25. Volumetric water content, 60 cm ¹	m ³ /m ³
	26. Relative permittivity (ε), 60 cm ¹	
	27. Temperature, 60 cm ¹	°C
	28. Bulk electrical conductivity, 60 cm ¹	dS/m
	29. Volumetric water content, 75 cm ¹	m ³ /m ³
	30. Relative permittivity (ε), 75 cm ¹	
	31. Temperature, 75 cm ¹	°C
	32. Bulk electrical conductivity, 75 cm ¹	dS/m
	33. Volumetric water content, 100 cm ¹	m ³ /m ³
	34. Relative permittivity (ε), 100 cm ¹	
	35. Temperature, 100 cm ¹	°C
	36. Bulk electrical conductivity, 100 cm ¹	dS/m
? !	Returns the SDI-12 address	

¹ Applies to the 1.0-meter probe only.

² *a* is the SDI-12 address. In the [SDI12Recorder\(\)](#) CRBasic instruction, the command parameter does not include the SDI-12 address because the address is a separate parameter.

NOTE:

SDI-12 sensor support (p. 20) describes the SDI-12 commands. Additional SDI-12 information is available at www.sdi-12.org .

8.2 Measurements at fast scan rates

Using the **SlowSequence** function allows the SDI-12 instruction to run as a background process, causing minimum interference to other measurements that use the analog hardware. Measuring the SoilVUE 10 in a **SlowSequence** section of the program allows faster programs to run as the main scan. However, if the data logger is too busy to complete all of its tasks, some slow sequence commands may be skipped, resulting in **NANs** (not a number) instead of measurements.

8.3 Measurement theory

The SoilVUE 10 is a multiparameter soil profile probe that measures soil volumetric water content using a time-domain reflectometry (TDR) method. The probe consists of TDR circuitry connected to a series of six or nine helical waveguides that makeup part of the overall threaded design.

The travel time for a pulsed electromagnetic signal along a waveguide is dependent on the velocity of the signal and the waveguide length. The velocity is dependent on the dielectric constant of the material surrounding the waveguide. This relationship can be expressed by:

$$\Delta t = \frac{2L\sqrt{K_a}}{c} \quad \text{Eq. 1}$$

where

K_a is the apparent permittivity

c is the velocity of electromagnetic signals in free space

Δt is the travel time

L is the waveguide length

Eq. 1 (p. 16) can be simplified to express the apparent permittivity as the ratio of the apparent probe length ($L_a = c \cdot \Delta t / 2$) to the real probe length.

$$K_a = (L_a / L)^2 \quad \text{Eq. 2}$$

The permittivity of water relative to other soil constituents is high. Consequently, changes in volumetric water content can be directly related to the change in the permittivity of bulk soil material. The relationship between permittivity and volumetric water content has been described

by, among others, Topp et al. (1980) and Ledieu et al. (1986) in an empirical fashion using both polynomial and linear forms (see [References](#) [p. 18]).

9. Maintenance and troubleshooting

NOTE:

All factory repairs and recalibrations require a returned material authorization (RMA) and completion of the “Statement of Product Cleanliness and Decontamination” form. Refer to the [Assistance](#) page near the end of this manual for more information.

The SoilVUE 10 does not require periodic maintenance. For troubleshooting, [Table 9-1](#) (p. 17) provides symptoms, possible causes, and solutions.

Table 9-1: Symptoms, possible causes, and solutions		
Symptom	Possible cause	Solution
All SoilVUE 10 output values read 0	No SDI12Recorder() instruction in data logger program Conditional statement that triggers readings is not evaluating as true	Add SDI12Recorder() instruction to data logger program Check logic of conditional statement that triggers readings
First value reads NAN , and all other values read 0 or never change from one measurement to another.	SoilVUE 10 SDI-12 address does not match address specified in data logger program SoilVUE 10 is not connected to the SDI-12 terminal specified in data logger program SoilVUE 10 not being powered	Change SoilVUE 10 SDI-12 address or modify program so they match Connect wire to correct terminal or modify program to match wiring Make sure the SoilVUE 10 is wired correctly and that it matches the data logger program
Readings erratic, including NANs and 9999999s	Multiple devices with same SDI-12 address sharing same U or C terminal	Connect each SDI-12 device to a different U or C terminal or give them unique SDI-12 addresses; ensure that the data logger program is revised to account for these changes

10. References

- Topp, G.C., J.L. Davis & A.P. Annan. 1980. "Electromagnetic determination of soil water content: measurements in coaxial transmission lines," *Water Resources Research*, v. 16, No. 3:574-582.
- Ledieu, J., P. De Ridder, P. De Clerck, and S. Dautrebande. 1986. "A method of measuring soil moisture by time-domain reflectometry," *J. Hydrol.* 88:319-328.

Appendix A. Importing *Short Cut* code into *CRBasic Editor*


Short Cut creates a .DEF file that contains wiring information and a program file that can be imported into *CRBasic Editor*. By default, these files reside in the C:\campbellsci\SCWin folder.

Import *Short Cut* program file and wiring information into *CRBasic Editor*:

1. Create the *Short Cut* program, then save it. Click the **Advanced** tab then the **CRBasic Editor** button. Your program file will open in CRBasic with a generic name. Provide a meaningful name and save the CRBasic program. This program can now be edited for additional refinement.

NOTE:

Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the program.

2. To add the *Short Cut* wiring information into the new CRBasic program, open the .DEF file located in the C:\campbellsci\SCWin folder. Copy the wiring information found at the beginning of the .DEF file.
3. Go into the CRBasic program and paste the wiring information at the beginning of the program.
4. In the CRBasic program, highlight the wiring information, right-click, and select **Comment Block**. This adds an apostrophe (') to the beginning of each of the highlighted lines, which instructs the data logger compiler to ignore those lines when compiling. The **Comment Block** feature is demonstrated at about 5:10 in the [CRBasic | Features](#) video .

Appendix B. SDI-12 sensor support

Serial Data Interface at 1200 baud (SDI-12) is a protocol developed to simplify sensor and data logger compatibility. Only three wires are necessary—serial data, ground, and 12 V. With unique addresses, multiple SDI-12 sensors can connect to a single SDI-12 terminal on a Campbell Scientific data logger.

This appendix discusses the structure of SDI-12 commands and the process of querying SDI-12 sensors. For more detailed information, refer to version 1.4 of the SDI-12 protocol, available at www.sdi-12.org.

For additional information, refer to the [SDI-12 Sensors | Transparent Mode](#) and [SDI-12 Sensors | Watch or Sniffer Mode](#) videos.

B.1 SDI-12 command basics

SDI-12 commands have three components:

- **Sensor address (a)** – a single character and the first character of the command. Use the default address of zero (0) unless multiple sensors are connected to the same port.
- **Command body** – an uppercase letter (the “command”), optionally followed by one or more alphanumeric qualifiers.
- **Command termination (!)** – an exclamation mark.

An active sensor responds to each command. Responses have several standard forms and always terminate with <CR> <LF> (carriage return and line feed). Standard SDI-12 commands are listed in [Table B-1](#) (p. 20).

Table B-1: Campbell Scientific sensor SDI-12 command and response set		
Name	Command ¹	Response
Acknowledge active	a!	a<CR> <LF>
Send identification	aI!	allccccccmmmmmmvvvxxx...xx <CR> <LF>
Start verification	aV!	atttn<CR> <LF>

Table B-1: Campbell Scientific sensor SDI-12 command and response set		
Name	Command ¹	Response
Address query	?!	a<CR><LF>
Change address	aAb!	b<CR><LF>
Start measurement	aM! aM1! . . . aM9!	atttn<CR><LF>
Start measurement and request CRC	aMC! aMC1! . . . aMC9!	atttn<CR><LF>
Start concurrent measurement	aC! aC1! . . . aC9!	atttnn<CR><LF>
Start doncurrent measurement and request CRC	aCC! aCC1! . . . aCC9!	atttnn<CR><LF>
Send data	aD0! . . . aD9!	a<values><CR><LF> or a<values><CRC><CR><LF>
Continuous measurement	aR0! . . . aR9!	a<values><CR><LF>
Continuous measurement and request CRC	aRC0! . . . aRC9!	a<values><CRC><CR><LF>
Extended commands	aXNNN!	a<values><CR><LF>
¹ Information on each of these commands is given in the following sections.		

B.2 Acknowledge active command (a!)

The acknowledge active command (a!) is used to test a sensor on the SDI-12 bus. An active sensor responds with its address.

B.3 Send identification command (aI!)

Sensor identifiers are requested by issuing command **aI!**. The reply is defined by the sensor manufacturer but usually includes the sensor address, SDI-12 version, manufacturer name, and sensor model information. Serial number or other sensor-specific information may also be included. Source: SDI-12: A Serial-Digital Interface Standard for Microprocessor-Based Sensors (see [References](#) [p. 1]).

Command: **aI!**

Response: *allccccccmmmmmmvvvxxx...xx<CR><LF>*

Where

a = sensor address

ll = SDI-12 version number (indicates compatibility)

cccccccc = eight-character vendor identification

mmmmmm = six characters specifying the sensor model

vvv = three characters specifying the sensor version (operating system)

xxx...xx = up to 13 optional characters used for a serial number or other specific sensor information that is not relevant for operation of the data logger

<CR> <LF> = terminates the response

B.4 Start verification command (aV!)

The response to a start verification command can include hardware diagnostics, but like the **aI!** command, the response is not standardized.

Command: **aV!**

Response: *atttfffhhn*<CR><LF>

Where

a = sensor address

ttt = time, in seconds, until verification information is available

fff = firmware (OS) version

hhh = hardware version

n = number of values to be returned when one or more subsequent **D!** commands are issued

B.5 Address query command (?!)

Command **?!** requests the address of the connected sensor. The sensor replies to the query with the address(*a*). This command should only be used with one sensor on the SDI-12 bus at a time.

B.6 Change address command (aAb!)

Multiple SDI-12 sensors can connect to a single SDI-12 terminal on a data logger. Each device on a single terminal must have a unique address.

A sensor address is changed with command **aAb!**, where *a* is the current address and *b* is the new address. For example, to change an address from 0 to 2, the command is **0A2!**. The sensor responds with the new address *b*, which in this case is 2.

NOTE:

Only one sensor should be connected to a particular terminal at a time when changing addresses.

B.7 Start measurement commands (aM!)

A measurement is initiated with the **M!** command. The response to each command has the form *atttn*<CR><LF>, where

a = sensor address

t = time, in seconds, until measurement data is available; when the data is ready, the sensor notifies the data logger, and the data logger begins issuing **D** commands

n = number of values returned when one or more subsequent **D** commands are issued; for the **aM!** command, *n* is an integer from 0 to 9

When **aM!** is issued, the data logger pauses its operation and waits until either it receives the data from the sensor or the time (*t*) expires. Depending on the scan interval of the data logger program and the response time of the sensor, this may cause skipped scans to occur. To avoid this, make sure your scan interval is longer than the longest measurement time (*t*).

Table B-2: Example aM! sequence	
0M!	The data logger makes a request to sensor 0 to start a measurement.
00352<CR><LF>	Sensor 0 immediately indicates that it will return two values within the next 35 seconds.
0<CR><LF>	Within 35 seconds, sensor 0 indicates that it has completed the measurement by sending a service request to the data logger.
0D0!	The data logger immediately issues the first D command to collect data from the sensor.
0+.859+3.54<CR><LF>	The sensor immediately responds with the sensor address and the two values.

B.8 Stopping a measurement command

A measurement command (**M!**) is stopped if it detects a break signal before the measurement is complete. A break signal is sent by the data logger before most commands.

A concurrent measurement command (**C!**) is aborted when another valid command is sent to the sensor before the measurement time has elapsed.

B.9 Send data command (**aD0!** ... **aD9!**)

The send data command requests data from the sensor. It is issued automatically with every type of measurement command (**aM!**, **aMC!**, **aC!**, **aCC!**). When the measurement command is **aM!** or **aMC!**, the data logger issues the **aD0!** command once a service request has been received from the sensor or the reported time has expired. When the data logger is issuing concurrent commands (**aC!** or **aCC!**), the send data command is issued after the required time has elapsed (no service request will be sent by the sensor). In transparent mode (see [SDI-12 transparent mode](#) [p. 24]), the user asserts this command to obtain data.

Depending on the type of data returned and the number of values a sensor returns, the data logger may need to issue **aD0!** up to **aD9!** to retrieve all data. A sensor may return up to 35 characters of data in response to a **D** command that follows an **M!** or **MC!** command. A sensor may return up to 75 characters of data in response to a **D** command that follows a **C!** or **CC!** command. Data values are separated by plus or minus signs.

Command: **aD0!** (**aD1!** ... **aD9!**)

Response: *a*<values><CR><LF> or *a*<values><CRC><CR><LF>

where

a = sensor address

<values> = values returned with a polarity sign (+ or –)

<CR><LF> = terminates the response

<CRC> = 16-bit CRC code appended if data was requested with **aMC!** or **aCC!**

B.10 SDI-12 transparent mode

System operators can manually interrogate and enter settings in probes using transparent mode. Transparent mode is useful in troubleshooting SDI-12 systems because it allows direct communication with probes. Data logger security may need to be unlocked before activating the transparent mode.

Transparent mode is entered while the computer is communicating with the data logger through a terminal emulator program. It is accessed through Campbell Scientific data logger support software or other terminal emulator programs. Data logger keyboards and displays cannot be used.

The terminal emulator is accessed through Campbell Scientific *Device Configuration Utility* software.

Watch [videos/sdi12-sensors-transparent-mode](#)  from the Campbell Scientific website.

Data loggers from other manufacturers will also have a transparent mode. Refer to those manuals for information on how to use their transparent mode.

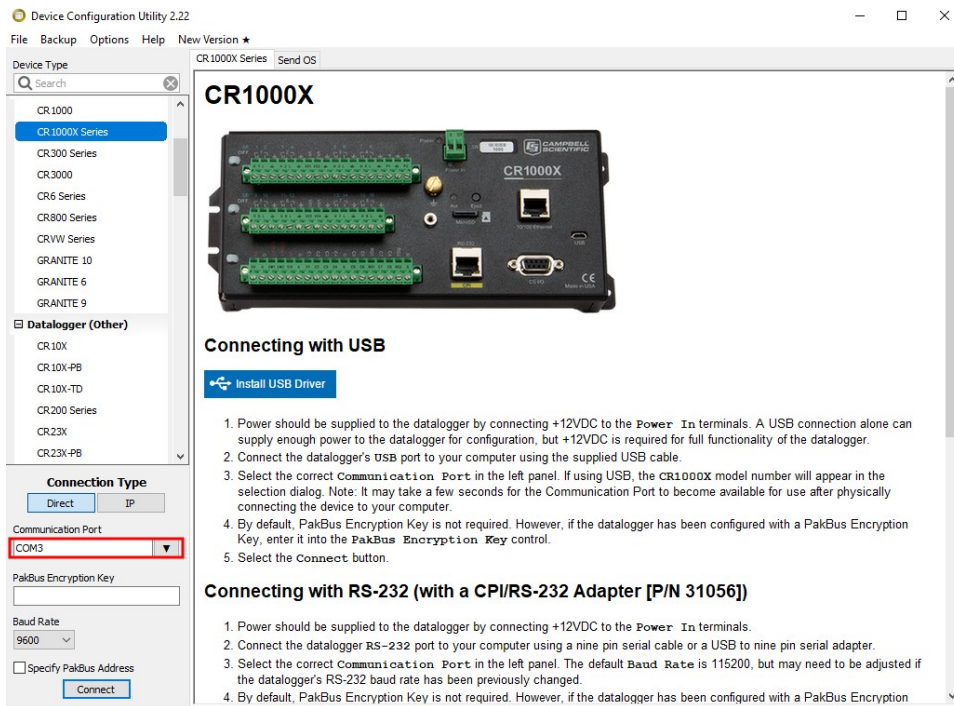
The following examples show how to enter transparent mode and change the SDI-12 address of an SDI-12 sensor. The steps shown in [Changing an SDI-12 address](#) (p. 25) are used with most Campbell Scientific data loggers.

B.10.1 Changing an SDI-12 address

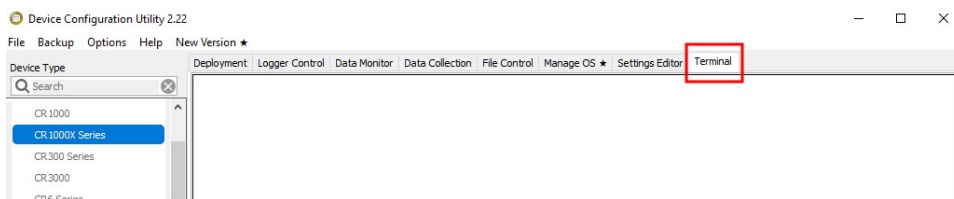
This example was done with a CR1000X, but the steps are only slightly different for Granite-series, CR6, CR800-series, CR300-series data loggers.

1. Connect an SDI-12 sensor to the CR1000X.
2. Open *Device Configuration Utility*.
3. Under **Device Type**, type the data logger model and double-click on the model type. This example uses a CR1000X directly connected to the computer USB port.

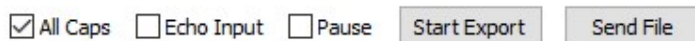
4. Select the correct **Communication Port** and click **Connect**.



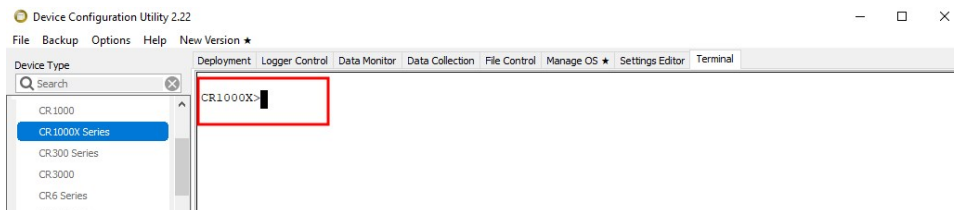
5. Click the **Terminal** tab.



6. Select **All Caps Mode**.



7. Press **Enter** until the data logger responds with the data logger (**CR1000X>**) prompt.



8. Type **SDI12** and press **Enter**.
9. At the **Select SDI12 Port** prompt, type the number corresponding to the control port where the sensor is connected and press **Enter**. In this example the sensor is connected to C3. The

response **Entering SDI12 Terminal** indicates that the sensor is ready to accept SDI-12 commands.

```
CR1000X>
CR1000X>SDI12
1: C1
2: C3
3: C5
4: C7
Select SDI12 Port: 2
```

10. To query the sensor for its current SDI-12 address, type **?!** and press **Enter**. The sensor responds with its SDI-12 address. If no characters are typed within 60 seconds, the mode is exited. In that case, simply type **SDI12** again, press **Enter**, and type the correct control port number when prompted.

```
?!
0
```

11. To change the SDI-12 address, type **aAb!**, where **a** is the current address from the previous step and **b** is the new address. Press **Enter**. The sensor changes its address and responds with the new address. In the following example, the sensor address is changed from 0 to B.


```
SDI12
SDI12>0AB!B
```

12. To exit SDI-12 transparent mode, click **Close Terminal**.

NOTE:

The transparent mode for the Granite-series, CR6, CR3000, CR800-series, CR300-series data loggers is similar to that shown for the CR1000X.

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General

- Protect from over-voltage.
- Protect electrical equipment from water.
- Protect from electrostatic discharge (ESD).
- Protect from lightning.
- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 6 meters (20 feet), or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.
- Only use power sources approved for use in the country of installation to power Campbell Scientific devices.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

Internal Battery

- Be aware of fire, explosion, and severe-burn hazards.
- Misuse or improper installation of the internal lithium battery can cause severe injury.
- Do not recharge, disassemble, heat above 100 °C (212 °F), solder directly to the cell, incinerate, or expose contents to water. Dispose of spent batteries properly.

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