# EnviroSMART™
# SOIL WATER CONTENT PROFILE PROBES
# INSTRUCTION MANUAL

**REVISION: 7/03**

# *Warranty and Assistance*

The **EnviroSMART™ SOIL WATER CONTENT PROFILE PROBES** are warranted by CAMPBELL SCIENTIFIC, INC. to be free from defects in materials and workmanship under normal use and service for twelve (12) months from date of shipment unless specified otherwise. Batteries have no warranty. CAMPBELL SCIENTIFIC, INC.'s obligation under this warranty is limited to repairing or replacing (at CAMPBELL SCIENTIFIC, INC.'s option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CAMPBELL SCIENTIFIC, INC. CAMPBELL SCIENTIFIC, INC. will return such products by surface carrier prepaid. This warranty shall not apply to any CAMPBELL SCIENTIFIC, INC. products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CAMPBELL SCIENTIFIC, INC. is not liable for special, indirect, incidental, or consequential damages.

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**CAMPBELL SCIENTIFIC, INC.**
RMA#_____
815 West 1800 North
Logan, Utah 84321-1784

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# *EnviroSMART™*
# *Soil Water Content Profile Probes*

## 1. General

EnviroSMART™ Probes measure soil water content profiles in a wide range of soil types for irrigation scheduling, waste water treatment, and other applications requiring continuous monitoring of water content and water movement in soil. Each probe requires installation with a specialized installation kit.

### 1.1 Calibration

EnviroSMART™ sensors produce readings which need to be converted to the real volumetric soil water content of a particular soil profile. The relationship between the "raw" sensor reading and the final measuring unit (Vol%) can be described by a mathematical relationship, which constitutes the calibration equation.

#### 1.1.1 Absolute Calibration

Sensors calibrated for a particular site, including the textural layers of a soil profile, will produce absolute and accurate soil water data. Absolute data, however, require that a sensor be calibrated for each soil type and each soil horizon. Absolute calibration is a costly and time consuming process, but must be done if absolute data are required.

#### 1.1.2 Relative Calibration

The other option is to work with relative data. Relative data are produced by an instrument calibrated for a range of soil types, and this calibration is used as a default calibration on all soil types. The readings cannot be considered as absolute data, but instead reflect soil water changes that can be used as key decision criteria in irrigation scheduling.

Relative data have been used since at least 1992 for irrigation management, isolating key factors such as depth of irrigation and rainfall, depth of the effective root zone, onset of crop water stress, and avoidance of water logging. Typically, economic gains recorded with Sentek sensor technologies in commercial agriculture are made using the concept of 'relative' change in soil water dynamics.

# 2. Specifications

| **Feature** | **EnviroSMART™ SDI-12** | **EnviroSMART™ Voltage** |
|---|---|---|
| Maximum cable length to logger or third party device | 60 m (200 ft)* | 2.0E-09 mV drop/ft cable (differential)**<br>1.6 mV drop/ft cable (single-ended)** |
| Maximum sensors per standard probe | 16 | 4 |
| Sensor Measuring Principle | High frequency capacitance | High frequency capacitance |
| Output Options | SDI-12 | Voltage |
| Protocol options | SDI-12 | 0 to 5 Volts (can be user specific) |
| Interface Measuring Principle | 16 Bit pulse count | 16 Bit pulse count |
| Output Resolution | 16 Bit | 12 Bit |
| Output Method | Serial data | Analogue |
| Current Consumption | 250 µA @ Sleep<br>66 mA @ Standby<br>100 mA @ Sampling | 0 mA @ Sleep<br><7 mA @ Standby<br>100 mA @ Sampling |
| Accuracy when calibrated | $R^2 = 0.992$ | $R^2 = 0.992$ |
| Resolution | 0.008% | 0.025% minimum or better depending on sensor output |
| Precision | ±0.003% Vol | ±0.003% Vol |
| Reading range | Oven dry to saturation | Oven dry to saturation |
| Temperature effects | ±3% 5°C to 35°C | ±3% 5°C to 35°C |
| Operating temperature range | -20°C to +75°C | 0°C to +70°C |
| Time to read one sensor | 1.1 seconds | 1.1 seconds |
| Sphere of influence | 99% of the reading is taken within a 10 cm radius from the outside of the access tube | 99% of the reading is taken within a 10 cm radius from the outside of the access tube |
| Sensor diameter | 50.5 mm | 50.5 mm |
| Access tube diameter | 56.5 mm | 56.5 mm |

* Based on SENSDI12CBL-L cable.

** Based on SENVOLTCBL-L cable with the interface drawing 100 mA of current.

# 3. Installation

Several configurations are possible when using the EnviroSMARTTM / EasyAG® Probes with Campbell Scientific dataloggers. Among those configuration are the following:

**Option 1 (Preferred)**

| Device | Function |
|---|---|
| Probe | Output scaled frequency |
| Datalogger | Store scaled frequency, calculate and store water content |

**Option 2**

| Device | Function |
|---|---|
| Probe | Output water content |
| Datalogger | Store water content |

Option 1 allows for use of data in spreadsheet programs as well as Sentek's ES4.1 Software. It also allows for application of new soil calibrations after data are collected. The preferred option is followed in this manual.

Refer to the installation manual published for each probe for information on access tube installation. Appendix A addresses probe assembly. Appendix B addresses probe normalization. Appendix C summarizes access tube installation. Appendix D summarizes site selection.

# 4. Probe Wiring

Tinned wires can simply be inserted into EnviroSMARTTM terminals. If wires are not tinned, depress the orange slotted gate key at each terminal before inserting wire.

## 4.1 SDI-12 Interface Wiring

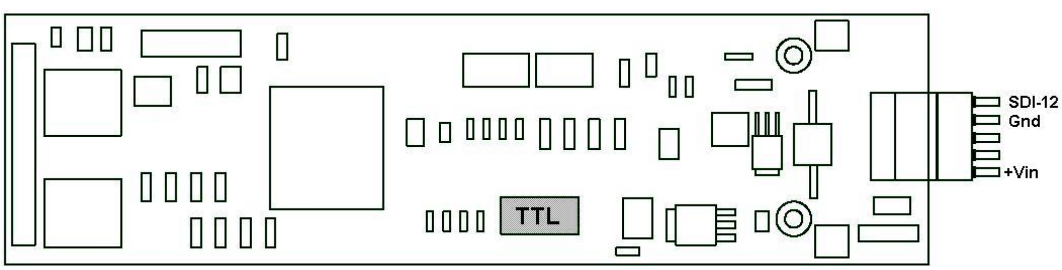



*FIGURE 1. EnviroSMARTTM SDI-12 Interface*

| Probe | Pin | CR10X / CR23X | CR200 Series |
|---|---|---|---|
| SDI-12 | 5 | C1 | C1 / SDI-12 |
| Gnd | 4 | G or ⏚ | ⏚ |
| +Vin | 1 | 12 V | SW Battery |

## 4.2 Voltage Interface Wiring

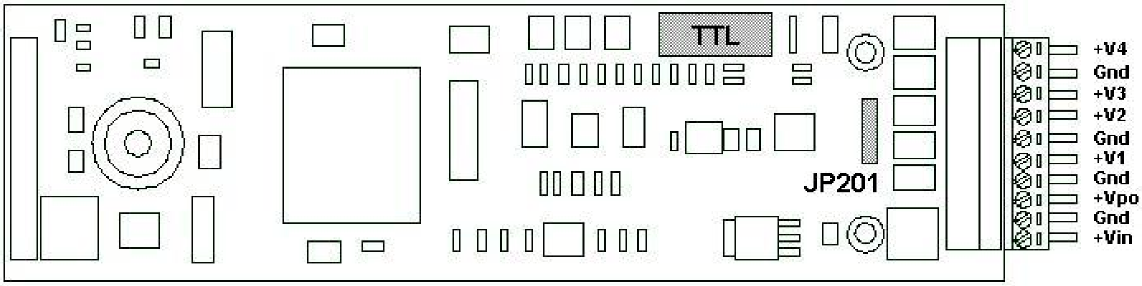



*FIGURE 2. EnviroSMART™ Voltage Interface*

| Probe | Pin | CR10X / CR23X |
|---|---|---|
| +V4 | 10 | SE4 |
| Gnd | 9 | AG |
| +V3 | 8 | SE3 |
| +V2 | 7 | SE2 |
| Gnd | 6 | AG |
| +V1 | 5 | SE1 |
| Gnd | 4 | AG |
| +Vpo | 3 | SW12V |
| Gnd | 2 | G |
| +Vin | 1 | 12 V |
| | | SW12V CTRL |
| | | C1 |

## 4.3 Cable Installation

Securely tighten the gland nut through which the cable passes into the probe cap. Inject a small amount of silicon sealant into the sensor end of the cable to ensure that water or water vapor will not pass into the probe.

# 5. Datalogger Programming

Example programs correspond to setup examples in Appendices A and B.

## 5.1 SDI-12 Interface Programming

Firmware Settings: Probe Configured to Output Scaled Frequency Data

Set Sensor Coefficients:
- Set A = 1
- Set B = 1
- Set C = 0

```
;{CR10X}

*Table 1 Program
  01:  900           Execution Interval (seconds)

;***Water Content Sensor Setup***

;Enter Coefficients to convert scaled frequencies to percent water content
;Defaults = Sentek default calibration
;---Enter A (default = Sentek default calibration Scaled F to %)
Calib_A = .1957
;---Enter B (default = Sentek default calibration SF to %)
Calib_B = .404
;---Enter C (default = Sentek default calibration SF to %)
Calib_C = .02852
;---Enter Mult to Convert % Water Content to inches water / 4 inches of soil
UnitScale = 0.04

1:  SDI-12 Recorder (P105)
  1:   0             SDI-12 Address
  2:   0             Start Measurement (aM0!)
  3:   1             Port
  4:   1             Loc [ SF_Top    ]
  5:   1.0           Mult
  6:   0             Offset

2:  Beginning of Loop (P87) ; ThetaV = (((SF - C) / A) to power of (1 / B))
  1:   0             Delay
  2:   3             Loop Count

3:  Z=X-Y (P35)
  1:   1 --          X Loc [ SF_Top    ]
  2:   13            Y Loc [ Calib_C   ]
  3:   5 --          Z Loc [ WC_Top    ]

4:  Z=X/Y (P38)
  1:   5 --          X Loc [ WC_Top    ]
  2:   10            Y Loc [ Calib_A   ]
  3:   5 --          Z Loc [ WC_Top    ]

5:  Z=1/X (P42)
  1:   11            X Loc [ Calib_B   ]
  2:   12            Z Loc [ RecipWC_B ]

6:  Z=X^Y (P47)
  1:   5 --          X Loc [ WC_Top    ]
  2:   12            Y Loc [ RecipWC_B ]
  3:   5 --          Z Loc [ WC_Top    ]

7:  End (P95)
```

```
8:  If time is (P92)
   1:    0              Minutes (Seconds --) into a
   2:    15             Interval (same units as above)
   3:    10             Set Output Flag High (Flag 0)

9:  Real Time (P77)
   1:    1220           Year, Day, Hour/Minute

10:  Sample (P70)
   1:    3              Reps
   2:    1              Loc [ SF_Top    ]

11:  Sample (P70)
   1:    3              Reps
   2:    5              Loc [ WC_Top    ]

*Table 2 Program
   02:  0.0000          Execution Interval (seconds)

*Table 3 Subroutines

End Program

-Input Locations-
1 SF_Top
2 SF_2nd
3 SF_3rd
4
5 WC_Top
6 WC_2nd
7 WC_3rd
8
9 _________
10 Calib_A
11 Calib_B
12 RecipWC_B
13 Calib_C
14 UnitScale
15 CSI_R
```

## 5.2 Voltage Interface Programming

Hardware Setting: JP201 Jumper Removed (Power-Up Mode)

Firmware Settings: Configure to Output Voltage Proportional to Scaled Frequency

Set Sensor Coefficients:

A = 1
B = 1
C = 0

Set Full Scale Voltage
- Set Voltage Lower Level: V*ll* = 0
- Set VWC Lower Level: N*ll* = 0

Set Full Scale Output
- Set Voltage Upper Level V*ul* = 2.5
- Set VWC Upper Level N*ul* = 1.0

Set Error Volts Ve = 3.0 (causes overrange error on CR10X Datalogger)

```
;{CR10X}
;
*Table 1 Program
  01: 900          Execution Interval (seconds)

;***Water Content Sensor Setup***

;Enter Coefficients to convert scaled frequencies to percent water content
;Defaults = Sentek default calibration
;---Enter A (default = Sentek default calibration Scaled F to %)
Calib_A = .1957
;---Enter B (default = Sentek default calibration SF to %)
Calib_B = .404
;---Enter C (default = Sentek default calibration SF to %)
Calib_C = .02852
;---Enter Multiplier to Convert % Water Content to inches water / 4 inches of soil
UnitScale = 0.04

1:  Do (P86)
  1:   41          Set Port 1 High

2:  Excitation with Delay (P22)
  1:   1           Ex Channel
  2:   5000        Delay W/Ex (0.01 sec units)
  3:   0           Delay After Ex (0.01 sec units)
  4:   0           mV Excitation

3:  Volt (SE) (P1)
  1:   3           Reps
  2:   25          2500 mV 60 Hz Rejection Range
  3:   1           SE Channel
  4:   1           Loc [ SF_Top   ]
  5:   .0004       Mult
  6:   0.0         Offset

4:  Do (P86)
  1:   51          Set Port 1 Low

5:  Beginning of Loop (P87) ; ThetaV = (((SF - C) / A) to power of (1 / B))
  1:   0           Delay
  2:   3           Loop Count
```

```
6:  Z=X-Y (P35)
   1:    1 --             X Loc [ SF_Top    ]
   2:    13               Y Loc [ Calib_C   ]
   3:    5 --             Z Loc [ WC_Top    ]

7:  Z=X/Y (P38)
   1:    5 --             X Loc [ WC_Top    ]
   2:    10               Y Loc [ Calib_A   ]
   3:    5 --             Z Loc [ WC_Top    ]

8:  Z=1/X (P42)
   1:    11               X Loc [ Calib_B   ]
   2:    12               Z Loc [ RecipWC_B ]

9:  Z=X^Y (P47)
   1:    5 --             X Loc [ WC_Top    ]
   2:    12               Y Loc [ RecipWC_B ]
   3:    5 --             Z Loc [ WC_Top    ]

10:  End (P95)

11:  If time is (P92)
   1:    0                Minutes (Seconds --) into a
   2:    15               Interval (same units as above)
   3:    10               Set Output Flag High (Flag 0)

12:  Real Time (P77)
   1     1220             Year, Day, Hour/Minute

13:  Sample (P70)
   1:    3                Reps
   2:    1                Loc [ SF_Top    ]

14:  Sample (P70)
   1:    3                Reps
   2:    5                Loc [ WC_Top    ]

*Table 2 Program
   02:  0.0000            Execution Interval (seconds)

*Table 3 Subroutines

End Program

-Input Locations-
1 SF_Top
2 SF_2nd
3 SF_3rd
4
5 WC_Top
6 WC_2nd
7 WC_3rd
8
9 _________
```

```
10 Calib_A
11 Calib_B
12 RecipWC_B
13 Calib_C
14 UnitScale
15 CSI_R
```

# 6. Care and Maintenance

Probe electronics will be damaged if exposed to water or condensation. A proper installation must include active desiccant in the cap of each probe. Be certain the gland nut through which the cable passes is tight. Also, maintain the silicon plug material in the sensor end of the cable to ensure water vapor does not pass into the probe through the cable.

# 7. Acknowledgements

Campbell Scientific, Inc. gratefully acknowledges the contribution of Sentek Pty Ltd to concepts, text, and images used in this manual.

# Appendix A.  Probe Assembly

*FIGURE A-1.  Finished EnviroSMART*[TM] *Assembly*

Figure A-1 shows a finished three-sensor probe.  Your probe may require more or less than three sensors at different spacing.

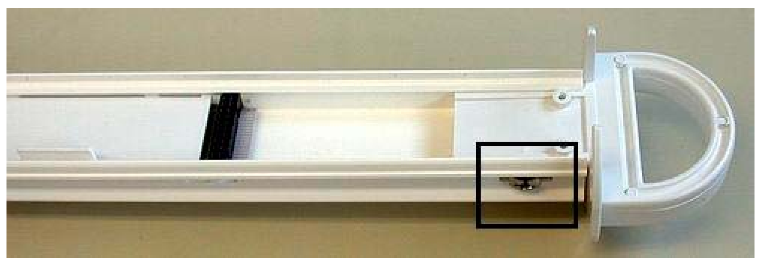


*FIGURE A-2.  Probe Rod Top*

Remove the probe rod from the access tube by removing the plug on one end of the tube.  The plug can be removed by shaking the tube vertically such that the rod internally hammers on the plug and eventually dislodges it.  Identify the "top" as indicated in Figure A-2.

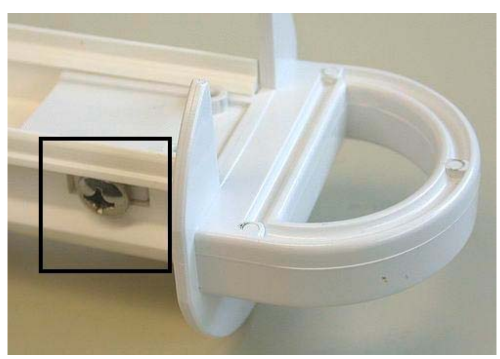


*FIGURE A-3.  Location of Large Handle Screws*

"Loosely" attach the handle to the rod with two of the large screws that came with the assembly as shown in Figure A-3.


FIGURE A-4.  Location of Small Main Board Screws

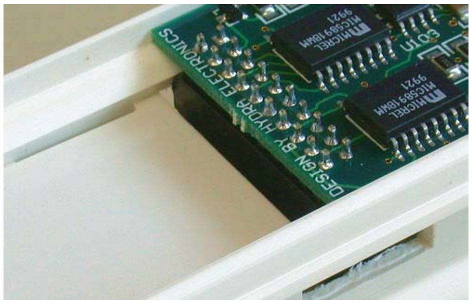



FIGURE A-5.  Securing Main Board Electrical Connection

Install the main board assembly as shown in Figure A-4 between the two sides of the mounting rail.  The header is plugged into the first connector in the rail as shown in Figure A-5.  Secure the main board to the probe with two of the small screws that came with the assembly.  Tighten the two large screws.


FIGURE A-6.  Possible Sensor Positions

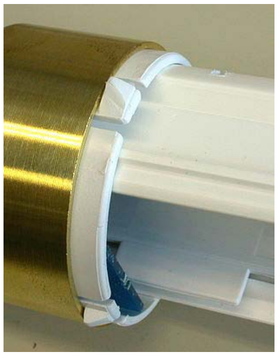


*FIGURE A-7.  Sensor Orientation*

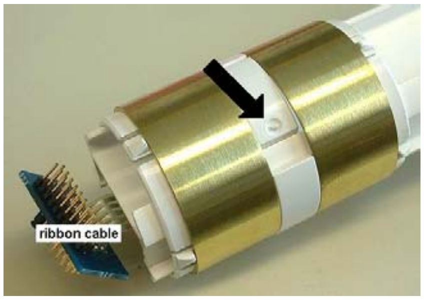



*FIGURE A-8.  Sensor Ribbon Cable*

Determine the number and locations of sensors that are to be installed.  They may or may not be as indicated in the example in Figure A-6.  Place the first sensor carefully over the rail, oriented as shown in Figure A-7.  To advance the sensor assembly to its location on the rail, press and hold the spot indicated by the arrow in Figure A-8.

**CAUTION** As you advance the sensor, carefully position the ribbon cable to prevent breaking it, as it will tend to catch, especially when first starting.

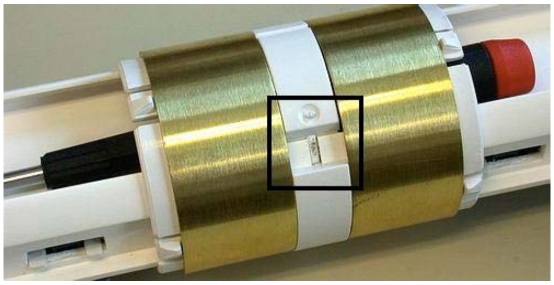


*FIGURE A-9.  Locking Sensor in Place*

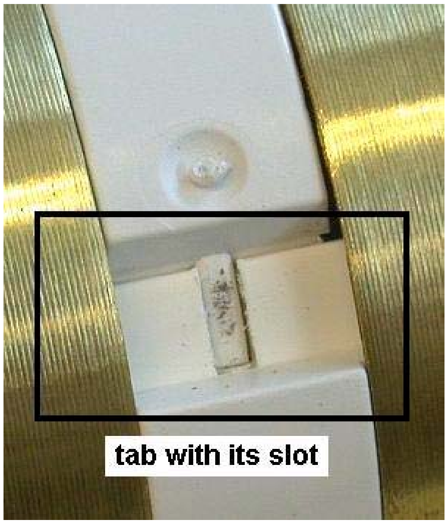



*FIGURE A-10.  Aligning Sensor Tab with Probe Slot*

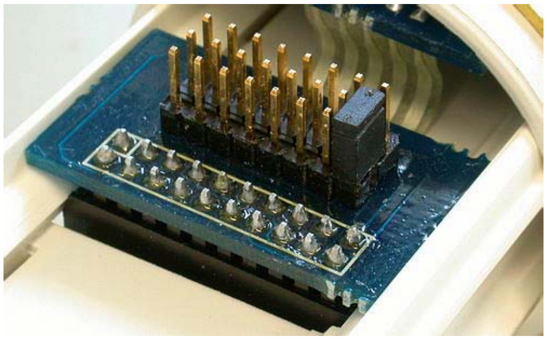


*FIGURE A-11.  Plugging in Ribbon Cable Header*

Advance the sensor to its proper location.  Align and snap the lock ring in place. Insert a screwdriver as shown in Figure A-9 and pull outward on the screwdriver after carefully aligning the tab with its slot in the rail, as shown in Figure A-10. After snapping in place, carefully plug the header on the ribbon cable into its proper connector in the rail as shown in Figure A-11.


*FIGURE A-12.  Sensor Addresses*

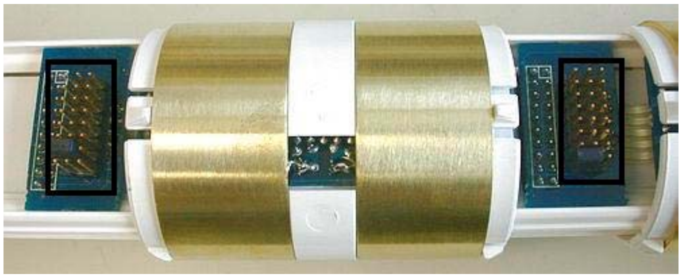


FIGURE A-13.  Location of Addressing Jumpers

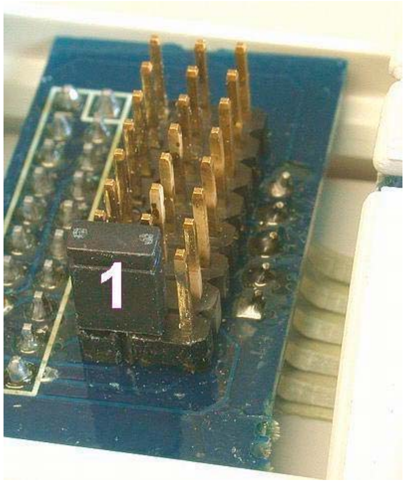



FIGURE A-14.  Location of Jumper 1

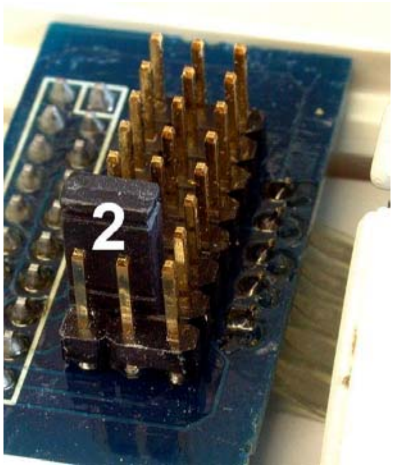



FIGURE A-15.  Location of Jumper 2

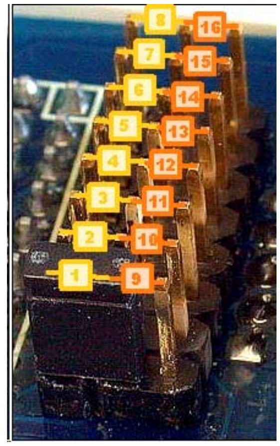



*FIGURE A-16.  Location of Jumpers 1..16*

After positioning and securing each sensor in its proper location, install the jumpers on the ribbon cable boards.  Begin at the main board end and install the jumpers on each sensor board in numeric sequence as shown in Figure A-12. Locate the sensor jumper pins as shown in Figure A-13.  Set sensor 1 jumper to the first position as shown in Figure A-14.  Set sensor 2 jumper to the second position as shown in Figure A-15.  Set subsequent jumpers as indicated in Figure A-16.  The position of the jumper on the header and the location of the sensor on the rail are NOT related and may or may not be the same.

# Appendix B.  Normalization and Function Test

Normalization is the setting of the range over which the sensors are effective. This range is bounded by the two extremes of air and water.

## B.1  Normalization

Connect +12 Volts DC and ground to the connector at the top of the probe as indicated in Figures B-1 or B-2.

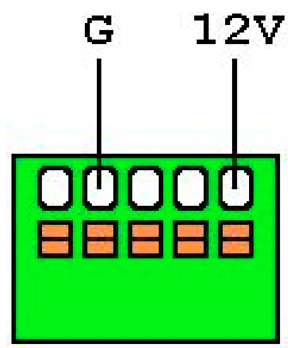



*FIGURE B-1.  SDI-12 Interface Power Connection*

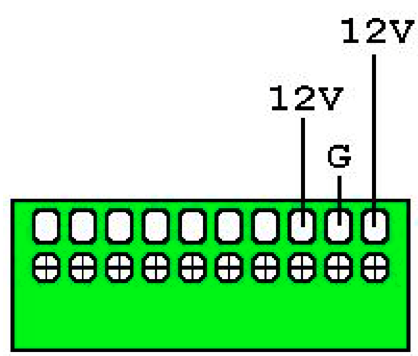



*FIGURE B-2.  Voltage Interface Power Connection*

Connect the Intelligent Probe Utility Cable (P/N SEN06020) to the TTL port near the top of the probe at the location indicated in Figures B-3 or B-4.

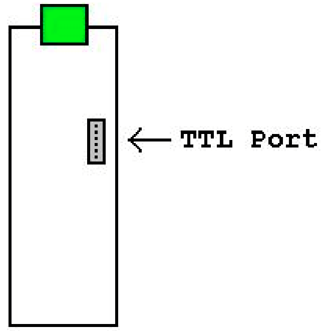



*FIGURE B-3.  SDI-12 Interface TTL Connection*

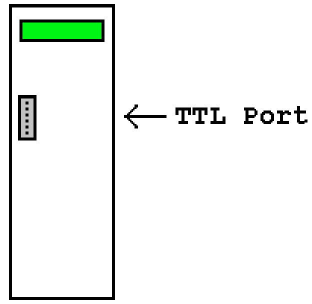



*FIGURE B-4. Voltage Interface TTL Connection*

Connect the other end of the utility cable to the serial port on a PC.  This may require a 9 to 25 pin serial adaptor.  CSI serial cable (P/N 7026) is available as an adaptor.

Start the IPConfig Utility (Intelligent Probe Utility Software, P/N SEN06025) on the PC by clicking on the IPConfig Utility icon (shown in Figure B-5).

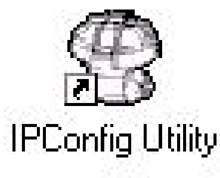



*FIGURE B-5.  IPConfig Utility Icon*

Click “Connect” in the upper right area of the IPConfig window.  The software will connect to the probe and set up a configuration window.

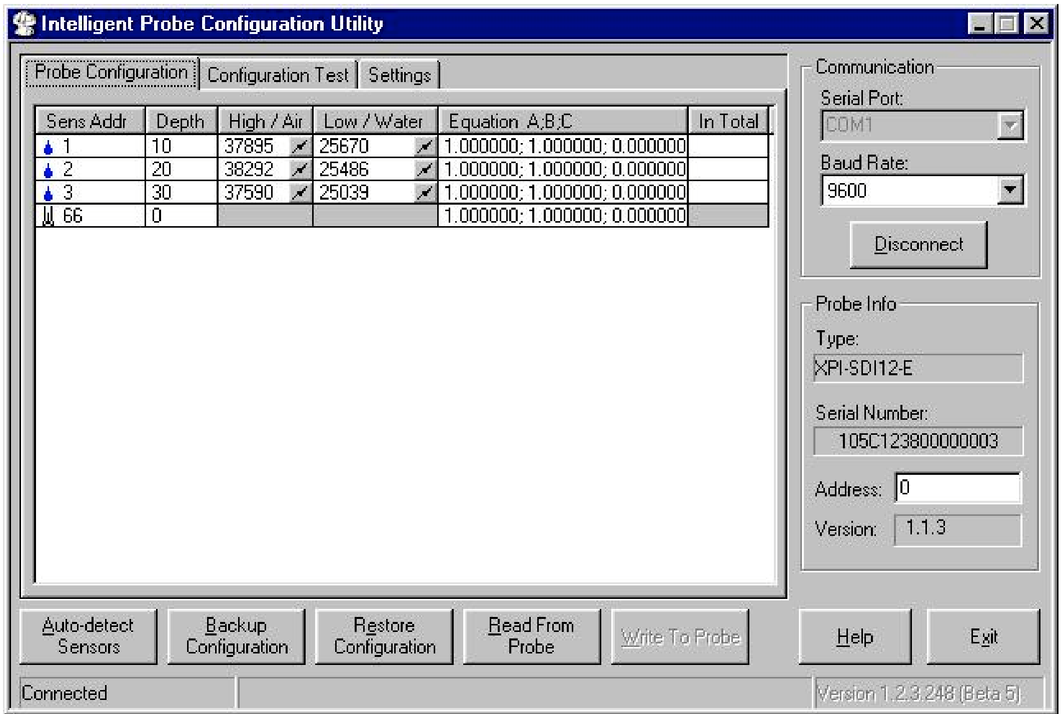



*Figure B-6.  IPConfig Probe Configuration Window*

Figure B-6 shows an IPConfig Utility Probe Configuration window after normalization is complete on a three-sensor probe with sensors placed at 10, 20, and 30 cm.  Complete the following operations for a new probe:

1. Click on “Auto-detect Sensors” in the lower left corner.  Wait until all sensors are auto-detected.  If the number of sensors detected does not correspond with the number of sensors on the probe, check to ensure that each sensor is addressed sequentially, beginning with address 1 on the top sensor.

2. Enter the depth of each sensor in the “Depth” column.  Each depth will be a multiple of 10.

3. Enter “1.000000;1.000000;0.000000” on each line in the “Equation A;B;C” column.

4. With the probe in the access tube, hold the probe in the air, away from any other object, with your hands away from the sensors, i.e. set the end of the probe on the floor and hold it upright.  For each sensor, press the “High / Air” toggle button .  Allow about 10 seconds, then toggle the button off.  Values will be within a few thousand of those shown in the example above.

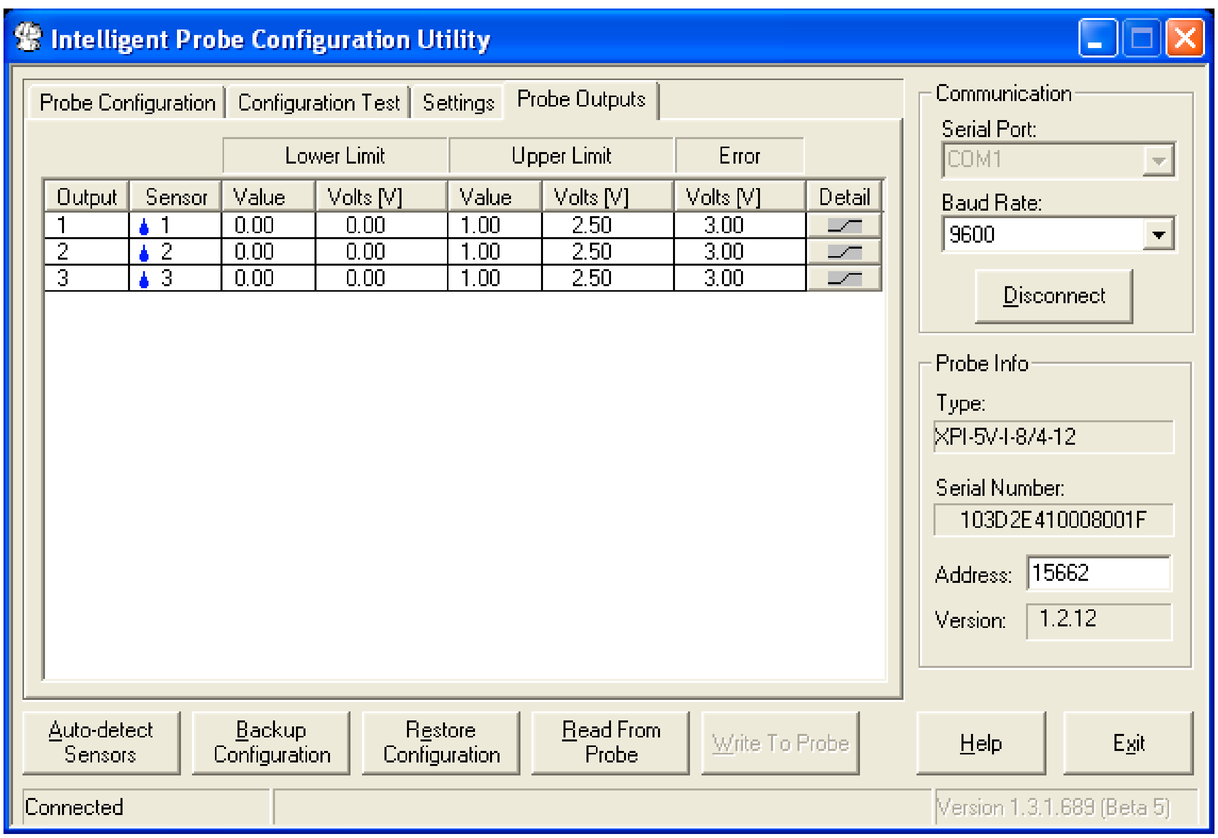
5. Fill the normalization chamber (P/N SEN70056) with water. Take the probe out of the access tube. For each sensor, slide the probe into the normalization chamber tube such that the sensor is in the center of the tube. Press the "Low / Water" toggle button. Allow about 10 seconds, then toggle the button off. Values will be within a few thousand of those shown in the example above.

6. On SDI-12 interfaces, set the probe address in the lower right area of the IPConfig window. The SDI-12 address is used in the datalogger program. If only one probe is to be used on a datalogger, you may leave the address at "0."

7. Press "Write to Probe" in the lower right of center of the window.

8. Press "Backup Configuration" in the lower left of center of the window. Use the default file name.

Normalization of the probe is now complete. Voltage interfaces require that the "Probe Outputs" tab be configured. The settings in this example correspond to the CR10X programming example in Section 5.2.



# B.2  Configuration Testing

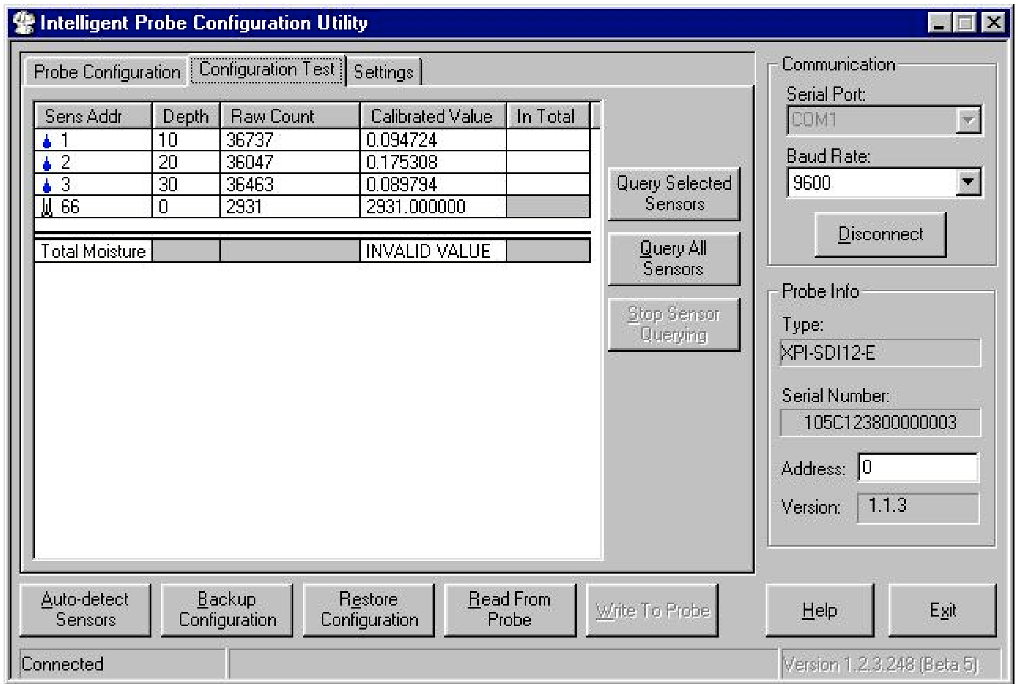



*FIGURE B-7.  IPConfig Configuration Test Window*

Test the configuration by going to the “Configuration Test” tab as shown in Figure B-7.  Again, with the probe in the access tube, hold the probe in the air, then press “Query All Sensors.”  Press “Stop Sensor Querying” when values appear in the window.  Raw counts should be close to the values shown in the example above.

# Appendix C. Access Tube Installation

The information below is a summary. Further information is provided in the Sentek Diviner2000® Installation Guide Version 1.0, available as a .PDF file from Campbell Scientific, Inc.

Sensors must be installed correctly into the soil medium. The soil around the sensor needs to be representative of the rest of the field.

The aim of the installation is to cause minimum disturbance to the crop and soil profile. Disturbances to the soil may produce pockets of air or loosely packed soil material. These conditions will cause preferential flow of irrigation water or rain to a greater depth compared with the rest of the field. Access tubes must be installed to fit tightly in the soil along their entire length.

Permanent errors can be introduced into the measurements through poor or hasty installations. Air gaps existing between the sensors (or access tubes) and the soil will bias sensor readings, i.e. the sensor will read high when the air gaps are filled with water and low when they drain. Poor installation is a primary source of inconsistencies between sensors.

The additional time taken in careful installation ensures access to accurate and meaningful data. Sentek has developed precision installation tools to be used for the installation of Sentek access tubes. The precision of the access tubes and tools is designed to complement the high value of the readings taken by the Sentek sensors.

Access tubes are to be installed at monitoring sites chosen using a series of proven evaluation methods. Monitoring sites must be selected so that information gathered from them is representative of surrounding crop / ground cover water use and soil water capacity. Appendix D discusses site selection.

Always try the standard manual installation method first. Alternatively, a slurry method is available for installations in soils with high stone and gravel content. However, the slurry method may have an impact on soil moisture readings at those sites.

To identify the tools required to install access tubes, examine the soil profile with a shovel or backhoe at the proposed monitoring sites.

## C.1 Standard Access Tube Installation

### C.1.1 Installation Tools

Toolkit items
Installation Toolkit No. 1
Items ordinarily required
1 x Regular Auger 47.0 mm
1 x Auger Cleaning Tool (small)
2 x Auger Extension Rods 0.5 m
3 x Auger Extension Rods 1.0 m
1 x Regular T-handle

2 x Tommy Bars
1 x Access Tube Cleaning Tool No. 1 – spiral
1 x Access Tube Cleaning Tool No. 2 – foam
1 x Access Tube Cleaning Tool No. 3 – rag tool
1 x Access Tube Cleaning Tool No. 4 – nylon brush
1 x Access Tube Bailer
1 x Expandable Bung Tightening Tool
1 x Dolly No.1
1 x Access Tube Cutting Tool No. 1
1 x Access Tube Cutting Tool No. 2
1 x Toolbag No. 1

Safety items
1 x Pair of Gloves
1 x Pair of Safety Goggles
1 x Plastic Sheet

Additional items for difficult soils
1 x Regular Auger 53.0 mm
1 x Regular Auger 56.0 mm
1 x Regular Auger Cleaning Tool – large

Installation Toolkit No. 2
1 x Access Tube Installation Tripod
3 x Tripod Anchor Pins
1 x Base Plate
1 x Auger Centralization Poly Guide
1 x Dolly No. 2
1 x Dolly No. 3
1 x Toolbag No. 2

## C.1.2  Installing the Access Tube

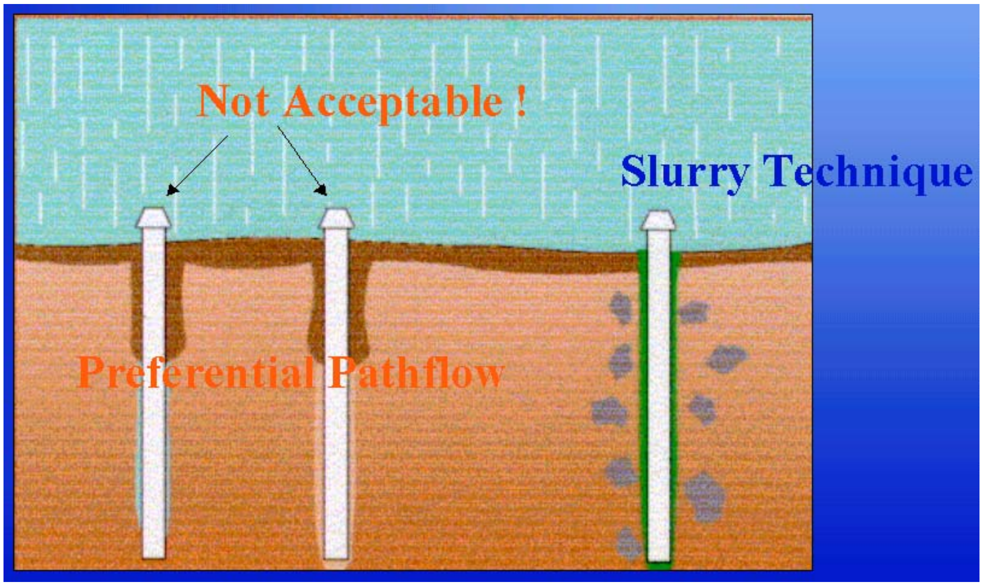



*Figure C-1.  Incorrect Installation*

To install the access tube, follow these steps (requires tool kits #1 and #2):

1. Put on the gloves.

2. Put on the safety goggles.

3. Select the 47 mm regular auger head.

4. Select the required extension rods and screw the auger head and the t-handle to the extension rods. The length of assembled auger must exceed the length of the access tube by at least 20 cm.

5. Insert the auger into the access tube while the tube is lying on the ground until the auger head protrudes by 20 cm.

6. Use a marking pen to mark the auger extension rod at the point where it disappears into the top of the access tube.

7. Remove the auger from the tube.

8. Select the yellow cutting edge and push it into the end of the access tube ensuring it fits squarely. Note: If you experience difficulties fitting the cutting edge onto the tube (1) turn the cutting edge on its side and, with a twisting motion, shave a layer of PVC from the lip of the access tube; and (2) carefully bounce the access tube and the partially fitted cutting edge on the side of the sledgehammer head.

9. Insert the access tube with fitted cutting edge into the tripod guide tube.

10. Select dolly no. 1 or dolly no. 2 and insert it into the top of the access tube.

11. Use a sledgehammer to tap the dolly until the access tube is embedded approximately 5-10 cm into the soil.

12. Place the auger inside the access tube and turn the auger handle. Auger ahead of the access tube by approximately 20 cm (until the pen mark made in Step 6 is flush with the top of the access tube).

13. Take the auger out of the tube and empty the soil using the small auger cleaning tool no. 1.

14. Select dolly no. 1 or dolly no. 2 and re-insert it into the top of the access tube.

15. Use the sledgehammer to drive the access tube further into the pre-drilled hole.

16. When you reach the bottom, remove the dolly. Again, auger ahead of the access tube by approximately 10-20 cm. Alternate between auguring and hammering until the dolly resting on top of the access tube touches the top of the tripod.

17. Insert dolly no. 3 and continue hammering and auguring until the mark on the dolly is level with the top of the tripod.

18. Remove the tripod by inserting the tommy bars into the holes of the tripod pins and pulling them upward with a twisting motion.

19. When all pins are removed carefully lift the tripod straight upward and off the access tube.

20. Try twisting and moving the access tube. It should not move. There should be no air gaps.

21. If there is an air gap, retrieve the access tube and start the installation process again at a site that is at least one meter away from the failed installation.

### C.1.3 Cleaning the Access Tube

The access tube must be cleaned before the top cap is installed and readings are taken. The bottom stopper is installed after cleaning in all soils except very wet and saturated soils. The type of soil at the installation site will determine which of the three cleaning methods is to be used. For instance, if you have dry/moist sandy to loamy soil conditions:

1. Detach auger head and attach cleaning tool no. 2 – foam.

2. Plunge foam tool up and down length of access tube.

3. Remove loose soil, dry sand, etc. from the bottom of the access tube by using cleaning tool no. 1.

4. Turn tool few times at the bottom of the access tube until sand collects on top of the spiral. Pull tool up and retrieve the material.

5. Select Access Tube Cleaning Tool no. 3 — rag tool. Insert a clean cotton cloth into the eyelet and saturate with denatured alcohol. Move this tool up and down the access tube to clean off the final dirt residue from the access tube.

6. After cleaning the tube, use a flashlight to inspect the inside of the access tube. You should be able to see clean walls and the lip of the cutting edge at the bottom.

### C.1.4 Installing the Bottom Stopper Bung

The bottom stopper bung is installed after the access tube has been cleaned. To install the bung:

1. Ensure access tube is clean.

2. Partially insert bung into access tube and hold it at the upper end so 75% of the top rubber ring is within the access tube.

3. Tighten the wing nut to the point where there is enough friction on the wall of the access tube to prevent the bung from turning in the tube while the wing nut is tightened.

4. Attach the bung tightening tool and auger extension rod and use the tommy bars to tighten it firmly to the extension rods.

5. Place the bung tightening tool over the wing nut and slowly push the bung down the access tube.  Allow air to escape until the bung rests on top of the internal cutting edge on the inside of the tube.

6. Slowly turn t-handle until you feel resistance to turning when the bung is sitting tight.

7. Twist tool clockwise quickly while pulling upwards.  This will release the spring on the tool from the wing nut and enable you to pull the tool out of the access tube.

### C.1.5  Installing the Top Cap

The top cap assembly is installed after the access tube has been cleaned and the bottom stopper fitted.  To install the top cap assembly follow these steps:

1. Ensure the 4 cm of the access tube protruding from the soil is clean on the inside and the outside.

2. With a silicon gun and new nozzle, apply three rings of silicon around outside of the access tube about 1 cm below the top rim of the tube.

3. Unscrew cap from top cap assembly base.

4. Take top cap base and push it onto the top of the access tube with a slight forward and backward rotating motion until the bottom foot of the top cap touches the undisturbed soil surface.

5. Wipe off excess silicon from the inside of the access tube.

6. Screw the cap back onto the top cap housing.

## C.2  Access Tube Removal

Requires took kits #1 and #3.

1. Unscrew the top cap.

2. Attach t-handle and bung tightening tool to the required auger extension rods.

3. Use tommy bars to tighten t-handle and bung tightening tool firmly to the extension rods.

4. Insert this tool into the access tube until you feel the top of the bottom stopper bung.

5. Turn the tool slowly until the slot of the tool slides over the wing nut, which causes the tool to drop 1 cm downward.  The spring on the side of the tool will make sure that enough pressure is applied on the wing nut to enable you to pull the stopper up once the wing nut has been loosened.

6. Turn the t-handle counter-clockwise until you can pull the bottom stopper upwards and remove it from the access tube. If the bung tightening tools starts to unscrew from the extension rod, remove the entire assembly and tighten the connection between the extension road and the bung tightening tool with the tommy bars.

7. Assemble the tripod.

8. Place the tripod so that the cable is centered over the access tube.

9. Slide the diagonal parts of the tube extraction tool so that they form a cylinder, which will slide the tool into the access tube.

10. Insert the tube extraction tool into the access tube and tap the horizontal bar of the tool with a small hammer.

11. Tapping the horizontal bar of this tool will cause the halves of the cylinder to slide apart and the tool will sedge itself to the inside walls of the access tube.

12. Put on the safety goggles.

13. Place the hook of the cable from the tripod through the upper eye of the extraction tool.

14. Put on the gloves and start turning the handle of the winch.

15. Apply more pressure until you see the upward movement of the access tube.

16. Winch the access tube carefully upward and out of the ground.

17. Remove the access tube from the extraction tripod for cleaning and storage.

18. To separate the top cap assembly base from the access tube, silicon can be loosened with the hot air stripper and the components cleaned with acetone.

*FIGURE C-2.  Installation Toolkit #1*

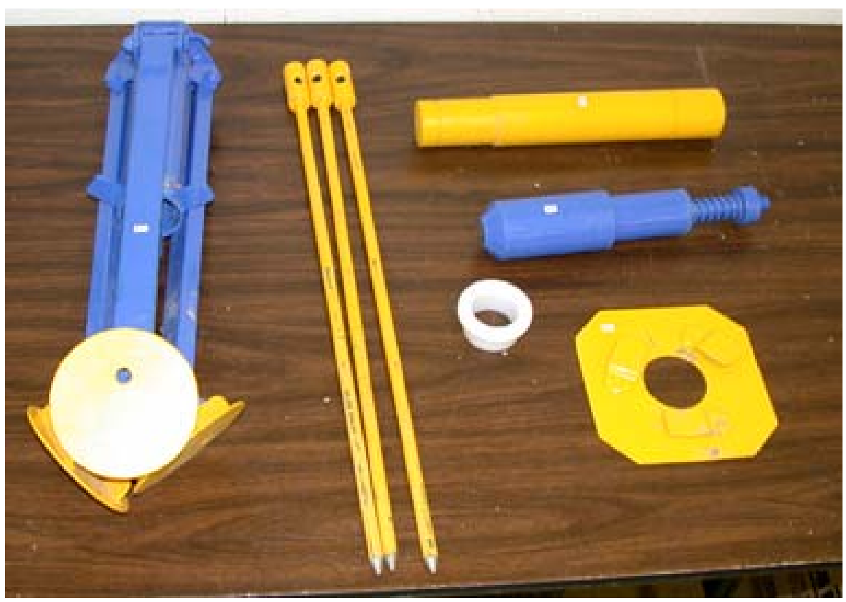


*FIGURE C-3.  Installation Toolkit #2*

# Appendix D.  Site Selection

Site selection is a critical process for all soil water sensors.  A properly selected site will reflect changes in soil moisture and plant water use trends over a larger area.  This area may be an entire field, sub-section of a field, a crop variety, a planting, a soil type, etc.  Putting a sensor in a 'dry zone' or under the influence of a malfunctioning sprinkler will invalidate data.

Site selection is carried out by identifying macro-zones and micro-zones.

Macro-zone selection divides the property in zones according to soil type, soil depth, water holding capacity, and water tables and salinity.  Irrigation applications can be specifically tailored to these zones to match soil and crop variability as a macro zone consists of areas with similar crop water use.

Micro-zone selection determines the position of access tubes in relation to the crop and irrigation system and considers the areas of the root zone, canopy spread, water distribution uniformity, and moisture pattern of drip irrigation. Measurements are taken from a small part of the root-zone.  If the extent and depth of the root-zone is misjudged and/or when sensors are placed in dry or wet spots associated with a bad distribution uniformity of water, the soil water data will not indicate optimal irrigation scheduling.

**Important factors to take into consideration for site selection are:**

1. Soil spatial variability
2. Topography
3. Aspect of sloping land
4. Crop type
5. Crop age
6. Crop planting density
7. Size and extent of the effective root system of the crop
8. Irrigation system layout and flexibility
9. Water Distribution uniformity
10. Moisture patterns under drip irrigation.