APPENDIX B

SENSOR GUIDELINES

APPENDIX B1: SENSOR SELECTION UNDER LIMITING CONDITIONS

The following table provides a quick guide for recommendations under common limiting conditions. For a full list of limiting conditions, refer to Table 4.

Limiting Condition	Recommendation	Unwanted outcome
High clay content/Bulk electrical conductivity (BEC)	• Use high frequency >1GHz sensors and smaller waveguides • Sensors should measure BEC • Conduct soil-specific calibration • Do not use TDR if Bulk Electrical Conductivity (BEC) is high	
Pre-installed sensors	• Conduct post-deployment activities or externally calibrate sensor in lab at an estimated bulk density with similar soil type estimated from SSURGO	• Uncertain improvement in accuracy • An independent validation through a higher-level research endeavor (modeling or other activities) may be required
Space constraints (cannot dig pit to horizontally install sensors)	• Use soil VUE TDR/Watermark sensors	• Lower accuracy
Volcanic soils	• Conduct soil-specific calibration	

APPENDIX B2: SENSOR CALIBRATION GUIDELINES

WHEN SHOULD SENSORS BE CALIBRATED?

Sensors must be calibrated according to their respective data quality/assurance tier guidelines. Sensor calibration must be performed per the following recommendations.

- **New installation**: Whenever a new site or station is planned.
- **Relocation of existing site**: If an existing station is moved and all sensors are relocated to a new borehole, the borehole must be characterized again by a soil scientist.
    - If the borehole is characterized differently from the first borehole that they were installed in, calibrations pertaining to Tiers I and II must be repeated (Chapter 8).
    - If the borehole is characterized as the same soil series, but the station is moved to a different landscape location, vegetation type, or cover, only calibration pertaining to Tier I must be repeated. A Tier II classification can be retained from the previous site.
    - If the borehole is characterized as the same soil series and the station is not moved far from the original location, no re-calibration is required.
- **Sensor relocation**: If a new sensor is installed close to an existing station to replace a failed sensor with similar soil type and bulk density, the existing calibration equations that were developed for the previous sensor can be used. However, if the sensor make and model is changed, a new calibration equation must be developed.

  *Information on sensor calibration can be found in Chapter 6 of this document.

CALIBRATION GUIDELINES

Tiers categories for calibration are listed from least to most rigorous.

Tier III

- Sensors should be factory calibrated. No additional calibration required.

Tier II

- Factory calibrations must be replaced with soil-specific calibration for each soil type and soil bulk density sensors will be installed in. This step can only be conducted post site characterization by a soil scientist and should be done for each sensor type-soil type combination at specific dry bulk densities.

Tier I

At least one post-validation activity must be performed in addition to soil-specific calibration performed in the lab. While most post-validation activities require modeling or expert involvement, field-based measurements offer an alternative post-validation activity that can be performed by network operators is described below. Note that any other post-deployment activity can also be performed in lieu of this process.

- Factory calibrations must be replaced with soil-specific calibrations.
- Post-validation calibration must be conducted.
    - Soil samples must be collected from several locations (at least 5) in the area surrounding the site (i.e., no variability in meteorological conditions).

- These locations must have the same soil series as the site of sensors installation.
- Samples must be collected under different wetness conditions (~ 6-10 time points total) that are preferably spread across different seasons from all depths that the sensors are installed in.
- Soil samples should be of a known volume to ensure bulk density and volumetric soil moisture can be calculated as explained in Appendix D.
- The average soil moisture value across all measured locations should be used to calibrate the installed soil moisture sensor. The calibration function can be estimated as explained in Chapter 6 of the Meter Group document for soil/point-specific calibration (here). This process must be done for each soil depth separately and the new calibration equation must be developed using the raw data (voltages) that the sensor measures. Linear or non-linear regression equations may be developed.

Note that several companies offer calibration services for a fee, and sensor calibration can be outsourced. If performing calibration in-house, follow instructions provided by Meter Group: https://metergroup.com/expertise-library/video-how-to-calibrate-meter-soil-moisture-sensors/. *Both video and text instructions are provided. While this methods example refers to one particular sensor model, the procedure remains the same for many other makes and models***.**

NOTE: A POORLY DONE CALIBRATION CAN MAKE SENSORS PERFORM WORSE THAN A FACTORY CALIBRATED SENSOR.