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Calibrating ECH_2O Soil Moisture Probes

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Soil specific calibration for ECH_2O probes is sometimes necessary when greater soil water content accuracy is desired. A variety of techniques can be used to evaluate water content but many of these can cause erroneous correlation because of non-uniform soil wetting, concentration of soil water near the ECH_2O sensor surface, and air gaps caused by soil drying. The objective of this note is to provide a detailed procedure similar to the one that was followed in the factory calibration of the ECH_2O probes.

Soil was prepared for analysis by breaking up large clods until all aggregates fit through a 5 mm screen. After sieving, the soil was poured into a large container and wetted with a measured amount of water. To prevent soil clumping, the water was added in small amounts so only enough water was added to thoroughly wet the surface. The wetted soil was mixed thoroughly with a hand trowel after each surface wetting. A standard amount of water was decided upon (through trial and error) that would increase the soil volumetric water content by 3 to 10% for each measurement (typically 250 ml). When all the water had been mixed into the soil, the soil was poured to a depth of approximately 10 cm in a 30 cm x 15 cm x 20 cm container. Before packing the soil, an ECH_2O probe was inserted in the soil with the width of the probe perpendicular to the soil surface. The soil was compacted by hand around the probe. Standardizing this portion of the calibration was important because soil to probe contact is critical. We found we could satisfactorily pack the soil by inserting the index and middle fingers into the soil on either side of the probe seven or eight times along its length. After packing the soil around the probe, more soil was added so the probe was buried at least 3 cm below the soil surface, and the soil surface was packed again using the front of a clenched fist. The ECH_2O probe was connected to a readout device and readings were collected.

After the ECH_2O probe readings were recorded, three volumetric soil samples were taken adjacent to the probe. A 16.1 cm^3 sampling cylinder was fully inserted into the soil and a soil core was removed and dispensed into a drying jar (core samplers and drying jars are available from Decagon). The jar was quickly sealed from the ambient air to reduce soil evaporation.

Soil samples were weighed and dried to determine gravimetric water content. Two techniques were used for drying, both detailed in Methods of Soil Analysis: Part 1- Physical and Mineralogical Methods (Ed. A. Klute, 1986), sections 21-2.2 and 21-2.3 (techniques for measuring gravimetric water content using a conventional oven and a microwave oven, respectively). Briefly, glass jars containing the soil samples were weighed on a precision balance and placed in a drying oven. To speed up the drying process, most samples were dried in a microwave oven for 10 min at full power (10 min was determined to be sufficient to fully dry soil samples). Alternately, soil samples were dried for 24 hours at 105∞ C in a conventional oven. Jar lids were replaced immediately after drying, and the samples were set to cool until the soil temperature was near ambient. After they had cooled, the soil samples were weighed again to determine dry weight and the jars themselves were weighed for a tare weight. Volumetric water content (q)

$$\theta = w\frac{\rho_b}{\rho_w}$$

was determined from the gravimetric water content (***w***)

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$$w = \frac{m_w}{m_m}$$

where ***m*** is mass and the subscripts ***w*** and ***m*** refer to water and minerals. The bulk density r_b is

$$\rho_b = \frac{m_m}{V_t}$$

where V_t is the total volume of the sample. The density of water, r_w, is 1 Mg m^{-3}.

The following is an example calculation of soil volumetric water content. The table contains the information collected during the soil sampling process.

Soil Sampling Volume (V_t)	16.1 cm^3
Soil Sample Initial Weight (with Jar)	84.065 g
Dried Sample Weight (with Jar)	81.113 g
Jar Weight (Tare)	57.894 g
Mass of water (Initial – Dry Weight) (m_w)	2.952 g
Mass of dry soil (Dry – Tare Weight) (m_m)	23.219 g

Using these values, volumetric water content is calculated by first evaluating the gravimetric water content and bulk density, then calculating volumetric water content using the equations below:

$$w = \frac{m_w}{m_m} = \frac{2.952\ g}{23.219\ g} = 0.127 \qquad \rho_b = \frac{m_m}{V_t} = \frac{23.219\ g}{16.1\ cm^3} = 1.44\ g\ cm^{-3}$$

$$\theta = w\frac{\rho_b}{\rho_w} = 0.127\left(\frac{1.44\ g\ cm^{-3}}{1\ g\ cm^{-3}}\right) = 0.183\ or\ 18.3\%$$

Calculation of individual water contents can be done very quickly in Microsoft Excel™. The following chart shows the cell operations:

Wet Soil	Dry Soil	Jar Tare	Water Wt	Soil Wt	Bulk Density	Vol. Water Cont	
84.0653	81.1129	57.8942	=+A1-B1	=B1-C1	=+E1/H2	=(D1/E1)*F1	
			m_w	m_m	ρ_b	sample volume	16.14784

To construct an entire calibration curve, water contents were obtained for each of the three replicates at each of the four to six soil water contents. The following table shows a *subsection* of water content calculations for a sandy loam soil calibration:

Sample #	Soil Weight	Dry Soil Wt (g)	Tare Wt (g)	Water Wt (g)	Soil Wt (g)	Bulk Density (Mg m^{-3})	θ (Vol. Water Content, m^3 m^{-3})	Ave. θ (m^3 m^{-3})
3.1	90.7245	87.726	59.5	2.9985	28.226	1.747974	0.185691	0.180381
3.2	95.5623	92.6741	64.7149	2.8882	27.9592	1.731452	0.17886	
3.3	88.3172	85.4656	57.8928	2.8516	27.5728	1.707523	0.176593	
4.1	92.2413	87.9917	59.5003	4.2496	28.4914	1.76441	0.263168	0.264335
4.2	97.6548	93.3893	64.7152	4.2655	28.6741	1.775724	0.264153	
4.3	91.0878	86.7976	57.8893	4.2902	28.9083	1.790228	0.265683	

Calibration curves were constructed by combining each ECH_2O probe reading with the average volumetric water content of the soil they were buried in. We obtained the following calibration curve for a sandy loam soil with a very low electrical conductivity:

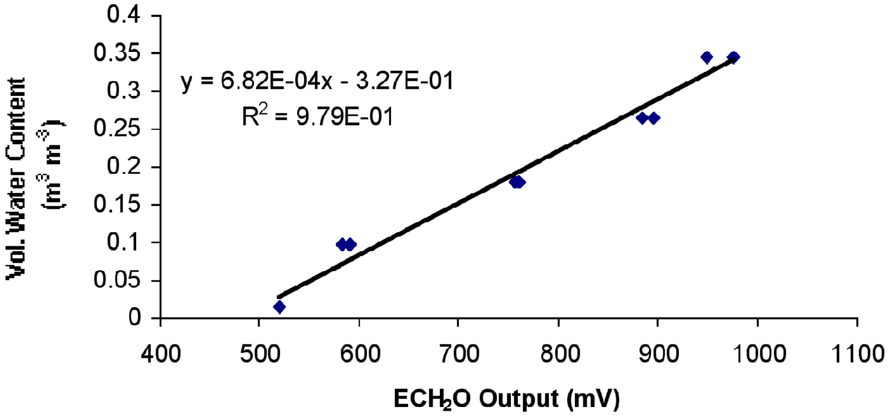

Fig. 2. ECH_2O calibration in a sandy loam

Note that the Smart Sensor version of this probe supplied by Onset converts the millivolt values from the ECH_2O to the corresponding uncalibrated volumetric water content values using the standard ECH_2O linear conversion equation. With this probe the calibration curve will be the relationship between the uncalibrated and calibrated water content values, so the X-axis in the above graph will be the uncalibrated values provided by the sensor.