Frequently Asked Questions about the ECH$_2$O Soil moisture Probes and Accessories

General

1. **How does the ECH$_2$O probe measure volumetric water content (VWC)?**
   The ECH$_2$O probes use capacitance to measure the dielectric permittivity of the surrounding medium. The volume of water in the total volume of soil most heavily influences the dielectric permittivity of the soil because the dielectric of water (80) is much greater than the other con-stituents of the soil (mineral soil, 4; organic matter, 4; air, 1). Thus, when the amount of water changes in the soil, the ECH$_2$O probe will measure a change in capacitance (from the change in dielectric permittivity) that can be directly correlated with a change in water content. Circuitry inside the ECH$_2$O probe changes the capacitance measurement into a proportional millivolt output.

2. **What is the difference between volumetric water content (VWC) and gravimetric water content (GWC)?**
   Gravimetric water content is the weight of soil water per unit weight of dry soil. Volumetric water content is the volume of soil water per unit of total volume. Volumetric and gravimetric water content are related by the bulk density of the soil. Gravimetric water content is the most easily measured, requiring only a glass jar with a lid, an accurate scale, and an oven. Indeed, while GWC may be more easily obtained and more intuitive, the output of most soil water content sensors (including ECH$_2$O probes) is correlated with VWC. One common calibration error is to relate probe output with GWC.

3. **Does the probe read water content at a certain point on the sensor, or does it average over the entire length?**
   The probe averages the volumetric water content over the entire length of the probe, with about a 2cm zone of influence along the length.

4. **Is the 2cm zone of influence with respect to the flat surface of the probe, or with respect to its edge?**
   The 2cm zone of influence is with respect to the flat surface; it has little or no sensitivity at the extreme edges of the probe. Also, the electromagnetic field produced by the probe decreases with distance from the probe surface.

5. **How long will the ECH$_2$O probes last in the field?**
   ECH$_2$O probes should last at least 3 years in the field. In fact, we expect them to last much longer than that. Since we began selling the probes in the spring of 2001, we have been constantly improving the probe to increase their longevity in the field. Starting with an improved strain relief in 2003, we then sealed the cable/overmold interface using a chemical that creates a physical bond between two plastics in April 2004. We sealed the entire circuit board surface with this chemical in September 2005, and increased the probe cable thickness while remov-

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ing the inductors in the plug head (January 2006). Ongoing testing has shown these new probes to be exceptionally robust, even in extreme conditions (submerged in 2.0 dS/m water at 60° C for weeks). Thus far, we have observed three basic modes of failure, all of which were dealt with through the changes to the probes noted above: first, water getting into the circuitry (solved by using the chemical sealant to seal the board surface and cable interface with the overmold), second, the breaking of inductors in the probe plug (solved by putting the inductors on the sensor and removing them from the plug), and third, broken probe cables because of rodent damage (improved through increased cable thickness and wire conductor gauge).

6. **What is the difference between the ECH_2O EC-5, EC-10 and EC-20 models?**
   While the EC-10 and -20 only differ in the length over which the measurement is averaged, the EC-5 is a completely redesigned sensor. While all measure water content using a dielectric measurement, the EC-5 uses a measurement frequency at 70 MHz, compared to the other sensors at about 10 MHz. Because of this increased measurement speed, the EC-5 is almost completely insensitive to differences in electrical conductivity (EC, tested to 8 dS/m) and soil texture. The EC-10 and -20 both have considerable sensitivity to EC (above 0.5 dS/m) and texture (coarse) that requires soil-specific calibration. The three probes also differ in length (5, 10, and 20 cm long probes) and sensitivity to changes in water content (EC-20 is nominally more sensitivity to water content change compared the EC-10 and EC-5.) Where installation is difficult, the EC-10 or EC-5 may be a more attractive option. For more detailed comparisons and specifications, please visit our specs page.

7. **Where does the ECH_2O-TE fit in to the ECH_2O probe family?**
   The ECH_2O-TE uses the same circuitry to measure water content as the EC-5 so has very little sensitivity to soil texture or EC. The main difference between the ECH_2O-TE and all the other ECH_2O probes is that it measures temperature and bulk electrical conductivity as well as water content. Because it outputs these three parameters, the ECH_2O-TE uses digital communication instead of analog (voltage) output. As a result, it will not work with most standard data loggers. Decagon's Em50 data logger is specially designed to measure the ECH_2O-TE. Other sensor interfaces will be available soon.

8. **Where would I choose the EC-5 over the EC-10 or EC-20?**
   Anytime where large sampling volume is not essential, where salinity is higher than 0.5 dS/m, or where you want consistent accuracy across a range of soil textures without soil specific calibration.

9. **Is the ECH_2O sensor itself exposed to the soil?**
   No. The copper traces used to measure water content are sealed between two pieces of epoxy-impregnated fiberglass (circuit board material). The EM field generated by the traces travels through the fiberglass and into the soil surrounding the probe.

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Measurement and Applications

1. **Can I measure the moisture content of grain using the ECH$_2$O probe?**
   We have not conducted any studies on this application. There may be limits on the accuracy of the ECH$_2$O because of the air gaps between the probe and the grain. It may be useful to use an evaluation ECH$_2$O unit to determine whether the ECH$_2$O probe could be used in your application.

2. **How would the ECH$_2$O probe function in a low-density medium like Perlite?**
   We recommend using an EC-5 or ECH$_2$O-TE in low density media like Perlite. From our testing so far, both of these probes perform very well in low density media.

3. **Can the ECH$_2$O probe measure the water content of organic matter and compost?**
   We would also recommend the EC-5 or ECH$_2$O-TE in these applications. Because they have a forked design instead of a blade, they can measure over a much larger range of water contents (all the way up to 100% volumetric water content (VWC).

4. **How does the probe respond to high soil moisture content?**
   The EC-10 and -20 tend to lose some resolution near saturation. However, they should still be able to differentiate between different moisture contents even at these high water contents. The EC-5 or –TE would be a much better option at high VWC because its output does not fall off when soil reaches saturation.

5. **Can the ECH$_2$O probe be used in soils at a depth between 0 - 5 cm?**
   ECH$_2$O probes can be used effectively at shallow depths, but temperature fluctuations are a con-sideration. Inherent in ECH$_2$O measurements, as with TDR and other capacitance probes, is a temperature dependence of 0.003 m 3 m -3 per degree C maximum, with typical of <0.001 m 3 m -3 ° C -1. Obviously, temperature fluctuations near the surface would be an issue in these measurements. We have worked on a method of removing some of the temperature depen-dence, which is available in an application note found here.

6. **What is the effect of temperature variation on ECH$_2$O probe output?**
   Recently, several studies have shown the temperature sensitivity of probes that measure the dielectric constant of soil. It is well known that the dielectric of water changes with tempera-ture, but theories to explain temperature sensitivity of soil dielectric are relatively new. The ECH$_2$O probe has a maximum temperature sensitivity of ~ 0.003 m3 m-3 per °C, similar to other sensors we tested and to data found in the literature. Details of this study can be found on our website at http://www.decagon.com/appnotes/echotempnote.pdf.

7. **Will the ECH$_2$O Probe be damaged by high soil surface temperatures?**
   Soil temperatures up to 60° C should not damage the ECH$_2$O probe. However, it is important

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to consider the temperature dependence of the probe output when determining whether the ECH_2O probe is appropriate for a given installation.

8. **I want to determine the water availability (water potential) of my soil. Are moisture release curves for soil available from Decagon to correlate water content and water potential?**
   Moisture release curves are different and specific for each soil in you are working with, and can be constructed by relating water content with water potential. Decagon offers a service to construct a moisture release curve for your soil (please contact us for details). If you would like to do it on your own, we may be able to help by suggesting methods for constructing a moisture release curve, or you can read our application note showing how to make a moisture release curve using a Decagon WP4 Water Potential Meter at www.decagon.com/appnotes/Soil-Curve.pdf.

Compatibility with other dataloggers and devices

1. **Is the ECH_2O probe compatible with my data logger?**
   As much as we'd like to, we cannot test the ECH_2O probe with every data logger that you could plug it into. The EC-10 and -20 probes require an excitation of 2 to 5V at 3mA for approximately 5 to 10 milliseconds. The EC-5 requires the same amount of excitation and voltage, but needs 10 mA. Although longer excitation times will not change probe output, Decagon does not recommend that the probe be constantly excited. The output of the probe is approximately proportional to the input; about 10 to 40% for 2.5V excitation and about 10 to 35% for 5V excitation. We use a 2.5V excitation for all of our probe calibrations, so excitation voltages other than 2.5V will require separate calibration by the user (Decagon also provides a calibration service at other voltages, contact us for details).

2. **How much resolution does my datalogger need to read the ECH_2O probes?**
   This depends on your preference. ECH_2O probe changes approximately 10 mV per % change in VWC. For a datalogger with 8 bits of resolution and a range of 0 to 2500 mV, you will have a resolution of 10 mV or 1% VWC for your probe output. For loggers with 12 bits of accuracy and the same range, you will resolve greater than 1mV or 0.1% VWC. Not surprisingly, the graphed data from the 12-bit dataloggers appears much more smooth than the 8-bit dataloggers. There are methods to double the resolution of the 8-bit loggers (to 5mV resolution over the ECH_2O range) though use of operation amplifiers. Contact your datalogger supplier for details.

3. **Can the ECH_2O probe be incorporated into a CSI weather station running on a CR10(X) datalogger?**
   The ECH_2O probe will function with all Campbell Scientific dataloggers. It will require one excitation voltage location (for up to 5 probes) and one single-ended input location for each probe. You can also multiplex them (up to 48 on one AM16/32).

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4. **How many ECH_2O probes can be excited by one excitation port on a CSI data logger?**
   Excitation voltage does not appear to be affected by the number of probes wired into the same excitation port. Thus, you should be able to hook up as many wires as will comfortably fit into the input channel. When connecting multiple wires into one excitation port, care must be taken to ensure that all wires are securely fastened into the wire lug.

5. **Will adding extra ECH_2O probes to my data logger's excitation port change the output of the probe?**
   The ECH_2O probes only draw 3 mA of current. Thus, when the data logger is exciting more than one probe, it is very unlikely that the excitation voltage will drop due to current drain.

6. **What will happen if I wire my ECH_2O probes to a data logger backwards?**
   Mis-wiring the ECH_2O probes will not damage the probes, however the output you read will not be correct. According to our tests with Campbell Scientific dataloggers, the output should not change at all. But, some customers have reported changes in ECH_2O readings when it is backwards. Thus if you are not finding probe output from 250 mV to 1000 mV with 2.5 V excitation, check to see if the probes are hooked up properly.

7. **How many probes can I use with a CSI AM16/32 multiplexer?**
   You can multiplex a maximum of 48 probes.

8. **Do you have recommendations for the wiring with the CSI AM16/32 multiplexer?**
   You will find a short application note, including wiring diagram and sample program on our website at http://www.decagon.com/appnotes/am416.pdf. This is not a procedure for the faint of heart. A better way to multiplex is by having the Short Cut generator (from CSI) create the program for you. Details on how to add in ECH_2O probes Short Cut files into your system are located at http://www.decagon.com/appnotes/EchoCSIappnote.pdf, and the program itself is located at http://www.decagon.com/software/EchoCSI.zip.

9. **Do I need special inductor adapter cables for each probe when using the multiplexer?**
   No. You will need standard 3.5 mm adapters that break out into three wires (available from Decagon) for all probes made before 1/06 (check the circular date stamp on the black probe overmolding). Probes made after 1/06 can be plugged into jack adapters or the cables can be cut and wired directly into the datalogger (see users manual).

10. **When are inductors required in the connection between the ECH_2O probe and other dataloggers?**
    As of 1/06, inductors are located on the probe board, so no inductors are needed. When using probes manufactured before 1/06, you should use 3.5 mm adapters that break out into three wires (available from Decagon). These allow you to use the inductor that is contained in the probe cable connector.

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Calibration

1. **Do ECH$_2$O probes need to be calibrated?**
   It depends on how much accuracy you would like from your results and what type of medium you are working in. The accuracy of the EC-10 and -20 probes is ± 3 to 4% in medium to fine-textured soils; but in organic soils, soils with high electrical conductivity (EC), or coarse-textured soils, the accuracy of these probes can decrease significantly. On the other hand, the EC-5 and ECH$_2$O-TE appear, after extensive testing, not to require calibration in any mineral soil, even those with even EC values, with an accuracy of ± 3%. However, we still encourage users to calibrate their probes to become familiar with them before putting them in the field. If you are concerned about accuracy, we offer a calibration service to calibrate your probes for you (please refer to our calibration page) or we recommend you calibrate the probes yourself (you can find details on our recommended calibration procedure on our website at http://www.decagon.com/appnotes/echocal.pdf).

2. **Can the ECH$_2$O probe be calibrated to measure the water content of organic matter and compost?**
   The results of EC-20 calibration in organic matter and peat moss can be found on our website at http://www.decagon.com/appnotes/ecorganic.pdf. Both of these media were consolidated when they were tested. Accurate calibration would be much more difficult if the medium were loose, such as compost.

   ECH$_2$O-TE and EC-5 probes are much better-suited for measuring organic matter and soilless media. So far, in testing rockwool and potting soil, consistent calibration curves were obtained regardless of electrical conductivity. Field tests of the probes have also show excellent response to soil water content changes.

3. **How can I calibrate my ECH$_2$O probes for a medium that Decagon has not tested?**
   We would recommend you take advantage of Decagon's calibration service or follow the calibration procedure described in our application note, located on the web at http://www.decagon.com/appnotes/echocal.pdf

4. **What is wrong with calibrating by adding a known weight of water to a known volume of soil and using the soil weight loss-over-time to correlate probe output with VWC?**
   Although, fundamentally, the evaporative weight loss of a soil should determine the change in VWC, the amount of water lost from the system will not be uniform across the vertical profile of the soil. Thus, even if the overall soil VWC has changed 5%, the actual VWC of the soil nearest the probe may have changed very little. Essentially, it is a problem of different sampling volumes (See Methods of Soil Analysis, Part 4-Physical Methods, J. Dane and G.C. Topp). Because of the likelihood of non-uniform wet-ting and drying, we encourage calibration using the procedure we define in our application note referenced above.

5. **Does the factory calibration that was supplied with my ECH$_2$O probe work for all soils?**
   According to our tests, most fine-textured soils with low ECs have a similar calibration func-

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tion for the EC-10 and -20. However, if you are concerned about the accuracy of your water content measurement, we would encourage you to use Decagon's calibration service or calibrate your probe(s) using our calibration procedure.

6. **Although you show a linear calibration, my results show some nonlinearity at very low and very high water contents. Why?**
   Generally, the ECH_2O probe has a linear calibration. However, as it approaches oven-dry or saturated soil conditions, probe sensitivity changes somewhat. If you are concerned about the ends of the spectrum, we would recommend using a quadratic calibration equation.

7. **Can I calibrate my ECH_2O probe by submerging it to different depths in water?**
   No. A calibration that relates the percentage of water covering the probe and the voltage output of the ECH_2O probe will not give an adequate soil calibration.

Installation and Operation

1. **How do I install the ECH_2O probe?**
   For shallow installations, simply cut a pilot hole in the soil using a shovel or a flat blade that is approximately the width of the probe and insert the ECH_2O probe into the hole. Then insert the shovel or blade a few inches away from the probe and squeeze the soil back toward the probe to improve soil-to-probe contact. For deep installation you can use Decagon's probe installation tool kit. This kit is comprised of a probe-shaped knife blade, slide-hammer, and extension rods to allow deeper installations with minimal soil disturbance.

2. **How "good" does the contact with the soil need to be? For instance: would the ECH_2O probe function if it is in partial contact with the soil, like a coarse gravel material, where there might be small air voids between the instrument and the soil?**
   Because the ECH_2O probe is most sensitive at the surface, even small air gaps that are not reflective of the overall soil water content would cause problems with the measurement. In this type of application, we would recommend that you obtain a loaner ECH_2O probe from Decagon (when available) to determine if it could be calibrated for your particular setup.

3. **I want to measure water content at several locations by inserting an ECH_2O probe into the ground, taking a reading, and removing it. Will it work?**
   The ECH_2O probes are designed to be installed in the ground and left in place for long term monitoring. Inserting the probes in the ground and taking a reading will give a value of water content at that location, but because water content varies considerably over small areas, changes in water content may be difficult to distinguish using this method. In addition, additional variability in probe water content readings could occur because of variable soil-to-probe contact.

4. **After installing the ECH_2O probes, I see some variability between readings, even though they are all buried at the same depth. Why?**
   Soil water content is inherently variable. Studies have shown soil water content to vary as

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much as ± 3% over a small area. Therefore, installing water content sensors in close proximity to each other does not guarantee that they will read the same value. Installation mistakes can also lead to difference in reading. Soil-to-probe contact is critical for accurate results. Therefore, during installation, you should make sure that the probe surfaces are snug against the soil surface. If a probe does not appear to be reading right, we recommend that you reinstall it in the soil.

5. **I cannot fit the entire probe into my plant pot. Can I just use a portion of the probe to measurewater content?**
   For potted plants, we recommendusing a smaller probe like the ECH$_2$O-TE or EC-5; they were designed to fit in small pots.

6. **What is the longest you'd recommend for a cable length from a datalogger to an ECH$_2$O sensor?**
   In our tests, we have successfully connected up to 5 of the 50 ft. (15.5m) extension cables sold by Decagon for a total length of 250 ft. (78m) with acceptable results. The issue with the length of the cable is most likely resistance. The longer the cable, the more resistance in the wire, which leads to a small signal loss (we saw a 14 mV loss under maximum load over 250 ft). If you decide to add your own cable, it must have a braid shield (or foil) connected to the probe ground to protect it from external noise. We do not recommend that you use single cable with multiple strands to wire several sensors to the datalogger. Each set of excitation and output should be surrounded by the ground shield.

7. **If I use 50 ft. (15.5m) extension cables from Decagon, how can I seal the 3.5mm connectors from moisture?**
   Sealing connections in the field is inherently difficult. Some researchers have successfully used sections of ¾ inch PVC pipe cut in half, filled with plumber's silicone, and clamped over the top of the connector. Our experience with heat shrink (even epoxy lined), has shown to be unreliable in some circumstances. Another good option is to purchase a length of raw cable from Decagon and splice it into the middle of the cable to increase the length. Decagon offers splice kits that create reliable and waterproof connection.

8. **Why does my probe read outside the 250 to 1000 mV range that Decagon states for probe output?**
   If an ECH$_2$O probe reads below 200 mV or above 1000 mV, there is a good chance that it is defective, assuming the probe is wired and operated correctly. If you have another ECH$_2$O probe, try plugging that probe into the readout device to ensure that the connector and readout device are functioning properly. If there is a problem with the probe, contact Decagon for a replacement.

9. **Why doesn't my EC-10 or -20 probe measure 100% when submerged in water?**
   For the EC-10 and EC-20, the optimal measurement range in soil is from oven dry to saturated water content, which is typically 40 to 50%. Above saturation, the change in probe output with increasing water content is near 0. The ECH$_2$O probe uses an electromagnetic (EM) field

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to sense the dielectric of the surrounding medium. As water content increases, the width of that EM field diminishes somewhat. As it approaches 100% VWC (water with no soil), the EM field diminishes to a fraction of its original size, and primarily senses the probe surface itself. Therefore, changes in water content above that level result in relatively the same millivolt output from the EC-10 and EC-20 probe. However, our tests on the EC-5 and ECH_2O-TE probe indicate that their response allows for measurements up to 90% VWC.

10. **I used a 5.0V excitation for the ECH_2O sensor and the output was 10% of the excitation in air and 34% submerged in water. The results at the wet end seemed to differ from the manual's specs (40%). Why?**
    The proportion of the output voltage to excitation voltage varies with the excitation voltage. An excitation of 5V diminishes the full-scale percentage of the ECH_2O output by a small amount (35% compared to 40%).

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