CaTeC

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INSIDE
NEW PRODUCTS FOR 2010–2011

RESEARCH BRIEFS
CURRENT SOIL, PLANT, AND WATER RESEARCH FROM AROUND THE WORLD

DECAGON EDUCATIONAL INITIATIVES AND RESEARCH GRANTS

G. A. Harris Fellowship

▲ Instrumenting canopy soil over 19 m off the ground.

Camila Tejo Haristoy is one of six 2010 winners of the G.A. Harris Fellowship. The fellowship provides $30,000 worth of instruments to graduate students in environmental and geotechnical fields. This year's competition focused on innovative soil and plant monitoring. Haristoy is studying canopy soil in Pacific Northwest Sitka Spruce.

For more information about the G.A. Harris Fellowship, visit decagon.com and choose "G.A.Harris Fellowship" on the "About Us" page (decagon.com/about-us/ga-harris-fellowship).

Research Briefs

Leaf Wetness Sensor—Quantifies the amount of fog available for use by the living fossil *Welwitschia Mirabilis*.
Page 9

Case Study: Complex Hydrology—Can it be hassle free?
Page 20 & 21

Sample Disturbance —A problem when measuring water potential?
Page 29

Porometer Research for Everyone

GET HIGH QUALITY DATA WITHOUT FANS, TUBES, OR PUMPS.

BREAKTHROUGH steady state technology (see details at right) makes accurate stomatal conductance measurements affordable and practical for everyday research. Detail water use, indicate water stress and compare physiological varieties. Add stomatal conductance data to any canopy study with this elegantly designed Leaf Porometer.

Applications

- Water Stress Measurements
- Variety Testing & Comparison
- Fundamental Research on Stomatal Function
- Teaching and Student Labs

Benefits

- Automatic sampling mode eliminates user subjectivity.
- Accurate Steady-State measurement.
- No tubes, pumps, or fans.

Leaf Porometer Specifications

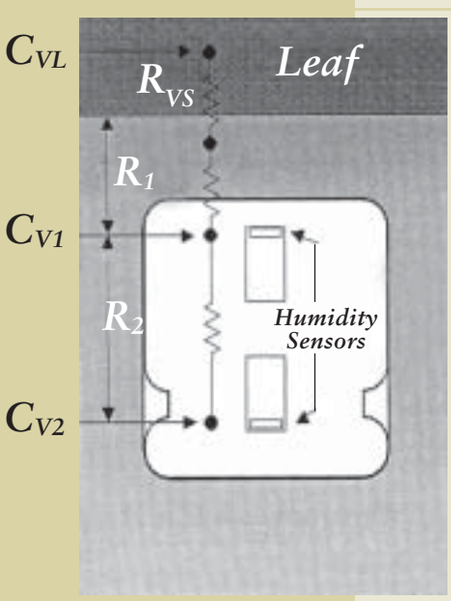
Conductance range
0 to 1000 mmol m^{-2} s^{-1}
Accuracy ± 10%
Operating Environment
5 to 40ºC, 10 to 90% RH, non-condensing
Units mmol $m^{-2}s^{-1}$, m^2s mol^{-1}, s/m
Measurement diameter 6.3 mm
Sensor head cable length 1.2 m (4 ft.)
Measurement time in Auto mode 30 s

See the extended specifications for the leaf porometer at www.decagon.com

Watch a 3 minute video introducing the Porometer at **www.decagon.com/education/video-index/**

Decagon's Steady State porometer measures stomatal conductance using a sensor head with a fixed diffusion path to the leaf. It measures the vapor concentration at two different locations in the diffusion path. It computes vapor flux from the vapor concentration measurements and the known conductance of the diffusion path using the following equation:

$$\frac{C_{vL}-C_{v1}}{R_{vs}+R_1}=\frac{C_{v1}-C_{v2}}{R_2}$$



Schematic illustrating how the porometer measures stomatal conductance.

Where C_{vL} is the vapor concentration at the leaf, C_{v1} and C_{v2} are the concentrations at the two sensor locations, R_s is the stomatal resistance, R_{v1} is the resistance between the leaf and the first sensor, and R_2 is the resistance between the two sensors. If the temperatures of the two sensors are the same, vapor concentration can be replaced with relative humidity, giving

$$R_{vs} = \frac{1-h_1}{h_2-h_1}R_2 - R_1$$

Conductance is the reciprocal of resistance, so $C_{vs} = 1/R_{vs}$. ■

Canopy Measurements PAR / LAI

Photosynthetically Active Radiation & Leaf Area Index

MEASURE BOTH PAR AND LAI WITH ONE LIGHTWEIGHT, STREAMLINED WAND

USE PAR DATA to estimate biomass production without destroying the crop (see details at right). Measure photosynthetically active radiation (PAR) and get leaf area index (LAI) values simultaneously in real time. Store approximately 9000 data points manually by pressing a button or automatically in unattended sampling mode.

AccuPAR LP-80 SPECIFICATIONS

Operating environment
0° to 50°C (32°-122°F),
0 to 100% relative humidity
Probe length 86.5 cm
Number of sensors 80
Overall length 102 cm (40.25 in)
Microcontroller dimensions
15.8 x 9.5 x 3.3 cm (6.2 x 3.75 x 1.3 in)
PAR range 0 to >2,500 µmol $m^{-2}s^{-1}$
Resolution 1 µmol $m^{-2}s^{-1}$
Minimum spatial resolution 1 cm
Data storage capacity 1MB RAM, 9000 readings
Unattended logging interval
User selectable, between 1 and 60 minutes
Instrument weight 1.22 kg (2.7 lbs)
Data retrieval Direct via RS-232 cable
Power 4, AA Alkaline cells
External PAR sensor connector
Locking 3-pin circular connector (2 m cable)
Extension cable option 7.6 m (25 ft)

INCLUDED ACCESSORIES

■ **EXTERNAL PAR SENSOR**
2 meter cable with connector for direct connection to the ceptometer's external port. Calibrated to provide an output of about 0.1 mV per µmol m^{-2} s^{-1} (calibration label provided).

■ **RS-232 CABLE—** for interfacing between your computer and the AccuPAR.

■ **CARRYING CASE**
Polyethylene hardened case with custom foam cutouts allow the instrument and its accessories to be safely stored inside.
3.6 kg, 11.8 x 24 x 109 cm.

Watch a 5 minute video on measuring PAR and LAI with the AccuPAR LP-80 at **www.decagon.com/education/video-index/**

The detailed processes in photosynthesis are complicated and hard to model. In many cases, however, it's possible to simplify the model by focusing on one or more of the limitations to assimilation.

Limited by Light, Limited by Water: Two Separate Approaches

We could postulate situations where light would be the limiting factor in assimilation, and others where water would be the limiting factor. Our models, in words, might be: assimilation is proportional to the plant's ability to capture light, or assimilation is proportional to the plant's ability to capture water. Both approaches can be useful in modeling biomass production.

Knowing Which Model to Use

The most efficient way to determine whether light or water is the limiting factor is to simply run both mathematical models daily to see which one predicts the lowest value. That value is the best predictor of dry matter production for the particular day on which it is run. The 2009 Decagon Canopy News feature article, Simple Models for Carbon Assimilation by Plants, describes the math involved and climatic data needed to run these two alternative predictors of dry matter accumulation and shows how to use them together to give the most accurate result. ■

To learn more about the relationship between light interception and biomass production, visit **www.decagon.com/canopynews2009**

Ready-to-Use Leaf Wetness Sensor

DETECT LEAF WETNESS DURATION WITH A SENSITIVE, CALIBRATED, STANDARDIZED SENSOR

Many diseases affect plants only when moisture is present on the leaf surface. The Dielectric Leaf Wetness Sensor determines the presence and duration of wetness on a leaf's surface, enabling researchers and growers to forecast disease and protect plant canopies. The Leaf Wetness Sensor approximates the thermal mass and radiative properties of leaves to closely mimic the wetness state of a real leaf. Because the sensor does not take resistance-based measurements, it requires no painting or user calibration, and it can detect ice formation as well.

Leaf Wetness Sensor Specifications

Measurement time 10 ms

Power 2.5 VDC @ 10 mA to 5 VDC @ 7 mA

Output 250 to 1500 mV

Operating Environment -20 to 60°C

Expected Lifetime

2+ years continuous use

Probe Dimensions

11.2 x 5.8 x 0.075 cm (4.4 x 2.3 x 0.029 in)

Cable Length

5 m standard, extension cables available

Connector type 3.5 mm plug

Datalogger Compatibility *(not exclusive)*

Decagon Em50, Em50R, Em50G

Campbell Scientific CR10, 10X, 21X, 23X, 1000, 3000, 5000

Applications

- Disease forecasting and modeling
- Ecological and Agricultural Research

Precipitation is usually assumed to be the primary input in a water balance. The Namib desert is hyper-arid in terms of rainfall, but experiences frequent coastal fog events, an environment that falls outside the realm of standard water balance model assumptions. The fog has been suggested to provide sufficient water to many of the endemic Namib plants up to approximately 60 kilometers inland. Quantifying fog contributions to the water balance is difficult.

Keir Soderberg, second place winner of the 2009 G.A. Harris Research Instruments Fellowship.

Leaf Wetness Sensor Quantifies Fog

Kier Soderberg, a PhD candidate at the University of Virginia, coupled the leaf wetness sensor with other environmental parameters to help quantify the amount of fog that the Namib plants such as *Welwitschia mirabilis* are able to utilize.

Welwitschia mirabilis, which has a lifespan of 400 to 1500 years, uses water from fog in order to survive.

Measure Other Unusual Variables

Do you have variables in your water balance that you are struggling to quantify? Innovative research sometimes requires innovative sensor solutions. Contact Decagon's application support specialists to help brainstorm ideas for your specific project. ■

See all the winners of the 2009 G.A. Harris Research Instruments Fellowship and download the 2010 application at **www.decagon.com/about-us/**

Complete Soil Moisture Analysis

Tools to measure, collect, and analyze your data.

Data Management

DataTrac 3 is a completely redesigned software package that helps you view and effectively manage your data.

DataTrac 3 does the heavy lifting—pulling the logger data, amending files, tracking nodes, graphing sets—so you can see what's going on with your study at any point without interrupting the data stream. Check in daily or weekly to add notes and make observations.

Soil Moisture and Environmental Sensors

ECH$_2$O soil moisture sensors deliver:

- Research Grade Accuracy— ±3 VWC in typical soils, can be calibrated for improved performance.
- Reliable Data—patented technology eliminates interference from salinity and texture differences.
- Practicality—low power, low-cost sensors allow you to characterize spatial variability more completely.
- Complete the system with environmental sensors for context to show why soil water content is changing.

Data Acquisition Systems

The Em50 series of loggers make data collection easy, whether you're installing a single station or a large, multi-station site.
All Em50 loggers are:

- Pre-programmed—plug the sensors in and start logging. No user programming required.
- Weatherproof—no extra enclosure needed.
- Internally powered—runs 6 months-2 years on enclosed AA batteries. No external power needed.
- Wireless options let you collect data from almost anywhere.

► **DataTrac 3—SOFTWARE**
DataTrac 3 graphical and database software organizes, graphs, and stores data from Em50 series or Em5b data loggers. Users can view and edit data in table format, create reports, and transfer data to other DataTrac 3 users.

Minimum System Requirements
Microsoft Windows XP or newer
Monitor set to display 1024 x 768 pixels (minimum)

DataTrac 3

ORGANIZE AND ANALYZE
YOUR SOIL MOISTURE DATA

Imagine having an assistant that brings you data, general trends, and specific problems from all of your research sites at the start of every day. DataTrac 3 is that assistant—a completely redesigned software package that lets you view and manage your data.

When DataTrac 3 is started, all of your most recent data downloads will be updated and graphed allowing you to see changes in real time. Instead of looking back at the data and wondering what happened, you can add event-related comments.

Just a few new features:

- Logger tree let you organize your data logger nodes during set-up.
- Annotate your notes on current thinking or relevant environmental conditions.
- Growing Tools let you create meaningful metrics such as vapor pressure deficit and growing degree days.

Contact Decagon for a free 30 day trial.

Research-Grade Soil Moisture Sensors

All sensor electrical interface: 3.5 mm plug or 3-wire.

MODEL	LENGTH	MEASUREMENT	RANGE	ACCURACY	BENEFITS
 **EC-5**	5 cm	Volumetric water content	0–100% VWC	± 3% VWC, typical mineral soils up to 8 dS/m Rockwool ± 3% VWC, 0.5 to 8 dS/m Potting Soil ± 3% VWC, 3 to 14 dS/m	Lowest cost for large sensor networks.
 **10HS**	10 cm	Dielectric permittivity, Volumetric water content	Apparent dielectric permittivity (ε_a): 1 (air) to 50, 0–57% VWC	(ε_a): ± 0.5 from ε_a of 2 to 10 ± 2.5 from ε_a of 10 to 50 ± 3% VWC, typical mineral soils up to 8 dS/m	Largest volume of influence decreases effects of heterogeneity.
 **5TM**	5 cm	Volumetric water content, Temperature, Dielectric Permittivity	Apparent dielectric permittivity (ε_a): 1 (air) to 80, 0–100% VWC Temperature -40 to 50 ºC	(ε_a): ± 1 ε_a (unitless) from 1–40 (soil range) ± 15% from 40–80 ± 3% VWC, typical mineral soils up to 8 dS/m Temperature ± 1 ºC	Include temperature dependencies in your study.
 **5TE**	5 cm	Volumetric water content, Temperature, Electrical conductivity, Dielectric Permittivity	Apparent dielectric permittivity (ε_a): 1 (air) to 80, 0–100% VWC Temperature -40 to 50 ºC EC 0 to 23 dS/m (bulk)	(ε_a): ± 1 ε_a (unitless) from 1–40 (soil range) ± 15% from 40–80 ± 3% VWC, typical mineral soils up to 8 dS/m Bulk EC ± 10% Temperature ± 1 ºC	Manage salts and fertilizers in your system.
 **MPS-1**	5 cm	Soil matric potential	-10 to -500 kPa	± 40% of reading from -10 to -50 kPa ± 20% of reading from -50 to -500 kPa	Maintenance-free water potential measurements that do not drift over time.

Above Ground Sensors

The Decagon system also allows you to characterize the environment above the soil surface. The sensors below can be used with the Em50 series data loggers and software to provide data on a variety of environmental variables.

The **Leaf Wetness Sensor** measures duration of leaf wetness and requires no painting or calibration and detects trace amounts of water or ice on the sensor surface.
Operating Environment -20 to 60° C

TEMP/RH Durable sensor measures relative humidity and temperature and outputs both values as a digital signal.

Probe RH Range 0 to 100% RH
RH Accuracy
±2% from 10–90% RH
±3% from 0–10% RH and 90–100% RH
Temperature Range -40 to 60 ° C

The **ECRN-100 Precipitation Sensor** is best for research applications and measuring rainfall.
Resolution 0.2 mm
Dimensions 17 cm x 14.2 cm

The **Pyranometer Model PYR** and the **PAR Photon Flux Sensor** are completely water proof, submersible and designed for continuous outdoor use. A leveling plate is included.

Cable length 1m
Range 0 to 2000 µmol / m^2 s (PAR)
Range 0 to 1750 W m^{-2} (PYR)
Dimensions 24mm diameter, 29 mm deep.
Accuracy ±5%

The **ECRN-50 Precipitation Sensor** is best for measuring irrigation events.
Resolution 1 mm
Dimensions 5 cm x 10 cm

SOIL TEMPERATURE SENSOR
model ECT
Range -40 to 60° C
Accuracy ±0.25° C

Cup Anemometer
The anemometer measures both wind speed (using windcups and a magnetic switch) and wind direction (with windvane and potentiometer). Includes sealed stainless-steelbearings for long life. The range and accuracy specifications of this unit have been verified in wind-tunnel tests (information available upon request). For use only with our Em50 or Em50R Data logger using ECH2O Utility.

Watch a 5 minute video showing the factory calibration process at **www.decagon.com/education/video-index/**

Spend more time with your data...

The Em50 series of data loggers are designed for researchers who just want quality data. You install the sensors, plug them into the logger, set the clock and measurement intervals, and start logging data. The Em50's primary advantage is simply this:

NO PROGRAMMING.

MEASUREMENT NODES—Em50 Logger

Channels 5.
Storage >36,000 scans - Each scan includes logger name, date, time, and 5 measurements.
Scan Interval User-programmable from 1/minute to 1/day. (minimum Em50G scan interval every 5 minutes).
Communication Serial RS232, USB, radio, cellular.
Power 5, AA alkaline batteries.
Dimensions 12.7 x 20.3 x 5.1 cm (5 x 8 x 2 in)
Enclosure Rating IP55, NEMA3.
Download software included with Em50 purchase.

CONTINUOUS MONITORING

◄ Em50 is a highly weather resistant logger for all Decagon sensors.

We recommend and support use of Campbell Scientific loggers with our sensors for applications requiring programming and/or control.

NO PROGRAMMING

Em50 Series Logger Options

1 Basic Data Logging

The standard Em50 data logger is the least expensive and has the longest battery life of all the Em50 series loggers. It requires a direct connection to a laptop or other computing device to download data. The Em50 option is best if:

- You don't need to access your data on a regular basis.
- Your site is so remote that you need the data logger batteries to last for over two years.

2 Long Distance Data Delivery

The Em50G remote data logger uses the cellular network to upload your data from the field to the internet. You can access the data at any time from any location that has an internet connection. The cellular modem is fully integrated with the logger making setup a snap. The logger comes ready to go right out of the box with a one-year pre-paid SIM card and subscription to the Decagon Data Service. Just plug in your sensors, set your measurement interval, and you're done. Your data will be waiting for you back at the office. The Em50G is the best option if:

- Your research sites have cell service.
- You want regular access to your data but can't visit your site to get it.

3 Local Data Connection

The Em50R wireless data logger uses long range 900 MHz* radio communication to send your data to a central data receiving location. No existing wireless infrastructure is necessary. The Em50R collects data at a single location and delivers data over short distances (2 to 5 miles). The Em50R is the best option if:

- You don't have cell coverage at your field site.
- You want to collect data from all your loggers at a central location.

**2.4 GHz radios available for global customers.*

Your Data, Delivered

Get your data in seconds on any computer with an internet connection.

You don't need a mobile phone, a solar panel, nor even a conversation with your local cell service provider to make this work.

Measure, log, and remotely transmit data from five Decagon sensors at up to 5 minute intervals.
You pick the times during the day when Em50G logger data is automatically sent to the Decagon Data Service via the integrated cellular module. Once uploaded, you have 24/7 access over the internet to your data stored on the Decagon Data Service. No logger programming or expert knowledge of cellular networks are necessary. Automatically download data to DataTrac or create Excel files on demand.

Share your data or not.
Sharing you data with trusted colleagues is as easy as sharing your subscription information.

- No-hassle cellular service included in the the box. First year service is pre-paid.
- Em50G can be used in 120 countries with more than 200 partner networks providing GSM/GPRS cellular services.
- Decagon Data Service (included with every Em50G) provides 24/7 access to data from anywhere you have cellular service.
- Data is confidential, encrypted, and password protected. Downloads from the Decagon Data Service are encrypted using the same security a your online bank account.
- Em50G provides go/no go cellular signal testing. Full cellular and data transfer testing available with included software.
- Em50G powers the sensors and the integrated cellular module on 5 AA batteries; no external power source needed.

Em50G Specifications

Input ports 5, 12-bit analog or 32-bit digital, compatible with any Decagon Devices sensor.

Data storage 1MB (36,800 scans on all 5 ports).

Memory type Non-volatile Flash

Logging interval 5 minutes to 24 hours, logged data is 1-minute average of user-specified interval.

Upload interval 1 to 6 times per day at user-specified times.

Operating environment
-30°C to 60°C, up to 100% RH

Battery service life 6+ months

External power None needed

Enclosure
Weatherproof, impact and UV-resistant polymer.

Enclosure dimensions
12.7 x 20.3 x 5.1 cm (5 x 8 x 2 in)

Enclosure access
Hinged door with eyelet for securing with user-supplied padlock.

Mounting 3.8 cm (1.5 inch) mast or wall mount

Local communication Dedicated serial port 3.5mm stereo jack for use with the Decagon Serial Cable Adapter (SCA) or Decagon USB Cable Adaptor (UCA)

Decagon Data Service
(included with every Em50G)

Data plan Annual subscription provided by Decagon Devices with over 200 GSM/GPRS partner networks in 120 countries.

Server location Decagon Network Operations Center, Pullman WA USA

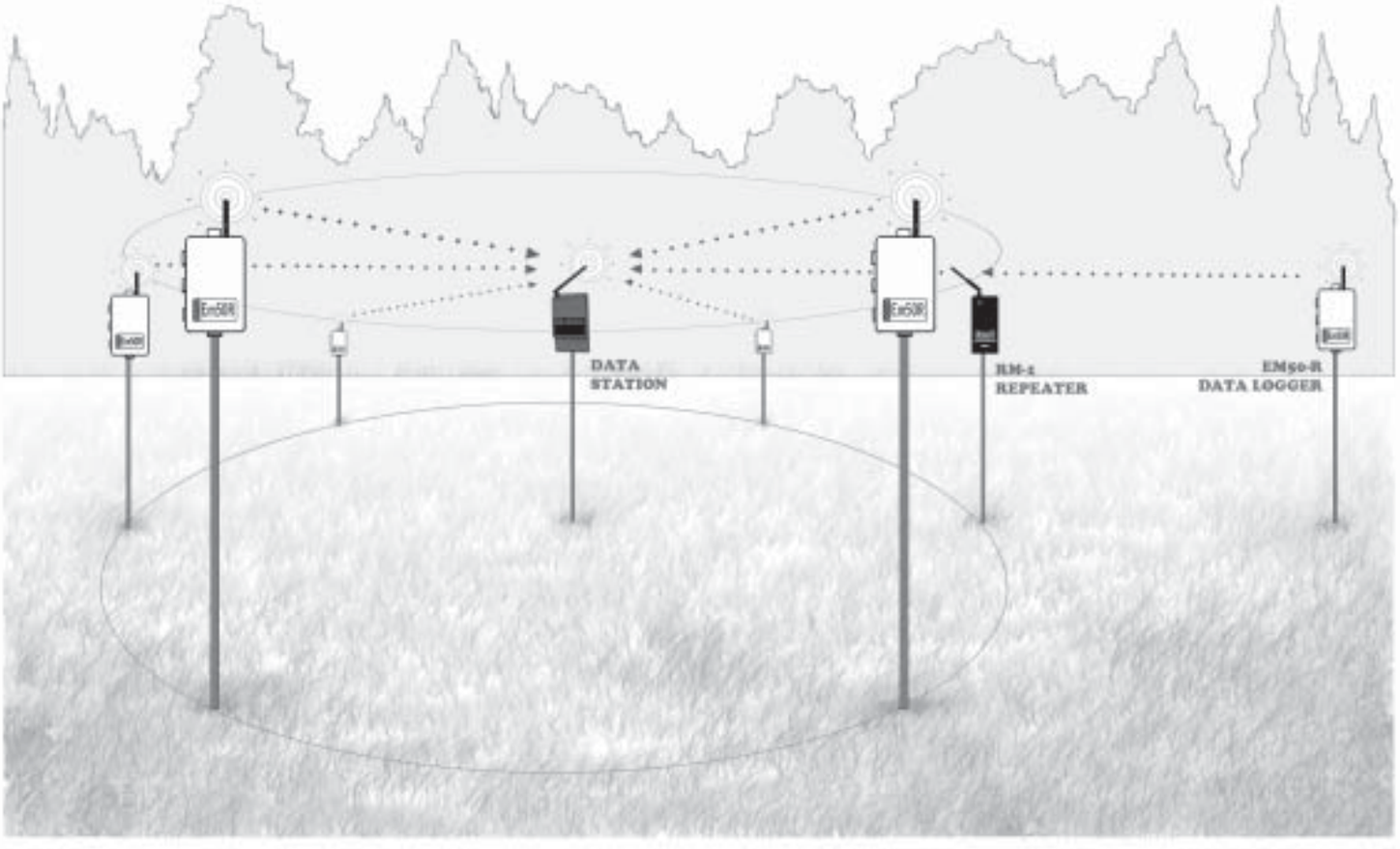
Data security SSL/TLS encrypted data transfer; a unique Device ID and password (provided with each logger) are necessary for accessing data from the server.

Cellular Frequency Quad-band (850/900/1800/1900 MHz) GSM/GPRS for use worldwide.

Software
ECHO Utility Software and DataTrac Software Demo

Transmit Data Locally

COLLECT DATA WIRELESSLY AT A SINGLE POINT



▲ Multiple Em50R loggers collect data then transmit to a nearby office (2 to 5 mile range).

The Em50R wireless data logger transmits data to a central receiving location using 900 MHz* radio communication. No existing wireless infrastructure is necessary. Multiple Em50R loggers are often used to collect data from many locations, which are then transmitted to a nearby office (2 to 5 mile range)

Benefits

- Long-range wireless radio allows large spatial monitoring.
- No need to visit each site after initial installation.
- No programming—only simple configuration.

Em50R Logger—MEASUREMENT NODES

Channels 5.
Storage >36,000 scans - Each scan includes logger name, date, time, and 5 measurements
Scan Interval User-programmable from 1/minute to 1/day
Communication 900 MHz radio*
Power 5, AA alkaline batteries
Battery service life 6+ months
Dimensions 12.7 x 20.3 x 5.1 cm (5 x 8 x 2 in)
**2.4 GHz radios available for global customers.*

◄ DataStation—BASE STATION

The DataStation radio base station collects and stores data from multiple Em50R data loggers.

18.4cm L x 10.5cm W x 2.86cm H (7.25”L x 4.125”W x 1.125”H)

- “Confirm Data Delivery” protocol allows complete and reliable data transfer.
- RS232 serial cable connectivity.
- Storage for over 28,000 broadcast packets.
- Flexible 12–24 V AC/DC power.
- Telemetry testing for connection quality analysis during set-up.
- Enclosures and solar panels for remote installs.

Accessories for multi-site installation.

Save your laptop by investing in an Archer Field PC. Laptops are great, but they require two hands and aren't built to be submersed, dropped, and driven around on dusty roads. Archer is built for frequent field trips, and it will last long after it has become worth the investment.

Archer Field PC
The ultra-rugged Archer Field PC is our recommended platform for managing data in-the-field. The Archer is water-proof, shock-resisitant, and remarkably versatile. The Archer is capable of a wide range of adaptations, including:

- Capture, map, or navigate using GPS options.
- Communicate wirelessly via Bluetooth, Wi-Fi.
- See your screen in the sun.
- 10+ hour battery life.
- Windows Mobile 6.1 operating system.
- Comes with ECH$_2$O Utility Mobile.

ECH$_2$O Utility software

Free software included with every Em50 Series and Em5b data logger. Configure sensors, change measurement intervals, monitor battery life and memory levels.

Em5b Logger
For EC-5, EC-10, EC-20, ECRN-50, ECT, & 10HS
Storage 3,300 scans, 1/minute to 1/day
Communication RS232
Power 4, AAA alkaline batteries, battery life 3+ yrs
Dimensions 8.7 x 6.2 x 3.5 cm (3.75 x 2.75 x 1.25 in)

Download software included with Em5b purchase.

▲ The Em5b has 5 channels that allow scientists on a tight budget to monitor soil moisture and other environmental parameters

◄ The ProCheck instantaneously displays calibrated or raw readings of any Decagon soil moisture or environmental sensor.

Use the instant-read ProCheck to test individual sensors for good installation.

ProCheck
For all Decagon sensors.
Channels 1
Storage 5,000 readings. Each reading includes sensor type, date, time, raw value, calibrated value and calibration coefficients.
Communication Serial RS232.
Power 4, AA alkaline batteries
Dimensions 15.5 x 9.5 x 3.5 cm (6 x 3.7 x 1.4 in)

CAPABILITIES
- Instantaneously read and store data from any Decagon sensor.
- Troubleshoot field measurements.
- Address sensors being used in SDI-12 mode.

CASE STUDY: COMPLEX HYDROLOGY ON THE PALOUSE

At Cook Farm, Decagon scientists and Washington State University researchers are calibrating, refining and testing an existing hydrologic model for the Palouse.

▲ **SOIL MOISTURE SYSTEM WITH TEMPERATURE / EC OPTION**
Each node has 5 soil moisture sensors monitoring the soil profile at one foot vertical intervals—the shallowest is a foot below the surface; the deepest five feet down. The sensors measure volumetric water content, soil temperature, and Electrical Conductivity. The Em50R logger stores the data internally and transmits it to the DataStation.

See sensors specifications on page 12.

"We have soil moisture sensors buried at the same depths all over the farm, but the volumetric water content readings can be different from location to location. Sometimes they seem almost random. When I flew over the farm this summer, suddenly I could see those variations in living color. Patterns of wheat senescence showed exactly what the sensors had been telling us—golden wheat in the dry areas, greener wheat in the valleys and every variation in between."

42
wireless logger nodes

200+
soil moisture sensors

Watch a 5 minute video of a Soil Moisture System installation at **www.decagon.com/education/video-index/**

"Hassle Free" Telemetry

▲ **DATASTATION INTEGRATED WITH AN EXISTING METEOROLOGICAL TOWER** The station gathers soil moisture, temperature, and EC data from all 42 loggers hourly.

See DataStation specifications on page 18.

YOU CAN SEE SIGNAL STRENGTH AND CONNECTION SPEED IN REAL-TIME AS YOU PICK THE BEST SPOT FOR A DATA LOGGER NODE SITE. IT'S SIMPLE. TEST FIRST AND INSTALL SECOND.

Watershed Characterization Package

The elements of this bundle were chosen to help you nail two tough components of the water balance: storage and deep percolation.

■ The drain gauge's elegant design ensures that water will flow through and not around it, giving you accurate deep percolation rate.

■ High accuracy water content sensors let you calculate storage from differences in profile water content.

■ Adding on a rain gauge gives you the downward "vertical water profile"—incoming, storage, and drainage.

Close Your Water Balance

WITH PRECIPITATION, SOIL STORAGE, AND DEEP DRAINAGE

- Get closer to **completing the water balance.**

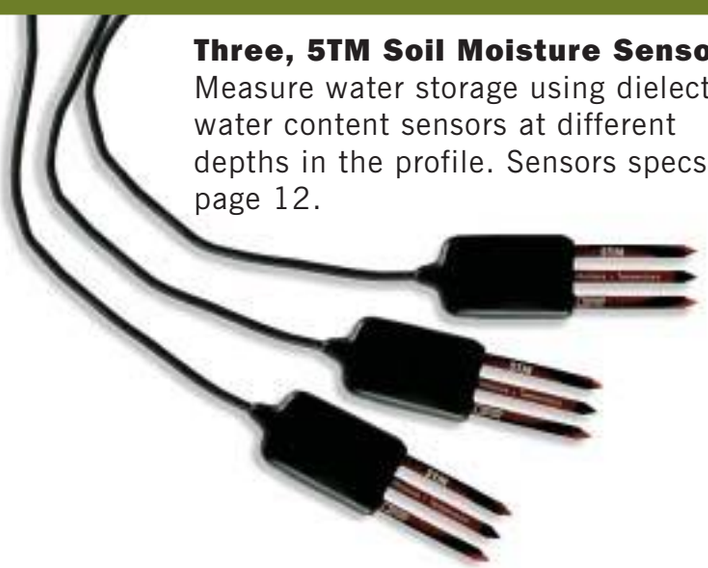
- Collect the data you need to calculate water input, storage, and drainage in the vadose zone.

- **Measure deep drainage** rather than estimating to reduce errors in water balance calculation

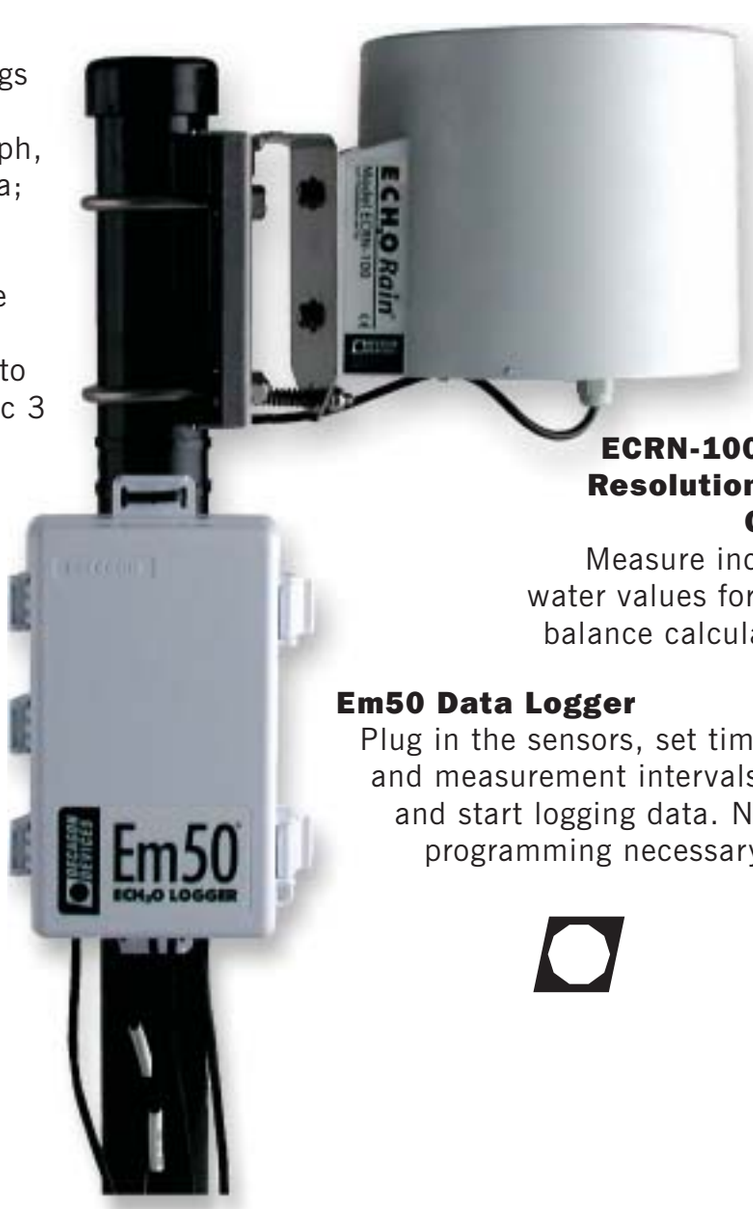
IN THE BOX
Standard Configuration #40525
Water Balance System
Drain Gauge G3
Three, 5TM Soil Moisture Sensors
ECRN-100 High Resolution Rain Gauge
Em50 Data Logger
DataTrac 3 Software
USB Cable
Batteries
Mounting hardware
Printed and electronic documentation
Contact Decagon to add telemetry options.

Drain Gauge G3
Measure deep drainage with this thoughtfully designed passive capillary lysimeter.
Drain Gauge G3 specs on page 37.

Three, 5TM Soil Moisture Sensors
Measure water storage using dielectric water content sensors at different depths in the profile. Sensors specs on page 12.



DataTrac 3 Software
Dynamic graphical interface brings data to life. Organize, graph, and store data; view and edit data in table format; create reports and transfer data to other DataTrac 3 users.



ECRN-100 High Resolution Rain Gauge
Measure incoming water values for water balance calculations.

Em50 Data Logger
Plug in the sensors, set time and measurement intervals, and start logging data. No programming necessary.

Irrigation Monitoring Package

The elements of this bundle were chosen specifically for you to see both how much water is in the soil and how much of that water is available to plants.

■ A matric potential sensor measures plant available water so you know when to turn irrigation on.

■ Soil moisture sensors let you know when you've reached field capacity and should turn irrigation off.

■ A pressure switch monitors pipes to make sure irrigation is happening as scheduled.

■ DataTrac lets you watch the interaction of all the sensors graphically.

▸ Know when to turn irrigation on.

Soil moisture sensors only measure volumetric water content. Use the matric potential sensor to monitor plant available water.

▸ Know when to turn irrigation off.

Fast-response soil moisture sensors let you track plant water use in real time and set an accurate *full* point that minimizes wasted water.

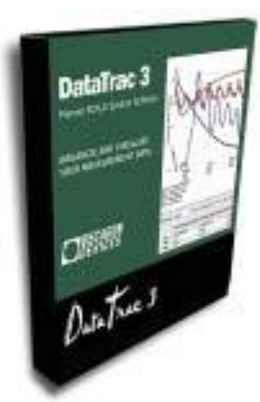
IN THE BOX
Standard Configuration #40523
Soil Moisture/Irrigation System
Two, 5TE Soil Moisture Sensors
MPS-1 Matric Potential Sensor
Pressure on/off switch
ECRN-100 Precipitation Sensor
Em50 Data Logger
DataTrac 3 Software
USB Cable
Batteries
Mounting hardware
Printed and electronic documentation
Contact Decagon to add telemetry options.

See sensor specs on pages 12 and 13.

Settling For 1 Water Parameter?

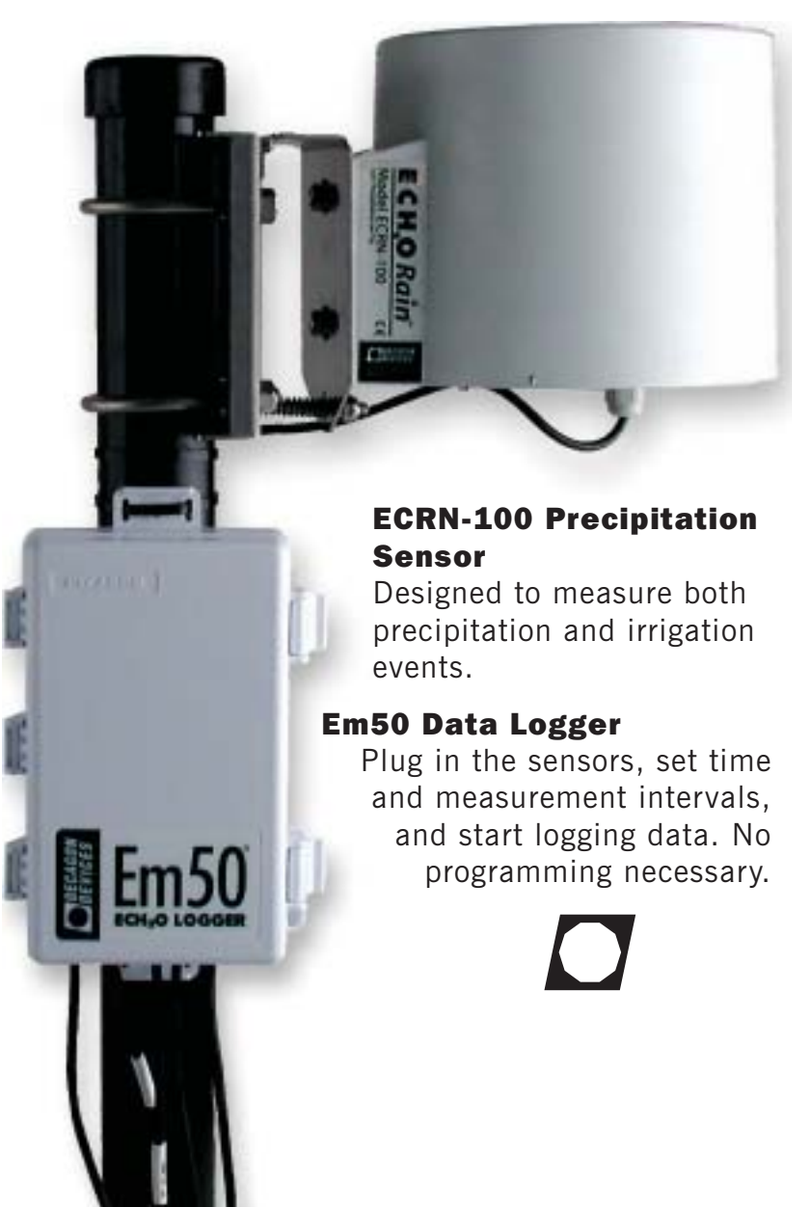
KNOW WHEN TO TURN IT ON
AND WHEN TO TURN IT OFF

Pressure On/Off Switch
Tracks irrigation events by recording when water is turned on and off.



DataTrac 3 Software
Dynamic graphical interface brings data to life. Organize, graph, and store data; view data in table format; create reports and transfer data to other DataTrac 3 users.

MPS-1 Matric Potential Sensor
This sensor goes beyond just water content to describe water availability. Measures 0 to -500 kPa.



ECRN-100 Precipitation Sensor
Designed to measure both precipitation and irrigation events.

Em50 Data Logger
Plug in the sensors, set time and measurement intervals, and start logging data. No programming necessary.

Two, 5TE Moisture Sensors
Soil moisture sensors located within and below the root zone track water content through the profile.

Essential Water Potential Data

MAKE FAST, ACCURATE WATER POTENTIAL MEASUREMENTS IN THE LAB

Measure the water potential of soil, soilless substrate, plant tissue, or any porous material in 5 to 10 minutes. Effective range: -0.1 to -300 MPa.*

The WP4C measures water potential by determining the relative humidity of the air above a sample in a closed chamber (an AOAC-approved method, conforms to ASTM 6836).

**Note: WP4C will read to 0 MPa, but readings of samples wetter than -0.1 MPa will have an increasing, and typically unacceptable, percentage of error. Some users may be able to make useful measurements in samples wetter than -0.1 MPa using special techniques. For more information, see the WP4C User Manual.*

WP4C SPECIFICATIONS

Operating Environment
5 to 43°C (41 to 110°F)
Temperature Control
15° to 40°C ± 0.2 °C
Sensors 1. Infrared temperature. 2. Chilled-mirror dewpoint.
Range 0 to -300 MPa
Accuracy ± 0.05 MPa from 0 to -5 MPa, ± 1% from -5 to -300 MPa
Read time Typically 5 to 10 minutes
Interface Cable Serial cable (included)
Data Communications
RS232 compatible, 8-bit ASCII code, 9600 baud, no parity, 1 stop bit
Weight 3.2 kg (5.2 kg shipping weight)
Universal Power 110/ 220V AC, 50/60Hz
Sample dish capacity 7ml recommended (15ml full)
25 plastic cups and 10 stainless steel cups included
Calibration Standard 0.5 molal KCl (-2.19MPa)

How does sample disturbance affect readings?
Read the "Effects of Sample Disturbance on Soil Water Potential Measurements" Application Note at **www.decagon.com/sampledisturbance**

New

NEW FEATURES

- **Precise Mode**—verifies full equilibrium before displaying a final reading.
- **Speedy Equilibration**—new hydrophobic teflon impregnated nickel alloy sample chamber coating reduces equilibration time.
- **Finely-Tuned Adjustments**—new algorithms allow precision calibration and ± 0.05 MPa (or better) accuracy.
- **Better range and accuracy**—resolves temperatures to a thousandth of a degree to push the functional range to -0.1 MPa.

Applications

- Soil moisture characteristics
- Root zone water potential profiles
- Leaf water potential
- Seed priming
- Seed water relations
- Expansive soil characterization

Fast Response Tensiometers

▲ **T5** mini-tensiometers are essential for the measurement of water potential in small spaces like soil columns, potted plants and in laboratory water flow experiments.

▲ **T4 Tensiometer** Standard tensiometer. External refilling optional.

▲ **T8 Tensiometer** Includes temperature measurement, water level indicator and external refilling option.

UMS designs and manufacturers tensiometers to make research easier. The pressure transducer-based sensors allow for precise measurement of water potential. A variety of sizes give you options for deployment from field to lab. Their newest tensiometer, the TS1, allows yearlong field deployment after installation.

▲ **TS1** The world's first smart tensiometer. Designed to be deployed in the field and left, the TS1 logs water potential data, self refills, monitors temperature, and self-empties when the temperature nears freezing to avoid damage.

◄ **Infield 7 Handheld digital display** interfaces with all UMS tensiometers for quick data collection.

TENSIOMETERS SPECIFICATIONS

Range 0 to -85 kPa*

Accuracy ± 0.5 kPa

Resolution 0.1 kPa

Cable length 5m

Hysteresis typ. 0.1% FS

Stability over one year typ. 0.5% FS

Sensor Piezoresisitve pressure transducer, overpressure max ± 3000 hPa

Electronics Wheatstone full bridge

Compatible with Infield 7

and Campbell Scientific dataloggers.

*With careful refilling, the T5 tensiometer can make measurements well below -85 kPa.

Thanks to cavitation, many scientists have a love-hate relationship with tensiometers. At one time, Georg von Unold was one of them. "They leaked and would quickly run dry," he recalls. "The ceramic membrane was not consistent, and it was easy to see that there was a large variation of pore sizes between the different individual tensiometers. The most difficult problem was that the water reservoirs were opaque, which meant I couldn't see if there were bubbles that may have occurred during refilling or if cavitation had occurred."

Precision Engineering, Meticulous Construction

After weeks of frustration, von Unold decided to start fresh and design a better tensiometer. By the time he'd finished, he had a master's degree and a company, UMS. The tensiometers he builds at UMS, thanks to precision German engineering, meticulous construction, and fanatical attention to detail, are modern classics with terrific accuracy and a range that (with a careful operator) can extend beyond -200 kPa.

Georg von Unold, UMS

See **www.decagondevices.com/** for more specs on these UMS Tensiometers. More information on the history and theory behind them will appear in the 2010 issue of Water Potential News.

von Unold describes these tensiometers as instruments "soil scientists and ecologists from a century—or even a few decades—ago could only have dreamed about." They certainly made us excited, which is why we offer UMS instrumentation to the U.S. market. ■

Measure Soil Hydraulic Properties

Hyprop

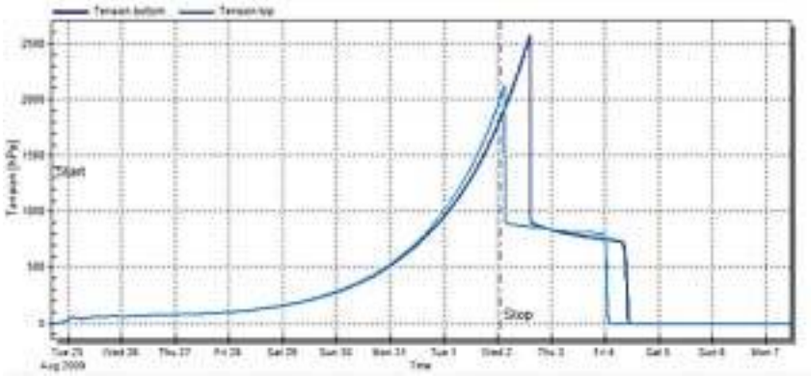
Forget the pain of using pressure plates. Use Hyprop to generate detailed moisture release curves, typically within a few days.

Just take your undisturbed sample, insert the measurement head, put it on the balance, and in less than a week, you have a detailed moisture release curve.

- Uses undisturbed soil samples.
- Works in all soil types
- Bonus feature gives unsaturated hydraulic conductivity values for the soil sample.

HYPROP SPECIFICATIONS
Range +2 kPa to -120 kPa / -250 kPa
Resolution 0.001 kPa
Accuracy ± 1.5 kPa

OPTIONAL LABORATORY SCALE SPECIFICATIONS
Measuring range 0 to 2.5kg
Resolution 0.01g
Accuracy ± 0.1g
Interface RS232



▲ Drying portion of the moisture curve generated by Hyprop.

Create Soil Moisture Release Curves

AquaSorp IG

INSERT SAMPLE, PRESS START, AND WALK AWAY

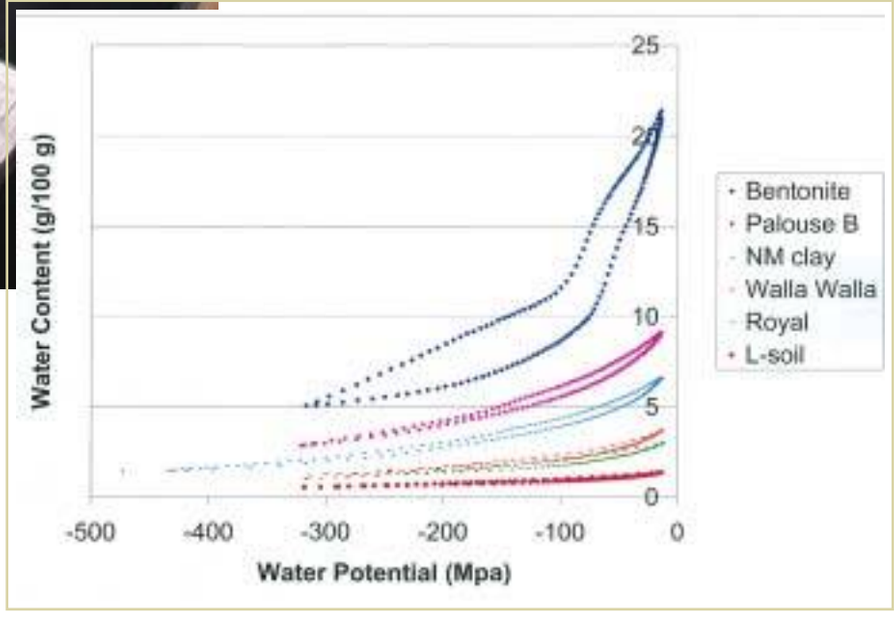
AQUASORP IG brings click and read efficiency to soil isotherms. In 24 to 48 hours, AquaSorp IG generates up to 200 data points (water potential vs. water content) in the wetting and drying directions. AquaSorp works in the dry range of water potential (-10 to -300 MPa). Whether you are studying adsorption/ desorption characteristics in dry soil or characterizing soil expansion, AquaSorp will provide the information you need with a fraction of the time and effort.

Specifications

Range -10 to -300 MPa.
Accuracy ±1MPa or ±1%
Temperature Operating Range 15 to 40° C
Size 44 w x 38 d x 28 h cm
Weight 19 kg

Benefits

- Rapid isotherm generation.
- Fast expansive soil characterization.



▼ Isotherm generated by the Aquasorp.

Monitor Water Potential In Situ

ACCURATE MEASUREMENTS IN ANY SOIL TYPE

INSTALL THE MPS-1 Water Potential Sensor down-hole, pack wet soil around it, plug the sensor into an Em50 or other compatible datalogger, and start logging water potential data. The MPS-1 integrates high-performance ceramic with new dielectric circuitry to measure a wide range of soil water potentials without user maintenance.

MPS-1 SPECIFICATIONS

Range -5 to -500 kPa
Accuracy
±40% of reading
Resolution
1 kPa from 0 to -100 kPa
4 kPa from -100 to -500 kPa
Measurement time 10 ms (milliseconds)
Power requirement 2 to 5 VDC @ ~10 mA
Output 525 to 925 mVDC independent of excitation voltage
Operating temperature -40 C to +50 C
Sensor dimensions 75 mm x 32 mm x 15 mm
Connector types 3.5 mm "stereo" plug
Cable length 5 m standard, extension cables available
Datalogger Compatibility (not exclusive)
Decagon Em50, Em50R, Em50G
Campbell Scientific CR10X, 21X, 23X, CR1000, CR3000, etc.

APPLICATIONS

- Water potential monitoring in vadoze zone.
- Crop stress.
- Waste water drainage studies.
- Irrigation monitoring and control.
- Plant water availability.

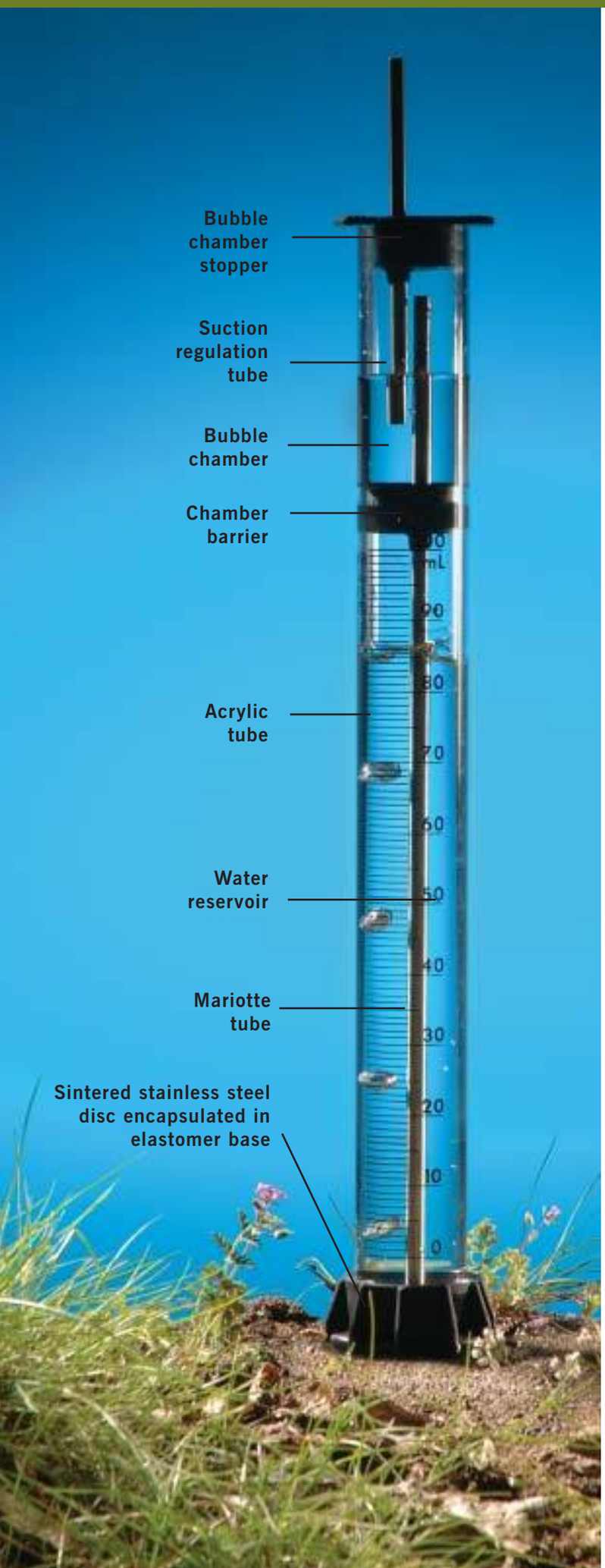
BENEFITS

- Continuous measurement of soil water potential.
- No complicated programming.
- No maintenance required after installation.

Learn more about the measurement of water potential methodologies and limitations at *www.decagon.com/waterpotential*

www.decagondevices.com

Measure Soil Hydraulic Conductivity



QUANTIFY SPATIAL VARIABILITY OF SOIL HYDRAULIC CONDUCTIVITY

Water movement in soil is spatially variable. The Mini Disk Infiltrometer is a quick way to test hydraulic conductivity and infiltration rates.

Backpackable

Small, compact, and simple, the Mini Disk Infiltrometer is a true field instrument. It can be tossed into a backpack with a bottle of water.

Quick Setup

Just fill the reservoir, set the suction, and start measuring infiltration. You don't have to pre-saturate the disk.

Straightforward Calculations

Enter infiltration and elapsed time data in the included spreadsheet calculator to find hydraulic conductivity.

Reliable

Both scientists and technicians have used the Mini Disk Infiltrometer to design irrigation systems, demonstrate hydraulic conductivity, evaluate erosion hazard, and gauge the impact of forest fires.

SPECIFICATIONS

Total Length 32.7 cm
Suction Range 0.5 to 7 cm of suction
Water Volume for Operation 135 mL
Diameter of Sintered Stainless Steel Disc
4.5 cm dia., 3 mm thick

USING THE INFILTROMETER TO ASSESS EROSION RISK

▲ After a fire, soil commonly becomes water repellent, just one factor in increased runoff.

Flagstaff, Arizona is typically a dry place. In August 2010, Flagstaff's residents experienced severe floods. Video footage shows churning rivers flowing down roadways and around and through homes. August's monsoon rains contributed the water, but the floods were actually caused by the 15,000 acre Shultz fire that raged around Flagstaff from April to July.

Floods Follow Fires

To Forest Service research engineer Dr. Peter Robichaud, the setup is classic. Robichaud, who studies post-fire erosion processes, says that after a fire, soil commonly becomes water repellent. That, together with loss of forest floor matter and ash clogging soil pores, creates a dramatic increase in runoff. "It's not just a 100% increase," he says. "It's orders of magnitude."

◄ 2010's Shultz Fire burned 15,000 acres of Arizona forest land.

Read the full article about Dr. Robichaud's research at www.decagon.com/robichaud or access his online Erosion Risk Management Tool at forest.moscowfsl.wsu.edu

Modeling to Improve Response

Robichaud's work in modeling post-fire erosion is used by many practitioners to assess the impacts of a fire, predict erosion, and make plans to manage and reduce the associated risks. Robichaud uses the Mini Disk Infiltrometer as a tool to characterize changes in the soil after a fire. "It's a practical instrument for fire assessment teams to use. It provides the information they need to help them determine the changes in infiltration characteristics."

▲ Residents of Flagstaff experienced significant flooding. "When you have steep slopes and high velocities, things can converge rather quickly," Dr. Robichaud says.

Monitor Solute Movement into Groundwater

MEASURE DEEP DRAINAGE AND SOLUTE FLUX WITHOUT THE BIG LYSIMETER PRICE TAG

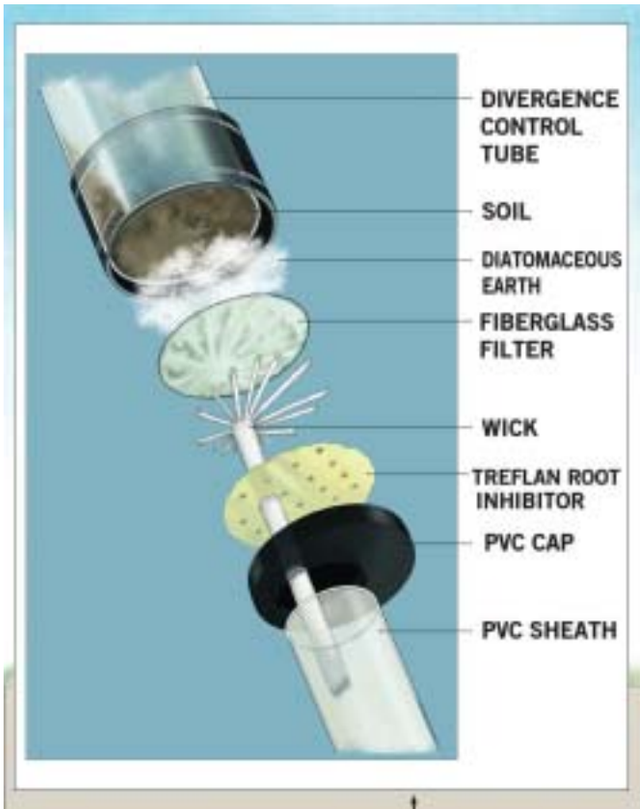
The new Drain Gauge G3 lets you measure drainage rates in unsaturated soils and collect soil water samples for chemical analysis.

Complete the Water Balance

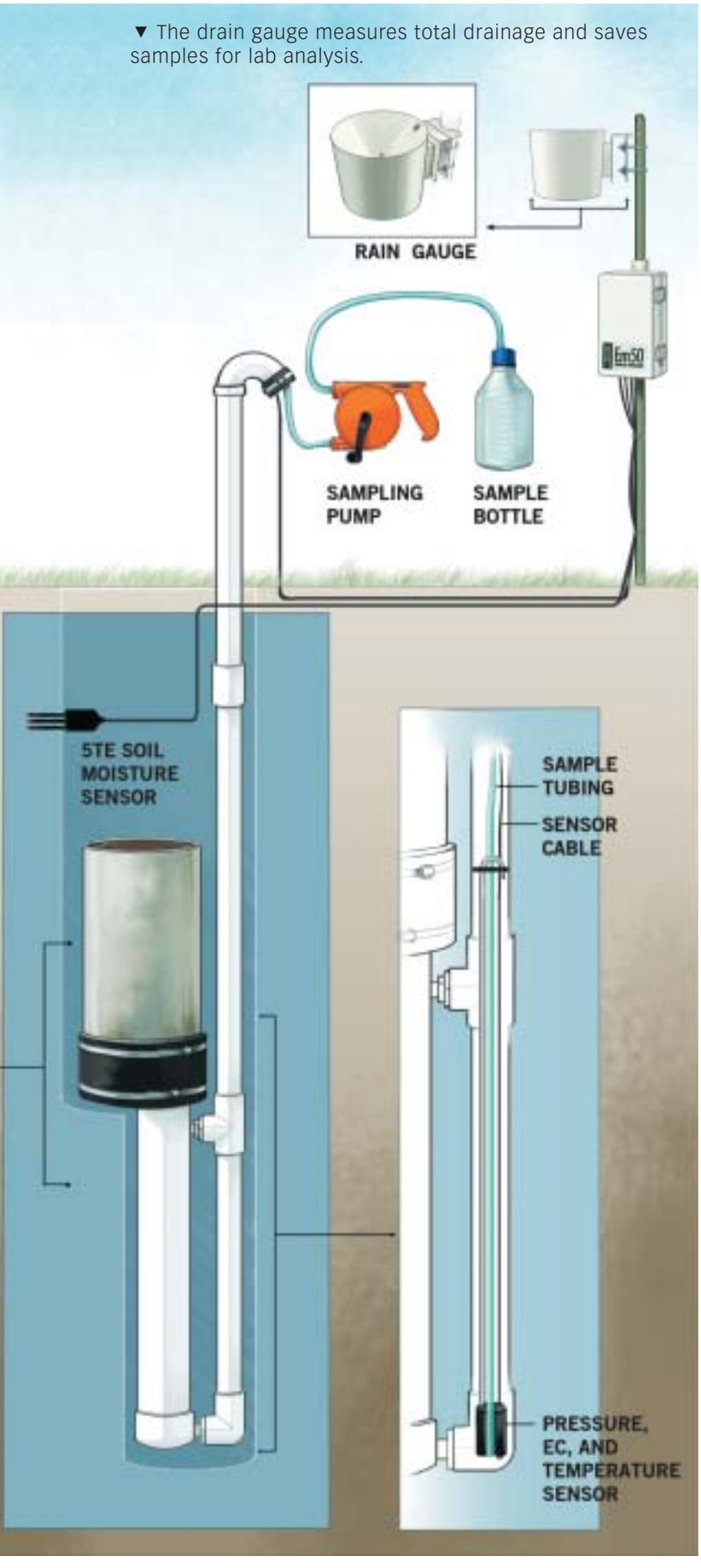
Water draining from the bottom of the soil profile is an important component of the water balance. It's usually estimated to be whatever is left over after the other components are measured, but these estimates are often subject to large errors. The drain gauge lets you measure deep drainage directly. Optional soil moisture and rain gauge sensors add data to complete the water balance.

Evaluate Groundwater Contamination

Typically, it's difficult to monitor contaminants until they reach the groundwater. The Drain Gauge lets you collect water just below the root zone and pump it to the surface for further analysis. Using the drainage rate and the chemical concentration in the drainage water, you can calculate the flux of chemical through the soil.



"I would put these everywhere—under farms, under golf courses, anywhere you want to know what's being leached into groundwater and how much of it there is. It gives you very good estimates, and the maintenance is essentially nil. You just dig a hole, chuck it in, and go on farming, or golfing, or fertilizing. All you have to do is get the water and analyze it."



▼ The drain gauge measures total drainage and saves samples for lab analysis.

FLUX DIVERGENCE—HOW TO MEASURE WHAT'S REALLY MOVING

Water is pulled through the soil in response to water potential gradients, or "soil suction." The two components of soil suction that are important in calculating water balance are matric suction and gravitational suction.

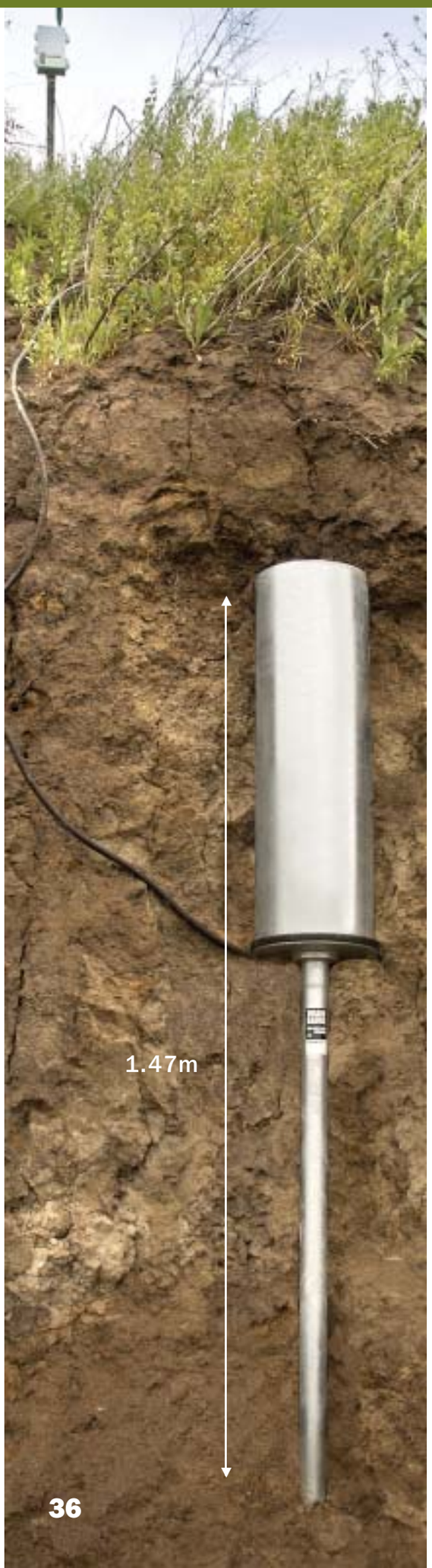
Collection Challenges

Gravitational suction—water movement due to the pull of gravity—is only significant in soils wetter than field capacity (33 kPa). Matric suction—water movement due to the attraction between water and soil particle surfaces—makes it difficult to collect water in a traditional pan lysimeter because the pan has no suction. Water, always moves towards areas of higher suction, will flow around the lysimeter unless the soil itself is very close to zero suction (saturation).

Creating Suction

This phenomenon is called flux divergence. The Drain Gauge uses a fiberglass wick to create a constant suction and a divergence control tube to minimize flux divergence and convergence. Find more information about the advantages and limitations of the Drain Gauge at decagon.com

Monitor Groundwater Leaching



MEASURE DEEP PERCOLATION RATES DIRECTLY

Determine the volume of water and chemicals draining from the vadose zone into groundwater. Our Drain Gauges measures flow rate in unsaturated soils and collects soil water samples for chemical analysis.

An ingenious duct and wick design maintains a flow rate within the gauge equivalent to that in surrounding soil. A surface port allows you to draw out samples to analyze for chemicals, fertilizers, and other contaminants.

DRAIN GAUGE APPLICATIONS

- Waste landfill sites, to advise operators when drainage is occurring and where cover systems need to be improved.
- Maximization of food processing waste applications by monitoring water drainage rates and water quality below the root zone.
- Environmental research measuring percolation and recharge rates.
- Farming operations, to measure and control irrigation during a cropping season.
- Recreational facilities, such as golf courses, to measure and control excess water and nutrient losses.

◄ **Drain Gauge G2 Constructed from Inert Materials**
Chemicals won't react with the tube, the sensors, or the collection reservoir.

New

DRAIN GAUGE G2
Flow Through Technology

Measurement Surface Area
324 cm^2

Sampling Reservoir Volume
150 mL

Accuracy
± 10%

Resolution
0.1 mm drainage

Suction at Intake
110cm (11 kPa)

Total length
147 cm

Divergence Control Tube (DCT) Length
60 cm

Measurement Time
10 ms

Power
2.5–3 VDC @ 3 mA, for 10 ms

Construction Material
Galvanized Steel DCT, inert polyethylene reservoir, and dry-fired fiberglass wick

Datalogger Compatibility
EM50/EM50R/EM50G and all Campbell Scientific Loggers

DRAIN GAUGE G3
Sample Capture Technology

Measurement Surface Area
507 cm^2

Sampling Reservoir Volume
3 L

Accuracy
± 10%

Resolution
0.1 mm drainage

Suction at Intake
110cm (11 kPa)

Total Length
147 cm

Divergence Control Tube (DCT) Length
60 cm

Measurement Time
150 ms

Power
3.6–15 VDC, 0.3 mA quiescent, 20 mA during 150 ms measurement

Construction Material
Stainless Steel or PVC DCT, inert PVC reservoir, polyethylene evacuation tube, dry fired fiberglass wick, and epoxy molded drainage sensor

Datalogger Compatibility
EM50/EM50R/EM50G and all Campbell Scientific Loggers w/ SDI-12 capability

▶ **New Drain Gauge G3** has surface port for easy access to drainage / temperature / EC sensor for maintenance.

Continuously Sample Nitrogen,

TENSIOMETER CONTROL ENSURES ACCURATE SAMPLE CONCENTRATIONS

Don't take a soil core every time you want data. Leave your experimental site undisturbed and take more meaningful pore water samples with UMS's pore water samplers.

How does it work?

A pore water system is a quick access point for extracting soil water. Rather than digging up a chunk of soil and performing an extraction every time you want a sample, you install a specially tipped tube in the soil. Soil water samples are gently extracted from soil pores using suction pressure matched to natural soil water tension.

Eliminates Spatial Variability

Sampling in the same undisturbed location every time gives you better data.

Uses Natural Sampling Suction

Precisely controlled tension means you sample what's actually in the soil water. Constant, unregulated tension preferentially samples the wet time periods, diluting your samples and giving inaccurate concentrations. UMS's unique tensiometer control matches sampler suction to the natural suction of the soil as conditions change for the most accurate sample concentrations.

Customized to Solute Type

UMS's patented silicone carbide tip is inert to a large range of compounds. Other tips are also available.

- Measure net mineralization rates.
- Sample for organic carbon.
- Quantify the presence of heavy metals, pesticides, and other contaminants.

Phosphorous, and More in Soil Water

SIC20
Silicon Carbide

Allows for sampling of a broad range of chemicals due to low sorption.

SK20
Aluminum Oxide Ceramic

Suitable for determination of nitrate and common organic and inorganic substances.

SPE20
Polyethylene Nylon Membrane

Specially suitable for heavy metals, herbicides, and pesticides.

PORE WATER SAMPLERS

SIC20
Shaft Diameter
20 mm; acrylic

Shaft Length
20 to 210 cm; customized to order

Porous Ceramic
20 mm dia.; 60 mm length

Bubble Point
-90 kPa

Suction Tube
Polyethylene; 1.6 mm i.d.; 2.8 mm o.d.

SK20
Shaft Diameter
20 mm; acrylic

Shaft Length
20 to 210 cm; customized to order

Porous Ceramic
20 mm dia.; 60 mm length

Bubble Point
-100 kPa

Suction Tube
Polyethylene; 1.6 mm i.d.; 2.8 mm o.d.

SPE20
Shaft Diameter
20 mm; acrylic

Shaft Length
20 to 210 cm; customized to order

Porous Ceramic
20 mm dia.; 60 mm length

Bubble Point
-100 kPa; but the PE cover allows water flow only up to -20 kPa

Suction Tube
Polyethylene; 1.6 mm i.d.; 2.8 mm o.d.

VACUUM SYSTEMS

VS/VS-pro/VS-Twin
Power Supply
10.5 to 15 VDC

Interface
tensioLINK, RS485

Memory
5000 readings

Vacuum Regulation Range
0 to -85 kPa

Dimensions
26 x 16 x 10 cm

Enclosure
Aluminum

Operating Temperature
-10°C to +45°C

VacuPorter electric pump
Max. Vacuum
-85 kPa

Max. Pressure
400 kPa

Capacity
10 liters/min

Batter Capacity
Internal rechargeable battery; 7 hours of operation

Case
30 x 25 x 13 cm

Weight
4.8 kg

VPS-2 hand-operated floor pump
Max. Vacuum
-85kPa

Capacity
0.41 liters per stroke

Model Heat Movement

■ **KS-1**
6cm needle length
Thermal conductivity of liquids.

■ **TR-1**
10cm needle length
Thermal conductivity or thermal resistivity of soil or porous materials. ASTM and IEEE compliant.

■ **SH-1**
30mm dual needle length
3 parameters- Thermal Conductivity, Thermal Diffusivity, and Specific Heat.

GET A HANDLE ON HEAT TRANSFER

FOLLOW THE HEAT transfer in the soil plant atmosphere continuum with the KD2 Pro Thermal Properties Analyzers. The KD2 Pro has three interchangeable sensors which measure thermal diffusivity and specific heat (heat capacity) measurement functions along with data storage capabilities and an automatic data collection mode. ■

- **Heated Needle Technology**
- **Requires No Calibration**
- **Displays in Engineering Units**
- **Small Needle Minimizes Soil Disturbance**

KD2 Pro Specifications

Measurement 90 Seconds

Accuracy*

± 5% to ± 10% Conductivity/Resistivity

± 10% Thermal Diffusivity

± 10% Specific Heat

Ranges*

K: 0.02 to 4 Wm^{-1} C^{-1}

D: 0.1 to 1.0 mm^2s^{-1}

R: 0.5 to 50 mC W^{-1}

C: 0.5 to 4 MJ m^{-3} C^{-1}

Data Storage 4095 readings

Environment –50 to 150°C

Case Size 15.5 x 9.5 x 3.5 cm

Power 4, AA Batteries

Sensors

KS-1, 6 cm, 1.27 mm Dia. needle

TR-1, 10 cm, 1.27 mm Dia. needle

SH-1, 30 mm, 1.27 mm Dia. 2 needles

**Accuracy and measurement range vary with sensor type.*

Cable 1m

► Each KD2 Pro comes factory calibrated and includes performance verification standards.

Watch a three and a half minute video on measuring soil thermal conductivity with the KD2 Pro at **www.decagon.com/education/video-index/**

Electrical Conductivity of Natural Waters

EC CONVERSIONS

dS/m = mS/cm = mmho/cm

µS/cm = µmho/cm

10 mS/cm = 1 S/m

0.097 dS/m Lake Superior

0.15 dS/m Columbia River (Wenatchee)

0.16 dS/m Sacramento River (Tisdale)

0.41 dS/m Snake River (Minidoka)

0.85 dS/m Lake Mead

1.06 dS/m Colorado River (Yuma)

1.16 dS/m Rio Grande River (El Paso)

3.21 dS/m Pecos River (Carlsbad)

43 dS/m Atlantic Ocean

158 dS/m Great Salt Lake

0.001 dS/m
Distilled Water

0.1–1.0 dS/m
Drinking water

EC @ 25 C dS/m	Sodium Chloride[2] g NaCl/kg H_2O	Potassium Chloride[2] g KCl/kg H_2O
0.1	0.0455	0.0446
0.2	0.0935	0.0930
0.5	0.2421	0.2456
1	0.4970	0.5120
2	1.0205	1.0673
5	2.6413	2.8186
10	5.4232	5.8758
20	11.1351	12.2490

USEFUL EQUATIONS

Concentration vs. EC for NaCl[3]

$C(gNaCl/100g\ H2O) = 0.497\ EC^{1.04}$ (EC in dS /cm)

Concentration vs. EC for KCl[4]

$C(gKCl/100g\ H2O) = 0.512\ EC^{1.04}$ (EC in dS /cm)

Concentration of total dissolved solids for typical natural waters vs. EC[3]

$C(mg\ solids / kg\ H2O) = 683\ EC^{1.04}$ (EC in dS /cm)

EC in all cases is assumed to be the value at 25°C.

Temperature correction of EC[3]

$$EC_{25} = \frac{EC_T}{1 + 0.019\ (T-25)}$$

where T is Celsius temperature and ECt - is the EC at that temperature.

[2] USDA Handbook 60 Diagnosis and Improvement of Saline and Alkali Soils
[3] CRC Handbook of Chemistry and Physics, 74th Edition
[4] Equation based on USDA Handbook 60 data
[5] Equation based on CRC Handbook data

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DECAGON DEVICES

www.decagon.com
Pullman, Washington

Essential Soil Moisture References

WATER CONTENT CONVERSIONS

w_d (kg/kg)	$w_d = \frac{M_w}{M_s}$	$w_d = \frac{w_w}{1 - w_w}$	$w_d = \frac{\rho_w}{\rho_{dry}}\theta$
w_w (kg/kg)	$w_w = \frac{w_d}{1 + w_d}$	$w_w = \frac{M_w}{M_w + M_s}$	$w_w = \frac{\rho_w}{\rho_{wet}}\theta$
θ ($m^3\ m^{-3}$)	$\theta = \frac{\rho_{dry}}{\rho_w} w_d$	$\theta = \frac{\rho_{wet}}{\rho_w} w_w$	$\theta = \frac{V_w}{V_t}$

DEFINITIONS

w_d	mass water content, dry basis
w_w	mass water content, wet basis
θ	volume water content
ρ_{dry}	dry bulk density (kg m^{-3}) = M_s/V_t
ρ_{wet}	wet bulk density (kg m^{-3}) = $(M_s + M_w)/V_t$
ρ_w	water density (kg m^{-3}) = 1000 kg m^{-3}
M_s	mass of dry solid
M_w	mass of water
V_w	volume of water
V_t	total volume, soil, water and air

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