Premier Issue

Building Lysimeters

GERMAN ENGINEERED, SURPRISINGLY AFFORDABLE

I've visited a lot of lysimeters in the last 18 months. Still, when I started touring the TERENO SoilCan project in Germany, I was a little overwhelmed. I saw over a hundred lysimeters built to test climate change, with monoliths swapped between sites all over Germany. It's a project that took an incredible amount of organization and patience.

Yet maybe the most astonishing thing is that with all that building, extracting, and moving, the project cost its sponsor, the Helmholtz Association, just 3.6 million euros. I've seen domestic projects comprising just a few lysimeters that used a similar number of research dollars.

A good lysimeter preserves even small pores and wormholes intact.

Why was Helmholtz able to be so efficient?

I think the key is UMS, our German partner. UMS has 30 years of experience building lysimeters. They've built hundreds, in terrain from farmland to mountains, rubble fields, and even permafrost. Their lysimeters are carefully thought out and beautifully engineered so each component works as part of the whole system.

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I'm excited to bring the German lysimeters to the United States, where UMS will be collaborating with us on domestic projects. If you want to see more about how a lysimeter is built, check out the photo story on page 3.

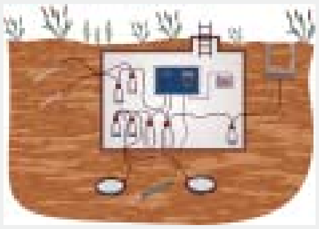
Sincerely,

Leo Rivera

Lysimeter Types

Pan

Static Tension



Controlled Tension

Weighing

	Pan	Static Tension	Controlled Tension	Weighing
HOW IT WORKS	A simple collection pan is buried in the soil to collect water draining from the root zone.	A collection device, typically a cylinder, is buried in the soil. Flow divergence is reduced by creating static tension with a vacuum pump or a wick (which acts as a hanging water column).	Suction plates are buried in the soil. A control system measures soil water tension and uses the vacuum pump to match the suction of the plates with the tension in the surrounding soil. Leachate is collected in an underground control room.	A large core of soil deep enough to encompass the root zone is removed. It is placed on a precision load cell which weighs the lysimeter continuously. In UMS lysimeters, the lower boundary is controlled with an active suction system to match tension in the native soil. Porous concrete well rings maintain temperature dynamics.
PROS	Most basic measurement of drainage; simple and inexpensive.	Relatively simple and inexpensive.	Very accurate drainage measurement method.	Best possible quantification of the hydrologic cycle for climate change, ecohydrology, and contaminant transport studies.
CONS	In unsaturated soil, water will flow around the lysimeter (flow divergence). Even with the best setup, commonly less than 10% of the drainage is collected.	Flow divergence is reduced but not eliminated. Flow convergence is possible (though uncommon).	Expensive to install and maintain, power-intensive.	Most expensive to install and maintain.
COMMENTS	Flow divergence problems can be mitigated somewhat by using a large measurement footprint (several m²) and vertical walls (all the way to the surface is the best).	Addition of a divergence control tube minimizes convergence and divergence.		

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Lysimeter installations start with the soil survey to see how the area is currently mapped. That information is refined by taking soil cores. The cores give insight into actual local conditions and also indicate if roots, rocks, and cavities might make installation challenging. Hard pans and boulders may preclude installation in certain locations.

Cutting Clearly

Four hydraulic cylinders are used to slowly press the lysimeter shell down into the soil. The cutting process is painstakingly slow and carefully monitored.

The lysimeter shell is made of smooth cold-forged stainless steel to reduce friction and risk of compaction as it cuts the core. When the monolith is completely cut, a polished shearing plate with a hydraulic drive gently shears off the bottom.

Turning without Deforming

Round bolts are welded on to the lysimeter shell at its balance point to allow smooth rotation. By lifting evenly and close to the balance point, UMS avoids deforming even small pores and wormholes. Induced torque is minimized and the load is evenly distributed over the bottom by short bolts and a large welded-on base plate.

Gentle Transportation

If they need to take the lysimeter to a different location (eg., in climate studies), UMS uses truck beds with special air suspension and shock detecting sensors.

Installing Suction Tubes

UMS installs a suction tube grid on the bottom of the lysimeter. Matric potential drives water movement in soil, so it is essential that the matric potential inside the lysimeter matches that of the surrounding field.

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Built for Thermal Equilibrium

UMS lysimeter well rings are made from porous concrete. Evaporation enthalpy maintains thermal equilibirum to ensure that chemical, microbial, and hydraulic processes inside the lysimeter match those in the surrounding field.

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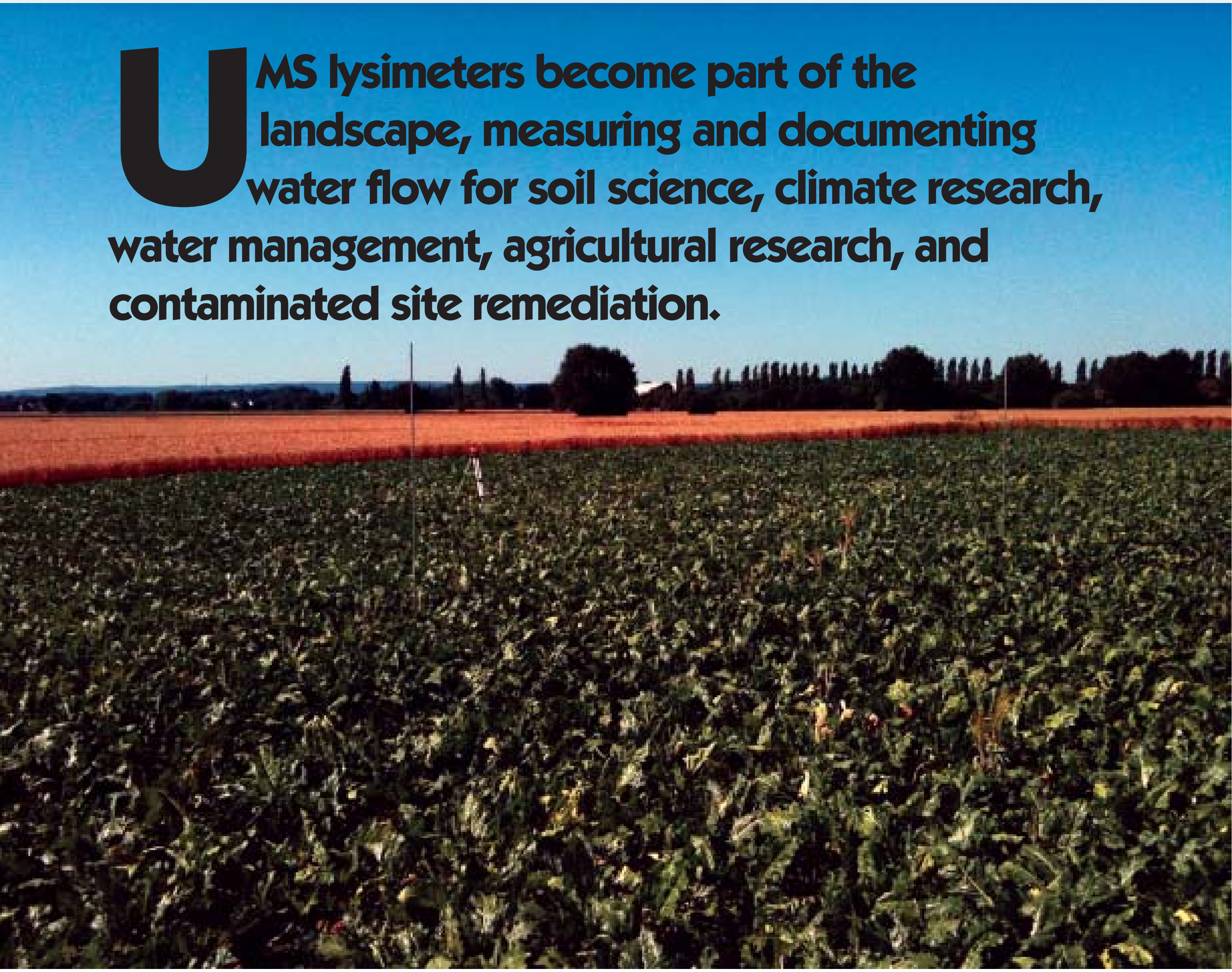
Custom Sensors Installed

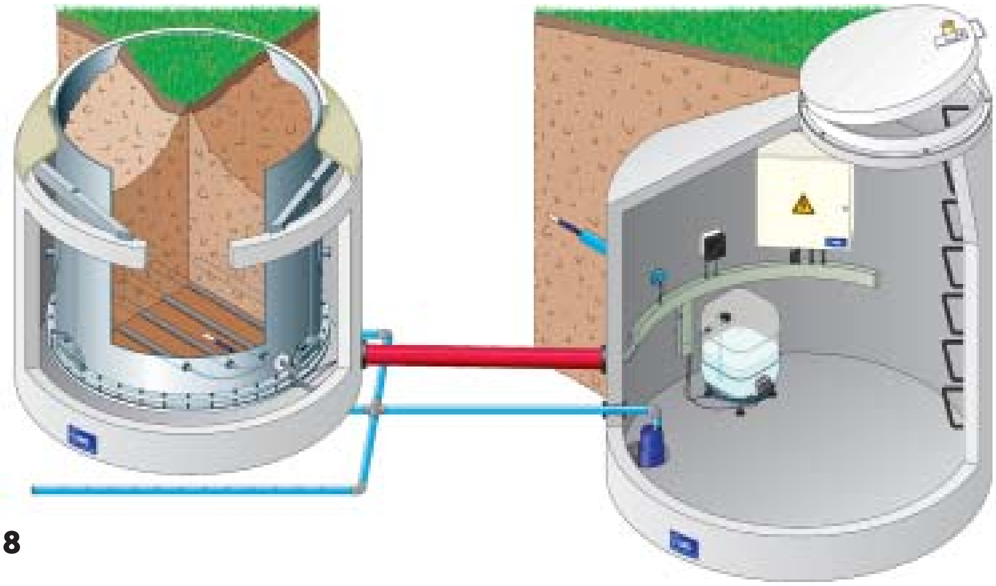
Sensors are installed at various depths to measure soil moisture, determine matric potential, and sample pore water among other things. After the sensors have been installed, the monolith is gently turned again and set on a load cell.

Sealed for Protection

The rim gap is sealed with lip to prevent intrusion of rain, snowmelt, and stones. The lip is designed not to influence weighing precision.

UMS lysimeters become part of the landscape, measuring and documenting water flow for soil science, climate research, water management, agricultural research, and contaminated site remediation.





Making Connections

The lysimeter is connected by wires and tubes to a below-ground cement service well, then soil is refilled around the lysimeter.

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Advances in Mini-Lysimeters

The mini lysimeter is about 1/3 the diameter of its larger cousin, and comes in 30, 60, and 120 cm lengths. The smallest of these lysimeters can be turned by hand. They're designed for researchers who want to measure on a smaller scale, or who can't justify the expense of a large lysimeter.

	MINI LYSIMETER	FULL SIZED LYSIMETERS
Diameter	30 cm	1 m
Height	30, 60, or 120 cm	1–2 m
Installation Time	1 week	1–2 months
Housing	Plastic, low-weight	Porous concrete
Field-identical Temperature Dynamics	No	Heat exchanger, porous concrete for better thermal conduction
Field-identical Water Tension	Tensiometer control, suction plate; removes but can't add water to maintain identical tension.	Tensiometer control, suction tube grid; removes and adds water to maintain identical tension.
Installation Method	3 long screws anchor a mechanical jack which pushes the lysimeter into the ground	4 hydraulic presses push against a backhoe shovel to press the lysimeter into the ground
Shearing	By hand	By hydraulic plate
Equipment Storage	Above ground weather-proof enclosure	Underground service well
Rotation of Monolith	By hand or strap and collar mechanism	By crane; round bolts welded to lysimeter shell.
Load Cell	Different cells; identical accuracy	
Leachate	Collected, weighed, and stored for analysis	

Case Study

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When it comes to the soil, water in doesn't necessarily result in water out. Dan Burgard, Principal Soil Scientist at Cascade Earth Sciences in Washington State, admits that this can be frustrating for people who want to see data about what's happening in the vadose zone.

Wastewater Treatment

Burgard is a consultant to industries, municipalities and farmers who apply waste water to crops for treatment. The land treatment process is a win-win—water and nutrients are reused as the water is being treated. But of course the effects of applying waste water have to be carefully monitored, which can be challenging.

Good Predictions Needed

"In the past, all we had was a water balance calculation to try to estimate the amount of water moving through the soil," says Burgard. Now Burgard uses the Drain Gauge—a simple wick lysimeter—to help make better predictions.

Drain Gauge Removes Guesswwork

The Drain Gauge quantifies and collects water draining from the bottom of the soil profile. It uses a fiberglass wick and divergence control tube to emulate the way water actually moves through the soil. It measures the rate of drainage using an electronic sensor and stores drainage water in a reservoir. Stored samples can be pumped to a surface port for further measurement and analysis.

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Burgard uses nitrogen concentration data and the amount of load to calculate a treatment efficiency number. In some cases he provides this data in reports to regulatory agencies, and it also helps remove some of the guesswork from his job.

Deep Drainage Data

"The Drain Gauge provides information about the actual performance of the land application process. It gives us the deep drainage number both in quality and quantity," he says. Knowing both is critical to analyzing the data properly.

Calculating Load

"There are some really scary concentrations that you can get coming out of the soil. But if you have a very high concentration of nitrate in a very small amount of water that's moving, the load overall is very small and the potential impact to ground water is small."

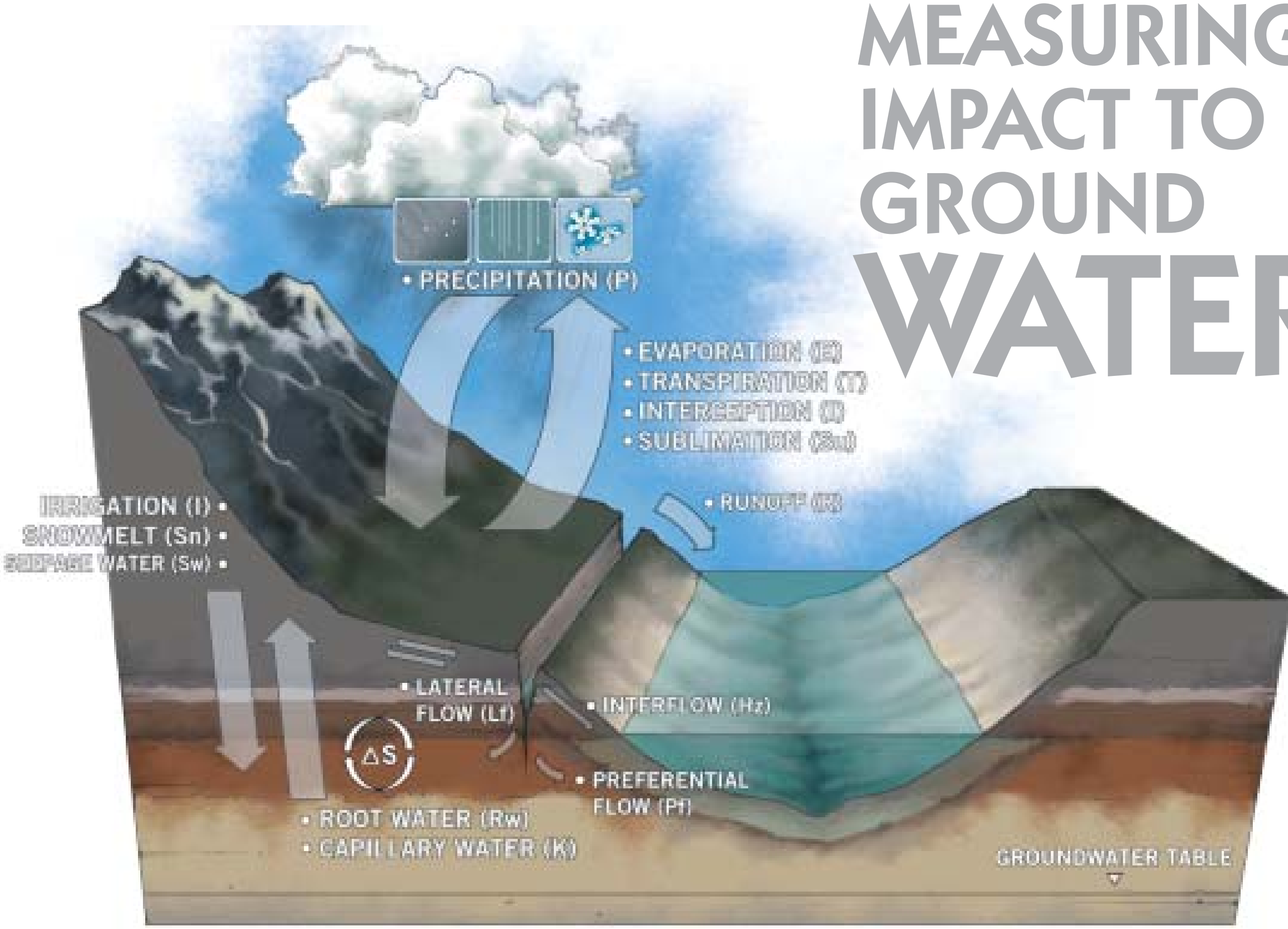
Concentrations in Context

Putting concentration data in context is one of the main advantages of the Drain Gauge, according to Burgard. "Suction samplers are often used to evaluate water but the challenge is that they only give a concentration. You can't really tie that to the flux because you don't know when the flux occurred, and you may be getting water that's retained in the soil, for example."

Representative Location

In order to collect useful data, the Drain Gauge must be located in a representative spot. "We have to set up something that's scientifically credible," he explains. "There's always concern about getting

MEASURING IMPACT TO GROUND WATER



The Drain Gauge quantifies deep drainage both in quality and quantity, removing some of the guesswork from Burgard's job.

sufficient representation of the variability that exists out in the field."

And they do see variability when they have multiple Drain Gauges, but it seems to be more related to the soil type itself than anything. "If we have sufficient representation of the dominant soil types, we get a reasonable representation of the variability that exists as long as we have reasonably uniform irrigation."

Dynamic System

Another challenge is that efficient irrigation can paradoxically make it harder to get regular samples. "It's a little more difficult to interpret data when you have very intermittent sample collection, but that's really what you want, because you're not leaching to the groundwater," Burgard explains.

"One of the hardest things is getting the regulatory agencies to understand that the soil is a dynamic system. It doesn't always give a sample. If there's no sample, that doesn't mean the system is not working."

In the long run, using a mix of data, Burgard's usually able to explain what's going on in the soil, both to his clients and to the regulatory agencies. And ultimately he can help them solve problems and come to solutions that everybody can live with, "at least for the time being." ■

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