California Department of Pesticide Regulation
Environmental Monitoring Branch
1001 I Street, Sacramento CA 95814-2828
P.O. Box 4015, Sacramento CA 95812-4015

STANDARD OPERATING PROCEDURE
Measuring Infiltration Rate with a Cornell Sprinkle Infiltrometer

---

KEY WORDS
Infiltrability, rainfall simulator, ring infiltrometer, sorptivity

APPROVALS

APPROVED BY: ______________________ DATE: 10/28/05
Kean S. Goh, Ph.D.
Environmental Monitoring Branch Management

APPROVED BY: ______________________ DATE: 10/26/2005
Frank C. Spurlock, Ph.D.
Environmental Monitoring Branch Senior Scientist

APPROVED BY: ______________________ DATE: Oct 5, 2005
Carissa Ganapathy
Environmental Monitoring Branch Quality Assurance Officer

PREPARED BY: ______________________ DATE: Oct. 20, 2005
Heidi Dietrich
Environmental Monitoring Branch Student Assistant

Environmental Monitoring Branch organization and personnel, such as management, senior scientist, quality assurance officer, project leader, etc., are defined and discussed in SOP ADMN002.

1.0 INTRODUCTION

Infiltration is the process of water moving into the soil. Infiltrability is the rate at which water enters the soil surface. Ring infiltrometers and rainfall simulators have been used for many years to investigate soil infiltrability and the processes of runoff and erosion. The Cornell Sprinkle Infiltrometer (Figure 1) combines the benefits of both ponding ring infiltrometers as well as rainfall simulators while remaining portable and water efficient enough to allow taking multiple samples at each site (Ogden et al., 1997). This method is a relatively easy, quick and repeatable way to measure initial and steady-state infiltrability for a variety of soils.

1.1 Purpose

This Standard Operating Procedure (SOP) details the calibration and use of the Cornell Sprinkle Infiltrometer. The method is adapted from *Field Procedures and Data Analysis for the Cornell Sprinkle Rainfall Simulator* (van Es and Schindelbeck, undated).

2.0 MATERIALS

2.1 Rainfall simulator Unit

- 2.1.1 Rainfall Simulator
- 2.1.2 Metal infiltration ring
- 2.1.3 Bubble tube with clamp
- 2.1.4 Large rubber stopper
- 2.1.5 Outflow tube

2.2 For Each Infiltration Unit

- 2.2.1 1 1000 mL plastic graduated cylinder
- 2.2.2 2 1000 mL plastic beakers
- 2.2.3 Stop watch
- 2.2.4 Field scale (battery operated)
- 2.2.5 5 gal tap water for each test
- 2.2.6 Data sheet
- 2.2.7 Storage bin w/ lid

2.3 Additional Tools

2.3.1 Plywood sheet
2.3.2 Dead-blow hammer (rubber mallet)
2.3.3 Grass shears
2.3.4 Turkey baster
2.3.5 Waterproof tarp
2.3.6 Large funnel
2.3.7 Silicone vacuum grease
2.3.8 Shade structure
2.3.9 5 gallon bucket
2.3.10 Shovel
2.3.11 Hand trowel
2.3.12 Sturdy work gloves
2.3.13 Level
2.3.14 Soil auger

3.0 PROCEDURES

3.1 Field Preparation

3.1.1 At the desired location, clear the soil surface of rocks, grass and other debris. It is important to remove anything that may clog the overflow stopper and tubing or cause soil disturbance while driving in the ring.

3.1.2 Be sure to avoid large cracks when working with dry or heavy clay soils. The presence of animal burrows can also interfere with accurate measurements. Multiple attempts may be necessary to find a suitable soil surface.

3.1.3 Position the infiltration ring so the hole and outflow tubing are in the natural downward slope of the site's micro-topography.

3.1.4 Once the ring is in place, set a piece of plywood flat across the top of the ring. Use a mallet to drive the ring into the ground by pounding on the plywood and then check for plum with a level. The ring should be inserted until the bottom of the outlet hole is flush with ground level.

3.1.5 Insert the outflow tubing and stopper to use as a guide for distance (30cm or more) to where a 1000 ml beaker should be placed. Dig a hole deep enough and wide enough to position the beaker so it sits slightly below ground level. A soil auger can help start the hole for the beaker. Dig a shallow trench with the hand trowel to accommodate the tubing and provide a downward slope to the beaker.

3.2 Filling the Rainfall Simulator

3.2.1 Place the rainfall simulator on a clean flat surface taking care to protect the drip tubes. Remove the large stopper. Pour water from carboys into the top until almost full but not above the last mark on the ruler (approximately 5 gallons). A large funnel with a mesh screen makes pouring easer and helps screen out debris that could clog the drip tubes. Replace stoppers firmly for an airtight fit using vacuum grease on both the large stopper and the interface of the bubble tube and the rainfall simulator. Air should only enter from the bubble tube.

3.2.2 A waterproof tarp on the ground can help keep equipment and staff clean and dry.

3.2.3 If needed, blow gently into the bubble tube for a few seconds to remove air bubbles from capillary tubes. This should be done before the first measurement but not subsequently. Seal the bubble tube with clamp. The rainfall simulator will not lose water when the bubble tube is sealed and the stopper is in place.

3.3 Final Assembly and Measurements

3.3.1 Carefully place full rainfall simulator onto the ring so that the bottom of the unit is flush with the top of the ring. Avoid bumping the ends of the capillary tubes with the ring. The tubes are fragile and can break.

3.3.2 Measure and record the initial height of the water (H1) in the infiltrometer by reading the height next to the ruler. Remove clamp from the bubble tube and start the stopwatch.

3.3.3 Watch the tubing for first sign of runoff into the beaker and record the time (T_{RO}) and water level. Take additional readings at regular intervals. 3 to 5 minute intervals are suggested but will depend on amount of runoff.

3.3.4 To take a reading, temporarily block outflow from the tubing and quickly switch beakers. At the same time, read water level from the ruler on the side of the infiltrometer. Record water level and time measurement was taken (t).

3.3.4.1 If bubbling from bubble tube interferes with taking a reading, put finger over tip of the bubble tube momentarily to stop the turbulence, then take reading.

3.3.5 Tare the graduated cylinder on the field balance and pour the water from the collection beaker into the cylinder being careful not to spill. Record weight (V_t) on data sheet. Discard water and store both cylinder and beaker tilted or upside down to drain residual water. Re-tare cylinder before every measurement.

3.3.6 For each interval, follow steps 3.3.4 through 3.3.5 for as long as desired or until water level reaches the bottom of the bubble tube. Do not allow water to drop below bottom of bubble tube

3.3.7 With the last readings (H2), (T_f), remove rainfall simulator from ring and place on a clean, flat surface. Allow water in ring to continue to flow out of tubing until it stops filling the beaker. Measure this amount. With the turkey baster, suck up any water puddled in ring then weigh, and record amount.

3.4 Clean Up

3.4.1 Empty leftover water from rainfall simulator. Remove infiltration ring and refill holes with displaced soil.

3.4.2 In lab, rinse rainfall simulator with a 10% solution of household bleach after each day of use. This will prevent microbial growth in capillary tubes.

4.0 CALCULATIONS

4.1 Simulated rainfall rate

4.1.1 The simulated rainfall rate (r, cm min^{-1}, constant throughout the experiment) is determined by

$r = [H1 - H2] / T_f$

Where

H1= initial water height in unit, cm

H2= final water height in unit. cm

T_f= last time measurement, min

4.2 Runoff rate

4.2.1 The runoff rate (ro_t, cm/min) is determined by

$ro_t = V_t / (457.30 * t)$

Where

457.30 = area of the ring, cm^2

t = time interval of runoff collection, min

V_t = runoff volume in graduated cylinder converted from grams water to cm^3 water

4.3 Infiltration rate

4.3.1 Infiltration rate (i_t cm min^{-1}) is determined by the difference between the rainfall rate and runoff rate

$i_t = r - ro_t$

Where

r = rainfall rate

ro_t = runoff rate

4.4 Estimation of Sorptivity

4.4.1 Sorptivity (S) is a soil hydraulic property that describes early infiltration independent of rainfall rate.

$S = (2T_{RO})^{0.5} * r$

Where

T_{RO} = time to initial runoff (min)

r = rate of runoff (cm/min)

5.0 TROUBLE SHOOTING AND MAINTANANCE

5.1 Field Trouble Shooting

5.1.1 If excessive time elapses while waiting for first discharge, a large crack in the soil or animal burrow may be present in the ring area. Remove rainfall simulator and ring and follow steps 3.1.1 to 3.1.5 again. Refill rainfall simulator and start measurements again.

5.1.2 Operation in direct sunlight may cause air bubbles to form and block capillary tubes, which will cause drip rate to slow or stop. Use shade structure or lid of container to shade rainfall simulator from the sun.

5.1.3 Additionally, filling carboys 24 hours before use will help allow for air to leave the water.

5.2 Special Maintenance

5.2.1 If a capillary tube is broken or becomes clogged, it can be replaced.

5.2.1.1 Grab defective coil using pliers and pull upwards. If it breaks, pull from underneath.

5.2.1.2 Clean old glue from hole with a scraper or putty knife. Do not use solvents to remove glue, as it will discolor acrylic.

5.2.1.3 Apply large dab of “Marine Goop” to empty hole and place new capillary tube into hole. Move tube up and down to form a good seal.

5.2.1.4 Allow to dry for 24 to 48 hours in a fume hood. Residual moisture will cause glue to fail.

5.2.1.5 Trim bottom of tubes to 1-2 cm in length or same length of other tubes.

5.2.1.6 Replacement parts can be ordered from Cornell.

6.0 STUDY-SPECIFIC DECISIONS

6.1 Rainfall Rate

Rainfall rates can be altered by changing the height of the air entry tube. It is desirable to have drip rates that ensure ponding and to achieve steady-state infiltration without requiring refilling the rainfall simulator. For most soil, a drip rate of 20 to 30 cm/h will achieve this. The rainfall simulator can be calibrated to drip at the desired rate. The drip rate may vary slightly in the field due to changes in water temperature.

6.2 Calibration Steps

6.2.1 Set the bubble tube to the desired level. The 30 cm/hr sprinkle rate is generally achieved when the bottom of the bubble tube is located at 10 cm above the bottom of the container.

6.2.2 Measure the height of water level in the rainfall simulator (H1).

6.2.3 Remove the clamp from the bubble tube, and start a stopwatch.

6.2.4 Allow for 3 minutes of sprinkling and read the water level exactly at this time (H2).

6.2.5 Calculate the rainfall rate (cm/min) as

$$[H1-H2] / t$$

Where
t = time (min)

6.2.6 If the actual rainfall rate is below the desired rate, move the bubble tube up. Move it down if it is above the desired rate.

6.2.7 Repeat the procedure until the desired rate is achieved. Note that the calibrated rainfall rate does not need to be very exact. The actual rate is determined for each field measurement.

6.3 Soil Property Data Collection

Depending on study objective, collection of soil property samples may be useful. Soil moisture, bulk density and texture measurements can provide valuable information about field conditions. Collection methods for these samples are detailed in SOP #s METH001.00, METH004.00, FSSO002.00 and FSSO001.00.

7.0 REFERENCES

Dietrich, H. (2005) Procedure for Determining Soil Particle Size Using the Hydrometer Method. SOP METH004.00. Environmental Monitoring Branch, DPR. Available on-line: http://www.cdpr.ca.gov/docs/empm/pubs/sop.htm.

Garretson, C. (1999a). Soil Water Content Determination. SOP METH001.00. Environmental Monitoring Branch, DPR. Available on-line: http://www.cdpr.ca.gov/docs/empm/pubs/sop.htm.

Garretson, C. (1999c). Soil Bulk Density Determination. SOP FSSO001.00. Environmental Monitoring Branch, DPR. Available on-line: http://www.cdpr.ca.gov/docs/empm/pubs/sop.htm.

Garretson, C. (1999b). Soil Sampling, Including Auger and Surface Soil Procedures. SOP FSSO002.00. Environmental Monitoring Branch, DPR. Available on-line: http://www.cdpr.ca.gov/docs/empm/pubs/sop.htm.

Van Es, H.M. and R.R. Schindelbeck (undated). Field Procedures and Data Analysis for the Cornell Sprinkle Rainfall Simulator. Instructions For Use and Instructions for Replacing Infiltrometer Tubes from the Cornell Precision Agriculture Website, available online at http://www.css.cornell.edu/research/precisionag/infiltrometer.htm.

Figure 1. Sprinkle Infiltrometer in the field