Soils Laboratory

Standard Operating Procedure

1. Title: **Amoozemeter Permeameter**
2. Reference Method: Amoozemeter User Manual.
3. Purpose: To measure *in situ* hydraulic conductivity (Ksat). The instrument implements a set of water-filled tubes connected to a larger measuring tube and a probe. The tubes are connected via airtight connection tubes and a vacuum is created inside the instrument, thus eliminating the force of gravity and measuring solely the hydraulic conductivity of the soil at a desired depth.
4. Materials
   1. Amoozemeter complete with all tubes and stoppers
      1. Optional: additional set of constant tubes (“extensions”) for holes deeper than 2m
   2. Auger set with 5 or 6cm (2-inch) diameter bit, additional brush and planar bits, auger extensions, and mallet
      1. Optional: 2 ½-inch auger bit for holes deeper than 3m
   3. Rigid metal locking tape measure
   4. Stop watch or watch capable of reading seconds
   5. Adequate water for each measurement (approx. 1L for constant-head, 5L for reservoirs)
      1. Optional (but helpful): squirt bottle or funnel to facilitate pouring water into tubes
      2. Optional: water filters or full-size Bounty paper towels for on-site filtration of collected stream water and funnel.
      3. Tap water should have dissolved air levels as low as possible. Collect tap water well in advance of device operation to allow air to escape. Alternatively, collect tap water from an outlet with no aerator and make sure that air does not mix with it while filling the tubes.
      4. If using distilled or deionized water, it is advised to add a 0.005M CaSO4 or 0.005 to 0.01M CaCl2 solution to the water to improve results.
      5. 4L is usually sufficient for most soils (sandy surface horizons may take substantially more water!)
      6. Water hose
   6. Tarps for soil storage and easy return
   7. Small line levels
   8. Flashlight
   9. Optional: water depth meter
   10. Optional: perforated 2-inch PVC pipe or well screen, for soils that may be prone to collapse
   11. Optional: tent, umbrella or other device to shade the permeameter if exposed to direct sunlight or rain
   12. Optional: thermometer
   13. Optional: gloves, insect repellent, sunscreen
   14. Optional: hand pump and tubing to remove water in hole if needing to repeat msmt
5. Site preparation
   1. Locate a small, uniform area within the landscape. Clear the area of debris and prepare a small, level area where the device can rest next to the hole.
   2. Place the Amoozemeter near the hole before the first reading, using a level to establish stable, even placement
   3. Measure the top of the mineral soil to the base of the reading column
   4. Auger after clearing the organic horizon
      1. Determine the soil depth interval where measurement is desired. The depth interval will correspond with the depth of water under the constant head at the bottom of the auger hole.
      2. SAVE ~100g THE SOIL MATERIAL FROM THE LAST BUCKET BEFORE THE MEASUREMENT DEPTH.
         1. Label with consistent naming convention
         2. To be sent to Allan Bacon upon return from field (~100g max)
      3. “Surface readings” are taken at a 15cm hole (see #5, below)
      4. Describe the soil profile and determine the depth of any impermeable layers within at least 60cm below the maximum depth.
   5. Bore a 5 or 6-cm diameter hole (document size on data sheet) into the area until the desired depth is reached. The hole must be at least 15cm, or 5 times the hole’s radius, below the surface. Do not apply excessive force when boring, as this will cause smearing.
      1. It is easiest to bore in short intervals and remove the soil inside the bit every few inches. Use the mallet to tap the bit and force the soil out of the auger. Save this soil on a tarp to examine the site’s profile and to refill the hole later.
      2. For deeper sites, it is easiest to start boring with a larger, 2 ½-inch auger, and then switch to the 5-6cm auger about 50cm before reaching the desired depth.
   6. Using the brush bit, lower the auger into the hole and slowly brush the sides at the bottom of the hole. Use the planar auger to cut and clean the bottom of the hole to form a cylindrical hole. Do not use excessive force to shape the bottom, as this will cause smearing.
      1. To check that the site is appropriate to test, tap the brush bit with the mallet. If the soil on the brush falls off easily, the site is appropriate. Otherwise, the site may be too saturated and return inconclusive results.
      2. Optional: Insert perforated pipe or well screen if soil is likely to collapse.
   7. Place the permeameter at the edge of the hole and record the hole’s depth from the bottom of the hole to the top of the device’s base.
      1. If the permeameter rests more than 1cm above the hole’s opening, record the distance from the device base to the hole’s opening.
      2. If needed, cover the device with the tent or umbrella.
6. Permeameter preparation
   1. Inspect tubes and stoppers for dirt, grime or cracks. If needed, lubricate the variable tube. Never lube the stoppers on the bubble tubes or reservoirs.
   2. Fill each of the constant-head tubes to the water level mark; a few millimeters of error are allowed in the tubes. Tightly secure the stoppers.
      1. Use clean water or water filtered sufficiently to remove large particles.
      2. Each constant tube corresponds to 50cm of depth, so it is only required to fill one tube for each 50cm of depth. For example, for a 145cm hole, only the first three tubes (including the constant-head tube with the shorter variable tube) need to be filled.
   3. Place the valve in “OFF” position. Remove the rubber stop from the opaque reservoir tube and fill the reservoir with water to the top. The water will gradually flow into the clear measuring reservoir to fill it. To speed up this process, add water to the top of the measuring reservoir. Tightly secure the stoppers to the reservoirs.
      1. Optional: to correct for temperature, record the temperature of the water inside both reservoirs to use later.
   4. Calculate required head pressure (see data sheet on Page 6 of this SOP) to adjust the constant-head tube settings. For example:
      1. For a hole depth of 182cm, and the reference level is 10cm (the distance from the bottom of the measurement reservoir’s ruler to the top of the device’s base is always 10cm), then the distance from the hole bottom to the reference level is 192cm.
      2. The ideal depth of the water is calculated using the proportion of radius to height. The height of water should ideally be at or less than 5 times the hole radius. *For a 3cm radius, the ideal water height is 15cm.*
      3. Thus, the constant-head tube setting in this case would be 192-15=177. Dividing by 50 (for each 50-cm constant tube) leaves a remainder of 27. Thus, the small variable tube should be positioned in the constant-head tube such that the distance from the tube’s water level to the bottom of the small variable tube is 27cm. This often requires adjustment to get bubbles into all of the bubble tubes.
   5. Connect the connecting tubes in the following order:
      1. Connector tube from constant-head with the variable tube stopper to connection on top of the adjacent constant tube stopper. Repeat this step until all required water-filled constant-head tubes are connected.
      2. Connector tube from final constant tube to connector tube from measuring reservoir stopper (attached to long thin tube on other side of stopper).
      3. Connector tube from measuring reservoir stopper to opaque reservoir stopper.
   6. With the connection between the two main water storage reservations disconnected and the tube between measurement reservoir and the first constant head tube pinched, turn the device to “2-ON” and allow water to flow into the probe tube. Raise the tubing at various places to eliminate air bubbles.
      1. Make sure to keep the probe horizontal or upward, such that the metal circle is at or above the level of the base. This prevents additional air from entering the tube.
      2. Turn off. For deep holes, allow a VERY slow drip.
   7. Quickly lower the probe into the hole until it rests on the bottom.
      1. Optional: turn the valve to “1-ON” to increase accuracy.
         1. For very low conductivity soils, this step is recommended to assure one can read changes in small increments.
         2. Once the valve is turned to “1-ON” for longer than a couple of minutes, it cannot be turned back to “2-ON” as this would cause malfunction (in re-equilibrating the reading and primary water reservoir)
   8. If the reservoir empties quickly, as can occur with high conductivity soils, refill the reservoir before continuing measurements to avoid running out of water.
      1. Turn the device to “OFF”.
      2. Pinch the constant tube-reservoir connection tube and unplug the opaque reservoir.
      3. Quickly pour additional water into the reservoir.
      4. Plug the reservoir, unpinch the connection tube and turn the device back to “2-ON”, then “1-ON” if desired.
7. Operation
   1. Once the probe is settled inside the hole, wait for the bubbling in the tubes to approach a constant bubble flow.
      1. Check that all the constant tubes are bubbling uniformly. If some are bubbling but not others, this indicates that there is a leak somewhere.
      2. In holes >2m deep, it is common that bubbles do not make it past the 5th tube. Check at least occasionally that water remains in the hole (Solinst water meter helps).
   2. Lower the measuring tape into the hole at the desired water level. This depth should be equal to the hole depth minus desired water depth, plus one or two centimeters to verify if the tip was actually submerged. Thus, the desired value on the tape should hit right below the device base.
   3. Raise the measuring tape out of the hole and examine the tip to see how much water touched it. If there is water present, proceed to the next section. If not, raise the variable tube in the constant-head tube one centimeter and repeat this section.
   4. Optional: to correct for temperature, record the temperature at the bottom of the hole to use later.
8. Measurement
   1. After the meter has reached equilibrium, measure the initial height by the reading on the measuring reservoir.
   2. Determine a desired time interval for measurements and take a height measurement at each time.
      1. To ensure accuracy, make sure to take measurements at time intervals accurate to seconds.
   3. Once water height has become stable for at least three measurements, the soil has reached equilibrium.
      1. Optional: To correct for temperature, record the temperature of the water inside both reservoirs immediately after completing the final measurement.
   4. AFTER THE FINAL READING, WITH THE WATER STILL FLOWING, MEASURE DEPTH OF WATER IN THE HOLE
9. Analysis
   1. Steady-state is achieved when cm drop reading is consistent for 3 time steps.
      1. For high conductivity soils, allow adequate time for equilibrium to establish. Taking 3 1-minute measurements, for example, may lead to erroneous results.
   2. Aggregate 3 time steps to calculate final k-sat measurement rather than averaging smaller/shorter time steps.
   3. The conversion factors for “2-ON” and “1-ON” are 105 cm2 and 20 cm2, respectively. This means that one cm drop in the measuring reservoir corresponds to 105 or 20 cm of water flow from the permeameter.
   4. The temperature of water entering soil at the bottom of the hole may affect the hydraulic conductivity of the soil. The steady-state flow rate and Ksat can be corrected for any temperature.
      1. To correct for temperature, multiply the final steady-state flow rate by the ratio of viscosity at the temperature during measurement and the reference temperature, which may be chosen as the mean annual soil temperature at the depth of interest. The temperature during measurement can be either the temperature at the bottom of the hole or the average of the temperatures taken inside the reservoirs.
10. Moving sites
    1. Remove the probe and wash off with clean water.
    2. To reduce water waste when moving sites, disconnect constant connection tubes by first pinching the connection tube and then disconnecting. This ensures that water will not move from one tube to another and change the water levels.
    3. Carry the device to the next location and repeat the procedure.
       1. If walking the device to a nearby site, the water can be left inside the tubes. If transporting the device long distances, especially in a vehicle, the device should be emptied of water before transport or secured well in an upright position.
11. Cleanup
    1. Turn the switch to “OFF” and remove the probe from the hole. Remove stoppers and pour water over probe to clean it off.
       1. Dry the device using gravity or paper towels if desired, but device can be stored damp if water is clean.
       2. If filtered stream water was used in the device, turn it upside down and hose it out to flush out any silt that may have settled in the device.
       3. Clean the device to prevent microorganism growth due to impurities in water.
    2. Refill the auger hole.
    3. Store the device in a cool, dark place to prevent stopper deformation due to light and heat. Do not store in direct sunlight or in places where temperature may rise above 50°C (120°F) (i.e. in a vehicle under the sun).

CCHP Data Sheet

Date: Location:

Soil and horizon:

Radius of hole (*r*): Depth from surface to hole bottom:

Distance from surface to reference level:

Total distance from reference level to hole bottom (*D*):

Desired depth of water in hole (*H*):

Desired distance to water level *d* = *D* - *H*:

Measured final value of d at steady state:

Final value of *H* = *D* - *d*:

Three-way valve position used: \_\_\_ 1-ON \_\_\_ 2-ON

Conversion factor: 20 cm2 105 cm2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Time | Change in time (min) | Water Level (cm) | Change in level (cm) | *Q*s  (cm3/min) |
|  | XXXXXXXX |  | XXXXXXXX | XXXXXXX |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

Steady-state *Q* \_\_\_\_\_\_\_\_\_

Steady-state *K*s \_\_\_\_\_\_\_\_\_