UVIVERSITY OF IDAHO
CE326/BAE356/FOR463
HYDROLOGIC MEASUREMENT TECHNIQUES

Laboratory Assignment #3

Student Name:

XXXXX

Title:

Infiltration Laboratory

[Note to Students: This is provided as a general example only. Notes are provided to show where the report could be improved. Variations are likely – discuss your report with the instructor if you have questions. Do NOT plagiarize this report!]

Date of Exercise:

Date of Submission:

Introduction

Infiltration is the term applied to the process of water entry into the soil, generally by downward flow through all or part of the soil surface. The rate of this process, relative to the rate of water supply, determines how much water will enter the root zone, and how much, if any, will run off (Hillel, 1998). Hydraulic conductivity is one of the most important parameters in characterizing the transport of fluids and solutes through the vadose zone, but presents significant practical difficulty in measurement. In vadose applications, knowledge of the saturated hydraulic conductivity is often of limited use, as saturated conditions are rare in most locations. Yet, few reliable methods exist for measuring the unsaturated hydraulic conductivity. One common approach to obtain the unsaturated hydraulic conductivity relationship is to measure both the saturated hydraulic conductivity and the water retention curve and estimate the unsaturated conductivity based on a conceptual model relating conductivity to water content (van Genuchten, 1980).

In general, two types of laboratory methods to measure the saturated hydraulic conductivity: constant-head and falling-head permeameters. It seems unrealistic however to measure the unsaturated hydraulic conductivity of the field soil by making laboratory measurements on discrete samples removed from their natural continuum. Such samples are generally dried, fragmented, and repacked into experimental containers so that the original structure is destroyed. Hence, it is necessary to device and test practical methods foe measuring the saturated hydraulic conductivity on a realistic scale in situ (Hillel, 1998). Field techniques to measure the saturated hydraulic conductivity can be divided into four categories: percolation tests, ring infiltrometers, disk infiltrometers and sprinkler infiltrometers.

Objectives

The main objective of this laboratory was to get acquainted with field methods commonly used to determine infiltration and/or selected soil properties. Field methods in the exercise were:

- Single Ring Infiltrometer
- Tension Infiltrometer
- Mini Disk Infiltrometer

Methodology

Infiltration experiments were conducted with three infiltrometers on a field in front of the Buchanan Engineering Laboratory. Procedures given in the assignment sheet, included as Appendix A, were followed. A summary of the methods used to compute hydraulic conductivity for each of the methods is provided here.

[Note: Even though procedures on handout were followed, a brief summary in your own words should be added. Include both *Field Methods* and *Analysis Methods*.]

Results

The ring infiltrometer measurement resulted in a hydraulic conductivity value of 1.3×10^{-3} cm/s. Table 1 shows the results of the tension infiltrometer measurements made with the Ankeney

Method program. [Note: should include reference.] The mini-disc infiltrometer value was $7.4x10^{-5}$ cm/s.

Table 1. Infiltration rates and saturated hydraulic conductivity using the Ankeny Method.

Tension (cm)	Infiltration Rate (cm^3/min)	Hydraulic Conductivity (cm/s)
0	11.74	$3.9x10^{-4}$
3	10.37	$3.5x10^{-4}$

[Note: all results could be presented on a single table or figure for easy comparison. Also, it might be ok to include some of the intermediate results, such as the graphs with computed slopes, in the Results section. Raw data here is not acceptable, however.]

Discussion

Measured saturated hydraulic conductivities obtained from the three methods vary proportional to the scale of the experiment. The largest K_{sat} ($1.3 *10^{-3}$ cm/s) was obtained with the Single Ring infiltrometer, which had the larger infiltration area. The values of K_{sat} obtained with the Tension infiltrometer were $3.9 *10^{-4}$ cm/s for the 0cm suction, and $3.5 *10^{-4}$ cm/s for the 3cm suction. The smallest value of K_{sat} ($7.4 *10^{-5}$ cm/s) was obtained with the Mini Disc infiltrometer. Even though the experiments were conducted in close proximity to each other some differences in measuring K_{sat} may be related to the heterogeneity within the silt loam soil.

[Note: It would be appropriate to compare the results to typical values for this soil.]

All of the applied methods/equipment have their limitations including measurement error. Brief descriptions of disadvantages and advantages for each instrument are given below.

Single Ring Infiltrometer

The single ring infiltrometer is inexpensive to construct and operate. One person can set up and run several tests simultaneously. The test, however, requires the most water of all three methods. The simplicity of the infiltrometer's design allows for ease in replication and operation. Lateral flow is the most serious limitation in using of ring infiltrometers (Hills, 1971). Another serious limitation is the method of placement. Hammering or jacking the rings into the ground can result in destruction of soil structure (for dry soils) or compression (for moist soils) influencing the true value of the saturated hydraulic conductivity. The practicality of the instrument is reduced by the fact the ring is relatively heavy. A flat undisturbed surface is required which sometimes may not be feasible. Edge effects may include flow along the edge of the cylinder causing the infiltration rate to be overestimate.

Tension Infiltrometer

The tension infiltrometer is a more complex device than the ring infiltrometer. Preferably, two persons are needed to conduct an infiltration experiment. It is critical to maintain excellent contact between the disc and the soil, which is not always easy to do especially when there is no loose fine soil close at hand to prepare the surface. A flat undisturbed surface is required which may not be feasible. During the experiment the mariotte bottle needs refilling for light textured soils. To do this, the tap has to be turned off which disrupts the experiment. One distinct advantage of disc permeameters in general is that they can operate in soils containing macropores because the pressure head along the bottom of the membrane during testing is maintained at a slight tension with respect to atmospheric pressure, so water does not flow into macropores Stephens (1996). On the other hand I think that this prevents to mimic the natural occurring conditions in soils with macropores.

Mini Disk Infiltrometer

The mini-disk infiltrometer is very simple, small and easy to use. It uses very little water in comparison to the other methods and can be easily operated by one person. Like in the disc infiltrometer method it is crucial to maintain excellent contact between the disc and the soil which was extremely difficult while running the experiment. The soil surface must be really smooth and level. Definitely a ring stand and clamp are necessary to suspend the infiltrometer due to its small dimensions and light weight. There were some difficulties taking the readings due to its small height.

The hydraulic conductivity is obviously affected by structure as well as by texture, being greater if the soil is highly porous, fractured or aggregated than if it is tightly compacted and dense. Hydraulic conductivity depends not only on total porosity but also on the sizes of conducting pores. Cracks, worm holes, and decayed root channels - generally called macropores - are present in the field and may affect flow in different ways, depending on the direction and conditions of the flow process. In general, these passages will run full of water and contribute to the observed flux and measured conductivity (Hillel, 1998).

Summary

In this laboratory students were acquainted with field methods commonly used to measure infiltration and calculate the saturated hydraulic conductivity. Three methods were used: Single Ring Infiltrometer, Tension Infiltrometer and Mini Disk Infiltrometer. The saturated hydraulic conductivity varied depending on the method applied, and was proportional to the scale of the instrument. Limitations associated with each device were discussed.

References

1. Hillel, D. 1998. Environmental Soil Physics. Academic Press.
2. Or, D., Jon M. Wraith, Markus Tuller. 2002. Agricultural and Environmental Soil Physics. Not published
3. Selker, J.S. et al.1999. Vadose zone processes. Lewis Publishers.
4. van Genuchten, M.T. 1980. A closed form equation for predicting the hydraulic conductivity of unsaturated soils." Soil Sci. Soc. Am. J. 44:892-898
5. Klute, A. et al. 1986. Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods. Second Edition. American Society of Agronomy, Inc.
6. Hills, R.C. 1971. Lateral flow under cylinder infiltrometers: A graphical correction procedure. J. Hydrology 13:153-162.
7. Stephens, Daniel B. 1996. Vadose Zone Hydrology. Lewis Publishers

Appendix A
Lab Handout

Appendix B

Ring Infiltrometer Data and Analysis

Data and results from the Single Ring infiltrometer test are listed in Tables 3a and 3b. [Note: Table numbering and format can be improved.]

Tab.3a Single Ring infiltrometer data

Time [min]	Height of water [in.]	Height of water [cm]	Volume of water [cm3]	Infiltration [cm]
0	2.25	5.72	9113.41	0
28	1.375	3.49	5569.30	2.22

Tab.3b Single Ring infiltrometer data

ring diameter	17.74	in
ring diameter	45.06	cm
ring area	1594.65	cm2
k	0.079375	cm/min
k	**0.001323**	**cm/s**

Appendix C
Tension Infiltrometer Data and Analysis

Tables 1 and 2 present the results obtained from the tension infiltrometer method for 3 cm and 0 cm tension, respectively. Figures C-1 and C-2 show cumulative infiltration versus time, and results of regressions for the steady state infiltration conditions. Steady infiltration rates were used as input for calculation of the saturated hydraulic conductivities by the Ankeny Method Program.

Tab.1 Tension infiltrometer data for 3 cm suction

Height of water in the cylinder [cm]	Elapsed time [sec]	Time differ. [sec]	Elapsed time [min]	Volume for given height [cm3]	Cumulative volume [cm3]
67.5	0	0	0.0	342.0	0.0
62	22	22	0.4	314.2	27.9
60	33	11	0.6	304.0	38.0
58	48	15	0.8	293.9	48.1
56	65	17	1.1	283.8	58.3
54	83	18	1.4	273.6	68.4
52	103	20	1.7	263.5	78.5
50	128	25	2.1	253.4	88.7
48	148	20	2.5	243.2	98.8
46	167	19	2.8	233.1	108.9
44	199	32	3.3	223.0	119.1
42	225	26	3.8	212.8	129.2
40	258	33	4.3	202.7	139.3
38	290	32	4.8	192.5	149.5
36	328	38	5.5	182.4	159.6
34	366	38	6.1	172.3	169.7
32	414	48	6.9	162.1	179.9
30	461	47	7.7	152.0	190.0
28	510	49	8.5	141.9	200.1
26	554	44	9.2	131.7	210.3
24	603	49	10.1	121.6	220.4
22	656	53	10.9	111.5	230.6
20	710	54	11.8	101.3	240.7
18	766	56	12.8	91.2	250.8
16	824	58	13.7	81.1	261.0
14	884	60	14.7	70.9	271.1
12	942	58	15.7	60.8	281.2
10	1005	63	16.8	50.7	291.4
8	1081	76	18.0	40.5	301.5
6	1140	59	19.0	30.4	311.6
4	1205	65	20.1	20.3	321.8

Tab.2 Tension infiltrometer data for 0 cm suction

Height of water in the cylinder [cm]	Elapsed time [sec]	Time differ. [sec]	Elapsed time [min]	Volume for given height [cm3]	Cumulative volume [cm3]
58.7	0	0	0.0	297.4	0.0
56	29	29	0.5	283.8	13.7
54	69	40	1.2	273.6	23.8
52	119	50	2.0	263.5	33.9
50	170	51	2.8	253.4	44.1
48	221	51	3.7	243.2	54.2
46	275	54	4.6	233.1	64.4
44	327	52	5.5	223.0	74.5
42	378	51	6.3	212.8	84.6
40	432	54	7.2	202.7	94.8
38	482	50	8.0	192.5	104.9
36	535	53	8.9	182.4	115.0
34	590	55	9.8	172.3	125.2
32	640	50	10.7	162.1	135.3
30	694	54	11.6	152.0	145.4
28	745	51	12.4	141.9	155.6
26	798	53	13.3	131.7	165.7
24	844	46	14.1	121.6	175.8
22	898	54	15.0	111.5	186.0
20	948	50	15.8	101.3	196.1

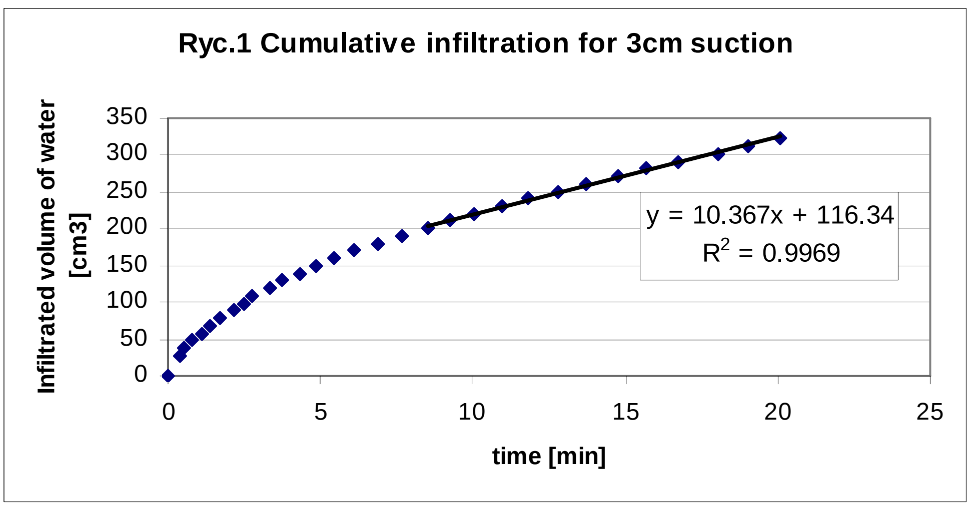

Figure C-1. Cumulative infiltration volume versus time for 3 cm suction in tension infiltrometer.

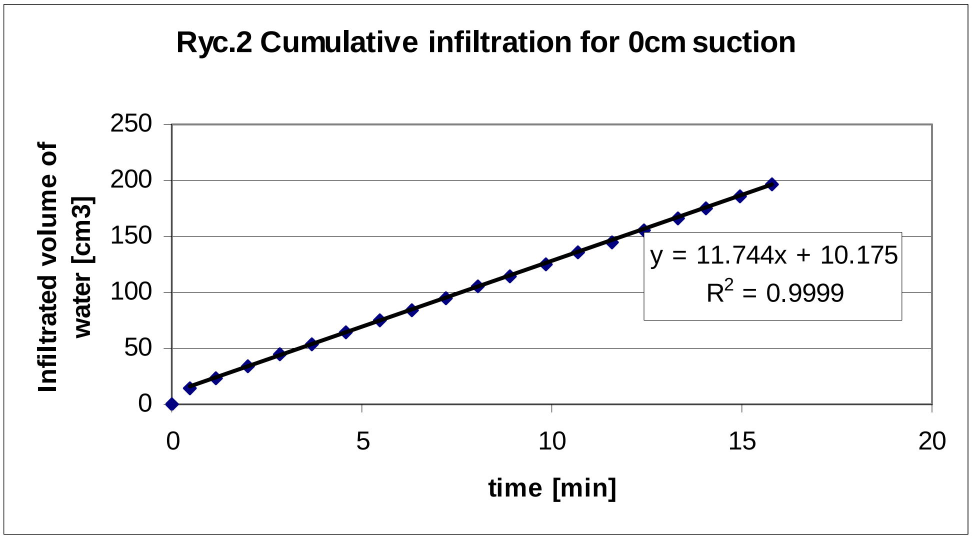

Figure C-2. Cumulative infiltration volume versus time for 0 cm suction in tension infiltrometer.

Appendix D
Mini-Disc Infiltrometer Data and Analysis

Table 4 lists data for the Mini Disk infiltrometer at 2cm suction. The parameters of the Mini Disk as well as relevant soil parameters for a silt loam soil are listed in Table 5. Figure 3 depicts the result of the Mini Disc infiltration experiment. A polynomial regression was applied to the data in Figure 3 to calculate the saturated hydraulic conductivity.

[Note: Again, table and figure numbering can be improved]

Tab.4 Mini Disc infiltrometer data for 2cm suction

Elapsed time [min]	Elapsed time [sec]	Reading volume [cm3]	Infiltrated volume [cm3]	SQRT time [-]	Infiltration [cm]
0	0	37.0	0.0	0.00	0.00
0.5	30	35.5	1.5	5.48	0.19
1	60	35.0	2.0	7.75	0.25
2	120	33.5	3.5	10.95	0.44
3	180	32.5	4.5	13.42	0.57
4	240	32.0	5.0	15.49	0.63
5	300	31.0	6.0	17.32	0.76
6	360	30.0	7.0	18.97	0.88
7	420	29.5	7.5	20.49	0.94
8	480	29.0	8.0	21.91	1.01
9	540	28.5	8.5	23.24	1.07
10	600	28.0	9.0	24.49	1.13
11	660	27.0	10.0	25.69	1.26
12	720	26.5	10.5	26.83	1.32

Tab.5 Other Mini Disc infiltrometer data

Mini Disc parameters			**silt loam soil parameters**		
radius	1.59	cm	alpha	0.02	1/cm
suction	2	cm	n	1.41	-
suction area	7.94	cm2	A(0.5)	8.1	-
			k	**0.000074**	**cm/s**

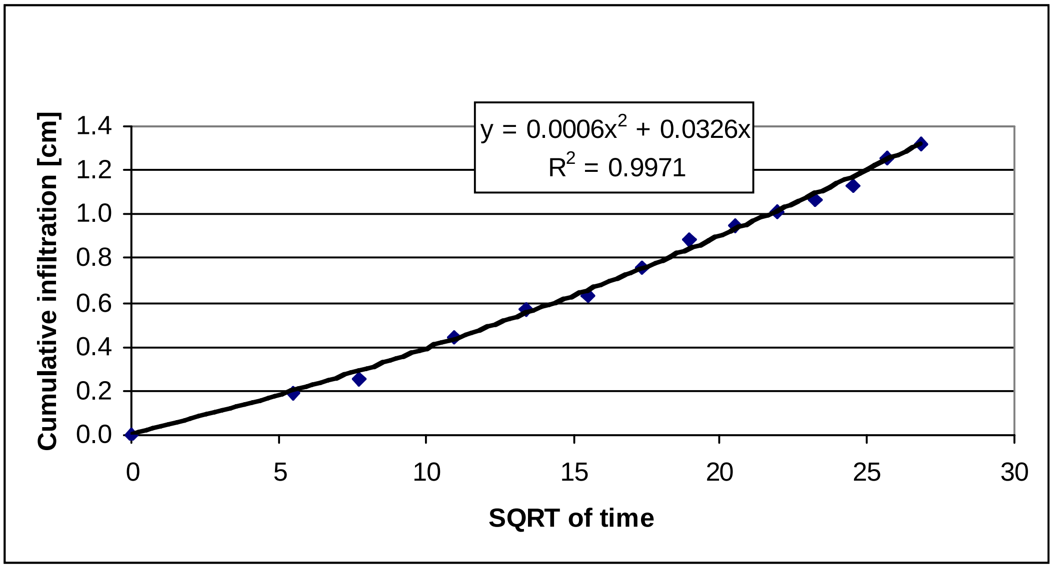

Figure 3. Cumulative infiltration volume at 2 cm suction in mini disc infiltrometer.