Consequences of Recreational Land Use at the Green Mountain Audubon Nature Center: Soil Infiltration and runoff rates

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The Green Mountian Audubon Center, in Huntington Vermont recieves a high amount of recreational land use. Different forms of land use have direct affects upon the infiltration and runoff rates of soils. The primary objective of our research was to analyze the affects of recreational land use on soil infiltration and runoff rates at the Audubon Nature Center in Huntington, Vermont. Our data showed that a natural control site had a steady state infiltration rate of 17.3 cm/hr when we simulated an average rainfall intensity of 17.4 cm/hr for 64 minutes. At an unpaved parking lot, an average rainfall intensity of 11.2 cm/hr was simulated for 2 trials, and an average steady state infiltration rate was reached after about 30 minutes. At a compacted trail, we simulated an average rainfall intensity of 14.8 cm/hr, and after about 20 minutes, a steady state infiltration rate of 9.75 cm/hr was reached. According to Dunne and Leopold (1977), every 100 years a 30 minute storm event will occur with a rainfall intensity of 9.0 cm/hr. Our data suggests that a rainfall event of this magnitude would cause runoff on the unpaved parking lot, and possibly the compacted trail. No natural rainfall event should ever cause runoff for the natural area.

Introduction

Different forms of land use have direct effects upon the infiltration and runoff rates of soils. Infiltration and runoff rates are dependent upon soil type, surface slope, density and type of vegetation, and soil condition (seasonal variations, soil saturation, soil compaction). (USDA,1998), (McNeill, 2001), (Jubenville, 1987). Changes in these characteristics, as a result of land use, often causes a reduction in infiltration and an increase in runoff. Increased runoff heightens the potential for erosion (Deluca, 1998). Runoff and erosion are possible carriers of pollutants deposited through human land use (USDA, 1998). Often runoff and its constituents, without the natural filtering mechanism of infiltration, flow directly into and contaminate water supplies. The primary objective of our research was to analyze the affects of recreational land use on soil infiltration and runoff rates at the Audubon Nature Center in Huntington, Vermont and to evaluate and discuss how our findings relate to the transport of pollutants into the Huntington River.

Methods

We preformed our research at three sites within the River Trail area of the Green Mountain Audubon Nature Center, located in Huntington Vermont (Figures 1-3). We chose each site to represent a different type of land use: the River Trail's unpaved parking lot, a site along the trail (sloping into the Huntington River), and the edge of a forest abutting a field. At the three sites we simulated rainfall to measure infiltration and runoff rates.

For each site we set up the Experimental Confined Rain Simulation and Runoff Collection apparatus, illustrated in figure 4. This set up consists of an area confined by a metal frame open approximately 10cm at the down slope end, with a funnel extending off the open end. Plaster around the edges of the down slope end prevents loss of runoff and forces water to flow out the funnel and into numbered runoff collection buckets (covered by a sheet of tin foil to prevent collection of rain instead of the desired runoff). The collection buckets reside within a larger stabilizing bucket within a dug out pit. We simulated rainfall using backpack pump sprayers. Rainfall was collected by three rain gauges within the confined area. Once runoff was seen, the time was recorded, collection bucket one was placed in the stabilizing bucket, and rainfall was measured in each rain gauge. Then, once a set amount of runoff was collected, depending upon observed relative runoff rates of the soil being sampled (e.g. a full bucket for a fast runoff rate, 1/4 a bucket for a slow rate); the time was recorded, the collection bucket was switched, and the cumulative rainfall was measured. This process was repeated until the end of each trial, which ideally was determined by a consistent time interval between approximately equal amounts of runoff (indicating infiltration and runoff rate stability). After each trial, the collected runoff for each time interval was measured and recorded. These data were later analyzed using Microsoft Excel™.

Two successive trials were conducted for both the parking lot and the trail sites, while only one trial was done for the natural control site. For the parking lot trials, three people participated; one sprayed, one recorded, and one person changed collection buckets and read rain gauges. For the natural site, two people participated; both sprayed, changed buckets, and read rain gauges. For the trail, two people participated; one sprayed and read rain gauges, while one recorded, read rain gauges, and changed collection buckets. The slope of each site was measured. For each site observations of erosion, soil type, and soil condition were noted.

Data, Observations, and Calculations

Soil conditions vary at each test site, resulting in different infiltration rates for each trial. Figure 5 has detailed descriptions and observations of each test site such as soil type, condition, compaction, and slope. A record of our data is included in the appendix. Through calculations (see Excel spreadsheet) included in the appendix, we determined infiltration and runoff rates for each trial. **For trial 1 at the parking lot**, 6.6 cm of rainfall was simulated at an intensity of 10.6 cm/hr for 37 minutes. After 3 minutes runoff was observed. After soil saturation, the steady state infiltration rate was 7.0 cm/hr (Figure 6). **For trial 2 at the parking lot**, 4.8 cm of rainfall was simulated at an intensity of 11.9 cm/hr for 24 minutes. After about 1 minute, runoff was observed. After soil saturation, the steady state infiltration rate was 8.5 cm/hr (Figure 7). **At the River Trail plot, trial 1** had approximately 5.1 cm of rain simulated at an intensity of 13.7 cm/hr, over 22 minutes. Runoff was observed after about 2 minutes. After soil saturation, the steady state infiltration rate was 8.5 cm/hr (figure 8). **For trial 2 at the River Trail**, approximately 4.8 cm of simulated rain fell over 18 minutes, yielding an intensity of 15.9 cm/hr. After less than one minute, runoff was observed. The steady state infiltration rate was 11.0 cm/hr (Figure 9). For the third site, **the natural area**, one trial was conducted as the duration for this trial lasted about 64 minutes. We simulated 18.5 cm of rainfall at an intensity of 17.4 cm/hr. Runoff was observed after 16 minutes, and at the end of the trial, the steady state infiltration rate was 17.3 cm/hr (Figure 10).

Discussion and Interpretation

Significantly more runoff was generated by the parking lot and the trail than by the natural area. At the natural area, two backpack sprayers were required at all times to sustain consistent runoff. When one sprayer ceased, to record data or check a gauge, an immediate drop in runoff was observed, evidencing the soil's great ability to allow infiltration. For trials 1 and 2 at the parking lot it took, respectively, 180 and 65 seconds to cause initial runoff, showing that capacity for infiltration greatly decreased with saturation. This was also seen for the River Trail trials 1 and 2, as it required 117 and 47 seconds, respectively, to cause initial runoff.

The condition of the soil at each site dictated how much of our simulated rainfall infiltrated the ground, and how much ran off into our collection buckets. At the natural site, we initially assumed there would be immeasurable runoff, due to undisturbed vegetated soil's ability to infiltrate (Thomas and Henden, 1996). Upon setting up the plot, we discovered that the area had been recently plowed. Plowing disturbs the soil, causing compaction, which in turn causes runoff (USDA, 1998). Another factor that likely caused increased runoff during our experiment was the state of the trail's soil at the beginning of trial 1. We began trial 1 with a centimeter thick layer of frost in the soil, which accounted for the soils lower capacity for infiltration compared to trial 2, where the soil was thawed (Jubenville 1987). The ECRSRC set up introduced error by allowing some of the runoff to escape the confined area, not reaching the collection bucket. This caused an over estimate in infiltration, since we assumed what rainfall was not running off was infiltrating.

After soil saturation, the natural area reached a steady state infiltration rate of 17.3 cm/hr, while the parking lot had an average infiltration rate of 7.75 cm/hr and the trail had an average infiltration rate of 9.75 cm/hr (Figures 6-10). The natural area, with saturated soils, was able to infiltrate 220% more than the parking lot and 177% more than the trails, which can be attributed to the greater soil compaction of the two disturbed sites compared to the natural area.

While performing this research, numerous motor vehicles drove in and out of the parking lot. Many of the people who visited the Nature Center brought their dogs to walk the trails.

Overall, the River Trail and its parking lot see a lot of traffic, accounting for the compaction of the soil.

Conclusions

After analyzing the infiltration and runoff rates of the parking lot, trail, and natural area, we conclude that human land use causes soil compaction which in turn causes soil to lose capacity for infiltration, creating runoff. The natural area reached a steady state infiltration rate of 17.3 cm/hr. The simulated rainfall intensity of 17.4 cm/hr is significantly greater than any expected rainfall VT would see in a storm event. According to Dunne and Leopold (1977), every one hundred years a 30 minute storm event will occur with a rainfall intensity of 9 cm /hr. At this rate there will never be runoff at the natural area because the infiltration rate exceeds the maximum rainfall rate. We calculated the parking lot's capacity for infiltration to be about 7.75 cm/hr, this is exceeded by the maximum rainfall event expected for the region, indicating that it may not have the capacity to filter pollution, preventing it from washing into the river (USDA, 1998). The estimated runoff rate for the trail is 9.75 cm/hr. We have concluded that these infiltration rates are underestimates so it is likely that the trail too would have runoff during the hundred-year storm event. If gasoline leaked in the parking lot, or garbage was thrown on the trail, during any significant rainfall event these pollutants would likely enter the river. Figure 9 discusses the unhealthy state of the shores of the Huntington River due to deforestation, and increased erosion and runoff. The shores adjacent to our test site exemplify an unhealthy riparian zone. In a healthy riparian zone, vegetated slopes prevent erosion and runoff with their stabilizing roots, allowing for water to infiltrate, and the soil to naturally filter pollutants. Since this is a heavily used recreational area, we suggest efforts be made to re-vegetate the shores of the Huntington River along the River Trail.

References

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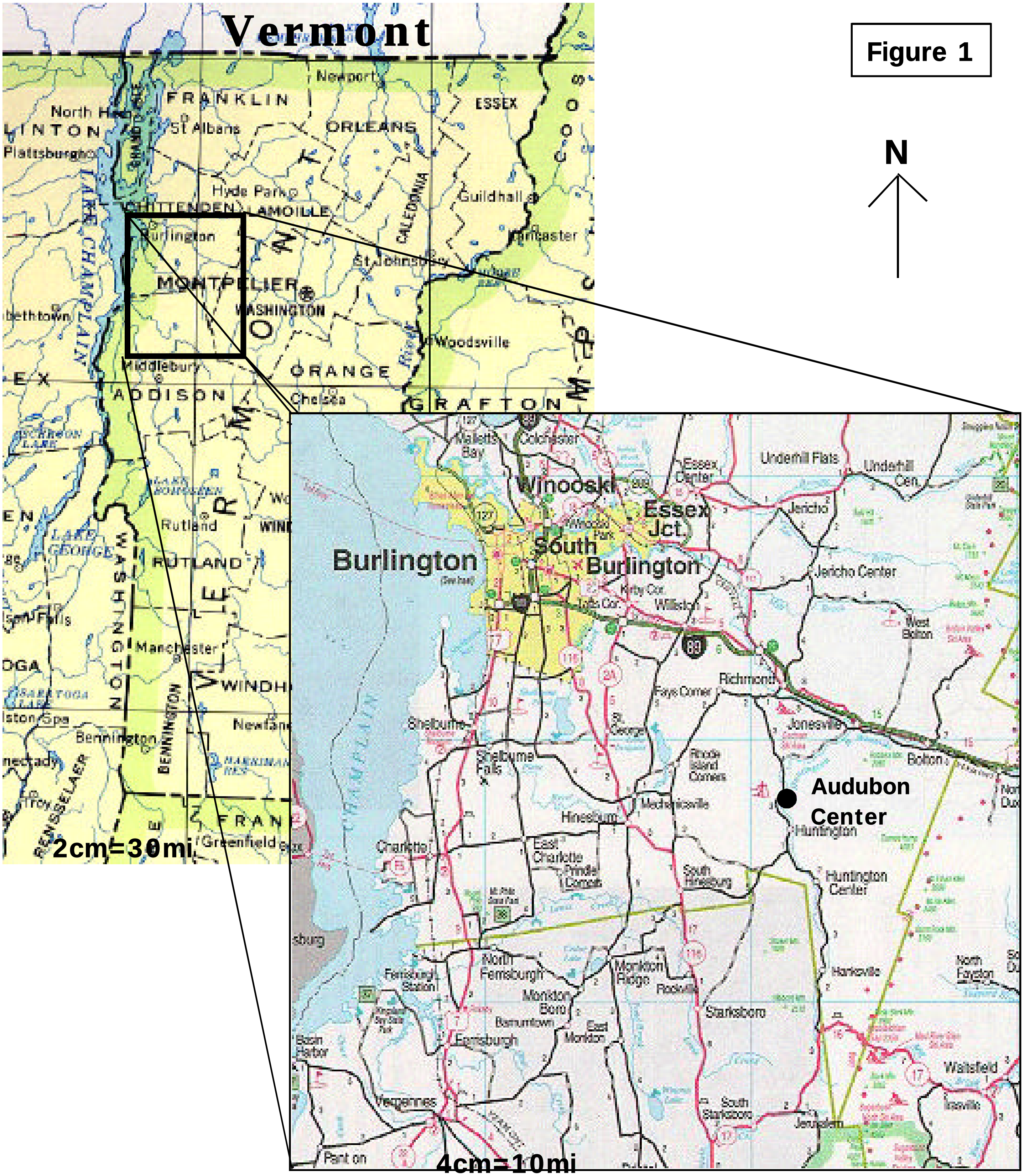


Figure 1: The Green Mountain Audubon Center is located near Huntington Vermont. At the audubon center we studied soil infiltration and runoff rates of three different areas. Our research addressed the problem of how human activity may change soil characteristics and discussed the implications of increased erosion.

Figure 2

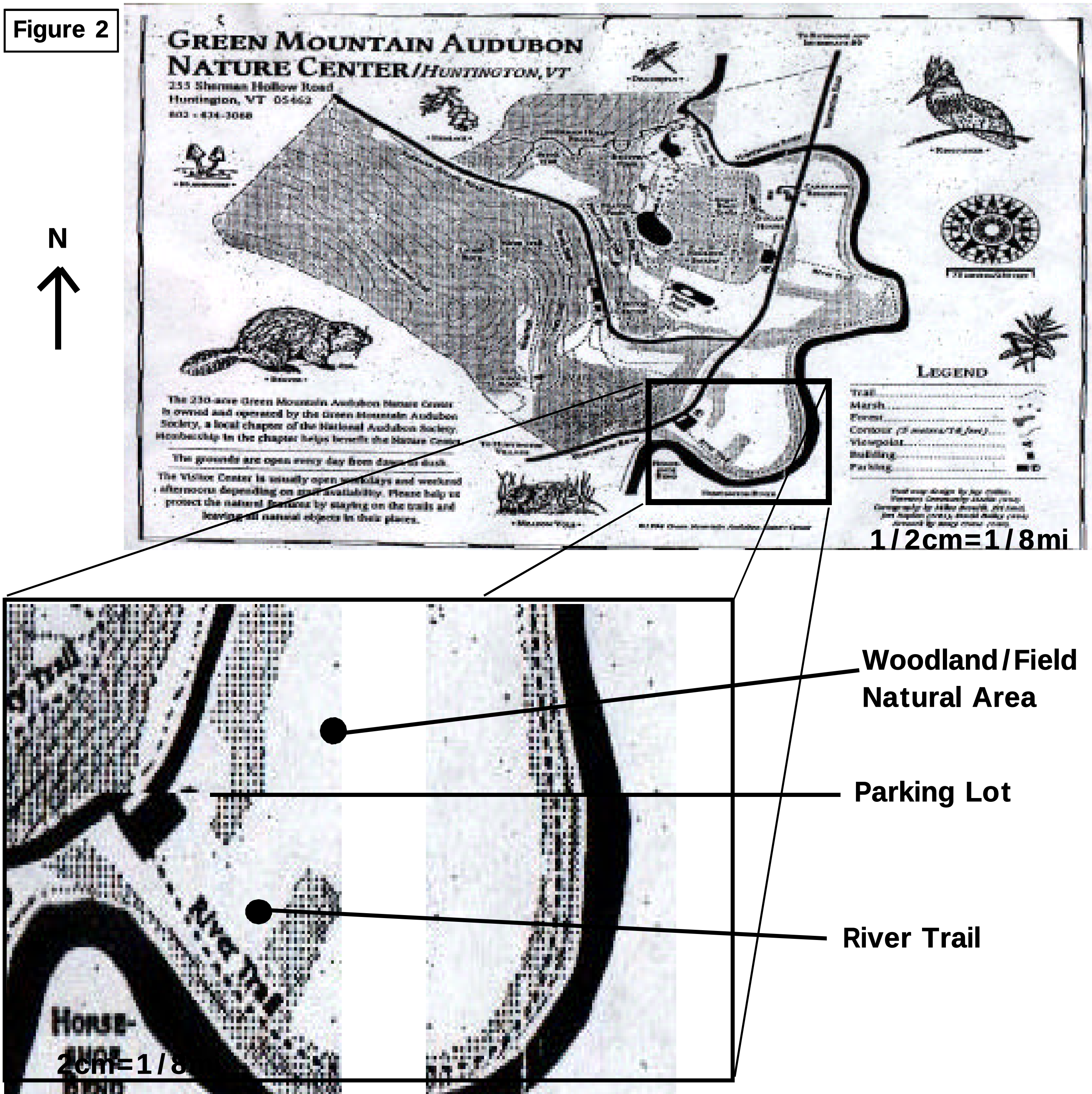


Figure 2: The [illegible]rail of t[illegible]reen Mountain Audubon Nature Center is located just off Huntington Road. The River Trail area is bordered by the Huntington River on the East and by a steep hill across the road to the West. The hill and the River Trail area both slope down to the east, clearly all drainage leads directly to the river. The area consists of a highly compacted limestone/gravel parking area, a well used recreational trail, and is surrounded by a mix of previously plowed fields and forest. Infiltration and runoff rates, for the three sites shown on the enlarged map, were measured by confined rainfall simulation and runoff collection.

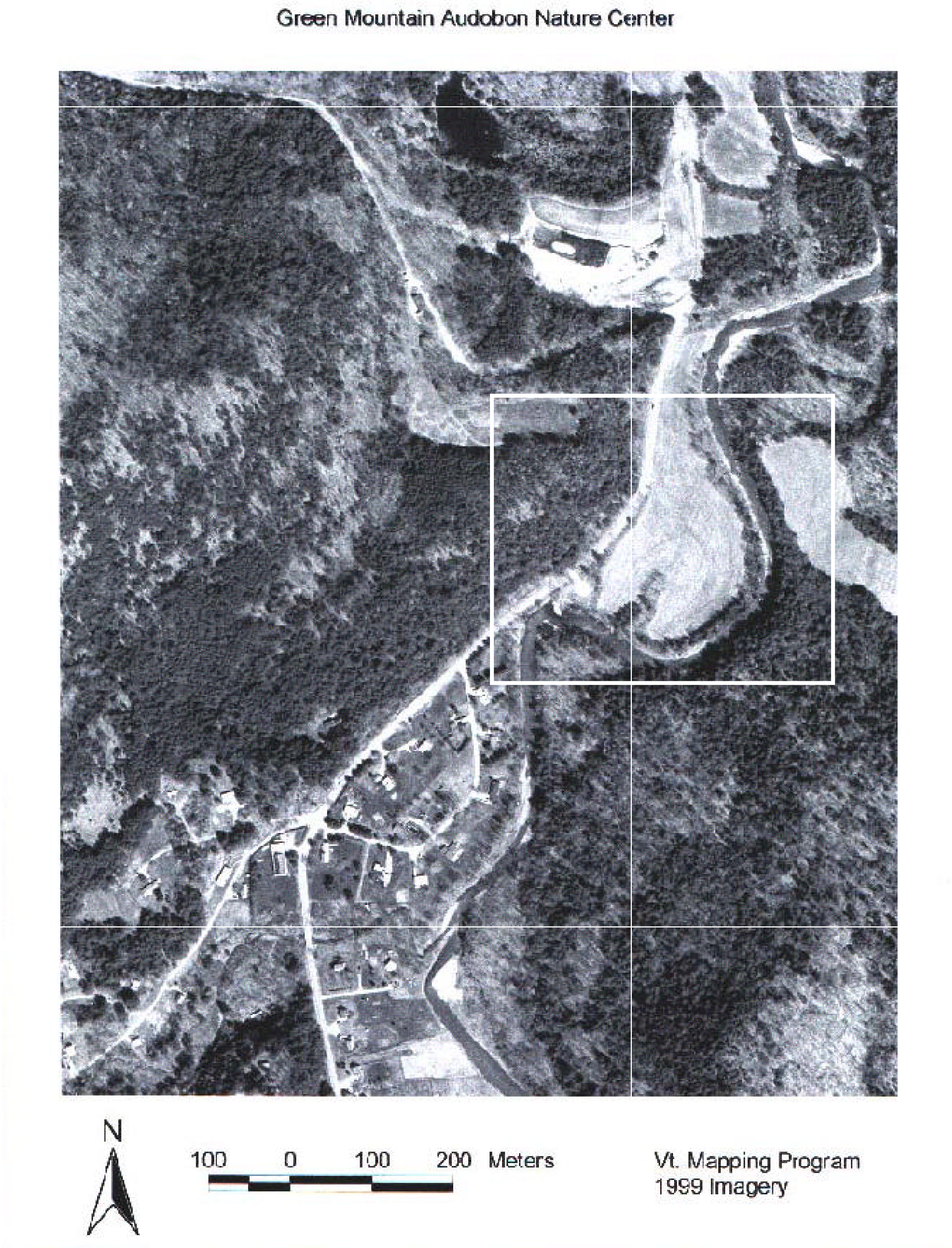


Figure 3: A photograph from the air of the River Trail area, highlighted above. The three test areas can be seen. The open field/thin forest was used as the natural constraint, the small parking lot (the very light rectangle just off Huntington road), and the trail which runs along the small stand of trees boardering the river.

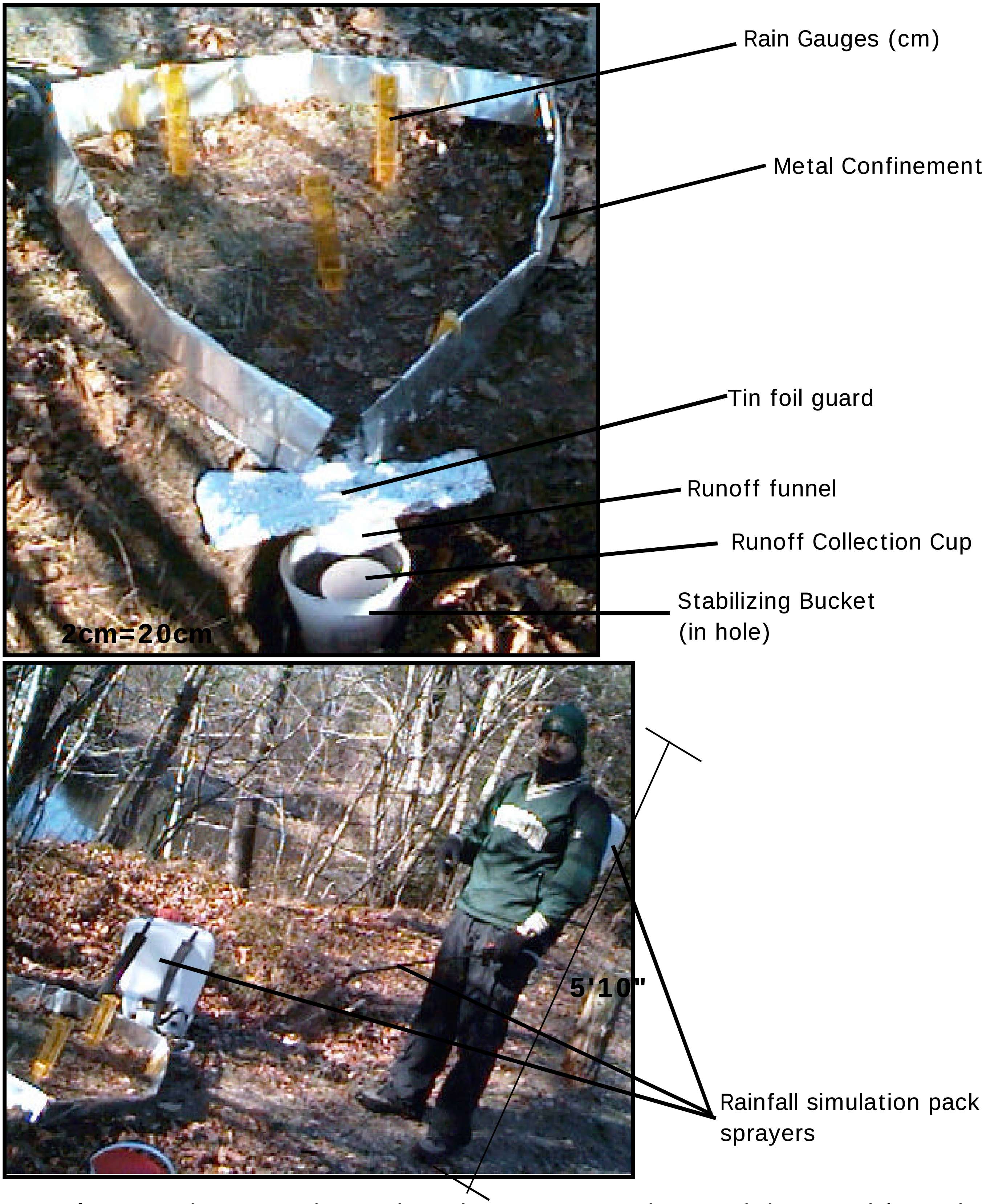


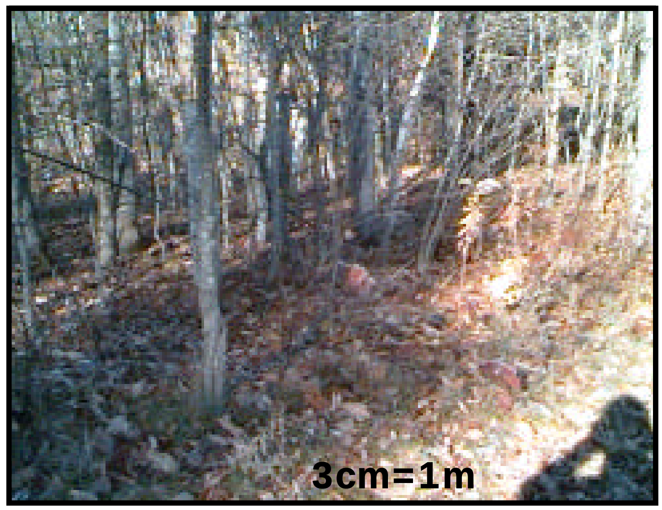
Figure 4: These two photos show the apparatus and most of the materials used in the experimental Confined Rain Simulation and Runoff Collection set up. Nathan is the scale in this photograph. (photographs taken by authors)

Figure 5

The River Trail parking lot was primarily composed of a mixture of highly compacted sand, gravel and limestone. Its slope, see countour lines in (figure 2), trended from the Huntington Road (to the Northwest) down towards the Huntington River (to the Southeast). The two trials were conducted in a plot which was set up on the southeast corner of the parking lot. The slope at this site was 3 degrees down and approximately perpendicular to the river. Between the parking lot and the river was a small portion of grass covered soil and a steep bank with some trees leading to the river.

The natural area was located to the North of the parking lot, at the edge of a forest. The plot was densely covered with grass and leaf litter, and it was surrounded by shrubs and trees. The hole dug for the collection bucket was approximately 12cm deep. The first 10cm consisted of a homogenous mixture of sand and silt. A uniform contact was observed between this layer and the one below, which was interpreted as a plow horizon. The field sloped to the East, toward the Huntington River. The dip angle of our plot was 11 degrees.

NW



The River Trail plot was located approximately 20m East of the parking lot on a small trail that connected to the main trail, sloping South at 6 degrees, directly towards the Huntington River. The soil was highly compacted and consisted of sand and silt. The trail was eroded into a gulley with steep banks approximately 1.5 m down the trail. The first trial was conducted while the upper 1 cm of soil was heavily frosted. For the second trial, the ground had sufficiently thawed.

S

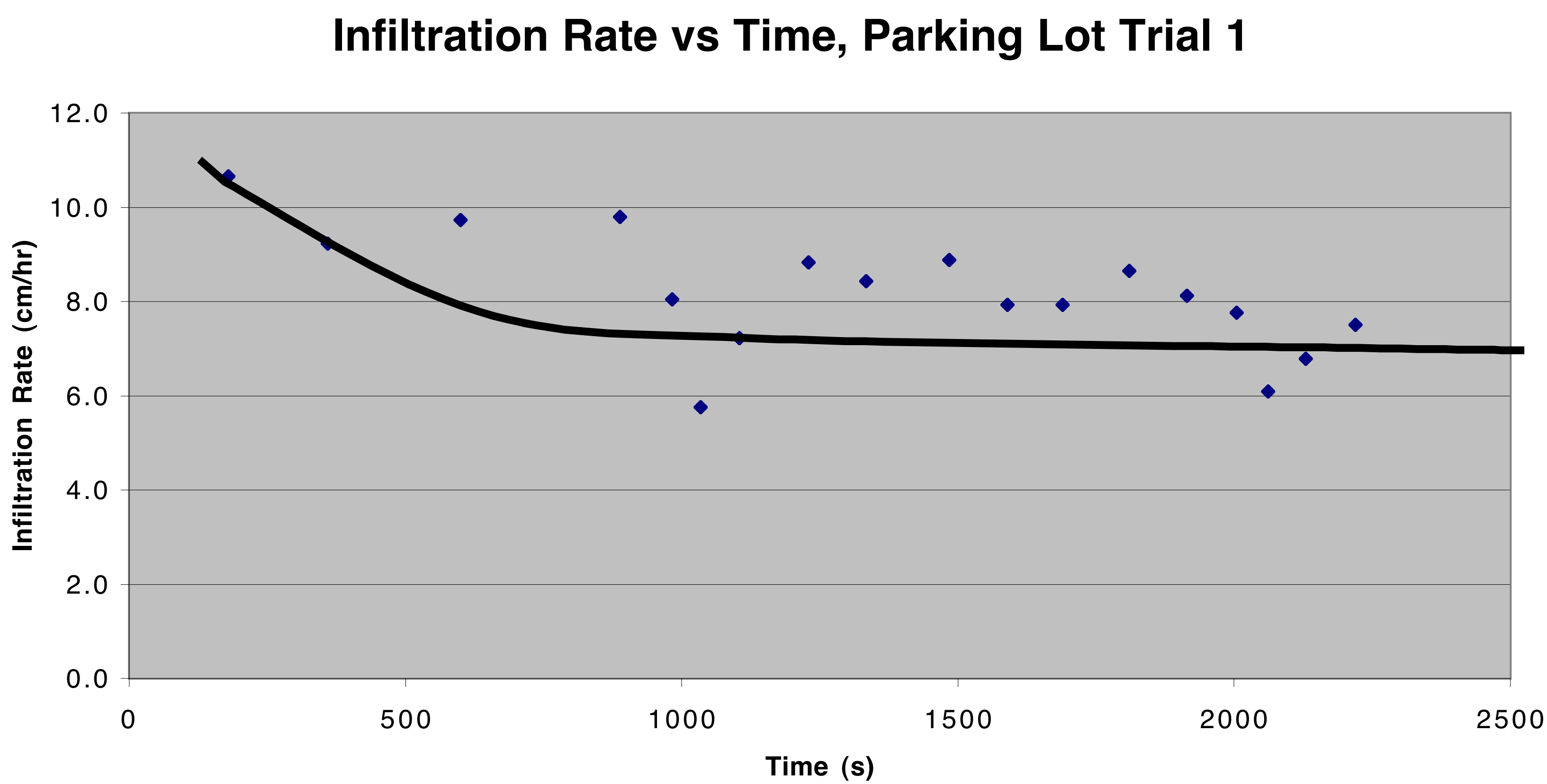


Figure 6: This is a graph of infiltration rate vs time. After intial runoff (the first diamond) the soil becomes saturated and the infiltration rate declined until it reached a steady state infiltration rate of about 7 cm/hr.

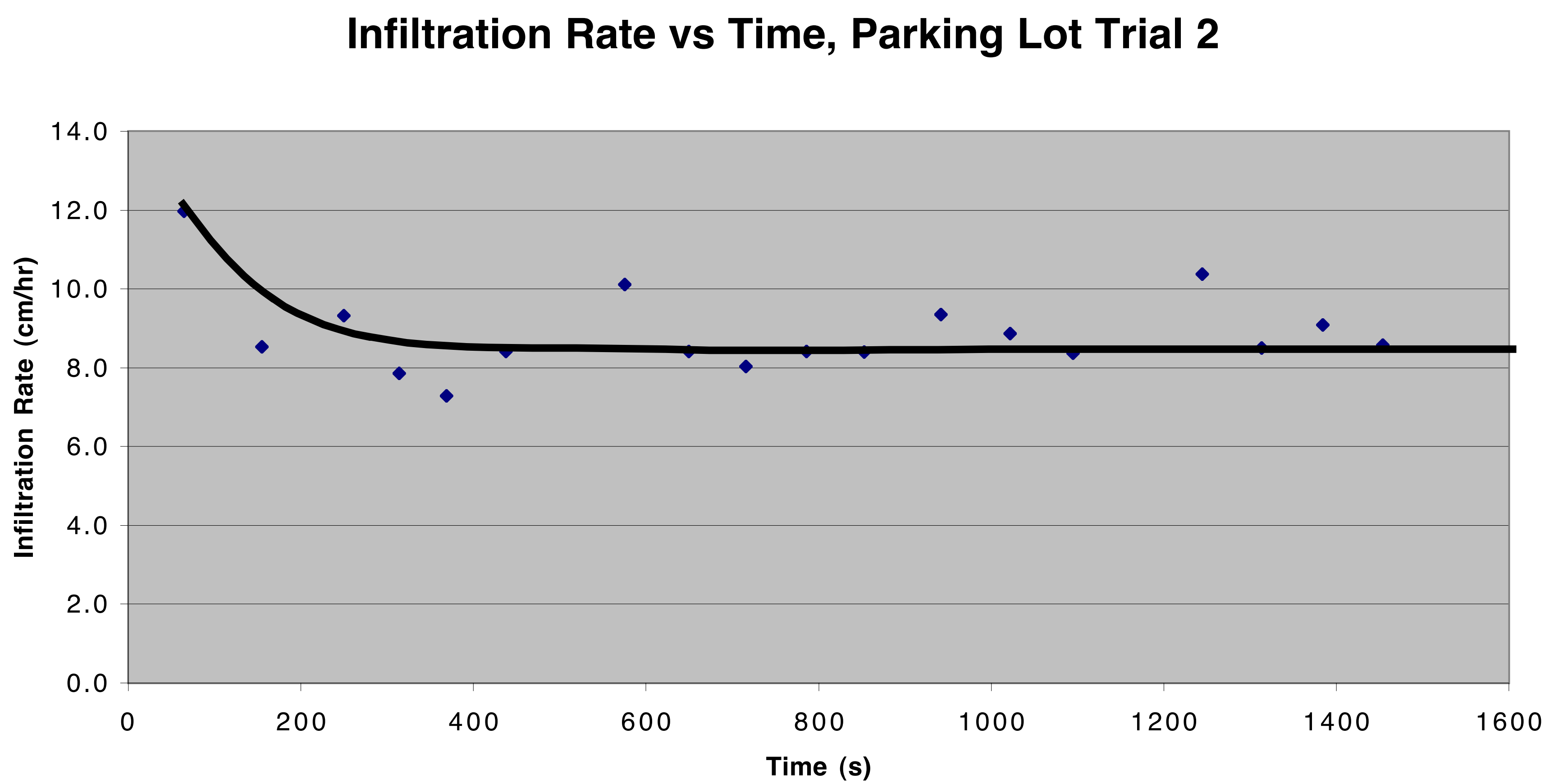


Figure 7: This is a graph of infiltration rate vs time. After intial runoff (the first diamond) the soil becomes saturated and the infiltration rate declined until it reached a steady state infiltration rate of about 8.5 cm/hr.

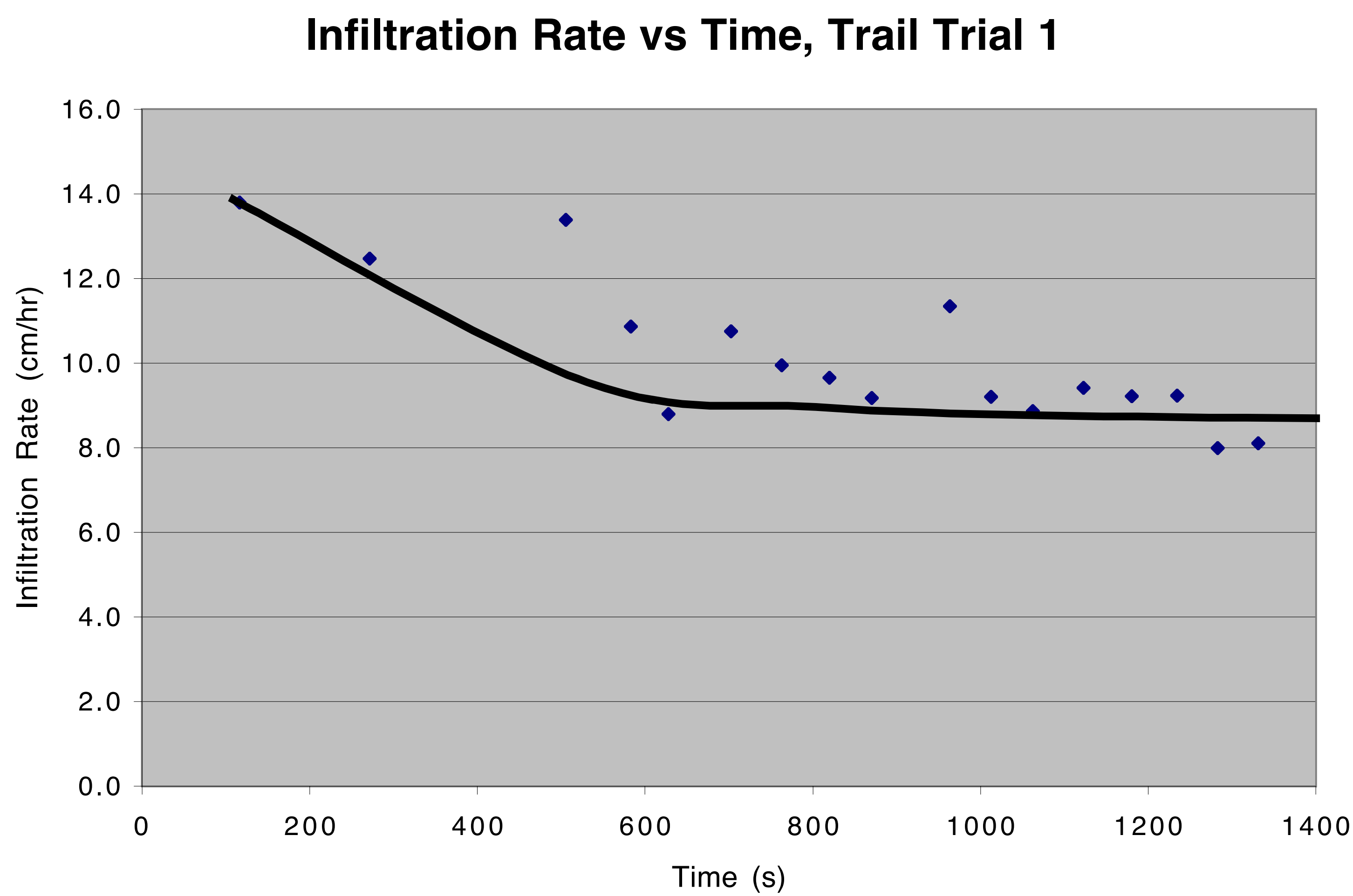


Figure 8: This is a graph of infiltration rate vs time. After intial runoff (the first diamond) the soil becomes saturated and the infiltration rate declined until it reached a steady state infiltration rate of about 8.5 cm/hr.

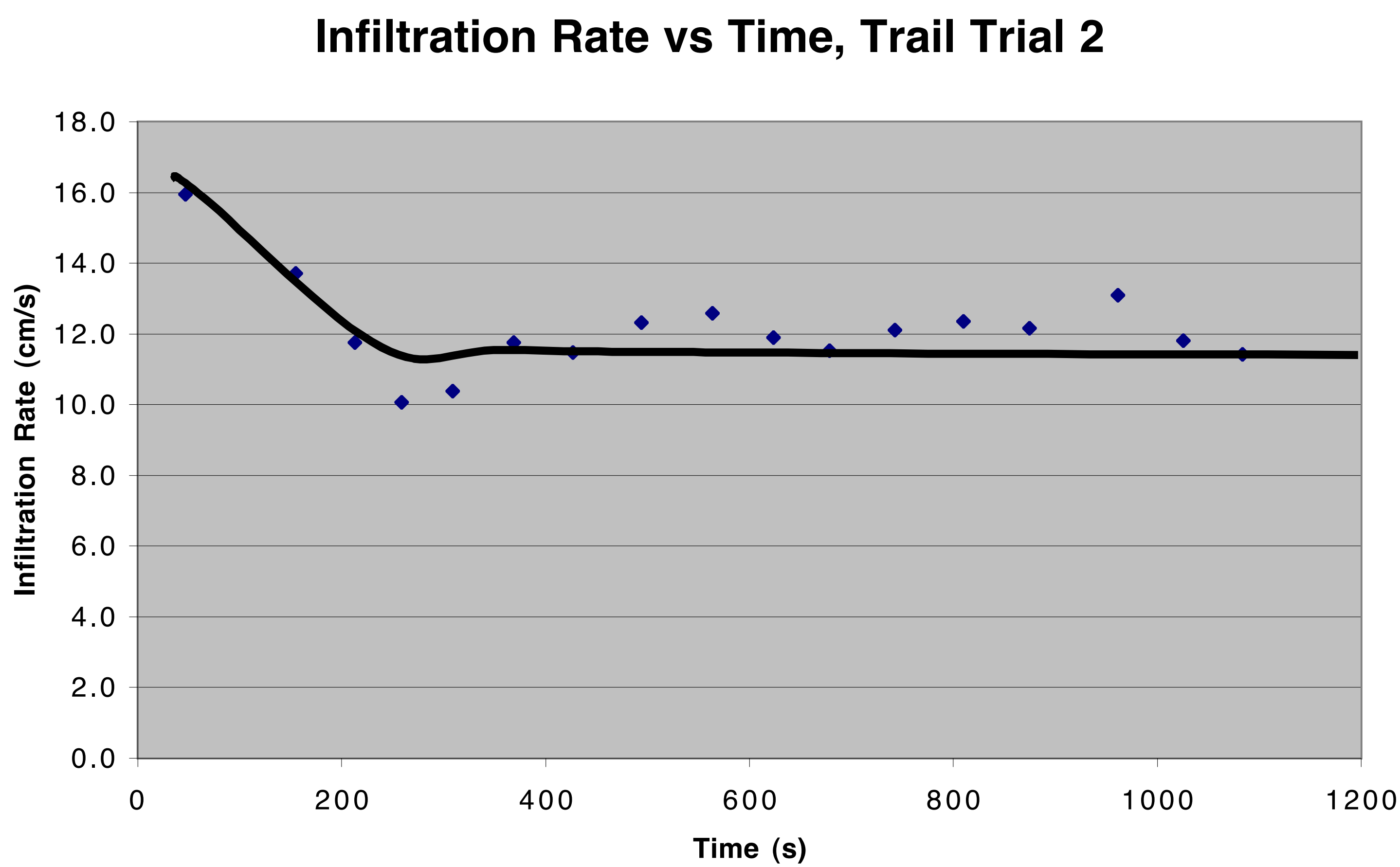


Figure 9: This is a graph of infiltration rate vs time. After intial runoff (the first diamond) the soil becomes saturated and the infiltration rate declined until it reached a steady state infiltration rate of about 11 cm/hr.

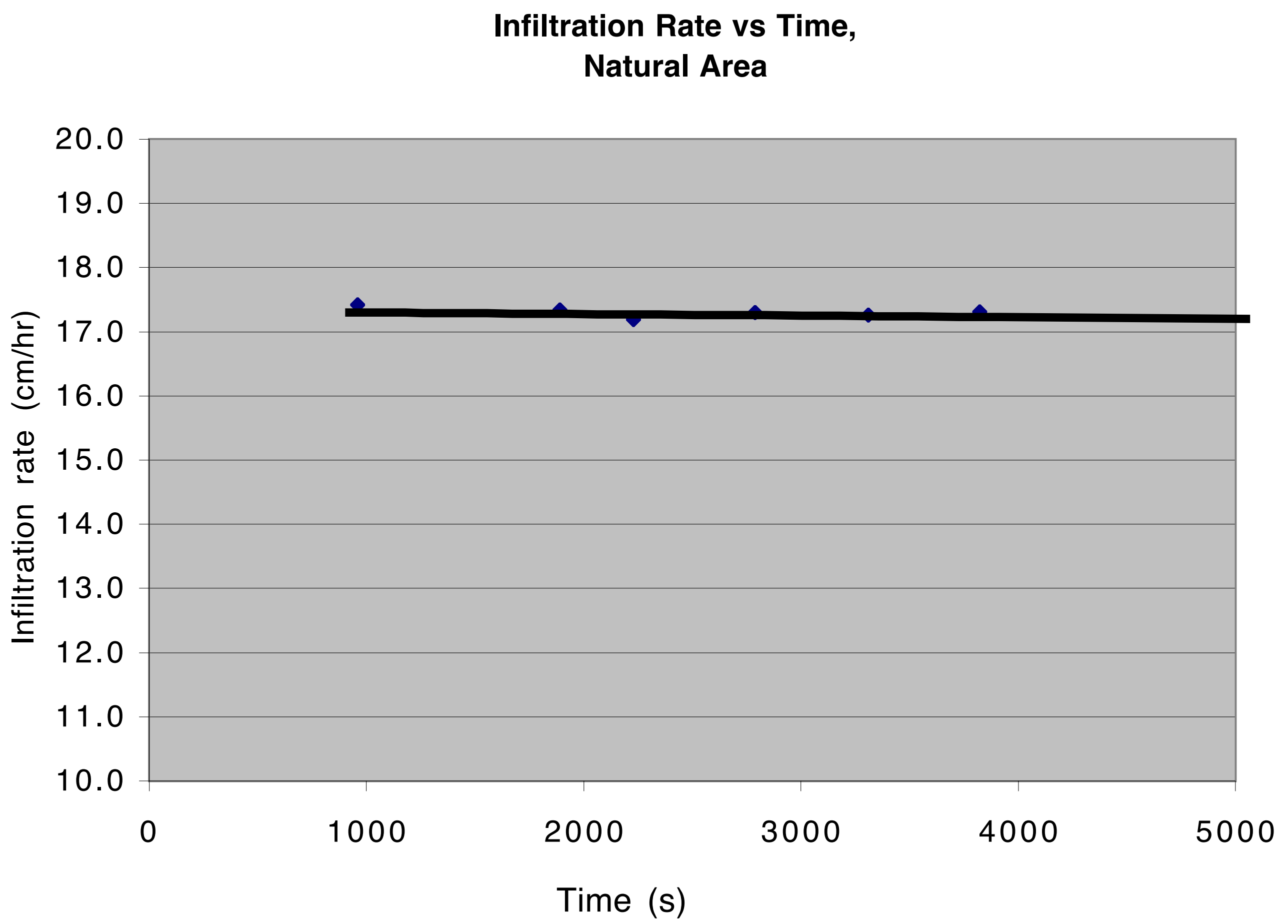


Figure 10: This is a graph plotting infiltration rate vs time for the natural area. Infiltration rate appears to remain steady at about 17.2 cm/hr through the duration of the trial. The first diamond indicates the time when initial runoff was observed.

Site Type	Average Simulated Rainfall Intensity	Duration of Experiment	Final Steady State Infiltration Rate
Natural Area	**17.4 cm/hr**	**63.75 minutes**	**17.3 cm/hr**
Trail, Trial 1	**13.7 cm/hr**	**22.2 minutes**	**8.5 cm/hr**
Trail, Trial 2	**15.9 cm/hr**	**18.07 minutes**	**11.0 cm/hr**
Parking Lot, Trial 1	**10.6 cm/hr**	**37 minutes**	**7.0 cm/hr**
Parking Lot, Trial 2	**11.9 cm/hr**	**24.23 minutes**	**8.5cm/hr**
* Rainfall Intensity of a Record Setting 2-hour Rainfall Event in Burlington,VT	**4.32 cm/hr**		

Figure 11: This is a table that summarizes the average simulated rainfall intensities, the length of each trial, and the final steady infiltration rate at the end of each trial. The * is the record setting intensity for a 2-hour rainfall event in Burlington, Vermont, set in September, 2001. (NOAA)

Figure 12: This sign is located at the River Trail. It describes that the River Trail runs from the Horseshoe Bend area of the Huntington River to the North End of the Audobon Nature Sanctuary. The section of land between the River Trail and the Huntington River is deemed an "unhealthy riparian zone," with uninhibited runoff of fertilizers and other pollutants washing over the eroding treeless banks into the river. The term riparian zone refers to a land and vegitation directly next to a river. This "buffer zone" protects water quality by filtering overlandrunoff of fertalizers, pesticides, soil, and other pollutants. Wildlife use riparian zones as places to rest, bathe, feed, and drink clean water. Many Vermont rivers are suffernig from silt covered bottoms, unshaded shallow waters, and nutrient bacterial pollution due to the elimination of trees in riparian zones. The shore of the Huntington River that abutted both the parking lot and the trail experiment sites was sparsely forested, but clearly attempting to re-vegitate. Here, an interpretation can be made that that in the recent past, these shores were bare, allowing uninhibited amounts of sediments and pollutants to flow into the river. In the natural area test sight, we interpreted the existence of a plow horizon, which is evidence that this area was used as some type of agricultural growing site. Any chemicals used in this area, which did not infiltrate, likely had no healthy riparian zone to flow through, as the shores had also been cleared, and washed right into the river.

Natural Area

Duration (sec)	Rainfall (cm)	Rainfall (cm^3)	Area (cm^2)	Runnoff (cm^3)
961	5.2	31257.6	6725	0
931	4.2	30281.8	6725	140
339	1.2	11026.4	6725	145
559	3.0	18182.1	6725	125
521	2.6	16946.1	6725	155
514	2.2	16718.4	6725	105
total seconds 3825	total cm 18.5			
total minutes 63.75				

Infiltration rate (cm/s)	infiltration rate (cm/hr)	g1 (cm)	g2 (cm)	g3 (cm)
0.004837	17.4	4.5	5.5	5.6
0.004814	17.3	4.9	3.8	4
0.004773	17.2	1.2	1.5	1
0.004803	17.3	3.2	3	2.8
0.004792	17.3	2.5	2.6	2.7
0.004806	17.3	3	1.4	2.3

infiltration (cm)	Average Rainfall (cm^3/s)		time	% Rainfall infiltrating
4.6		32.5	961	100
4.5			1892	99.5
1.6	Average Rainfall		2231	98.3
2.7	(cm/hr)		2790	99.4
2.5		17.4	3311	99.1
2.5			3825	99.3

Runoff Rate cm/hr	Rainfall cm/hr	% Rainfall running off
0	19.5	0
0.08	16.4	0.5
0.23	13.1	1.7
0.12	19.3	0.6
0.16	18.0	0.9
0.11	15.6	0.7
	17.0	

Trail Trial 1

Duration (sec)	Rainfall (cm)	Rainfall (cm^3)	Area (cm^2)	Runnoff (cm^3)
117	0.2	3012.6	6725	0
155	0.6	3991.1	6725	380
234	0.6	6025.2	6725	175
77	0.6	1982.7	6725	420
45	0.2	1158.7	6725	420
75	0.2	1931.2	6725	425
60	0.2	1544.9	6725	430
57	0.1	1467.7	6725	440
51	0.1	1313.2	6725	440
93	0.3	2394.6	6725	425
49	0.3	1261.7	6725	420
50	0.4	1287.4	6725	460
60	0.2	1544.9	6725	490
58	0.3	1493.4	6725	495
54	0.2	1390.4	6725	460
48	0.4	1235.9	6725	520
49	0.1	1261.7	6725	520
1332	5.1			
22.2				

infiltration (cm)	Infiltration rate (cm/s)	g1	g2	g3
0.4480	0.0038	0.2	0.1	0.2
0.5370	0.0035	0.4	0.5	0.9
0.8699	0.0037	0.8	0.5	0.6
0.2324	0.0030	0.6	1	0.3
0.1098	0.0024	0.1	0.3	0.1
0.2240	0.0030	0.2	0.2	0.3
0.1658	0.0028	0.2	0.2	0.2
0.1528	0.0027	0.1	0.1	0.2
0.1298	0.0025	0.1	0.1	0.2
0.2929	0.0031	0.3	0.3	0.4
0.1252	0.0026	0.1	0.5	0.2
0.1230	0.0025	0.5	0.4	0.2
0.1569	0.0026	0.2	0.3	0.2
0.1485	0.0026	0.2	0.3	0.3
0.1384	0.0026	0.25	0.15	0.1
0.1065	0.0022	0.75	0.35	0.2
0.1103	0.0023	0.2	0.1	0.1
	0.0028	5.2	5.4	4.7

infiltration rate (cm/hr)	% Rainfall infiltrating	
13.7838	100.0	Avg rainfll cm^3/s
12.4714	90.6	25.74887387
13.3834	95.9	
10.8639	90.1	Average rainfall (cm/hr)
8.7875	62.5	13.78378378
10.7503	72.9	
9.9474	68.0	
9.6515	50.9	
9.1654	50.9	
11.3374	81.0	
9.1954	76.6	
8.8589	81.3	
9.4120	68.8	
9.2151	72.4	
9.2237	59.0	
7.9845	82.2	
8.1029	42.0	
10.1256		

Runoff Rate cm/hr	Rainfall cm/hr	% Rainfall running off	time
0.0	5.1	0.0	117.0
1.3	13.9	9.4	272.0
0.4	9.7	4.1	506.0
2.9	29.6	9.9	583.0
5.0	13.3	37.5	628.0
3.0	11.2	27.1	703.0
3.8	12.0	32.0	763.0
4.1	8.4	49.1	820.0
4.6	9.4	49.1	871.0
2.4	12.9	19.0	964.0
4.6	19.6	23.4	1013.0
4.9	26.4	18.7	1063.0
4.4	14.0	31.2	1123.0
4.6	16.6	27.6	1181.0
4.6	11.1	41.0	1235.0
5.8	32.5	17.8	1283.0
5.7	9.8	58.0	1332.0
	15.03750795		

Trail trial 2

Duration (sec)	Rainfall (cm)	Rainfall (cm^3)	Area (cm^2)	Runnoff (cm^3)
47	0.27	1399.59	6725	0
108	0.43	3216.09	6725	450
58	0.23	1727.16	6725	455
46	0.20	1369.82	6725	505
50	0.23	1488.93	6725	520
60	0.23	1786.72	6725	470
58	0.23	1727.16	6725	485
67	0.33	1995.17	6725	455
70	0.27	2084.50	6725	440
60	0.20	1786.72	6725	455
55	0.30	1637.82	6725	455
64	0.20	1905.83	6725	460
67	0.30	1995.17	6725	450
65	0.23	1935.61	6725	460
87	0.43	2590.74	6725	465
64	0.50	1905.83	6725	495
58	0.20	1727.16	6725	490
1084	4.80			
18.067				

infiltration (cm)	Infiltration rate (cm/s)	g1	g2	g3
0.2081	0.0044	0.2	0.2	0.4
0.4113	0.0038	0.2	0.7	0.4
0.1892	0.0033	0.2	0.2	0.3
0.1286	0.0028	0.4	0.1	0.1
0.1441	0.0029	0.3	0.2	0.2
0.1958	0.0033	0.2	0.3	0.2
0.1847	0.0032	0.3	0.2	0.2
0.2290	0.0034	0.2	0.3	0.5
0.2445	0.0035	0.25	0.4	0.15
0.1980	0.0033	0.15	0.1	0.35
0.1759	0.0032	0.3	0.4	0.2
0.2150	0.0034	0.3	0.2	0.1
0.2298	0.0034	0.2	0.3	0.4
0.2194	0.0034	0.1	0.4	0.2
0.3161	0.0036	0.4	0.4	0.5
0.2098	0.0033	0.4	0.8	0.3
0.1840	0.0032	0.3	0.2	0.1
	0.0034			

infiltration rate (cm/hr)	% Rainfall infiltrating	
15.9410	100.00	
13.7105	84.56	Avg rainfll cm^3/cm
11.7415	71.00	29.78
10.0641	62.45	
10.3737	66.86	
11.7477	70.05	average rainfall cm/hr
11.4646	69.09	15.94
12.3056	79.70	
12.5761	75.46	
11.8815	66.17	
11.5124	77.45	
12.0934	65.80	
12.3456	77.70	
12.1526	70.69	
13.0798	84.04	
11.8006	85.28	
11.4185	63.57	
12.1299		

Runoff Rate cm/hr	Rainfall cm/hr	% Rainfall running off	time
0.00	20.43	0.00	47.00
2.23	14.44	15.44	155.00
4.20	14.48	29.00	213.00
5.88	15.65	37.55	259.00
5.57	16.80	33.14	309.00
4.19	14.00	29.95	369.00
4.48	14.48	30.91	427.00
3.64	17.91	20.30	494.00
3.36	13.71	24.54	564.00
4.06	12.00	33.83	624.00
4.43	19.64	22.55	679.00
3.85	11.25	34.20	743.00
3.60	16.12	22.30	810.00
3.79	12.92	29.31	875.00
2.86	17.93	15.96	962.00
4.14	28.13	14.72	1026.00
4.52	12.41	36.43	1084.00
	16.01829836		

Parking Lot trial1

Duration (sec)	Rainfall (cm)	Rainfall (cm^3)	Area (cm^2)	Runnoff (cm^3)
180	1.08	3274.46	6150	0
180	0.42	3274.46	6150	440
240	0.43	4365.95	6150	380
289	0.37	5257.33	6150	425
94	0.13	1710.00	6150	420
52	0.37	945.95	6150	435
70	0.17	1273.40	6150	410
125	0.27	2273.93	6150	390
105	0.45	1910.10	6150	400
150	0.48	2728.72	6150	455
105	0.40	1910.10	6150	490
100	0.23	1819.14	6150	465
121	0.40	2201.16	6150	415
104	0.33	1891.91	6150	450
90	0.27	1637.23	6150	445
57	0.13	1036.91	6150	445
68	0.27	1237.02	6150	450
90	0.37	1637.23	6150	485
2220	6.57			
37				

infiltration (cm)	Infiltration rate (cm/s)	g1	g2	g3
0.5324	0.0030	1.25	1.25	0.75
0.4609	0.0026	0.5	0.25	0.5
0.6481	0.0027	0.4	0.5	0.4
0.7857	0.0027	0.25	0.5	0.35
0.2098	0.0022	0.1	0.1	0.2
0.0831	0.0016	0.2	0.3	0.6
0.1404	0.0020	0.1	0.3	0.1
0.3063	0.0025	0.4	0.1	0.3
0.2455	0.0023	0.5	0.4	0.45
0.3697	0.0025	0.2	0.7	0.55
0.2309	0.0022	0.7	0.2	0.3
0.2202	0.0022	0.1	0.2	0.4
0.2904	0.0024	0.3	0.4	0.5
0.2345	0.0023	0.4	0.4	0.2
0.1939	0.0022	0.2	0.4	0.2
0.0962	0.0017	0.2	0.1	0.1
0.1280	0.0019	0.2	0.5	0.1
0.1874	0.0021	0.3	0.2	0.6
	0.00227157			

infiltration rate (cm/hr)	% Rainfall infiltrating	Average rainfall cm/hr
		10.64864865
10.6486	100.00	
9.2178	82.83	Avg rainfll cm^3/cm
9.7218	85.74	18.19144144
9.7878	81.15	
8.0332	48.78	
5.7518	80.71	
7.2201	60.00	
8.8223	76.22	
8.4187	85.55	
8.8730	84.69	
7.9169	80.08	
7.9267	67.60	
8.6410	83.13	
8.1158	78.05	
7.7543	72.87	
6.0787	45.73	
6.7749	72.56	
7.4942	78.49	
8.177651072		

Runoff Rate cm/hr	Rainfall cm/hr	% Rainfall running off	time
0.00	21.67	0.00	180.0
1.43	8.33	17.17	360.0
0.93	6.50	14.26	600.0
0.86	4.57	18.85	889.0
2.62	5.11	51.22	983.0
4.90	25.38	19.29	1035.0
3.43	8.57	40.00	1105.0
1.83	7.68	23.78	1230.0
2.23	15.43	14.45	1335.0
1.78	11.60	15.31	1485.0
2.73	13.71	19.92	1590.0
2.72	8.40	32.40	1690.0
2.01	11.90	16.87	1811.0
2.53	11.54	21.95	1915.0
2.89	10.67	27.13	2005.0
4.57	8.42	54.27	2062.0
3.87	14.12	27.44	2130.0
3.15	14.67	21.51	2220.0
	11.57		

Parking Lot trial 2

Duration (sec)	Rainfall (cm)	Rainfall (cm^3)	Area (cm^2)	Runnoff (cm^3)
65	0.1	1328.8	6150	0
90	0.5	1839.9	6150	530
95	0.3	1942.1	6150	430
64	0.2	1308.4	6150	450
55	0.2	1124.4	6150	440
69	0.2	1410.6	6150	420
138	0.3	2821.2	6150	440
74	0.4	1512.8	6150	450
66	0.2	1349.3	6150	445
70	0.2	1431.1	6150	425
67	0.3	1369.7	6150	410
89	0.3	1819.5	6150	400
80	0.4	1635.5	6150	425
73	0.3	1492.4	6150	450
150	0.4	3066.5	6150	410
69	0.2	1410.6	6150	410
71	0.2	1451.5	6150	350
69	0.3	1410.6	6150	400
1454	4.8			
24.23333333				

infiltration (cm)	Infiltration rate (cm/s)	g1 (cm)	g2 (cm)	g3 (cm)
0.2	0.0033	0.1	0.1	0.1
0.2	0.0024	0.8	0.3	0.3
0.2	0.0026	0.1	0.5	0.3
0.1	0.0022	0.1	0.3	0.25
0.1	0.0020	0.1	0.1	0.45
0.2	0.0023	0.2	0.3	0.2
0.4	0.0028	0.3	0.3	0.25
0.2	0.0023	0.6	0.4	0.05
0.1	0.0022	0.1	0.1	0.25
0.2	0.0023	0.1	0.2	0.3
0.2	0.0023	0.2	0.3	0.25
0.2	0.0026	0.3	0.3	0.3
0.2	0.0025	0.6	0.3	0.25
0.2	0.0023	0.35	0.3	0.25
0.4	0.0029	0.25	0.4	0.4
0.2	0.0024	0.2	0.3	0.15
0.2	0.0025	0.1	0.3	0.25
0.2	0.0024	0.3	0.2	0.4
	0.0025			

infiltration rate (cm/hr)	% Rainfall infiltrating	
		Average rainfall cm/hr
12.0	100	11.96698762
8.5	81.5	
9.3	76.7	
7.9	66.2	Avg rainfll cm^3/cm
7.3	67.0	20.4
8.4	70.7	
10.1	74.7	
8.4	79.1	
8.0	51.8	
8.4	65.4	
8.4	73.3	
9.3	78.3	
8.9	82.0	
8.4	75.6	
10.4	81.0	
8.5	69.2	
9.1	73.7	
8.6	78.3	
8.8740		

Runoff Rate cm/hr	Rainfall cm/hr	% Rainfall running off	time
0.0	5.5	0.0	65
3.4	18.7	18.5	155
2.6	11.4	23.3	250
4.1	12.2	33.8	314
4.7	14.2	33.0	369
3.6	12.2	29.3	438
1.9	7.4	25.3	576
3.6	17.0	20.9	650
3.9	8.2	48.2	716
3.6	10.3	34.6	786
3.6	13.4	26.7	853
2.6	12.1	21.7	942
3.1	17.3	18.0	1022
3.6	14.8	24.4	1095
1.6	8.4	19.0	1245
3.5	11.3	30.8	1314
2.9	11.0	26.3	1385
3.4	15.7	21.7	1454
	12.3		

Runoff Team: **Alysa Snyder, Nathan Toké**
Date/Time of test: **11/02/01**

17 cm/hr
3825 sec
63 min 45 sec

Location of test: **Prevously Plowed Field/Forest Natural Area**
Test area: **6725cm^2**
Last Rainfall time/ amount:
Number of backpacks used: **2backpacks at a time**

	Time	**Rain Collectors (depth in cm)**		
start time	3:35:00	#1	#2	#3
1st Runoff B1 in	3:51:01	4.5	5.5	5.6
B1 to B2	4:06:32	9.4	9.3	9.6
B2 to B3	4:12:11	10.6switch	10.8	10.6
B3 to B4	4:21:30	3.2 +10.6	3 +10.8	2.8 +10.6
B4 to B5	4:30:11	5.7 +10.6	5.6 +10.8	5.5 +10.6
B5 out	4:38:45	8.7 +10.6	7 +10.8	7.8 +10.6

Volume of water in buckets (mL) Avg total 18.5

Bucket 1	140
B2	145
B3	125
B4	155
B5	105

Notes: the plot area was changed to 6725^cm2 for the last three trials.
-This plot was the natural area of the river trail which was a young forest surrounding a recently plowed field. The entire area had been plowed in the past. The hole dug for the plot showed a plow horizon one shovel length deep. This plot was on the forest and field boundary.
-2 backpacks were used at once for a total of 6 in all and runoff which was not initially expected did occurr. The runoff rate however was slow and most appeared to infiltrate, if the intensity was decreased to one sprayer then the runoff nearly would hault and a recovery period was necessary to get a run off rate of was was observed prior to refilling a back pack.
-the plot was on an 11 degree slope.

Also Note!: No sediment was collected for any of the plots along the river trail, it was obvious that there was no significant suspended sediment load. so this part of the proposal has been eliminated. Another elimination is the coffee can infiltration rate. We do not believe this test to be accurate and have not the time to go out a 4th time, plus this test will yield a runoff and infiltration rate.

-the slope for the river trail plot was 6 degrees and for the parking lot it was 3 degrees.

37min for
6.6cm total
avg intensity 11.6

Runoff Team: **Alysa Snyder, Nathan Toké**
Date/Time of test: **11/02/01**

Location of test: **Parking lot trial 1 (limestone/very compacted gravel and soil)**
Test area: **6150cm^2**
Last Rainfall time/ amount:
Number of backpacks used: **1backpack at a time 2 total**

	Time	**Rain Collectors (depth in cm)**		
start time	1:09:00pm	#1	#2	#3
1st Runoff B1 in	1:12:00	1.25	1.25	0.75
B1 to B2	1:15:00	1.75	1.5	1.25
B2 to B3	1:19:00	2.15	2	1.65
B3 to B4	1:23:49	2.4	2.5	2
B4 to B5	1:25:23	2.5	2.6	2.2
B5 to B6	1:26:15	2.7	2.9	2.8
B6 to B7	1:27:25	2.8	3.2	2.9
B7 to B8	1:29:30 + time out until 1:31	3.2	3.3	3.2
B8 to B9	1:32:45	3.7	3.7	3.65
B9 to B10	1:35:15	3.9	4.4	4.2
B10 to B11	1:37:00	4.6	4.6	4.5
B11 to B12	1:38:40	4.7	4.8	4.9
B12 to B13	1:40:41	5	5.2	5.4
B13 to B14	1:42:25	5.4	5.6	5.6
B14 to B15	1:43:55	5.6	6	5.8
B15 to B16	1:44:53	5.8	6.1	5.9
B16 to B17	1:46:01	6	6.6	6
B17 out	1:47:31	6.3	6.8	6.6

- infiltration seepage into hole caused a need to pause in filling of 7

avg 6.57

Volume of water in buckets (mL)

Bucket 1	440
B2	380
B3	425
B4	420
B5	435
B6	410
B7	390
B8	400
B9	455
B10	490
B11	465
B12	415
B13	450
B14	445
B15	445
B16	450
B17	485

4.87
1454 sec
12.3 cm/hr avg intensity

Runoff Team: Alysa Snyder, Nathan Toké
Date/Time of test: **11/02/01**

Location of test: **Parking lot trial 2 (ground already partially saturated)**
Test area: **6150cm^2**
Last Rainfall time/ amount:
Number of backpacks used: **1backpack at a time**

	Time	**Rain Collectors (depth in cm)**		
start time	2:08:40pm	#1	#2	#3
1st Runoff B1 in	2:09:45	0.1	0.1	0.1
B1 to B2	2:11:15	0.9	0.4	0.4
B2 to B3	2:12:50	1	0.9	0.7
B3 to B4	2:13:54	1.1	1.2	0.95
B4 to B5	2:14:49	1.2	1.3	1.4
B5 to B6	2:15:58	1.4	1.6	1.6
B6 to B7	2:18:16	1.7	1.9	1.95
B7 to B8	2:19:30	2.3	2.3	2
B8 to B9	2:20:36	2.4	2.4	2.25
B9 to B10	2:21:46	2.5	2.6	2.55
B10 to B11	2:22:53	2.7	2.9	2.8
B11 to B12	2:24:22	3	3.2	3.1
B12 to B13	2:25:42	3.6	3.5	3.35
B13 to B14	2:26:55	3.95	3.8	3.6
B14 to B15	2:29:25 backpack switch	4.2	4.2	4
B15 to B16	2:30:34	4.4	4.5	4.15
B16 to B17	2:31:45	4.5	4.8	4.4
B17 out	2:32:54	4.8	5	4.8

-paused while filling 6 and 15 avg total 4.87

Volume of water in buckets (mL)

Bucket 1	530
B2	430
B3	450
B4	440
B5	420
B6	440
B7	450
B8	445
B9	425
B10	410
B11	400
B12	425
B13	450
B14	410
B15	410
B16	350
B17	400

Runoff Team: **Alysa Snyder, Nathan Toké**
Date/Time of test: **11/02/01**

1332 sec

15 cm/hr

Location of test: **River Trail Trial 1**
Test area: **6725cm^2**
Last Rainfall time/ amount:
Number of backpacks used: **1backpack at a time**

	Time	**Rain Collectors (depth in cm)**		
start time	9:07:28	#1	#2	#3
1st Runoff B1 in	9:09:25	0.2	0.1	0.2
B1 to B2	9:12:00	0.6	0.6	1.1
B2 to B3	9:15:54	1.4	1.1	1.7
B3 to B4	9:43:30	2	2.1	2
B4 to B5	9:44:15	2.1	2.4	2.1
B5 to B6	9:45:30	2.3	2.6	2.4
B6 to B7	9:46:30	2.5	2.8	2.6
B7 to B8	9:47:27	2.6	2.9	2.8
B8 to B9	9:48:18	2.7	3	3
B9 to B10	9:49:51	3	3.3	3.4
B10 to B11	9:50:40	3.1	3.8	3.6
B11 to B12	9:51:30	3.6	4.2	3.8
B12 to B13	9:52:30	3.8	4.5	4
B13 to B14	9:53:28	4	4.8	4.3
B14 to B15	9:54:22	4.25	4.95	4.4
B15 to B16	9:55:10	5	5.3	4.6
B16 out	9:55:59	5.2	5.4	4.7

Avg total 5.1

Volume of water in buckets (mL)

Bucket 1	380
B2	175
B3	420
B4	420
B5	425
B6	430
B7	440
B8	440
B9	425
B10	420
B11	460
B12	490
B13	495
B14	460
B15	520
B16	520

Runoff Team: **Alysa Snyder, Nathan Toké**
Date/Time of test: **11/02/01**

4.83 in
1084 sec
16

Location of test: **River Trail Trial 2**
Test area: **6725cm^2**
Last Rainfall time/ amount:
Number of backpacks used: **1backpack at a time**

	Time	**Rain Collectors (depth in cm)**		
start time	10:07:19	#1	#2	#3
1st Runoff B1 in	10:08:06	0.2	0.2	0.4
B1 to B2	10:09:54	0.4	0.9	0.8
B2 to B3	10:10:52	0.6	1.1	1.1
B3 to B4	10:11:40	1	1.2	1.2
B4 to B5	10:12:30	1.4	1.4	1.4
B5 to B6	10:13:30	1.6	1.7	1.6
B6 to B7	10:14:28	1.9	1.9	1.8
B7 to B8	10:15:35	2.1	2.2	2.3
B8 to B9	10:16:45	2.35	2.6	2.45
B9 to B10	10:17:45	2.5	2.7	2.8
B10 to B11	10:18:40	2.8	3.1	3
B11 to B12	10:19:44	3.1	3.3	3.1
B12 to B13	10:20:51	3.3	3.6	3.5
B13 to B14	10:21:56	3.4	4	3.7
B14 to B15	10:23:23	3.8	4.4	4.2
B15 to B16	10:24:27	4.2	5.2	4.5
B16 out	10:25:25	4.5	5.4	4.6

Avg total 4.83

Volume of water in buckets (mL)

Bucket 1	450
B2	455
B3	505
B4	520
B5	470
B6	485
B7	455
B8	440
B9	455
B10	455
B11	460
B12	450
B13	460
B14	465
B15	495
B16	490