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Infiltration Through Disturbed Urban Soils and Compost-Amended Soil Effects on Runoff Quality and Quantity

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Infiltration Through Disturbed Urban Soils and Compost-Amended Soil Effects on Runoff Quality and Quantity

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E. Timothy Oppelt, Director
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Abstract

This project examined a common, but poorly understood, problem associated with land development, namely the modifications made to soil structure and the associated reduced rainfall infiltration and increased runoff. The project was divided into two separate major tasks:

1. testing infiltration rates of impacted soils, and

2. enhancing soils by amending with compost to increase infiltration and prevent runoff.

The first part of this project examined this problem by conducting more than 150 infiltration tests in disturbed urban soils and by comparing these data with site conditions. A complete factorial experiment fully examined the effects, and interactions, of soil texture, soil moisture, and compaction. In addition, age since development was also briefly examined. It was found that compaction had dramatic effects on infiltration rates through sandy soils, while compaction was generally just as important as soil moisture at sites with predominately clay soils. Moisture levels had little effect on infiltration rates at sandy sites. Because of the large amounts of variability in the infiltration rates found, it is important that engineers obtain local data to estimate the infiltration rates associated with local development practices.

The other series of tests examined the benefits of adding large amount of compost to a glacial till soil at the time of development. Compost-amended soils were found to have significantly increased infiltration rates, but increased concentrations of nutrients in the surface runoff. The overall mass of nutrient discharges will most likely decrease when using compost, although the collected data did not always support this hypothesis. The sorption and ion-exchange properties of the compost reduced the concentration of many cations and toxicants in the infiltrating water, but nutrient concentrations significantly increased. In addition, the compost-amended test plots produced superior turf, with little or no need for establishment or maintenance fertilization.

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Section 1
Project Description and Introduction

Project Tasks

The two main tasks of this project were to:

1) examine the effects that urbanization has on soil structure and how compaction affects infiltration of rainwater, and
2) examine the effectiveness of using compost as a soil amendment to increase rainwater infiltration, and to reduce the quantity and/or intensity of surface and subsurface runoff from land development.

This project also examined the effectiveness of compost-amended soil in reducing the transport of dissolved or suspended nutrients and metals in runoff.

Field Studies on Infiltration Capabilities of Disturbed Urban Soils (Task 1)

Prior research by Pitt (1987) examined runoff losses from paved and roofed surfaces in urban areas and showed significant losses at these surfaces during the small and moderate sized events of most interest for water quality evaluations. However, Pitt and Durrans (1995) also examined runoff and pavement seepage on highway pavements and found that very little surface runoff entered typical highway pavement. During earlier research, it was also found that disturbed urban soils did not behave as indicated by stormwater models.

Early unpublished double-ring infiltration tests conducted by the Wisconsin Department of Natural Resources (DNR) in Oconomowoc, Wisconsin, (shown in Table 1-1) indicated highly variable infiltration rates for soils that were generally sandy (Natural Resources Conservation Service (NRCS) A/B hydrologic group soils) and dry. The median initial rate was about 75 mm/hr (3 in/hr), but ranged from 0 to 640 mm/hr (0 to 25 in/hr). The final rates also had a median value of about 75 mm/hr (3 in/hr) after at least 2 hr of testing, but ranged from 0 to 380 mm/hr (0 to 15 in/hr). Many infiltration rates actually increased with time during these tests. In about 1/3 of the cases, the infiltration rates remained very close to zero, even for these sandy soils. Areas that experienced substantial disturbances or traffic (such as school playing fields), and siltation (such as in some grass swales) had the lowest infiltration rates. It was hoped that more detailed testing could explain some of the large variations observed.

The first major task of this project was to attempt to explain much of the variation observed in earlier infiltration tests of disturbed urban soils. During recent tests conducted in the Birmingham, Alabama area by the authors with the assistance of University of Alabama at Birmingham (UAB) hydrology students, approximately 150 double-ring infiltration tests were conducted. These tests were separated into eight categories of soil conditions (comprising a full factorial experiment). Factors typically considered to cause infiltration rate variations are texture and moisture. These Alabama tests examined texture and moisture, plus soil compaction (as measured by a cone penetrometer and by site history). It was also hoped that age since disturbance and cover condition could be used to explain some of the variation, but these conditions were unevenly represented at the test sites and complete statistical examinations of these additional factors could not be performed.

Table 1-1. Ranked Oconomowoc, Wisconsin double ring infiltration test results (dry conditions)

Initial Rate, mm/hr mm/hr (in/hr)	Final Rate (after 2 hr), mm/hr (in/hr)	Total Observed Rate Range, mm/hr (in/hr)
640 (25)	380 (15)	280–635 (11–25)
560 (22)	431 (17)	430–610 (17–24)
370 (14.7)	240 (9.4)	240–430 (9.4–17)
150 (5.8)	240 (9.4)	5–240 (0.2–9.4)
140 (5.7)	240 (9.4)	130–240 (5.1–9.6)
120 (4.7)	91 (3.6)	79–160 (3.1–6.3)
100 (4.1)	170 (6.8)	74–170 (2.9–6.80
79 (3.1)	84 (3.3)	61–97 (2.4–3.8)
66 (2.6)	64 (2.5)	41–66 (1.6–2.6)
8 (0.3)	3 (0.1)	<3–8 (<0.1–0.3)
8 (0.3)	43 (1.7)	8–81 (0.3–3.2)
5 (0.2)	<3 (<0.1)	<3–5 (<0.1–0.2)
<3 (<0.1)	15 (0.6)	<3 –15 (<0.1–0.6)
<3 (<0.1)	<3 (<0.1)	all <3 (<0.1)
<3 (<0.1)	<3 (<0.1)	all <3 (<0.1)
<3 (<0.1)	<3 (<0.1)	all <3 (<0.1)

Source: unpublished data from the WI Department of Natural Resources

Infiltration Mechanisms

Infiltration rainfall losses on pervious surfaces are controlled by three mechanism, the initial entry of the water through the soil/plant surface (percolation), followed by movement of the water through the vadose (unsaturated) zone, and finally, depleting of the soil water storage capacity. Overall infiltration is the least of these three rates, and the surface runoff rate is assumed to be the excess of the rainfall intensity greater than the infiltration rate. The infiltration rate typically decreases during the rain. Storage capacity is recovered when the movement of the water through the soil is faster than the percolation rate, which usually takes place after the rainfall has ended.

The surface entry rate of water may be affected by the presence of a thin layer of silts and clay particles at the surface of the soil and vegetation. These particles may cause a surface seal that would decrease a normally high infiltration rate. The movement of water through the soil depends on the characteristics of the underlying soil. Water cannot enter soil faster than it is being transmitted away, so this movement rate affects the overall infiltration rate. The depletion of available storage capacity in the soil also affects the overall infiltration rate. The storage capacity of soil depends on thickness, moisture content, and porosity. Many factors, i.e. texture, root development, structure, and presence of organic matter, affect the porosity of soil.

The infiltration of water into the surface soil is responsible for the largest abstraction (loss) of rainwater in natural areas. Once the infiltration capacity of the soil has been reached, most of the rain will become surface runoff. The infiltration capacity of most soils allows low intensity rainfall to totally infiltrate, unless the soil voids become saturated or the underlying soil is much more compact than the top layer (Morel-Seytoux 1978). High intensity rainfalls generate substantial runoff because the infiltration capacity of the upper soil layer is surpassed, even though the underlying soil might be very dry.

The classical assumption is that the infiltration capacity of a soil is highest at the very beginning of a storm and decreases with time (Willeke 1966). The moisture content of the soil, whether it was initially dry or still wet from a recent storm, will have a great effect on the infiltration capacity of certain soils (Morel-Seytoux 1978). Horton (1939) is credited with defining infiltration capacity and deriving an appropriate working equation. Horton defined infiltration capacity as “...the maximum rate at which water can enter the soil at a particular point under a given set of conditions” (Morel-Seytoux 1978).

Horton Equation

One of the oldest and most widely used infiltration equations was developed by Horton (1939). This equation was used in this study to compare the measured equation parameters with published literature values. The equation is as follows:

$$f = f_c + (f_o - f_c)e^{-kt} \tag{1-1}$$

where:
f= infiltration capacity (in/hr),
f_o = initial infiltration capacity (in/hr),
f_c = final infiltration capacity (in/hr),
k = empirical constant (hr^{-1})

This equation assumes that the rainfall intensity is greater than the infiltration capacity at all times and that the infiltration rate decreases with time (Bedient and Huber 1992). The capacity of the soil decreases as the time of the storm increases because the pores in the soil become saturated with water and do not allow water to continuously infiltrate through the surface (Bedient and Huber 1992). The Horton equation's major drawback is that it does not consider storage availability in the soil after varying amounts of infiltration have occurred, but only considers infiltration as a function of time (Akan 1993).

It is recommended that f_c, f_o, and k all be obtained through field data, but they are rarely measured locally. More commonly, they are determined through calibration of relatively complex stormwater drainage models, or by using values published in the literature. The use of published values in place of reliable field data is the cause of much concern by many (Akan 1993). The following lists include commonly used Horton infiltration parameter values:

Soil Type	f_o (in/hr)
Dry sandy soils with little to no vegetation	5
Dry loam soils with little to no vegetation	3
Dry clay soils with little to no vegetation	1
Dry sandy soils with dense vegetation	10
Dry loam soils with dense vegetation	6
Dry clay soils with dense vegetation	2
Moist sandy soils with little to no vegetation	1.7
Moist loam soils with little to no vegetation	1
Moist clay soils with little to no vegetation	0.3
Moist sandy soils with dense vegetation	3.3
Moist loam soils with dense vegetation	2
Moist clay soils with dense vegetation	0.7

Soil Type	f_c mm/hr	(in/hr)	k (1/min)
Clay loam, silty clay loams	0–1.3	(0–0.05)	0.069
Sandy clay loam	1.3–3.8	(0.05–0.15)	0.069
Silt loam, loam	3.8–7.6	(0.15–0.30)	0.069
Sand, loamy sand, sandy loams	7.6–11.4	(0.30–0.45)	0.069

Source: Akan 1993.

The above k values are not divided into categories, with only a single value used for all conditions (Akan 1993). The units of the k value are listed as 1/min instead of 1/hr because the time steps commonly used in urban hydrology are measured in minutes, while the infiltration rates are commonly measured in units of inches per hour. These values will be compared to the measured values obtained during this study by calibrating the Horton equation.

Soil Modifications to Enhance Infiltration

Turf scientists have been designing turf areas with rapid infiltration capabilities for playing fields for many years. It is thought that some of these design approaches could be used in other typical urban areas to enhance infiltration and reduce surface runoff. The second major task of this project conducted by the College of Forestry Resources (CFR) at the University of Washington (UW) in the Seattle, Washington area and discussed in further detail in the next section, measured the benefits of amending urban soils with compost. It was hoped that one of the benefits of compost-amended soils would be to improve the infiltration characteristics of these soils, along with providing some filtration/sorption benefits to capture stormwater pollutants before they enter the groundwater.

Several golf course and athletic field test sites were examined in Alabama during this study to document how turf areas can be constructed to enhance infiltration. These areas were designed to rapidly dry-off following a rain to minimize downtime due to excessive soil moisture levels. Turf construction techniques were reviewed at three sites: an intramural playing field at UAB, the UAB practice football field, and a local golf course.

The UAB intramural field has a simple fishbone drainage design of multiple 100 mm (4in.) wide trenches with a filter fabric wrapped pipe laid 30 cm (12 in.) deep. A thick sand backfill was used and then the area was recapped with sod. The drainage pipe was directed to the storm drainage system. A trunk line of 100 mm (4 in.) corrugated pipe is the “spine” of the system with smaller 75 mm (3 in.) pipes stemming off from the main line. All the pipes rest on a gravel base with a sand backfill. This system feeds to a larger basin that collects the stormwater and takes it to the existing storm drainage system. The golf course has the same basic fishbone design noted above, but differs in the sizes of the individual pipes. The drainpipes are 3 m (10 ft.) apart in trenches filled with 75 mm (3 in.) of gravel. The pipes are then covered with 30 cm (12 in.) of sand with the top 50 mm (2 in.) of the sand consisting of a blend of sand and peat moss. This particular mixture is known as the USGA greens sand mix and is readily available because of its popularity in golf course drainage design. If the backfill sand particles are too large, clay is added to the mixture to slow the drainage. However, if the sand particles are too small, the soil will compact too tightly and will not give the desired results. In all of these cases, standing water is rare after rain has stopped, even considering the generally flat playing fields and very high rainfall intensities occurring in the Birmingham area. It is likely that similar soil construction (without subsurface drainage in most cases) could be used in high density urban areas to enhance stormwater infiltration.

Field Studies on Compost-Amended Soils (Task 2)

This second project task examined the benefits of using compost as a soil amendment to improve the infiltration capacity and pollutant retention capacity of disturbed urban soils. Currently, due to their wide distribution and inherent stability, most residential housing developments in the Seattle, Washington area are sited on the Alderwood soil series, which is characterized by a compacted subsurface layer that restricts vertical water flow. When disturbed (and particularly when disturbed with cut and fill techniques as with residential or commercial development), uneven water flow patterns develop due to restricted permeability. This contributes to excessive overland flow (especially during storm events) and transport of dissolved and suspended particulates to surface waters.

Research has demonstrated compost’s effectiveness in improving the soil physical properties of porosity and continuity of macropores which influence soil-water relationships. Compost’s chemical properties can also be valuable in some cases, such as in complexing potentially harmful trace metals including copper, lead, and zinc. Under this premise, the effectiveness of using compost to increase stormwater infiltration and water holding capacity of glacial till soils was examined during special tests in the Seattle area. The project also examined whether or not increasing the infiltrative and retentive capacity of glacial till soils (Alderwood series) can increase the contact with and retention of nutrients and metals by soil absorptive mechanisms.

The CFR (Harrison et al. 1997) has examined the effectiveness of using compost as a soil amendment to increase surface water infiltration and to reduce the quantity and/or intensity of surface runoff and subsurface flow from land development projects. In addition, runoff and subsurface flow was evaluated for dissolved nutrients and other constituents.

The CFR utilized the existing Urban Water Resource Center (UWRC) project site at the UW's Center for Urban Horticulture (CUH) to conduct the study. The UWRC designed large plywood beds to contain the soil and soil-compost mixes. Additional sites of a similar design were also constructed at Timbercrest and Woodmoor public schools in cooperation with the Woodinville Water District.

These test plots at the CUH were developed and tested previously during a study conducted for the city of Redmond, Washington (Harrison, *et al*. 1997). The following paragraphs summarize some of the findings and conclusions from that earlier study, conducted when the test plots were newly constructed:

> The earlier study specifically examined the use of compost as an amendment to Alderwood series soil to increase water-holding capacity, reduce peak flow runoff, and decrease phosphorus in both surface runoff and subsurface flows. Seven 2.4 x 9.8 m (8 x 32 ft) beds were constructed out of plywood lined with plastic and filled with Alderwood subsoil or mixtures of soil and compost. Surface and subsurface flow samples were obtained over the period from March 7 to June 9, 1995, during a series of seven simulated rainfall events. To create different antecedent soil moisture conditions, some storm events were quickly followed by another event. Simulated rainfall was applied at total amounts ranging from 19 to 62.4 mm (0.76 to 2.46 in.) per storm, with rainfall intensities ranging from 7.4 to 16 mm (0.29 to 0.63 in/hr). Compost amendments had the following effects on physical water properties:
>
> - Water-holding capacity of the soil was about doubled with a 2:1 compost:soil amendment.
> - Water runoff rates were moderated with the compost amendment, with the compost-amended soil showing greater lag time to peak flow at the initiation of a rainfall event and greater base flow in the interval following a rainfall event.
>
> At the start of the rainfall events, there was an increased lag time before significant runoff occurred. The compost-amended plots continued to store higher rates and total amounts of water for a longer period of time. Total storage increased by about 65%, and the field capacity increased by about 60%, with compost amendment. During one test with a rainfall intensity of 8mm/hr (0.3 in/hr), the control (unamended) plot required about 30 min to respond with total surface runoff and subsurface flow > .25 mm/hr (0.01 in/hr). The compost-amended site, however, required nearly twice as long to respond with a similar flow. It required 0.75 hr from the start of the rainfall simulation for the total flow to become > 2.5mm/hr (0.1 in/hr) in the unamended soil, while it required 1.75 hr for the compost-amended soil to increase to that rate. In order for the total runoff (surface plus subsurface flows) to reach 90% of the input rainfall intensity, it required nearly 2.0 hr for the unamended site, compared to 5.25 hr for the compost-amended site. Following the cessation of rainfall, it required 0.75 hr for total runoff in the unamended site to drop to <10% of the rainfall intensity, where it required 1.5 hr for the compost-amended site. Similar results occurred during the other tests using smaller rainfall intensities and total amounts, including one series of natural rainfall events. Compost-amended soils consistently had longer lag times to response, longer times to peak flows, higher base flows, higher total storage, and smaller total runoff than unamended soils. This indicated that compost-amended soils have better water-holding and runoff characteristics than the unamended Alderwood soils.
>
> Using compost amendments during the wettest parts of the winter would likely have minimal effects on the runoff (surface plus subsurface) from the Alderwood soils, because there is very little transpiration during this time. However, during the early fall and late spring seasons, the additional water-holding capacity of the compost-amended soils would result in additional transpiration from the plots and possibly lower the need for irrigation. Despite the lack of probable effects on total runoff during the winter season, the effect on peak-storm surface flows would clearly be significant.
>
> Nutrient concentrations (total phosphorus (P), soluble-reactive P and nitrate-nitrogen) in the surface runoff and subsurface flows were also measured for a series of artificial and natural rainfall events during this earlier study. For the overall study, which included fertilizer treatments, the following results were observed:

- Runoff from the compost-amended soil had 24% lower average total P concentration (2.05 vs. 2.54 mg/L) compared to the Alderwood soil that did not receive compost.
- Soluble-reactive P was 9% lower in the compost-amended soil (1.09 vs 1.19 mg/L) compared to the Alderwood soil that did not receive compost amendment.
- Nitrate-nitrogen was 17% higher in the compost-amended soil (1.68 vs 1.39 mg/L) compared to the Alderwood soil that did not receive compost amendment.

Overall, the amended sites had somewhat higher NO_3-N concentrations. In any case, the nutrient concentrations in the runoff collected from compost-amended plots versus the unamended plots did not show large differences. The water flow data from several storm events was coupled with the nutrient concentration data to generate fluxes of nutrients from the plots. When these fluxes were summed, the compost-amended soils showed the following, compared to the unamended soils:

- 70% less total P,
- 58% less soluble-reactive P, and
- 7% less nitrate in runoff compared to runoff from the glacial till-only soil.

These differences in fluxes were attributed more to the changes in water flux rates than to water chemistry, but both accounted for the lowered P with compost amendment.

The artificial storms utilized in these studies represent intense rains having 25 to 100 year return intervals. It would be expected that the differences between the glacial till-only soil and the compost-amended glacial till soil would be greater at less-intense rainfall events, though the peak rates of runoff of both are likely to be reduced.

These earlier study results were the basis for this project. The results of the earlier study pointed out the promise of the use of organic amendments for improving water-holding capacity, runoff properties and runoff water quality of Alderwood soils converted to turfgrass during urban development. This project examined some of these same test plots at the CUH several years after their initial establishment, and during natural rains, to see if their behavior was substantially different with time. In addition, new test sites were established at two high-school locations for comparison.

Section 2
Methodology and Test Site Descriptions

Sampling and Test Site Descriptions

Infiltration Tests in Disturbed Urban Soils (Task 1)

Birmingham, Alabama, the location of many of the test sites for disturbed urban soils, receives about 1400 mm (54 in.) of rain and about 110 separate rain events per year. Typical antecedent dry periods range from about 2 to 5 days and it is unusual to go more than 10 days without recorded rainfall. The driest months are October and November, averaging 66 and 91 mm (2.6 and 3.6 in.), respectively, while March is the wettest month averaging 160 mm (6.3 in.) of rainfall. Snow is rare, with snowfalls of 130 mm (5 in.) or more occurring about once every 10 years. The growing season (temperature > 28° F) is at least 243 days per year in 5 out of 10 years. Average daily maximum temperatures are about 90° F in the summer months (June through August) and about 55° F in the winter months (December through February). Average daily minimum temperatures are about 65 to 70° F in the summer and about 34° F in the winter. The extreme recorded temperatures in Birmingham have ranged from about 0 to 110° F. Many of the sandy soil tests were located near Mobile, Alabama, where the rainfall is about 10 in. more than in Birmingham, and the summers are hotter and more humid. Table 2-1 briefly describes the test locations and site conditions, while site maps are presented in Appendix A. The following paragraphs briefly describe the test locations where infiltration tests were conducted.

Location # 1: Homewood Park

Homewood Park is located off Oxmoor Road between Highway 31 and Green Springs Highway, in Homewood (Jefferson County), Alabama. The park was developed in the early 1950s. One of the test areas is located by the first of two bridges that passes over Griffin Creek. The second test site lies at the base of the hill where a recreation

Table 2-1. Infiltration test site locations and conditions

Site #	Location	Land Use	Age (years)	Texture[1]	Compaction[2] (psi)
1a 1b	Homewood Park	Recreational	>40	Clayey	100-200 >300
2a 2b	Chadwich, Helena	Medium density residential	<1	Clayey Clayey	150 >300
3a 3b 3c	South Lakeshore Drive	Commercial	>25	Sandy Sandy Clayey	>300 225 280
4a 4b 4c	Private Residence Backyard (West Jefferson)	Low density residential	>30	Clayey Clayey Sandy	200 >300 200-250
5a 5b	Private Residence Backyard (Trussville)	Medium density residential	>30	Clayey Sandy	150-200 >300
6	Littlefield Farms	Agricultural	>10	Sandy	>300
7a 7b	Wildwood Apartment Complex (Homewood)	High density residential	<1	Clayey	>300 <150
8	Private Residence Backyard (Birmingham)	Medium density residential	>30	Clayey	>300
9a 9b 9c	Jasper Golf Course (Walker County)	Recreational	<5 <5 >10	Sandy Sandy Sandy	150-175 >300 100
10	Private Residence Backyard (Gulf Shores)	Medium density residential	>20	Sandy	100

(1) texture: “clayey” > 50% clay + silt fraction; “sandy” > 50% sand fraction
(2) compaction: “compacted” >300 psi; noncompacted <300 psi

center and pool are located. Both of these sites are in the main part of the park and are traversed by most visitors. The texture of the soil did not vary between the two sites.

NRCS general soil type: Holston-Townley-Urban Land Well drained soils that are moderately and slowly permeable and urban land; formed in alluvium and colluvium and in residuum from shale and siltstone.

Specific soil type at Homewood Park: Holston-Urban land complex with 2 to 8% slopes. Soil analysis at Homewood Park during these tests indicated a clay loam texture with 35% sand and 65% clay that is consistent compared to the Jefferson County Soil Survey. The soil survey indicates a high percentage of clay that makes plant growth difficult. Frequent watering is required to sustain long-term plant growth.

Location # 2: Chadwick, Helena

This site is located in Helena, approximately 8 km (5 mi) from the I-65 Valleydale Road exit in Shelby County, Alabama. Chadwick is a new subdivision located at the Pelham/Helena border. The first phase of the subdivision was built approximately 2 years ago, with the last phase presently being completed. Relatively new subdivisions to the east and farmland to the west border the area.

It is obvious from the red color of the soil that it is predominately composed of clay. The soil has little variability over the area of the subdivision. Residents in the subdivision have replaced the top layer of the clayey soil with purchased topsoil so that flowers and shrubbery will grow in the flowerbeds. Standing water in the yards is drained by homeowner installed French drains.

The designers of the storm drainage systems used a Rational method coefficient of 0.7 to 0.75 because the home lots are small and contained large amounts of pavement, and because of the predominately clayey soils.

NRCS general soil type: Minvale-Etowah-Tupelo Deep, nearly level to moderately steep, well drained and somewhat poorly drained soils that have a loamy or clayey subsoil; formed in residuum of limestone or cherty limestone and in alluvium.

Specific soil type at Chadwick: Dewey clay loam at 2 to 6% slopes. Soil analysis during these tests at the Chadwick Subdivision indicated a clay texture with 96% clay and 4% sand that is consistent compared to the Shelby County

Soil Survey. The soil survey indicates a high percentage of clay that causes very low natural fertility and very low organic matter.

Location # 3: South Lakeshore Drive

South Lakeshore Drive runs parallel to Lakeshore Drive in Homewood (Jefferson County), Alabama. It is approximately 2.4 km (1.5 mi) away from the Wildwood Shopping Center and 0.8 km (0.5 mi) away from Homewood High School.

Two different sites were tested at this location. The first was off the road in a currently undeveloped and lightly wooded area. This general area has been the focus of many studies concerning commercial development and recreational facilities. The second location is immediately off the main roadway by a power pole marked with a half-mile marker. This area is very popular with walkers, joggers, and cyclists because it is a flat, long road that only has heavy traffic around school opening and closing hours. The area was heavily disturbed about 25 years ago. The texture of the soils varied from location to location.

NRCS general soil type: Holston-Townley-Urban land. These are well-drained soils that are moderately and slowly permeable, plus urban land; formed in alluvium and colluvium and in residuum from shale and siltstone.

Specific soil type at South Lakeshore Dr.: Sullivan-State complex at 0 to 2% slopes. Soil analysis during these tests at South Lakeshore Drive indicated a sandy loam texture with 65% sand and 35% clay that is consistent compared to the Jefferson County Soil Survey. The soil survey indicates a high percentage of sand, which provides adequate moisture for plant growth throughout the growing season.

Location # 4: Private Residence Backyard (West Jefferson)

This site is a low-density residential area located in western Jefferson County, Alabama. The home was built over 30 years ago. The clayey soil varies in compactness throughout the yard. The yard also contained many large fire ant colonies and gopher holes that likely affected soil compaction.

NRCS general soil type: Montevallo-Nauvoo. These are well drained soils that are moderately permeable; formed in residuum from shale, siltstone, and sandstone.

Specific soil type at this site: Montevallo-Nauvoo association, steep at 6 to 55% slopes. Soil analysis during these tests at this backyard indicated a clay loam texture with 25% sand and 75% clay which is consistent compared to the Jefferson County Soil Survey. The soil survey indicates a high percentage of clay which is not suited for the cultivation of crops.

Location #5: Private Residence Backyard (Trussville)

This site is located in Grayson Valley, near the Grayson Valley Country Club, in Trussville (Jefferson County), Alabama. The age of the home is around 30 years. The house is elevated from the road with a gently sloping front and back yard. The soil varies in texture from one side of the yard to the other. The soil closest to the house is primarily sandy, while the soil taken near a tree across the yard is clayey.

NRCS general soil type: Holston-Townley-Urban land. These are well drained soils that are moderately and slowly permeable and Urban land; formed in alluvium and colluvium, and in residuum from shale and siltstone.

Specific soil type at this site: Montevallo-Nauvoo-Urban land complex at 10 to 40% slopes. The soil analysis during these tests at this backyard indicated a clay loam texture with 40% sand and 60% clay which is consistent compared to the Jefferson County Soil Survey. The soil survey shows a high percentage of clay with soil moisture not adequate for plant growth.

Location #6: Littlefield Farms

Littlefield farms lies between County Roads 164 and 51 in Chilton County, Alabama. The sample site is located on the edge of the lawn and is used as a farmer's road surrounding an annually worked field. Cows also lightly graze the area.

The soil was last heavily disturbed here many years ago, and Zoysia sod was laid approximately 10 years ago. Erosion at a nearby hill has caused an additional 10 cm (4 in.) of top soil to be deposited on the sod. The soil texture can be classified as a sandy loam. The sieve analyses showed a fairly consistent soil texture in all samples.

NRCS general soil type: Ruston-Ora-Bowie association. These are deep, well-drained and moderately well-drained soils; a fragipan in some places, plinthite in other places.

Specific soil type at Littlefield Farms: Luverne fine sandy loam at 10 to 15% slopes. The soil analysis during these tests at Littlefield Farm indicated a sandy loam texture with 65% sand and 35% clay which is consistent compared to the Chilton County Soil Survey. This soil is well suited for trees and the fertility rate is acceptable for crops.

Location #7: Wildwood Crossing Apartment Complex (Homewood)

The Wildwood Apartments are a newly constructed complex located just off Lakeshore Drive in Jefferson County, Alabama. The test site was located in front of a newly constructed and unoccupied apartment building. This site is located in a high-density residential and commercial area.

The soil was heavily disturbed within the past year due to cut and fill operations. Some areas within this site were compacted by heavy equipment used during construction. The sample area has freshly laid sod.

NRCS general soil type: Montevallo-Nauvoo. Well drained soils that are moderately permeable; formed in residuum from shale, siltstone, and sandstone.

The specific soil type at this site is Nauvoo-Montevallo, steep at 10 to 40% slope. The surface layer of the Nauvoo soil is typically about 5 in. of fine sandy loam with clay loam subsoils. The surface layer of the Motevallo soil is about 16 in. of shaly silt loam with underlying weathered shale. The water capacity is moderate to very low. The soil analysis of the sample from this site indicated a clayey texture with 57% clay. Montevallo soils are not suited to cultivated crops because of the steep slopes, the hazard of erosion and shallow soil depth. Native soils are better suited to cultivate crops, however the slope and hazard of erosion create limitations.

Location #8: Private Residence Backyard (Birmingham)

This site is located near the intersection of Green Springs Avenue and Green Springs Highway in the city of Birmingham, Jefferson County. This site is covered with a typical, well-established residential type turf. It has been over twenty years since the soil was last heavily disturbed.

NRCS general soil type: Urban land–Tupelo-Decatur: Urban land and moderately well and well drained soils that are slowly and moderately permeable; soils formed in cherty limestone colluvium or residuum.

The specific soil type is Decatur-Urban land complex, with 2 to 8% slopes. Decatur soils typically have about a 7 inch layer of silt loam with clay subsoil. Decatur soils have a high water capacity. The soil analysis for the sample from this site indicated a clayey texture with 67% silts and clay which is consistent with the Jefferson County, Alabama, soil survey.

Location #9: Jasper Golf Course (Walker County)

This site located off Highway 78 in Walker County was chosen because it provided a variety of sandy-site conditions. The course was constructed more than ten years ago and has undergone remodeling in some areas within the past four or five years.

NRCS general soil type: Sunlit-Townley-Sipsey: Moderately deep and shallow, gently sloping to very steep, well drained soils that have a loamy or clayey subsoil; formed in material weathered from shale, siltstone, and sandstone.

Specific soil type at this site: Sunlight-Townley complex. This complex consists of channery silt loam, channery silty clay loam, silt loam, gravely loam, and clay, throughout the soil profile. This complex is steep at 15 to 45% slopes. The composition of this soil was modified during construction of the golf course, therefore the soil found at this site is not consistent with the Walker County, Alabama, soil survey. Soil analysis from this site indicated a sandy texture with between 76 and 98% sand. The soil survey indicates that this soil is not suited to cultivated crops because the soil is droughty and prone to erosion problems on steeper slops. This soil has moderate to slow permeability, and low fertility.

Location #10: Private Residence Backyard (Gulf Shores)

This private residence is located in Gulf Shores, Baldwin County, in south Alabama. The house at this site was constructed more than twenty years ago. The sod and underlying soil has not been disturbed since that time. Vehicles are parked on soil at the front portion of this site, therefore the soil there is highly compacted.

NRCS general soil type: Norfolk-Klej-Goldsboro association. Deep, moderately well drained and well drained soils which are nearly level to gently sloping soils of uplands.

Specific soil type at this site: Plummer-loamy sand or sand throughout the profile and flat at 0 to 5% slopes. Soil analysis during tests at this site indicated a sandy texture with 96% sand and 4% silt and clay, which is consistent compared to the Baldwin County Soil Survey. The soil survey indicates that this soil is not suited to cultivated crops due to low fertility, low moisture-holding capacity, rapid permeability and high water table.

Compost-Amended Soil and Soil Only Test Sites (Task 2)

The field study sites for testing the benefits of compost-amended soils were all located in the Seattle area. Seattle is relatively wet, receiving about 35 in. of rain a year; however, the typical rain intensity is quite low. Many of the tests were conducted at the existing test beds located at the UW's CUH demonstration site. Additional tests were conducted at newly established test sites at the Timbercrest High School and at the Woodmoor High School in Northern King County (Figure 2-1). The high school sites are characterized as having poorly-sorted and compacted glacial till soils of the Alderwood soil series. The three sites are typical of the problem areas for urban runoff in the region, and represent development on glacial till soils in watersheds having water bodies of high quality. The three sites demonstrate three replications of control and compost-amended soils for this study. The high school students analyzed some samples and prepared a local report.

Figure 2-1. Location of field installations at Timbercrest and Woodmoor high schools.

The CFR utilized the existing CUH site and associated UW facilities. The system included two different Alderwood glacial till soils that were transported to the site, and several mixtures of the glacial till soils and compost mixtures readily available in the Seattle area. Two plots each of glacial till-only soil and 2:1 mixtures of soil:compost were studied. The soil-compost mixture rates were also the same for the Timbercrest and Woodmoor sites, using Cedar Grove compost.

The two composts used at the CUH sites were Cedar Grove and GroCo. The GroCo compost-amended soil at the CUH test site is a sawdust/municipal waste mixture (3:1 ratio, by volume) that is composted in large windrows for at least 1 year. The Cedar Grove compost is a yard waste compost that is also composted in large windrows.

Measurement of Site Parameters

Measurement of Infiltration Rates in Disturbed Urban Soils (Task1)

Experimental Design

A series of 153 double ring infiltrometer tests were conducted in disturbed urban soils in the Birmingham, and Mobile, Alabama, areas. The tests were organized in a complete 2^3 factorial design (Box, *et al*. 1978) to examine the effects of soil moisture, soil texture, and soil compactness on water infiltration through historically disturbed urban soils. Turf age was also examined, but insufficient sites were found to thoroughly examine the effects of age on infiltration rates. Ten sites were selected representing a variety of desired conditions (compaction and texture) and numerous tests were conducted at each test site area. Soil moisture and texture were determined by standard laboratory soil analyses. Compaction was measured in the field using a cone penetrometer and confirmed by the site history. Moisture levels were increased using long-duration surface irrigation before most of the saturated soil tests. From 12 to 27 replicate tests were conducted in each of the eight experimental categories in order to measure the variations within each category for comparison to the variation between the categories. Table 2.2. shows the categories tested .

Table 2-2. Experimental design categories for infiltration

Category	Moisture	Texture	Compaction	Number of Tests
1	Saturated	Clay	Compacted	18
2	Saturated	Clay	Non-compacted	27
3	Saturated	Sand	Compacted	18
4	Saturated	Sand	Non-compacted	12
5	Dry	Clay	Compacted	15
6	Dry	Clay	Non-compacted	17
7	Dry	Sand	Compacted	21
8	Dry	Sand	Non-compacted	24

Soil infiltration was expected to be related to the time since the soil was disturbed by construction or grading operations (turf age). In most new developments, compact soils are expected to be dominant, with reduced infiltration compared to pre-construction conditions. In older areas, the soil may have recovered some of its infiltration capacity due to root structure development and soil insects or other digging animals. Soils with a variety of times since development, ranging from current developments to those about 50 years old, were included in the sampling program. However, these sites were poorly distributed in their representation of the other primary test conditions and these effects were not directly determined. The Wisconsin DNR and the University of Wisconsin (Bannerman, personal communication) have conducted some soil infiltration tests on loamy soils to examine the effects of age of urbanization on soil infiltration rates. Their preliminary tests have indicated that several decades may be necessary before compacted loam soils recover to conditions similar to pre-development conditions.

Table 2-3 shows the analytical measurement methods used for measuring the infiltration rates, and supporting measurements, during the tests of infiltration at disturbed urban sites. All measurements were taken in natural soils in the field (leaving the surface sod in place), with no manipulation besides possibly increasing the moisture content before "wet" soil tests were conducted (if needed). At each site location, a field sample was obtained for a soil classification. The following paragraphs discuss these methods further.

Table 2-3. QA objectives for detection limits, precision, and accuracy for critical infiltration rate measurements in disturbed urban soils

Class	Compound	Method	Reporting Units	MDL	Precision	Accuracy
Infiltration rates through disturbed urban soils	double-ring infiltration rate measurements	ASTM D3385-94	in/hr	0.05	10%	NA
	soil texture	ASTM D 422-63, D 2488-93, and 421	Plots	NA	10%	NA
	Soil moisture (analytical balance)	ASTM D 2974-87	Percentage of moisture in soil (mg)	5% (0.1 mg)	10% (1%)	na (0.2 mg)
	soil compaction	Cone pentrometer	Psi	5	10%	NA
	soil age	Age of development	Years	NA	NA	NA

NA = Not applicable

Infiltration Rate Measurements

The infiltration test procedure included several measurements. Before a test was performed, the compaction of the soil was measured with the DICKEY-john Soil Compaction Tester Penetrometer and a sample was obtained to analyze moisture content. TURF-TEC Infiltrometers were used to measure the soil infiltration rates. These small devices have an inner ring about 64 mm (2.5 in.) in diameter and an outer ring about 110 mm (4.25 in.) in diameter. The water depth in the inner compartment starts at 125 mm (5 in.) at the beginning of the test, and the device is pushed into the ground 50 mm (2 in.). The rings are secured in a frame with a float in the inner chamber and a pointer next to a stop watch. These units are smaller than standard double-ring infiltrometers, but their ease of use allowed many tests under a variety of conditions. The use of three infiltrometers placed close together, i.e., within one meter of each other, also enabled better site variability to be determined than if one larger unit was used.

Both the inner and outer compartments of the infiltrometer were filled with clean water by first filling the inner compartment and then allowing it to overflow into the outer compartment. As soon as the measuring pointer reached the beginning of the scale, the timer was started. Readings were taken every five minutes for two hours. The two hour test was chosen to replicate the typical two hour rain duration and the expected time needed to reach saturation. The instantaneous infiltration rates were calculated by noting the drop of water level in the inner compartment over the 5-minute time period.

A total of 153 test were performed. The actual infiltration test procedure followed several basic steps. Whenever a test was performed, the compaction of the area was measured with the DlCKEYjohn Soil Compaction Tester Penetrometer and a sample was obtained to analyze the moisture content. Then, three TURF-TEC Infiltrometers were pushed into the turf. This was accomplished by pushing down on the handles and twisting slightly until the saturn ring was level with the surrounding turf. Each test was given a label consisting of four letters followed by a number and another letter. The first four letters help explain the characteristics of each observation.

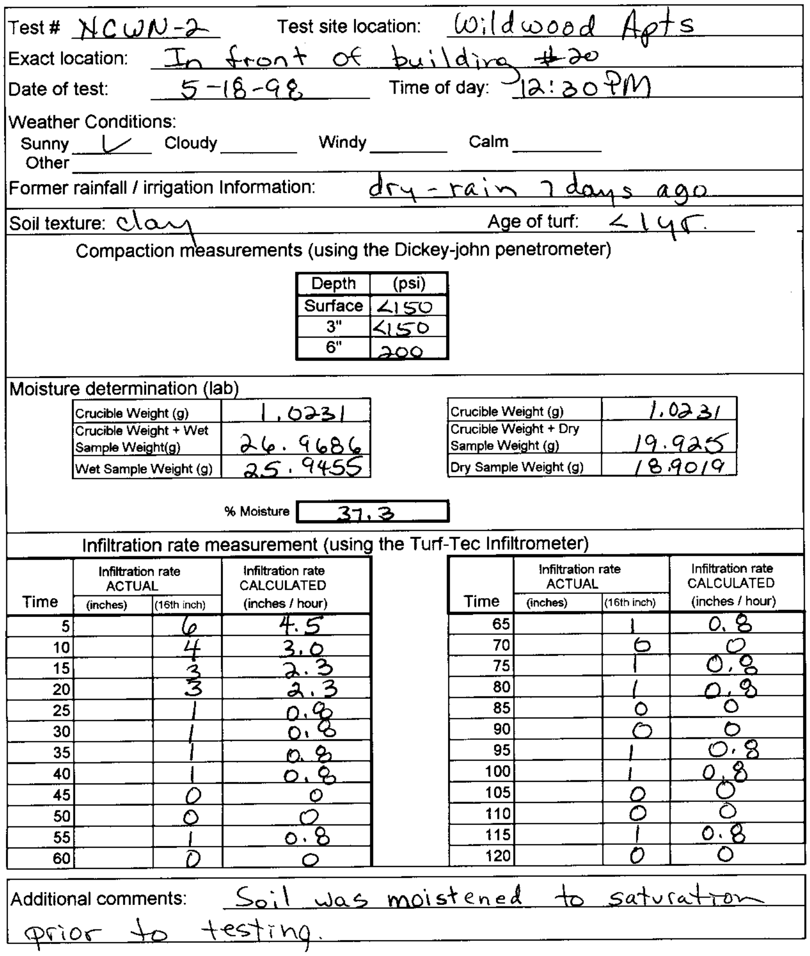
- The first letter designates the age of the turf: N for new and O for old.
- The second letter designates the predominant soil texture: S for sand and C for clay.
- The third letter designates the soil moisture: W for wet or (saturated) and D for dry (non-saturated).
- The forth letter designates the soil compaction: C for compacted and N for non-compacted.
- The number and final letter designate the test number.

As an example NSWC-1C would represent a newly disturbed site on a sandy textured soil that is wet and compacted, tested at site #1, and with the “c” infiltrometer. Table 2-4 defines the different levels for the experimental factors.

Table 2-4. Experimental conditions for infiltration

	Moisture	Disturbance	Soil Texture
Enhanced infiltration	Dry (<20% moisture)	Uncompacted (<300 psi)	Sandy (per ASTM D 2487 definition)
Decreased infiltration	Wet (>20% moisture)	Compact (>300 psi)	Clayey (per ASTM D 2487 definition)

Tests were recorded on a field observation sheet as shown in Figure 2-2. Each document contained information such as: relative site information, testing date and time, compaction data, moisture data, and water level drops over time, with the corresponding calculated infiltration rate for the 5-minute intervals. Tables containing all of the site measurements are in Appendix B and show the calculated infiltration rates (in/hr) for each 5-minute increment (the times shown are the test durations at the end of the 5-minute measurement periods, and the rates correspond to the 5-minute incremental rates for the preceding 5 minute period).



Test # NCWN-2 Test site location: Wildwood Apts

Exact location: In front of building #20

Date of test: 5-18-98 Time of day: 12:30 PM

Weather Conditions:

Sunny ✓ Cloudy ____ Windy ____ Calm ____

Other ____

Former rainfall / irrigation Information: dry - rain 7 days ago

Soil texture: clay Age of turf: < 1 yr.

Compaction measurements (using the Dickey-john penetrometer)

Depth	(psi)
Surface	<150
3"	<150
6"	200

Moisture determination (lab)

Crucible Weight (g)	1.0231
Crucible Weight + Wet Sample Weight(g)	26.9686
Wet Sample Weight (g)	25.9455

Crucible Weight (g)	1.0231
Crucible Weight + Dry Sample Weight (g)	19.925
Dry Sample Weight (g)	18.9019

% Moisture 37.3

Infiltration rate measurement (using the Turf-Tec Infiltrometer)

Time	Infiltration rate ACTUAL		Infiltration rate CALCULATED
	(inches)	(16th inch)	(inches / hour)
5		6	4.5
10		4	3.0
15		3	2.3
20		3	2.3
25		1	0.8
30		1	0.8
35		1	0.8
40		1	0.8
45		0	0
50		0	0
55		1	0.8
60		0	0

Time	Infiltration rate ACTUAL		Infiltration rate CALCULATED
	(inches)	(16th inch)	(inches / hour)
65		1	0.8
70		0	0
75		1	0.8
80		1	0.8
85		0	0
90		0	0
95		1	0.8
100		1	0.8
105		0	0
110		0	0
115		1	0.8
120		0	0

Additional comments: Soil was moistened to saturation prior to testing.

Figure 2-2. Field observation sheet.

Soil Moisture Measurements

The weather occurring during the testing enabled most site locations to produce a paired set of dry and wet tests. Moisture values relating to dry or wet soils are highly dependent on soil texture and were mostly determined by the length of antecedent dry period before the test. The dry tests were taken during periods of little rain, which typically extended for as long as two weeks with no rain and with sunny, hot days. The saturated tests were conducted through artificial soaking of the ground or after prolonged rain.

The soil moisture was measured in the field using a portable moisture meter (for some tests) and in the laboratory using standard soil moisture methods (for all tests). The moisture content, as defined by Das (1994), is the ratio of the weight of water to the weight of solids in a given volume of soil. Soil moisture was determined in the laboratory using the ASTM D 2974-87 method, by weighing the soil sample with its natural moisture content and recording the mass. The sample was then oven dried and its dry weight recorded. For typical sandy and clayey soils at the candidate test areas, the dry soils had moisture contents ranging from 5 to 20% (averaging 13%) water, while wet soils had moisture contents ranging from 20 to 40% (averaging 27%) water.

Soil Texture Measurements

The texture of the samples was determined by ASTM standard sieve analyses to verify the soil texture estimated in the field and for comparison to the NRCS soil maps. The sieve analysis used was the ASTM D 422-63 *Standard Test Method For Particle Size Analysis of Soils* for the particles larger than the No. 200 sieve, along with ASTM D 2488-93 *Standard Practice for Description and Identification of Soils (Visual - Manual Procedure).* The sample was prepared based on ASTM 421 *Practice for Dry Preparation of Soil Samples for Particle Size Analysis and Determination of Soil Constants.* The procedure requires a representative dry sample of the soil to be tested. After the material was dried and weighed, it was then crushed to allow a precise sieve analysis. The sample was then treated with a dispersing agent (sodium hexametaphosphate) and water at the specified quantities. The mixture was then washed over a No. 200 sieve to remove all soil particles smaller than the 0.075 mm openings. The sample was then dried again and a dry weight obtained. At that point, the remaining sample was placed in a sieve stack containing No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, No. 200 sieves, and the pan. The sieves were then placed in a mechanical shaker and allowed to separate onto their respective sieve sizes. The cumulative weight retained on each sieve was then recorded.

The designation for the sand or clay categories follows the *Unified Soil Classification System*, ASTM D 2487. Sandy soils required that more than half of the material be larger than the No. 200 sieve, and more than half of that fraction be smaller than the No. 4 sieve. Similarly, for clayey soils, more than half of the material is required to be smaller than the No. 200 sieve.

Soil Compaction Measurements

Before infiltration testing, the compaction of the test areas was obtained by pushing a DlCKEYjohn Soil Compaction Tester Pentrometer into the ground and recording the readings from the gauge. For these tests, compact soils were defined as a reading of greater than 300 psi at a depth of 75 mm (3 in.), while non-compacted soils had readings of less than 300 psi. Compaction was confirmed based on historical use of the test site location (especially the presence of parked vehicles, unpaved lanes, well-used walkways, etc.).

Soils, especially clayey soils, are obviously spongier and softer when wet then when extremely dry. Because the cone pentrometer measurements were sensitive to moisture, measurements were not made for saturated conditions and the degree of soil compaction was also determined based on the history of the specific site. Other factors that were beyond the control of the experiments, but also affected infiltration rates, included bioturbation by ants, gophers and other small burrowing animals, worms, and plant roots.

Soil/Compost Test Site Characterization (Task 2)

Plot Establishment

Figure 2-3 shows the layout of the CUH test plots. Test plots 1, 2, 5 and 6 were used during these current tests. Plots 1 and 2 were the control and amended plots for the Cedar Grove (CG) compost, while plots 5 and 6 were the control and amended plots for the GroCo compost. The Alderwood glacial till soil in plots 1 and 2 were obtained from a different location than the Alderwood glacial till soil in plots 5 and 6. The soil and compost for this study was mixed on an asphalt surface with a bucket loader and hauled and dumped into the plot bays. A system of collection buckets to allow sampling of both surface runoff and subsurface flows at intervals ranging from 15 minutes to longer was located at the CUH site, along with a tipping bucket rain gage. Similar setups were also installed at the two high school locations for these experiments.

Plots were planted using a commercial turfgrass mixture during the Spring, 1994, season for the CUH sites and in the fall of 1997 for the Timbercrest and Woodmoor sites. Fertilizer was added to all plots during plot establishment (16-4-8 $N\text{-}P_2O_5\text{-}K_2O$) broadcast spread over the study bays at the rate of 0.024 kg fertilizer/m^2 (0.005 lb fertilizer/ft^2) as recommended on the product's label. The initial application resulted in an application of 0.010 kg (0.023 lb) of elemental phosphorus (P) as orthophosphate (PO_4^-) per plot, or 0.00043 kg P/m^2 (0.000087 lb P/ft^2). This resulted in an application of 0.091 kg (0.20 lb) of elemental nitrogen (N) as ammonium (NH_4^+) and nitrate (NO_3^-) (undetermined distribution) per plot, or 0.0039 kg N/m^2 (0.00080 lb N/ft^2). Due to the poor growth of turf on the control plots, and in order to simulate what would have likely been done anyway on a typical residential lawn, an additional application of 0.024 kg/m^2 (0.005 lb/ft^2) was made to the CUH control plots on May 25, 1995.

Characterization of Compost-Amended Soils

Table 2-5 shows the measurement methods used for the physical tests conducted at the test sites.

Table 2-5. QA Objectives for Detection Limits, Precision, and Accuracy for Critical Measurements at Compost-Amended Soil Test Sites

Class	Compound	Method	Reporting Units	MDL	Precision[1]	Accuracy[2]
Infiltration rates through compost-amended soils	double-ring infiltration rate measurements	ASTM D3385-94	In/hr	0.05	10%	NA
	soil texture	ASTM D 422-63, D 2488-93, and 421	plots	NA	10%	NA
	bulk density	SSSA-P	kg/m	5	10%	NA
	water holding capacity	SSSA-P	L/m	1	10%	NA
	surface and subsurface flows	Direct measurement of flows using custom made tipping buckets	L/s	0.1	10%	NA

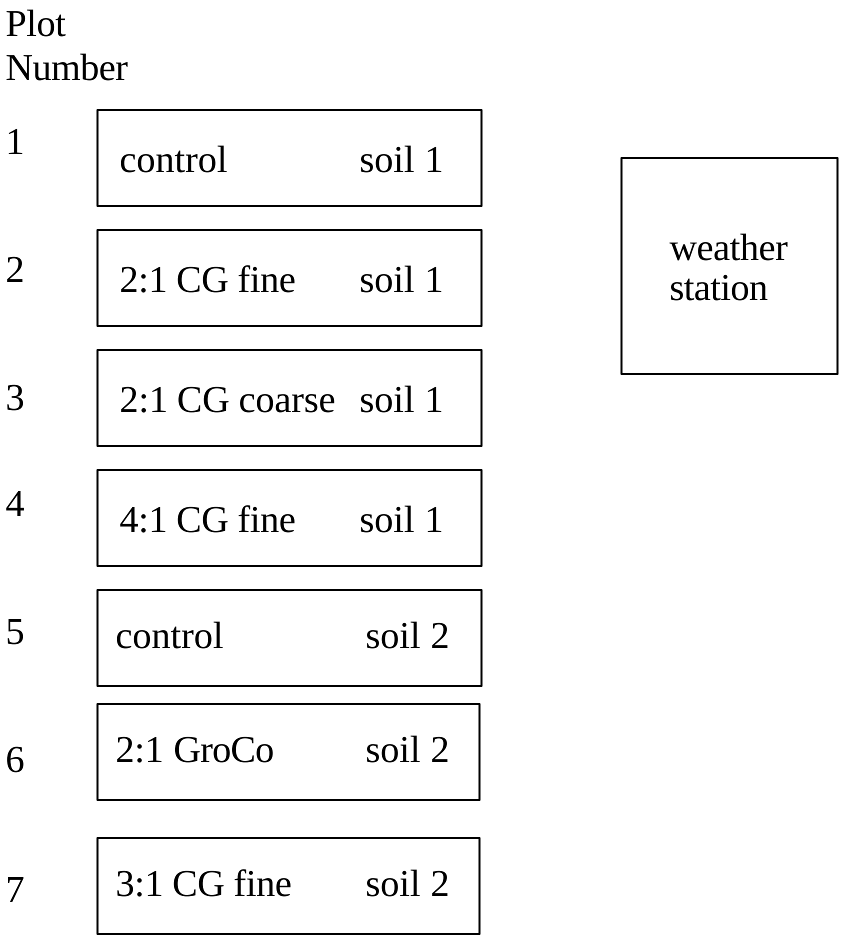
[1] expressed as relative percent difference

[2] expressed as percent recovery, unless otherwise noted

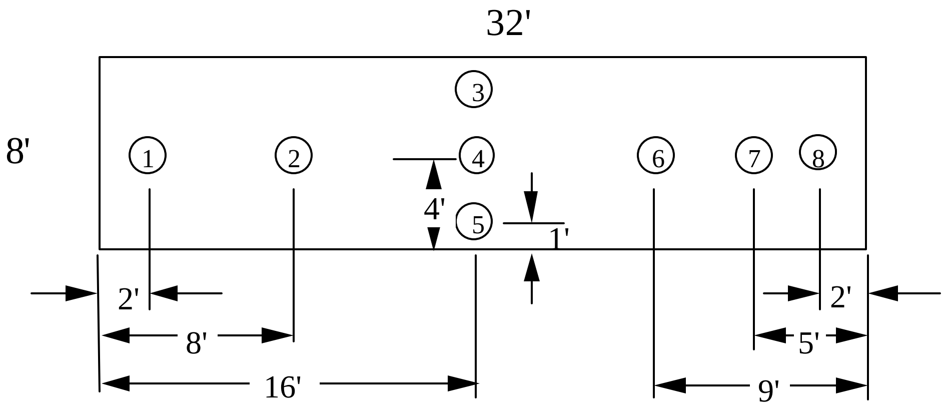
The study design for this phase of the research was a randomized complete block design, with four blocks of two treatments. Treatments included the following:

(1) control turf plots with Alderwood soil-only, and
(2) compost-amended turf plots with a 2:1 soil:compost mixture.

Figure 2-3. University of Washington Center for Urban Horticulture compost amendment research site layout.



Detail of Soil Sampling Scheme



The four blocks were tested at the three locations, with one block each at Timbercrest and Woodmoor High School, and two blocks at the CUH facility. The blocks are differentiated by differences in the native soil characteristics. Differences in the physical and chemical parameters of the infiltrating water during this study were examined using nonparametric comparison tests, augmented with exploratory data analyses procedures.

Soil and soil/compost mixture samples were taken 1 month after the initiation of the study and analyzed by the CFR analytical labs for the following parameters:

1) total carbon (C),
2) total N,
6) bulk density,
7) particle density,
3) gravimetric water holding capacity (field capacity) moisture,
4) volumetric water holding capacity (field capacity) moisture,
5) total porosity,
8) particle size analysis, and
9) soil structure.

Total C and N were determined using an automated CHN analyzer because they were considered to be the primary measures of productivity in these soils. Bulk density was estimated using a coring device of known volume (bulk density soil sampler). The core was removed, oven dried, and weighed. Bulk density was calculated as the oven dry weight divided by the core volume. Particle density was determined by using a gravimetric displacement. A known weight of soil or soil/compost mixture was placed in a volumetric flask containing water. The volume of displacement was measured and particle density was calculated by dividing the oven-dried weight by displaced volume.

Gravimetric water holding capacity was determined using a soil column extraction method that approximates field capacity by drawing air downward through a soil column. Soil or soil/compost mixture was placed into 50 ml syringe tubes and tapped down (not compressed directly) to achieve the same bulk density as the field bulk density measured with coring devices. The column was saturated by drawing 50 ml of water through the soil column, then brought to approximate field capacity by drawing 50 ml of air through the soil or soil/compost column.

Volumetric water holding capacity was calculated by multiplying gravimetric field capacity by the bulk density. Total porosity was calculated by using the following function:

$$\text{Total porosity} = 1- (\text{bulk density} / \text{particle density}) \times 100\% \qquad (2\text{-}1)$$

Particle size distribution was determined both by sieve analysis and sedimentation analysis for particles less than 0.5 mm in size. Due to the light nature of the organic matter amendment, particle size analysis was sometimes difficult, and may have been slightly inaccurate. Soil structure was determined using the feel method and comparing soil and soil/compost mixture samples to known structures.

Before any runoff tests were conducted, background soil samples were analyzed. The relative concentrations and mass of nutrients and metal species in the soil and compost was of interest, as is the mass movement into and out of the soil. Additionally, because some nutrients interact strongly with several soil metals, determining these elements and relative amounts would be useful in making inferences about nutrient and metal retention or loss in runoff. Another important aspect was the possibility of establishing a concentration gradient in the soil profile.

Flow Measurements at Field Test Sites

The design for the test bay system developed by the UWRC (Harrison, *et al*. 1997) was used to enclose soil-compost mixes and collect surface and subsurface runoff. These systems consist of enclosed bays with tipping buckets attached to data recorders. Similar systems were constructed and used at Timbercrest and Woodmoor high schools.

Glacial till soil was added to the bays and compacted before adding compost. Cedar Grove compost was added at a 2:1 soil:compost rate and rototilled into the soil surface. Particular attention was placed on simulating a compacted glacial till layer to represent natural field conditions. Once installed, all bays were cropped with perennial ryegrass. Separate surface runoff and subsurface flow collectors were installed within each bay. Collection basins were equipped with tipping buckets to record flow over time at 15-minute intervals.

The large plywood bays containing soil and soil-compost mixes were used in the CUH field studies. Irrigation water was supplied from a nearby existing water supply system. An overhead sprinkler system was used during previous studies (Harrison, *et al*. 1997) to simulate actual rainfall events. Monthly sampling of water leaving the sites following natural rainfall events had been initially planned.

Double-ring infiltration tests, based on ASTM method D 3385, were performed. However, due to the small size of the plots and the potential for destruction of the plots by installation of large rings, the small ring was 7.5 cm in diameter and the large ring was 14 cm in diameter. The rings were driven into the soil to a maximum depth of 7.5 cm. Measurements were taken on surface infiltration only.

Sub-surface flows and surface runoff during rains were measured and sampled using special tipping-bucket flow monitors which collected the samples from the tubing shown in Figure 2-4. The flow amounts and rates were measured by the tipping-bucket devices which were attached to an electronic recorder, as shown in Figure 2-5. Each tip of the bucket was calibrated for each site and checked on a regular basis to give rates of surface and subsurface runoff from all plots.

The Timbercrest High School and WoodMoor High School field sites in Northern King County, Washington were located on poorly-sorted, compacted Glacial Till soils of the Alderwood soil series. Sampling installations included *in-situ* installations similar to those pictured in Figures 2-4 and 2-5. Surface runoff and subsurface flows were collected from bucket tips during 7 separate intervals, as shown on Table 2-6.

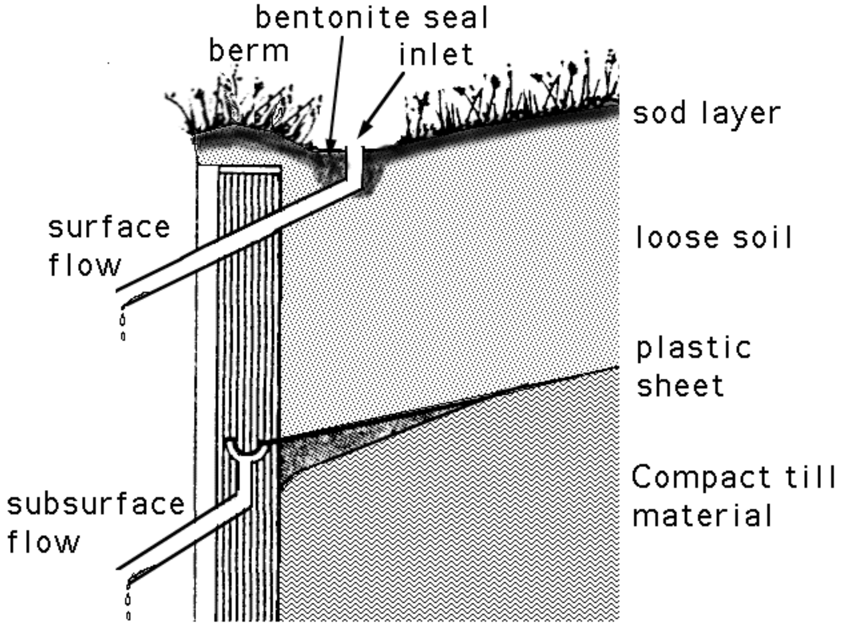


Figure 2-4. Drawing of surface and subsurface flow collectors for use in field sites.

Figure 2-5. Picture of the tipping bucket installation for monitoring surface runoff and subsurface flows at the University of Washington Center for Urban Horticulture

Table 2-6. Collection periods and rain quantities

Period	Period start date (and time)	Period end date (and time)	Total time during period (days)	Total rainfall during period at UW sites (mm)	Total rainfall during period at new sites (mm)
1	Dec. 5, 1997 (08:05)	Dec. 17, 1997 (12:30)	12.2	46.2	(not measured)
2	Dec. 17, 1997 (12:45)	Jan. 3, 1998 (12:10)	17.0	34.5	27.2
3	Jan. 4, 1998 (12:40)	Feb. 18, 1998 (16:20)	45.2	288	250
4	Feb. 18, 1998 (16:55)	March 14, 1998 (17:15)	24.0	79.6	68.1
5	March 14, 1998 (17:15)	April 14, 1998 (18:30)	31.1	65.4	76.2
6	April 14, 1998 (18:30)	May 27, 1998 (12:20)	42.7	(not measured)	54.6
7	May 27, 1998 (12:20)	June 25, 1998 (17:15)	29.2	(not measured)	33.8

There were several problems with flow monitoring and water sampling at the sites, especially at the new test sites. At Timbercrest, the very high water table and the pressure on the sealed container that was supposed to exclude surface water from entering the collector box, caused the tipping buckets to function improperly. Thus, they were removed and collection bottles were substituted that did not record flow versus time. Problems were not as severe at the Woodmoor site, and samples were collected versus time for the duration of the study. At the CUH site, tipping buckets did not record during the last two time periods. However, during each of the 5 to 6 fully monitored time periods at each site, many individual rains were included in the data.

Both surface runoff and subsurface flow were separately collected following the seven rainfall periods during the months of December 1997 through June 1998. Surface runoff and subsurface flows were collected monthly from the surface and subsurface collection basins. At the beginning of the project, to help establish the new turf, a typical lawn herbicide/fertilizer combination was broadcast spread over the study bays at the rate recommended on the product label.

Samples were collected in polypropylene bottles and immediately placed in cold storage on-site. Subsurface flow samples were collected in a similar manner. Sample times varied depending on antecedent soil moisture and amount of flow generated by simulated rainfall. All water samples were immediately taken to the analytical lab and stored at 4°C until analysis.

Water Quality Sampling and Analysis at Compost Amended Soil Test Sites

Analytical Measurements and Procedures

Selected laboratory noncritical measurements were made to supplement the above critical physical measurements. These included periodic particle size analyses and toxicity screening analyses, plus nutrient and heavy metal analyses at the compost-amended test sites. The following list shows these measurements that were also conducted on the samples collected from the Seattle area tests:

Acid hydrolyzable P, Chlorine (Cl), nitrite (NO_2), NO_3, PO_4^- – P, sulfate (SO_4) and
Total arsenic (As), boron (B), barium (Ba), calcium (Ca), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), magnesium (Mg), potassium (K), manganese (Mn), N, sodium (Na), nickel (Ni), P, lead (Pb), sulfer (S), selenium (Se), and zinc (Zn)

All work was done in accordance with UW analytical laboratory QA/QC procedures. In addition, most of the surface runoff and subsurface flow samples were also screened for toxicity (using the Azur Microtox® procedure) and analyzed for particle sizes (using a Coulter counter) at UAB's Department of Civil and Environmental Engineering laboratory. Table 2-7 summarizes the laboratory methods and procedures.

Table 2-7. Analytical methods

Class	Compound	Method
Soil analyses	Bray extractable P	SSSA-C
	Total N	EPA 351.1,350.1
	Total As, B, Ba, Ca, Cd, Cr, Cu, Fe, Mg, K, Mn, Na, Ni, P, Pb, S, Se, Zn	EPA 6010 after digestion using EPA 3050
Surface Runoff and Subsurface Flow Analysis	Phosphate-P	EPA 300.0
	Acid hydrolyzable P	APCA 4500-P
	Total N	EPA 351.1,350.1
	Cl, NO_2, NO_3, SO_4	EPA 300.0
	Total As, B, Ba, Ca, Cd, Cr, Cu, Fe, Mg, K, Mn, Na, Ni, P, Pb, S, Se, Zn	EPA 6010 after digestion using EPA 3010

EPA = EPA standard methods
APCA = American Public Health Assoc. Std. Methods for examination of water and wastewater. 1992.
SSSA-P = Soil Science Society of America. Methods of Soil Analysis. Part1 - Physical and mineralogical methods, 2nd edition
SSSA-C = Soil Science Society of America. Methods of Soil Analysis. Part2 - Chemical and microbiological properties, 2nd edition

Basic Data Analysis Procedures

Factorial Experimental Designs

Factorial experiments are described in Box *et al*. (1978) and in Berthouex and Brown (1994). Both of these books include many alternative experimental designs and examples of this method. Berthouex and Brown (1994) state that "experiments are done to:

1) screen a set of factors (independent variables) and learn which produce an effect,
2) estimate the magnitude of effects produced by experimental factors,
3) develop an empirical model, and
4) develop a mechanistic model."

They concluded that factorial experiments are efficient tools in meeting the first two objectives and are also excellent for meeting the third objective in many cases. Information obtained during the experiments can also be very helpful in planning the strategy for developing mechanistic models. Factorial experimental designs enable a large number of possible factors that may influence the experimental outcome to be simultaneously evaluated.

Box, *et al*. (1978) presents a comprehensive description of many variations of factorial experimental designs. A simple 2^3 design may include the three experimental factors of temperature, catalyst, and concentrations at two levels each. All possible combinations of these three factors are tested, representing each corner of a cube. The experimental results are placed at the appropriate corners. Significant effects can be easily seen by comparing values on opposite faces of the cube. If the values on one face are consistently larger than the opposite face, then the experimental factor separating the faces likely has a significant effect on the outcome of the experiments. The analysis of the results to identify the significant factors is straight-forward.

One of the major advantages of factorial experimental designs is that the main effect of each factor and the effects of all possible interactions of all of the factors can be examined with relatively few experiments. The initial experiments are usually conducted with each factor tested at two levels (a high and a low level). All possible combinations of these factors are then tested. Table 2-8 shows an experimental design for testing 4 factors that will be used during this research. This experiment therefore requires 2^4 (16) separate experiments to examine the main effects and all possible interactions of these four factors. The signs signify the experimental conditions for each main factor during each of the 16 experiments. The shaded main factors are the experimental conditions, while the other columns specify the data reduction procedures for the other interactions. A plus sign shows when the factor is to be held at the high level and a minus sign for the low level. This table also shows all possible two-way, three-way, and four-way interactions, in addition to the main factors. Simple analyses of the experimental results allow the significance of each of these factors and interactions to be determined. In the case of Task1, the following list shows the four factors and the associated levels for tests conducted to identify factors affecting surface runoff characteristics:

M: Soil moisture (saturated or wet: +; dry: -)
T: Soil texture (clayey: +; sandy: -)
C: Compaction (compacted: +; undisturbed or non-compacted: -)
A: Age of Development (new: +; old: -)

The experiments were conducted under two conditions at each site, when the site soils were dry and when the site soils were saturated. Saturated soils were developed by artificial irrigation, if necessary, while dry soil could only occur naturally. From 6 to 12 replicates were conducted for each of the 16 scenarios. The infiltration data is then analyzed by fitting the data to the Horton-infiltration equation, described previously. The replicates of the infiltration-equation parameters were the primary values evaluated by the factorial process.

Replicate observations enhance the data analysis efforts and grouped standard error values can be calculated (Box, *et al*. 1978) to identify the significant factors affecting runoff characteristics. Even when observations for some of the experimental conditions are incomplete, a fractional factorial design can still be used to organize the data and to calculate the effects for all of the main factors and most of the interactions.

Once the initial experiments are completed, follow-up experiments can be efficiently designed to examine the linearity of the effects of the significant factors by conducting response surface experimental designs. In addition, further experiments can be conducted and merged with these initial experiments to examine other factors that were not considered in the first experiments. Because of the usefulness and adaptability of factorial experimental designs, Berthouex and Brown (1994) recommend that they "should be the backbone of an experimenter's design strategy."

Table 2-8. Factorial Experimental Design for Four Factors and 16 Experiments

Experiment #	M	T	C	A	MT	MC	MA	TC	TA	CA	MTC	MTA	TCA	MTCA
1	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	-	+	+	+	-	-	-	+	+	+	-	-	+	-
3	+	-	+	+	-	+	+	-	-	+	-	-	-	-
4	-	-	+	+	+	-	-	-	-	+	+	+	-	+
5	+	+	-	+	+	-	+	-	+	-	-	+	-	-
6	-	+	-	+	-	+	-	-	+	-	+	-	-	+
7	+	-	-	+	-	-	+	+	-	-	+	-	+	+
8	-	-	-	+	+	+	-	+	-	-	-	+	+	-
9	+	+	+	-	+	+	-	+	-	-	+	-	-	-
10	-	+	+	-	-	-	+	+	-	-	-	+	-	+
11	+	-	+	-	-	+	-	-	+	-	-	+	+	+
12	-	-	+	-	+	-	+	-	+	-	+	-	+	-
13	+	+	-	-	+	-	-	-	-	+	-	-	+	+
14	-	+	-	-	-	+	+	-	-	+	+	+	+	-
15	+	-	-	-	-	-	-	+	+	+	+	+	-	-
16	-	-	-	-	+	+	+	+	+	+	-	-	-	+

The following factors would require the selection of eight sampling locations:

1) sandy, old and compacted
2) sandy, new and compacted
3) sandy, old and undisturbed
4) sandy, new and undisturbed
5) clayey, old and compacted
6) clayey, new and undisturbed
7) clayey, old and compacted
8) clayey, new and undisturbed

Comparison Tests

Berthouex and Brown (1994) and Gilbert (1987) present excellent summaries of the most common statistical tests that are used for data comparisons in environmental investigations. The significance test results (the α value) indicates the level of confidence that the two sets of observations are the same (e.g., comparing the control soil site with the compost-amended soil site). Generally, an α level of less than 0.05 is used to signify significant differences between two sets of observations. For this project, even if the α level was significant (less than 0.05), the infiltration rate difference may not have been very important. Therefore, the importance of the level of infiltration rate differences were also graphically presented using grouped box plots to indicate the range and variations of the infiltration characteristics at each of the test locations.

The main types of comparison tests are separated into independent and paired tests. These can be further separated into tests that require specific probability distribution characteristics (parametric tests) and tests that do not have as many restrictions based on probability distribution characteristics of the data (nonparametric data). When the parametric test requirements are met, they should be used as parametric tests have more statistical power than nonparametric test. However, if information concerning the probability distributions is not available, or the distributions do not behave correctly, then the somewhat less powerful nonparamteric tests should be used.

Paired observations are the preferential method of data gathering over the use of independent test. In many cases, however, observations cannot be related to each other. An example is a series of observations at two separate locations during all the rain events for a season. Unless the sites are very close together, the rains are likely to vary considerably at the two locations, disallowing a paired analysis. However, if data were collected simultaneously, e.g., the test and control plots for the CUH site, paired tests can be used to control all factors that may influence the outcome, resulting in a more efficient statistical analysis. Paired experimental designs ensure that uncontrolled factors basically influence both sets of data observations equally (Berthouex and Brown 1994).

The parametric tests used for comparisons are the t-tests, i.e. both independent and paired t-tests. All statistical analyses software and most spreadsheet programs contain both of these basic tests. These tests require that the variances of the sample sets be the same and do not vary over the range of the values. These tests also require that the probability distributions be Gaussian. Transformations can be used to modify the data sets to Gaussian distributions. Log-transformations can be used to produce Gaussian distributions for most water quality data. Square root transformations are also commonly used to make the variance constant over the data range, especially for biological observations (Sokal and Rohlf 1969). In all cases, it is necessary to confirm these requirements before the standard t-tests are used.

Nonparametrics: Statistical Methods Based on Ranks by Lehman and D'Abrera (1975) is a comprehensive general reference on nonparametric statistical analyses. Gilbert (1987) presents an excellent review of nonparametric alternatives to the t-tests, especially for environmental investigations from which the following discussion is summarized. Even though the nonparametric tests remove many of the restrictions associated with the t-tests, the t-tests should be used if justifiable. Unfortunately, seldom are the t-test requirements easily met with environmental data and the slight loss of power associated with using the nonparametric tests is much more acceptable than misusing the t-tests. Besides having few data distribution restrictions, many of the nonparametric tests can also accommodate a few missing data, or observations below the detection limits. The following paragraphs briefly describe the features of the nonparametric tests that were used to compare the data sets during this research.

Nonparametric Tests for Paired Data Observations

The sign test is the basic nonparametric test for paired data. It is simple to compute and has no requirements pertaining to data distributions. A few “not detected” observations can also be accommodated. Two sets of data are compared and the differences are used to assign positive and negative signs. If the value in one data set is greater than the corresponding value in the other data set, a positive is assigned. A negative sign is assigned if the one value is less than the corresponding value in the other data set. The number of positive signs are added and a statistical table (such as in Lehman and D’Abrera 1975) is used to determine if the number of positive signs found is unusual for the number of data pairs examined.

The Wilcoxon signed rank test (not to be confused with the Wilcoxon rank sum test, which is for independent data observations) has more power than the sign test, but it requires that the data distributions be symmetrical (but with no specific distribution type). Without transformations, this requirement is difficult to justify for water quality data. This test requires that the differences between the data pairs in the two data sets be calculated and ranked before checking with a special statistical table (as in Lehman and D’Abrera 1975). In the simplest cases, comparisons can be easily made to determine the statistical significance of the differences.

Friedman’s test is an extension of the sign test for several related data groups. There are no data distribution requirements and the test can accommodate a moderate number of “non-detectable” values, but missing values are not allowed.

Nonparametric Tests for Independent Data Observations

As for the t-tests, paired test experimental designs are superior to independent designs for nonparametric tests because of their ability to cancel out confusing properties. The Wilcoxon rank sum test is the basic nonparametric test for independent observations. The test statistic is also easy to compute and compare to the appropriate statistical table (as in Lehman and D'Abrera 1975). The Wilcoxon rank sum test requires that the probability distributions of the two data sets be the same (and therefore have the same variances). There are no other restrictions on the data distributions (they do not have to be symmetrical, for example). A moderate number of "non-detectable" values can be accommodated by treating them as ties.

The Kruskal-Wallis test is an extension of the Wilcoxon rank sum test and allows evaluations of several independent data sets, instead of just two. Again, the distributions of the data sets must all be the same, but they can have any shape. A moderate number of ties and non-detectable values can also be accommodated.

Additional Statistical Tests

Other tests were used to supplement the basic tests described above. These were mostly exploratory data analysis methods, including grouped box plots, 3D surface plots, Pearson correlation matrices, cluster analyses, and principal component analyses. These tests identified simple and complex inter-relationships between site factors and measurements. These supplemented the above described factor analyses and comparison tests. All statistical tests were conducted using SYSTAT, version 8, and SigmaPlot, version 4, all from SPSS Software.

Section 3
Results of Infiltration Tests in Disturbed Urban Soils (Task 1)

The data collected during these tests, and the detailed statistical analyses, are included in Appendices B through F. Appendix B lists the observed infiltration rates for all tests, Appendix C contains summaries of site conditions and the fitted infiltration equation parameters, and Appendices D through F show the factorial test calculations and models.

Calculated Infiltration Rates and Fitted Models

Exploratory Data Analyses

The initial analysis was to prepare simple plots of the infiltration data in order to observe major trends and groupings of the data. Three-D plots were prepared for the compaction and moisture factors for each major soil texture (sand and clay). These plots are shown in Figures 3-1 and 3-2. Four general categories were observed to be unique:

- Noncompacted-sandy soils
- Compacted-sandy soils
- Dry-noncompacted-clayey soils
- All other clayey soils (compacted and dry, plus all saturated conditions)

These analyses show that compaction had the greatest effect on infiltration rates in sandy soils, with little detrimental effects associated with soil moisture. Compaction and moisture affected clayey soils. Compaction had about the same effect as moisture on clayey soils, with saturated-compacted-clayey soils having the least effective infiltration.

Fitting Observed Data to the Horton Infiltration Equation

Data from each site test was fitted to the Horton infiltration equation and the equation coefficients were statistically analyzed using factorial analysis procedures. Figures 3-3 through 3-6 show the observed infiltration rates, and the fitted Horton equation parameters for the four general categories, as found in the three dimensional plots of Figure 3-1 and 3-2.

Figure 3-3 demonstrates that noncompacted sand is the urban soil condition with the greatest infiltration potential. In addition, this condition is the only one of the four major categories that had an obvious decrease in infiltration with time during the tests. The observed infiltration rates occur in a relatively even, but broad, band. Three of the 36 tests had very low initial rates, but were within the typical band of observations after about ten minutes. Some initial wetting, or destruction of a surface crust, was apparently necessary before the site infiltration rate stabilized. Table 3-1 summarizes the observed Horton equation parameter values, compared to the typical published parameter values, for sandy soils.

The observed infiltration ratess differed greatly from the published values. Typically, published values reflected moisture effects to the Horton infiltration equation and the equation coefficients, while the observations indicated very small effects associated with moisture for sandy soils, and very large effects associated with compaction. The constant-final-infiltration rates were larger than typically assumed, with infiltration rates for noncompacted, sandy soils of about 350 mm/hr (14 in/hr), ranging from about 125 to 635 mm/hr (5 to 25 in/hr) during the tests. The comparable published rates were less than 25 mm/hr (1 in/hr). The infiltration rates leveled-off to the constant-final values after about 30 to 45 min.

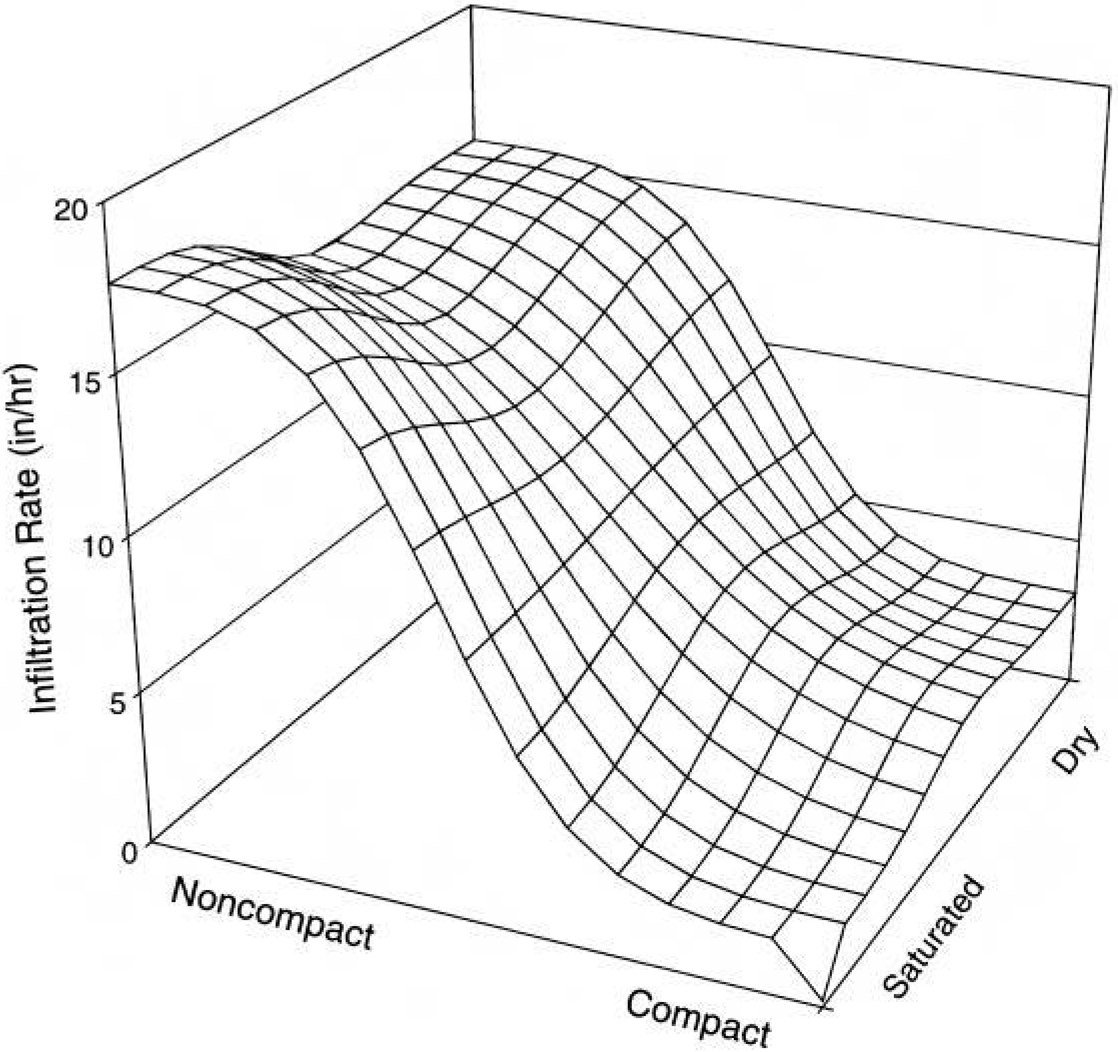


Figure 3-1. Three dimensional plot of infiltration rates for sandy soils.

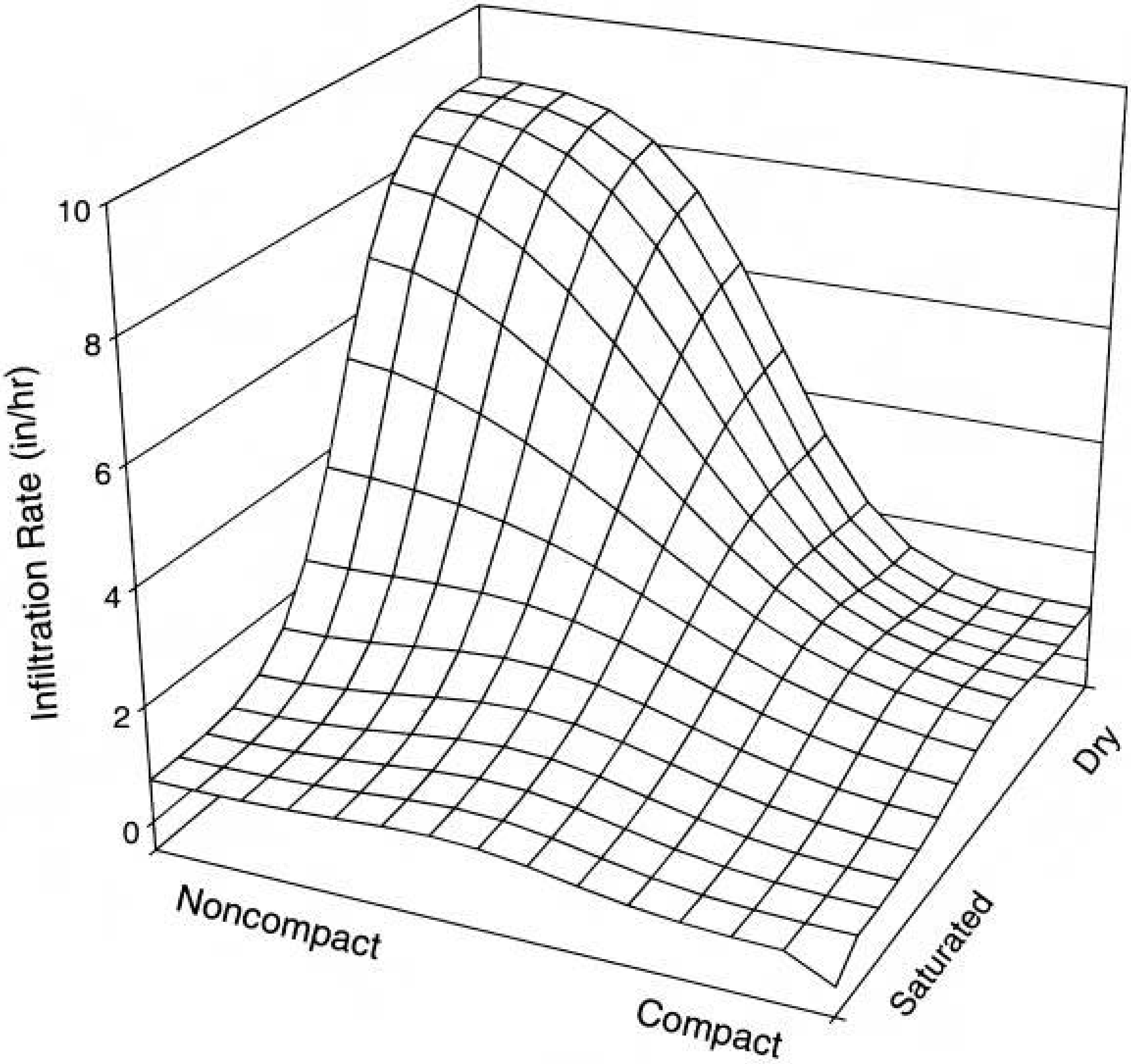
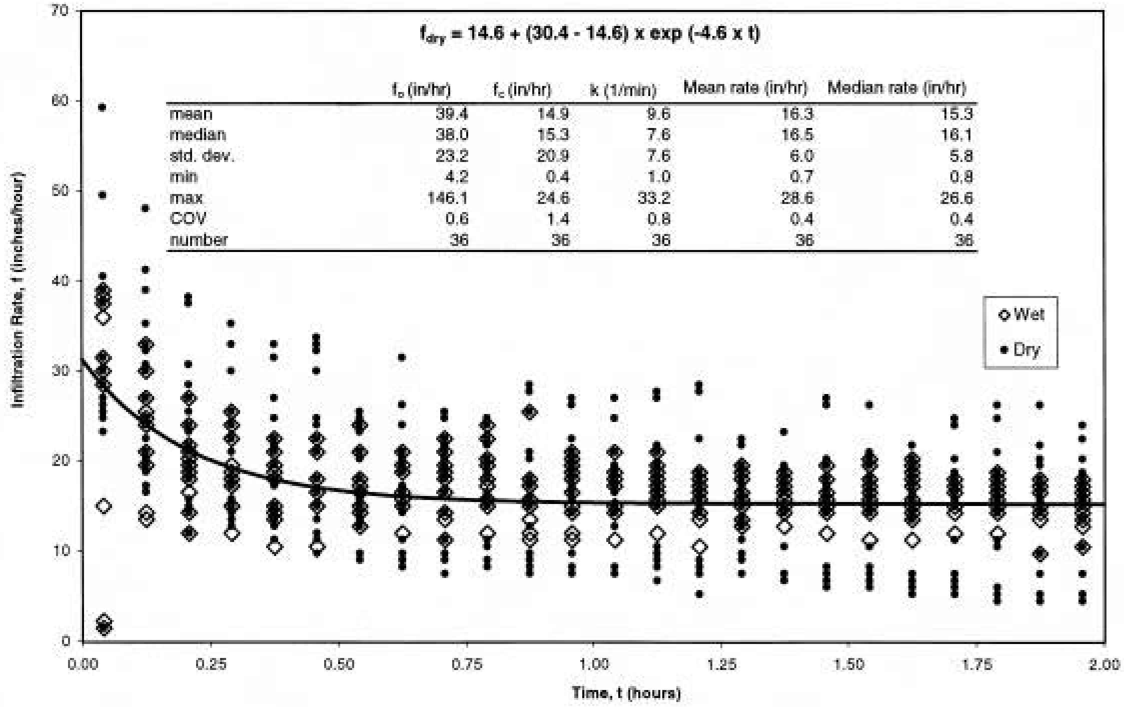


Figure 3-2. Three dimensional plot of infiltration rates for clayey soils.

Table 3-1. Observed and published Horton equation parameter values for sandy soils

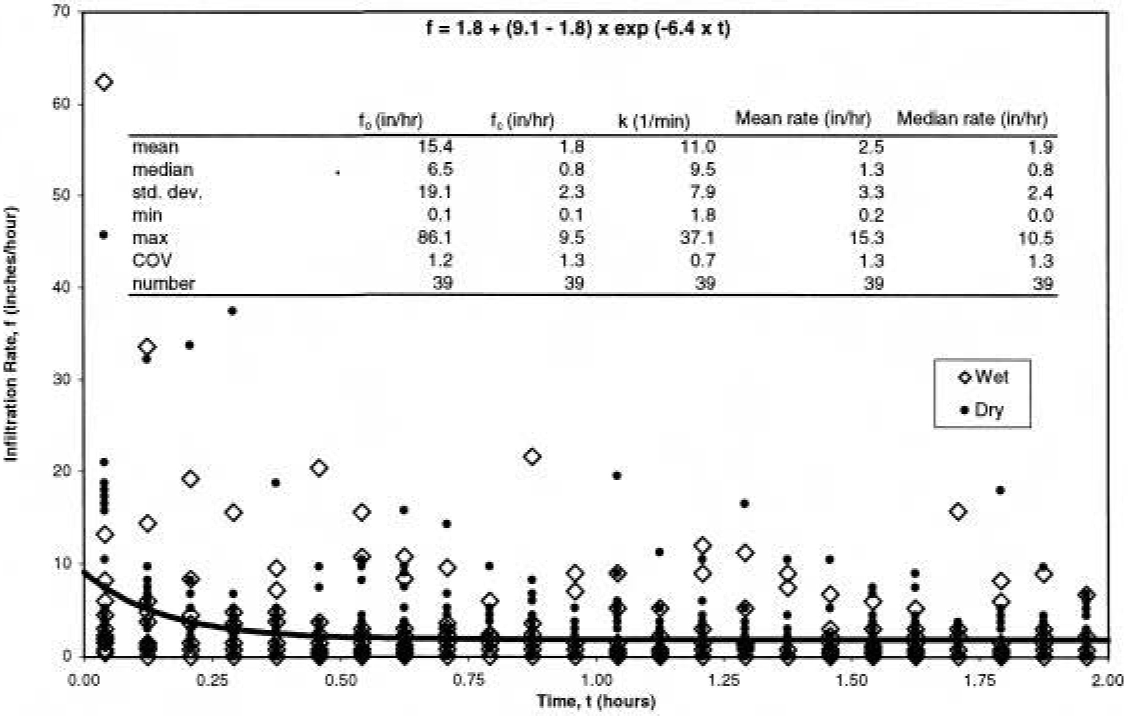
	f_o mm/hr (in/hr)		f_c mm/hr (in/hr)		k (1/min)	
	mean	range	mean	range	mean	Range
Observed noncompacted-sandy soils	990 (39)	110–3710 (4.2–146)	380 (15)	10–640 (0.4–25)	9.6	1.0–33
Observed compacted-sandy soils	380 (15)	3–2200 (0.1–86)	46 (1.8)	3–240 (0.1–9.5)	11	1.8–37
Published values		43–250 (1.7–10)		7.6–11 (0.30–0.45)		0.069

Figure 3-4 shows the observed infiltration rates and the fitted Horton equation parameter values for compacted-sandy soils. The observed rates are significantly less than for the above noncompacted-sandy soils. The effect of compaction on sandy soils is very large, reducing the infiltration rates by between 5 and 10 times. Some initial rates were very large, but the rates decreased quickly with time. After 20 to 30 minutes, they are all within about 0 to 500 mm/hr (0 to 20 in/hr), with most of the 39 observations less than 125 mm/hr (5 in/hr).



	f_o (in/hr)	f_c (in/hr)	k (1/min)	Mean rate (in/hr)	Median rate (in/hr)
mean	39.4	14.9	9.6	16.3	15.3
median	38.0	15.3	7.6	16.5	16.1
std. dev.	23.2	20.9	7.6	6.0	5.8
min	4.2	0.4	1.0	0.7	0.8
max	146.1	24.6	33.2	28.6	26.6
COV	0.6	1.4	0.8	0.4	0.4
number	36	36	36	36	36

Figure 3-3. Infiltration measurements for noncompacted-sandy soils.



	f_o (in/hr)	f_c (in/hr)	k (1/min)	Mean rate (in/hr)	Median rate (in/hr)
mean	15.4	1.8	11.0	2.5	1.9
median	6.5	0.8	9.5	1.3	0.8
std. dev.	19.1	2.3	7.9	3.3	2.4
min	0.1	0.1	1.8	0.2	0.0
max	86.1	9.5	37.1	15.3	10.5
COV	1.2	1.3	0.7	1.3	1.3
number	39	39	39	39	39

Figure 3-4. Infiltration measurements for compacted-sandy soils.

Figure 3-5 is a similar plot for dry-noncompacted-clayey soils which was the highest infiltration rate category for clayey soils. No significant change in infiltration rates were seen as a function of time, with all test average values within the range of 8 to 500 mm/hr (0.3 to 20 in/hr) and a mean rate of about 230 mm/hr (9 in/hr) for all 18 tests. Figure 3-6 shows the observed test results for the other clayey soils (dry and compact, and all saturated conditions). These rates were the lowest observed. Some initial values of the saturated-noncompacted-clayey soils were greater than later values, although most of the 60 sets of test data indicated infiltration rates were within a relatively narrow range of less than 125 mm/hr (5 in/hr). Table 3-2 shows the observed Horton equation parameters as compared to published values. The mean clayey-soil rates of infiltration were all greater than the published values, although the compacted and saturated clays were much closer to the published values than the observed rates of dry clayey soil.

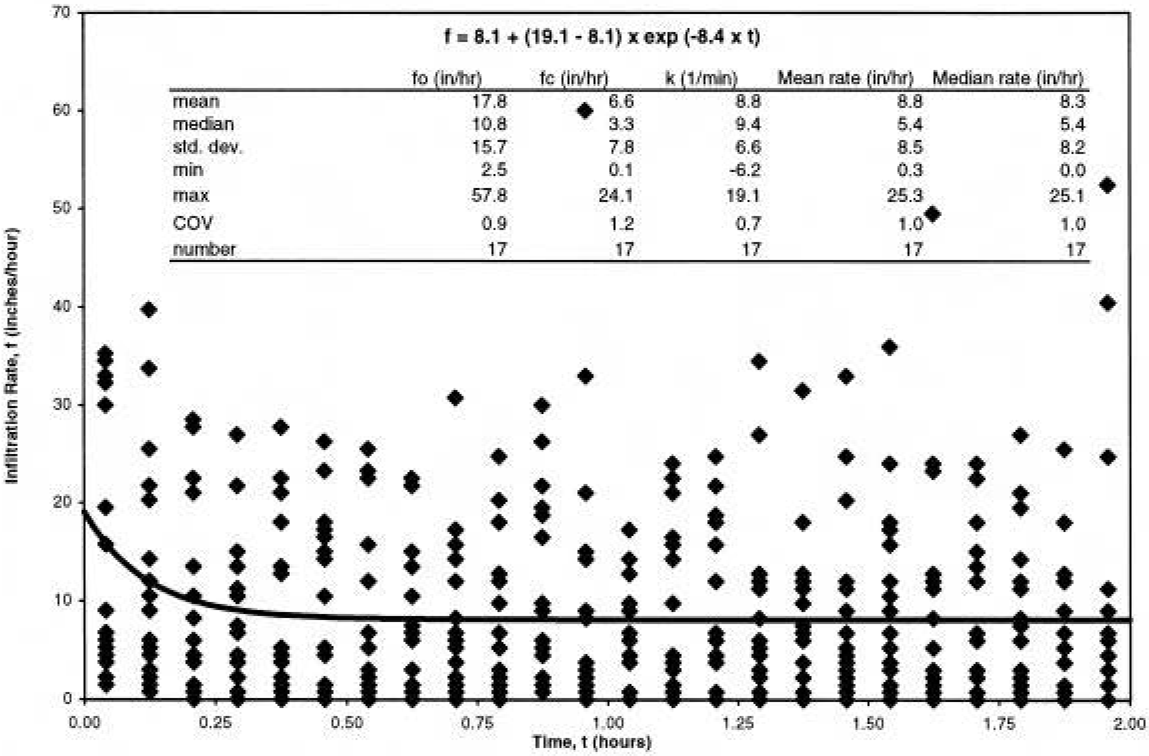
Table 3-2. Clayey soil Horton Equation parameter observed and published values

	f_o mm/hr (in/hr)		f_c mm/hr (in/hr)		k (1/min)	
	mean	range	mean	range	mean	range
Observed dry-noncompacted-clayey soils	460 (18)	64–1500 (2.5–58)	170 (6.6)	3–610 (0.1–24)	8.8	-6.2–19
Published values for dry-clayey soils		30–50 1–2		0–1 0–0.05	0.069	
Observed for all other clayey soils (compacted and dry, plus all saturated conditions)	86 (3.4)	0–1200 (0–48)	10 (0.4)	-15–170 (-0.6–6.7)	5.6	0–46
Published values for saturated-clayey soils		8–18 (0.3–0.7)		0–1 (0–0.05)	0.069	

Time-Averaged Infiltration Rates

Because of the wide range in observed rates for each of the major categories, it may not matter much which infiltration rate equation is used. The residuals are all relatively large and it may be more important to consider the random nature of infiltration about any fitted model and to address the considerable effect that soil compaction has on infiltration. It may therefore be necessary to use a Monte Carlo stochastic component in a runoff model to describe this variation.

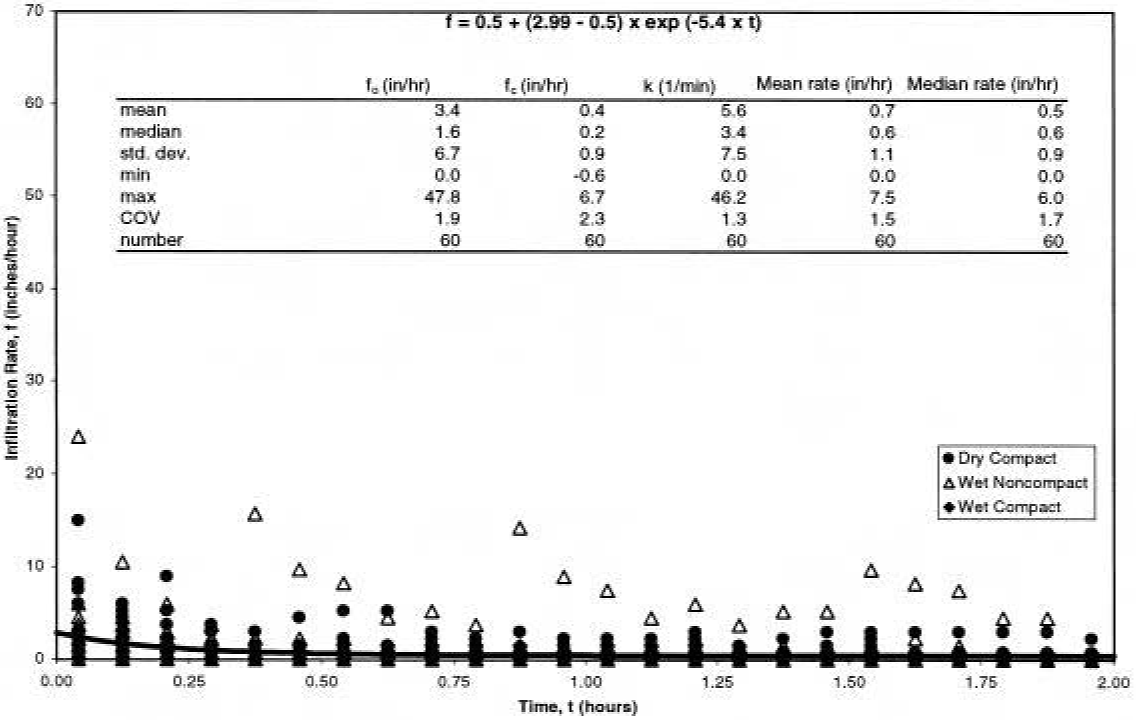
Table 3-3 shows the measured infiltration rates for each of the four major soil categories, separated into several time increments. This table shows the observed rates of infiltration for each test averaged for different storm durations (15, 30, 60, and 120 min). Also shown are the ranges and COV values for each duration and condition. As an example of a Monte Carlo type approach, a routine in a model could select an infiltration rate, associated with the appropriate soil category, based on the storm duration. The selection of a storm-averaged rate would be from a random distribution (likely a log-normal distribution) using the mean and standard deviation values shown on this table.



$f = 8.1 + (19.1 - 8.1) \times \exp(-8.4 \times t)$

	fo (in/hr)	fc (in/hr)	k (1/min)	Mean rate (in/hr)	Median rate (in/hr)
mean	17.8	6.6	8.8	8.8	8.3
median	10.8	3.3	9.4	5.4	5.4
std. dev.	15.7	7.8	6.6	8.5	8.2
min	2.5	0.1	-6.2	0.3	0.0
max	57.8	24.1	19.1	25.3	25.1
COV	0.9	1.2	0.7	1.0	1.0
number	17	17	17	17	17

Figure 3-5. Infiltration measurements for dry-noncompacted-clayey soils.



$f = 0.5 + (2.99 - 0.5) \times \exp(-5.4 \times t)$

	f_o (in/hr)	f_c (in/hr)	k (1/min)	Mean rate (in/hr)	Median rate (in/hr)
mean	3.4	0.4	5.6	0.7	0.5
median	1.6	0.2	3.4	0.6	0.6
std. dev.	6.7	0.9	7.5	1.1	0.9
min	0.0	-0.6	0.0	0.0	0.0
max	47.8	6.7	46.2	7.5	6.0
COV	1.9	2.3	1.3	1.5	1.7
number	60	60	60	60	60

Figure 3-6. Infiltration measurements for wet-noncompacted, dry-compacted, and wet-compacted clayey soils.

Table 3-3. Soil infiltration rates for different categories and storm durations

Sand, Noncompacted (in/hr)

	15 minutes	30 minutes	60minutes	120 minutes
mean	22.9	19.5	16.9	15.0
median	25.0	19.7	17.4	15.7
std. dev.	10.6	9.1	8.0	7.2
min	1.3	0.8	0.6	0.5
max	43.0	38.0	32.4	28.6
COV	0.5	0.5	0.5	0.5
number	36	36	36	36

Sand, Compacted

	15 minutes	30 minutes	60minutes	120 minutes
mean	6.7	4.9	3.8	3.0
median	4.3	2.9	1.9	1.3
std. dev.	8.8	6.9	5.4	4.4
min	0.1	0.2	0.2	0.2
max	36.5	29.1	23.8	21.3
COV	1.3	1.4	1.4	1.5
number	39	39	39	39

Clay, Dry, Noncompacted

	15 minutes	30 minutes	60minutes	120 minutes
mean	12.7	10.8	9.6	8.8
median	7.6	6.3	5.8	5.4
std. dev.	10.8	9.5	8.9	8.5
min	1.0	0.5	.5	0.3
max	32.0	29.0	26.5	25.3
COV	0.9	0.9	0.9	1.0
number	18	18	18	18

All other clayey soils (compacted and dry, plus all saturated conditions)

	15 minutes	30 minutes	60minutes	120 minutes
mean	1.8	1.3	1.0	0.7
median	1.3	1.0	0.8	0.6
std. dev.	2.3	1.7	1.3	1.1
min	0.0	0.0	0.0	0.0
max	13.5	11.4	9.4	7.5
COV	1.3	1.3	1.4	1.5
number	60	60	60	60

Figures 3-7 through 3-10 are probability plots showing the observed infiltration rates for each of the four major soil categories, separated by the four event durations. Each figure has four separate plots representing the storm event averaged infiltration rates corresponding to storm durations from 15 min to 2 hr. As indicated previously, the infiltration rates became relatively steady after about 30 to 45 minutes during most tests. Therefore, the 2-hr average rate could likely be used for most events of longer duration. As expected, these plots which show higher rates for shorter rain durations. The probability distributions are closer to being log-normal than the normal plots shown. However, because three of the test categories had many observations of zero-infiltration rates, log-normal probability plots were not possible.

For this approach, the soil texture and compaction classification would remain fixed for an extended simulation period (unless the soils underwent an unlikely recovery operation to reduce soil compaction). Clayey soils would be affected by the antecedent, inter-event period which would define the moisture level at the beginning of the rains. Soil moisture recovery periods are highly dependent on site-specific soil and climatic conditions and are calculated using various methods in continuous simulation urban runoff models. The existing models assume that the recovery period is much longer than the period needed to produce saturation. As noted above, saturation (defined here as when the infiltration rate reaches a constant value) occurred in less than an hour during these tests. A simple estimate of the time needed for recovery of soil moisture levels is given by the NRCS in TR-55 (McCuen 1998). The NRCS developed three antecedent soil moisture conditions as follows:

- Condition I: soils are dry but not to the wilting point
- Condition II: average conditions
- Condition III: heavy rainfall, or lighter rainfall and low temperatures, have occurred within the last five days, producing saturated soil.

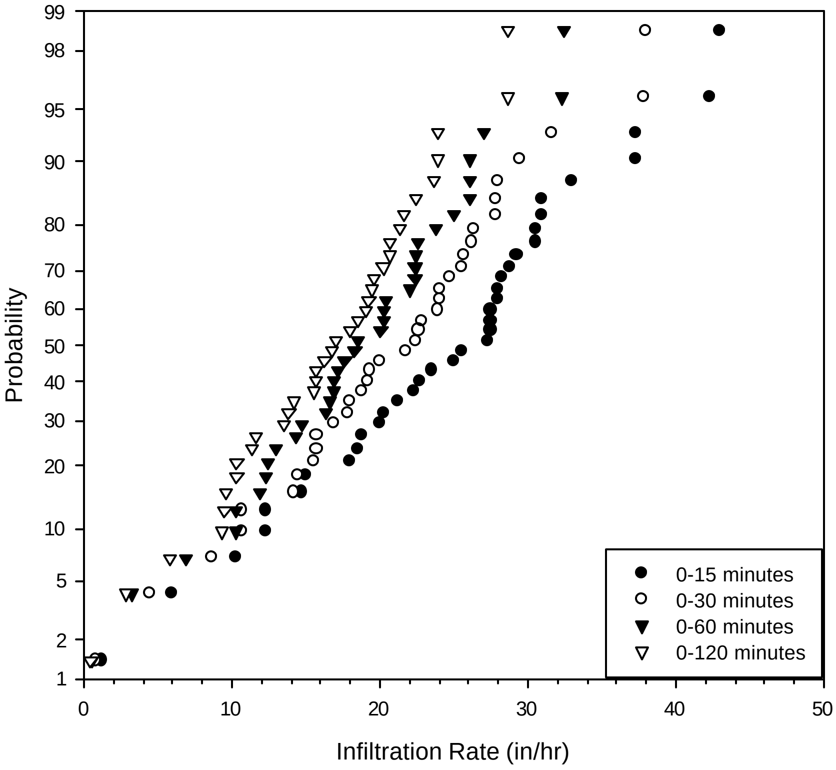


Figure 3-7. Probability plots for infiltration measurements for noncompacted-sandy soils.

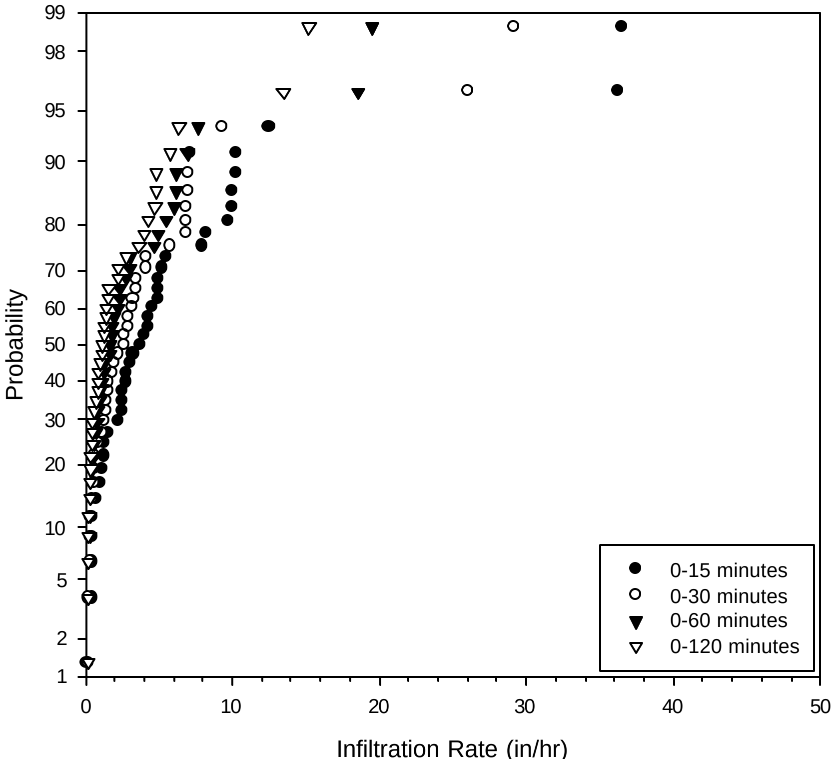


Figure 3-8. Probability plots for infiltration measurements for compacted-sandy soils.

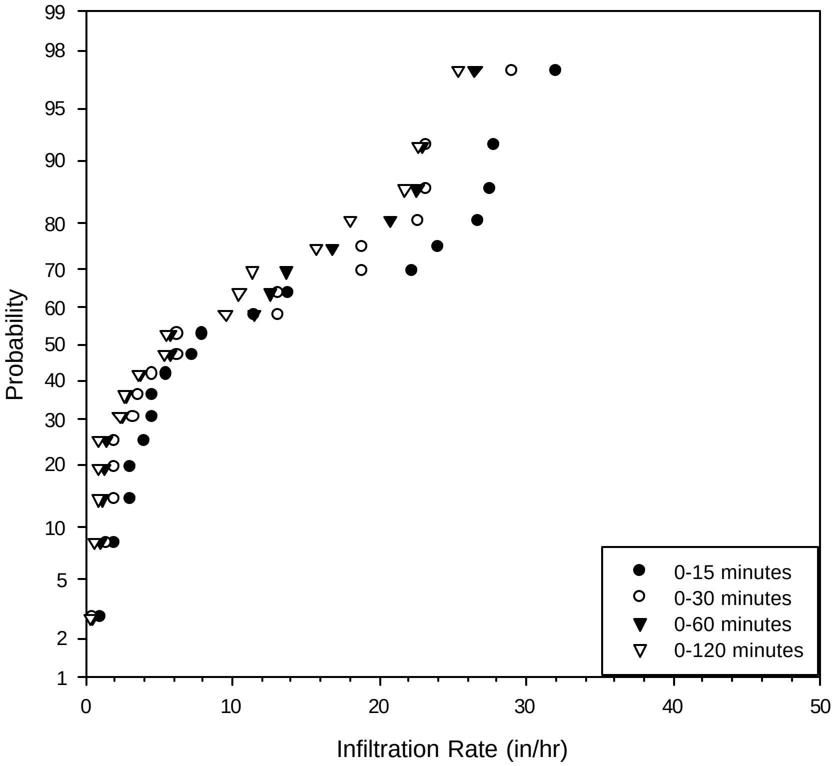


Figure 3-9. Probability plots for infiltration measurements for dry-noncompacted-clayey soils.

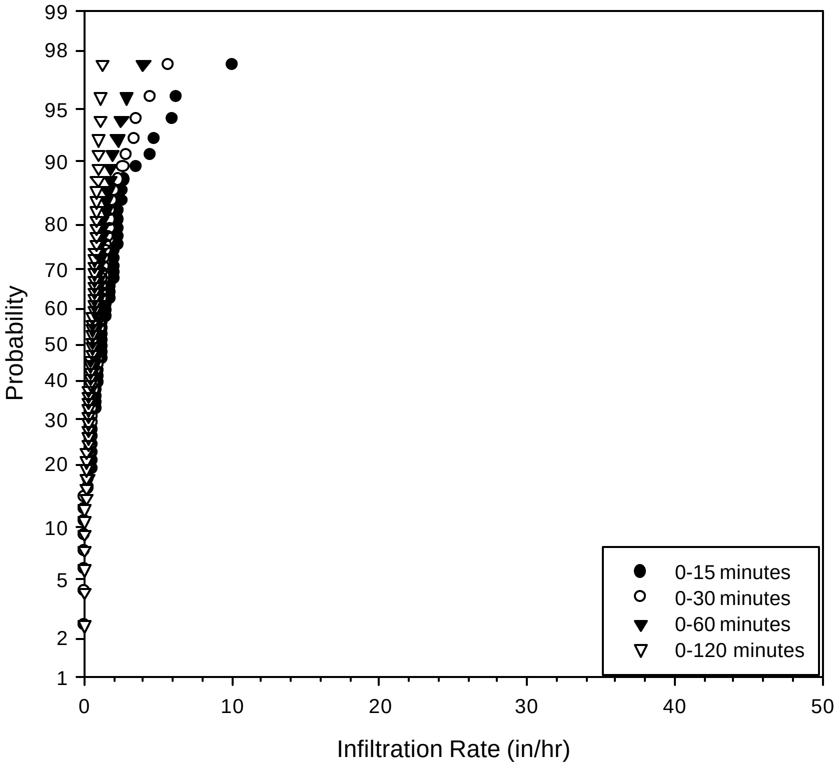


Figure 3-10. Probability plots for infiltration measurements for wet-noncompacted, dry-compacted, and wet-compacted, clayey soils.

Seasonal rainfall limits (McCuen 1998) for these three conditions are presented in Table 3-4 (from the NRCS). Therefore, as a rough guide, saturated-soil conditions for clayey soils may be assumed if the preceding 5-day total rainfall was greater than about 25 mm (1 in.) during the winter, or greater than about 50 mm (2 in.) during the summer. Otherwise, the "other" infiltration conditions for clayey should be assumed.

Table 3-4. Total five-day antecedent rainfall for different moisture conditions

	Dormant Season mm/hr (in/hr)	Growing Season mm/hr (in/hr)
Condition I	<13 (0.5)	<36 (1.4)
Condition II	13–28 (0.5–1.1)	36–53 (1.4–2.1)
Condition III	>28 (1.1)	>53 (2.1)

Box Plot Analyses of Infiltration Measurements

Tukey box plots (Figures 3-11 through 3-17) were prepared to obtain a graphical comparison of the four major soil categories for the seven infiltration parameters examined: the Horton f_o, f_c, and k parameters, plus the time-averaged infiltration rates for durations of 15, 30, 60 and 120 min. Each box represents the data for one of the major soil categories. The length of the boxes indicate the 25th and 75th percentiles of the data, the line inside the box marks the value of the 50th percentile (median), the capped bars indicate the

10th and 90th percentiles, and the circular symbols show the extreme data values. The percentiles for all analysis are summarized in Table 3-5.

Figure 3-11 shows that Horton's initial infiltration rate (f_o) values are similar for the soil groups clay-other and sand-compact. The soil groups clay-dry-noncompact and sand-noncompact are also similar. This pattern is even more evident in Figure 3-12, which shows Horton's infiltration capacity (f_c) (constant, final rate). As shown in Figure 3-13, the Horton decay constant (k) does not have a large variation from one soil group to the next. The percentiles for the average infiltration rates for the different storm durations (15, 30, 60 and 120 minutes) showed much more variation between soil groups than the other parameters (Figures 3-14 through 3-17). The sand, non-compact, category has the fastest rates, along with the widest range of values, while the clay, other, category, has the slowest rates, and the least variation (all close to zero). The other data groupings also show relatively wide variations in the time-averaged infiltration rates, further re-enforcing the need to consider uncertainty during infiltration analyses.

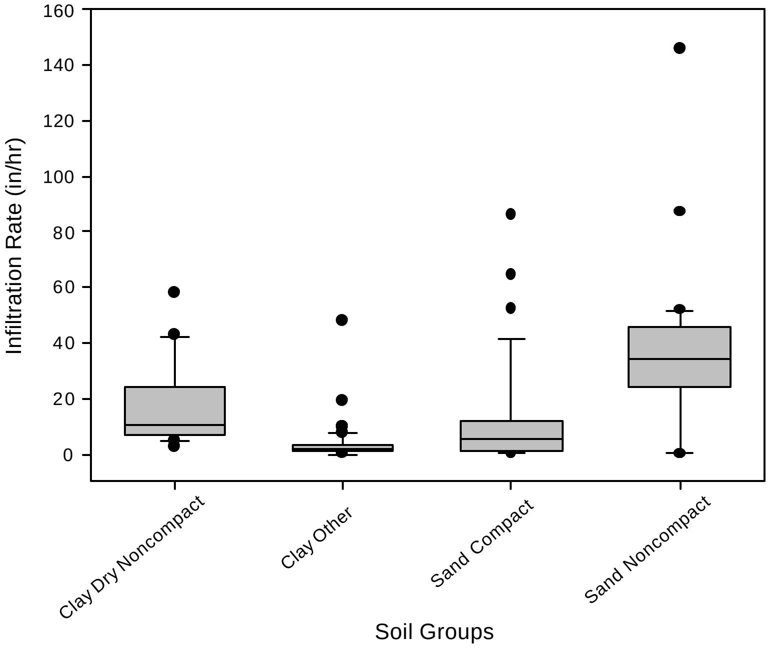


Figure 3-11. Horton's Equation values for initial infiltration - f_o.

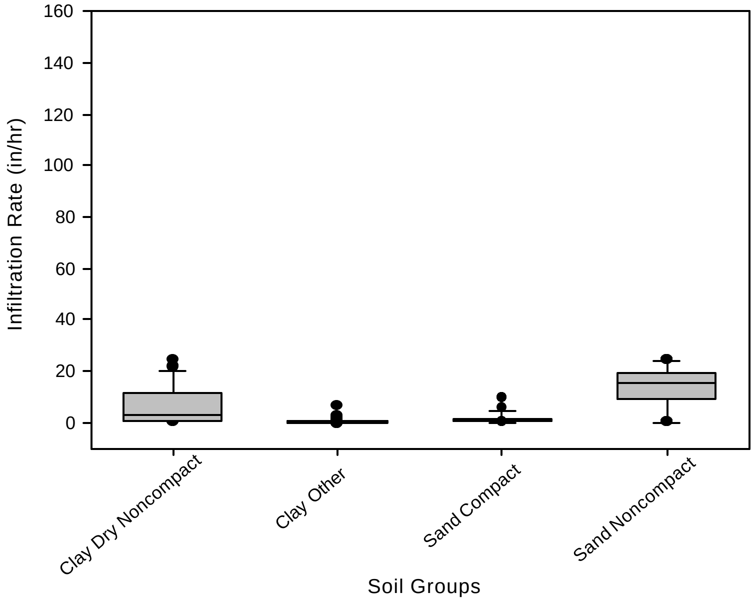


Figure 3-12. Horton's Equation for infiltration capacity – f_c.

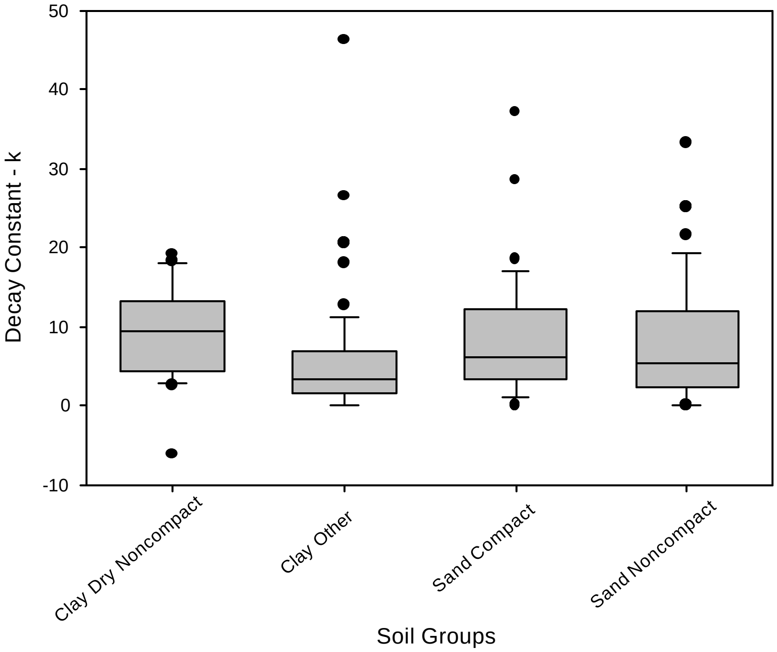


Figure 3-13. Horton's Equation decay constant – k.

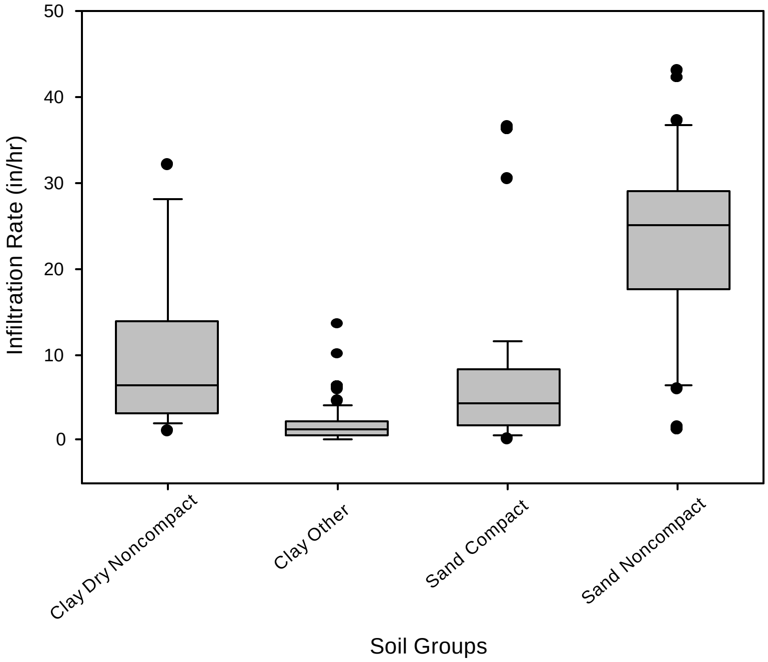


Figure 3-14. Infiltration rates at 15 minutes.

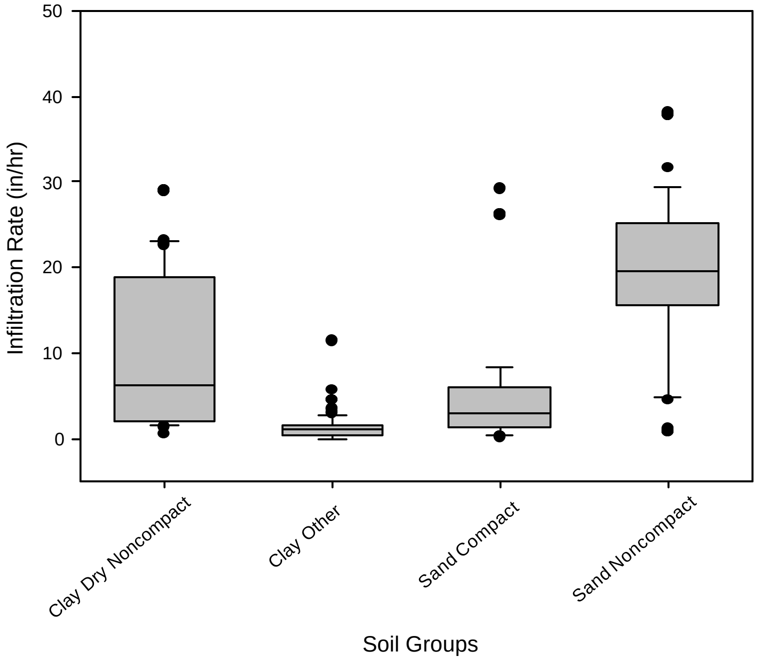


Figure 3-15. Infiltration rates at 30 minutes.

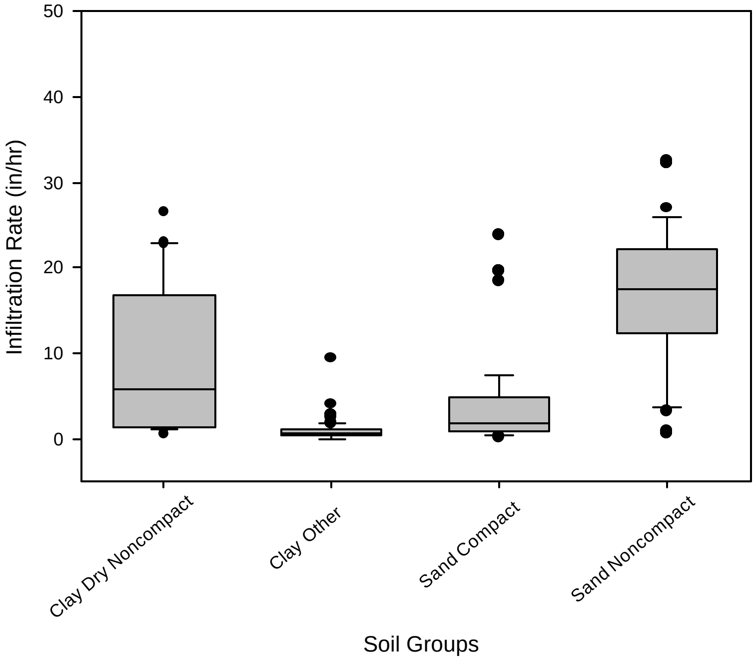


Figure 3-16. Infiltration rates at 60 minutes.

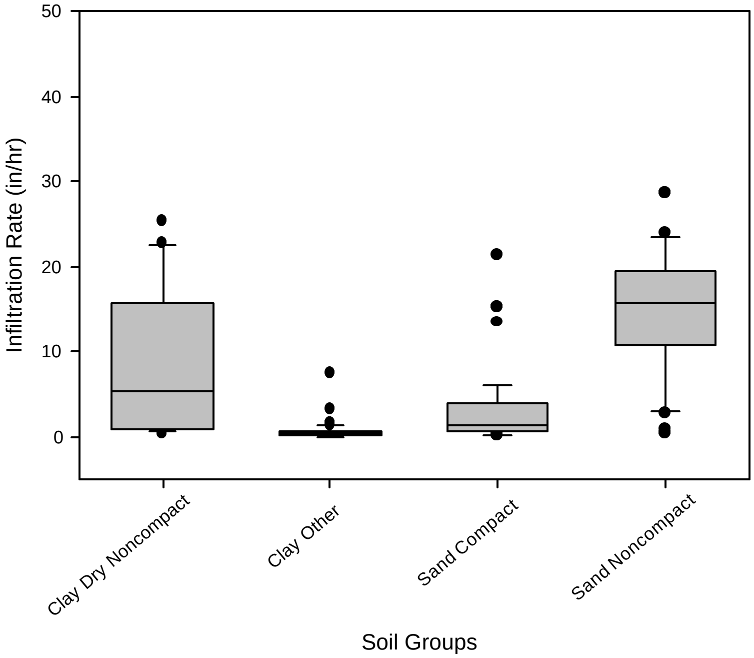


Figure 3-17. Infiltration rates at 120 minutes.

Table 3-5. Summary of box plot probabilities for the infiltration parameters.

Infilatration Parameter	Soil Group	90%	75%	Median	25%	10%
f_o	Clay - Dry Noncompact	42	24	11	7	5
(in/hr)	Clay - Other	7	3.75	2	1	0
	Sand - Compact	42	12	5	1.5	0
	Sand - Noncompact	52	46	34	24	0.25
f_c	Clay - Dry Noncompact	20	12	3	0.75	0.25
(in/hr)	Clay - Other	0.75	0.5	0.25	0	0
	Sand - Compact	5	1.25	0.5	0.25	0
	Sand - Noncompact	24	19	15	9	0
k	Clay - Dry Noncompact	18	13	9.5	4.5	3
	Clay - Other	11	6.5	3.75	1.75	0
	Sand - Compact	17	12	6	3	1
	Sand - Noncompact	19	12	5	2	0
15 minutes averaged	Clay - Dry Noncompact	28	14	6	3	2
(in/hr)	Clay - Other	4	2	1	0.25	0
	Sand - Compact	12	8	4	2	0.5
	Sand - Noncompact	37	29	25	17.5	6.5
30 minutes averaged	Clay - Dry Noncompact	23	19	6	2	1.75
(in/hr)	Clay - Other	2.5	1.75	1	0.25	0
	Sand - Compact	8	6	2.75	1.75	0.25
	Sand - Noncompact	29	26	20	16	5
60 minutes averaged	Clay - Dry Noncompact	23	17	6	2	1.5
(in/hr)	Clay - Other	2	1	0.5	0.25	0
	Sand - Compact	0.75	5	2	1	0.25
	Sand - Noncompact	26	22	17.5	12	4
120 minutes averaged	Clay - Dry Noncompact	22.5	16	5	1	0.75
(in/hr)	Clay - Other	1.25	0.75	0.5	0.25	0
	Sand - Compact	6	4	1	0.5	0
	Sand - Noncompact	24	20	16	11	3

Relationships Between Infiltration Parameters and Site Conditions

A series of statistical tests were conducted to investigate the inter-relationships and/or redundancies of the infiltration parameters and site conditions. These tests were all conducted using SYSTAT, version 8. The first analysis was a standard Pearson correlation matrix which identifies simple correlations between parameters. The results of this test identified a few pairs of infiltration parameters that were highly correlated with one another, but no site conditions were highly correlated to any other site conditions or to any of the infiltration parameters. This indicates that the site factors examined were generally independent and could be used in further analyses, and there may not be much real difference when choosing between alternative infiltration models because of the large amount of variability in the measured rate parameters. The correlations greater than 0.7 are presented in Table 3-6. It is seen that most of the time-averaged rates are highly correlated with each other and with the Horton initial and final rate parameters (but not the Horton decay rate parameter, k).

More complex inter-relationships were investigated by conducting a hierarchical cluster analyses. Figure 3-18 is a dendogram illustrating simple and complex relationships between the tested parameters and site conditions. The time-averaged rates are all closely related (as expected) and are obviously not independent indicators of infiltration conditions. The Horton final-infiltration-rate parameter, f_c is more closely related to the time-averaged rates than to f_o, the Horton initial-rate parameter. All of the other parameters and site conditions are significantly less interrelated.

Table 3.6 Infiltration parameters and site condition correlations exceeding 0.7

Correlation with	15 minute averaged rate	30 minute averaged rate	60 minute averaged rate	120 minute averaged rate
15 minute averaged rate	---	0.994	0.979	0.958
30 minute averaged rate	0.994	---	0.993	0.994
60 minute averaged rate	0.979	0.993	---	0.979
120 minute averaged rate	0.958	0.978	0.995	---
median infiltration rate	0.825	0.854	0.878	0.825
standard deviation of infiltration rate	0.793	0.772	0.749	0.793
f_C Horton parameter	0.780	0.804	0.818	0.780
f_0 Horton parameter	0.717	0.700	NA	NA

NA- not applicable; value less than 0.7

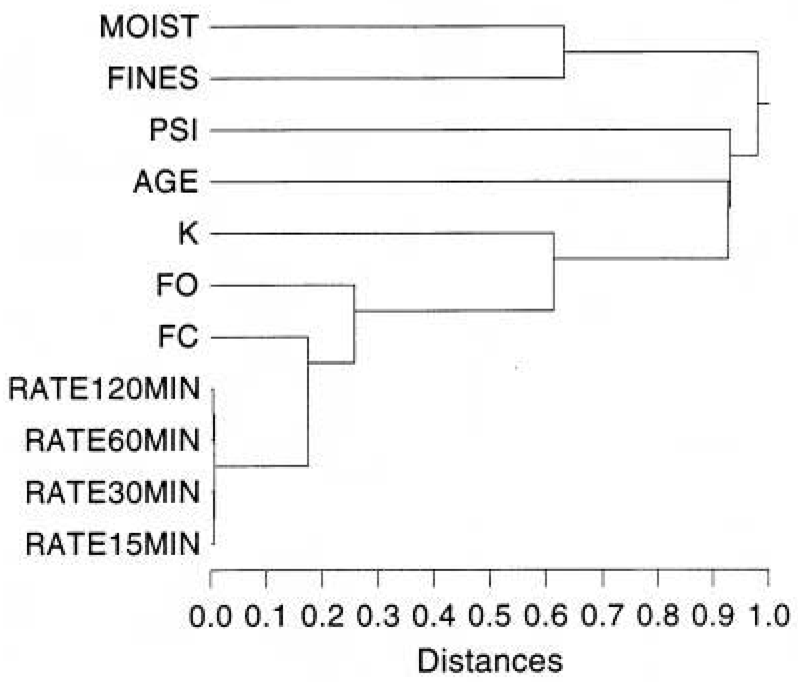


Figure 3-18. Dendogram to investigate complex inter-relationships between site conditions and infiltration parameters.

A principal component of the final analysis was to investigate groupings of the data. This analysis groups test parameters into principal component groups that are most interrelated and ranks the components in importance to explain the overall variation of the data. When testing these data, the first principal component explained about 52% of the total variance and was composed of time-averaged rate values alone (15, 30, 60, 120 minute averaged rates, plus the median rate). The second principal component explained another 12% of the total variance and was comprised of site conditions (compaction, moisture, and texture). The third component added another 8% of the variance and was dominated by the Horton rate constant k. These first three principal components contained about 72% of the total variance. The remaining 28% of the variance was associated with less important principal components that were associated with all of the site conditions and measurement parameters combined.

Factorial Analyses of Infiltration Measurements

A factorial analysis was performed on the infiltration parameters calculated from the observed field data to determine the importance of the different site characteristics. First, a 2^3 factorial design was used to evaluate all data for the effects of soil moisture, soil texture and soil compactness on each of the infiltration parameters, f_o, f_c, k, and on the time-averaged infiltration rates for 15, 30, 60 and 120 min. These analyses identified the significant site factors needed to best predict the infiltration parameters. The previous correlation tests found no redundancies in the site parameters, so all infiltration rate data and site data were used in this series of analyses.

Appendices D, E, and F contain the factorial analysis details, including the residual analyses for the different models. Figure 3-19 is an example of the basic analyses for all of the data (both sand and clay textures combined) and shows the graphical results for $f_{o.}$ It was determined, based on the pooled standard error and the probability plot of the effects, that the soil texture plus the soil compaction (T + C) has the most significant effect on f_o for this condition. The clay observations alone (Appendix F) are forced to consider the interaction of moisture and compaction, and not rely solely on the standard error or the probability plot due to the obvious non-orthogonal behavior of these parameters on the 3D plot.

The model for f_o was determined to be:

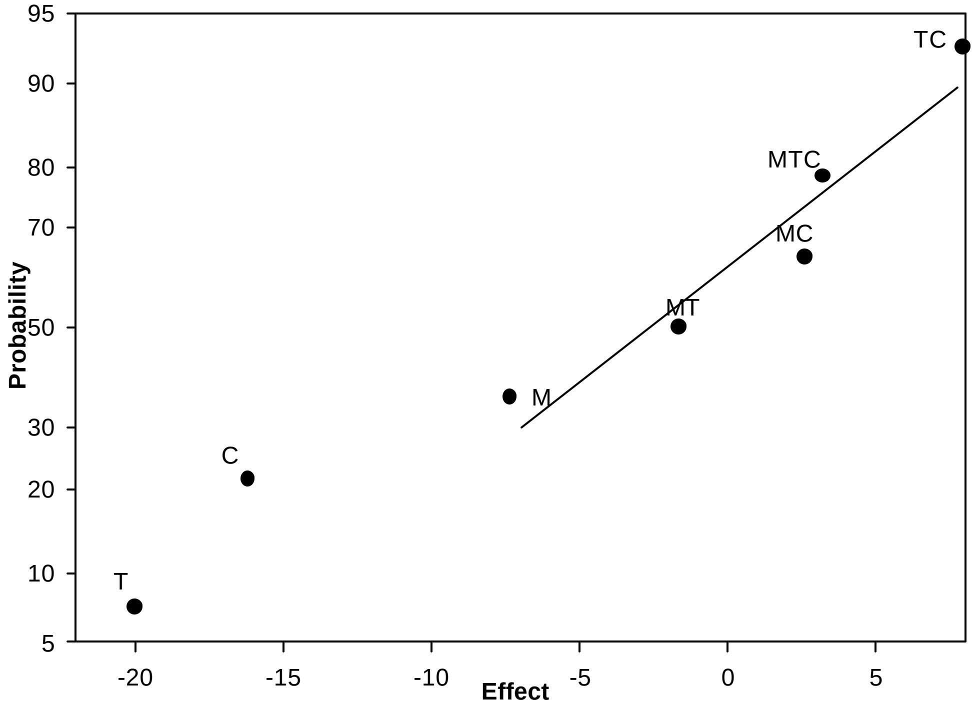
f_o = overall average ± (effect of texture/2) ± (effect of compaction/2)
or
$f_o = 17.26 \pm (T/2) \pm (C/2)$
or
$f_o = 17.26 \pm (-20.02/2) \pm (-16.19/2)$.

Therefore, four possible conditions, and predicted f_o rates, are identified:

Clay and compact (T+ and C+), $f_o = 17.26 – 10.01 – 8.08 = -0.83$in/hr, assumed to be 0 in/hr.
Clay and non-compact (T+ and C-), $f_o = 17.26 – 10.01 + 8.08 = 15.33$in/hr
Sand and compact (T- and C+), $f_o = 17.26 + 10.01 – 8.08 = 19.19$in/hr
Sand and non-compact (T- and C-), $f_o = 17.26 + 10.01 + 8.08 = 35.35$in/hr

Of course, the four significant figures for the predicted values of f_o are unreasonable, considering the large variation in the observed values.

This model was then compared with the 152 individual observed values. The resulting residuals were plotted as a probability plot (Figure 3-20). Although there are some outliers, this model is suitable for approximately 90 percent of the data (about 15 data observations do not fit the straight line very well). Table 3-7 is a summary of the results of the factorial analysis on each parameter. Some analyses showed that a combined effect (interaction) was most significant. An example of a combined effect would be the interaction of moisture and compaction (M x C).



C = Compaction, M = Moisture and T = Texture

Figure 3-19. Probability plot of the factorial analysis effects on f_o.

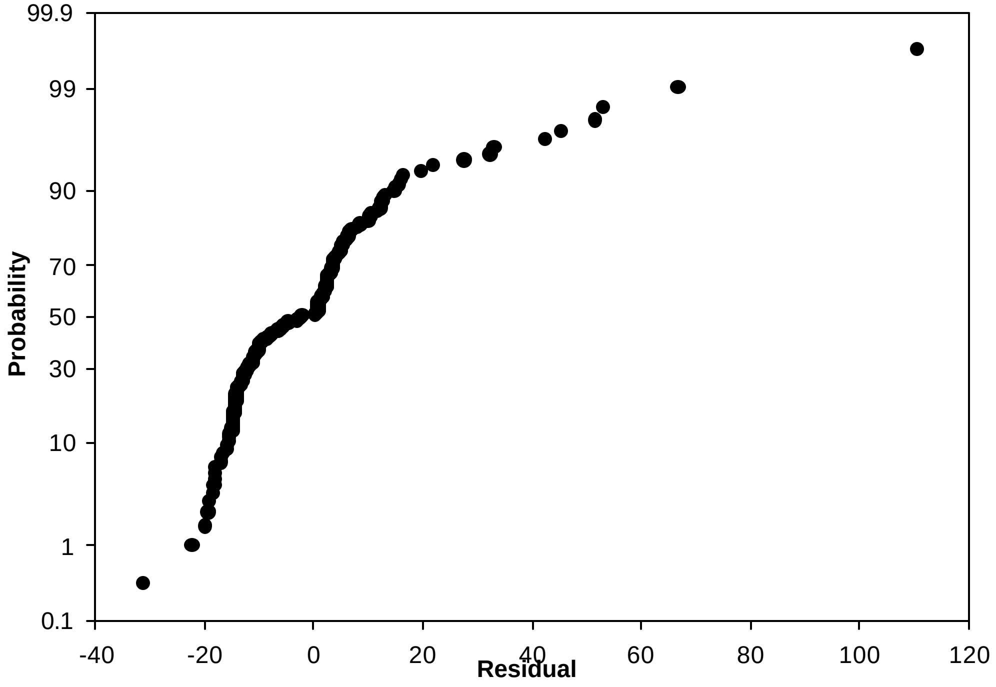


Figure 3-20. Probability plot of the residuals resulting from the comparison of the model to the observed values.

Table 3-7. All texture soil results of the factorial analysis effects for each parameter.

Parameter	Average Value	Important Effects/ Model Equations	Texture (Clay=+/Sand=-)	Compacted (Yes=+/No=-)	Model Value
f_o (in/hr)	17.26	Texture + Compaction	+	+	0 (-0.84)
		$f_o = 17.26 \pm (T/2) \pm (C/2)$	+	-	15.35
		$f_o = 17.26 \pm (-20.02/2) \pm (-16.19/2)$	-	+	19.18
			-	-	35.37
f_c (in/hr)	5.27	Texture + Compaction	+	+	0 (-1.92)
		$f_c = 5.27 \pm (T/2) \pm (C/2)$	+	-	6.43
		$f_c = 5.27 \pm (-6.02/2) \pm (-8.35/2)$	-	+	4.10
			-	-	12.45
k	8.30	Texture	+	+	5.96
		$k = 8.30 \pm (T/2)$	+	-	5.96
		$k = 8.30 \pm (-4.68/2)$	-	+	10.64
			-	-	10.64
15 minutes	9.80	Texture x Compaction	+	+	12.70
(in/hr)		$f_{15\ min} = 9.80 \pm (TC/2)$	+	-	6.89
		$f_{15\ min} = 9.80 \pm (5.81/2)$	-	+	6.89
			-	-	12.70
30 minutes	8.06	Texture x Compaction	+	+	10.66
(in/hr)		$f_{30\ min} = 8.06 \pm (TC/2)$	+	-	5.46
		$f_{30\ min} = 8.06 \pm (5.20/2)$	-	+	5.46
			-	-	10.66
60 minutes	6.89	Texture x Compaction	+	+	9.22
(in/hr)		$f_{60\ min} = 6.89 \pm (TC/2)$	+	-	4.57
		$f_{60\ min} = 6.89 \pm (4.65/2)$	-	+	4.57
			-	-	9.22
120 minutes	6.04	Texture x Compaction	+	+	8.20
(in/hr)		$f_{120\ min} = 6.04 \pm (TC/2)$	+	-	3.88
		$f_{120\ min} =6.04 \pm (4.32/2)$	-	+	3.88
			-	-	8.20

This analysis shows that soil texture had a significant and important effect for all parameters. Therefore, to produce a model that is more sensitive and accurate, the data was separated into two groups according to texture, clay or sand, for a 2^2 factorial analysis of data. The results for the sandy texture soil are shown on Table 3-8. Compaction of the sandy soil has the greatest effect on the infiltration parameters. This analysis showed that this infiltration model is acceptable for approximately 80% of the data. See Appendix E for the complete factorial analysis of each parameter for the observed data for sandy soils.

Table 3-9 shows the results for the factorial analysis for the data corresponding to the clay texture. The effects of moisture combined with compaction have the greatest effect on the clay soils. The results show the model is good for about 80% of the data. See Appendix F for the complete factorial analysis of each parameter for the observed data for clay.

Table 3-8. Sand texture soil results of the factorial analysis effects for each parameter.

Parameter	Average Value	Important Effects/ Model Equation	Compaction	Model Value
f_o (in/hr)	24.63	Compaction $f_o = 24.63 \pm (C/2)$ $f_c = 24.63 \pm (-4.11/2)$	+ -	22.57 26.68
f_c (in/hr)	6.67	Compaction $f_c = 6.67 \pm (C/2)$ $f_c = 6.67 \pm (-13.01/2)$	+ -	0.16 13.17
k	10.42	Average k = 10.42	+ -	10.42 10.42
15 minutes (in/hr)	15.01	Compaction $f_{15\ min} = 15.01 \pm (C/2)$ $f_{15\ min} = 15.01 \pm (-16.75/2)$	+ -	6.63 23.38
30 minutes (in/hr)	12.43	Compaction $f_{30\ min} = 12.43 \pm (C/2)$ $f_{30\ min} = 12.43 \pm (-15.10/2)$	+ -	4.88 19.98
60 minutes (in/hr)	10.64	Compaction $f_{60\ min} = 10.64 \pm (C/2)$ $f_{60\ min} = 10.64 \pm (-13.65/2)$	+ -	3.81 17.46
120 minutes (in/hr)	9.35	Compaction $f_{120\ min} = 9.35 \pm (C/2)$ $f_{120\ min} = 9.35 \pm (-12.69/2)$	+ -	3.01 15.70

Table 3-9. Clay texture soil results of the factorial analysis effects for each parameter.

Parameter	Average Value	Important Effects/ Model Equation	Moisture x Compaction	Model Value
f_o (in/hr)	7.25	Moisture x Compaction $f_o = 7.25 \pm (MC/2)$ $f_o = 7.25 \pm (5.85/2)$	+ -	10.18 4.33
f_c (in/hr)	2.26	Moisture x Compaction $f_c = 2.26 \pm (MC/2)$ $f_c = 2.26 \pm (3.49/2)$	+ -	4.00 0.51
k	5.96	Moisture x Compaction k = 5.96 ± (MC/2) k = 5.96 ± (0.43/2)	+ -	6.17 5.74
15 minutes (in/hr)	4.22	Moisture x Compaction $f_{15\ min} = 4.22 \pm (MC/2)$ $f_{15\ min} = 4.22 + (3.84/2)$	+ -	6.14 2.30
30 minutes (in/hr)	3.45	Moisture x Compaction $f_{30\ min} = 3.45 \pm (MC/2)$ $f_{30\ min} = 3.45 + (3.41/2)$	+ -	5.15 1.74
60 minutes (in/hr)	2.97	Moisture x Compaction $f_{60\ min} = 2.97 \pm (MC/2)$ $f_{15\ min} = 2.97 + (3.29/2)$	+ -	4.62 1.33
120 minutes (in/hr)	2.60	Moisture x Compaction $f_{120\ min} = 2.60 \pm (MC/2)$ $f_{120\ min} = 2.60 \pm (3.25/2)$	+ -	4.22 0.97

Effects of Age on Infiltration Parameters

There may be some recovery of infiltration rates over time due to plant root activity, soil insects and small burrowing animals reducing soil compaction. Roger Bannerman at the Wisconsin DNR (personal communication) has supported soil scientists from the University of Wisconsin to examine potential recovery of infiltration capacity with time after development. The University of Wisconsin tests were conducted with loam soils and preliminary findings indicated that up to several decades were needed for natural recovery of infiltration capacity. UAB hydrology classes have examined the use of lawn aerators to speed up this recovery, but with poor success (most of the tests were conducted on extremely dry, clayey soils). Data collected during these current tests were evaluated to also examine effects of development age on infiltration.

Turf age was considered when choosing test locations. Unfortunately, the test locations that were selected had insufficient age variations in all groupings to include this variable in the complete factorial analysis. Scatter plots were therefore constructed to determine if the turf age had an obvious visual influence on infiltration rates. A plot was prepared for each infiltration parameter to test for changes over time. Extreme values for the Horton parameters f_o and f_c seemed to increase over time for all soil groups, except the noncompact sand (Figures 3-21 through 3-28). The infiltration capacity (f_c) for noncompact sand appeared to actually decrease over time (possibly due to siltation). The plots for the other parameters, which are not shown, had highly random results with no apparent relationships to age, even for the extreme values.

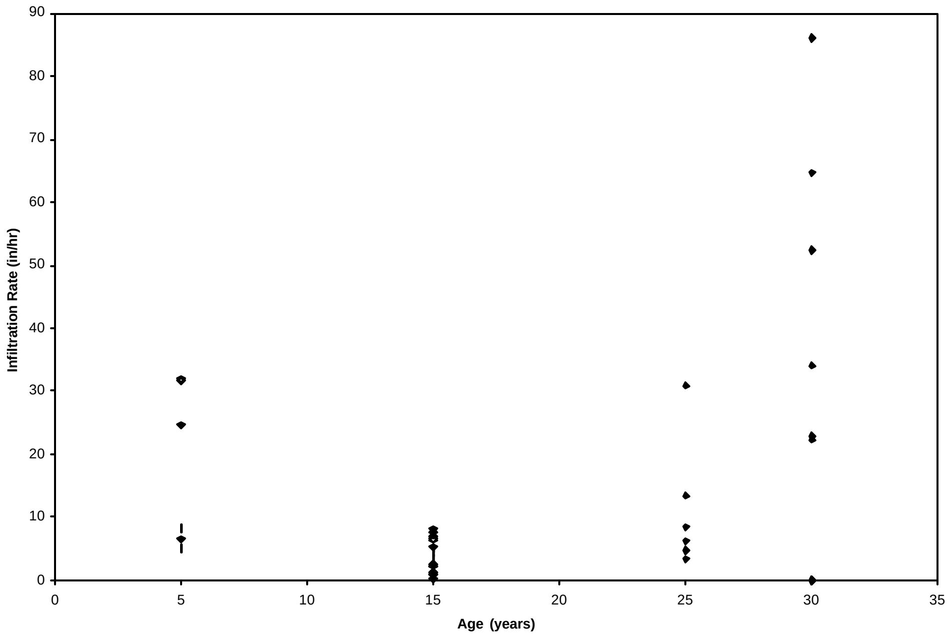


Figure 3-21. f_o vs. age for sand – compact.

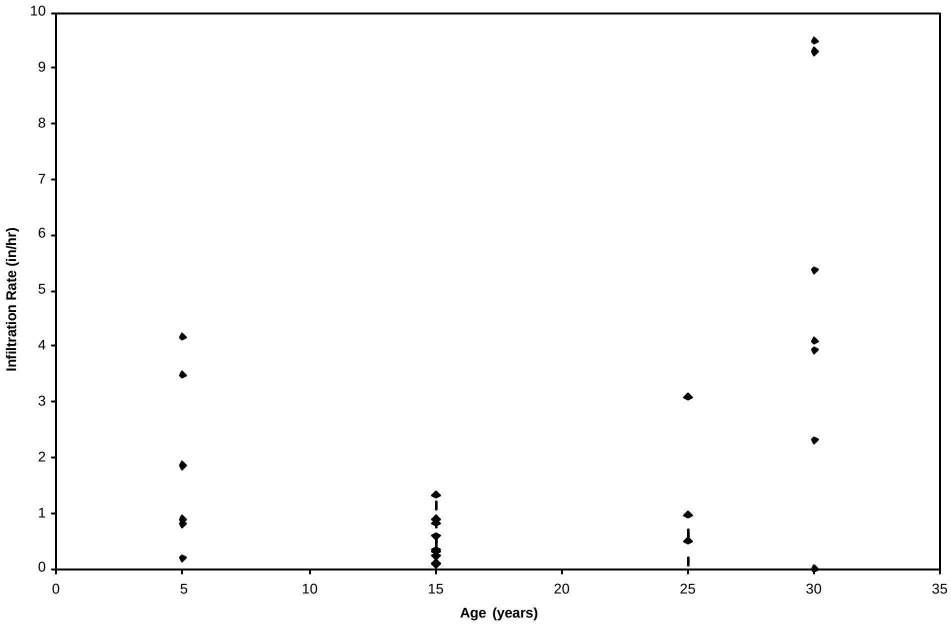


Figure 3-22. f_c vs. age for sand – compact.

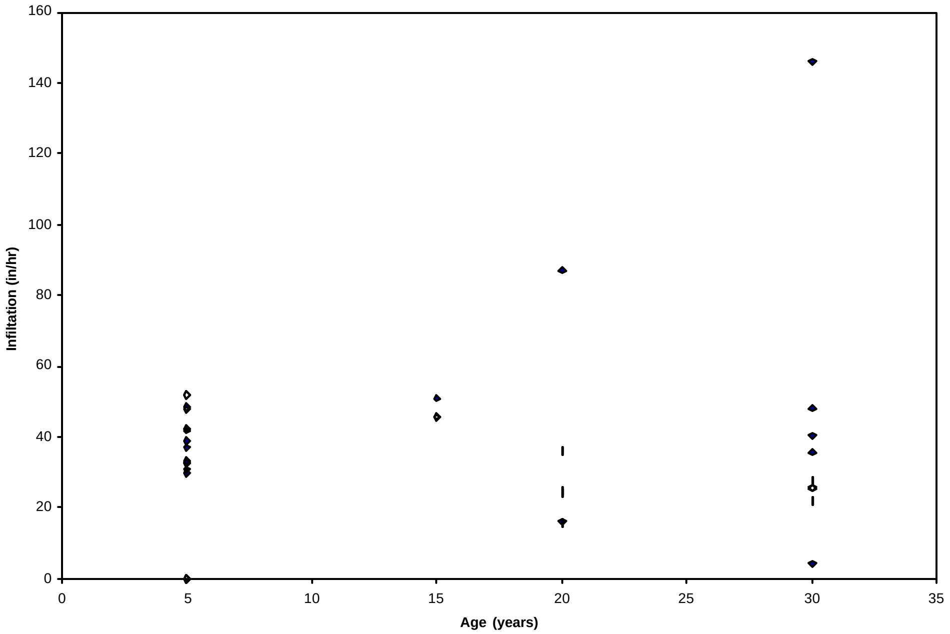


Figure 3-23. f_o vs. age for sand – noncompact.

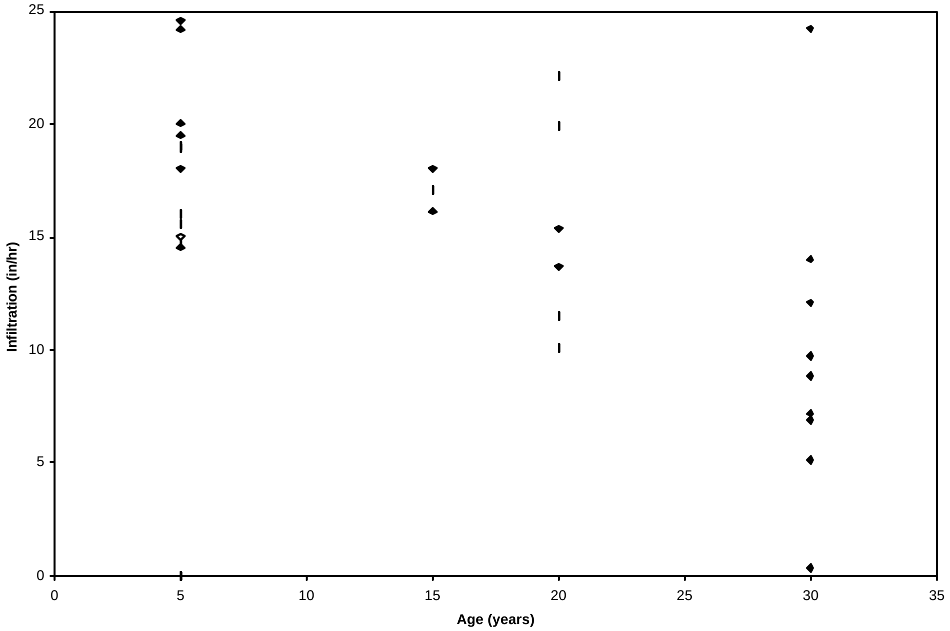


Figure 3-24. f_c vs. age for sand – noncompact.

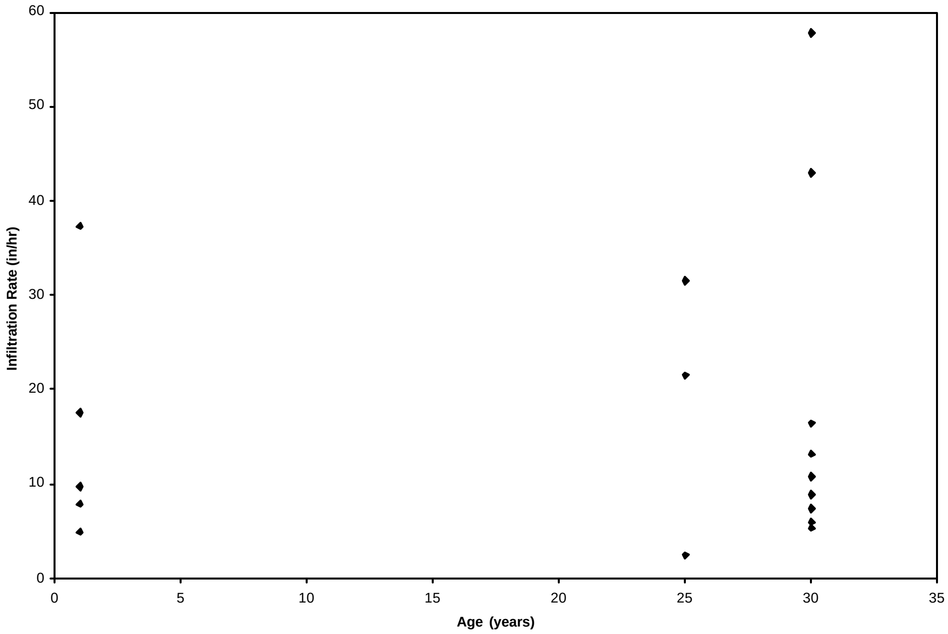


Figure 3-25. f_o vs. age for dry noncompact clay

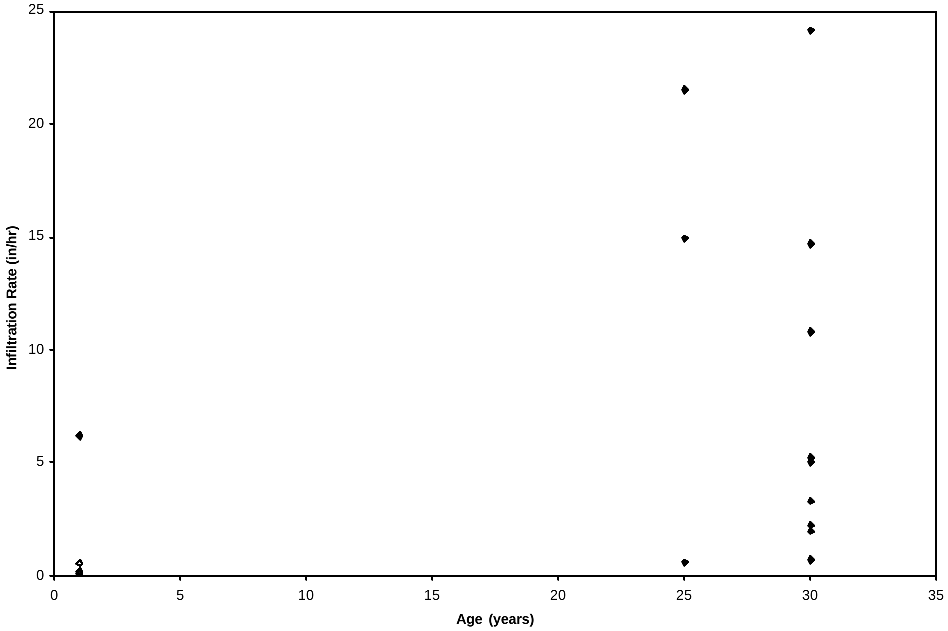


Figure 3-26. f_c vs. age for dry noncompact clay

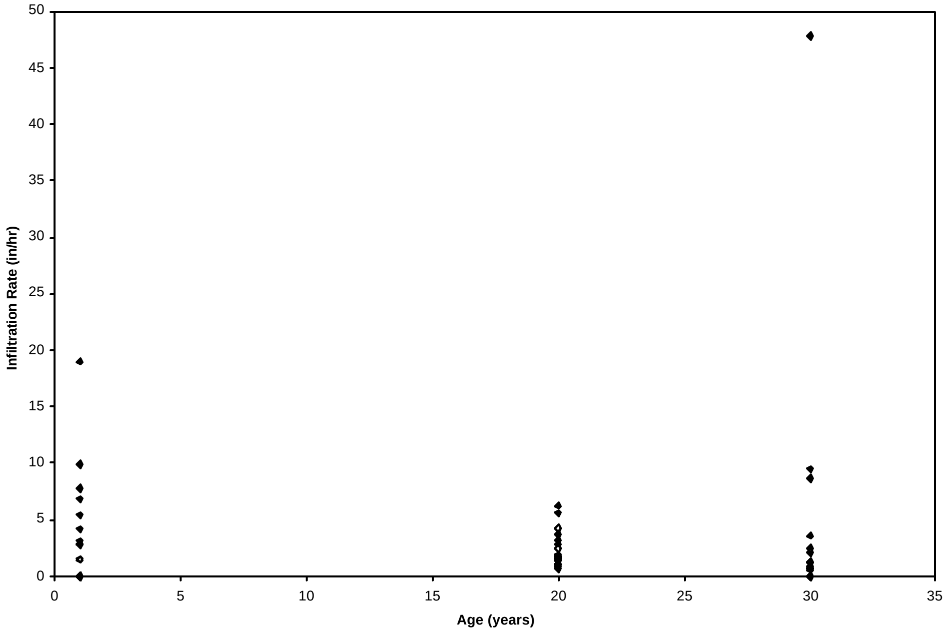


Figure 3-27. f_o vs. age for clay- dry compact, wet compact and wet noncompact.

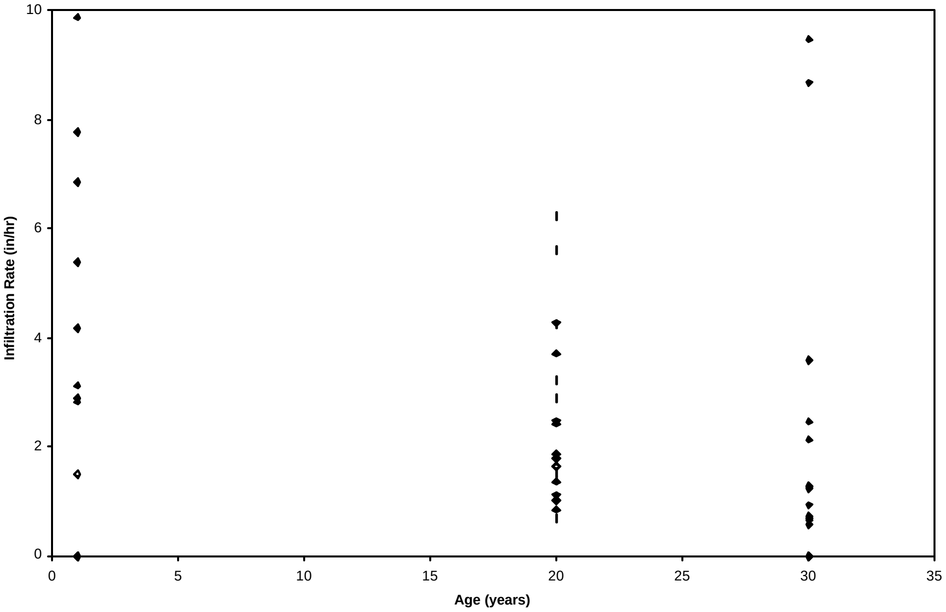


Figure 3-28. f_c vs. age for clay- dry compact, wet compact and wet noncompact.

Section 4
Results of Compost-Amended Soil Tests (Task 2)

All of the compost-amended site test water quality data are presented in Appendix G, while Appendix H includes the flow measurements and mass discharge data. This section contains the results of various data evaluation efforts.

Soil and Compost Analysis

The terminology used in industry and science for compost and soil properties is somewhat inconsistent. In this report, percent by weight uses an oven-dried basis for calculation. Volumes can change depending on handling, storage, moisture content and other factors. Also, the density (weight per unit volume) of compost is usually much lower, 0.2 to 0.3 g/cm^3, than that of soil, 1.0 to 1.4 g/cm^3. A weight percent change from compost amendment is usually much lower than a volume unit change, and moisture capacity based on volume may be much different than moisture capacity based on weight.

The total C, total N, bulk density, particle density, gravimetric-water-holding capacity (field capacity) moisture, volumetric-water-holding-capacity (field capacity) moisture, total porosity, particle-size analysis, and soil structure of soil and soil/compost mixtures is given in Table 4-1. Results show large changes in the chemical and physical properties of the soil/compost mixtures due to the compost amendment.

Total C and organic matter was enhanced by adding compost, increasing from 0.1 to 0.4% C to about 1.1 to 5.2% C by weight. Total N was also enhanced, increasing from 0.02 to 0.08% to about 0.06 to 0.35% with the compost amendment. Gravimetric-field-moisture capacity increased significantly from 24% to 35% with the compost amendment. Volumetric-field-moisture capacity was also increased from 46 to 50% by the addition of compost.

Total porosity was increased from 41 to 48%. Bulk density was decreased from about 1.7 to 1.1 g/cm^3. Particle density was decreased from about 2.5 to 2.1 g/cm^3. Particle size analysis was not greatly affected by the compost amendment. Soil structure, which is not a quantitative property, was also not greatly affected by compost amendment.

Thus, there was a generally beneficial effect of the compost amendment in regards to nutrient content as well as soil physical properties known to affect water relations in soils.

Water Quantity Observations at Test Plots

This study utilized a dual tipping bucket system to measure surface runoff and subsurface flows versus time. As pointed out earlier, the tipping buckets did not accurately record all surface runoff or subsurface seepage at the test sites due to unexpected leakage or faulty operation of the tipping buckets. However, most of the surface runoff and subsurface flow information was obtained.

Table 4-1. Analysis of chemical and physical properties of soil-only and soil-compost treatments

Site	treatment	sample #	total C	total N	Field Capacity g/g	Field Capacity ml/ml	Total Porosity	Bulk Density	Particle Density
			%	%	%	%	%	g/cm^3	g/cm^3
CUH plot 1	no-compost	1	0.23	0.02	25	39	33	1.55	2.33
CUH plot 2	compost	1	3.14	0.20	38	41	46	1.08	1.99
CUH plot 5	no-compost	1	0.11	0.05	29	41	41	1.42	2.42
CUH plot 6	compost	1	1.15	0.06	35	36	48	1.03	1.97
Timbercrest	compost	1	5.23	0.35	45	50	48	1.10	2.10
Timbercrest	no-compost	1	0.34	0.08	28	46	35	1.65	2.54
Woodmoor	no-compost	1	0.42	0.04	24	37	36	1.54	2.42
Woodmoor	compost	1	3.56	0.22	42	43	45	1.03	1.87
CUH plot 1	no-compost	2	0.26	0.02	21	44	30	1.74	1.95
CUH plot 2	compost	2	3.24	0.22	31	46	50	1.17	2.07
CUH plot 5	no-compost	2	0.12	0.04	32	33	48	1.30	2.03
CUH plot 6	compost	2	1.02	0.07	37	39	57	.93	2.05
Timbercrest	no-compost	2	0.30	0.06	31	53	35	1.83	3.03
Timbercrest	compost	2	5.48	0.33	54	44	43	1.20	1.91
Woodmoor	no-compost	2	0.36	0.04	27	35	35	1.23	2.85
Woodmoor	compost	2	4.23	0.21	41	45	37	0.84	1.87

Site	treatment	sample #	Particle Size Analysis 2-0.02	0.02-0.005	0.005-0.002	<.002	soil structure by visual and feel method
			< 2mm parts percentage				
			%	%	%	%	
CUH plot 1	no-compost	1	85	10	3	2	single grain / weak granular
CUH plot 2	compost	1	82	13	4	1	single grain / weak granular
CUH plot 5	no-compost	1	80	13	5	2	single grain / weak granular
CUH plot 6	compost	1	79	14	4	3	single grain / weak granular
Timbercrest	no-compost	1	75	19	4	2	single grain / weak granular
Timbercrest	compost	1	82	13	4	1	single grain / weak granular
Woodmoor	no-compost	1	77	14	5	4	single grain / weak granular
Woodmoor	compost	1	78	17	3	2	single grain / weak granular
CUH plot 1	no-compost	2	85	10	3	2	single grain / weak granular
CUH plot 2	compost	2	84	10	5	1	single grain / weak granular
CUH plot 5	no-compost	2	79	13	6	2	single grain / weak granular
CUH plot 6	compost	2	79	15	3	3	single grain / weak granular
Timbercrest	no-compost	2	75	18	5	2	single grain / weak granular
Timbercrest	compost	2	80	14	5	1	single grain / weak granular
Woodmoor	no-compost	2	78	13	4	4	single grain / weak granular
Woodmoor	compost	2	81	14	4	2	single grain / weak granular

Infiltration rate measurements were also made at the test plots using the ASTM D3385-94 double ring method. Table 4-2 shows the results of these tests, contrasting the measured infiltration rates at the compost-amended test plots with the rates measured at the test plots that only contained soil. The use of compost-amended soil resulted in significantly increased infiltration rates compared to soil alone. The infiltration rate increased from 1.5 to 10 times the untreated rates and should substantially decrease the runoff volumes and flow rates from turf areas during rain storms. These lower runoff volumes and flow rates would decrease many detrimental stormwater effects, including reduced mass discharges of pollutants, reduced downstream flooding, and improved in-stream habitat conditions for aquatic life. The additional infiltrating water would release more slowly to the surface waters after the initial runoff flows subsided, or would recharge deeper groundwaters, depending on subsurface soil conditions. The soil structure at the Alderwood soil sites would likely prevent much of this increased infiltrating water from reaching deeper groundwaters, but the compost amendments would still improve surface water flow characteristics, as extensively evaluated by Harrison *et al.* (1997) during the initial tests at the CUH test plots. Even though temperature was not monitored during this study, landscaped areas are an important moderating factor in controlling elevated runoff temperatures of urban stormwater. A healthier turf stand should also provide lower temperature runoff than bare soil, or a poor turf stand.

Table 4-2. Infiltration rate measurements at field test plots

Location	Test Plot Treatment	Average Infiltration Rate (cm/hr) (in/hr)	Improvement with Compost (ratio)
CUH plot 1	Alderwood soil A	1.2 (0.5)	
CUH plot 2	Alderwood soil A with Cedar Grove compost	7.5 (3.0)	6.3
CUH plot 5	Alderwood soil B	0.8 (0.3)	
CUH plot 6	Alderwood soil B with GroCo compost	8.4 (3.3)	10.5
Timbercrest	Alderwood soil C	0.7 (0.3)	
Timbercrest	Alderwood soil C with Cedar Grove compost	2.3 (0.9)	3.3
Woodmoor	Alderwood soil D	2.1 (0.8)	
Woodmoor	Alderwood soil D with Cedar Grove compost	3.4 (1.3)	1.5

As noted above, surface runoff and subsurface flows were monitored over several extended periods at the test plot sites. Table 4-3 summarizes the surface runoff and subsurface flow data from the complete set of flow data presented in Appendix G. This table shows the fractions of the total rainfall that resulted in surface runoff, subsurface flow, and other losses (assumed to be mostly evapotranspiration). The surface runoff fraction is the volumetric runoff coefficient (Rv) and is the simple ratio of runoff depth to rainfall depth. The four soil-only Alderwood test plots were quite different, with average Rv values ranging from about 0.01 to 0.25, reflecting a large amount of variability of infiltration conditions for this soil type. The age of construction of the test plots does not explain this variation.

The soil-only and compost-amended-soil test plots at the CUH site were quite similar, with both test plots in each pair having very similar Rv values (even though the infiltration measurements reported previously indicated large differences). In contrast, the newer test plots at Timbercrest and Woodmoor showed significant decreases in surface runoff for the compost-amended test plots, compared to the soil-only test plots. In fact, very little surface runoff was observed at the Timbercrest compost-amended test plot while the soil-only plot at Timbercrest had an average Rv of only about 0.04. Therefore, the improved infiltration improvement at Timbercrest is not very important from a flow perspective but could be from a mass pollutant runoff perspective. However, the Woodmoor site showed large and important improvements in infiltration conditions, with the Rv being reduced from about 0.25 (relatively large for a soil), to a much smaller Rv of about 0.05.

In addition, the evapotranspiration rates increased with all compost-amended soils, although by only a very small amount at one of the CUH test plot pairs. The increase in evapotranspiration ranged from about 33 to 100% at the newer sites at Timbercrest and Woodmoor.

Table 4-3. Water flow fractions (range and flow-weighted averages)

Location	Treatment	Surface runoff	Subsurface flow	Evapotranspiration
CUH plot 1	Alderwood soil A	0.004 – 0.011 (0.009)	0.50 – 1.00 (0.74)	0.00 – 0.49 (0.25)
CUH plot 2	Alderwood soil A and Cedar Grove compost	0.005 – 0.010 (0.009)	0.45 – 0.89 (0.74)	0.11 – 0.54 (0.25)
	Ratio of compost to soil average fraction	0.98	1.00	1.01
CUH plot 5	Alderwood soil B	0.15 – 0.26 (0.22)	0.39 – 0.83 (0.59)	0.02 – 0.44 (0.19)
CUH plot 6	Alderwood soil B and GroCo compost	0.001 – 0.42 (0.25)	0.00 – 0.77 (0.46)	0.13 – 1.00 (0.29)
	Ratio of compost to soil average fraction	1.10	0.78	1.57
Timbercrest	Alderwood soil C	0.006 – 0.13 (0.040)	0.32 – 0.39 (0.35)	0.54 – 0.68 (0.61)
	Alderwood soil C and Cedar Grove compost	0.00 – 0.00 (0.00)	0.02 – 0.43 (0.19)	0.57 – 0.98 (0.81)
	Ratio of compost to soil average fraction	0.00	0.54	1.33
Woodmoor	Alderwood soil D	0.022 – 0.38 (0.25)	0.13 – 0.74 (0.59)	0.00 – 0.84 (0.16)
	Alderwood soil D and Cedar Grove compost	0.00 – 0.092 (0.045)	0.03 – 0.79 (0.64)	0.15 – 0.97 (0.31)
	Ratio of compost to soil average fraction	0.18	1.08	1.97

Water Quality Observations at Test Plots

Visual Appeal of Test Sites and Need for Fertilization

All test sites began with bare ground and inorganic fertilizer was applied in equal rates at all test sites. All sites did grow grass, however, it became apparent that it would be very difficult to achieve the same visual appeal even with inorganic fertilizer application to the unamended soil, in comparison to the compost-amended soils.

The compost-amended plots developed a dark green color quickly, and achieved 100% coverage much more rapidly than the unamended plots. The compost-amended turf was lush and no soil could be seen through the grass while the unamended plots had many bare spots with exposed soil. The growth rates of turf were also greater for the amended sites and this continued throughout the duration of the study.

Overall Range of Water Quality Observations in Surface Runoff and Subsurface Flows

Results for each sample and QA/QC are given in Appendix G and J, respectively. The water quality measurement results (averages, number of samples and standard deviations) are summarized in Table 4-4.

It is obvious that there is a very large variation in water quality in the surface runoff and subsurface flow samples. For instance, the average total P (TP) concentration for all samples analyzed was 2.76 mg/L, while the minimum P was 0.00 and the maximum 125 mg/L. This high degree of variation in concentration is not unexpected, considering the variety of sampling conditions: test plots with treatments ranging from surface runoff with high water flow in a very infertile, unfertilized glacial till soil to surface runoff and subsurface flows in soils freshly fertilized with soluble NPK fertilizers.

The sampling scheme was organized with a complete block design in order to recognize significant differences between the test plots and between surface runoff and subsurface flows. The following subsection presents the statistical analyses for these comparisons. Before those results are presented, it is worthwhile to examine patterns between the water quality constituents. The following discussion therefore presents the results of simple Pearson correlation analyses, cluster analyses, and principal component analyses that were conducted using the complete data set as presented in Appendix G (except for those analyses resulting in mostly non detected observations). SYSTAT, version 8, was used to conduct these statistical tests.

A Pearson correlation matrix compared all data. High correlations by this analysis would imply close and simple relationships between the contrasted parameters. As an example, it would be expected that many of the nutrients would be highly correlated with each other because of their common source (chemical fertilizer). Table 4-5 shows the correlation pairings that had correlation coefficients greater than 0.7, when all of the water quality data were compared.

The correlation of particle sizes was not included in Table 4-5. The Tenth percentile particle size had a correlated pairing with the Fiftieth percentile particle size (0.791) a s did the Ninetieth percentile particle size with the Fiftieth percentile particle size (0.721). Other correlations not included in Table 4.5 are:

- The largest correlation with NO_3 was with Ca at 0.335.
- Cu had many non detected values; the largest correlation with Cu was with toxicity at 0.342.
- The largest correlations with Fe were with Si at 0.532 and Al at 0.530.
- The largest correlations with Zn were with Al at 0.416, Si at 0.392, and with toxicity at 0.349.
- The largest correlations with toxicity were with S at 0.549, Na at 0.539, SO_4 at 0.594, and Cl at 0.551.

Table 4-4a. Species and elemental concentration averages

			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	tmt	type	PO4-P	Hydr P	TOT-P	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
Timbercrest	comp	lower																
Timbercrest	comp	upper	124.8	15.5	125.2	360.0	0.0	1.7	479.4	0.0	223.0	1.3	0.0	0.0	0.2	74.1	0.0	0.0
Timbercrest	no-comp	lower	0.1	0.3	0.5	0.3	0.0	1.6	2.4	2.2	4.0	7.8	0.0	0.0	0.1	23.2	0.0	0.1
Timbercrest	no-comp	upper	0.0	0.1	0.0	0.0	0.0	0.1	1.6	1.4	1.2	2.5	0.0	0.0	0.0	5.1	0.0	0.0
CUH	comp	lower	0.7	0.5	1.0	0.0	0.0	0.5	2.1	1.3	1.0	5.2	0.0	0.1	0.0	18.8	0.0	0.0
CUH	comp	lower	3.1	3.9	3.9	1.3	0.0	15.3	7.1	10.0	2.9	0.3	0.0	0.0	0.0	31.9	0.0	0.0
CUH	comp	upper	0.9	0.8	1.3	1.9	0.0	0.4	3.5	1.6	0.4	0.9	0.0	0.0	0.0	6.0	0.0	0.0
CUH	comp	upper	3.3	3.3	4.4	3.7	0.0	7.1	8.7	10.3	1.7	0.3	0.0	0.0	0.0	10.3	0.0	0.0
CUH	no-comp	lower	0.0	0.6	0.7	0.1	0.0	0.0	1.7	1.6	0.0	1.0	0.0	0.0	0.0	9.5	0.0	0.0
CUH	no-comp	lower	0.5	0.3	0.6	0.4	0.0	3.7	2.0	2.9	0.5	0.3	0.0	0.0	0.0	12.1	0.0	0.0
CUH	no-comp	upper	0.3	0.3	0.5	1.1	0.0	0.5	2.7	1.9	0.6	24.0	0.0	0.0	0.1	5.3	0.0	0.0
CUH	no-comp	upper	1.0	0.9	1.2	0.8	0.0	3.8	3.5	4.9	0.7	3.0	0.0	0.0	0.0	5.4	0.0	0.0
CUH	precip	precip	0.1	0.0	0.1	0.2	0.0	0.1	1.3	1.0	0.4	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Woodmoor	comp	lower	1.8	2.2	2.9	22.5	0.0	0.5	45.7	38.4	18.3	1.4	0.0	0.1	0.1	93.3	0.0	0.1
Woodmoor	comp	upper	1.1	1.9	2.5	10.7	0.0	0.3	20.1	10.6	2.5	1.1	0.0	0.1	0.1	57.2	0.0	0.0
Woodmoor	no-comp	lower	0.1	0.0	0.1	0.3	0.0	0.6	1.6	2.2	1.8	0.6	0.0	0.0	0.0	34.6	0.0	0.0
Woodmoor	no-comp	upper	0.1	0.2	0.4	0.3	0.0	0.0	1.5	1.9	0.8	4.6	0.0	0.0	0.1	31.1	0.0	0.0
Woodmoor	precip	precip	0.0	0.0	0.0	0.2	0.0	0.2	0.4	1.3	0.5	0.0	0.0	0.0	0.0	0.8	0.0	0.0

			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
Timbercrest	comp	lower															
Timbercrest	comp	upper	0.0	0.1	361.1	11.2	0.0	0.0	14.0	0.0	125.2	0.0	356.3	0.0	0.1	6.3	0.0
Timbercrest	no-comp	lower	0.0	4.6	6.2	2.8	0.5	0.0	2.0	0.0	0.5	0.0	3.9	0.2	0.0	9.6	0.0
Timbercrest	no-comp	upper	0.0	1.5	2.7	0.9	0.0	0.0	1.7	0.0	0.0	0.0	1.4	0.0	0.0	4.0	0.0
CUH	comp	lower	0.0	4.0	10.6	6.8	0.3	0.0	2.2	0.0	1.0	0.0	2.0	0.2	0.0	17.4	0.0
CUH	comp	lower	0.0	1.4	24.8	6.1	0.3	0.0	4.8	0.0	3.9	0.0	4.1	0.0	0.0	6.9	0.0
CUH	comp	upper	0.0	1.5	3.7	2.2	0.2	0.0	1.5	0.0	1.3	0.0	0.9	0.1	0.0	4.9	0.0
CUH	comp	upper	0.0	0.8	29.2	2.4	0.2	0.0	3.6	0.0	4.4	0.0	2.7	0.0	0.2	1.8	0.0
CUH	no-comp	lower	0.0	1.8	2.6	4.7	0.0	0.0	3.1	0.0	0.7	0.0	0.4	0.1	0.0	10.7	0.0
CUH	no-comp	lower	0.0	0.1	7.3	5.9	0.0	0.0	5.2	0.0	0.6	0.0	0.9	0.1	0.1	7.7	0.0
CUH	no-comp	upper	0.0	5.9	3.5	4.7	0.0	0.0	6.0	0.0	0.6	0.0	0.9	0.3	0.3	55.2	0.0
CUH	no-comp	upper	0.0	0.9	12.9	2.2	0.0	0.0	3.6	0.0	1.2	0.0	1.2	0.1	0.2	9.0	0.0
CUH	precip	precip	0.0	0.1	2.4	0.1	0.0	0.0	0.6	0.0	0.1	0.0	0.5	0.0	0.0	0.1	0.0
Woodmoor	comp	lower	0.0	3.1	131.5	32.4	4.5	0.0	14.1	0.1	2.9	0.0	21.3	0.3	0.0	8.3	0.0
Woodmoor	comp	upper	0.0	2.0	86.2	19.8	1.4	0.0	6.1	0.0	2.5	0.0	4.5	0.2	0.1	6.4	0.0
Woodmoor	no-comp	lower	0.0	4.8	6.1	6.5	1.2	0.0	2.6	0.0	0.1	0.0	2.6	0.1	0.0	8.3	0.0
Woodmoor	no-comp	upper	0.0	8.4	4.0	5.8	2.9	0.0	1.7	0.0	0.4	0.0	1.3	0.2	0.2	11.3	0.0
Woodmoor	precip	precip	0.0	0.0	3.9	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.4	0.0	0.2	0.0	0.0

Table 4-4b. Species and elemental concentration sample numbers

			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	tmt	type	PO4-P	Hydr P	TOT-P	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
Timbercrest	comp	lower																
Timbercrest	comp	upper	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Timbercrest	no-comp	lower	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Timbercrest	no-comp	upper	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2
CUH	comp	lower	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	comp	lower	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	no-comp	lower	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	no-comp	lower	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
CUH	no-comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	no-comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	precip	precip	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7
Woodmoor	comp	lower	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Woodmoor	comp	upper	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Woodmoor	no-comp	lower	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Woodmoor	no-comp	upper	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Woodmoor	precip	precip	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
Timbercrest	comp	lower															
Timbercrest	comp	upper	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Timbercrest	no-comp	lower	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Timbercrest	no-comp	upper	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
CUH	comp	lower	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	comp	lower	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	no-comp	lower	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	no-comp	lower	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
CUH	no-comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	no-comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	precip	precip	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Woodmoor	comp	lower	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Woodmoor	comp	upper	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Woodmoor	no-comp	lower	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Woodmoor	no-comp	upper	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Woodmoor	precip	precip	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 4-4c. Species and elemental concentration standard deviations

			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	tmt	type	PO4-P	Hydr P	TOT-P	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
Timbercrest	comp	lower																
Timbercrest	comp	upper																
Timbercrest	no-comp	lower	0.1	0.1	0.2	0.5	0.0	1.5	1.2	2.1	0.5	6.4	0.0	0.0	0.0	15.3	0.0	0.1
Timbercrest	no-comp	upper	0.0	0.2	0.0	0.0	0.0		0.2	1.3	1.3	0.3	0.0	0.0	0.0	4.9	0.0	0.0
CUH	comp	lower	0.6	0.7	0.9	0.0	0.0	1.1	1.3	1.0	0.9	4.5	0.0	0.1	0.0	4.6	0.0	0.0
CUH	comp	lower	3.1	3.0	3.5	2.0	0.0	26.6	4.9	11.3	4.3	0.6	0.0	0.0	0.0	47.8	0.0	0.0
CUH	comp	upper	0.6	0.8	1.1	2.5	0.0	0.5	3.0	0.8	0.3	0.6	0.0	0.1	0.0	8.6	0.0	0.0
CUH	comp	upper	2.4	2.5	3.2	7.0	0.0	5.5	10.7	8.2	1.0	0.7	0.0	0.0	0.0	7.1	0.0	0.0
CUH	no-comp	lower	0.0	1.6	1.7	0.0	0.0	0.0	1.5	0.9	0.0	1.0	0.0	0.0	0.0	4.7	0.0	0.0
CUH	no-comp	lower	0.5	0.4	0.6	0.4	0.0	4.7	1.6	3.4	0.5	0.5	0.0	0.0	0.0	7.1	0.0	0.0
CUH	no-comp	upper	0.3	0.3	0.4	1.6	0.0	0.6	2.5	1.1	0.4	28.2	0.0	0.1	0.1	0.7	0.0	0.0
CUH	no-comp	upper	1.3	1.3	1.5	0.8	0.0	3.8	2.9	4.8	0.4	5.7	0.0	0.0	0.0	2.3	0.0	0.0
CUH	precip	precip	0.1	0.0	0.2	0.2	0.0	0.1	0.7	0.3	0.1	0.0	0.0	0.1	0.0	0.3	0.0	0.0
Woodmoor	comp	lower	1.1	1.7	1.9	27.4	0.0	1.1	54.3	79.8	32.2	2.0	0.0	0.0	0.1	67.1	0.0	0.0
Woodmoor	comp	upper	0.4	1.1	1.2	12.2	0.0	0.5	20.0	7.9	1.8	2.0	0.0	0.0	0.1	8.2	0.0	0.0
Woodmoor	no-comp	lower	0.1	0.0	0.1	0.3	0.0	1.5	0.9	1.5	2.7	0.9	0.0	0.0	0.0	27.7	0.0	0.0
Woodmoor	no-comp	upper	0.1	0.5	0.7	0.4	0.0	0.0	0.7	1.1	1.2	5.8	0.0	0.0	0.0	26.8	0.0	0.0
Woodmoor	precip	precip																

			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
Timbercrest	comp	lower															
Timbercrest	comp	upper															
Timbercrest	no-comp	lower	0.0	3.6	3.0	1.6	0.6	0.0	0.4	0.1	0.2	0.0	0.8	0.1	0.1	7.7	0.0
Timbercrest	no-comp	upper	0.0	0.2	2.6	0.5	0.0	0.0	1.6	0.0	0.1	0.0	1.5	0.0	0.0	0.2	0.0
CUH	comp	lower	0.0	1.9	8.1	1.0	0.4	0.0	0.7	0.1	0.9	0.0	1.2	0.1	0.1	8.3	0.0
CUH	comp	lower	0.0	1.8	20.9	5.1	0.8	0.0	5.2	0.0	3.5	0.0	4.6	0.0	0.0	5.8	0.0
CUH	comp	upper	0.0	1.9	0.9	3.0	0.4	0.0	0.9	0.0	1.1	0.0	0.4	0.0	0.1	6.0	0.0
CUH	comp	upper	0.0	1.7	23.8	1.4	0.3	0.0	2.6	0.1	3.2	0.0	1.6	0.0	0.1	1.2	0.0
CUH	no-comp	lower	0.0	2.9	1.2	1.4	0.0	0.0	0.8	0.0	1.7	0.0	0.4	0.0	0.0	3.3	0.0
CUH	no-comp	lower	0.0	0.2	6.2	4.1	0.0	0.0	1.7	0.0	0.6	0.0	0.7	0.0	0.2	5.2	0.0
CUH	no-comp	upper	0.0	6.0	1.0	2.8	0.0	0.0	4.3	0.1	0.3	0.0	0.7	0.3	0.2	65.6	0.0
CUH	no-comp	upper	0.0	1.4	11.1	0.7	0.0	0.0	2.2	0.0	1.5	0.0	0.5	0.1	0.1	13.5	0.0
CUH	precip	precip	0.0	0.1	1.8	0.1	0.0	0.0	0.2	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0
Woodmoor	comp	lower	0.0	3.1	122.5	26.2	5.6	0.0	14.9	0.1	1.9	0.0	27.4	0.3	0.0	4.1	0.0
Woodmoor	comp	upper	0.0	2.2	53.4	4.6	1.5	0.0	3.1	0.0	1.2	0.0	2.1	0.1	0.2	3.2	0.0
Woodmoor	no-comp	lower	0.0	6.7	4.4	5.0	1.9	0.0	1.4	0.0	0.1	0.0	3.1	0.1	0.1	6.0	0.0
Woodmoor	no-comp	upper	0.0	9.4	2.8	4.8	3.9	0.0	0.7	0.0	0.7	0.0	1.5	0.1	0.4	3.0	0.0
Woodmoor	precip	precip															

Table 4-5. Observed data correlations exceeding 0.7

Correlation with	PO_4	TP	NH_4	TN	Cl	SO_4	Al	Ca	K	Mg	Mn	Na	S	Si
PO_4	X	0.998	0.975	0.955	---	0.949	---	---	---	---	---	---	0.981	---
TP	0.998	X	0.976	0.958	---	0.945	---	---	---	---	---	---	0.979	---
NH_4	0.975	0.976	X	0.995	---	0.977	---	---	0.773	---	---	---	0.994	---
TN	0.955	0.958	0.995	X	---	0.978	---	---	0.828	---	---	---	0.987	---
Cl	---	---	---	---	X	---	---	---	---	0.699	---	0.723	---	---
SO_4	0.949	0.945	0.977	0.978	---	X	---	---	0.774	---	---	---	0.998	---
Al	---	---	---	---	---	---	X	---	---	---	---	---	---	0.964
Ca	---	---	---	---	---	---	---	X	---	0.901	0.758	0.739	---	---
K	---	---	0.773	0.828	---	0.774	---	---	X	---	---	---	---	---
Mg	---	---	---	---	0.699	---	---	0.901	---	X	---	0.810	---	---
Mn	---	---	---	---		---	---	0.758	---	---	X	---	---	---
Na	---	---	---	---	0.723	---	---	0.739	---	0.810	---	X	---	---
S	0.981	0.979	0.994	0.987	---	0.988	---	---	---	---	---	---	X	---
Si	---	---	---	---	---	---	0.964	---	---	---	---	---	---	X

These correlation coefficients of Table 4-5 show the expected strong correlations between the nutrient parameters and between other obviously related parameters (such as SO_4 and S, major cations and major anions, and particle sizes). It is surprisingly to note the poor correlation between NO_3 and TN (0.011) and between NO_3 and NH_4 (0.002). The strongest correlations with toxicity were for salinity parameters (NaCl and SO_4), pointing out the sensitivity of the test organism (a marine phytobacterium) with salinity.

More complex inter-relationships between the chemical parameters can be identified through cluster analyses. Figure 4-1 is a dendogram showing the close relationships between the nutrients, and less clear relationships for many of the other parameters. Phosphate and total phosphorus, along with ammonium and total nitrogen, have the closest and simplest relationships, while nitrate is poorly related to any other parameter. The major cations and major anions have a somewhat more complex inter-relationship, while toxicity was affected by all of the major ions, plus the nutrients.

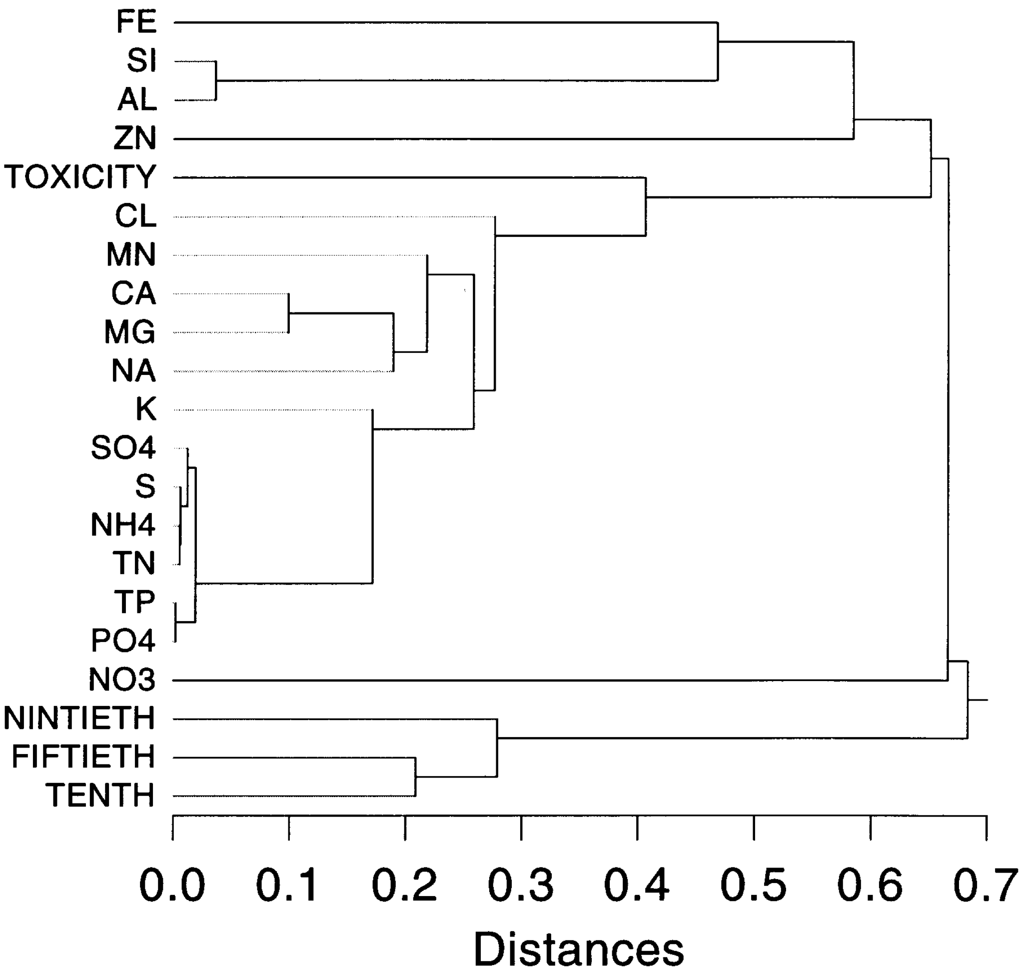


Figure 4-1. Dendogram showing complex relationships of monitored chemical parameters at soil and amended soil test sites.

A principal component evaluation of all of the water quality parameters was conducted. This analysis also groups the parameters into components that are closely related. In this case, three components accounted for about 75% of the total variance of the data. The first component accounted for about 45% of the variance and is mostly associated with the following 11 parameters: NH_4, TN, Cl, SO_4, Ca, K, Mg, Mn, Na, S, and toxicity. This component is mostly made of the major cations and anions, plus the nitrogen compounds, and toxicity. The second most important component explained a further 18% of the variance and is mostly associated with the following six parameters: Al, Fe, Si, and the three particle size parameters. The final principal component explained about 12% of the total variance and is comprised of the following four parameters: PO_4, TP, NO_3, and Zn. Less important components accounted for the remaining 25% of the total variance and were comprised of combinations of all of the water quality parameters.

Appendix I summarizes some water quality criteria and goals and is presented as a general reference for comparison to the measured water quality at the test sites. The following briefly lists some of these criteria and goals for the water quality constituents measured during this study:

Phosphate	0.1 mg/L goal to prevent eutrophication in flowing waters
Ammonia	as low as 0.11 mg/L for warm water and pH of 9, to 2.5 mg/L for cold water and pH of 6.5
Nitrate	10 mg/L for human health
Chloride	250 mg/L for human health
Zinc	5 mg/L (human health, through consumption of fish) 33 at 25 mg/L hardness to 140 mg/L at 140 mg/L hardness for chronic exposure to fish

Many of the observed phosphate and ammonia concentrations exceeded the above water quality goals during all test conditions. However, only the maximum observed nitrate values exceeded the nitrate standard, and no chloride or zinc observations exceeded any of the listed criteria.

The average soluble-reactive P (PO_4-P) concentration for all analyzed samples was 2.3 mg/L, while the minimum P was below detection, and the maximum was 125 mg/L. The average PO_4-P concentration measured is considerably above the State of Washington Water Quality recommendations for freshwater, according to WAC 173-201 (1992), which is 0.1 mg/L for flowing water not discharging directly into a lake or impoundment. The ammonium-N concentration averaged 6.6 mg/L, while the minimum ammonium-N was below detection, and the maximum was 360 mg/L. The NO_3-N concentration averaged 2.6 mg/L, while the minimum NO_3-N was below detection, and the maximum was 74 mg/L.

Overall, 72% of the 63 samples analyzed were not toxic (<20% light reductions), 25% were moderately toxic (light reductions of 20 to 60%), and 3% (2 samples) were highly toxic (>60% light reductions). The toxic samples from the Woodmoor test sites were a surface runoff sample from the soil-only plot (2/20/98), and a subsurface flow sample from the compost-amended soil plot (1/5/98).

A few samples had significantly larger concentrations than most of the others, as listed below. These noted constituent concentrations were all much larger than for the other samples (typically at least 10 times greater):

- Woodmoor, Cedar Grove compost-amended test plot:
  1/5/98, the first sample collected from this test plot, subsurface flow sample only (no surface runoff sample was available for analysis): NH_4 (59.4 mg/L), TN (118 mg/L), Cl (181 mg/L), Ca (190 mg/L), K (283 mg/L), Mg (70 mg/L), Mn (13 mg/L), Na (36 mg/L), and S (65 mg/L).

  2/20/98, the next sample after the above analyses (surface runoff, subsurface flow concentrations): NH_4 (27, 43.9 mg/L), TN (48, 90 mg/L), SO_4 (4.8, 11 mg/L), Ca (52, 132 mg/L), and K (158, 241 mg/L).

  3/15/98, the next sample after the above analyses (surface runoff only, as no subsurface flow sample was available for analysis): NH_4 (19 mg/L), TN (34 mg/L), and K (117 mg/L).

- Timbercrest, Cedar Grove compost-amended test plot:
  6/26/98, surface runoff sample only (the subsurface sample was not available for analysis): PO_4 (125 mg/L), TP (125 mg/L), NH_4 (360 mg/L), TN (479 mg/L), SO_4 (223 mg/L), K (361 mg/L), and S (356 mg/L).

Water draining from the compost amended Woodmoor site was strongly influenced by the initial Cedar Grove compost amendment which leached nutrients and other minerals. The compost-amended plot showed dramatic decreases in concentrations with time, as shown on Figures 4-2 and 4-3. These figures show decreasing concentrations with time for phosphorus and nitrogen compounds in the subsurface flows for the compost-amended Woodmoor test plot. No noticeable concentration trends are seen for the soil-only test plots. The nitrogen compounds in the subsurface flow from the compost-amended plot approached the subsurface flow concentrations from the soil-only plot after about six months. However, the phosphorus compounds remained high at the end of this period, although the concentrations decreased substantially from the beginning of the test period. As shown in the following subsections, the phosphorus concentrations in the runoff from the compost-amended test plots at the CUH test plots remained two to three times higher than from the soil-only test plots, even after several years.

Both surface runoff and subsurface flows were very high on 2/20/98 at the Woodmoor Cedar Grove compost-amended test plot. That set of analyses showed large increases (about doubling the concentrations) in constituent concentrations after infiltrating through the compost-amended soil. The one very high value at Timbercrest (6/26/98) was also at the compost-amended test plot, but data was only available for the surface runoff. Therefore, it could not be confirmed if the surface runoff was also high, or if earlier samples were even higher (expected).

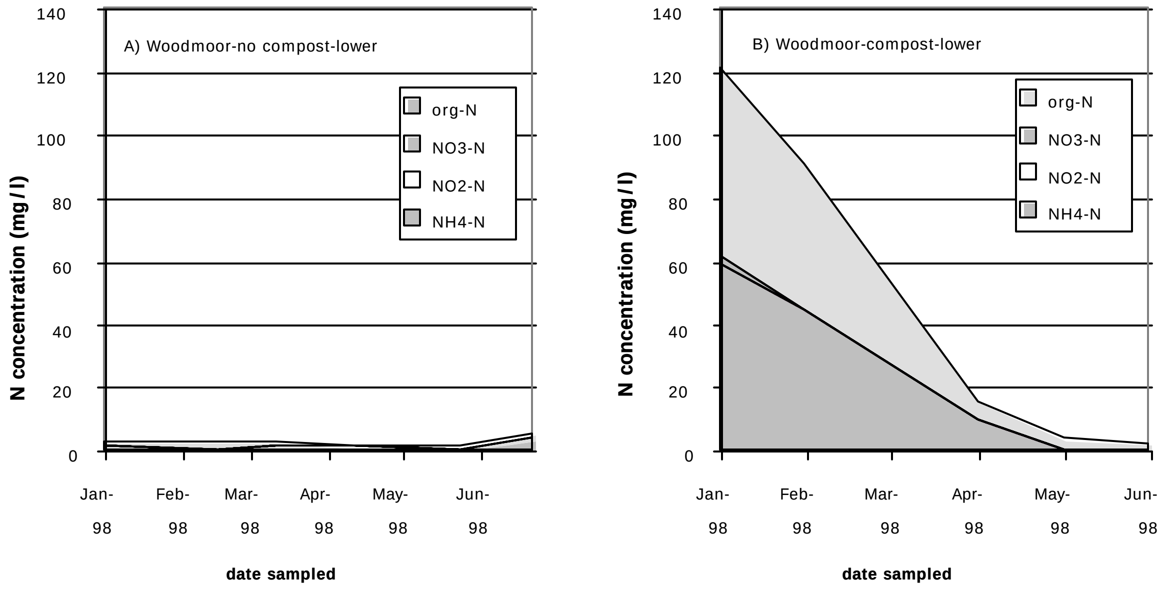


Figure 4-2. Species and elemental concentration averages in subsurface flows (nitrogen).

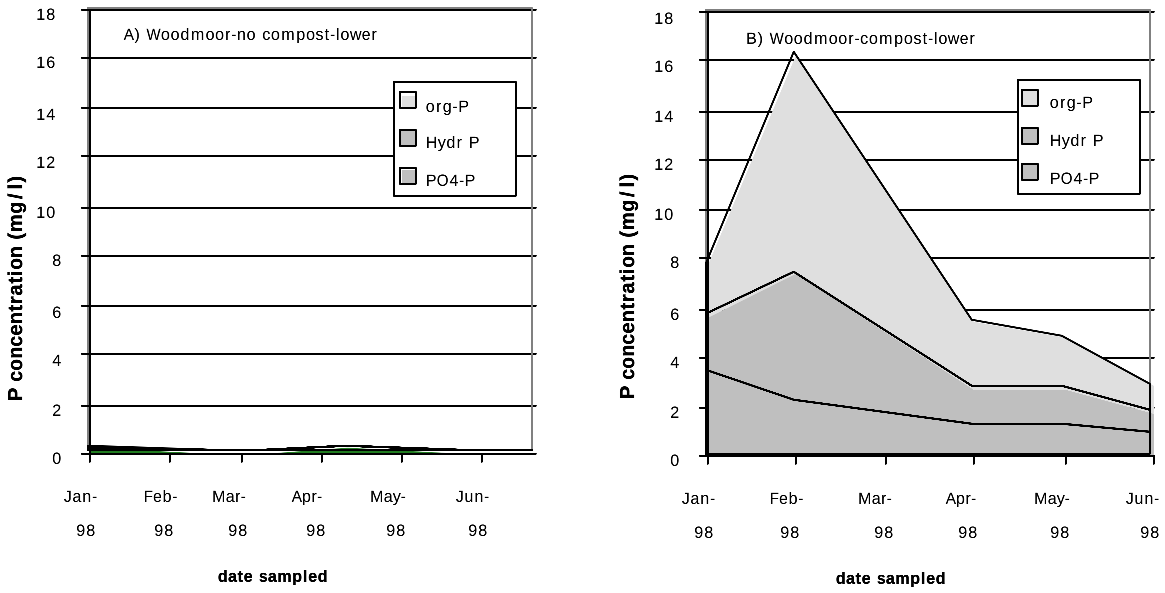


Figure 4-3. Species and elemental concentration averages in subsurface flows (phosphorus).

Comparison of Water Quality from Amended vs. Unamended Test Plots

Table 4-6 summarizes the average concentrations of constituents for surface runoff and subsurface flow samples separated by "soil-only" test plots and "soil plus compost" test plots. This table shows the average observations along with the coefficient of variations (standard deviation divided by the average value). The table only shows data for tests having both surface runoff and subsurface flow samples. The subsurface flows in the soil-only test plots mostly had lower concentrations of constituents than the associated surface runoff. The exceptions (NO_3, SO_4, Ca, Mg, and S) had slightly elevated concentrations (increases of about 10 to 30%) in the subsurface flows in comparison to the surface runoff. However, there were more constituents that were in higher concentrations in subsurface flows, compared to surface runoff, for the compost-amended soil test plots. In addition, the increases were generally larger (as much as 2.5 times greater) than for the increases observed at the soil-only test plots. The constituents with elevated concentrations in the subsurface flows compared to surface runoff at the compost-amended test plots were NO_3, TN, SO_4, Al, Ca, Fe, K, Mg, Mn, Na, and S.

The surface runoff from the compost-amended soil sites had greater concentrations of almost all constituents, compared to the surface runoff from the soil-only test sites. Interestingly, the only exceptions were for the cations Al, Fe, Mn, Zn, and Si, plus toxicity, which were all lower in the surface runoff from the compost-amended soil test sites. The increased concentrations in the surface runoff and subsurface flows from the compost-amended soil test site as compared to the soil-only site were quite large, typically in the range of 5 to 10 times greater. The exceptions were Fe, Zn, and toxicity. Toxicity tests indicated reduced toxicity with filtration at both the soil-only and at the compost-amended test sites.

Figures G-1 through G-29 are the particle size distributions for the analyzed samples. The particle size distributions remained about the same for all test conditions with slightly larger particles for the compost-amended soil test sites.

Statistical tests determined the significance of the differences noted above. Tables G-3 and G-4 (in Appendix G) summarize the surface runoff and subsurface flow quality for different categories of samples for most of the analyses (excluding those that were not detected in the majority of the samples). The analyses included on these tables are:

- nutrients (PO_4, total P, NH_4, NO_3, and total N)
- major ions (Cl, SO_4, Ca, K, Fe, Mg, Mn, Na, Si, and S)
- heavy metals (Al, Cu, and Zn)
- particle sizes (10th, 50th, and 90th percentile sizes, by volume)
- toxicity (percent light decrease using Microtox®)

Table 4-6. Average (and COV) values for all runoff and subsurface flow samples

Constituent (mg/L, unless noted)	Soil-only Plots		Soil plus Compost Plots	
	Surface Runoff	Subsurface Flows	Surface Runoff	Subsurface Flows
PO_4-P	0.27 (1.4)	0.17 (2.0)	1.9 (1.0)	1.8 (1.2)
TP	0.49 (1.0)	0.48 (2.2)	2.7 (0.9)	2.5 (1.1)
NH_4-N	0.65 (1.7)	0.23 (1.3)	4.1 (1.8)	3.5 (3.0)
NO_3-N	0.96 (1.4)	1.2 (2.5)	3.0 (1.6)	6.2 (2.8)
TN	2.5 (0.9)	1.9 (0.7)	8.4 (1.5)	10 (2.1)
Cl	2.4 (1.0)	2.1 (0.9)	6.7 (1.1)	5.0 (1.6)
SO_4-S	0.68 (1.1)	0.95 (2.0)	1.5 (0.9)	2.4 (1.4)
Al	11 (1.8)	1.7 (2.1)	0.7 (1.6)	2.4 (1.6)
Ca	12 (1.5)	17 (0.7)	18 (1.1)	35 (1.1)
Cu	0.01 (0.8)	0.01 (1.6)	0.02 (1.2)	0.02 (0.9)
Fe	4.6 (1.4)	2.8 (1.6)	1.2 (1.5)	2.6 (0.9)
K	5.4 (1.0)	4.6 (0.8)	30 (1.3)	34 (1.6)
Mg	3.9 (0.8)	5.0 (0.6)	5.8 (1.2)	10 (1.1)
Mn	0.75 (2.9)	0.41 (2.8)	0.36 (1.9)	0.80 (2.4)
Na	3.8 (0.9)	3.4 (0.5)	3.2 (0.8)	4.6 (1.2)
S	1.1 (0.8)	1.3 (1.5)	2.5 (0.8)	4.7 (1.6)
Zn	0.2 (1.2)	0.05 (2.2)	0.14 (1.1)	0.03 (1.8)
Si	26 (1.7)	8.9 (0.5)	4.2 (1.1)	11 (0.7)
10th percentile size (μm)	2.9 (0.7)	3.1 (0.4)	2.8 (0.3)	3.5 (0.6)
50th percentile size (μm)	12 (1.0)	13 (0.6)	15 (0.4)	14 (0.7)
90th percentile size (μm)	45 (0.5)	41 (0.5)	46 (0.4)	47 (0.6)
Toxicity (% light decrease)	25 (0.7)	13 (0.5)	16 (0.8)	10 (1.1)

The data in these tables are only for paired analyses, where both surface runoff and subsurface flow samples were analyzed (except for rainfall). Table G-3 compares surface runoff and subsurface flow quality at each test site using the non-parametric Kurskall-Wallis test. The 14 categories examined are shown in Table 4-7 (group 1 compared to group 2, group 3 compared to group 4, etc.):

Table 4-7. Categories examined

Group	Sample type	Treatment	Location	Number of Samples in Group
1	Surface runoff	Alderwood, soil C	Timbercrest	2
2	Subsurface flow	Alderwood, soil C	Timbercrest	2
3	Surface runoff	Alderwood, soil A	CUH	7
4	Subsurface flow	Alderwood, soil A	CUH	7
5	Surface runoff	Alderwood, soil A and CG compost	CUH	7
6	Subsurface flow	Alderwood, soil A and CG compost	CUH	7
7	Surface runoff	Alderwood, soil B	CUH	6
8	Subsurface flow	Alderwood, soil B	CUH	6
9	Surface runoff	Alderwood, soil B and GroCo compost	CUH	7
10	Subsurface flow	Alderwood, soil B and GroCo compost	CUH	7
11	Surface runoff	Alderwood, soil D	Woodmoor	5
12	Subsurface flow	Alderwood, soil D	Woodmoor	5
13	Surface runoff	Alderwood, soil D and CG compost	Woodmoor	4
14	Subsurface flow	Alderwood, soil D and CG compost	Woodmoor	4

Similarly, Table G-4 summarizes the same water quality constituents and compares all surface runoff at composite-amended sites vs. non-amended sites, and also subsurface flows at all compost-amended sites vs. non-amended sites.

Few significant differences were noted in Table G-3 because of the relatively small number of samples in each of the many different categories. The following list shows the comparisons that had probabilities of being the same in each of the two data sets being compared with values of 0.1 or less (" ≤ 0.1). These comparisons examined surface runoff vs. subsurface flow water quality (with the ratio of average subsurface flow to surface runoff concentrations shown in parentheses):

CUH (Alderwood soil A only)
- PO_4 (0.54)
- TP (0.40)
- NH_4 (0.19)
- SO_4 (0.38)
- Al (0.04)
- Ca (1.6)
- Fe (0.08)
- Na (0.56)
- S (0.43)
- Zn (0.23)
- 10th (1.51)
- toxicity (0.54)

CUH (Alderwood soil A and Cedar Grove compost)
- NH_4 (0.05)
- Al (11.3)
- Ca (4.4)
- Cu (2.5)
- Fe (9.6)
- Mg (4.6)
- Na (1.6)
- Zn (0.06)
- Si (11.7)
- toxicity (0.46)

CUH (Alderwood soil B only)
- SO4 (0.63)
- Ca (2.7)
- Mg (2.4)
- Na (2.0)
- Zn (0.13)
- Si (2.1)

CUH (Alderwood soil B and GroCo compost)
- none

Timbercrest (Alderwood soil C only)
- none

Woodmoor (Alderwood soil D only)
- Si (0.56)

Woodmoor (Alderwood soil D and Cedar Grove compost)
- Cl (0.3)

The following lists a similar summary of the significant differences shown on Table G-4. These comparisons contrasted water quality at all soil-only sites and at composted-amended sites for surface runoff and subsurface flows separately (the ratios of compost-amended site data to soil-only site data are shown in parentheses):

Surface Runoff
- PO_4 (6.9)
- TP (5.6)
- TN (3.4)
- SO_4 (2.2)
- Al (0.07)
- Cu (3.6)
- Fe (0.26)
- K (5.6)
- S (2.3)
- Si (0.16)

Subsurface Flows
- PO_4 (10.5)
- TP (5.3)
- TN (5.2)
- SO_4 (2.5)
- Ca (2.1)
- Cu (4.1)
- K (7.4)
- Mg (2.0)
- S (3.5)

Mass Discharges of Nutrients and other Water Quality Constituents

The mass discharges of water and nutrients were calculated for each sampling period. As noted previously, compost-amended soils increased concentrations of many constituents in the surface runoff. However, the compost amendments also significantly decreased the amount of surface runoff leaving the test plots, at least for a few years. Table 4-8 summarizes these expected changes in surface runoff and subsurface flow mass pollutant discharges associated with compost-amended soils, using the paired data only. The concentration increases were multiplied by the runoff reduction factors to obtain these relative mass discharge changes. The decreases in runoff volume were for the newer test sites. The older test sites had less dramatic reductions in runoff values. The older sites also had smaller concentration increases associated with the addition of compost to the soil. All of the surface runoff mass discharges are reduced by large amounts (2 to 50 percent of the unamended discharges). However, many of the subsurface flow mass discharges are expected to increase, especially for ammonia (340% increase), phosphate (200% increase), plus total phosphorus, nitrates, and total nitrogen (all with 50% increases). Most of the other constituent mass discharges in the amended plot subsurface flows are expected to decrease.

The compost has significant sorption capacity and ion exchange capacity that is responsible for pollutant reductions in the infiltrating water. However, the compost also leaches large amounts of nutrients to the surface and subsurface waters.

Table 4-8. Changes in Pollutant Discharges from Surface Runoff and Subsurface Flows at New Compost-Amended Sites, Compared to Soil-Only Sites

Constituent	Surface Runoff Discharges, Amended-Soil Compared to Unamended Soil (ratio)	Subsurface Flow Discharges, Amended-Soil Compared to Unamended Soil (ratio)
Runoff Volume	0.09	0.29
Phosphate	0.62	3.0
Total phosphorus	0.50	1.5
Ammonium nitrogen	0.56	4.4
Nitrate nitrogen	0.28	1.5
Total nitrogen	0.31	1.5
Chloride	0.25	0.67
Sulfate	0.20	0.73
Calcium	0.14	0.61
Potassium	0.50	2.2
Magnesium	0.13	0.58
Manganese	0.042	0.57
Sodium	0.077	0.40
Sulfur	0.21	1.0
Silica	0.014	0.37
Aluminum	0.006	0.40
Copper	0.33	1.2
Iron	0.023	0.27
Zinc	0.061	0.18

Since Table 4-8 was based on paired analyses only (requiring both surface runoff and subsurface flow data for the calculations), the values may over-predict the benefits of compost-amended soils. The analysis did not include the three samples with very high concentration, as these samples did not have the appropriate paired data for comparison/confirmation. On the other hand, the mass discharge calculations shown in Appendix H are likely overly conservative because the few extremely high values greatly distort the averaged values used in the calculations.

Section 5
Conclusions

This project evaluated a widespread problem, decreased infiltration due to disturbed soils, and a potential solution, soil amendment with compost. The elements associated with the problem of disturbing natural soils during land development were examined over a wide variety of site conditions (soil texture, age, moisture, and compaction) and at several locations. A large number of infiltration tests were conducted to identify the factors significantly affecting infiltration parameters. In addition, the project also examined a potential solution, amending soils with large amounts of compost, to reduce the problems associated with altering the surface and subsurface hydrology during development. The benefits of compost amendment were measured at special test plots exposed to typical developmental construction practices.

Infiltration Rates in Disturbed Urban Soils (Task 1)

The initial exploratory analyses of the data showed that sandy soil was mostly affected by compaction, with little change due to moisture levels. However, the clayey soils were affected by a strong interaction of compaction and moisture. The variations of the observed infiltration rates in each category were relatively large, but four soil conditions were found to be distinct, as shown in Table 5-1. The data from each individual test were fitted to the Horton equation, but the resulting equation coefficients were relatively imprecise (Table 5-2) and it may not matter which infiltration model is used, as long as the uncertainty is considered in the evaluation. Therefore, when modeling runoff from urban soils, it may be best to assume relatively constant infiltration rates throughout an event, and to utilize Monte Carlo procedures to describe the observed random variations about the predicted mean value, possibly using the time-averaged infiltration rates and COV values shown in Table 5-3.

Table 5-1. Infiltration Rates for Significant Groupings of Soil Texture, Moisture, and Compaction Conditions

Group	Number of tests	Average infiltration rate, mm/hr (in/hr)	COV
noncompacted sandy soils	36	414 (16.3)	0.4
compact sandy soils	39	64 (2.5)	0.2
noncompacted and dry clayey soils	18	220 (8.8)	1.0
all other clayey soils (compacted and dry, plus all saturated conditions)	60	20 (0.7)	1.5

Table 5-2. Observed Horton Equation Parameter Values for Sandy and Clayey Soils

	f_o mm/hr (in/hr)		f_c mm/hr (in/hr)		k (1/min)	
	mean	**range**	**Mean**	**range**	**mean**	**range**
Observed noncompacted sandy soils	990 (39)	110–3700 (4.2–146)	381 (15)	10–635 (0.4–25)	9.6	1.0–33
Observed compact sandy soils	381 (15)	3–2200 (0.1–86)	46 (1.8)	3–240 (0.1–9.5)	11	1.8–37
Observed dry noncompacted clayey soils	460 (18)	64–1500 (2.5–58)	170 (6.6)	3–610 (0.1–24)	8.8	-6.2–19
Observed for all other clayey soils (compacted and dry, plus all saturated conditions)	86 (3.4)	0–1200 (0–48)	10 (0.4)	-15–170 (-0.6–6.7)	5.6	0–46

Very large errors in soil infiltration rates can easily be made if published soil maps and most available models are used for typically disturbed urban soils, as these tools ignore compaction. Knowledge of compaction (which can be mapped using a cone penetrometer, or estimated based on expected activity on grassed areas) can be used to more accurately predict stormwater runoff quantity.

Table 5-3. Soil Infiltration Rates for Different Categories and Storm Durations, mean (COV)

	15 minutes mm/hr (in/hr)	30 minutes mm/hr (in/hr)	60minutes mm/hr (in/hr)	120 minutes mm/hr (in/hr)
Sand, Non-compacted	582 (22.9) [0.4]	495 (19.5) [0.4]	429 (16.9) [0.4]	414 (16.3) [0.4]
Sand, Compacted	170 (6.7) [0.2]	120 (4.9) [0.2]	97 (3.8) [0.2]	64 (2.5) [0.2]
Clay, Dry Non-compacted	323 (12.7) [1.0]	244 (10.8) [1.0]	240 (9.6) [1.0]	220 (8.8) [1.0]
All other clayey soils (compacted and dry, plus all saturated conditions)	46 (1.8) [1.5]	25 (1.3) [1.5]	25 (1.0) [1.5]	20 (0.7) [1.5]

In most cases, the mapped soil textures were similar to what was actually measured in the field. However, important differences were found during many of the 153 tests. Table 5-1 showed the 2-hr averaged infiltration rates and their COVs in each of the four major groupings. Although these COV values can be generally high (up to 1.5), they are much less than if compaction was ignored. The results of the factorial analysis indicated that the best models were separated by the soil texture. For more accurate modeling, it is recommended that site specific data be obtained. Once the texture, moisture and compaction of the soil are known, the models presented in Section 3 can be used. The high variations within each of these categories makes it difficult to identify legitimate patterns, implying that average infiltration rates within each event may be most suitable for predictive purposes. The remaining uncertainty can probably best be described using Monte Carlo components in runoff models.

The measured infiltration rates during these tests were all substantially larger than expected, but comparable to previous standard double-ring infiltrometer tests in urban soils. Other researchers have noted the general over-predictions of ponding by infiltrometers as compared to actual observations during natural rains. In all cases, these measurements are suitable to indicate the relative effects of soil texture, compaction, and moisture of infiltration rates, plus the measured values can be directly used to predict the infiltration rates that may be expected from stormwater infiltration controls that utilize ponding. Additional research is needed in other urban areas to measure site specific effects of these soil conditions on infiltration rates.

Water Quality and Quantity Effects of Amending Soils with Compost (Task 2)

There was a substantial difference in appearance of amended and unamended plots. There was insufficient grass growth in the unamended plots, even following initial establishment fertilization. The compost-amended plots were very attractive and needed no fertilization. In fact, the initial establishment fertilization may not have been necessary based on studies at the University of Washington of growing turfgrass in similar compost-amended soils without inorganic fertilization. Besides fertilizer applications, other external sources of nutrients to the test plots included wildlife (especially geese that were noted to selectively graze the compost-amended plots).

Application of compost material similar to that used during these studies would be possible by applying 10 cm (4 in.) of compost onto the surface of a soil and tilling to a total depth of 30 cm (12 in.), including the compost amendment (20 cm (8 in.) into the soil). Mixing would need to be thorough and deep to achieve the conditions of this study. However, this may not be possible with most existing construction equipment.

The results of this study clearly show that amending soil with compost alters soil properties known to affect water relations of soils, i.e., the water holding capacity, porosity, bulk density, and structure, as well as increasing soil C and N, and probably other nutrients as well. The mobilization of these constituents probably led to the observed increases in P and N compounds in surface runoff compared to unamended soil plots.

Results of the earlier Redmond-sponsored tests (Harrison, *et al*. 1997) were somewhat different than the current study. Some of these differences were likely associated with the age of the test plots, different rainfall conditions, and other site characteristics. The results of the earlier study clearly showed that compost amendment is an effective means of decreasing peak flows from all but the most severe storm events, even following very wet, antecedent conditions. The compost-amendment doubled water-holding capacity. Storms up to 20 mm (0.8 in.) total rainfall were buffered in amended soils and did not result in significant peak flows, whereas without the amendment, only storms of about 10 mm (0.4 in.) total rainfall could be similarly buffered.

This study found that the infiltration rate increased by 1.5 to 10.5 times after amending the soil with compost, compared to unamended sites (Table 4-2). There were mixed results with surface runoff of the compost-amended plots. The two older CUH test plots appeared to have no effect, the Woodmoor site had a ratio of 5.6 reduced runoff and the Timbercrest site had no reported runoff (Table 4-3). Because the older CUH sites did not show any runoff improvements in these test while the new Timbercrest and Woodmoore sites did, further study should determine if possible, the limits of effectiveness of compost amendment, i.e. age or decay rate, and a maintenance/reapplication schedule.

If a significant percentage of the disturbed glacial till soils as described in this report were amended with compost, it could have a significant beneficial effect on watershed hydrology. The absolute amount depends on many factors, but it is clear that compost amendment can retain runoff on-site and reduce the rate of runoff from all but the most intense storm events, especially during the early critical years following development.

One drawback is that the concentrations of many pollutants increased in the surface runoff, especially associated with leaching of nutrients from the compost. The surface runoff from the compost-amended soils had greater concentrations of almost all constituents, compared to the surface runoff from the soil-only test sites. The only exceptions were some cations (Al, Fe, Mn, Zn, Si), and toxicity, which were all lower in the surface runoff from the compost-amended soil test sites. The concentration increases in the surface runoff and subsurface flows from the compost-amended soil test site were quite large, typically in the range of 5 to 10 times greater. Subsurface flow concentration increases for the compost-amended soil test sites were also common and about as large. The only exceptions being for Fe, Zn, and toxicity. Toxicity tests indicated reduced toxicity with filtration at both the soil-only and at the compost-amended test sites, likely due to the sorption or ion exchange properties.

When the decreased surface flow quantities were considered in conjunction with the increased surface runoff concentrations, it was found that all of the surface runoff mass discharges were reduced by large amounts (to 2 to 50 percent of the unamended discharges). However, many of the subsurface flow mass discharges are expected to increase, especially for ammonia, phosphate, total phosphorus, nitrates, and total nitrogen. The large phosphorus and nitrogen compound concentrations found in surface runoff and subsurface flows at the compost-amended soil sites decreased significantly during the time of the tests (about 6 months). The older CUH test sites also had lower nutrient concentrations than the new sites, but still had elevated concentrations when compared to the soil-only test plots.

In conclusion, adding large amounts of compost to marginal soils enhanced many desirable soil properties, including improved water infiltration (and attendant reduced surface runoff), increased fertility, and significantly enhanced aesthetics of the turf. The need for continuous fertilization to establish and maintain the turf is reduced, if not eliminated, at compost-amended sites. Unfortunately, the compost also increased the concentrations of many nutrients in the runoff, especially when the site was newly developed but with increased infiltration of the soil, the nutrient mass runoff would be significantly decreased. Further research is needed to determine the optimum amount of compost amendment to benefit urban soils without the associated problems of leaching nutrients.

Section 6
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Appendix A
Location Maps for Infiltration Tests

Figures in Appendix A:

Figure A-1. Infiltration Sites in Chadwick - Helena, Al

Figure A-2. Infiltration Test Sites at Homewood Park - Homewood, Al

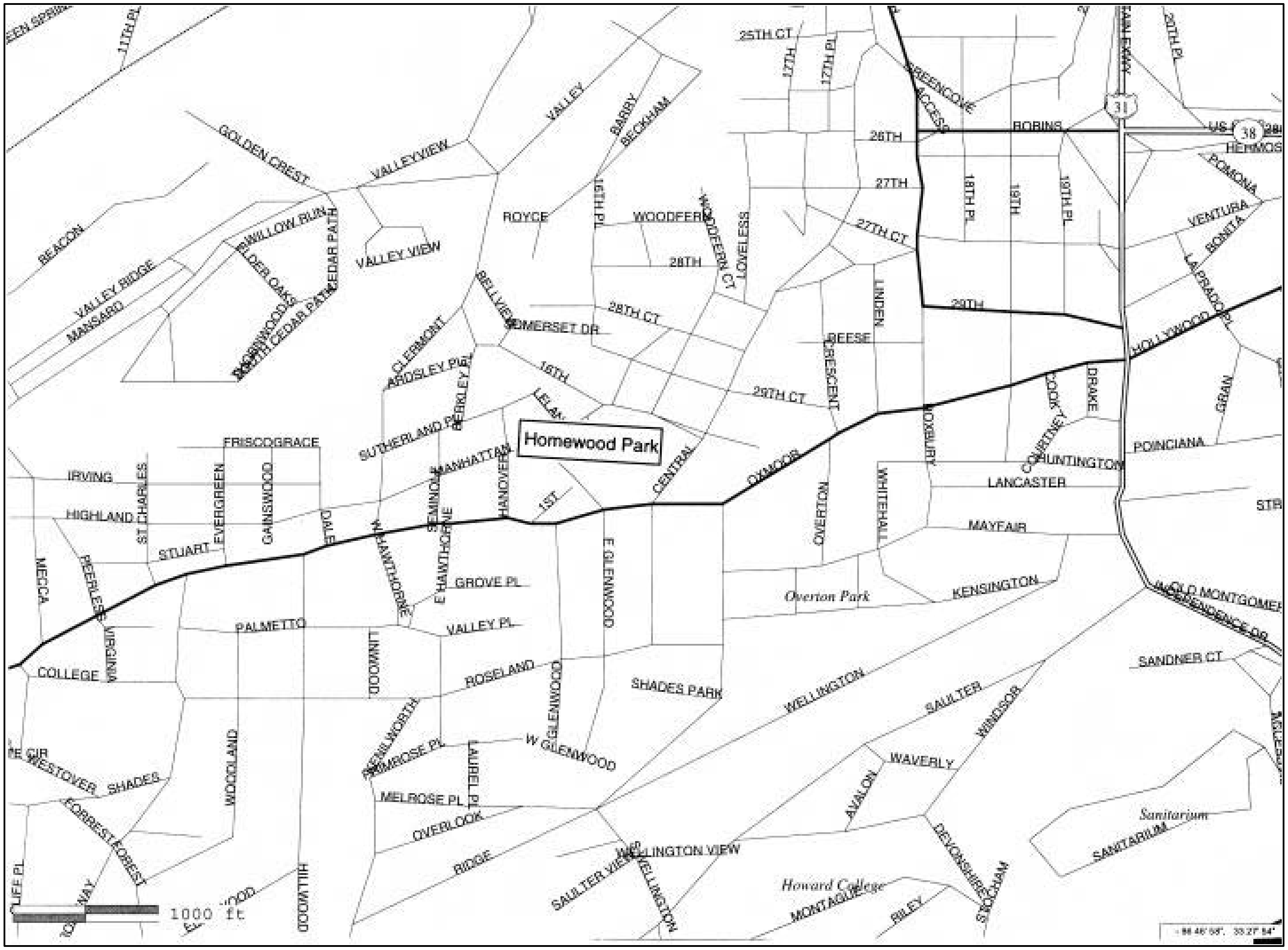


Figure A-3. Infiltration Test Sites at the Jasper Golf Course

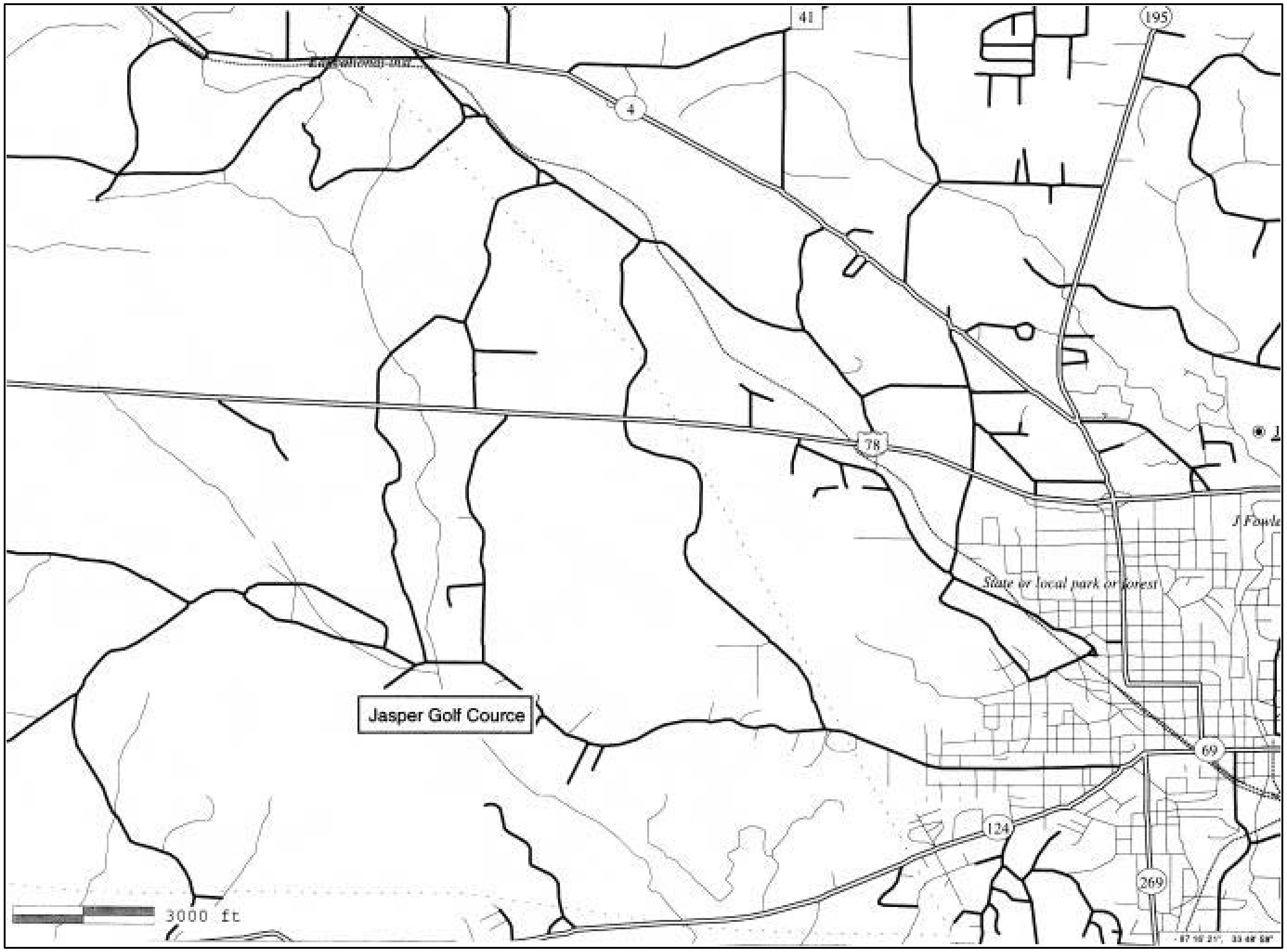


Figure A-4. Infiltration Test Sites at Littlefield Farms - Chilton County, Al

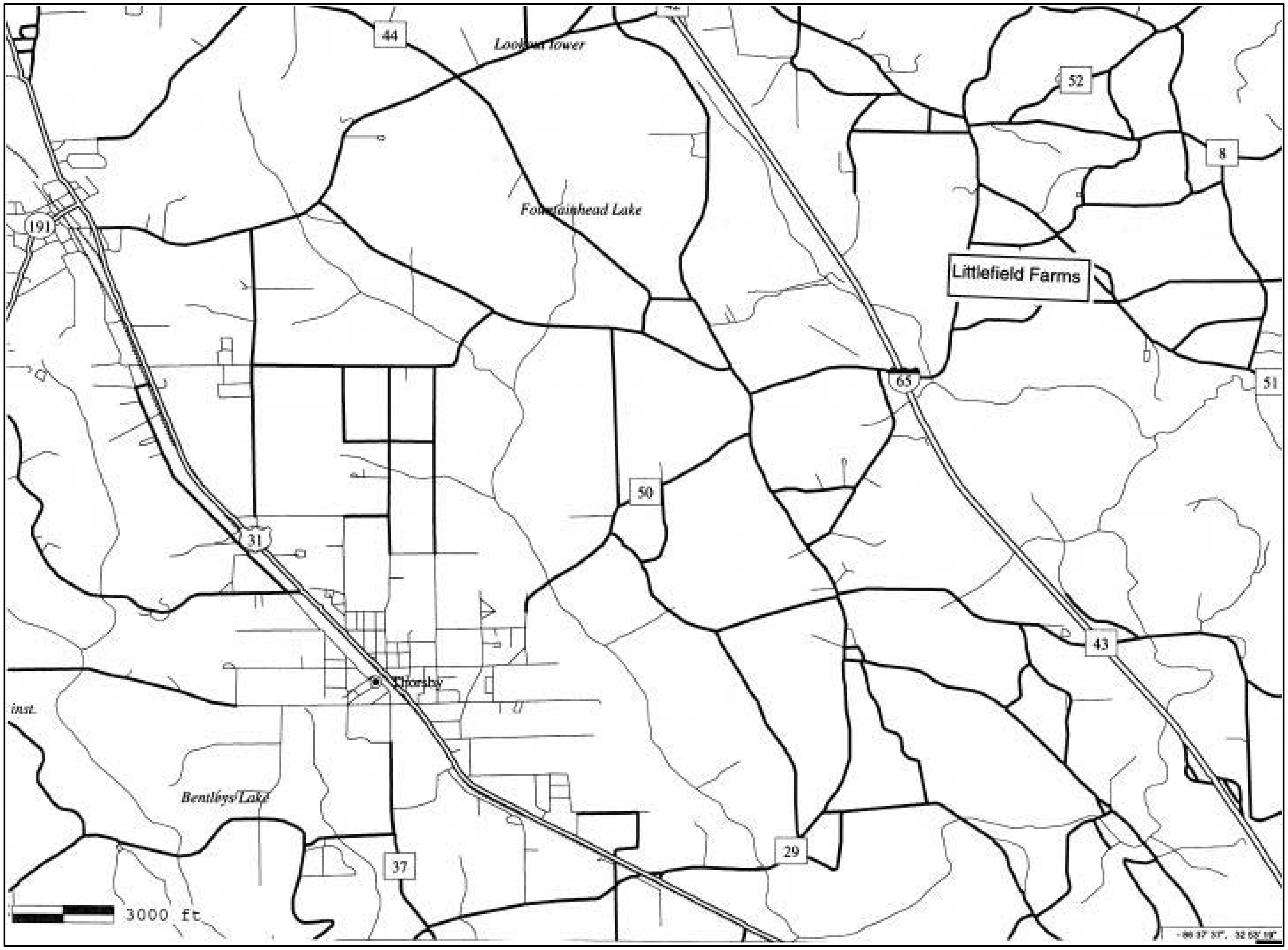


Figure A-5. Infiltration Test Sites at Private Residence - Birmingham, Al

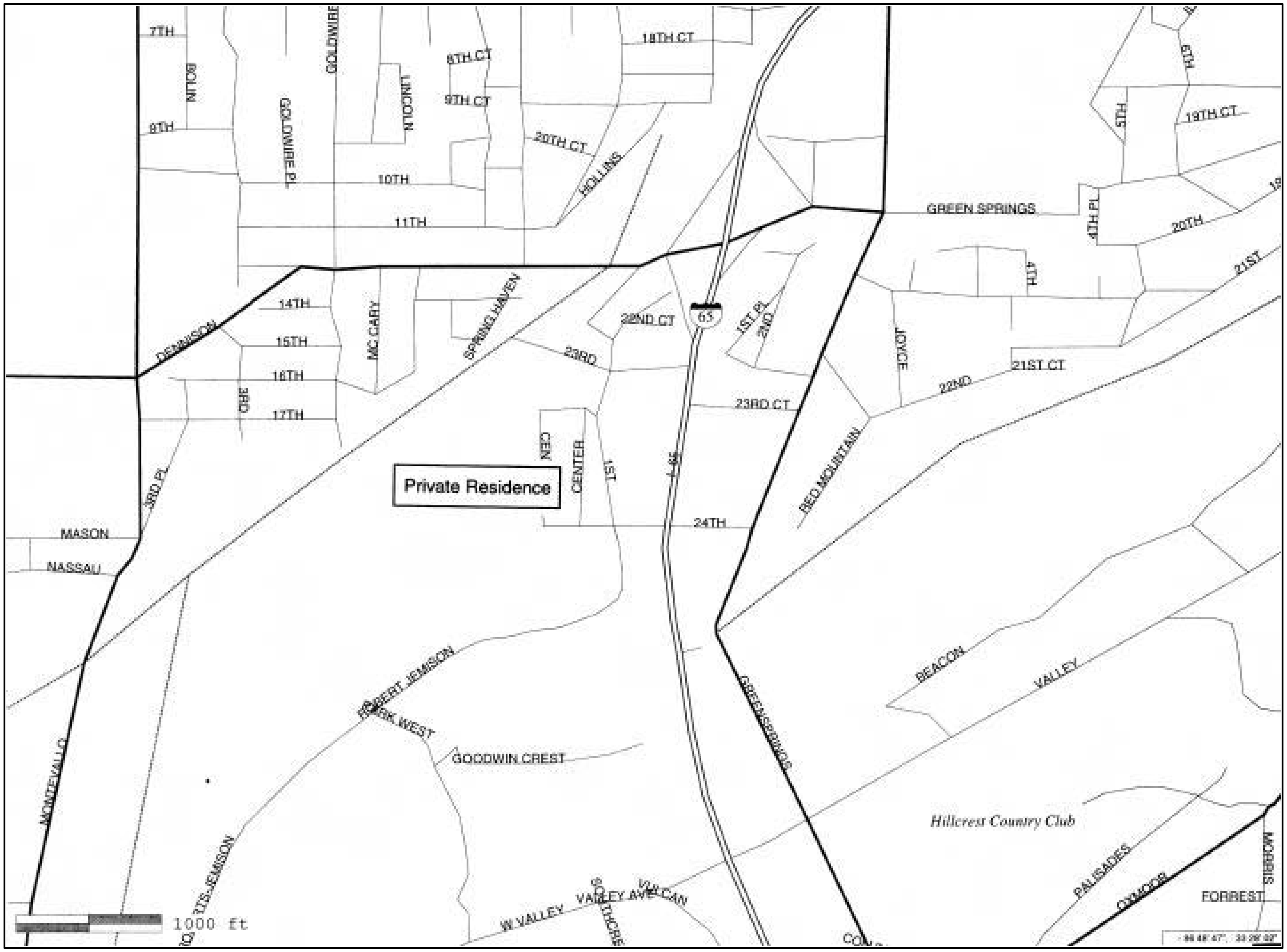


Figure A-6. Infiltration Test Sites at Private Residence - Gulf Shores, Al

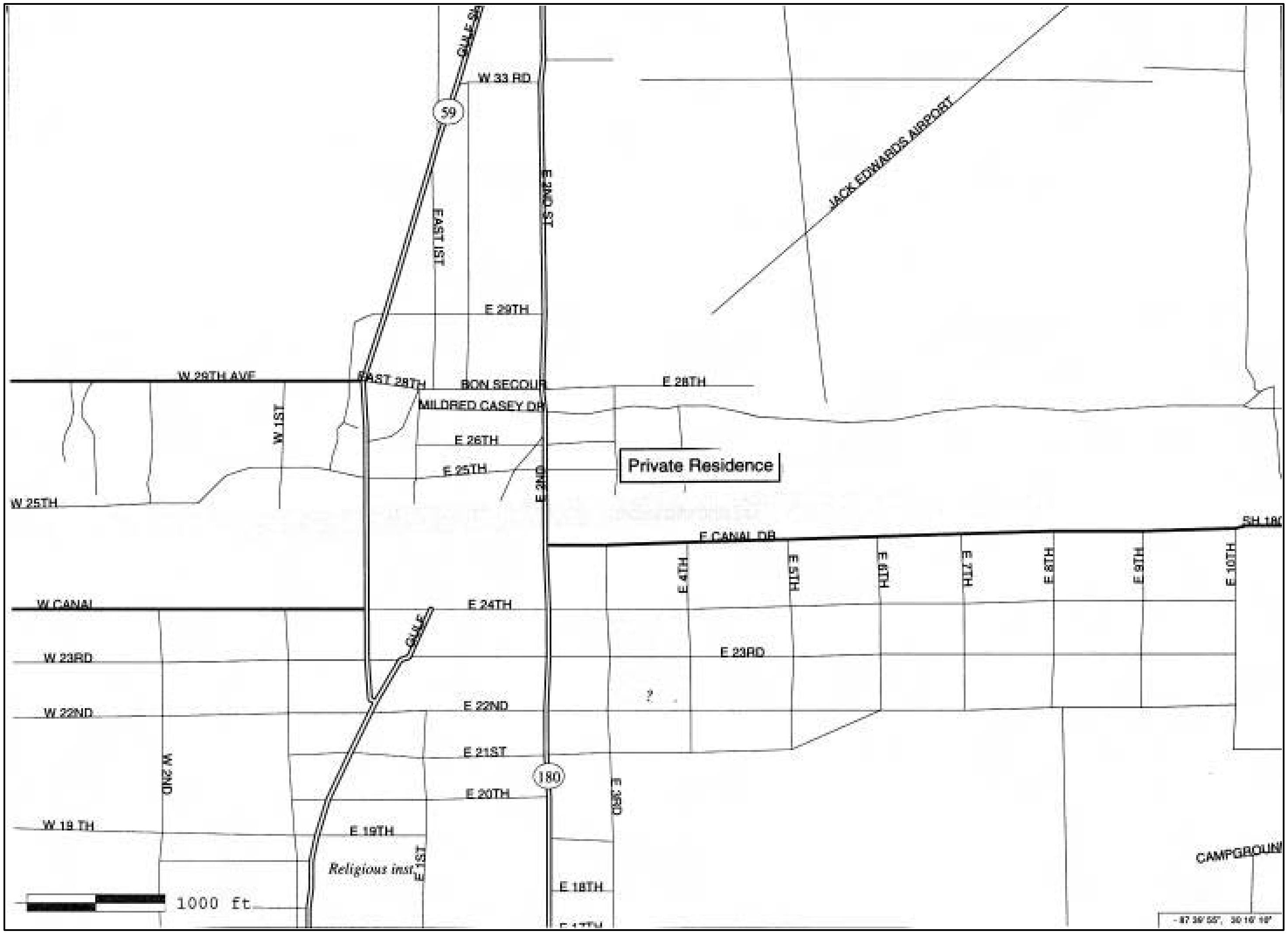


Figure A-7. Infiltration Test Sites at Private Residence - Trussville, Al

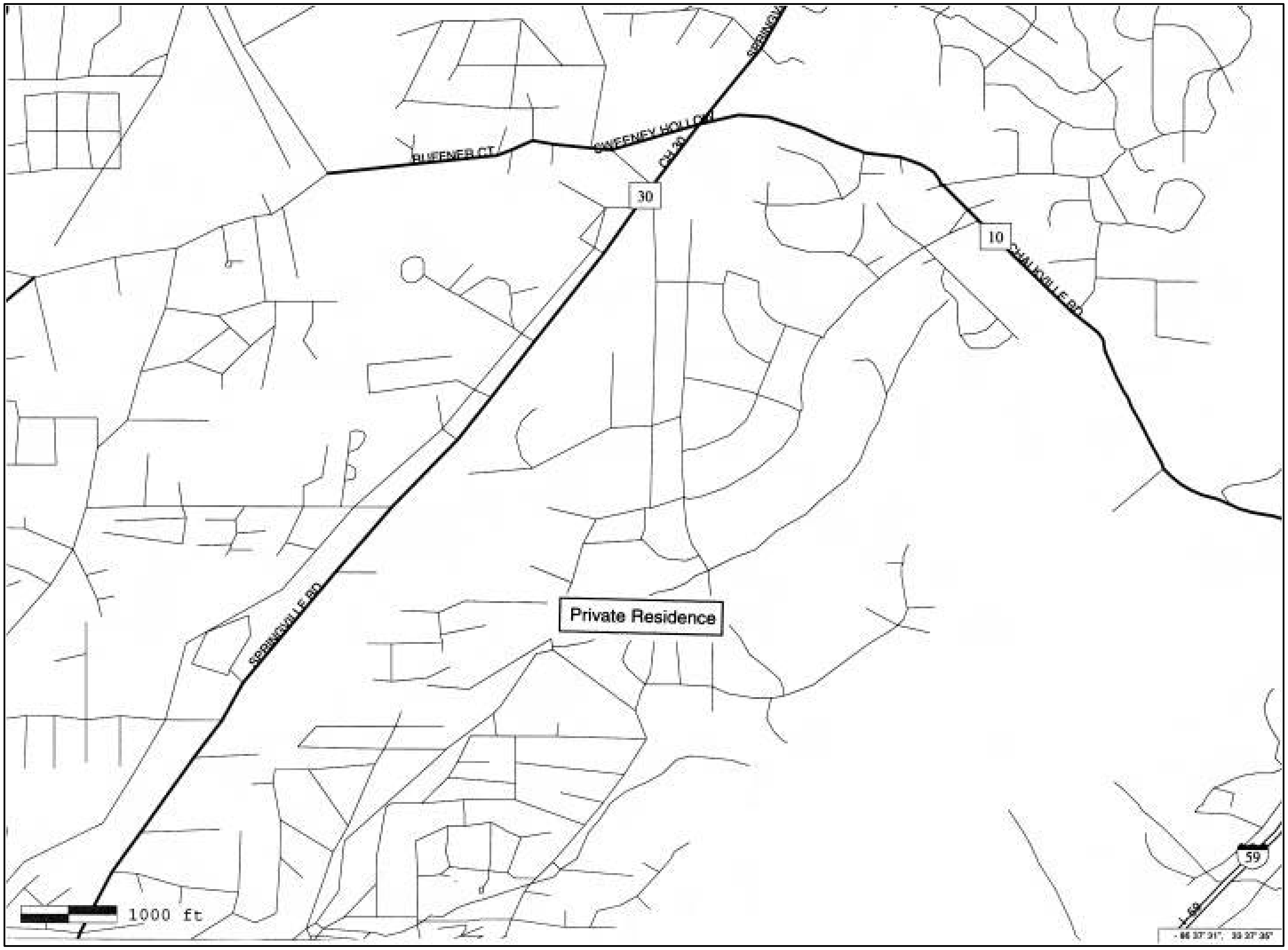


Figure A-8. Infiltration Test Sites at Private Residence - West Jefferson County, Al

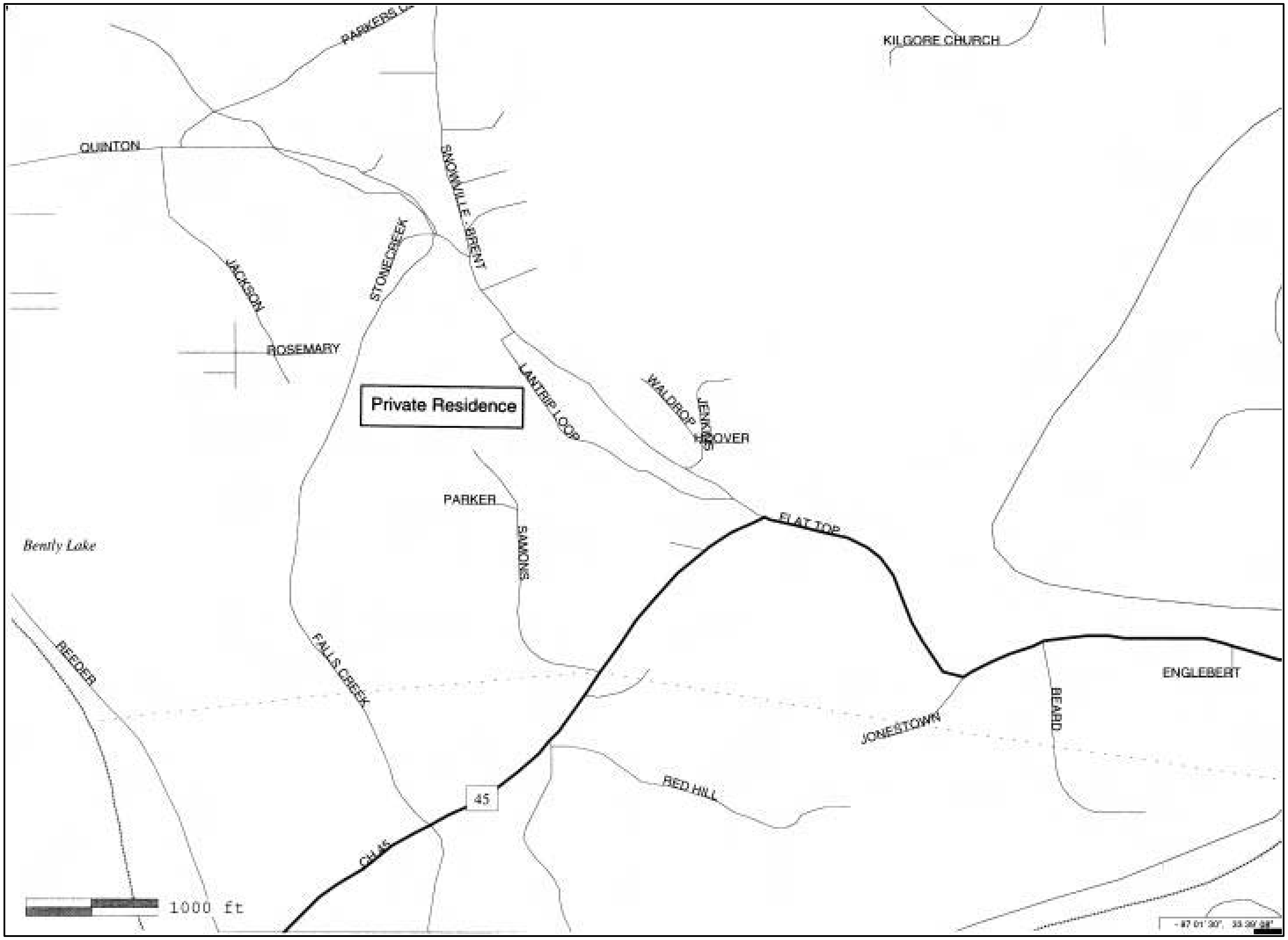
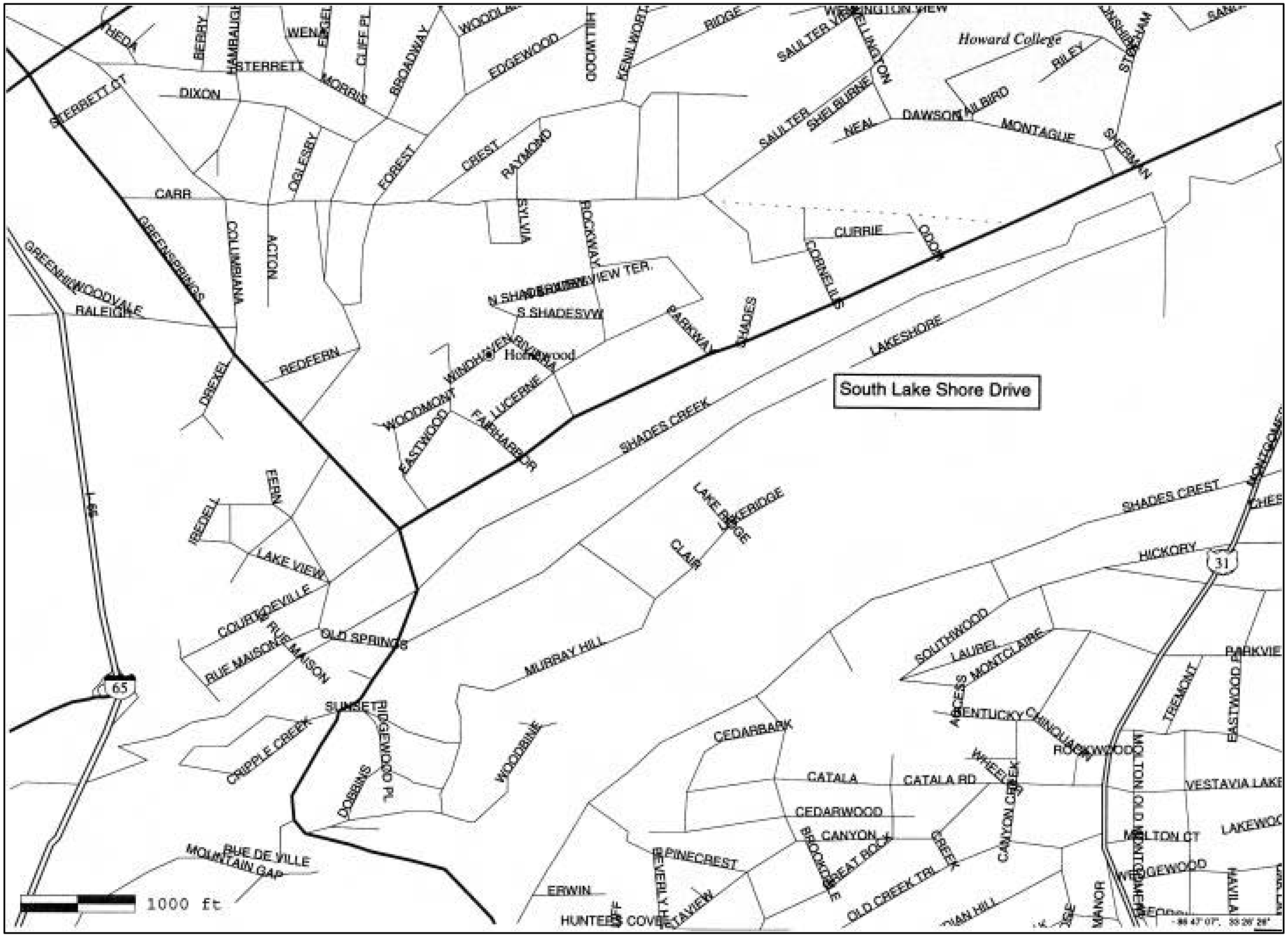
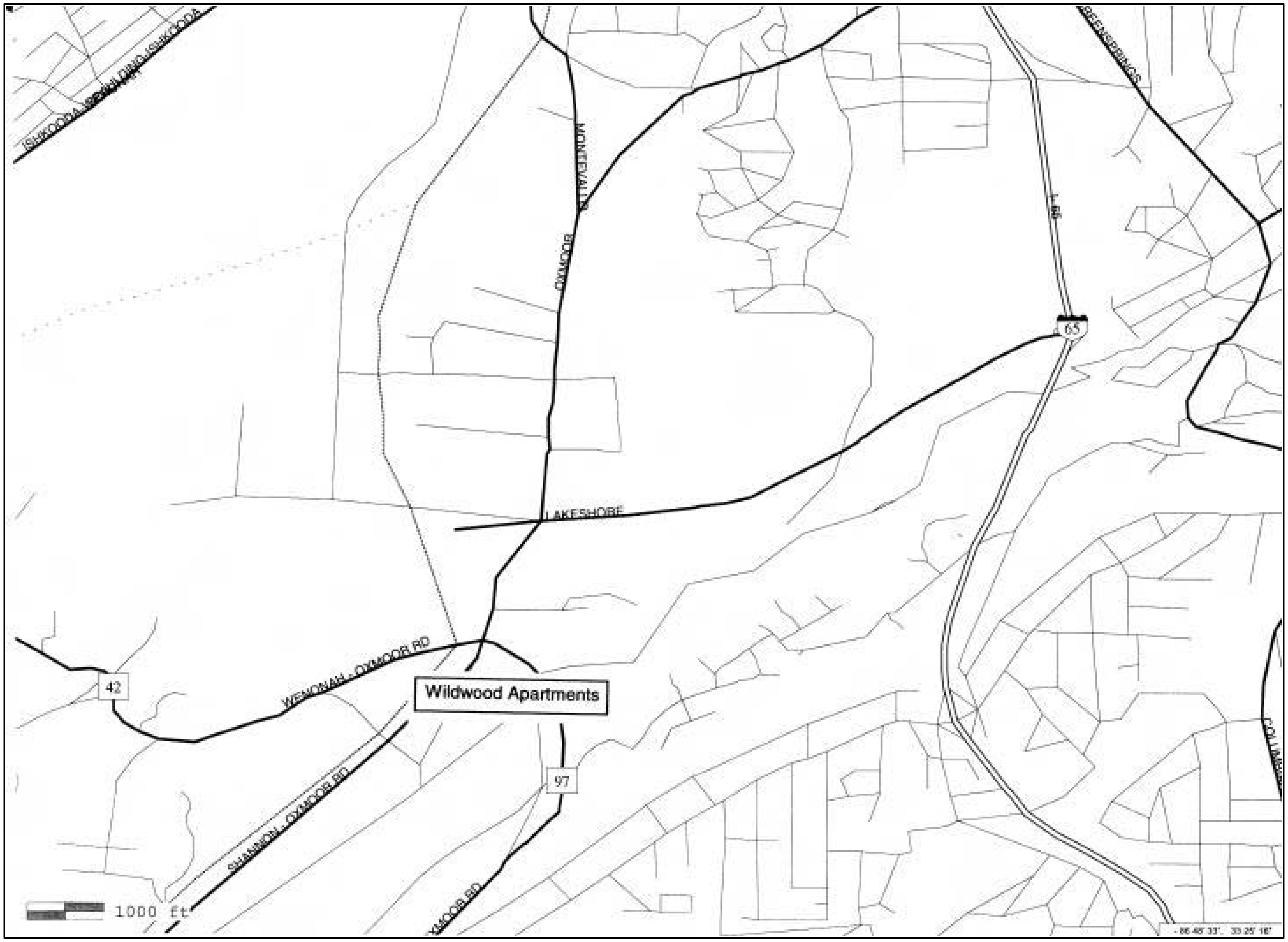


Figure A-9. Infiltration Test Sites at South Lake Shore Drive, Homewood, Al



A-10

Figure A-10. Infiltration Test Sites at Wildwood Apartments, Homewood, Al



Appendix B
Individual Infiltration Test Results

List of Table in Appendix B:

Table B-1. Clay – New Dry Compact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	NCDC-1A	NCDC-1B	NCDC-1C	NCDC-2A	NCDC-2B	NCDC-2B
0.04	3.00	3.00	7.50	1.50	6.00	15.00
0.13	2.25	0.75	2.25	4.50	4.50	6.00
0.21	0.75	2.25	3.75	0.75	3.75	9.00
0.29	1.50	1.50	1.50	0.00	0.00	3.00
0.38	1.50	1.50	0.75	0.00	0.75	0.00
0.46	0.75	0.00	4.50	0.75	0.75	0.75
0.54	0.75	0.75	2.25	0.00	2.25	0.00
0.63	0.75	0.75	1.50	0.75	0.75	0.00
0.71	1.50	1.50	3.00	0.00	2.25	0.00
0.79	1.50	0.75	1.50	1.50	0.00	0.00
0.88	0.00	0.75	0.00	0.00	0.00	0.00
0.96	0.75	1.50	1.50	0.75	0.00	0.00
1.04	0.75	0.75	0.75	0.00	1.50	0.00
1.13	0.00	0.00	1.50	0.75	0.75	0.75
1.21	1.50	0.75	2.25	0.75	0.75	0.00
1.29	0.75	1.50	0.00	0.00	0.00	0.00
1.38	0.75	0.00	0.75	0.00	0.75	0.00
1.46	0.75	0.75	1.50	0.75	1.50	0.75
1.54	0.00	1.50	2.25	0.00	0.75	0.00
1.63	0.00	0.00	0.75	0.00	0.00	0.00
1.71	0.00	0.75	0.00	0.00	0.00	0.00
1.79	0.75	0.00	0.75	0.75	0.00	0.75
1.88	0.00	0.75	0.00	0.00	0.00	0.00
1.96	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.84	0.91	1.69	0.56	1.13	1.50
Median	0.75	0.75	1.50	0.00	0.75	0.00
Standard Deviation	0.78	0.77	1.72	0.97	1.59	3.61
COV	0.92	0.84	1.02	1.73	1.42	2.40
f_c	0.41	0.66	1.27	0.29	0.52	0.04
f_o	2.83	2.88	9.88	3.13	7.77	18.99
k	2.64	4.08	9.48	4.80	5.70	6.36

Table B-2. Clay – New Dry Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	NCDN-1A	NCDN-1B	NCDN-1C	NCDN-2A	NCDN-2B	NCDN-2C
0.04	30.00	9.00	2.25	19.50	6.00	5.25
0.13	33.75	3.00	0.75	14.25	3.00	2.25
0.21	8.25	0.00	0.00	0.75	0.00	1.50
0.29	10.50	0.00	0.00	13.50	2.25	0.75
0.38	4.50	0.00	0.00	12.75	0.00	0.75
0.46	26.25	0.00	0.00	18.00	0.75	1.50
0.54	6.75	0.00	0.75	0.00	1.50	0.00
0.63	6.00	0.75	0.75	21.75	0.00	0.75
0.71	8.25	0.00	0.00	6.75	0.00	0.00
0.79	12.00	0.00	0.00	12.75	0.75	1.50
0.88	9.75	0.75	1.50	16.50	0.75	0.75
0.96	8.25	0.00	0.00	15.00	2.25	0.75
1.04	6.75	0.75	0.00	6.00	0.00	0.00
1.13	4.50	0.75	0.00	21.00	0.75	1.50
1.21	4.50	0.00	0.00	6.00	0.00	0.00
1.29	2.25	0.00	0.00	12.00	0.00	0.75
1.38	6.00	0.00	0.00	0.00	0.75	0.00
1.46	6.75	0.00	0.00	9.00	2.25	1.50
1.54	9.00	0.00	1.50	18.00	0.00	0.75
1.63	5.25	0.00	0.00	11.25	0.00	0.75
1.71	6.00	0.00	0.00	6.75	0.00	0.00
1.79	8.25	0.00	0.00	0.00	0.00	0.00
1.88	0.75	0.00	0.00	6.75	0.75	0.00
1.96	4.50	0.00	0.00	3.00	0.00	0.00
Mean	9.53	0.63	0.31	10.47	0.91	0.88
Median	6.75	0.00	0.00	11.63	0.38	0.75
Standard Deviation	8.36	1.90	0.62	6.88	1.42	1.14
COV	0.88	3.04	1.99	0.66	1.56	1.31
f_c	6.20	0.13	0.21	NA	0.57	0.56
f_o	37.31	17.57	4.91	NA	9.73	7.91
k	4.60	15.90	19.11	NA	12.21	10.70

Table B-3. Clay – New Wet Compact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	NCWC-1A	NCWC-1B	NCWC-1C	NCWC-2A	NCWC-2B	NCWC-2C
0.04	0.00	0.00	0.00	3.00	0.75	1.50
0.13	0.00	0.00	0.00	2.25	1.50	0.75
0.21	0.00	0.00	0.00	2.25	1.50	1.50
0.29	0.00	0.00	0.00	0.00	0.00	0.75
0.38	0.00	0.00	0.00	0.00	0.00	0.00
0.46	0.00	0.00	0.00	0.00	0.00	0.75
0.54	0.00	0.00	0.00	0.75	0.00	0.75
0.63	0.00	0.00	0.00	0.00	0.00	0.00
0.71	0.00	0.00	0.00	0.00	0.00	0.75
0.79	0.00	0.00	0.00	0.00	0.00	0.00
0.88	0.00	0.00	0.00	1.50	0.00	0.75
0.96	0.00	0.00	0.00	0.00	0.00	0.00
1.04	0.00	0.00	0.00	0.00	0.00	0.00
1.13	0.00	0.00	0.00	0.00	1.50	0.00
1.21	0.00	0.00	0.00	0.75	1.50	0.75
1.29	0.00	0.00	0.00	0.00	0.75	0.00
1.38	0.00	0.00	0.00	0.00	0.00	0.00
1.46	0.00	0.00	0.00	0.00	0.00	0.00
1.54	0.00	0.00	0.00	0.75	0.75	0.75
1.63	0.00	0.00	0.00	0.00	0.00	0.00
1.71	0.00	0.00	0.00	0.00	0.75	0.00
1.79	0.00	0.00	0.00	0.75	0.00	0.00
1.88	0.00	0.00	0.00	0.00	0.00	0.00
1.96	0.00	0.00	0.00	0.00	0.75	0.00
Mean	0.00	0.00	0.00	0.50	0.41	0.38
Median	0.00	0.00	0.00	0.00	0.00	0.00
Standard Deviation	0.00	0.00	0.00	0.88	0.58	0.49
COV	NA	NA	NA	1.75	1.44	1.32
f_c	0.00	0.00	0.00	0.20	0.32	0.08
f_o	0.00	0.00	0.00	4.18	1.51	1.51
k	0.00	0.00	0.00	6.24	6.06	2.28

Table B-4. Clay – New Wet Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	NCWN-1A	NCWN-1B	NCWN-1C	NCWN-2A	NCWN-2B	NCWN-2C
0.04	0.00	0.00	0.00	4.50	6.00	3.00
0.13	0.00	0.00	0.00	3.00	4.50	1.50
0.21	0.00	0.00	0.00	2.25	3.00	2.25
0.29	0.00	0.00	0.00	2.25	3.75	1.50
0.38	0.00	0.00	0.00	0.75	2.25	0.75
0.46	0.00	0.00	0.00	0.75	0.75	1.50
0.54	0.75	0.00	0.00	0.75	1.50	0.75
0.63	0.00	0.00	0.00	0.75	0.75	0.75
0.71	0.00	0.00	0.00	0.00	0.75	0.75
0.79	0.00	0.00	0.00	0.00	0.75	0.75
0.88	0.00	0.00	0.00	0.75	0.75	0.75
0.96	0.00	0.00	0.00	0.00	0.00	0.75
1.04	0.00	0.00	0.00	0.75	0.75	0.00
1.13	0.00	0.00	0.00	0.00	0.00	0.75
1.21	0.00	0.00	0.00	0.75	0.00	0.75
1.29	0.00	0.00	0.00	0.75	0.75	0.00
1.38	0.00	0.00	0.00	0.00	0.75	0.00
1.46	0.00	0.00	0.00	0.00	0.00	0.00
1.54	0.00	0.00	0.00	0.75	0.00	0.75
1.63	0.00	0.00	0.00	0.75	0.75	0.00
1.71	0.00	0.00	0.00	0.00	0.00	0.75
1.79	0.00	0.00	0.00	0.00	0.00	0.75
1.88	0.00	0.00	0.00	0.75	0.75	0.00
1.96	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.03	0.00	0.00	0.84	1.19	0.78
Median	0.00	0.00	0.00	0.75	0.75	0.75
Standard Deviation	0.15	0.00	0.00	1.11	1.59	0.75
COV	4.90	NA	NA	1.32	1.34	0.96
f_c	0.04	0.00	0.00	0.33	0.24	0.30
f_o	-0.03	0.00	0.00	5.39	6.86	2.91
k	7.74	0.00	0.00	46.20	3.36	2.52

Table B-5. Clay – Old Dry Compact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	OCDC-1A	OCDC-1B	OCDC-1C	OCDC-2A	OCDC-2B	OCDC-2C	OCDC-3A	OCDC-3B	OCDC-3C
0.04	3.00	8.25	2.25	2.25	1.50	2.25	0.75	1.50	0.75
0.13	1.50	5.25	1.50	2.25	1.50	1.50	0.75	0.75	0.00
0.21	1.50	5.25	1.50	0.75	0.75	0.75	0.75	0.75	0.75
0.29	1.50	3.75	0.75	0.75	0.75	0.75	0.00	0.75	0.75
0.38	0.75	3.00	1.50	0.75	0.75	0.75	0.00	0.75	0.75
0.46	0.75	1.50	0.75	0.00	0.75	0.75	0.00	0.00	0.00
0.54	0.75	5.25	0.75	1.50	0.75	0.75	0.75	0.75	0.00
0.63	1.50	5.25	0.75	0.75	0.00	0.75	0.00	0.75	0.00
0.71	0.75	3.00	0.75	0.75	0.75	0.75	0.00	0.75	0.75
0.79	0.75	2.25	0.75	0.75	0.75	1.50	0.00	0.00	0.00
0.88	0.75	3.00	0.00	0.00	0.00	0.75	0.75	0.00	0.75
0.96	0.75	2.25	0.75	0.75	0.75	0.75	0.00	0.00	0.00
1.04	0.75	2.25	0.75	0.75	0.75	1.50	0.75	0.75	0.00
1.13	0.75	2.25	0.75	0.75	0.75	0.75	0.00	0.00	0.00
1.21	0.75	3.00	0.75	0.00	0.00	0.00	0.00	0.00	0.75
1.29	0.75	1.50	0.00	0.75	0.75	0.75	0.00	0.00	0.00
1.38	0.75	2.25	0.75	0.00	0.00	0.75	0.00	0.75	0.00
1.46	0.75	3.00	0.75	0.75	0.00	0.00	0.00	0.00	0.00
1.54	0.75	3.00	0.00	0.00	0.75	0.75	0.75	0.00	0.75
1.63	0.75	3.00	0.00	0.75	0.00	0.75	0.00	0.00	0.00
1.71	0.00	3.00	0.75	0.00	0.75	0.00	0.00	0.75	0.75
1.79	0.75	3.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00
1.88	0.75	3.00	0.75	0.75	0.00	0.75	0.00	0.00	0.00
1.96	0.75	2.25	0.75	0.00	0.75	0.00	0.00	0.00	0.00
Mean	0.94	3.31	0.78	0.66	0.56	0.75	0.22	0.38	0.28
Median	0.75	3.00	0.75	0.75	0.75	0.75	0.00	0.00	0.00
Standard Deviation	0.55	1.53	0.52	0.64	0.46	0.54	0.35	0.44	0.37
COV	0.59	0.46	0.66	0.97	0.81	0.72	1.59	1.18	1.32
f_c	0.79	2.77	0.58	0.45	0.38	0.27	0.14	0.13	0.18
f_o	3.60	9.48	2.46	2.89	1.66	1.63	1.10	1.39	0.69
k	7.29	5.89	3.99	5.12	3.02	1.21	5.17	2.32	2.06

Table B-6. Clay – Old Dry Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	OCDN-1A	OCDN-1B	OCDN-1C	OCDN-2A	OCDN-2B	OCDN-2C	OCDN-3A	OCDN-3B	OCDN-3C
0.04	32.25	33.00	34.50	15.75	1.50	2.25	3.75	3.75	4.50
0.13	25.50	21.75	20.25	12.00	10.50	9.00	1.50	5.25	4.50
0.21	22.50	27.75	28.50	13.50	6.00	6.00	0.75	4.50	4.50
0.29	21.75	13.50	15.00	13.50	7.50	6.75	0.75	4.50	3.75
0.38	22.50	27.75	21.00	13.50	5.25	5.25	0.75	2.25	1.50
0.46	14.25	15.00	16.50	10.50	5.25	5.25	0.75	1.50	0.75
0.54	25.50	23.25	25.50	12.00	3.00	5.25	0.75	1.50	0.75
0.63	15.00	22.50	13.50	10.50	6.75	6.00	0.75	3.00	1.50
0.71	17.25	14.25	12.00	6.75	5.25	6.00	0.75	1.50	2.25
0.79	18.00	24.75	9.75	12.00	6.75	5.25	0.75	2.25	2.25
0.88	19.50	26.25	18.75	9.00	5.25	6.00	0.75	1.50	2.25
0.96	15.00	21.00	60.00	9.00	3.75	3.75	0.75	1.50	1.50
1.04	17.25	12.75	9.75	9.00	4.50	4.50	0.75	3.75	0.00
1.13	16.50	22.50	14.25	9.75	3.75	4.50	0.75	3.75	0.75
1.21	21.75	24.75	15.75	12.00	6.00	6.75	0.75	3.75	0.75
1.29	12.75	8.25	27.00	11.25	5.25	6.00	0.00	2.25	4.50
1.38	11.25	31.50	12.75	12.00	6.75	7.50	0.75	2.25	3.75
1.46	20.25	24.75	11.25	12.00	5.25	4.50	0.75	2.25	3.75
1.54	15.75	24.00	10.50	12.00	5.25	6.75	0.75	3.00	3.75
1.63	12.00	23.25	49.50	8.25	3.00	3.00	0.75	2.25	1.50
1.71	18.00	22.50	15.00	13.50	2.25	2.25	0.75	2.25	2.25
1.79	14.25	21.00	19.50	11.25	6.00	7.50	0.75	1.50	2.25
1.88	12.75	18.00	9.00	12.00	5.25	5.25	0.75	1.50	0.75
1.96	11.25	40.50	52.50	11.25	6.00	6.75	0.00	1.50	1.50
Mean	18.03	22.69	21.75	11.34	5.25	5.50	0.84	2.63	2.31
Median	17.25	22.88	16.13	12.00	5.25	5.63	0.75	2.25	2.25
Standard Deviation	5.23	7.01	14.12	2.01	1.86	1.64	0.67	1.15	1.45
COV	0.29	0.31	0.65	0.18	0.35	0.30	0.80	0.44	0.63
f_c	14.93	21.51	0.58	10.79	5.00	5.23	0.72	2.24	1.98
f_o	31.58	21.51	2.46	16.42	13.22	10.81	7.40	5.34	5.99
k	2.64	-6.17	3.99	4.92	10.59	10.38	17.09	3.75	5.52

Table B-6. Clay – Old Dry Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values (Continued)

Time Step (hr)	OCDN-4A	OCDN-4B	OCDN-4C
0.04	35.25	34.50	6.75
0.13	39.75	21.75	6.00
0.21	21.00	10.50	3.75
0.29	27.00	11.25	2.25
0.38	27.75	18.00	3.75
0.46	23.25	17.25	4.50
0.54	22.50	15.75	2.25
0.63	7.50	7.50	1.50
0.71	30.75	15.75	3.75
0.79	20.25	12.75	3.00
0.88	30.00	21.75	4.50
0.96	33.00	14.25	3.00
1.04	9.00	14.25	3.75
1.13	24.00	15.75	3.00
1.21	18.75	18.00	4.50
1.29	34.50	27.00	3.00
1.38	9.75	18.00	3.75
1.46	33.00	3.00	3.75
1.54	36.00	17.25	3.75
1.63	24.00	12.75	2.25
1.71	24.00	12.00	3.00
1.79	27.00	12.00	3.00
1.88	25.50	18.00	3.75
1.96	24.75	9.00	3.00
Mean	25.34	15.75	3.56
Median	25.13	15.75	3.75
Standard Deviation	8.39	6.43	1.15
COV	0.33	0.41	0.32
f_c	24.15	14.70	3.30
f_o	42.97	57.82	8.90
k	7.59	18.17	9.37

Table B-7. Clay – Old Wet Compact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	OCWC-1A	OCWC-1B	OCWC-1C	OCWC-2A	OCWC-2B	OCWC-2C	OCWC-3A	OCWC-3B	OCWC-3C
0.04	0.00	0.00	0.00	2.25	1.50	1.50	2.25	1.50	1.50
0.13	0.00	0.00	0.00	0.75	0.00	2.25	0.75	0.75	2.25
0.21	0.00	0.00	0.00	0.75	0.75	0.75	0.75	1.50	1.50
0.29	0.00	0.00	0.00	0.75	0.75	0.75	1.50	0.75	0.75
0.38	0.00	0.00	0.00	0.75	0.75	0.75	0.75	0.00	0.75
0.46	0.00	0.00	0.00	0.75	0.00	1.50	0.75	0.75	0.75
0.54	0.00	0.00	0.00	0.00	0.75	0.75	0.75	0.00	0.75
0.63	0.00	0.00	0.00	0.75	0.75	0.00	0.75	0.75	1.50
0.71	0.00	0.00	0.00	0.75	0.00	1.50	0.00	0.75	0.75
0.79	0.00	0.00	0.00	0.75	0.75	0.75	1.50	0.00	0.75
0.88	0.00	0.00	0.00	0.75	0.00	0.75	0.75	0.75	0.75
0.96	0.00	0.00	0.00	0.75	0.75	0.00	0.00	0.75	0.75
1.04	0.00	0.00	0.00	0.75	0.00	0.75	1.50	0.75	0.75
1.13	0.00	0.00	0.00	0.75	0.75	0.75	0.75	0.75	0.75
1.21	0.00	0.00	0.00	0.00	0.75	0.75	0.75	0.75	0.00
1.29	0.00	0.00	0.00	0.75	0.00	0.00	0.75	0.75	0.75
1.38	0.00	0.00	0.00	0.75	0.00	0.75	0.75	0.75	0.75
1.46	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.75	0.75
1.54	0.00	0.00	0.00	0.75	0.00	0.75	0.75	0.75	0.00
1.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75
1.71	0.00	0.00	0.00	0.75	0.75	0.75	0.75	0.75	0.00
1.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75
1.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.00
1.96	0.00	0.00	0.00	0.00	0.00	0.75	0.75	0.00	0.75
Mean	0.00	0.00	0.00	0.59	0.41	0.69	0.72	0.63	0.78
Median	0.00	0.00	0.00	0.75	0.38	0.75	0.75	0.75	0.75
Standard Deviation	0.00	0.00	0.00	0.49	0.44	0.58	0.56	0.42	0.52
COV	NA	NA	NA	0.83	1.09	0.85	0.78	0.68	0.66
f_c	0.00	0.00	0.00	0.54	-0.22	0.35	0.67	0.57	0.45
f_o	0.00	0.00	0.00	4.25	0.85	1.78	5.61	1.81	1.88
k	0.00	0.00	0.00	17.92	0.55	1.89	26.48	7.08	1.89

Table B-7. Clay – Old Wet Compact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values (Continued)

Time Step (hr)	OCWC-4A	OCWC-4B	OCWC-4C
0.04	1.50	0.75	1.50
0.13	1.50	1.50	3.00
0.21	1.50	0.75	1.50
0.29	0.75	0.75	0.75
0.38	0.75	0.75	0.75
0.46	0.75	0.75	0.75
0.54	0.75	0.75	0.75
0.63	0.75	0.75	0.00
0.71	0.75	0.75	0.75
0.79	0.75	0.00	0.00
0.88	0.75	0.75	0.75
0.96	0.00	0.75	0.75
1.04	0.75	0.75	0.00
1.13	0.75	0.75	0.75
1.21	0.75	0.75	0.00
1.29	1.50	0.00	0.75
1.38	0.75	0.75	0.00
1.46	0.75	0.00	0.75
1.54	0.75	0.75	0.00
1.63	0.00	0.75	0.75
1.71	0.75	0.75	0.00
1.79	0.75	0.00	0.75
1.88	0.75	0.75	0.00
1.96	0.00	0.00	0.00
Mean	0.78	0.63	0.63
Median	0.75	0.75	0.75
Standard Deviation	0.41	0.36	0.69
COV	0.53	0.58	1.10
f_c	0.67	0.16	0.31
f_o	1.80	1.04	2.47
k	3.82	0.62	3.14

Table B-8. Clay – Old Wet Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	OCWN-1A	OCWN-1B	OCWN-1C	OCWN-2A	OCWN-2B	OCWN-2C	OCWN-3A	OCWN-3B	OCWN-3C
0.04	24.00	4.50	1.50	0.75	1.50	2.25	0.75	0.75	0.75
0.13	10.50	1.50	0.75	0.75	0.75	0.75	0.75	0.75	0.00
0.21	6.00	0.75	0.75	0.00	0.00	0.00	0.00	0.00	0.75
0.29	2.25	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.00
0.38	15.75	1.50	0.00	0.00	0.75	0.75	0.00	0.00	0.00
0.46	9.75	0.75	0.00	0.00	0.75	0.75	0.00	0.00	0.00
0.54	8.25	1.50	0.00	0.75	0.00	0.00	0.00	0.00	0.00
0.63	4.50	0.75	0.75	0.00	0.00	0.75	0.00	0.00	0.00
0.71	5.25	0.00	0.00	0.00	0.75	0.75	0.00	0.00	0.00
0.79	3.75	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.00
0.88	14.25	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.96	9.00	0.75	0.00	0.00	0.75	0.00	0.00	0.00	0.00
1.04	7.50	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.00
1.13	4.50	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.21	6.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.29	3.75	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00
1.38	5.25	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.46	5.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.54	9.75	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.63	8.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.71	7.50	0.75	0.75	0.00	0.00	0.00	0.00	0.00	0.00
1.79	4.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.88	4.50	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.96	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	7.53	0.72	0.22	0.13	0.28	0.25	0.06	0.06	0.06
Median	6.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Standard Deviation	4.96	0.95	0.41	0.29	0.43	0.53	0.21	0.21	0.21
COV	0.66	1.32	1.89	2.28	1.54	2.11	3.39	3.39	3.39
f_c	6.67	0.52	0.11	0.07	-0.55	-0.24	-0.01	-0.01	-0.01
f_o	47.83	8.69	2.13	1.24	0.70	0.58	1.27	1.27	0.93
k	20.51	17.12	8.42	8.70	0.50	0.82	8.13	8.13	6.45

Table B-8. Clay – Old Wet Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values (Continued)

Time Step (hr)	OCWN-4A	OCWN-4B	OCWN-4C	OCWN-5A	OCWN-5B	OCWN-5C	OCWN-6A	OCWN-6B	OCWN-6C
0.04	0.75	3.75	3.00	3.75	3.75	2.25	0.75	1.50	1.50
0.13	0.75	1.50	2.25	3.75	1.50	3.00	0.75	1.50	0.75
0.21	0.75	2.25	1.50	0.75	0.75	0.75	0.75	0.75	0.75
0.29	0.00	1.50	1.50	1.50	0.00	1.50	0.75	1.50	1.50
0.38	0.00	2.25	0.75	0.75	0.75	1.50	0.00	0.75	0.75
0.46	0.00	2.25	1.50	1.50	0.75	2.25	0.75	0.75	0.75
0.54	0.75	2.25	1.50	0.75	0.75	1.50	0.00	0.75	0.75
0.63	0.00	1.50	0.75	1.50	0.75	1.50	0.75	0.00	0.75
0.71	0.00	1.50	1.50	1.50	0.00	1.50	0.00	0.75	0.75
0.79	0.00	1.50	1.50	0.75	0.00	1.50	0.00	0.75	0.00
0.88	0.75	0.75	1.50	0.75	0.75	0.75	0.75	0.75	0.75
0.96	0.00	1.50	0.75	0.00	0.00	0.75	0.00	0.75	0.00
1.04	0.00	1.50	0.75	0.75	0.00	0.75	0.00	0.00	0.75
1.13	0.00	1.50	1.50	0.00	0.00	0.00	0.75	0.75	0.00
1.21	0.75	2.25	1.50	0.75	0.75	0.75	0.75	0.00	0.75
1.29	0.00	1.50	1.50	0.00	0.00	0.75	0.75	0.75	0.75
1.38	0.00	1.50	1.50	0.00	0.75	0.00	0.00	0.00	0.00
1.46	0.00	1.50	0.75	0.00	0.00	0.75	0.75	0.00	0.75
1.54	0.00	0.75	1.50	0.75	0.00	0.00	0.75	0.75	0.00
1.63	0.00	2.25	0.75	0.00	0.00	0.75	0.00	0.00	0.00
1.71	0.75	1.50	0.75	0.75	0.00	0.75	0.75	0.75	0.75
1.79	0.00	0.75	0.75	0.00	0.00	0.00	0.00	0.00	0.00
1.88	0.00	0.75	0.75	0.00	0.75	0.75	0.00	0.00	0.75
1.96	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.22	1.63	1.25	0.84	0.50	1.00	0.41	0.56	0.56
Median	0.00	1.50	1.50	0.75	0.00	0.75	0.75	0.75	0.75
Standard Deviation	0.35	0.69	0.61	1.04	0.82	0.79	0.38	0.51	0.46
COV	1.59	0.42	0.49	1.24	1.64	0.79	0.94	0.90	0.81
f_c	0.15	1.35	1.09	0.31	0.30	-0.19	0.36	0.07	0.25
f_o	1.11	3.22	3.71	4.28	6.24	2.43	1.01	1.54	1.37
k	5.40	3.11	7.22	3.54	12.63	0.90	4.17	1.33	1.55

Table B-8. Clay – Old Wet Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values (Continued)

Time Step (hr)	OCWN-7A	OCWN-7B	OCWN-7C
0.04	0.75	0.75	0.75
0.13	0.00	0.00	0.00
0.21	0.75	0.75	0.75
0.29	0.00	0.75	0.75
0.38	0.75	0.00	0.00
0.46	0.00	0.75	0.00
0.54	0.00	0.75	0.75
0.63	0.75	0.00	0.00
0.71	0.00	0.00	0.00
0.79	0.00	0.00	0.75
0.88	0.00	0.00	0.00
0.96	0.00	0.00	0.00
1.04	0.75	0.75	0.00
1.13	0.00	0.00	0.00
1.21	0.00	0.00	0.00
1.29	0.00	0.00	0.00
1.38	0.00	0.75	0.00
1.46	0.00	0.00	0.75
1.54	0.00	0.00	0.00
1.63	0.00	0.00	0.00
1.71	0.00	0.75	0.00
1.79	0.00	0.00	0.00
1.88	0.75	0.00	0.00
1.96	0.00	0.00	0.75
Mean	0.19	0.25	0.22
Median	0.00	0.00	0.00
Standard Deviation	0.33	0.36	0.35
COV	1.77	1.44	1.59
f_c	0.10	0.11	0.13
f_o	0.67	0.70	0.72
k	2.80	1.84	2.92

Table B-9. Sand – New Dry Compact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	NSDC-1A	NSDC-1B	NSDC-1C	NSDC-2A	NSDC-2B	NSDC-2C
0.04	3.00	5.25	4.50	17.25	10.50	18.00
0.13	6.00	6.75	1.50	6.75	3.00	6.75
0.21	2.25	0.75	2.25	5.25	2.25	5.25
0.29	2.25	0.75	0.00	4.50	2.25	3.75
0.38	0.75	0.75	0.00	5.25	1.50	4.50
0.46	1.50	1.50	0.00	3.75	1.50	3.00
0.54	1.50	0.00	0.00	3.75	1.50	3.75
0.63	0.75	0.75	0.75	3.75	1.50	3.00
0.71	0.75	1.50	0.00	5.25	3.00	3.00
0.79	0.75	1.50	0.75	5.25	2.25	3.75
0.88	0.75	1.50	0.00	3.00	1.50	3.00
0.96	0.75	0.75	0.00	2.25	2.25	2.25
1.04	0.00	0.75	0.00	6.00	0.75	5.25
1.13	0.75	1.50	0.75	5.25	1.50	3.00
1.21	1.50	0.75	0.00	4.50	2.25	3.75
1.29	0.75	1.50	0.75	1.50	1.50	3.00
1.38	1.50	0.75	0.00	3.00	0.75	3.00
1.46	0.75	0.00	0.00	2.25	1.50	2.25
1.54	0.75	1.50	0.00	6.75	3.75	2.25
1.63	0.00	0.75	0.00	3.75	2.25	3.00
1.71	0.75	0.00	0.00	3.75	1.50	3.75
1.79	1.50	0.75	0.00	4.50	1.50	4.50
1.88	1.50	1.50	0.75	4.50	1.50	3.00
1.96	0.75	0.75	0.00	4.50	2.25	6.00
Mean	1.31	1.34	0.50	4.84	2.25	4.28
Median	0.75	0.75	0.00	4.50	1.50	3.38
tandard Deviation	1.22	1.53	1.03	2.96	1.89	3.15
COV	0.93	1.14	2.06	0.61	0.84	0.74
f_c	0.80	0.88	0.19	4.17	1.85	3.49
f_o	5.03	8.16	6.48	31.95	24.58	31.62
k	3.90	7.32	9.54	18.06	23.22	16.02

Table B-10. Sand – New Dry Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	NSDN-1A	NSDN-1B	NSDN-1C	NSDN-2A	NSDN-2B	NSDN-2C	NSDN-3A	NSDN-3B	NSDN-3C
0.04	39.00	40.50	49.50	26.25	27.00	28.50	24.75	25.50	23.25
0.13	35.25	48.00	41.25	32.25	30.75	30.75	18.75	20.25	16.50
0.21	37.50	38.25	38.25	25.50	28.50	30.75	12.00	15.00	14.25
0.29	21.00	35.25	33.00	22.50	22.50	30.00	13.50	12.75	15.00
0.38	27.00	31.50	33.00	21.75	21.00	24.75	12.75	11.25	13.50
0.46	30.00	33.75	33.00	24.75	24.00	32.25	11.25	9.75	12.00
0.54	21.00	25.50	24.75	20.25	20.25	23.25	9.00	9.00	9.75
0.63	26.25	31.50	31.50	20.25	20.25	24.00	9.75	8.25	9.00
0.71	21.75	24.75	25.50	20.25	21.00	24.75	9.00	7.50	9.75
0.79	21.75	24.00	24.75	18.75	19.50	21.75	9.00	8.25	10.50
0.88	21.00	27.75	28.50	18.00	18.00	20.25	9.00	7.50	8.25
0.96	22.50	27.00	26.25	18.75	18.00	20.25	8.25	7.50	7.50
1.04	21.00	24.75	27.00	19.50	21.00	24.75	7.50	8.25	7.50
1.13	21.75	27.00	27.75	17.25	16.50	19.50	9.75	8.25	9.00
1.21	22.50	28.50	27.75	15.75	15.75	18.75	8.25	9.00	7.50
1.29	18.00	21.75	22.50	18.00	16.50	17.25	7.50	9.00	7.50
1.38	19.50	23.25	23.25	18.00	15.00	19.50	7.50	7.50	6.75
1.46	20.25	26.25	27.00	15.75	15.00	16.50	6.75	7.50	6.00
1.54	21.00	26.25	26.25	15.75	15.75	17.25	6.75	7.50	6.00
1.63	18.75	21.75	21.75	15.75	17.25	18.00	6.00	6.75	6.00
1.71	20.25	24.75	24.00	15.75	18.75	18.75	6.00	6.75	5.25
1.79	21.00	26.25	24.75	15.00	17.25	18.00	5.25	6.00	4.50
1.88	19.50	26.25	21.75	15.75	14.25	20.25	5.25	5.25	4.50
1.96	20.25	22.50	24.00	15.75	17.25	18.75	5.25	5.25	4.50
Mean	23.66	28.63	28.63	19.47	19.63	22.44	9.53	9.56	9.34
Median	21.00	26.25	26.63	18.38	18.38	20.25	8.63	8.25	7.88
Standard Deviation	5.90	6.47	6.69	4.27	4.35	4.89	4.49	4.71	4.52
COV	0.25	0.23	0.23	0.22	0.22	0.22	0.47	0.49	0.48
f_c	20.04	24.19	24.58	14.68	15.57	15.02	24.58	0.00	0.00
f_o	42.17	47.72	51.84	29.86	30.76	32.55	51.84	0.00	0.00
k	3.00	2.64	3.36	1.50	1.80	1.02	3.36	0.00	0.00

Table B-10. Sand – New Dry Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values (Continued)

Time Step (hr)	NSDN-4A	NSDN-4B	NSDN-4C
0.04	27.00	30.00	28.50
0.13	18.75	22.50	21.00
0.21	14.25	15.75	14.25
0.29	12.75	15.00	14.25
0.38	15.00	14.25	15.00
0.46	13.50	15.00	15.00
0.54	15.75	16.50	15.75
0.63	16.50	14.25	15.00
0.71	16.50	14.25	14.25
0.79	15.75	16.50	15.00
0.88	12.75	15.75	15.75
0.96	18.00	16.50	15.75
1.04	18.00	16.50	16.50
1.13	15.75	17.25	15.00
1.21	14.25	16.50	15.00
1.29	12.75	15.75	15.00
1.38	16.50	17.25	14.25
1.46	15.75	17.25	14.25
1.54	18.00	16.50	15.00
1.63	16.50	15.00	13.50
1.71	16.50	15.75	15.00
1.79	17.25	16.50	14.25
1.88	17.25	15.75	15.00
1.96	15.75	15.75	13.50
Mean	16.28	16.75	15.66
Median	16.13	16.13	15.00
Standard Deviation	2.86	3.26	3.09
COV	0.18	0.19	0.20
f_c	15.02	0.00	0.00
f_o	32.55	0.00	0.00
k	1.02	0.00	0.00

Table B-11. Sand – New Wet Compact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	NSWC-1A	NSWC-1B	NSWC-1C	NSWC-2A	NSWC-2B	NSWC-2C
0.04	2.25	2.25	0.38	8.25	1.50	1.88
0.13	1.50	1.13	0.00	6.00	1.50	1.50
0.21	0.75	0.00	0.00	4.50	0.00	1.50
0.29	0.75	0.00	0.00	3.00	0.75	0.75
0.38	0.75	0.00	0.75	3.75	0.00	1.50
0.46	0.75	0.38	0.00	3.75	0.00	0.75
0.54	0.75	0.75	0.38	3.00	0.75	1.50
0.63	2.25	0.75	0.38	3.00	0.75	0.75
0.71	0.00	0.75	0.00	3.00	0.75	1.50
0.79	0.00	0.00	0.75	2.25	0.00	1.50
0.88	0.75	0.75	0.00	1.50	0.75	1.50
0.96	0.75	0.75	0.00	1.50	0.75	0.75
1.04	0.75	0.38	0.75	0.75	0.00	1.50
1.13	0.75	0.38	0.75	0.75	0.75	0.75
1.21	0.75	0.75	0.00	0.75	0.75	0.75
1.29	1.13	0.75	0.00	0.75	0.75	1.50
1.38	0.75	0.00	0.00	0.75	0.00	0.75
1.46	0.38	0.75	0.38	0.75	0.75	1.50
1.54	1.13	0.75	0.38	0.00	0.00	0.75
1.63	0.38	0.75	1.50	0.75	0.75	1.50
1.71	0.75	3.00	0.00	0.75	0.75	0.00
1.79	1.50	0.38	0.00	0.75	0.75	0.75
1.88	0.75	0.00	0.00	0.75	0.75	2.25
1.96	0.75	0.00	0.00	0.75	0.75	0.75
Mean	0.88	0.64	0.27	2.16	0.59	1.17
Median	0.75	0.75	0.00	1.13	0.75	1.50
Standard Deviation	0.55	0.71	0.39	2.01	0.44	0.51
COV	0.63	1.11	1.47	0.93	0.74	0.44
f_c	0.81	0.58	0.30	0.53	0.56	1.13
f_o	3.38	4.98	0.15	8.09	2.31	2.26
k	12.60	22.26	3.12	2.28	12.24	8.94

Table B-12. Sand – New Wet Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	NSWN-1A	NSWN-1B	NSWN-1C	NSWN-2A	NSWN-2B	NSWN-2C
0.04	37.50	37.50	39.00	31.50	30.00	28.50
0.13	30.00	27.00	33.00	24.00	21.00	19.50
0.21	24.00	18.00	27.00	21.00	19.50	18.75
0.29	22.50	24.00	25.50	18.00	18.00	18.00
0.38	21.00	19.50	22.50	18.00	15.00	15.00
0.46	22.50	22.50	21.00	18.00	16.50	15.00
0.54	24.00	21.00	24.00	18.00	16.50	14.25
0.63	19.50	15.00	16.50	18.75	15.00	15.00
0.71	22.50	19.50	21.00	18.00	16.50	14.25
0.79	24.00	22.50	24.00	19.50	18.00	15.00
0.88	18.00	18.00	25.50	18.00	17.25	15.00
0.96	19.50	19.50	21.00	18.00	16.50	14.25
1.04	18.00	17.25	17.25	18.75	15.00	14.25
1.13	21.00	21.00	19.50	18.00	16.50	15.00
1.21	18.00	18.00	18.00	18.75	15.75	14.25
1.29	19.50	19.50	18.75	18.00	15.00	13.50
1.38	18.00	18.00	18.75	18.00	16.50	15.00
1.46	19.50	19.50	19.50	18.00	15.75	15.00
1.54	19.50	18.00	18.00	17.25	16.50	14.25
1.63	20.25	19.50	18.75	18.00	15.00	14.25
1.71	18.00	18.00	17.25	18.00	15.00	15.00
1.79	18.75	18.00	18.75	17.25	15.75	14.25
1.88	18.00	17.25	18.00	18.00	16.50	15.00
1.96	18.00	17.25	17.25	17.25	15.00	13.50
Mean	21.31	20.22	21.66	19.00	17.00	15.66
Median	19.50	19.50	19.50	18.00	16.50	15.00
Standard Deviation	4.49	4.48	5.39	3.01	3.15	3.12
COV	0.21	0.22	0.25	0.16	0.19	0.20
f_c	19.49	18.95	19.02	18.03	16.00	14.54
f_o	42.00	48.61	42.52	38.92	37.06	33.36
k	6.12	11.21	4.41	10.38	10.14	8.10

Table B-13. Sand – Old Dry Compact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	OSDC-1A	OSDC-1B	OSDC-1C	OSDC-2A	OSDC-2B	OSDC-2C	OSDC-3A	OSDC-3B	OSDC-3C
0.04	4.50	5.25	18.75	2.25	1.50	2.25	3.00	5.25	3.75
0.13	0.75	1.50	6.75	7.50	5.25	3.75	6.75	8.25	8.25
0.21	1.50	2.25	5.25	2.25	6.75	8.25	3.00	1.50	3.00
0.29	0.75	1.50	5.25	0.00	4.50	1.50	1.50	2.25	1.50
0.38	0.75	1.50	3.75	3.00	3.75	1.50	1.50	1.50	1.50
0.46	0.75	1.50	2.25	3.75	1.50	1.50	1.50	2.25	1.50
0.54	0.75	0.75	9.75	1.50	3.00	0.75	1.50	1.50	1.50
0.63	0.00	1.50	5.25	1.50	3.00	1.50	0.75	1.50	1.50
0.71	0.75	0.75	4.50	1.50	1.50	0.75	1.50	1.50	0.75
0.79	0.75	1.50	3.75	1.50	1.50	0.75	0.75	0.75	1.50
0.88	0.75	0.75	3.00	0.75	2.25	0.75	1.50	0.75	1.50
0.96	0.75	1.50	3.75	0.75	1.50	0.75	0.75	0.75	1.50
1.04	0.75	0.75	3.00	0.75	1.50	0.75	0.75	1.50	1.50
1.13	0.00	0.75	3.00	0.75	1.50	0.75	0.75	1.50	0.75
1.21	0.75	0.75	3.00	0.75	1.50	0.75	1.50	0.75	0.75
1.29	0.00	0.75	2.25	0.75	0.75	0.75	0.75	1.50	0.75
1.38	0.00	0.75	2.25	0.75	0.75	0.75	1.50	0.75	0.75
1.46	0.75	0.75	1.50	0.75	1.50	0.00	0.75	0.00	0.75
1.54	0.00	0.75	3.00	0.75	0.75	0.00	0.00	0.75	0.75
1.63	0.75	0.75	1.50	0.75	2.25	0.75	1.50	0.75	1.50
1.71	0.00	0.00	1.50	0.00	0.75	0.00	0.75	1.50	0.75
1.79	0.75	0.75	1.50	0.75	1.50	0.75	0.75	0.75	0.75
1.88	0.75	0.75	0.75	0.00	2.25	0.75	0.75	0.75	0.75
1.96	0.75	0.75	0.75	0.75	0.75	0.00	0.75	0.75	0.75
Mean	0.75	1.19	4.00	1.41	2.16	1.25	1.44	1.63	1.59
Median	0.75	0.75	3.00	0.75	1.50	0.75	1.13	1.50	1.50
Standard Deviation	0.88	0.99	3.75	1.58	1.54	1.69	1.33	1.72	1.60
COV	1.18	0.83	0.94	1.13	0.71	1.36	0.92	1.06	1.00
f_c	0.61	0.97	3.09	0.33	1.33	0.42	0.82	0.90	0.89
f_o	13.36	8.45	30.88	4.40	7.09	6.44	5.27	7.71	6.50
k	28.50	13.86	14.04	1.80	3.24	3.90	3.48	4.50	3.78

Table B-13. Sand – Old Dry Compact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values (Continued)

Time Step (hr)	OSDC-4A	OSDC-4B	OSDC-4C	OSDC-5A	OSDC-5B	OSDC-5C
0.04	5.00	8.00	12.00	7.50	16.50	45.75
0.13	2.00	1.00	9.00	1.50	8.25	32.25
0.21	9.00	8.00	2.00	2.25	3.00	33.75
0.29	14.00	14.00	11.00	0.00	3.00	37.50
0.38	4.00	3.00	0.00	0.75	3.75	18.75
0.46	7.00	8.00	10.00	0.00	3.00	9.75
0.54	13.00	14.00	5.00	0.75	2.25	10.50
0.63	9.00	11.00	15.00	0.75	2.25	15.75
0.71	2.00	2.00	6.00	0.75	2.25	14.25
0.79	8.00	8.00	13.00	0.75	1.50	9.75
0.88	13.00	14.00	5.00	0.75	8.25	6.75
0.96	2.00	3.00	10.00	0.75	5.25	3.00
1.04	7.00	9.00	6.00	0.75	3.00	19.50
1.13	10.00	12.00	13.00	0.00	3.75	11.25
1.21	14.00	0.00	5.00	0.75	3.00	10.50
1.29	2.00	4.00	12.00	0.75	3.75	16.50
1.38	5.00	7.00	2.00	0.75	3.00	10.50
1.46	8.00	8.00	9.00	0.75	2.25	10.50
1.54	12.00	14.00	15.00	0.00	3.00	7.50
1.63	6.00	8.00	5.00	0.75	2.25	9.00
1.71	11.00	13.00	9.00	0.75	2.25	0.75
1.79	0.00	1.00	0.00	0.00	1.50	18.00
1.88	4.00	6.00	5.00	0.75	1.50	9.75
1.96	8.00	10.00	12.00	0.75	2.25	6.75
Mean	7.29	7.75	7.96	0.97	3.78	15.34
Median	7.50	8.00	9.00	0.75	3.00	10.50
Standard Deviation	4.20	4.50	4.52	1.47	3.23	11.22
COV	0.58	0.58	0.57	1.52	0.85	0.73
f_c	3.93	4.10	0.00	0.00	0.00	9.29
f_o	22.84	34.10	0.00	0.00	0.00	52.34
k	10.74	18.54	0.00	0.00	0.00	3.52

Table B-14. Sand – Old Dry Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	OSDN-1A	OSDN-1B	OSDN-1C	OSDN-2A	OSDN-2B	OSDN-2C	OSDN-3A	OSDN-3B	OSDN-3C
0.04	24.75	25.50	23.25	59.25	1.50	2.25	22.50	30.00	30.75
0.13	18.75	20.25	16.50	17.25	39.00	3.00	12.00	19.50	23.25
0.21	12.00	15.00	14.25	14.25	23.25	2.25	11.25	21.00	24.00
0.29	13.50	12.75	15.00	17.25	15.75	1.50	11.25	15.00	15.00
0.38	12.75	11.25	13.50	17.25	11.25	0.00	12.75	24.00	27.00
0.46	11.25	9.75	12.00	15.00	16.50	0.75	9.00	16.50	22.50
0.54	9.00	9.00	9.75	12.75	13.50	0.00	1.50	21.00	27.00
0.63	9.75	8.25	9.00	17.25	11.25	0.75	9.75	15.00	21.75
0.71	9.00	7.50	9.75	11.25	9.75	0.00	11.25	15.00	19.50
0.79	9.00	8.25	10.50	8.25	11.25	0.75	11.25	13.50	20.25
0.88	9.00	7.50	8.25	7.50	9.75	0.00	13.50	21.00	18.00
0.96	8.25	7.50	7.50	17.25	9.75	0.75	7.50	15.00	16.50
1.04	7.50	8.25	7.50	12.75	8.25	0.00	12.75	9.75	24.75
1.13	9.75	8.25	9.00	10.50	6.75	0.75	9.00	9.75	18.00
1.21	8.25	9.00	7.50	17.25	5.25	0.00	3.00	15.00	21.00
1.29	7.50	9.00	7.50	9.75	11.25	0.75	11.25	12.75	21.00
1.38	7.50	7.50	6.75	10.50	7.50	0.00	9.75	14.25	21.75
1.46	6.75	7.50	6.00	8.25	8.25	0.75	9.75	18.00	24.00
1.54	6.75	7.50	6.00	10.50	8.25	0.00	9.00	15.00	23.25
1.63	6.00	6.75	6.00	7.50	5.25	0.75	9.75	12.00	18.75
1.71	6.00	6.75	5.25	11.25	7.50	0.75	9.00	13.50	23.25
1.79	5.25	6.00	4.50	10.50	11.25	0.00	13.50	18.75	21.00
1.88	5.25	5.25	4.50	9.75	7.50	0.75	9.75	12.75	21.00
1.96	5.25	5.25	4.50	10.50	7.50	0.00	9.75	12.00	18.75
Mean	9.53	9.56	9.34	14.31	11.13	0.69	10.41	16.25	21.75
Median	8.63	8.25	7.88	11.25	9.75	0.75	9.75	15.00	21.38
Standard Deviation	4.49	4.71	4.52	10.16	7.35	0.83	3.82	4.71	3.56
COV	0.47	0.49	0.48	0.71	0.66	1.20	0.37	0.29	0.16
f_c	6.90	7.20	5.13	12.10	8.85	0.36	9.74	14.03	24.24
f_o	25.65	25.52	21.97	146.09	48.06	4.19	35.70	27.66	40.42
k	3.48	4.62	1.92	25.08	7.20	7.32	17.22	3.24	16.74

Table B-14. Sand – Old Dry Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values (Continued)

Time Step (hr)	OSDN-4A	OSDN-4B	OSDN-4C
0.04	15.75	36.00	36.75
0.13	11.25	27.00	20.25
0.21	9.75	30.00	25.50
0.29	9.00	25.50	19.50
0.38	9.75	24.00	18.00
0.46	8.25	24.75	24.00
0.54	6.75	22.50	21.75
0.63	7.50	25.50	23.25
0.71	12.00	24.00	21.00
0.79	11.25	24.00	19.50
0.88	10.50	22.50	18.00
0.96	12.00	27.00	21.00
1.04	9.75	21.00	17.25
1.13	9.75	21.75	18.75
1.21	12.00	24.00	21.75
1.29	11.25	25.50	21.00
1.38	11.25	22.50	20.25
1.46	9.00	18.00	15.00
1.54	11.25	24.00	21.00
1.63	10.50	21.00	18.00
1.71	11.25	21.75	18.00
1.79	9.00	24.00	21.00
1.88	9.75	15.75	17.25
1.96	9.75	21.00	18.00
Mean	10.34	23.88	20.66
Median	10.13	24.00	20.25
Standard Deviation	1.81	3.92	4.17
COV	0.17	0.16	0.20
f_c	10.09	22.15	19.93
f_o	24.15	36.14	87.08
k	21.54	4.02	33.18

Table B-15. Sand – Old Wet Compact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	OSWC-1A	OSWC-1B	OSWC-1C	OSWC-2A	OSWC-2B	OSWC-2C	OSWC-3A	OSWC-3B	OSWC-3C
0.04	2.25	4.50	3.00	1.50	0.75	0.75	0.75	0.75	0.75
0.13	3.75	3.75	3.75	0.75	0.75	1.50	0.75	0.75	0.75
0.21	1.50	1.50	0.75	0.00	0.00	0.75	0.00	0.00	0.00
0.29	1.50	1.50	0.75	0.75	0.00	0.00	0.00	0.00	0.00
0.38	0.75	0.00	0.00	0.00	0.00	0.75	0.00	0.75	0.75
0.46	1.50	0.75	0.00	0.00	0.00	0.00	0.75	0.00	0.00
0.54	0.75	0.75	0.00	0.00	0.75	0.00	0.00	0.00	0.75
0.63	0.75	0.00	0.00	0.75	0.00	0.75	0.00	0.00	0.00
0.71	0.75	1.50	0.00	0.00	0.00	0.00	0.75	0.00	0.00
0.79	0.75	0.75	0.75	0.00	0.00	0.75	0.00	0.75	0.75
0.88	0.75	0.75	0.00	0.75	0.75	0.00	0.75	0.00	0.00
0.96	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00
1.04	1.50	0.75	0.00	0.75	0.00	0.00	0.00	0.75	0.00
1.13	0.75	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00
1.21	0.75	1.50	0.75	0.00	0.00	0.00	0.00	0.00	0.00
1.29	0.00	0.75	0.00	0.75	0.00	0.75	0.75	0.00	0.00
1.38	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.46	0.75	1.50	0.00	0.75	0.00	0.75	0.00	0.00	0.00
1.54	0.75	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00
1.63	0.75	1.50	0.75	0.75	0.00	0.75	0.00	0.00	0.00
1.71	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00
1.79	0.75	0.00	0.00	0.75	0.00	0.75	0.00	0.00	0.00
1.88	0.75	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.75
1.96	0.75	0.00	0.75	0.75	0.00	0.00	0.00	0.00	0.00
Mean	0.97	0.91	0.47	0.38	0.16	0.41	0.25	0.16	0.19
Median	0.75	0.75	0.00	0.00	0.00	0.38	0.00	0.00	0.00
Standard Deviation	0.78	1.17	0.96	0.44	0.31	0.44	0.36	0.31	0.33
COV	0.81	1.29	2.05	1.18	1.99	1.09	1.44	1.99	1.77
f_c	0.63	0.51	0.12	0.33	0.11	0.33	0.22	0.09	0.09
f_o	3.37	6.20	4.66	2.65	1.27	1.31	1.29	1.06	0.83
k	3.60	6.78	6.24	15.96	9.72	5.10	11.94	6.18	3.24

Table B-15. Sand – Old Wet Compact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values (Continued)

Time Step (hr)	OSWC-4A	OSWC-4B	OSWC-4C
0.04	62.40	13.20	6.00
0.13	33.60	4.80	14.40
0.21	19.20	3.60	8.40
0.29	15.60	3.60	4.80
0.38	9.60	4.80	7.20
0.46	20.40	0.00	2.40
0.54	15.60	2.40	10.80
0.63	8.40	1.20	10.80
0.71	3.60	2.40	9.60
0.79	6.00	2.40	2.40
0.88	21.60	3.60	2.40
0.96	9.00	0.00	7.05
1.04	9.00	0.00	5.25
1.13	5.25	0.75	2.25
1.21	12.00	3.00	9.00
1.29	11.25	0.75	5.25
1.38	9.00	7.50	7.50
1.46	6.75	3.00	2.25
1.54	6.00	3.00	6.00
1.63	2.25	3.00	5.25
1.71	15.75	2.25	3.00
1.79	8.25	1.50	6.00
1.88	9.00	3.00	1.50
1.96	6.75	0.75	2.25
Mean	13.59	2.94	5.91
Median	9.00	2.70	5.63
Standard Deviation	12.52	2.81	3.38
COV	0.92	0.96	0.57
f_c	9.49	2.32	5.37
f_o	86.09	22.36	64.65
k	9.06	14.88	37.08

Table B-16. Sand – Old Wet Noncompact
Raw Infiltration Data (in/hr), Statistics and Horton Equation Values

Time Step (hr)	OSWN-1A	OSWN-1B	OSWN-1C	OSWN-2A	OSWN-2B	OSWN-2C
0.04	37.50	36.00	38.25	15.00	1.50	2.25
0.13	24.75	25.50	25.50	14.25	19.50	13.50
0.21	21.75	20.25	21.00	14.25	16.50	12.00
0.29	17.25	18.75	19.50	12.00	15.00	12.00
0.38	18.00	18.75	21.00	13.50	14.25	10.50
0.46	15.00	16.50	18.00	15.00	15.00	10.50
0.54	15.00	17.25	16.50	14.25	18.00	12.75
0.63	21.00	18.75	15.75	12.00	15.75	12.00
0.71	18.75	18.00	16.50	13.50	14.25	11.25
0.79	20.25	18.00	17.25	12.00	15.75	12.00
0.88	15.75	17.25	18.00	12.00	13.50	11.25
0.96	20.25	18.75	15.00	12.00	15.00	11.25
1.04	21.00	18.00	18.00	14.25	15.00	11.25
1.13	18.75	17.25	18.00	12.00	15.75	12.00
1.21	16.50	16.50	17.25	15.75	13.50	10.50
1.29	15.75	16.50	15.75	15.00	16.50	12.75
1.38	18.75	15.75	16.50	14.25	17.25	12.75
1.46	18.00	15.00	15.75	14.25	16.50	12.00
1.54	20.25	15.75	15.00	15.00	15.75	11.25
1.63	17.25	18.00	14.25	13.50	15.75	11.25
1.71	17.25	16.50	15.00	14.25	16.50	12.00
1.79	18.75	17.25	15.00	12.00	16.50	12.00
1.88	18.00	17.25	14.25	15.00	13.50	9.75
1.96	16.50	15.75	14.25	15.00	12.75	10.50
Mean	19.25	18.47	17.97	13.75	14.97	11.22
Median	18.38	17.25	16.50	14.25	15.75	11.63
tandard Deviation	4.53	4.26	5.06	1.26	3.25	2.10
COV	0.24	0.23	0.28	0.09	0.22	0.19
f_c	18.03	17.09	16.14	13.68	15.37	11.51
f_o	51.06	45.49	45.88	16.11	24.81	15.64
k	12.60	9.78	7.92	13.74	19.62	17.40

Appendix C
Summaries of Site Conditions and Infiltration Results

List of Tables in Appendix C:

Table C-1. Summary of Observed Data and Calculated Results by Location

Test #	Location	Compaction (psi)	%Moist	% Clay & Silts	%Sand	Soil Group	Factorial Group	age	land use	15 min (in/hr)	30 min (in/hr)	60 min (in/hr)	120 min (in/hr)	Mean (f in/hr)	Median (f in/hr)	Standard Deviation (f)	COV (f)	fc (in/hr)	fo (in/hr)	k
NCDC-1A	Chadwick, Helena	>300	18.6	96.2	3.7	CO	5	1	res	2.0	1.6	1.3	0.8	0.8	0.8	0.8	0.9	0.4	2.8	2.6
NCDC-1B	Chadwick, Helena	>300	18.6	96.2	3.7	CO	5	1	res	6.0	3.5	2.3	1.4	0.9	0.8	0.8	0.8	0.7	2.9	4.1
NCDC-1C	Chadwick, Helena	>300	18.6	96.2	3.7	CO	5	1	res	4.5	3.4	2.5	1.7	1.7	1.5	1.7	1.0	1.3	9.9	9.5
NCDC-2A	Chadwick, Helena	>300	13.7	96.2	3.7	CO	5	1	res	2.3	1.3	0.9	0.6	0.6	0.0	1.0	1.7	0.3	3.1	4.8
NCDC-2B	Chadwick, Helena	>300	13.7	96.2	3.7	CO	5	1	res	4.8	2.6	1.8	1.1	1.1	0.8	1.6	1.4	0.5	7.8	5.7
NCDC-2C	Chadwick, Helena	>300	13.7	96.2	3.7	CO	5	1	res	10.0	5.6	2.8	1.5	1.5	0.0	3.6	2.4	0.0	19.0	6.4
NCDN-1A	Chadwick, Helena	100	17.0	96.2	3.7	CDN	6	1	res	24.0	18.9	13.7	9.5	9.5	6.8	8.4	0.9	6.2	37.3	4.6
NCDN-1B	Chadwick, Helena	100	17.0	96.2	3.7	CDN	6	1	res	4.0	2.0	1.1	0.6	0.6	0.0	1.9	3.0	0.1	17.6	15.9
NCDN-1C	Chadwick, Helena	100	17.0	96.2	3.7	CDN	6	1	res	1.0	0.5	0.5	0.3	0.3	0.0	0.6	2.0	0.2	4.9	19.1
NCDN-2A	Chadwick, Helena	100	17.0	96.2	3.7	CDN	6	1	res	11.5	13.1	12.6	10.5	10.5	11.6	6.9	0.7	NA	NA	NA
NCDN-2B	Chadwick, Helena	100	17.0	96.2	3.7	CDN	6	1	res	3.0	2.0	1.4	0.9	0.9	0.4	1.4	1.6	0.6	9.7	12.2
NCDN-2C	Chadwick, Helena	100	17.0	96.2	3.7	CDN	6	1	res	3.0	2.0	1.3	0.9	0.9	0.8	1.1	1.3	0.6	7.9	10.7
NCWC-1A	Chadwick, Helena	>300	40.7	96.2	3.7	CO	1	1	res	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0
NCWC-1B	Chadwick, Helena	>300	40.7	96.2	3.7	CO	1	1	res	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0
NCWC-1C	Chadwick, Helena	>300	40.7	96.2	3.7	CO	1	1	res	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0
NCWN-1A	Chadwick, Helena	150	35.8	96.2	3.7	CO	2	1	res	0.0	0.0	0.3	0.2	0.0	0.0	0.2	4.9	0.0	0.0	7.7
NCWN-1B	Chadwick, Helena	150	35.8	96.2	3.7	CO	2	1	res	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0
NCWN-1C	Chadwick, Helena	150	35.8	96.2	3.7	CO	2	1	res	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0
OCDC-2A	Homewood Park	>300	5.0	67.1	31.5	CO	5	20	rec	1.8	1.1	0.9	0.7	0.7	0.8	0.6	1.0	0.5	2.9	5.1
OCDC-2B	Homewood Park	>300	5.0	67.1	31.5	CO	5	20	rec	1.3	1.0	0.8	0.6	0.6	0.8	0.5	0.8	0.4	1.7	3.0
OCDC-2C	Homewood Park	>300	5.0	67.1	31.5	CO	5	20	rec	1.5	1.1	1.0	0.8	0.8	0.8	0.5	0.7	0.3	1.6	1.2
OCDC-3A	Homewood Park	>300	5.0	67.1	31.5	CO	5	20	rec	0.8	0.4	0.3	0.2	0.2	0.0	0.3	1.6	0.1	1.1	5.2
OCDC-3B	Homewood Park	>300	5.0	67.1	31.5	CO	5	20	rec	1.0	0.8	0.6	0.4	0.4	0.0	0.4	1.2	0.1	1.4	2.3
OCDC-3C	Homewood Park	>300	5.0	67.1	31.5	CO	5	20	rec	0.5	0.5	0.4	0.3	0.3	0.0	0.4	1.3	0.2	0.7	2.1

Table C-1. Summary of Observed Data and Calculated Results by Location (Continued)

Test #	Location	Compaction (psi)	%Moist	% Clay & Silts	%Sand	Soil Group	Factorial Group	age	land use	15 min (in/hr)	30 min (in/hr)	60 min (in/hr)	120 min (in/hr)	Mean (f in/hr)	Median (f in/hr)	Standard Deviation (f)	COV (f)	fc (in/hr)	fo (in/hr)	k
OCWC-2A	Homewood Park	>300	21.0	67.1	31.5	CO	1	20	rec	1.3	1.0	0.8	0.6	0.6	0.8	0.5	0.8	0.5	4.2	17.9
OCWC-2B	Homewood Park	>300	21.0	67.1	31.5	CO	1	20	rec	0.8	0.6	0.6	0.4	0.4	0.4	0.4	1.1	-0.2	0.8	0.5
OCWC-2C	Homewood Park	>300	21.0	67.1	31.5	CO	1	20	rec	1.5	1.3	0.9	0.7	0.7	0.8	0.6	0.8	0.3	1.8	1.9
OCWC-3A	Homewood Park	>300	21.0	67.1	31.5	CO	1	20	rec	1.3	1.1	0.9	0.7	0.7	0.8	0.6	0.8	0.7	5.6	26.5
OCWC-3B	Homewood Park	>300	21.0	67.1	31.5	CO	1	20	rec	1.3	0.9	0.7	0.6	0.6	0.8	0.4	0.7	0.6	1.8	7.1
OCWC-3C	Homewood Park	>300	21.0	67.1	31.5	CO	1	20	rec	1.8	1.3	1.1	0.8	0.8	0.8	0.5	0.7	0.4	1.9	1.9
OCWC-4A	Homewood Park	>300	21.0	67.1	31.5	CO	1	20	rec	1.5	1.1	0.9	0.8	0.8	0.8	0.4	0.5	0.7	1.8	3.8
OCWC-4B	Homewood Park	>300	21.0	67.1	31.5	CO	1	20	rec	1.0	0.9	0.8	0.6	0.6	0.8	0.4	0.6	0.2	1.0	0.6
OCWC-4C	Homewood Park	>300	21.0	67.1	31.5	CO	1	20	rec	2.0	1.4	0.9	0.6	0.6	0.8	0.7	1.1	0.3	2.5	3.1
OCWN-4A	Homewood Park	240	21.0	67.1	31.5	CO	2	20	rec	0.8	0.4	0.3	0.2	0.2	0.0	0.3	1.6	0.1	1.1	5.4
OCWN-4B	Homewood Park	240	21.0	67.1	31.5	CO	2	20	rec	2.5	2.3	1.9	1.6	1.6	1.5	0.7	0.4	1.4	3.2	3.1
OCWN-4C	Homewood Park	240	21.0	67.1	31.5	CO	2	20	rec	2.3	1.8	1.5	1.3	1.3	1.5	0.6	0.5	1.1	3.7	7.2
OCWN-5A	Homewood Park	150	23.0	67.1	31.5	CO	2	20	rec	2.8	2.0	1.4	0.8	0.8	0.8	1.0	1.2	0.3	4.3	3.5
OCWN-5B	Homewood Park	150	23.0	67.1	31.5	CO	2	20	rec	2.0	1.3	0.8	0.5	0.5	0.0	0.8	1.6	0.3	6.2	12.6
OCWN-5C	Homewood Park	150	23.0	67.1	31.5	CO	2	20	rec	2.0	1.9	1.6	1.0	1.0	0.8	0.8	0.8	-0.2	2.4	0.9
OCWN-6A	Homewood Park	110	23.0	67.1	31.5	CO	2	20	rec	1.3	1.1	0.9	0.6	0.4	0.8	0.4	0.9	0.4	1.0	4.2
OCWN-6B	Homewood Park	110	23.0	67.1	31.5	CO	2	20	rec	0.8	0.6	0.4	0.4	0.6	0.8	0.5	0.9	0.1	1.5	1.3
OCWN-6C	Homewood Park	110	23.0	67.1	31.5	CO	2	20	rec	1.0	1.0	0.8	0.6	0.6	0.8	0.5	0.8	0.2	1.4	1.5
NSDC-1A	Jasper Golf Course(Walker County	>300	5.7	2.0	98.0	SC	7	5	rec	3.8	2.6	1.8	1.3	1.3	0.8	1.2	0.9	0.8	5.0	3.9
NSDC-1B	Jasper Golf Course(Walker County	>300	5.7	2.0	98.0	SC	7	5	rec	4.3	2.6	1.8	1.3	1.3	0.8	1.5	1.1	0.9	8.2	7.3
NSDC-1C	Jasper Golf Course(Walker County	>300	5.7	2.0	98.0	SC	7	5	rec	2.8	1.4	0.8	0.5	0.5	0.0	1.0	2.1	0.2	6.5	9.5
NSDC-2A	Jasper Golf Course(Walker County	>300	5.7	2.0	98.0	SC	7	5	rec	9.8	7.1	5.5	4.8	4.8	4.5	3.0	0.6	4.2	31.9	18.1
NSDC-2B	Jasper Golf Course(Walker County	>300	5.7	2.0	98.0	SC	7	5	rec	5.3	3.5	2.8	2.3	2.3	1.5	1.9	0.8	1.9	24.6	23.2
NSDC-2C	Jasper Golf Course(Walker County	>300	5.7	2.0	98.0	SC	7	5	rec	10.0	6.9	5.0	4.3	4.3	3.4	3.1	0.7	3.5	31.6	16.0

Table C-1. Summary of Observed Data and Calculated Results by Location (Continued)

Test #	Location	Compaction (psi)	%Moist	% Clay & Silts	%Sand	Soil Group	Factorial Group	age	land use	15 min (in/hr)	30 min (in/hr)	60 min (in/hr)	120 min (in/hr)	Mean (f in/hr)	Median (f in/hr)	Standard Deviation (f)	COV (f)	fc (in/hr)	fo (in/hr)	k
NSDN-1A	Jasper Golf Course(Walker County)	100	2.6	4.0	96.0	SN	8	5	rec	42.3	37.9	32.3	28.6	23.7	21.0	5.9	0.2	20.0	42.2	3.0
NSDN-1B	Jasper Golf Course(Walker County)	100	2.6	4.0	96.0	SN	8	5	rec	43.0	38.0	32.4	28.6	28.6	26.3	6.5	0.2	24.2	47.7	2.6
NSDN-1C	Jasper Golf Course(Walker County)	100	2.6	4.0	96.0	SN	8	5	rec	28.0	25.5	22.4	19.5	28.6	26.6	6.7	0.2	24.6	51.8	3.4
NSDN-2A	Jasper Golf Course(Walker County)	100	2.6	27.0	73.0	SN	8	5	rec	28.8	25.6	22.6	19.6	19.5	18.4	4.3	0.2	14.7	29.9	1.5
NSDN-2B	Jasper Golf Course(Walker County)	100	2.6	27.0	73.0	SN	8	5	rec	30.0	29.5	25.9	22.4	19.6	18.4	4.3	0.2	15.6	30.8	1.8
NSDN-2C	Jasper Golf Course(Walker County)	100	2.6	27.0	73.0	SN	8	5	rec	18.5	15.5	12.3	9.5	22.4	20.3	4.9	0.2	15.0	32.6	1.0
NSDN-3A	Jasper Golf Course(Walker County)	150	5.3	4.0	98.0	SN	8	5	rec	20.3	15.8	11.9	9.6	9.5	8.6	4.5	0.5	24.6	51.8	3.4
NSDN-3B	Jasper Golf Course(Walker County)	150	5.3	4.0	98.0	SN	8	5	rec	18.0	15.8	12.4	9.3	9.6	8.3	4.7	0.5	0.0	0.0	0.0
NSDN-3C	Jasper Golf Course(Walker County)	150	5.3	4.0	98.0	SN	8	5	rec	20.0	16.9	16.4	16.3	9.3	7.9	4.5	0.5	0.0	0.0	0.0
NSDN-4A	Jasper Golf Course(Walker County)	150	5.3	4.0	98.0	SN	8	5	rec	22.8	18.8	17.2	16.8	16.3	16.1	2.9	0.2	15.0	32.6	1.0
NSDN-4B	Jasper Golf Course(Walker County)	150	5.3	4.0	98.0	SN	8	5	rec	21.3	18.0	16.6	15.7	16.8	16.1	3.3	0.2	0.0	0.0	0.0
NSDN-4C	Jasper Golf Course(Walker County)	150	5.3	4.0	98.0	SN	8	5	rec	1.5	1.1	0.9	0.9	15.7	15.0	3.1	0.2	0.0	0.0	0.0
NSWN-1A	Jasper Golf Course(Walker County)	200	20.9	27.0	73.0	SN	4	5	rec	37.3	31.6	27.0	23.7	21.3	19.5	4.5	0.2	19.5	42.0	6.1
NSWN-1B	Jasper Golf Course(Walker County)	200	20.9	27.0	73.0	SN	4	5	rec	27.5	24.8	22.0	20.2	20.2	19.5	4.5	0.2	19.0	48.6	11.2
NSWN-1C	Jasper Golf Course(Walker County)	200	20.9	27.0	73.0	SN	4	5	rec	33.0	28.0	25.0	21.7	21.7	19.5	5.4	0.2	19.0	42.5	4.4
NSWN-2A	Jasper Golf Course(Walker County)	200	20.9	19.0	73.0	SN	4	5	rec	25.5	21.8	20.1	19.0	19.0	18.0	3.0	0.2	18.0	38.9	10.4
NSWN-2B	Jasper Golf Course(Walker County)	200	20.9	19.0	73.0	SN	4	5	rec	23.5	20.0	18.3	17.0	17.0	16.5	3.1	0.2	16.0	37.1	10.1
NSWN-2C	Jasper Golf Course(Walker County)	200	20.9	19.0	73.0	SN	4	5	rec	22.3	19.1	16.9	15.7	15.7	15.0	3.1	0.2	14.5	33.4	8.1
OSWN-1A	Jasper Golf Course(Walker County)	175	23.2	5.0	95.0	SN	4	15	rec	28.0	22.4	20.4	19.3	19.3	18.4	4.5	0.2	18.0	51.1	12.6
OSWN-1B	Jasper Golf Course(Walker County)	175	23.2	5.0	95.0	SN	4	15	rec	27.3	22.6	20.3	18.5	18.5	17.3	4.3	0.2	17.1	45.5	9.8
OSWN-1C	Jasper Golf Course(Walker County)	175	23.2	5.0	95.0	SN	4	15	rec	28.3	23.9	20.2	18.0	18.0	16.5	5.1	0.3	16.1	45.9	7.9
NSWC-1A	Littlefield Farms	>300	28.1	32.5	64.0	SC	3	15	ag	6.3	4.9	3.6	2.2	0.9	0.8	0.5	0.6	0.8	3.4	12.6
NSWC-1B	Littlefield Farms	>300	28.1	32.5	64.0	SC	3	15	ag	1.1	0.6	0.6	0.6	0.6	0.8	0.7	1.1	0.6	5.0	22.3
NSWC-1C	Littlefield Farms	>300	28.1	32.5	64.0	SC	3	15	ag	0.1	0.2	0.2	0.3	0.3	0.0	0.4	1.5	0.3	0.1	3.1

Table C-1. Summary of Observed Data and Calculated Results by Location (Continued)

Test #	Location	Compaction (psi)	%Moist	% Clay & Silts	%Sand	Soil Group	Factorial Group	age	land use	15 min (in/hr)	30 min (in/hr)	60 min (in/hr)	120 min (in/hr)	Mean (f in/hr)	Median (f in/hr)	Standard Deviation (f)	COV (f)	fc (in/hr)	fo (in/hr)	k
NSWC-2A	Littlefield Farms	>300	28.1	32.5	64.0	SC	3	15	ag	1.0	0.6	0.6	0.6	2.2	1.1	2.0	0.9	0.5	8.1	2.3
NSWC-2B	Littlefield Farms	>300	28.1	32.5	64.0	SC	3	15	ag	1.6	1.3	1.3	1.2	0.6	0.8	0.4	0.7	0.6	2.3	12.2
NSWC-2C	Littlefield Farms	>300	28.1	32.5	64.0	SC	3	15	ag	30.5	26.3	23.8	21.3	1.2	1.5	0.5	0.4	1.1	2.3	8.9
OSDC-2A	Littlefield Farms	>300	11.2	32.5	64.0	SC	7	15	ag	4.0	3.1	2.2	1.4	1.4	0.8	1.6	1.1	0.3	4.4	1.8
OSDC-2B	Littlefield Farms	>300	11.2	32.5	64.0	SC	7	15	ag	5.5	4.1	3.0	2.2	2.2	1.5	1.5	0.7	1.3	7.1	3.2
OSDC-2C	Littlefield Farms	>300	11.2	32.5	64.0	SC	7	15	ag	4.5	2.9	1.9	1.2	1.3	0.8	1.7	1.4	0.4	6.4	3.9
OSDC-3A	Littlefield Farms	>300	7.0	32.5	64.0	SC	7	15	ag	4.3	2.9	2.0	1.4	1.4	1.1	1.3	0.9	0.8	5.3	3.5
OSDC-3B	Littlefield Farms	>300	7.0	32.5	64.0	SC	7	15	ag	5.0	3.5	2.3	1.6	1.6	1.5	1.7	1.1	0.9	7.7	4.5
OSDC-3C	Littlefield Farms	>300	7.0	32.5	64.0	SC	7	15	ag	5.0	3.3	2.3	1.6	1.6	1.5	1.6	1.0	0.9	6.5	3.8
OSWC-2A	Littlefield Farms	>300	23.7	32.5	64.0	SC	3	15	ag	2.5	1.4	0.8	0.5	0.4	0.0	0.4	1.2	0.3	2.6	16.0
OSWC-2B	Littlefield Farms	>300	23.7	32.5	64.0	SC	3	15	ag	0.5	0.3	0.3	0.2	0.2	0.0	0.3	2.0	0.1	1.3	9.7
OSWC-2C	Littlefield Farms	>300	23.7	32.5	64.0	SC	3	15	ag	1.0	0.6	0.5	0.4	0.4	0.4	0.4	1.1	0.3	1.3	5.1
OSWC-3A	Littlefield Farms	>300	23.7	32.5	64.0	SC	3	15	ag	0.5	0.4	0.3	0.3	0.3	0.0	0.4	1.4	0.2	1.3	11.9
OSWC-3B	Littlefield Farms	>300	23.7	32.5	64.0	SC	3	15	ag	0.5	0.4	0.3	0.2	0.2	0.0	0.3	2.0	0.1	1.1	6.2
OSWC-3C	Littlefield Farms	>300	23.7	32.5	64.0	SC	3	15	ag	0.5	0.4	0.3	0.2	0.2	0.0	0.3	1.8	0.1	0.8	3.2
OCWN-7A	Private Residence (Birmingham)	180	47.9	58.0	42.0	CO	2	30	res	0.5	0.4	0.3	0.2	0.2	0.0	0.3	1.8	0.1	0.7	2.8
OCWN-7B	Private Residence (Birmingham)	180	47.9	58.0	42.0	CO	2	30	res	0.5	0.5	0.3	0.3	0.3	0.0	0.4	1.4	0.1	0.7	1.8
OCWN-7C	Private Residence (Birmingham)	180	47.9	58.0	42.0	CO	2	30	res	0.5	0.4	0.3	0.2	0.2	0.0	0.3	1.6	0.1	0.7	2.9
OSDN-4A	Private Residence (Gulf Shores)	250	9.7	9.0	91.0	SN	8	20	res	12.3	10.6	10.3	10.3	10.3	10.1	1.8	0.2	10.1	24.1	21.5
OSDN-4B	Private Residence (Gulf Shores)	250	9.7	9.0	91.0	SN	8	20	res	31.0	27.9	26.1	23.9	23.9	24.0	3.9	0.2	22.1	36.1	4.0
OSDN-4C	Private Residence (Gulf Shores)	250	9.7	9.0	91.0	SN	8	20	res	27.5	24.0	22.4	20.7	20.7	20.3	4.2	0.2	19.9	87.1	33.2
OSWN-2A	Private Residence (Gulf Shores)	100	25.4	9.0	91.0	SN	4	20	res	14.5	14.0	13.3	13.8	13.8	14.3	1.3	0.1	13.7	16.1	13.7
OSWN-2B	Private Residence (Gulf Shores)	100	25.4	9.0	91.0	SN	4	20	res	17.0	16.4	15.6	15.6	15.0	15.8	3.3	0.2	15.4	24.8	19.6
OSWN-2C	Private Residence (Gulf Shores)	100	25.4	9.0	91.0	SN	4	20	res	12.5	11.9	11.7	11.6	11.2	11.6	2.1	0.2	11.5	15.6	17.4

Table C-1. Summary of Observed Data and Calculated Results by Location (Continued)

Test #	Location	Compaction (psi)	%Moist	% Clay & Silts	%Sand	Soil Group	Factorial Group	age	land use	15 min (in/hr)	30 min (in/hr)	60 min (in/hr)	120 min (in/hr)	Mean (f in/hr)	Median (f in/hr)	Standard Deviation (f)	COV (f)	fc (in/hr)	fo (in/hr)	k
OCDN-1A	Private Residence (Trussville)	150	18.7	61.6	35.8	CDN	6	25	res	26.8	23.1	20.8	18.0	18.0	17.3	5.2	0.3	14.9	31.6	2.6
OCDN-1B	Private Residence (Trussville)	150	18.7	61.6	35.8	CDN	6	25	res	27.5	23.1	22.6	22.7	22.7	22.9	7.0	0.3	21.5	21.5	-6.2
OCDN-1C	Private Residence (Trussville)	150	18.7	61.6	35.8	CDN	6	25	res	27.8	22.6	22.9	21.8	21.8	16.1	14.1	0.6	0.6	2.5	4.0
OSDC-1A	Private Residence (Trussville)	>300	13.0	34.4	61.0	SC	7	25	res	2.3	1.5	1.1	0.8	0.8	0.8	0.9	1.2	0.6	13.4	28.5
OSDC-1B	Private Residence (Trussville)	>300	13.0	34.4	61.0	SC	7	25	res	3.0	2.3	1.7	1.2	1.2	0.8	1.0	0.8	1.0	8.5	13.9
OSDC-1C	Private Residence (Trussville)	>300	13.0	34.4	61.0	SC	7	25	res	10.3	7.0	6.0	4.0	4.0	3.0	3.8	0.9	3.1	30.9	14.0
OSWC-1A	Private Residence (Trussville)	>300	32.6	34.4	61.0	SC	3	25	res	2.5	1.9	1.3	1.0	1.0	0.8	0.8	0.8	0.6	3.4	3.6
OSWC-1B	Private Residence (Trussville)	>300	32.6	34.4	61.0	SC	3	25	res	0.8	0.5	0.4	0.4	0.9	0.8	1.2	1.3	0.5	6.2	6.8
OSWC-1C	Private Residence (Trussville)	>300	32.6	34.4	61.0	SC	3	25	res	3.3	2.0	1.3	0.9	0.5	0.0	1.0	2.0	0.1	4.7	6.2
OCDC-1A	Private Residence (West Jefferson)	>300	7.1	67.0	27.7	CO	5	30	res	2.0	1.5	1.2	0.9	0.9	0.8	0.6	0.6	0.8	3.6	7.3
OCDC-1B	Private Residence (West Jefferson)	>300	7.1	67.0	27.7	CO	5	30	res	6.3	4.5	4.0	3.3	3.3	3.0	1.5	0.5	2.8	9.5	5.9
OCDC-1C	Private Residence (West Jefferson)	>300	7.1	67.0	27.7	CO	5	30	res	1.8	1.4	1.0	0.8	0.8	0.8	0.5	0.7	0.6	2.5	4.0
OCDN-2A	Private Residence (West Jefferson)	200	9.9	67.0	27.7	CDN	6	30	res	13.8	13.1	11.5	11.3	11.3	12.0	2.0	0.2	10.8	16.4	4.9
OCDN-2B	Private Residence (West Jefferson)	200	9.9	67.0	27.7	CDN	6	30	res	8.0	6.3	5.8	5.3	5.3	5.3	1.9	0.4	5.0	13.2	10.6
OCDN-2C	Private Residence (West Jefferson)	200	9.9	67.0	27.7	CDN	6	30	res	7.3	6.3	5.8	5.5	5.5	5.6	1.6	0.3	5.2	10.8	10.4
OCDN-3A	Private Residence (West Jefferson)	200	18.3	67.0	27.7	CDN	6	30	res	2.0	1.4	1.1	0.8	0.8	0.8	0.7	0.8	0.7	7.4	17.1
OCDN-3B	Private Residence (West Jefferson)	200	18.3	67.0	27.7	CDN	6	30	res	4.5	3.6	2.8	2.6	2.6	2.3	1.1	0.4	2.2	5.3	3.7
OCDN-3C	Private Residence (West Jefferson)	200	18.3	67.0	27.7	CDN	6	30	res	4.5	3.3	2.5	2.3	2.3	2.3	1.4	0.6	2.0	6.0	5.5
OCDN-4A	Private Residence (West Jefferson)	200	15.7	67.0	27.7	CDN	6	30	res	32.0	29.0	26.5	25.3	25.3	25.1	8.4	0.3	24.1	43.0	7.6
OCDN-4B	Private Residence (West Jefferson)	200	15.7	67.0	27.7	CDN	6	30	res	22.3	18.9	16.8	15.8	15.8	15.8	6.4	0.4	14.7	57.8	18.2
OCDN-4C	Private Residence (West Jefferson)	200	15.7	67.0	27.7	CDN	6	30	res	5.5	4.5	3.8	3.6	3.6	3.8	1.2	0.3	3.3	8.9	9.4
OCWC-1A	Private Residence (West Jefferson)	>300	20.1	67.0	27.7	CO	1	30	res	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0
OCWC-1B	Private Residence (West Jefferson)	>300	20.1	67.0	27.7	CO	1	30	res	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0
OCWC-1C	Private Residence (West Jefferson)	>300	20.1	67.0	27.7	CO	1	30	res	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0

Table C-1. Summary of Observed Data and Calculated Results by Location (Continued)

Test #	Location	Compaction (psi)	%Moist	% Clay & Silts	%Sand	Soil Group	Factorial Group	age	land use	15 min (in/hr)	30 min (in/hr)	60 min (in/hr)	120 min (in/hr)	Mean (f in/hr)	Median (f in/hr)	Standard Deviation (f)	COV (f)	fc (in/hr)	fo (in/hr)	k
OCWN-2A	Private Residence (West Jefferson)	200	25.6	67.0	27.7	CO	2	30	res	0.5	0.3	0.2	0.1	0.1	0.0	0.3	2.3	0.1	1.2	8.7
OCWN-2B	Private Residence (West Jefferson)	200	25.6	67.0	27.7	CO	2	30	res	0.5	0.5	0.4	0.2	0.3	0.0	0.4	1.5	-0.6	0.7	0.5
OCWN-2C	Private Residence (West Jefferson)	200	25.6	67.0	27.7	CO	2	30	res	0.3	0.4	0.3	0.2	0.3	0.0	0.5	2.1	-0.2	0.6	0.8
OCWN-3A	Private Residence (West Jefferson)	200	25.6	67.0	27.7	CO	2	30	res	0.5	0.3	0.2	0.1	0.1	0.0	0.2	3.4	0.0	1.3	8.1
OCWN-3B	Private Residence (West Jefferson)	200	25.6	67.0	27.7	CO	2	30	res	0.5	0.5	0.4	0.2	0.1	0.0	0.2	3.4	0.0	1.3	8.1
OCWN-3C	Private Residence (West Jefferson)	200	25.6	67.0	27.7	CO	2	30	res	0.3	0.4	0.3	0.2	0.1	0.0	0.2	3.4	0.0	0.9	6.4
OSDN-3A	Private Residence (West Jefferson)	200	16.2	24.3	73.8	SN	8	30	res	25.0	19.4	14.7	11.4	10.4	9.8	3.8	0.4	9.7	35.7	17.2
OSDN-3B	Private Residence (West Jefferson)	200	16.2	24.3	73.8	SN	8	30	res	1.3	0.8	0.6	0.5	16.3	15.0	4.7	0.3	14.0	27.7	3.2
OSDN-3C	Private Residence (West Jefferson)	200	16.2	24.3	73.8	SN	8	30	res	1.3	0.8	0.6	0.5	21.8	21.4	3.6	0.2	24.2	40.4	16.7
OCWN-1A	South Lakeshore Drive	180	21.7	64.3	32.7	CO	2	30	com	13.5	11.4	9.4	7.5	7.5	6.0	5.0	0.7	6.7	47.8	20.5
OCWN-1B	South Lakeshore Drive	180	21.7	64.3	32.7	CO	2	30	com	2.3	1.5	1.1	0.7	0.7	0.8	1.0	1.3	0.5	8.7	17.1
OCWN-1C	South Lakeshore Drive	180	21.7	64.3	32.7	CO	2	30	com	1.0	0.5	0.3	0.2	0.2	0.0	0.4	1.9	0.1	2.1	8.4
OSDC-4A	South Lakeshore Drive	>300	9.3	30.1	62.3	SC	7	30	com	10.3	6.9	6.1	4.8	4.8	3.8	3.1	0.7	3.9	22.8	10.7
OSDC-4B	South Lakeshore Drive	>300	9.3	30.1	62.3	SC	7	30	com	10.0	7.0	6.2	4.8	4.8	4.1	3.4	0.7	4.1	34.1	18.5
OSDC-4C	South Lakeshore Drive	>300	9.3	30.1	62.3	SC	7	30	com	12.5	9.3	7.6	6.4	6.4	5.3	3.6	0.6	0.0	0.0	0.0
OSDC-5A	South Lakeshore Drive	>300	17.4	32.0	61.5	SC	7	30	com	2.8	1.5	1.1	0.8	1.0	0.8	1.5	1.5	0.0	0.0	0.0
OSDC-5B	South Lakeshore Drive	>300	17.4	32.0	61.5	SC	7	30	com	8.3	5.8	4.7	3.7	3.8	3.0	3.2	0.9	0.0	0.0	0.0
OSDC-5C	South Lakeshore Drive	>300	17.4	32.0	61.5	SC	7	30	com	36.3	29.1	19.6	15.2	15.3	10.5	11.2	0.7	9.3	52.3	3.5
OSDN-1A	South Lakeshore Drive	225	17.7	32.0	61.5	SN	8	30	com	37.3	26.4	18.5	13.5	9.5	8.6	4.5	0.5	6.9	25.6	3.5
OSDN-1B	South Lakeshore Drive	225	17.7	32.0	61.5	SN	8	30	com	6.0	4.5	3.3	2.8	9.6	8.3	4.7	0.5	7.2	25.5	4.6
OSDN-1C	South Lakeshore Drive	225	17.7	32.0	61.5	SN	8	30	com	10.3	8.6	6.9	5.8	9.3	7.9	4.5	0.5	5.1	22.0	1.9
OSDN-2A	South Lakeshore Drive	200	16.7	32.0	61.5	SN	8	30	com	29.3	22.9	17.6	14.2	14.3	11.3	10.2	0.7	12.1	146.1	25.1
OSDN-2B	South Lakeshore Drive	200	16.7	32.0	61.5	SN	8	30	com	29.3	22.9	17.6	14.2	11.1	9.8	7.4	0.7	8.8	48.1	7.2
OSDN-2C	South Lakeshore Drive	200	16.7	32.0	61.5	SN	8	30	com	25.0	19.4	14.7	11.4	0.7	0.8	0.8	1.2	0.4	4.2	7.3

Table C-1. Summary of Observed Data and Calculated Results by Location (Continued)

Test #	Location	Compaction (psi)	%Moist	% Clay & Silts	%Sand	Soil Group	Factorial Group	age	land use	15 min (in/hr)	30 min (in/hr)	60 min (in/hr)	120 min (in/hr)	Mean (f in/hr)	Median (f in/hr)	Standard Deviation (f)	COV (f)	fc (in/hr)	fo (in/hr)	k
OSWC-4A	South Lakeshore Drive	>300	22.4	32.0	61.5	SC	3	30	com	36.5	26.0	18.5	13.5	13.6	9.0	12.5	0.9	9.5	86.1	9.1
OSWC-4B	South Lakeshore Drive	>300	22.4	32.0	61.5	SC	3	30	com	5.0	4.1	3.1	2.8	2.9	2.7	2.8	1.0	2.3	22.4	14.9
OSWC-4C	South Lakeshore Drive	>300	22.4	32.0	61.5	SC	3	30	com	8.0	6.3	6.9	5.8	5.9	5.6	3.4	0.6	5.4	64.7	37.1
NCWC-2A	Wildwood Apartments	>300	37.3	68.0	32.0	CO	1	1	res	2.5	1.3	0.8	0.5	0.5	0.0	0.9	1.8	0.2	4.2	6.2
NCWC-2B	Wildwood Apartments	>300	37.3	68.0	32.0	CO	1	1	res	1.3	0.6	0.3	0.4	0.4	0.0	0.6	1.4	0.3	1.5	6.1
NCWC-2C	Wildwood Apartments	>300	37.3	68.0	32.0	CO	1	1	res	1.3	0.9	0.6	0.4	0.4	0.0	0.5	1.3	0.1	1.5	2.3
NCWN-2A	Wildwood Apartments	150	37.3	68.0	32.0	CO	2	1	res	2.3	1.8	1.1	0.7	0.8	0.8	1.1	1.3	0.3	5.4	46.2
NCWN-2B	Wildwood Apartments	150	37.3	68.0	32.0	CO	2	1	res	3.5	2.9	1.8	1.1	1.2	0.8	1.6	1.3	0.2	6.9	3.4
NCWN-2C	Wildwood Apartments	150	37.3	68.0	32.0	CO	2	1	res	2.3	1.8	1.3	0.8	0.8	0.8	0.7	1.0	0.3	2.9	2.5

Table C-2. Variance of Triplicate Tests by Location

Test #	15 min			30 min			60 min			120 min			f_c		
	Mean	Std. Dev.	COV	Mean	Std. Dev.	COV	Mean	Std. Dev.	COV	Mean	Std. Dev.	COV	Mean	Std. Dev.	COV
NCDC-1	4.17	2.02	0.48	2.83	1.05	0.37	2.00	0.66	0.33	1.31	0.43	0.33	0.78	0.44	0.56
NCDC-2	5.67	3.96	0.70	3.17	2.24	0.71	1.81	0.97	0.54	1.06	0.47	0.44	0.28	0.24	0.85
NCDN-1	9.67	12.50	1.29	7.13	10.20	1.43	5.10	7.44	1.46	3.49	5.23	1.50	2.18	3.48	1.60
NCDN-2	5.83	4.91	0.84	5.71	6.42	1.13	5.13	6.50	1.27	4.08	5.53	1.35	0.57	0.00	0.00
NCWC-1	0.00	0.00	NA	0.00	0.00	NA	0.00	0.00	NA	0.00	0.00	NA	0.00	0.00	NA
NCWN-1	0.00	0.00	NA	0.00	0.00	NA	0.10	0.18	1.73	0.05	0.09	1.73	0.01	0.02	1.73
OCDC-2	1.50	0.25	0.17	1.08	0.07	0.07	0.90	0.13	0.15	0.66	0.09	0.14	0.37	0.09	0.24
OCDC-3	0.75	0.25	0.33	0.54	0.19	0.35	0.42	0.13	0.31	0.29	0.08	0.27	0.15	0.03	0.17
OCWC-2	1.17	0.38	0.33	0.96	0.31	0.33	0.77	0.19	0.25	0.56	0.14	0.25	0.22	0.39	1.81
OCWC-3	1.42	0.29	0.20	1.08	0.19	0.18	0.88	0.19	0.21	0.71	0.08	0.11	0.56	0.11	0.20
OCWC-4	1.50	0.50	0.33	1.13	0.25	0.22	0.85	0.10	0.11	0.68	0.09	0.13	0.38	0.26	0.69
OCWN-4	1.83	0.95	0.52	1.46	0.97	0.67	1.23	0.82	0.66	1.03	0.73	0.71	0.86	0.63	0.74
OCWN-5	2.25	0.43	0.19	1.71	0.40	0.24	1.27	0.40	0.32	0.78	0.26	0.33	0.14	0.28	2.04
OCWN-6	1.00	0.25	0.25	0.92	0.26	0.28	0.69	0.23	0.33	0.51	0.09	0.18	0.23	0.14	0.63
NSDC-1	3.58	0.76	0.21	2.21	0.72	0.33	1.46	0.56	0.38	1.05	0.48	0.45	0.62	0.38	0.60
NSDC-2	8.33	2.67	0.32	5.83	2.02	0.35	4.42	1.46	0.33	3.79	1.36	0.36	3.17	1.19	0.38
NSDN-1	37.75	8.45	0.22	33.79	7.18	0.21	29.06	5.74	0.20	25.57	5.29	0.21	22.93	2.52	0.11
NSDN-2	25.75	6.31	0.25	23.54	7.23	0.31	20.25	7.13	0.35	17.20	6.79	0.39	15.09	0.45	0.03
NSDN-3	19.42	1.23	0.06	16.13	0.65	0.04	13.56	2.45	0.18	11.73	3.94	0.34	8.19	14.19	1.73
NSDN-4	15.17	11.86	0.78	12.63	9.97	0.79	11.58	9.22	0.80	11.09	8.87	0.80	5.01	8.67	1.73
NSWN-1	32.58	4.89	0.15	28.13	3.44	0.12	24.67	2.52	0.10	21.84	1.73	0.08	19.15	0.29	0.02
NSWN-2	23.75	1.64	0.07	20.29	1.34	0.07	18.42	1.60	0.09	17.22	1.68	0.10	16.19	1.76	0.11
OSWN-1	27.83	0.52	0.02	22.96	0.80	0.04	20.31	0.13	0.01	18.56	0.65	0.03	17.09	0.94	0.06
NSWC-1	2.50	3.29	1.31	1.90	2.59	1.37	1.49	1.86	1.25	1.02	1.00	0.98	0.57	0.25	0.45
NSWC-2	11.04	16.85	1.53	9.40	14.60	1.55	8.55	13.17	1.54	7.69	11.80	1.53	0.74	0.34	0.46
OSDC-2	4.67	0.76	0.16	3.38	0.66	0.20	2.35	0.58	0.25	1.58	0.54	0.34	0.69	0.55	0.79
OSDC-3	4.75	0.43	0.09	3.21	0.31	0.10	2.21	0.18	0.08	1.55	0.10	0.06	0.87	0.04	0.05
OSWC-2	1.33	1.04	0.78	0.75	0.57	0.76	0.50	0.25	0.50	0.34	0.17	0.48	0.26	0.13	0.50
OSWC-3	0.50	0.00	0.00	0.38	0.00	0.00	0.29	0.04	0.12	0.20	0.05	0.24	0.13	0.08	0.59

Table C-2. Variance of Triplicate Tests by Location (Continued)

Test #	f_o			k			Location	% Clay & Silts	%Sand	%Moist	Compaction (psi)	age	Soil Group
	Mean	Std. Dev.	COV	Mean	Std. Dev.	COV							
NCDC-1	5.20	4.06	0.78	5.40	3.61	0.67	Chadwick, Helena	96.2	3.7	18.6	>300	1	CO
NCDC-2	9.96	8.16	0.82	5.62	0.78	0.14	Chadwick, Helena	96.2	3.7	13.7	>300	1	CO
NCDN-1	19.93	16.33	0.82	13.20	7.62	0.58	Chadwick, Helena	96.2	3.7	17.0	100	1	CDN
NCDN-2	8.82	1.29	0.15	11.46	1.07	0.09	Chadwick, Helena	96.2	3.7	17.0	100	1	CDN
NCWC-1	0.00	0.00	NA	0.00	0.00	NA	Chadwick, Helena	96.2	3.7	40.7	>300	1	CO
NCWN-1	-0.01	0.02	-1.73	2.58	4.47	1.73	Chadwick, Helena	96.2	3.7	35.8	150	1	CO
OCDC-2	2.06	0.72	0.35	3.12	1.95	0.63	Homewood Park	67.1	31.5	5.0	>300	20	CO
OCDC-3	1.06	0.35	0.33	3.18	1.73	0.54	Homewood Park	67.1	31.5	5.0	>300	20	CO
OCWC-2	2.29	1.75	0.77	6.78	9.67	1.42	Homewood Park	67.1	31.5	21.0	>300	20	CO
OCWC-3	3.10	2.17	0.70	11.81	12.96	1.10	Homewood Park	67.1	31.5	21.0	>300	20	CO
OCWC-4	1.77	0.72	0.41	2.53	1.69	0.67	Homewood Park	67.1	31.5	21.0	>300	20	CO
OCWN-4	2.68	1.38	0.51	5.24	2.06	0.39	Homewood Park	67.1	31.5	21.0	240	20	CO
OCWN-5	4.32	1.90	0.44	5.69	6.15	1.08	Homewood Park	67.1	31.5	23.0	150	20	CO
OCWN-6	1.30	0.27	0.21	2.35	1.58	0.67	Homewood Park	67.1	31.5	23.0	110	20	CO
NSDC-1	6.56	1.57	0.24	6.92	2.84	0.41	Jasper Golf Course(Walker County)	2.0	98.0	5.7	>300	5	SC
NSDC-2	29.38	4.16	0.14	19.10	3.71	0.19	Jasper Golf Course(Walker County)	2.0	98.0	5.7	>300	5	SC
NSDN-1	47.24	4.85	0.10	3.00	0.36	0.12	Jasper Golf Course(Walker County)	4.0	96.0	2.6	100	5	SN
NSDN-2	31.06	1.37	0.04	1.44	0.39	0.27	Jasper Golf Course(Walker County)	27.0	73.0	2.6	100	5	SN
NSDN-3	17.28	29.93	1.73	1.12	1.94	1.73	Jasper Golf Course(Walker County)	4.0	98.0	5.3	150	5	SN
NSDN-4	10.85	18.79	1.73	0.34	0.59	1.73	Jasper Golf Course(Walker County)	4.0	98.0	5.3	150	5	SN
NSWN-1	44.38	3.68	0.08	7.24	3.54	0.49	Jasper Golf Course(Walker County)	27.0	73.0	20.9	200	5	SN
NSWN-2	36.45	2.83	0.08	9.54	1.25	0.13	Jasper Golf Course(Walker County)	19.0	73.0	20.9	200	5	SN
OSWN-1	47.48	3.11	0.07	10.10	2.36	0.23	Jasper Golf Course(Walker County)	5.0	95.0	23.2	175	15	SN
NSWC-1	2.84	2.46	0.87	12.66	9.57	0.76	Littlefield Farms	32.5	64.0	28.1	>300	15	SC
NSWC-2	4.22	3.35	0.79	7.82	5.07	0.65	Littlefield Farms	32.5	64.0	28.1	>300	15	SC
OSDC-2	5.98	1.40	0.23	2.98	1.07	0.36	Littlefield Farms	32.5	64.0	11.2	>300	15	SC
OSDC-3	6.49	1.22	0.19	3.92	0.52	0.13	Littlefield Farms	32.5	64.0	7.0	>300	15	SC
OSWC-2	1.74	0.78	0.45	10.26	5.45	0.53	Littlefield Farms	32.5	64.0	23.7	>300	15	SC
OSWC-3	1.06	0.23	0.22	7.12	4.43	0.62	Littlefield Farms	32.5	64.0	23.7	>300	15	SC

Table C-2. Variance of Triplicate Tests by Location (Continued)

Test #	15 min			30 min			60 min			120 min			f_c		
	Mean	Std. Dev.	COV	Mean	Std. Dev.	COV	Mean	Std. Dev.	COV	Mean	Std. Dev.	COV	Mean	Std. Dev.	COV
OCWN-7	0.50	0.00	0.00	0.42	0.07	0.17	0.29	0.04	0.12	0.22	0.03	0.14	0.12	0.02	0.15
OSDN-4	23.58	9.97	0.42	20.83	9.05	0.43	19.58	8.24	0.42	18.29	7.07	0.39	17.39	6.42	0.37
OSWN-2	14.67	2.25	0.15	14.08	2.25	0.16	13.54	1.98	0.15	13.64	1.99	0.15	13.52	1.94	0.14
OCDN-1	27.33	0.52	0.02	22.96	0.29	0.01	22.08	1.17	0.05	20.82	2.46	0.12	12.34	10.70	0.87
OSDC-1	5.17	4.42	0.86	3.58	2.98	0.83	2.92	2.69	0.92	1.98	1.76	0.89	1.55	1.34	0.86
OSWC-1	2.17	1.28	0.59	1.46	0.83	0.57	0.98	0.52	0.54	0.75	0.33	0.44	0.42	0.26	0.63
OCDC-1	3.33	2.53	0.76	2.46	1.77	0.72	2.06	1.68	0.81	1.68	1.42	0.85	1.38	1.21	0.88
OCDN-2	9.67	3.56	0.37	8.54	3.97	0.46	7.69	3.30	0.43	7.39	3.43	0.46	7.01	3.28	0.47
OCDN-3	3.67	1.44	0.39	2.75	1.21	0.44	2.10	0.91	0.43	1.93	0.95	0.49	1.65	0.81	0.49
OCDN-4	19.92	13.40	0.67	17.46	12.31	0.71	15.67	11.41	0.73	14.89	10.92	0.73	14.05	10.44	0.74
OCWC-1	0.00	0.00	NA	0.00	0.00	NA	0.00	0.00	NA	0.00	0.00	NA	0.00	0.00	NA
OCWN-2	0.42	0.14	0.35	0.38	0.13	0.33	0.31	0.13	0.40	0.17	0.05	0.29	-0.24	0.31	-1.29
OCWN-3	0.42	0.14	0.35	0.38	0.13	0.33	0.31	0.13	0.40	0.17	0.05	0.29	-0.01	0.00	-0.38
OSDN-3	9.17	13.71	1.50	6.96	10.75	1.55	5.27	8.16	1.55	4.10	6.30	1.53	16.00	7.45	0.47
OCWN-1	5.58	6.88	1.23	4.46	6.01	1.35	3.60	5.07	1.41	2.82	4.09	1.45	2.44	3.67	1.51
OSDC-4	10.92	1.38	0.13	7.71	1.34	0.17	6.65	0.85	0.13	5.31	0.92	0.17	2.68	2.32	0.87
OSDC-5	15.75	17.97	1.14	12.13	14.88	1.23	8.46	9.78	1.16	6.57	7.62	1.16	3.10	5.36	1.73
OSDN-1	17.83	16.95	0.95	13.17	11.62	0.88	9.56	7.96	0.83	7.35	5.50	0.75	6.41	1.12	0.17
OSDN-2	27.83	2.45	0.09	21.71	2.02	0.09	16.65	1.70	0.10	13.25	1.62	0.12	7.10	6.06	0.85
OSWC-4	16.50	17.39	1.05	12.13	12.06	0.99	9.50	8.03	0.85	7.35	5.50	0.75	5.72	3.60	0.63
NCWC-2	1.67	0.72	0.43	0.92	0.31	0.34	0.58	0.25	0.43	0.43	0.07	0.15	0.20	0.12	0.60
NCWN-2	2.67	0.72	0.27	2.13	0.65	0.31	1.38	0.39	0.28	0.85	0.18	0.21	0.29	0.05	0.16

Table C-2. Variance of Triplicate Tests by Location (Continued)

Test #	f_o			k			Location	% Clay & Silts	%Sand	%Moist	Compaction (psi)	age	Soil Group
	Mean	Std. Dev.	COV	Mean	Std. Dev.	COV							
OCWN-7	0.69	0.03	0.04	2.52	0.59	0.23	Private Residence (Birmingham)	58.0	42.0	47.9	180	30	CO
OSDN-4	49.12	33.41	0.68	19.58	14.68	0.75	Private Residence (Gulf Shores)	9.0	91.0	9.7	250	20	SN
OSWN-2	18.86	5.16	0.27	16.92	2.97	0.18	Private Residence (Gulf Shores)	9.0	91.0	25.4	100	20	SN
OCDN-1	18.52	14.79	0.80	0.15	5.52	36.06	Private Residence (Trussville)	61.6	35.8	18.7	150	25	CDN
OSDC-1	17.57	11.79	0.67	18.80	8.40	0.45	Private Residence (Trussville)	34.4	61.0	13.0	>300	25	SC
OSWC-1	4.74	1.41	0.30	5.54	1.70	0.31	Private Residence (Trussville)	34.4	61.0	32.6	>300	25	SC
OCDC-1	5.18	3.77	0.73	5.72	1.66	0.29	Private Residence (West Jefferson)	67.0	27.7	7.1	>300	30	CO
OCDN-2	13.48	2.82	0.21	8.63	3.22	0.37	Private Residence (West Jefferson)	67.0	27.7	9.9	200	30	CDN
OCDN-3	6.24	1.06	0.17	8.79	7.25	0.82	Private Residence (West Jefferson)	67.0	27.7	18.3	200	30	CDN
OCDN-4	36.56	25.08	0.69	11.71	5.66	0.48	Private Residence (West Jefferson)	67.0	27.7	15.7	200	30	CDN
OCWC-1	0.00	0.00	NA	0.00	0.00	NA	Private Residence (West Jefferson)	67.0	27.7	20.1	>300	30	CO
OCWN-2	0.84	0.35	0.42	3.34	4.64	1.39	Private Residence (West Jefferson)	67.0	27.7	25.6	200	30	CO
OCWN-3	1.16	0.20	0.17	7.57	0.97	0.13	Private Residence (West Jefferson)	67.0	27.7	25.6	200	30	CO
OSDN-3	34.59	6.46	0.19	12.40	7.94	0.64	Private Residence (West Jefferson)	24.3	73.8	16.2	200	30	SN
OCWN-1	19.55	24.71	1.26	15.35	6.24	0.41	South Lakeshore Drive	64.3	32.7	21.7	180	30	CO
OSDC-4	18.98	17.38	0.92	9.76	9.31	0.95	South Lakeshore Drive	30.1	62.3	9.3	>300	30	SC
OSDC-5	17.45	30.22	1.73	1.17	2.03	1.73	South Lakeshore Drive	32.0	61.5	17.4	>300	30	SC
OSDN-1	24.38	2.08	0.09	3.34	1.36	0.41	South Lakeshore Drive	32.0	61.5	17.7	225	30	SN
OSDN-2	66.11	72.65	1.10	13.20	10.29	0.78	South Lakeshore Drive	32.0	61.5	16.7	200	30	SN
OSWC-4	57.70	32.43	0.56	20.34	14.79	0.73	South Lakeshore Drive	32.0	61.5	22.4	>300	30	SC
NCWC-2	2.40	1.54	0.64	4.86	2.24	0.46	Wildwood Apartments	68.0	32.0	37.3	>300	1	CO
NCWN-2	5.05	2.00	0.40	17.36	24.98	1.44	Wildwood Apartments	68.0	32.0	37.3	150	1	CO

Appendix D
Factorial Test Results for All Soil Infiltration Tests Combined

Figures and Tables in Appendix D:

Figure D-1. Results of Factorial Analysis for f_o
All Data

Moisture (Wet=+/Dry=-)	Texture (Clay=+/Sand=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	+	1	1.59	0.78	18
+	+	-	2	3.95	3.49	27
+	-	+	3	12.05	11.25	18
+	-	-	4	36.79	6.95	12
-	+	+	5	4.69	2.55	15
-	+	-	6	18.77	7.38	17
-	-	+	7	18.34	5.98	21
-	-	-	8	41.91	11.93	24
		overall average		17.26		
		calculated polled S.E		7.30		

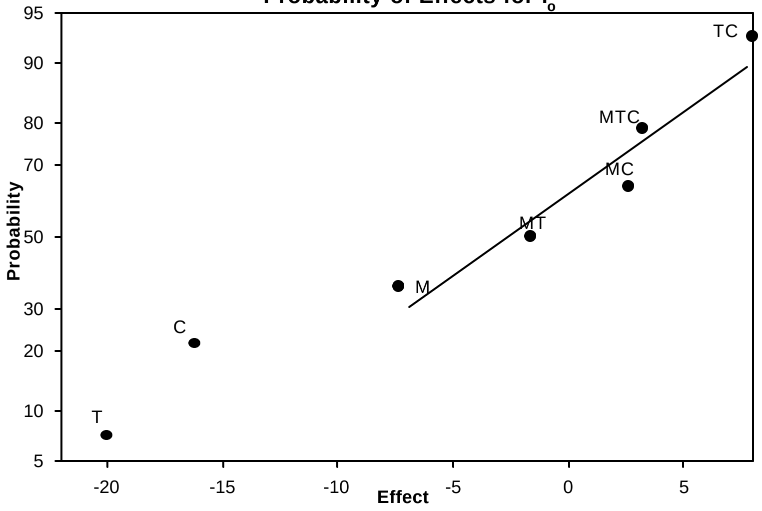
Factorial Group	effect	rank	Prob
T	-20.02	1	7.14
C	-16.19	2	21.43
M	-7.33	3	35.71
MT	-1.63	4	50.00
MC	2.64	5	64.29
MTC	3.22	6	78.57
TC	7.97	7	92.86

$f_o = 17.26 \pm (T/2) \pm (C/2)$

$f_o = 17.26 \pm (-20.02/2) \pm (-16.19/2)$

T	C	Calculated Values
+	+	-0.84
+	-	15.35
-	+	19.18
-	-	35.37

Probability of Effects for f_o



Probability of Residuals for f_o

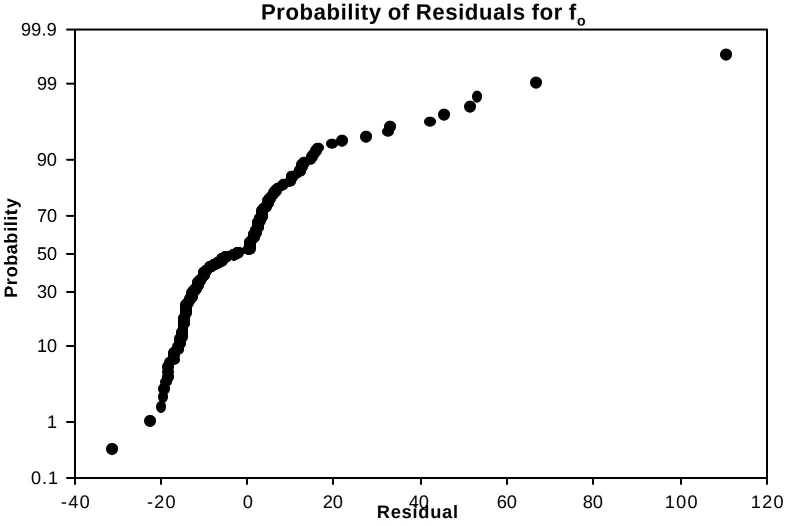


Figure D-2. Results of Factorial Analysis for f_c
All Data

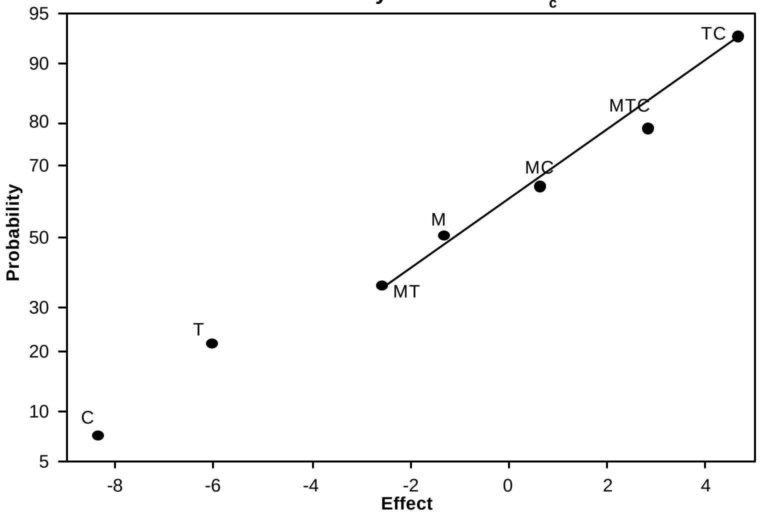
Moisture (Wet=+/Dry=-)	Texture (Clay=+/Sand=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	+	1	0.23	0.13	18
+	+	-	2	0.43	0.50	27
+	-	+	3	1.31	1.13	18
+	-	-	4	16.49	1.40	12
-	+	+	5	0.59	0.35	15
-	+	-	6	7.78	4.00	17
-	-	+	7	2.25	0.98	21
-	-	-	8	13.08	2.78	24
			overall average	5.27		
			calculated polled S.E	1.90		

Factorial Group	effects	rank	Prob
C	-8.35	1	7.14
T	-6.02	2	21.43
MT	-2.55	3	35.71
M	-1.31	4	50.00
MC	0.66	5	64.29
MTC	2.83	6	78.57
TC	4.66	7	92.86

$f_c = 5.27 \pm (T/2) \pm (C/2)$

$f_c = 5.27 \pm (-6.02/2) \pm (-8.35/2)$

T	C	Calculated Values
+	+	-1.92
+	-	6.43
-	+	4.10
-	-	12.45


Probability of Effects for f_c

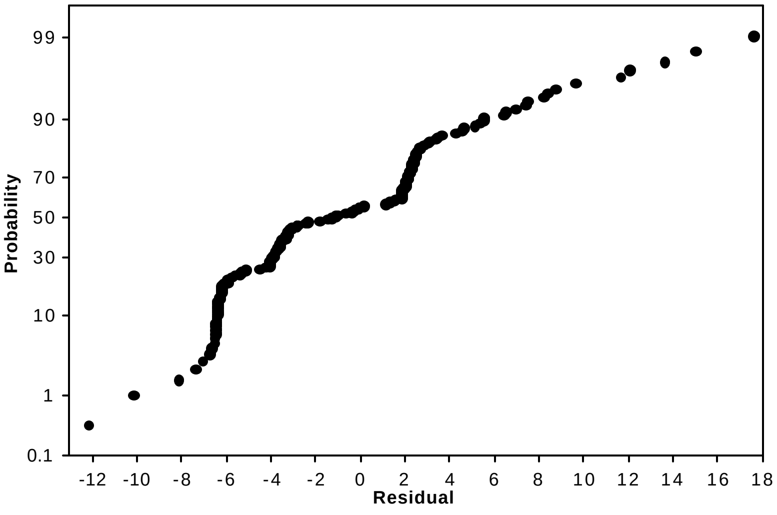

Probability of Residuals for f_c

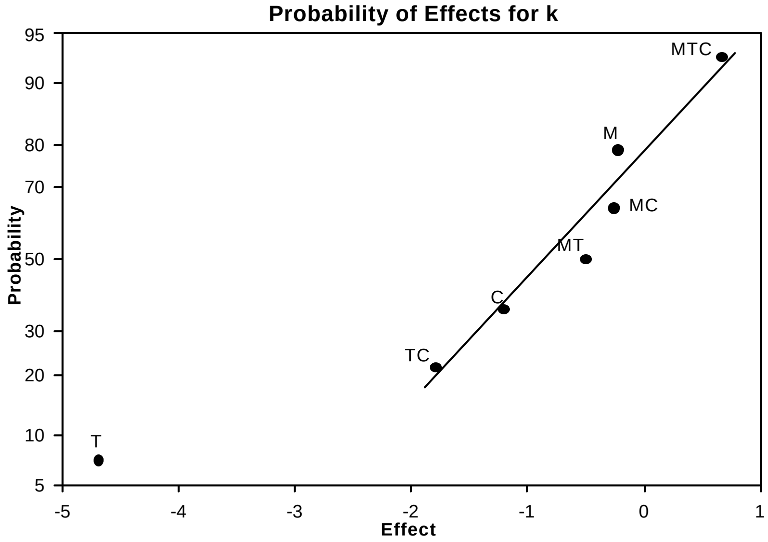
Figure D-3. Results of Factorial Analysis for k
All Data

Moisture (Wet=+/Dry=-)	Texture (Clay=+/Sand=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	+	1	4.33	3.33	18
+	+	-	2	6.89	3.60	27
+	-	+	3	10.63	3.98	18
+	-	-	4	10.95	2.54	12
-	+	+	5	4.61	1.14	15
-	+	-	6	8.02	3.86	17
-	-	+	7	11.26	3.34	21
-	-	-	8	9.75	3.61	24
			overall average	8.30		
			calculated polled S.E	3.29		

	effect	rank	Prob
T	-4.68	1	7.14
TC	-1.79	2	21.43
C	-1.20	3	35.71
MT	-0.50	4	50.00
MC	-0.25	5	64.29
M	-0.21	6	78.57
MTC	0.67	7	92.86

k = 8.30 ± (T/2)
k = 8.30 ± (-4.68/2)

T	C	Calculated Values
+	+	5.96
+	-	5.96
-	+	10.64
-	-	10.64



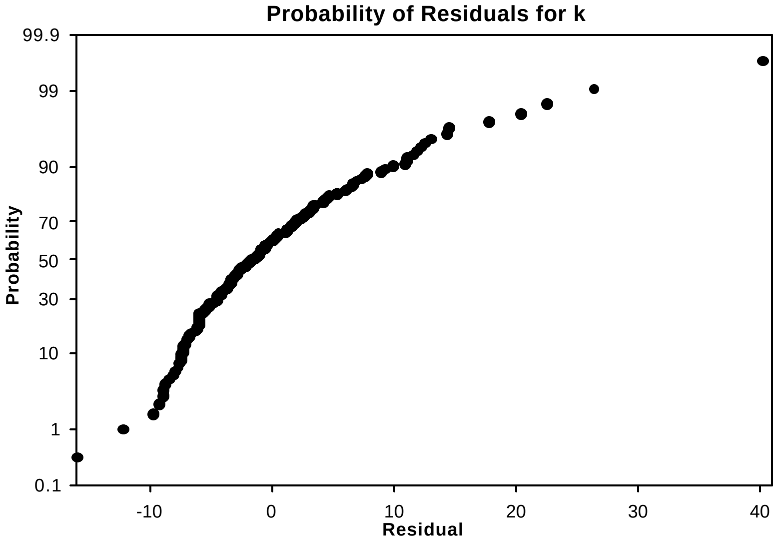


Figure D-4. Results of Factorial Analysis for Infiltration at 15 Minutes
All Data

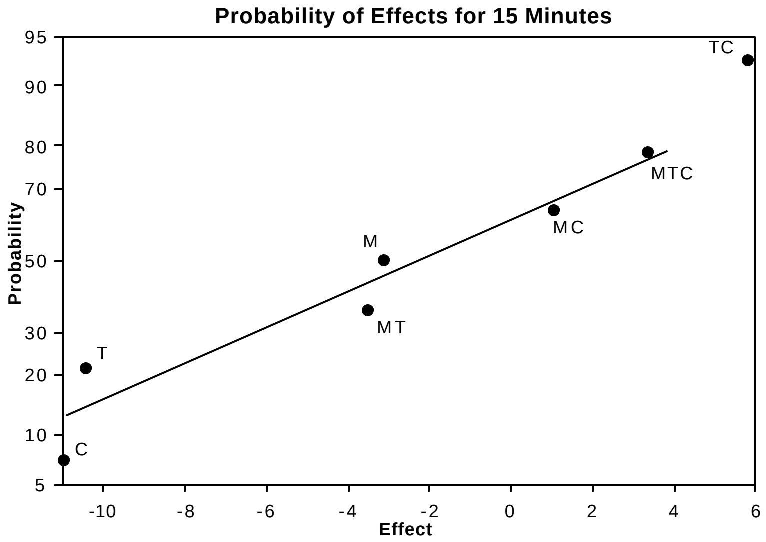
Moisture (Wet=+/Dry=-)	Texture (Clay=+/Sand=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	+	1	0.96	0.37	18
+	+	-	2	1.63	0.99	27
+	-	+	3	5.67	4.91	18
+	-	-	4	24.71	4.21	12
-	+	+	5	3.08	0.00	15
-	+	-	6	12.68	5.10	17
-	-	+	7	7.60	3.17	21
-	-	-	8	22.06	4.87	24
			overall average	9.80		
			calculated polled S.E	3.62		

Factorial Group	effects	rank	Prob
C	-10.94	1	7.14
T	-10.42	2	21.43
MT	-3.48	3	35.71
M	-3.11	4	50.00
MC	1.09	5	64.29
MTC	3.37	6	78.57
TC	5.81	7	92.86

$f_{15\ min} = 9.80 \pm (TC/2)$

$f_{15\ min} = 9.80 \pm (5.81/2)$

T	C	Calculated Values
+	+	12.70
+	-	6.89
-	+	6.89
-	-	12.70



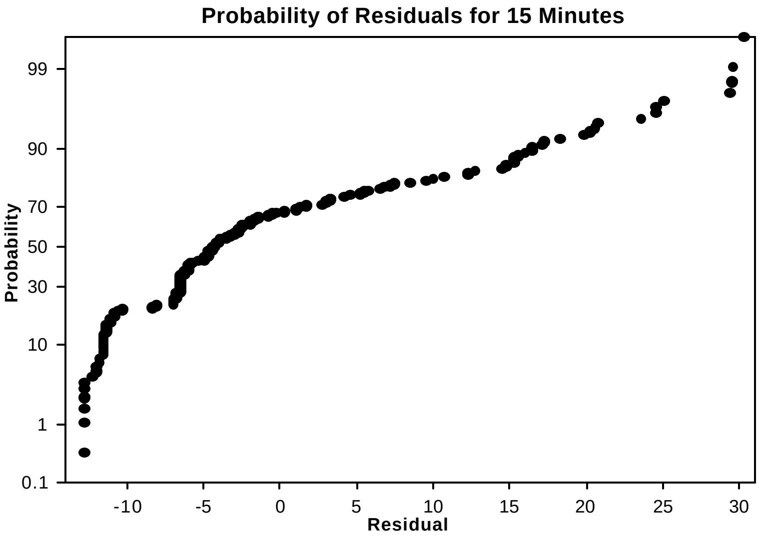


Figure D-5. Results of Factorial Analysis for Infiltration at 30 Minutes
All Data

Moisture (Wet=+/Dry=-)	Texture (Clay=+/Sand=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	+	1	0.68	0.25	18
+	+	-	2	1.31	0.83	27
+	-	+	3	4.33	3.83	18
+	-	-	4	21.36	3.24	12
-	+	+	5	2.02	0.00	15
-	+	-	6	10.76	4.48	17
-	-	+	7	5.43	2.57	21
-	-	-	8	18.59	4.27	24
			overall average	8.06		
			calculated polled S.E	2.99		

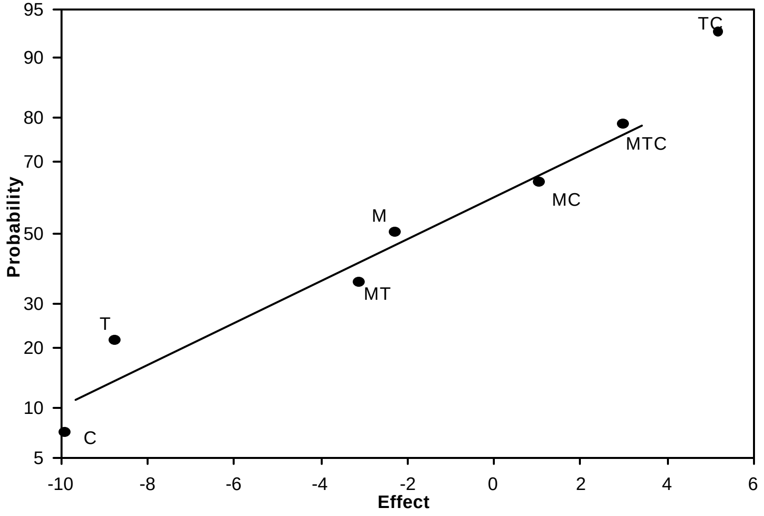
Factorial Group	effects	rank	Prob
C	-9.89	1	7.14
T	-8.74	2	21.43
MT	-3.11	3	35.71
M	-2.28	4	50.00
MC	1.06	5	64.29
MTC	2.99	6	78.57
TC	5.20	7	92.86

$f_{30\ min}$ = 8.06 ± (TC/2)

$f_{30\ min}$ = 8.06 ± (5.20/2)

T	C	Calculated Values
+	+	10.66
+	-	5.46
-	+	5.46
-	-	10.66

Probability of Effects for 30 Minutes



Probability of Residuals for 30 Minutes

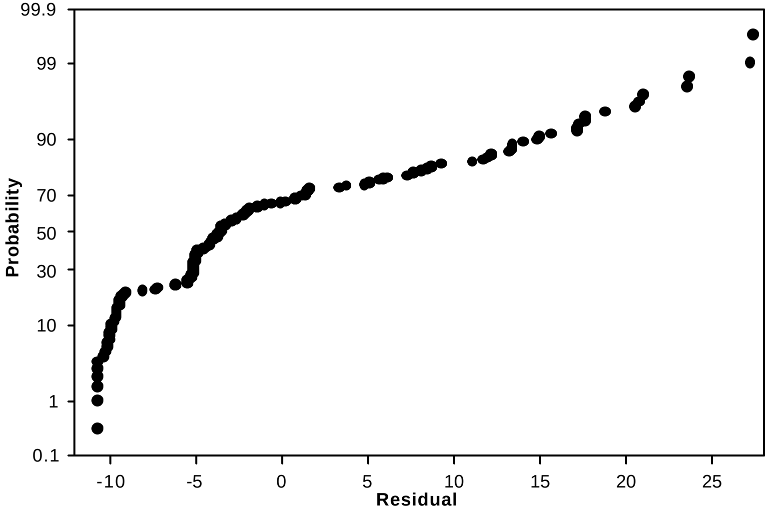


Figure D-6. Results of Factorial Analysis for Infiltration at 60 Minutes
All Data

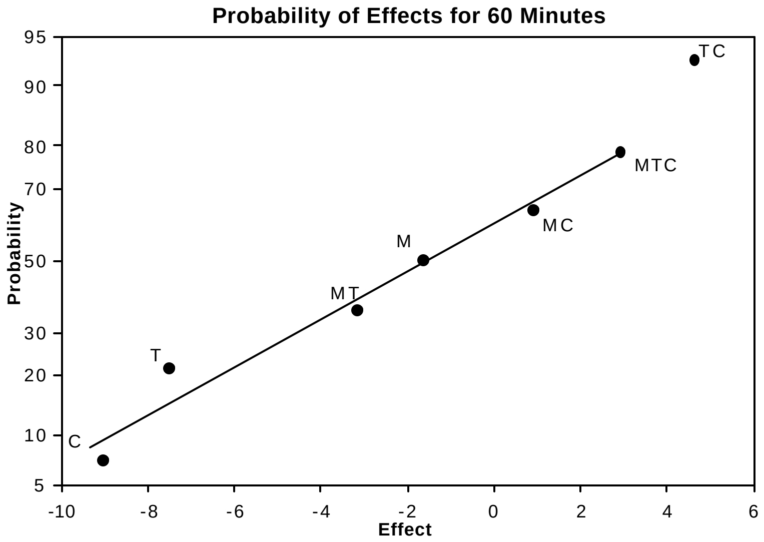
Moisture (Wet=+/Dry=-)	Texture (Clay=+/Sand=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	+	1	0.51	0.19	18
+	+	-	2	1.02	0.68	27
+	-	+	3	3.55	3.15	18
+	-	-	4	19.23	2.56	12
-	+	+	5	1.44	0.00	15
-	+	-	6	9.63	4.22	17
-	-	+	7	4.07	1.79	21
-	-	-	8	15.69	3.71	24
			overall average	6.89		
			calculated polled S.E	2.55		

Factorial Group	effects	rank	Prob
C	-9.00	1	7.14
T	-7.49	2	21.43
MT	-3.14	3	35.71
M	-1.63	4	50.00
MC	0.91	5	64.29
MTC	2.94	6	78.57
TC	4.65	7	92.86

$f_{60\ min}$ = 6.89 ± (TC/2)

$f_{60\ min}$ = 6.89 ± (4.65/2)

T	C	Calculated Values
+	+	9.22
+	-	4.57
-	+	4.57
-	-	9.22


Probability of Effects for 60 Minutes

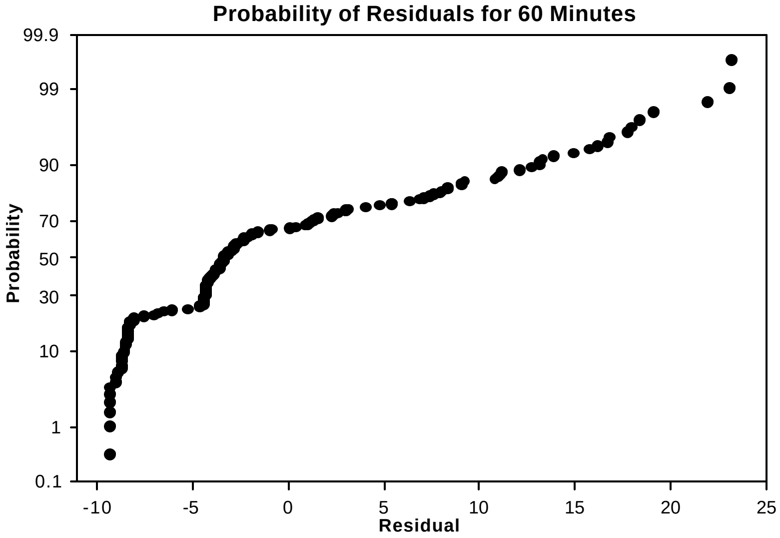

Probability of Residuals for 60 Minutes

Figure D-7. Results of Factorial Analysis for Infiltration at 120 Minutes
All Data

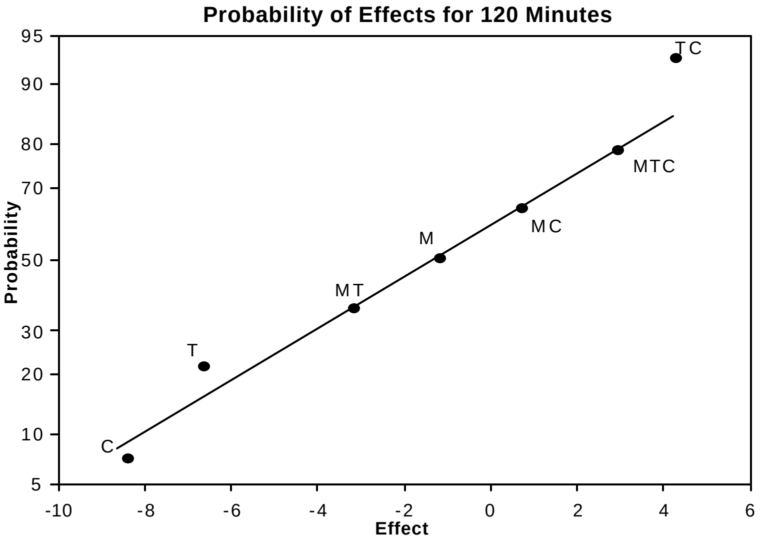
Moisture (Wet=+/Dry=-)	Texture (Clay=+/Sand=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	+	1	0.40	0.15	18
+	+	-	2	0.73	0.55	27
+	-	+	3	2.89	2.65	18
+	-	-	4	17.82	1.94	12
-	+	+	5	1.00	0.00	15
-	+	-	6	8.77	4.02	17
-	-	+	7	3.12	1.42	21
-	-	-	8	13.57	3.33	24
			overall average	6.04		
			calculated polled S.E	2.25		

Factorial Group	effects	rank	Prob
C	-8.37	1	7.14
T	-6.63	2	21.43
MT	-3.16	3	35.71
M	-1.16	4	50.00
MC	0.74	5	64.29
MTC	2.97	6	78.57
TC	4.32	7	92.86

$f_{120\ min} = 6.04 \pm (TC/2)$

$f_{120\ min} = 6.04 \pm (4.32/2)$

T	C	Calculated Values
+	+	8.20
+	-	3.88
-	+	3.88
-	-	8.20



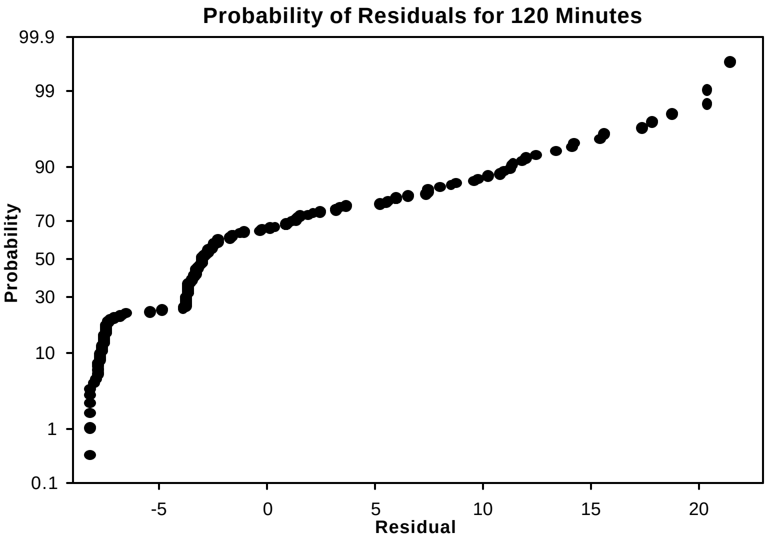


Table D-1. Factorial Analysis for Infiltration Tests
All Data

Test #	M (Moisture)	T (Texture)	C (Compaction)	Factorial Group	f_c (in/hr)	f_o (in/hr)	k	min 15 (in/hr)	min 30 (in/hr)	min 60 (in/hr)	min 120 (in/hr)
NCWC-1A	+	+	+	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NCWC-1B	+	+	+	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NCWC-1C	+	+	+	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NCWC-2A	+	+	+	1	0.2	4.2	6.2	2.5	1.3	0.8	0.5
NCWC-2B	+	+	+	1	0.3	1.5	6.1	1.3	0.6	0.3	0.4
NCWC-2C	+	+	+	1	0.1	1.5	2.3	1.3	0.9	0.6	0.4
OCWC-1A	+	+	+	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OCWC-1B	+	+	+	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OCWC-1C	+	+	+	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OCWC-2A	+	+	+	1	0.5	4.2	17.9	1.3	1.0	0.8	0.6
OCWC-2B	+	+	+	1	-0.2	0.8	0.5	0.8	0.6	0.6	0.4
OCWC-2C	+	+	+	1	0.3	1.8	1.9	1.5	1.3	0.9	0.7
OCWC-3A	+	+	+	1	0.7	5.6	26.5	1.3	1.1	0.9	0.7
OCWC-3B	+	+	+	1	0.6	1.8	7.1	1.3	0.9	0.7	0.6
OCWC-3C	+	+	+	1	0.4	1.9	1.9	1.8	1.3	1.1	0.8
OCWC-4A	+	+	+	1	0.7	1.8	3.8	1.5	1.1	0.9	0.8
OCWC-4B	+	+	+	1	0.2	1.0	0.6	1.0	0.9	0.8	0.6
OCWC-4C	+	+	+	1	0.3	2.5	3.1	2.0	1.4	0.9	0.6
NCWN-1A	+	+	-	2	0.0	0.0	7.7	0.0	0.0	0.3	0.2
NCWN-1B	+	+	-	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NCWN-1C	+	+	-	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NCWN-2A	+	+	-	2	0.3	5.4	46.2	2.3	1.8	1.1	0.7
NCWN-2B	+	+	-	2	0.2	6.9	3.4	3.5	2.9	1.8	1.1
NCWN-2C	+	+	-	2	0.3	2.9	2.5	2.3	1.8	1.3	0.8
OCWN-1A	+	+	-	2	6.7	47.8	20.5	13.5	11.4	9.4	7.5
OCWN-1B	+	+	-	2	0.5	8.7	17.1	2.3	1.5	1.1	0.7
OCWN-1C	+	+	-	2	0.1	2.1	8.4	1.0	0.5	0.3	0.2
OCWN-2A	+	+	-	2	0.1	1.2	8.7	0.5	0.3	0.2	0.1
OCWN-2B	+	+	-	2	-0.6	0.7	0.5	0.5	0.5	0.4	0.2
OCWN-2C	+	+	-	2	-0.2	0.6	0.8	0.3	0.4	0.3	0.2
OCWN-3A	+	+	-	2	0.0	1.3	8.1	0.5	0.3	0.2	0.1
OCWN-3B	+	+	-	2	0.0	1.3	8.1	0.5	0.5	0.4	0.2
OCWN-3C	+	+	-	2	0.0	0.9	6.4	0.3	0.4	0.3	0.2
OCWN-4A	+	+	-	2	0.1	1.1	5.4	0.8	0.4	0.3	0.2
OCWN-4B	+	+	-	2	1.4	3.2	3.1	2.5	2.3	1.9	1.6
OCWN-4C	+	+	-	2	1.1	3.7	7.2	2.3	1.8	1.5	1.3
OCWN-5A	+	+	-	2	0.3	4.3	3.5	2.8	2.0	1.4	0.8
OCWN-5B	+	+	-	2	0.3	6.2	12.6	2.0	1.3	0.8	0.5

Table D-1. Factorial Analysis for Infiltration Tests
All Data (Continued)

Test #	M (Moisture)	T (Texture)	C (Compaction)	Factorial Group	f_c (in/hr)	f_o (in/hr)	k	min 15 (in/hr)	min 30 (in/hr)	min 60 (in/hr)	min 120 (in/hr)
OCWN-5C	+	+	-	2	-0.2	2.4	0.9	2.0	1.9	1.6	1.0
OCWN-6A	+	+	-	2	0.4	1.0	4.2	1.3	1.1	0.9	0.6
OCWN-6B	+	+	-	2	0.1	1.5	1.3	0.8	0.6	0.4	0.4
OCWN-6C	+	+	-	2	0.2	1.4	1.5	1.0	1.0	0.8	0.6
OCWN-7A	+	+	-	2	0.1	0.7	2.8	0.5	0.4	0.3	0.2
OCWN-7B	+	+	-	2	0.1	0.7	1.8	0.5	0.5	0.3	0.3
OCWN-7C	+	+	-	2	0.1	0.7	2.9	0.5	0.4	0.3	0.2
NSWC-1A	+	-	+	3	0.8	3.4	12.6	6.3	4.9	3.6	2.2
NSWC-1B	+	-	+	3	0.6	5.0	22.3	1.1	0.6	0.6	0.6
NSWC-1C	+	-	+	3	0.3	0.1	3.1	0.1	0.2	0.2	0.3
NSWC-2A	+	-	+	3	0.5	8.1	2.3	1.0	0.6	0.6	0.6
NSWC-2B	+	-	+	3	0.6	2.3	12.2	1.6	1.3	1.3	1.2
NSWC-2C	+	-	+	3	1.1	2.3	8.9	30.5	26.3	23.8	21.3
OSWC-1A	+	-	+	3	0.6	3.4	3.6	2.5	1.9	1.3	1.0
OSWC-1B	+	-	+	3	0.5	6.2	6.8	0.8	0.5	0.4	0.4
OSWC-1C	+	-	+	3	0.1	4.7	6.2	3.3	2.0	1.3	0.9
OSWC-2A	+	-	+	3	0.3	2.6	16.0	2.5	1.4	0.8	0.5
OSWC-2B	+	-	+	3	0.1	1.3	9.7	0.5	0.3	0.3	0.2
OSWC-2C	+	-	+	3	0.3	1.3	5.1	1.0	0.6	0.5	0.4
OSWC-3A	+	-	+	3	0.2	1.3	11.9	0.5	0.4	0.3	0.3
OSWC-3B	+	-	+	3	0.1	1.1	6.2	0.5	0.4	0.3	0.2
OSWC-3C	+	-	+	3	0.1	0.8	3.2	0.5	0.4	0.3	0.2
OSWC-4A	+	-	+	3	9.5	86.1	9.1	36.5	26.0	18.5	13.5
OSWC-4B	+	-	+	3	2.3	22.4	14.9	5.0	4.1	3.1	2.8
OSWC-4C	+	-	+	3	5.4	64.7	37.1	8.0	6.3	6.9	5.8
NSWN-1A	+	-	-	4	19.5	42.0	6.1	37.3	31.6	27.0	23.7
NSWN-1B	+	-	-	4	19.0	48.6	11.2	27.5	24.8	22.0	20.2
NSWN-1C	+	-	-	4	19.0	42.5	4.4	33.0	28.0	25.0	21.7
NSWN-2A	+	-	-	4	18.0	38.9	10.4	25.5	21.8	20.1	19.0
NSWN-2B	+	-	-	4	16.0	37.1	10.1	23.5	20.0	18.3	17.0
NSWN-2C	+	-	-	4	14.5	33.4	8.1	22.3	19.1	16.9	15.7
OSWN-1A	+	-	-	4	18.0	51.1	12.6	28.0	22.4	20.4	19.3
OSWN-1B	+	-	-	4	17.1	45.5	9.8	27.3	22.6	20.3	18.5
OSWN-1C	+	-	-	4	16.1	45.9	7.9	28.3	23.9	20.2	18.0
OSWN-2A	+	-	-	4	13.7	16.1	13.7	14.5	14.0	13.3	13.8
OSWN-2B	+	-	-	4	15.4	24.8	19.6	17.0	16.4	15.6	15.6
OSWN-2C	+	-	-	4	11.5	15.6	17.4	12.5	11.9	11.7	11.6
NCDC-1A	-	+	+	5	0.4	2.8	2.6	2.0	1.6	1.3	0.8

Table D-1. Factorial Analysis for Infiltration Tests
All Data (Continued)

Test #	M (Moisture)	T (Texture)	C (Compaction)	Factorial Group	f_c (in/hr)	f_o (in/hr)	k	min 15 (in/hr)	min 30 (in/hr)	min 60 (in/hr)	min 120 (in/hr)
NCDC-1B	-	+	+	5	0.7	2.9	4.1	6.0	3.5	2.3	1.4
NCDC-1C	-	+	+	5	1.3	9.9	9.5	4.5	3.4	2.5	1.7
NCDC-2A	-	+	+	5	0.3	3.1	4.8	2.3	1.3	0.9	0.6
NCDC-2B	-	+	+	5	0.5	7.8	5.7	4.8	2.6	1.8	1.1
NCDC-2C	-	+	+	5	0.0	19.0	6.4	10.0	5.6	2.8	1.5
OCDC-1A	-	+	+	5	0.8	3.6	7.3	2.0	1.5	1.2	0.9
OCDC-1B	-	+	+	5	2.8	9.5	5.9	6.3	4.5	4.0	3.3
OCDC-1C	-	+	+	5	0.6	2.5	4.0	1.8	1.4	1.0	0.8
OCDC-2A	-	+	+	5	0.5	2.9	5.1	1.8	1.1	0.9	0.7
OCDC-2B	-	+	+	5	0.4	1.7	3.0	1.3	1.0	0.8	0.6
OCDC-2C	-	+	+	5	0.3	1.6	1.2	1.5	1.1	1.0	0.8
OCDC-3A	-	+	+	5	0.1	1.1	5.2	0.8	0.4	0.3	0.2
OCDC-3B	-	+	+	5	0.1	1.4	2.3	1.0	0.8	0.6	0.4
OCDC-3C	-	+	+	5	0.2	0.7	2.1	0.5	0.5	0.4	0.3
NCDN-1A	-	+	-	6	6.2	37.3	4.6	24.0	18.9	13.7	9.5
NCDN-1B	-	+	-	6	0.1	17.6	15.9	4.0	2.0	1.1	0.6
NCDN-1C	-	+	-	6	0.2	4.9	19.1	1.0	0.5	0.5	0.3
NCDN-2A	-	+	-	6	NA	NA	NA	11.5	13.1	12.6	10.5
NCDN-2B	-	+	-	6	0.6	9.7	12.2	3.0	2.0	1.4	0.9
NCDN-2C	-	+	-	6	0.6	7.9	10.7	3.0	2.0	1.3	0.9
OCDN-1A	-	+	-	6	14.9	31.6	2.6	26.8	23.1	20.8	18.0
OCDN-1B	-	+	-	6	21.5	21.5	-6.2	27.5	23.1	22.6	22.7
OCDN-1C	-	+	-	6	20.1	20.1	-10.0	27.8	22.6	22.9	21.8
OCDN-2A	-	+	-	6	10.8	16.4	4.9	13.8	13.1	11.5	11.3
OCDN-2B	-	+	-	6	5.0	13.2	10.6	8.0	6.3	5.8	5.3
OCDN-2C	-	+	-	6	5.2	10.8	10.4	7.3	6.3	5.8	5.5
OCDN-3A	-	+	-	6	0.7	7.4	17.1	2.0	1.4	1.1	0.8
OCDN-3B	-	+	-	6	2.2	5.3	3.7	4.5	3.6	2.8	2.6
OCDN-3C	-	+	-	6	2.0	6.0	5.5	4.5	3.3	2.5	2.3
OCDN-4A	-	+	-	6	24.1	43.0	7.6	32.0	29.0	26.5	25.3
OCDN-4B	-	+	-	6	14.7	57.8	18.2	22.3	18.9	16.8	15.8
OCDN-4C	-	+	-	6	3.3	8.9	9.4	5.5	4.5	3.8	3.6
NSDC-1A	-	-	+	7	0.8	5.0	3.9	3.8	2.6	1.8	1.3
NSDC-1B	-	-	+	7	0.9	8.2	7.3	4.3	2.6	1.8	1.3
NSDC-1C	-	-	+	7	0.2	6.5	9.5	2.8	1.4	0.8	0.5
NSDC-2A	-	-	+	7	4.2	31.9	18.1	9.8	7.1	5.5	4.8
NSDC-2B	-	-	+	7	1.9	24.6	23.2	5.3	3.5	2.8	2.3
NSDC-2C	-	-	+	7	3.5	31.6	16.0	10.0	6.9	5.0	4.3

Table D-1. Factorial Analysis for Infiltration Tests
All Data (Continued)

Test #	M (Moisture)	T (Texture)	C (Compaction)	Factorial Group	f_c (in/hr)	f_o (in/hr)	k	min 15 (in/hr)	min 30 (in/hr)	min 60 (in/hr)	min 120 (in/hr)
OSDC-1A	-	-	+	7	0.6	13.4	28.5	2.3	1.5	1.1	0.8
OSDC-1B	-	-	+	7	1.0	8.5	13.9	3.0	2.3	1.7	1.2
OSDC-1C	-	-	+	7	3.1	30.9	14.0	10.3	7.0	6.0	4.0
OSDC-2A	-	-	+	7	0.3	4.4	1.8	4.0	3.1	2.2	1.4
OSDC-2B	-	-	+	7	1.3	7.1	3.2	5.5	4.1	3.0	2.2
OSDC-2C	-	-	+	7	0.4	6.4	3.9	4.5	2.9	1.9	1.2
OSDC-3A	-	-	+	7	0.8	5.3	3.5	4.3	2.9	2.0	1.4
OSDC-3B	-	-	+	7	0.9	7.7	4.5	5.0	3.5	2.3	1.6
OSDC-3C	-	-	+	7	0.9	6.5	3.8	5.0	3.3	2.3	1.6
OSDC-4A	-	-	+	7	3.9	22.8	10.7	10.3	6.9	6.1	4.8
OSDC-4B	-	-	+	7	4.1	34.1	18.5	10.0	7.0	6.2	4.8
OSDC-4C	-	-	+	7	5.5	34.3	14.9	12.5	9.3	7.6	6.4
OSDC-5A	-	-	+	7	0.7	16.3	19.9	2.8	1.5	1.1	0.8
OSDC-5B	-	-	+	7	3.0	27.3	13.7	8.3	5.8	4.7	3.7
OSDC-5C	-	-	+	7	9.3	52.3	3.5	36.3	29.1	19.6	15.2
NSDN-1A	-	-	-	8	20.0	42.2	3.0	42.3	37.9	32.3	28.6
NSDN-1B	-	-	-	8	24.2	47.7	2.6	43.0	38.0	32.4	28.6
NSDN-1C	-	-	-	8	24.6	51.8	3.4	28.0	25.5	22.4	19.5
NSDN-2A	-	-	-	8	14.7	29.9	1.5	28.8	25.6	22.6	19.6
NSDN-2B	-	-	-	8	15.6	30.8	1.8	30.0	29.5	25.9	22.4
NSDN-2C	-	-	-	8	15.0	32.6	1.0	18.5	15.5	12.3	9.5
NSDN-3A	-	-	-	8	6.9	25.6	3.5	20.3	15.8	11.9	9.6
NSDN-3B	-	-	-	8	7.2	25.5	4.6	18.0	15.8	12.4	9.3
NSDN-3C	-	-	-	8	5.1	22.0	1.9	20.0	16.9	16.4	16.3
NSDN-4A	-	-	-	8	15.2	40.8	18.4	22.8	18.8	17.2	16.8
NSDN-4B	-	-	-	8	15.9	41.1	13.3	21.3	18.0	16.6	15.7
NSDN-4C	-	-	-	8	14.8	39.2	13.4	1.5	1.1	0.9	0.9
OSDN-1A	-	-	-	8	9.6	88.6	9.6	37.3	26.4	18.5	13.5
OSDN-1B	-	-	-	8	2.3	25.4	17.6	6.0	4.5	3.3	2.8
OSDN-1C	-	-	-	8	4.4	13.2	2.8	10.3	8.6	6.9	5.8
OSDN-2A	-	-	-	8	12.1	146.1	25.1	29.3	22.9	17.6	14.2
OSDN-2B	-	-	-	8	8.8	48.1	7.2	29.3	22.9	17.6	14.2
OSDN-2C	-	-	-	8	0.4	4.2	7.3	25.0	19.4	14.7	11.4
OSDN-3A	-	-	-	8	9.7	35.7	17.2	25.0	19.4	14.7	11.4
OSDN-3B	-	-	-	8	14.0	27.7	3.2	1.3	0.8	0.6	0.5
OSDN-3C	-	-	-	8	24.2	40.4	16.7	1.3	0.8	0.6	0.5
OSDN-4A	-	-	-	8	10.1	24.1	21.5	12.3	10.6	10.3	10.3
OSDN-4B	-	-	-	8	22.1	36.1	4.0	31.0	27.9	26.1	23.9
OSDN-4C	-	-	-	8	19.9	87.1	33.2	27.5	24.0	22.4	20.7

Table D-1. Factorial Analysis for Infiltration Tests
All Data (Continued)

group statistics	f_c (in/hr)	f_o (in/hr)	k	min 15	min 30	min 60	min 120
1 average	0.2	1.6	4.3	1.0	0.7	0.5	0.4
1 std error	0.1	0.8	3.3	0.4	0.3	0.2	0.1
1 number	18.0	18.0	18.0	18.0	18.0	18.0	18.0
2 average	0.4	4.0	6.9	1.6	1.3	1.0	0.7
2 std error	0.5	3.5	3.6	1.0	0.8	0.7	0.5
2 number	27.0	27.0	27.0	27.0	27.0	27.0	27.0
3 average	1.3	12.1	10.6	5.7	4.3	3.6	2.9
3 std error	1.1	11.2	4.0	4.9	3.8	3.1	2.6
3 number	18.0	18.0	18.0	18.0	18.0	18.0	18.0
4 average	16.5	36.8	11.0	24.7	21.4	19.2	17.8
4 std error	1.4	7.0	2.5	4.2	3.2	2.6	1.9
4 number	12.0	12.0	12.0	12.0	12.0	12.0	12.0
5 average	0.6	4.7	4.6	3.1	2.0	1.4	1.0
5 std error	0.4	2.5	1.1	1.4	0.8	0.5	0.4
5 number	15.0	15.0	15.0	15.0	15.0	15.0	15.0
6 average	7.8	18.8	8.0	12.7	10.8	9.6	8.8
6 std error	4.0	7.4	3.9	5.1	4.5	4.2	4.0
6 number	17.0	17.0	17.0	18.0	18.0	18.0	18.0
7 average	2.3	18.3	11.3	7.6	5.4	4.1	3.1
7 std error	1.0	6.0	3.3	3.2	2.6	1.8	1.4
7 number	21.0	21.0	21.0	21.0	21.0	21.0	21.0
8 average	13.2	41.9	9.7	22.1	18.6	15.7	13.6
8 std error	2.9	11.9	3.6	4.9	4.3	3.7	3.3
8 number	24.0	24.0	24.0	24.0	24.0	24.0	24.0

Table D-1. Factorial Analysis for Infiltration Tests
All Data (Continued)

		f_c (in/hr)	f_o (in/hr)	k	min 15	min 30	min 60	min 120
overall average		5.3	17.3	8.3	9.8	8.1	6.9	6.0
total obs		152.0	152.0	152.0	153.0	153.0	153.0	153.0
calc. polled S.E.		1.9	7.3	3.3	3.6	3.0	2.5	2.3
based on averages of replicates								
Moisture	M	-1.3	-7.3	-0.2	-3.1	-2.3	-1.6	-1.2
Texture	T	-6.1	-20.0	-4.7	-10.4	-8.7	-7.5	-6.6
Compaction	C	-8.4	-16.2	-1.2	-10.9	-9.9	-9.0	-8.4
moisture x texture	MT	-2.5	-1.6	-0.5	-3.5	-3.1	-3.1	-3.2
moisture x compaction	MC	0.7	2.6	-0.2	1.1	1.1	0.9	0.7
texture x compaction	TC	4.7	8.0	-1.8	5.8	5.2	4.7	4.3
moisture x texture x compaction	MTC	2.8	3.2	0.7	3.4	3.0	2.9	3.0

Appendix E
Factorial Test Results for Sandy Soil Infiltration Tests

Figures and Tables in Appendix E:

Figure E-1. Results of Factorial Analysis for f_c
Sand

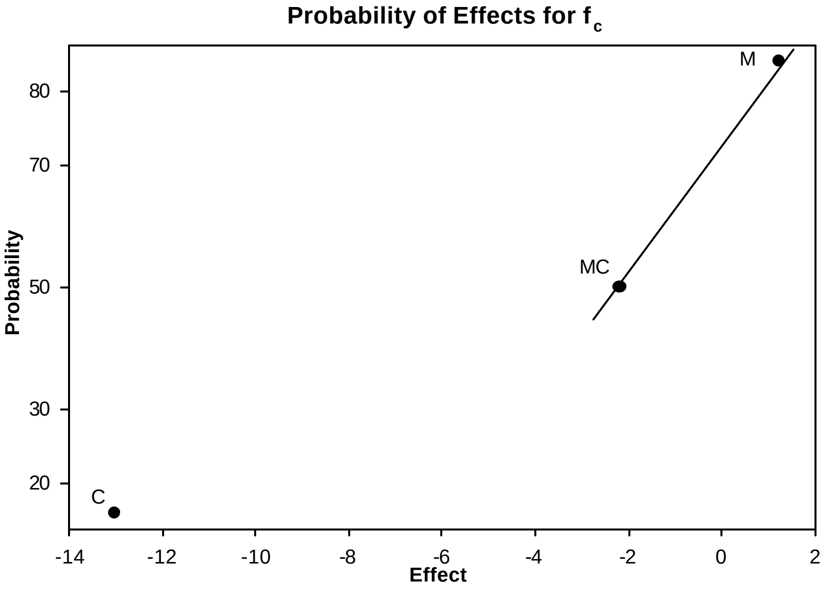
Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error
+	+	1	1.90	0.78
+	-	2	1.51	1.48
-	+	3	9.41	3.61
-	-	4	13.86	2.39
		overall average	6.67	
		calculated polled S.E	2.32	

$f_c = 6.67 \pm (C/2)$

$f_c = 6.67 \pm (-13.01/2)$

C	Calculated Values
+	0.16
-	13.17

Factorial Group	sorted effects	rank	Prob
C	-13.01	1	16.67
MC	-2.17	2	50.00
M	1.23	3	83.33



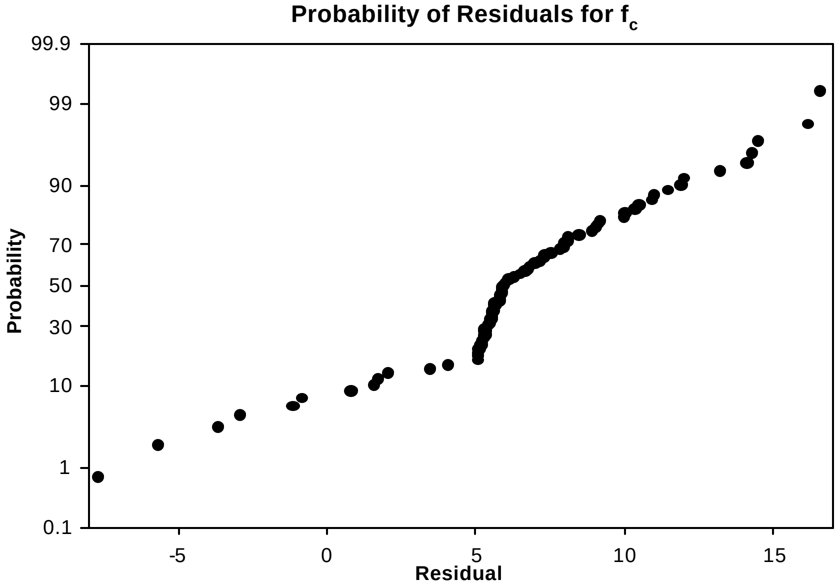


Figure E-2. Results of Factorial Analysis for f_o
Sand

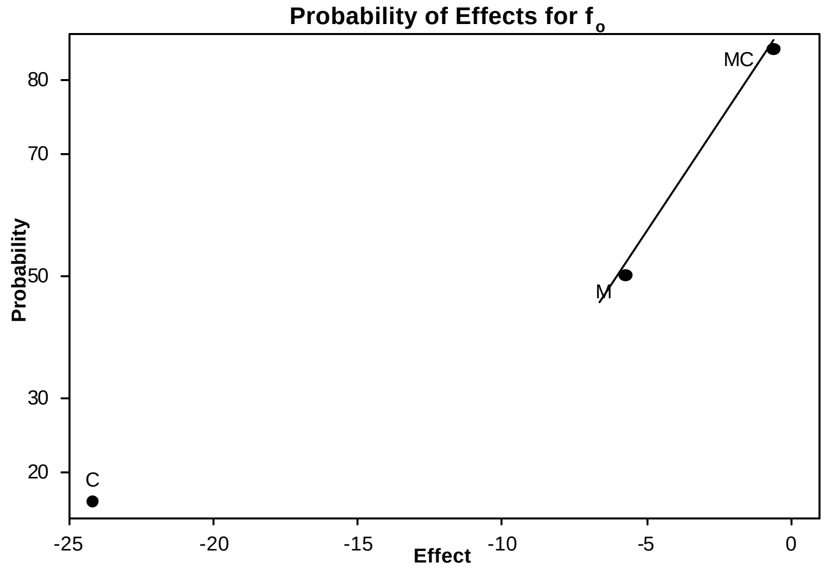
Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error
+	+	1	16.06	5.62
+	-	2	10.95	8.70
-	+	3	29.08	10.08
-	-	4	42.42	12.08
		overall average	24.63	
		calculated polled S.E	9.42	

$f_o = 24.63 \pm (C/2)$

$f_c = 24.63 \pm (-4.11/2)$

C	Calculated Values
+	22.57
-	26.68

Factorial Group	sorted effects	rank	Prob
C	-24.15	1	16.67
M	-5.70	2	50.00
MC	-0.58	3	83.33



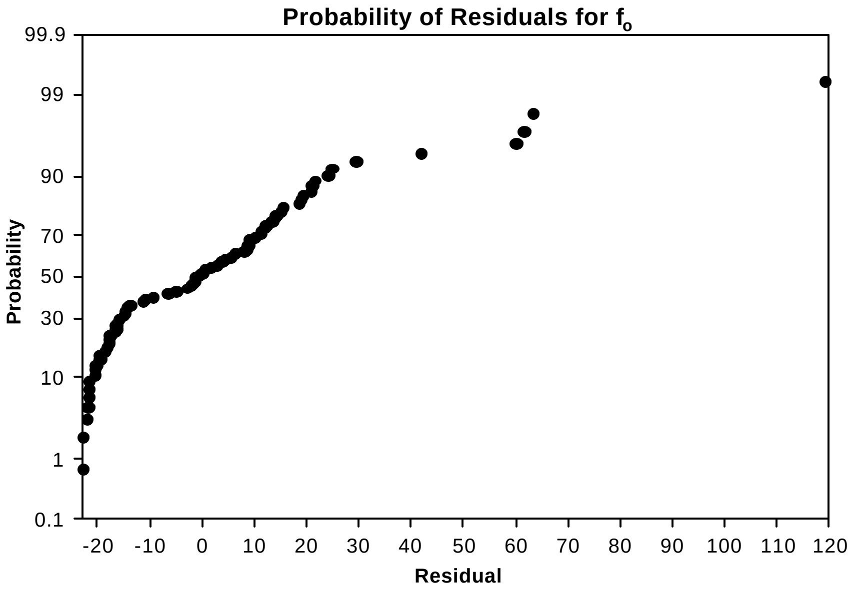


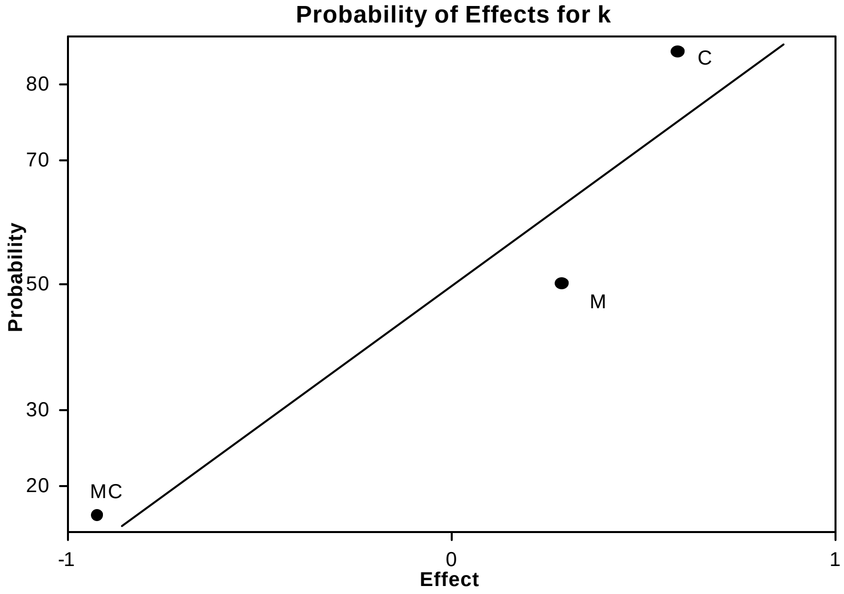
Figure E-3. Results of Factorial Analysis for k
Sand

Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error
+	+	1	11.07	3.67
+	-	2	9.60	3.84
-	+	3	8.65	3.70
-	-	4	12.37	3.06
		overall average	10.42	
		calculated polled S.E	3.58	

Factorial Group	sorted effects	rank	Prob
MC	-0.92	1	16.67
M	0.29	2	50.00
C	0.59	3	83.33

k = 10.42
k = 10.42

T	C	Calculated Values
+	+	10.42
+	-	10.42
-	+	10.42
-	-	10.42



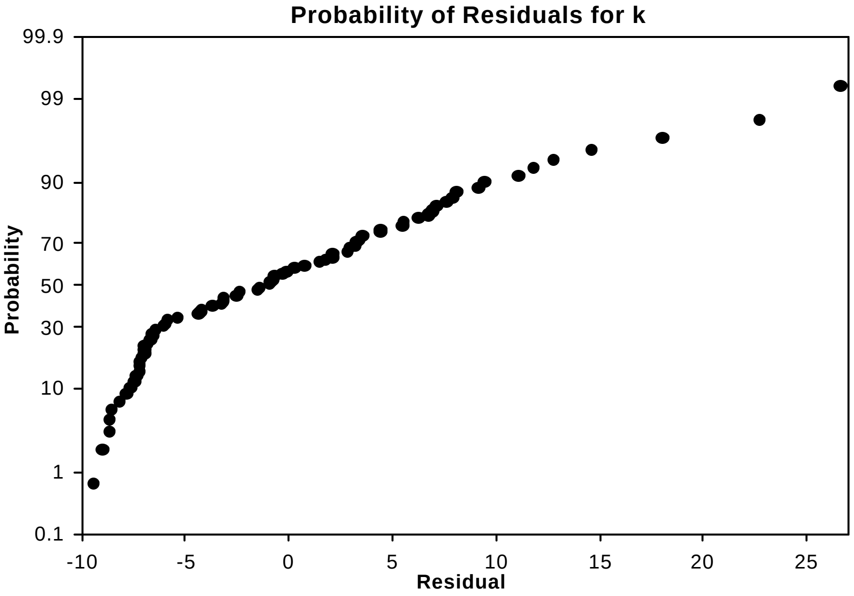


Figure E-4. Results of Factorial Analysis for Infiltration at 15 Minutes
Sand

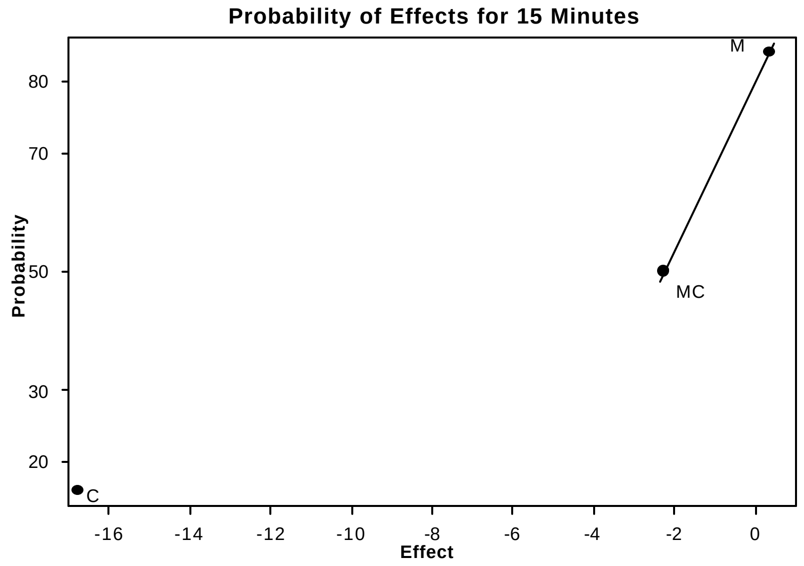
Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	1	5.67	4.91	18
+	-	2	24.71	4.21	12
-	+	3	7.60	3.17	21
-	-	4	22.06	4.87	24
		overall average	15.01		
		calculated polled S.E	4.35		

$f_{15\ min} = 15.01 \pm (C/2)$

$f_{15\ min} = 15.01 \pm (-16.75/2)$

Factorial Group	effects	rank	Prob
C	-16.75	1	16.67
MC	-2.28	2	50.00
M	0.36	3	83.33

M	C	Calculated Values
+	+	6.63
+	-	23.38
-	+	6.63
-	-	23.38


Probability of Effects for 15 Minutes

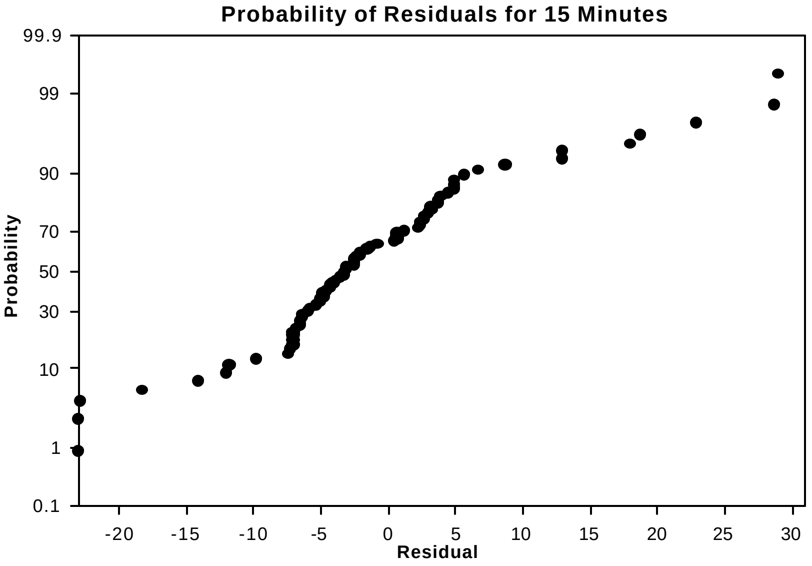

Probability of Residuals for 15 Minutes

Figure E-5. Results of Factorial Analysis for Infiltration at 30 Minutes
Sand

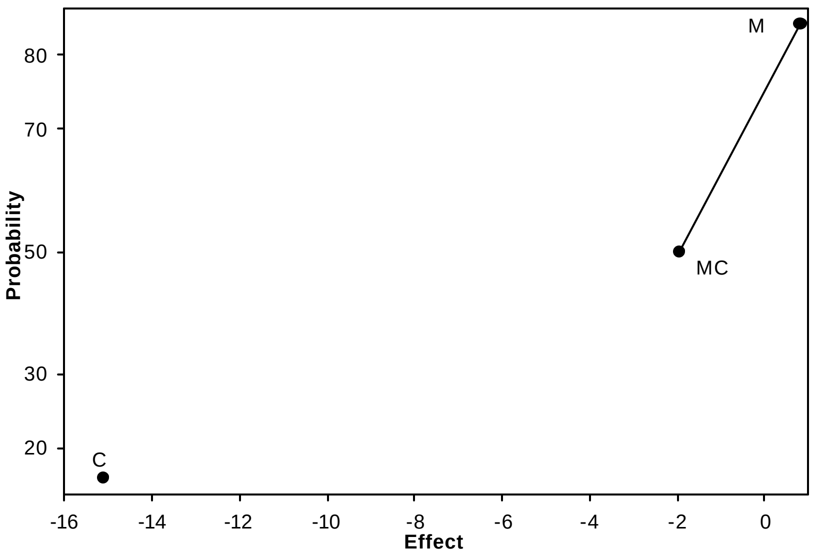
Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	1	4.33	3.83	18
+	-	2	21.36	3.24	12
-	+	3	5.43	2.57	21
-	-	4	18.59	4.27	24
		overall average	12.43		
		calculated polled S.E	3.53		

$f_{30\ min} = 12.43 \pm (C/2)$

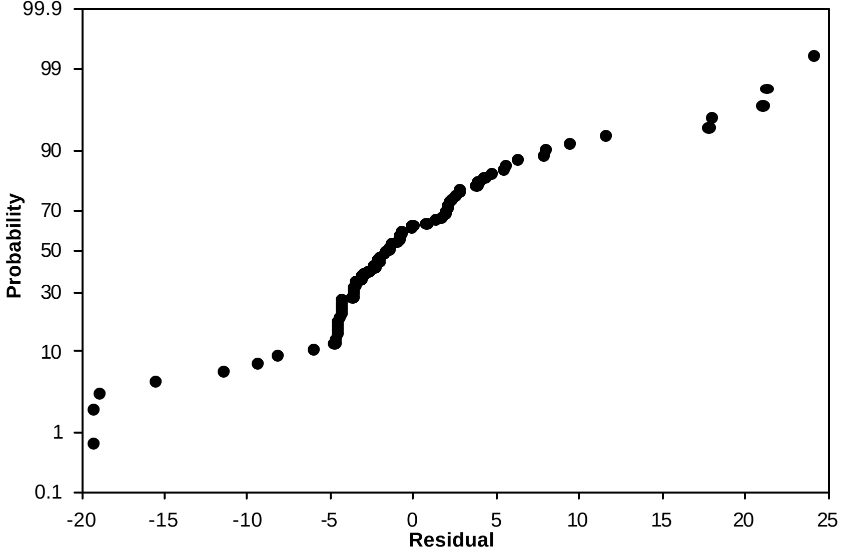
$f_{30\ min} = 12.43 \pm (-15.10/2)$

Factorial Group	effects	rank	Prob
C	-15.10	1	16.67
MC	-1.94	2	50.00
M	0.83	3	83.33

M	C	Calculated Values
+	+	4.88
+	-	19.98
-	+	4.88
-	-	19.98



Probability of Effects for 30 Minutes



Probability of Residuals for 30 Minutes

Figure E-6. Results of Factorial Analysis for Infiltration at 60 Minutes
Sand

Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	1	3.55	3.15	18
+	-	2	19.23	2.56	12
-	+	3	4.07	1.79	21
-	-	4	15.69	3.71	24
		overall average	10.64		
		calculated polled S.E	2.89		

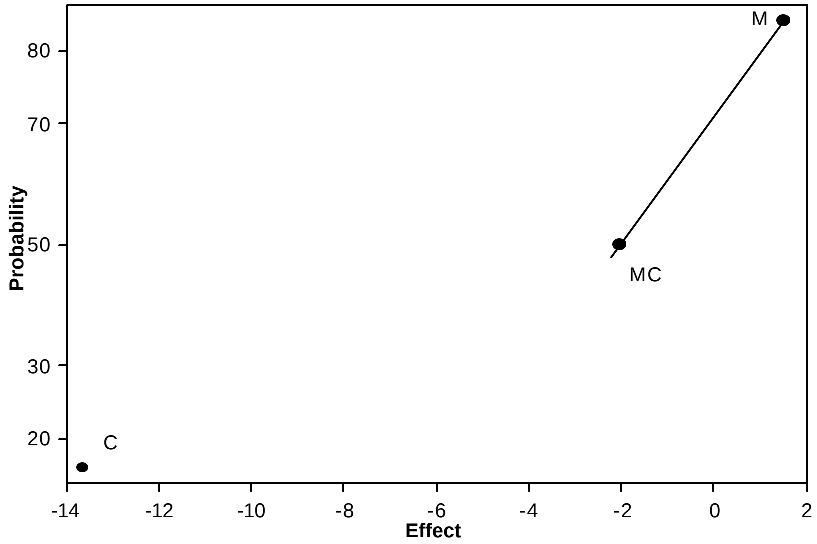
$f_{60\ min} = 10.64 \pm (C/2)$

$f_{60\ min} = 10.64 \pm (-13.65/2)$

Factorial Group	effects	rank	Prob
C	-13.65	1	16.67
MC	-2.03	2	50.00
M	1.52	3	83.33

M	C	Calculated Values
+	+	3.81
+	-	17.46
-	+	3.81
-	-	17.46

Probability of Effects for 60 Minutes



Probability of Residuals for 60 Minutes

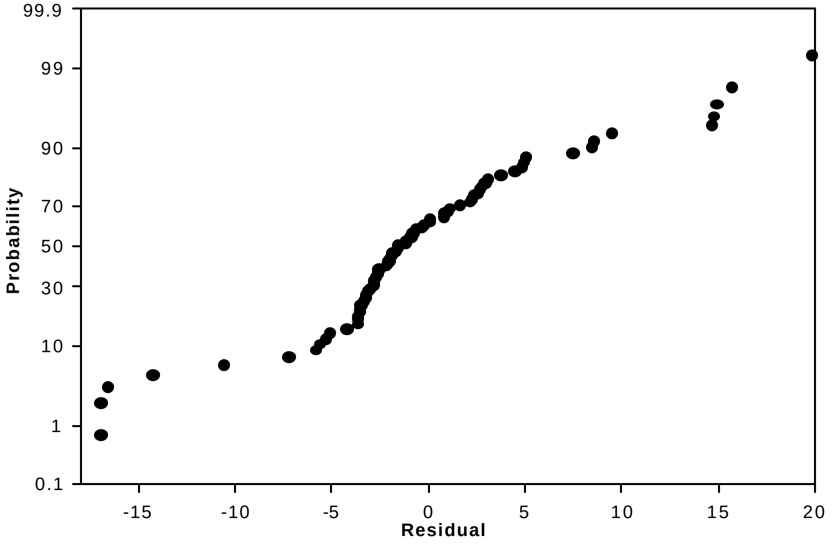


Figure E-7. Results of Factorial Analysis for Infiltration at 120 Minutes
Sand

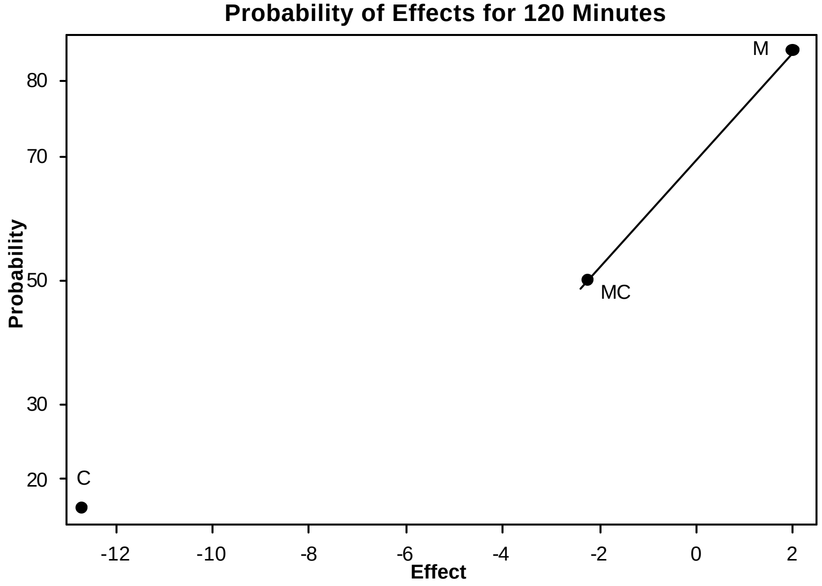
Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	1	2.89	2.65	18
+	-	2	17.82	1.94	12
-	+	3	3.12	1.42	21
-	-	4	13.57	3.33	24
		overall average	9.35		
		calculated polled S.E	2.44		

$f_{120\ min} = 9.35 \pm (C/2)$

$f_{120\ min} = 9.35 \pm (-12.69/2)$

Factorial Group	effects	rank	Prob
C	-12.69	1	16.67
MC	-2.23	2	50.00
M	2.01	3	83.33

M	C	Calculated Values
+	+	3.01
+	-	15.70
-	+	3.01
-	-	15.70


Probability of Effects for 120 Minutes

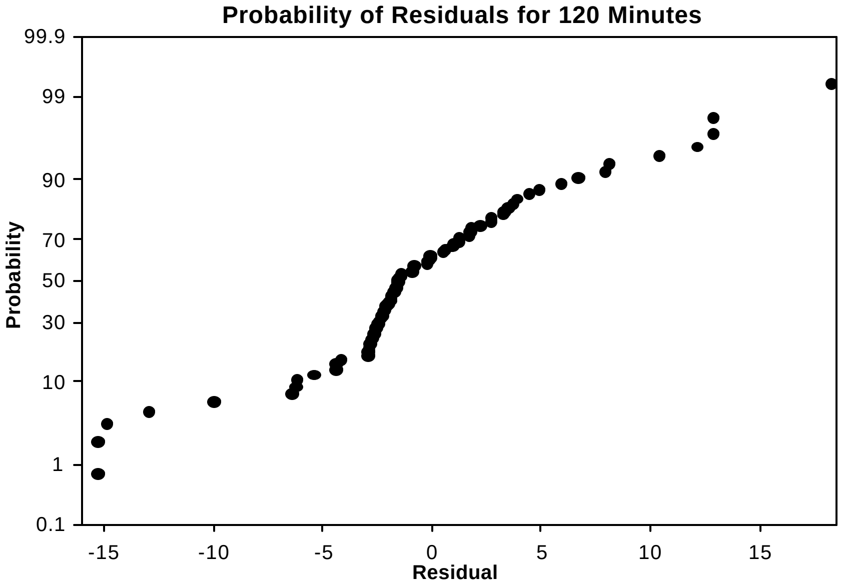

Probability of Residuals for 120 Minutes

Table E-1. Factorial Analysis for Infiltration Test - Sand

	M (Moisture)	C (Compaction)	Factorial Group	Observed f_c (in/hr)	Observed f_o (in/hr)	Observed k	Observed min 15	Observed min 30	Observed min 60	Observed min 120
OSWC-4C	+	+	1	0.8	5.0	3.9	8.0	6.3	6.9	5.8
OSWC-4B	+	+	1	0.9	8.2	7.3	5.0	4.1	3.1	2.8
OSWC-4A	+	+	1	0.2	6.5	9.5	36.5	26.0	18.5	13.5
OSWC-3C	+	+	1	4.2	31.9	18.1	0.5	0.4	0.3	0.2
OSWC-3B	+	+	1	1.9	24.6	23.2	0.5	0.4	0.3	0.2
OSWC-3A	+	+	1	3.5	31.6	16.0	0.5	0.4	0.3	0.3
OSWC-2C	+	+	1	0.6	13.4	28.5	1.0	0.6	0.5	0.4
OSWC-2B	+	+	1	1.0	8.5	13.9	0.5	0.3	0.3	0.2
OSWC-2A	+	+	1	3.1	30.9	14.0	2.5	1.4	0.8	0.5
OSWC-1C	+	+	1	0.3	4.4	1.8	3.3	2.0	1.3	0.9
OSWC-1B	+	+	1	1.3	7.1	3.2	0.8	0.5	0.4	0.4
OSWC-1A	+	+	1	0.4	6.4	3.9	2.5	1.9	1.3	1.0
NSWC-2C	+	+	1	0.8	5.3	3.5	30.5	26.3	23.8	21.3
NSWC-2B	+	+	1	0.9	7.7	4.5	1.6	1.3	1.3	1.2
NSWC-2A	+	+	1	0.9	6.5	3.8	1.0	0.6	0.6	0.6
NSWC-1C	+	+	1	3.9	22.8	10.7	0.1	0.2	0.2	0.3
NSWC-1B	+	+	1	4.1	34.1	18.5	1.1	0.6	0.6	0.6
NSWC-1A	+	+	1	5.5	34.3	14.9	6.3	4.9	3.6	2.2
OSWN-2C	+	-	2	0.7	16.3	19.9	12.5	11.9	11.7	11.6
OSWN-2B	+	-	2	3.0	27.3	13.7	17.0	16.4	15.6	15.6
OSWN-2A	+	-	2	9.3	52.3	3.5	14.5	14.0	13.3	13.8
OSWN-1C	+	-	2	0.8	3.4	12.6	28.3	23.9	20.2	18.0
OSWN-1B	+	-	2	0.6	5.0	22.3	27.3	22.6	20.3	18.5
OSWN-1A	+	-	2	0.3	0.1	3.1	28.0	22.4	20.4	19.3
NSWN-2C	+	-	2	0.5	8.1	2.3	22.3	19.1	16.9	15.7
NSWN-2B	+	-	2	0.6	2.3	12.2	23.5	20.0	18.3	17.0
NSWN-2A	+	-	2	1.1	2.3	8.9	25.5	21.8	20.1	19.0
NSWN-1C	+	-	2	0.6	3.4	3.7	33.0	28.0	25.0	21.7
NSWN-1B	+	-	2	0.5	6.2	6.8	27.5	24.8	22.0	20.2
NSWN-1A	+	-	2	0.1	4.7	6.2	37.3	31.6	27.0	23.7
OSDC-5C	-	+	3	0.3	2.6	16.0	36.3	29.1	19.6	15.2
OSDC-5B	-	+	3	0.1	1.3	9.7	8.3	5.8	4.7	3.7
OSDC-5A	-	+	3	0.3	1.3	5.1	2.8	1.5	1.1	0.8
OSDC-4C	-	+	3	0.2	1.3	11.9	12.5	9.3	7.6	6.4
OSDC-4B	-	+	3	0.1	1.1	6.2	10.0	7.0	6.2	4.8
OSDC-4A	-	+	3	0.1	0.8	3.2	10.3	6.9	6.1	4.8
OSDC-3C	-	+	3	9.5	86.1	9.1	5.0	3.3	2.3	1.6
OSDC-3B	-	+	3	2.3	22.4	14.9	5.0	3.5	2.3	1.6
OSDC-3A	-	+	3	5.4	64.7	37.1	4.3	2.9	2.0	1.4
OSDC-2C	-	+	3	20.0	42.2	3.0	4.5	2.9	1.9	1.2
OSDC-2B	-	+	3	24.2	47.7	2.6	5.5	4.1	3.0	2.2
OSDC-2A	-	+	3	24.6	51.8	3.4	4.0	3.1	2.2	1.4
OSDC-1C	-	+	3	14.7	29.9	1.5	10.3	7.0	6.0	4.0
OSDC-1B	-	+	3	15.6	30.8	1.8	3.0	2.3	1.7	1.2
OSDC-1A	-	+	3	15.0	32.6	1.0	2.3	1.5	1.1	0.8
NSDC-2C	-	+	3	6.9	25.6	3.5	10.0	6.9	5.0	4.3
NSDC-2B	-	+	3	7.2	25.5	4.6	5.3	3.5	2.8	2.3
NSDC-2A	-	+	3	5.1	22.0	1.9	9.8	7.1	5.5	4.8
NSDC-1C	-	+	3	15.2	40.8	18.4	2.8	1.4	0.8	0.5
NSDC-1B	-	+	3	15.9	41.1	13.3	4.3	2.6	1.8	1.3
NSDC-1A	-	+	3	14.8	39.2	13.4	3.8	2.6	1.8	1.3
OSDN-4C	-	-	4	9.6	88.6	9.6	27.5	24.0	22.4	20.7
OSDN-4B	-	-	4	2.3	25.4	17.6	31.0	27.9	26.1	23.9
OSDN-4A	-	-	4	4.4	13.2	2.8	12.3	10.6	10.3	10.3
OSDN-3C	-	-	4	12.1	146.1	25.1	1.3	0.8	0.6	0.5
OSDN-3B	-	-	4	8.8	48.1	7.2	1.3	0.8	0.6	0.5
OSDN-3A	-	-	4	0.4	4.2	7.3	25.0	19.4	14.7	11.4
OSDN-2C	-	-	4	9.7	35.7	17.2	25.0	19.4	14.7	11.4
OSDN-2B	-	-	4	14.0	27.7	3.2	29.3	22.9	17.6	14.2
OSDN-2A	-	-	4	21.2	40.4	16.7	29.3	22.9	17.6	14.2
OSDN-1C	-	-	4	10.1	24.1	21.5	10.3	8.6	6.9	5.8
OSDN-1B	-	-	4	22.1	36.1	4.0	6.0	4.5	3.3	2.8
OSDN-1A	-	-	4	19.9	87.1	33.2	37.3	26.4	18.5	13.5
NSDN-4C	-	-	4	19.5	42.0	6.1	1.5	1.1	0.9	0.9
NSDN-4B	-	-	4	19.0	48.6	11.2	21.3	18.0	16.6	15.7
NSDN-4A	-	-	4	19.0	42.5	4.4	22.8	18.8	17.2	16.8
NSDN-3C	-	-	4	18.0	38.9	10.4	20.0	16.9	16.4	16.3
NSDN-3B	-	-	4	16.0	37.1	10.1	18.0	15.8	12.4	9.3
NSDN-3A	-	-	4	14.5	33.4	8.1	20.3	15.8	11.9	9.6

Table E-1. Factorial Analysis for Infiltration Test – Sand (Continued)

	M (Moisture)	C (Compaction)	Factorial Group	Observed f_c (in/hr)	Observed f_0 (in/hr)	Observed k	Observed min 15	Observed min 30	Observed min 60	Observed min 120
NSDN-2C	-	-	4	18.0	51.1	12.6	18.5	15.5	12.3	9.5
NSDN-2B	-	-	4	17.1	45.5	9.8	30.0	29.5	25.9	22.4
NSDN-2A	-	-	4	16.1	45.9	7.9	28.8	25.6	22.6	19.6
NSDN-1C	-	-	4	13.7	16.1	13.7	28.0	25.5	22.4	19.5
NSDN-1B	-	-	4	15.4	24.8	19.6	43.0	38.0	32.4	28.6
NSDN-1A	-	-	4	11.5	15.6	17.4	42.3	37.9	32.3	28.6

group statistics	f_c (in/hr)	f_0 (in/hr)	k	min 15	min 30	min 60	min 120
1 average	1.9	16.1	11.1	5.7	4.3	3.6	2.9
1 std error	0.8	5.6	3.7	4.9	3.8	3.1	2.6
1 number	18.0	18.0	18.0	18.0	18.0	18.0	18.0
2 average	1.5	10.9	9.6	24.7	21.4	19.2	17.8
2 std error	1.5	8.7	3.8	4.2	3.2	2.6	1.9
2 number	12.0	12.0	12.0	12.0	12.0	12.0	12.0
3 average	9.4	29.1	8.6	7.6	5.4	4.1	3.1
3 std error	3.6	10.1	3.7	3.2	2.6	1.8	1.4
3 number	21.0	21.0	21.0	21.0	21.0	21.0	21.0
4 average	13.9	42.4	12.4	22.1	18.6	15.7	13.6
4 std error	2.4	12.1	3.1	4.9	4.3	3.7	3.3
4 number	24.0	24.0	24.0	24.0	24.0	24.0	24.0

		f_c (in/hr)	f_o (in/hr)	k	min 15	min 30	min 60	min 120
	overall averag	6.7	24.6	10.4	15.0	12.4	10.6	9.4
	total obs	75.0	75.0	75.0	75.0	75.0	75.0	75.0
	calc. polled S.	2.3	9.4	3.6	4.3	3.5	2.9	2.4
	based on averages of replicates							
Moisture	M	-9.9	-22.2	-0.2	0.4	0.8	1.5	2.0
Compaction	C	-2.0	-4.1	-1.1	-16.8	-15.1	-13.7	-12.7
moisture x compaction	MC	2.4	9.2	2.6	-2.3	-1.9	-2.0	-2.2

Appendix F
Factorial Results for Clay Soil Infiltration Tests

List of Tables and Figures in Appendix F:

Figure F-1. Results of Factorial Analysis for f_o
Clay

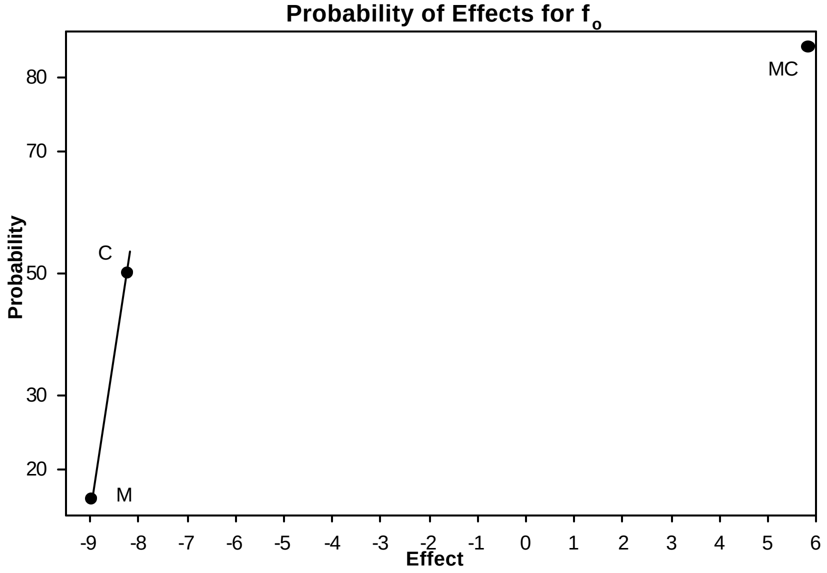
Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	1	1.59	0.78	18
+	-	2	3.95	3.48	27
-	+	3	4.70	2.55	15
-	-	4	18.76	7.38	17
		overall average	7.25		77
		calculated polled S.E	4.29		

$f_o = 7.25 \pm (MC/2)$

$f_o = 7.25 \pm (5.85/2)$

Factorial Group	effects	rank	Prob
M	-8.96	1	16.67
C	-8.21	2	50.00
MC	5.85	3	83.33

M	C	Calculated Values
+	+	10.18
+	-	4.33
-	+	4.33
-	-	10.18



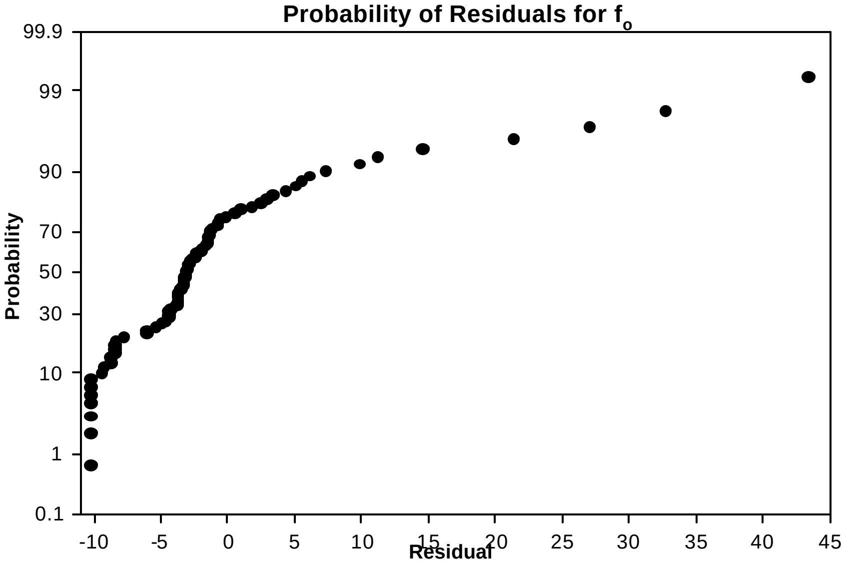


Figure F-2. Results of Factorial Analysis for f_c
Clay

Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	1	0.23	0.13	18
+	-	2	0.42	0.50	27
-	+	3	0.60	0.36	15
-	-	4	7.78	3.99	17
		overall average	2.26		77
		calculated polled S.E	2.02		

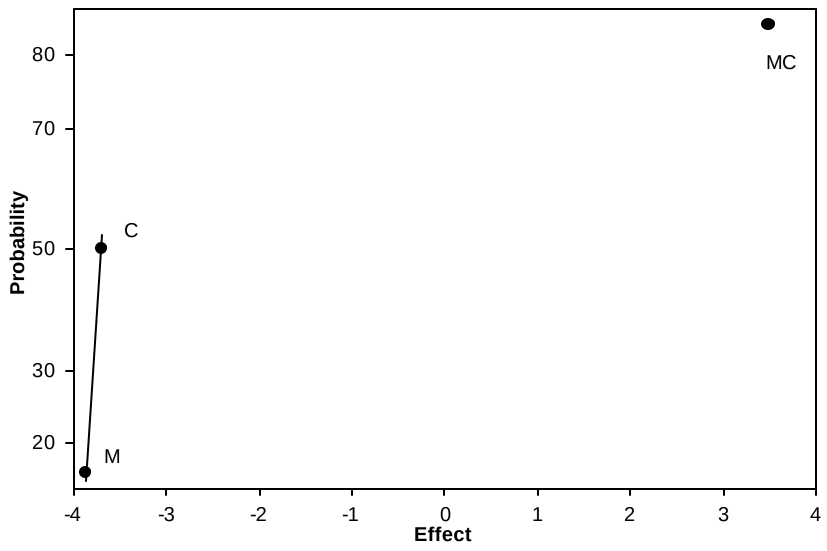
$f_c = 2.26 \pm (MC/2)$

$f_c = 2.26 \pm (3.49/2)$

Factorial Group	effects	rank	Prob
M	-3.86	1	16.67
C	-3.69	2	50.00
MC	3.49	3	83.33

M	C	Calculated Values
+	+	4.00
+	-	0.51
-	+	0.51
-	-	4.00

Probability of Effects for f_c



Probability of Residuals for f_c

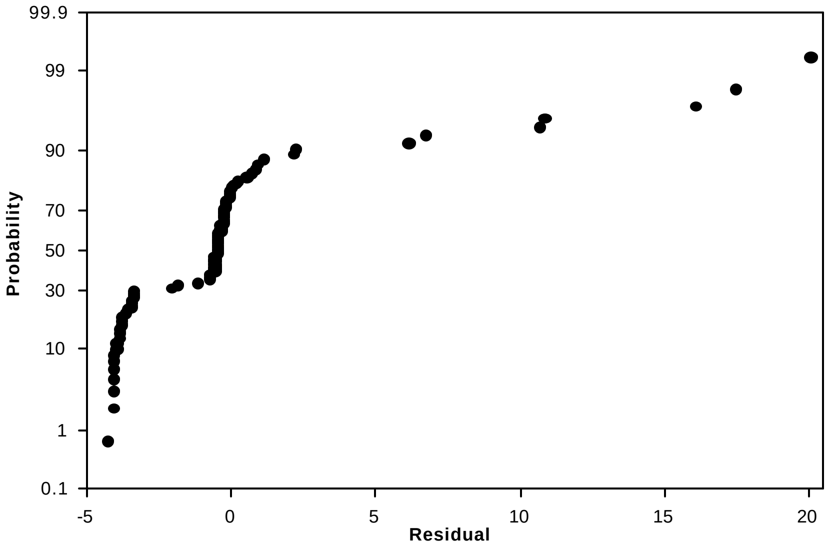


Figure F-3. Results of Factorial Analysis for k
Clay

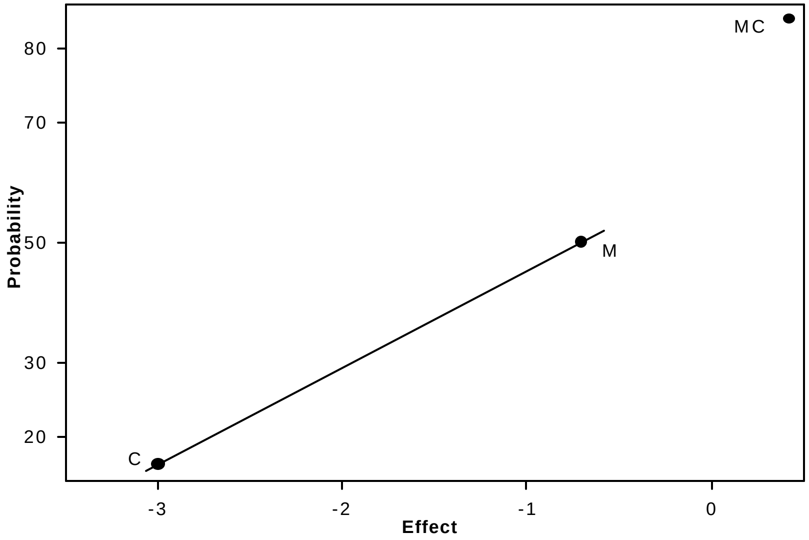
Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	1	4.33	3.33	18
+	-	2	6.87	3.60	27
-	+	3	4.61	1.14	15
-	-	4	8.02	3.86	17
		overall average	5.96		77
		calculated polled S.E	3.17		

k = 5.96 ± (MC/2)
k = 5.96 ± (0.43/2)

	effects sorted	rank	Prob
C	-2.99	1	16.67
M	-0.70	2	50.00
MC	0.43	3	83.33

M	C	Calculated Values
+	+	6.17
+	-	5.74
-	+	5.74
-	-	6.17

Probability of Effects for k



Probability of Residuals for k

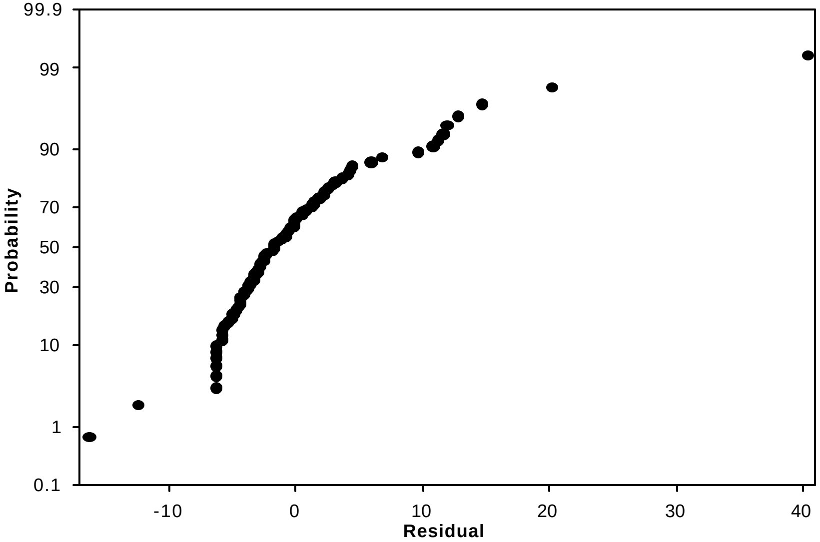


Figure F-4. Results of Factorial Analysis for Infiltration at 15 Minutes
Clay

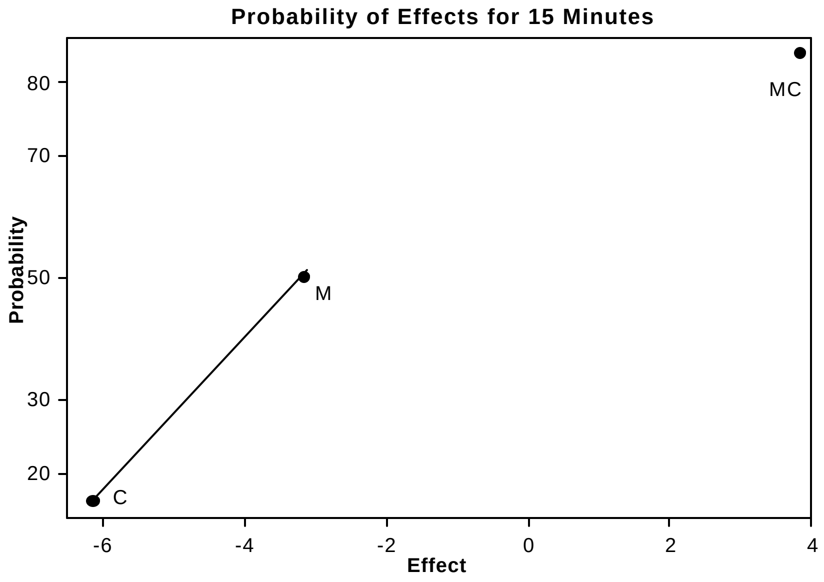
Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	1	1.51	0.70	18
+	-	2	3.79	2.07	27
-	+	3	0.82	0.29	15
-	-	4	10.78	5.21	17
		overall average	4.22		77
		calculated polled S.E	2.83		

$f_{15\ min} = 4.22 \pm (MC/2)$

$f_{15\ min} = 4.22 + (3.84/2)$

	effects	rank	Prob
C	-6.12	1	16.67
M	-3.15	2	50.00
MC	3.84	3	83.33

M	C	Calculated Values
+	+	6.14
+	-	2.30
-	+	2.30
-	-	6.14



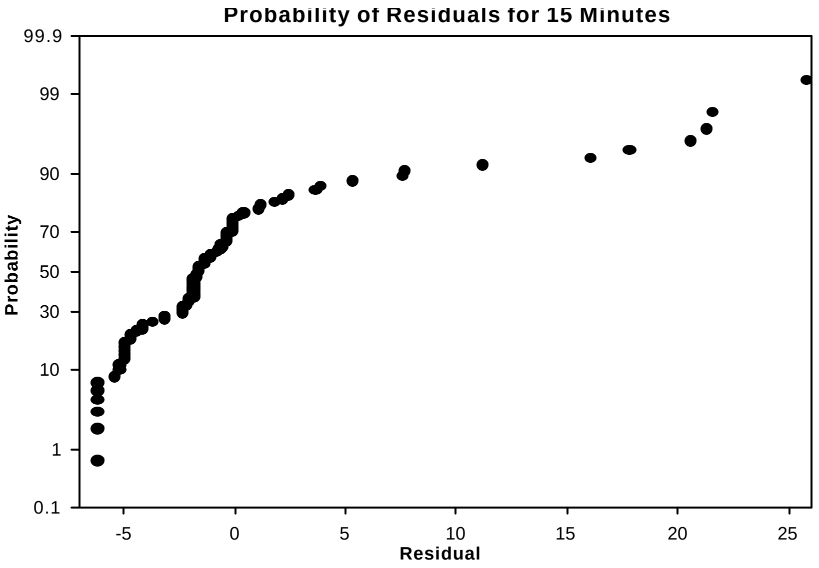


Figure F-5. Results for Factorial Analysis for Infiltration at 30 Minutes
Clay

Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	1	1.16	0.51	18
+	-	2	2.81	1.74	27
-	+	3	0.68	0.24	15
-	-	4	9.15	4.55	18
		overall average	3.45		78
		calculated polled S.E	2.45		

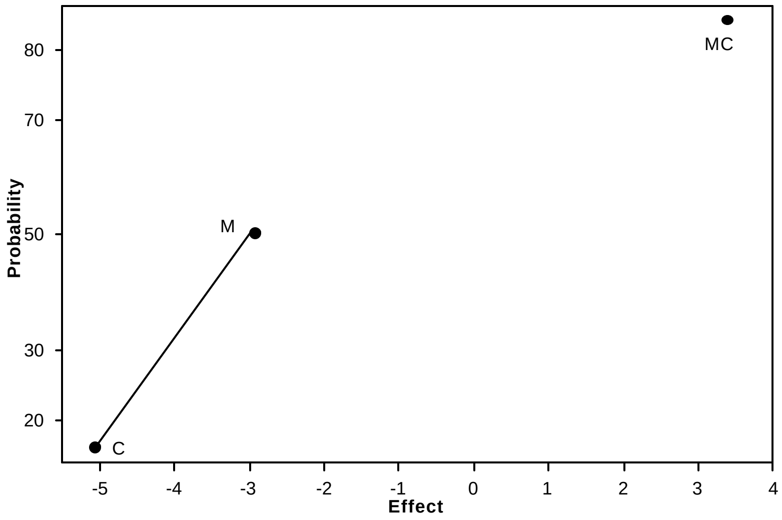
$f_{30\ min} = 3.45 \pm (MC/2)$

$f_{30\ min} = 3.45 + (3.41/2)$

	effects	rank	Prob
C	-5.06	1	16.67
M	-2.92	2	50.00
MC	3.41	3	83.33

M	C	Calculated Values
+	+	5.15
+	-	1.74
-	+	1.74
-	-	5.15

Probability of Effects for 30 Minutes



Probability of Residuals for 30 Minutes

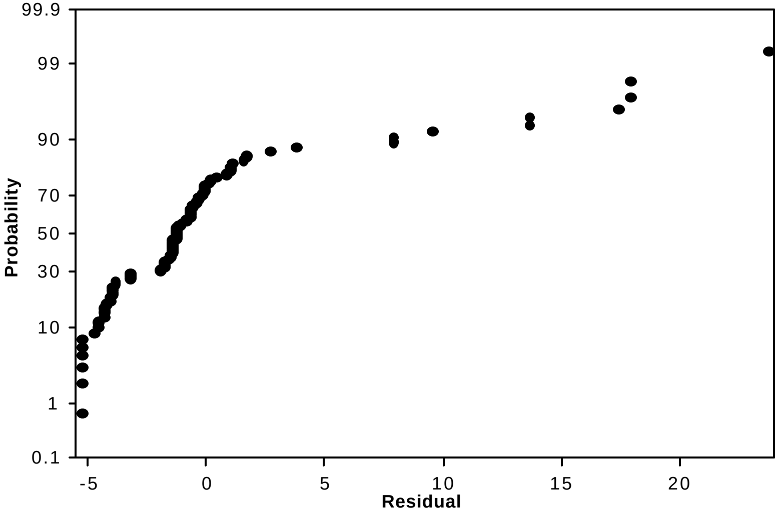


Figure F-6. Results of Factorial Analysis for Infiltration at 60 Minutes
Clay

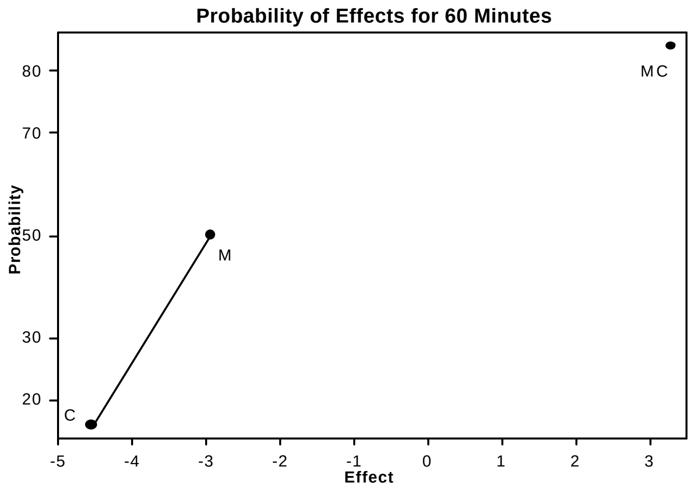
Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	1	0.90	0.42	18
+	-	2	2.13	1.41	27
-	+	3	0.53	0.19	15
-	-	4	8.34	4.33	18
		overall average	2.97		78
		calculated polled S.E	2.45		

	effects	rank	Prob
C	-4.53	1	16.67
M	-2.92	2	50.00
MC	3.29	3	83.33

$f_{60\ min} = 2.97 \pm (MC/2)$

$f_{15\ min} = 2.97 + (3.29/2)$

M	C	Calculated Values
+	+	4.62
+	-	1.33
-	+	1.33
-	-	4.62



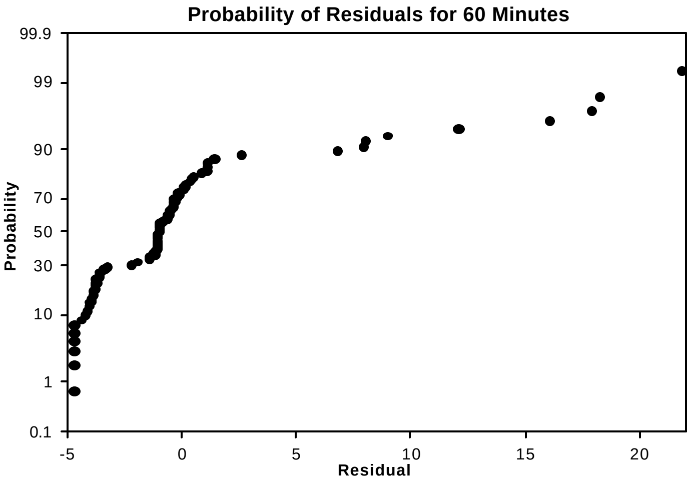


Figure F-7. Results of Factorial Analysis for Infiltration at120 Minutes
Clay

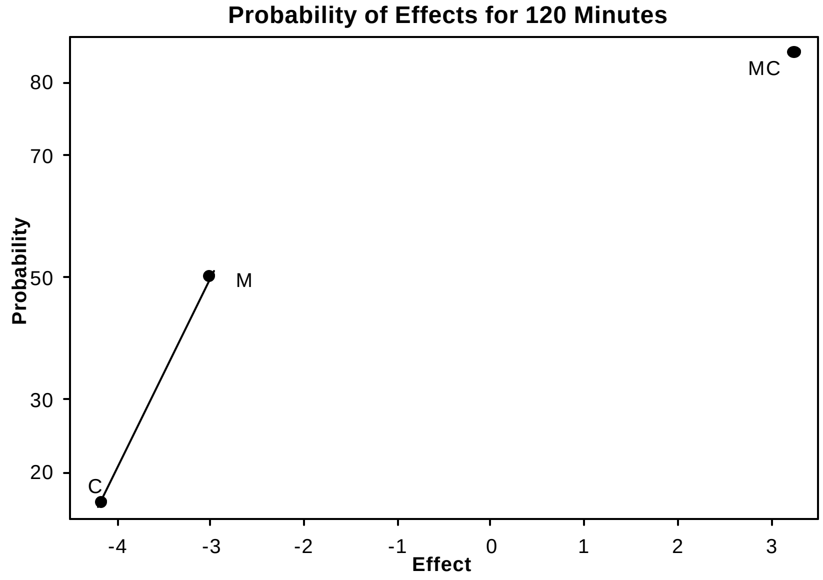
Moisture (Wet=+/Dry=-)	Compacted (Yes=+/No=-)	Factorial Group	Average	Standard Error	Number
+	+	1	0.64	0.42	18
+	-	2	1.55	1.41	27
-	+	3	0.40	0.19	15
-	-	4	7.81	4.33	18
		overall average	2.60		78
		calculated polled S.E	2.45		

	effects	rank	Prob
C	-4.16	1	16.67
M	-3.01	2	50.00
MC	3.25	3	83.33

$f_{120\ min}$ = 2.60 ± (MC/2)

$f_{120\ min}$ = 2.60 ± (3.25/2)

M	C	Calculated Values
+	+	4.22
+	-	0.97
-	+	0.97
-	-	4.22



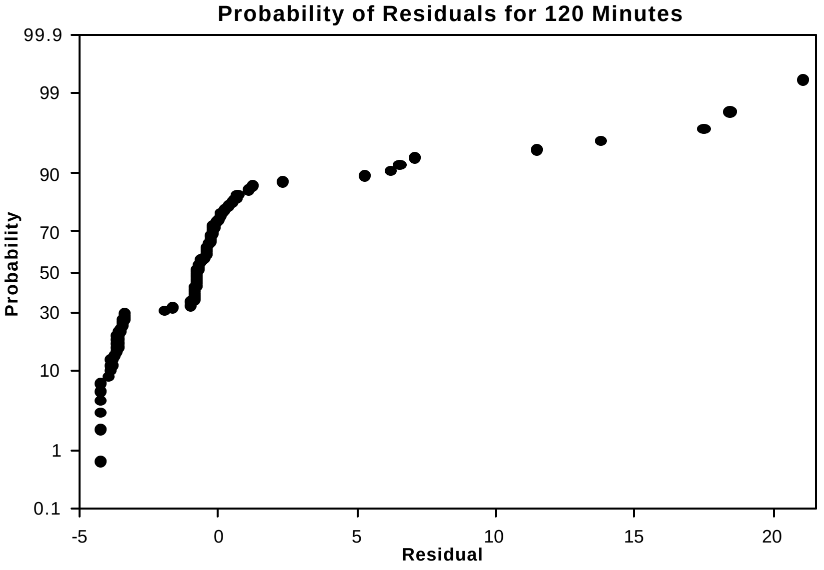


Table F-1. Factorial Analysis for Infiltration Test
Clay

	M (Moisture)	C (Compaction)	Factorial Group	f_c (in/hr)	f_o (in/hr)	k	min 15	min 30	min 60	min 120
NCWC1A	+	+	1	0.0	0.0	0.0	0.3	0.4	0.3	0.2
NCWC1B	+	+	1	0.0	0.0	0.0	0.5	0.5	0.4	0.2
NCWC1C	+	+	1	0.0	0.0	0.0	0.5	0.3	0.2	0.1
NCWC2A	+	+	1	0.2	4.2	6.2	0.3	0.4	0.3	0.2
NCWC2B	+	+	1	0.3	1.5	6.1	0.5	0.5	0.4	0.2
NCWC2C	+	+	1	0.1	1.5	2.3	0.5	0.3	0.2	0.1
OCWC1A	+	+	1	0.0	0.0	0.0	0.5	0.5	0.4	0.3
OCWC1B	+	+	1	0.0	0.0	0.0	1.0	0.8	0.6	0.4
OCWC1C	+	+	1	0.0	0.0	0.0	0.8	0.4	0.3	0.2
OCWC2A	+	+	1	0.5	4.2	17.9	1.5	1.1	1.0	0.8
OCWC2B	+	+	1	-0.2	0.8	0.5	1.3	1.0	0.8	0.6
OCWC2C	+	+	1	0.3	1.8	1.9	1.8	1.1	0.9	0.7
OCWC3A	+	+	1	0.7	5.6	26.5	1.8	1.4	1.0	0.8
OCWC3B	+	+	1	0.6	1.8	7.1	6.3	4.5	4.0	3.3
OCWC3C	+	+	1	0.4	1.9	1.9	2.0	1.5	1.2	0.9
OCWC4A	+	+	1	0.7	1.8	3.8	2.3	1.8	1.3	0.8
OCWC4B	+	+	1	0.2	1.0	0.6	3.5	2.9	1.8	1.1
OCWC4C	+	+	1	0.3	2.5	3.1	2.3	1.8	1.1	0.7
NCWN1A	+	-	2	0.0	0.0	7.7	1.0	0.5	0.3	0.2
NCWN1B	+	-	2	0.0	0.0	0.0	2.3	1.5	1.1	0.7
NCWN1C	+	-	2	0.0	0.0	0.0	13.5	11.4	9.4	7.5
NCWN2A	+	-	2	0.3	5.4	46.2	2.0	1.4	0.9	0.6
NCWN2B	+	-	2	0.2	6.9	3.4	1.0	0.9	0.8	0.6
NCWN2C	+	-	2	0.3	2.9	2.5	1.5	1.1	0.9	0.8
OCWN1A	+	-	2	6.7	47.8	20.5	0.0	0.0	0.0	0.0
OCWN1B	+	-	2	0.5	8.7	17.1	0.0	0.0	0.0	0.0
OCWN1C	+	-	2	0.1	2.1	8.4	0.0	0.0	0.3	0.2
OCWN2A	+	-	2	0.1	1.2	8.7	1.3	0.9	0.6	0.4
OCWN2B	+	-	2	-0.6	0.7	0.5	1.3	0.6	0.3	0.4
OCWN2C	+	-	2	-0.2	0.6	0.8	2.5	1.3	0.8	0.5
OCWN3A	+	-	2	0.0	1.3	8.1	0.0	0.0	0.0	0.0
OCWN3B	+	-	2	0.0	1.3	8.1	0.0	0.0	0.0	0.0
OCWN3C	+	-	2	0.0	0.9	6.4	0.0	0.0	0.0	0.0
OCWN4A	+	-	2	0.1	1.1	5.4	3.0	2.0	1.3	0.9
OCWN4B	+	-	2	1.4	3.2	3.1	3.0	2.0	1.4	0.9
OCWN4C	+	-	2	1.1	3.7	7.2	11.5	13.1	12.6	10.5
OCWN5A	+	-	2	0.3	4.3	3.5	1.0	0.5	0.5	0.3
OCWN5B	+	-	2	0.3	6.2	12.6	4.0	2.0	1.1	0.6
OCWN5C	+	-	2	-0.2	2.4	0.9	24.0	18.9	13.7	9.5
OCWN6A	+	-	2	0.4	1.0	4.2	10.0	5.6	2.8	1.5
OCWN6B	+	-	2	0.1	1.5	1.3	4.8	2.6	1.8	1.1
OCWN6C	+	-	2	0.2	1.4	1.5	2.3	1.3	0.9	0.6
OCWN7A	+	-	2	0.1	0.7	2.8	4.5	3.4	2.5	1.7
OCWN7B	+	-	2	0.1	0.7	1.8	6.0	3.5	2.3	1.4
OCWN7C	+	-	2	0.1	0.7	2.9	2.0	1.6	1.3	0.8
NCDC1A	-	+	3	0.4	2.8	2.6	0.5	0.4	0.3	0.2
NCDC1B	-	+	3	0.7	2.9	4.1	0.5	0.5	0.3	0.3
NCDC1C	-	+	3	1.3	9.9	9.5	0.5	0.4	0.3	0.2
NCDC2A	-	+	3	0.3	3.1	4.8	1.0	1.0	0.8	0.6
NCDC2B	-	+	3	0.5	7.8	5.7	0.8	0.6	0.4	0.4

Table F-1. Factorial Analysis for Infiltration Test
Clay (Continued)

	M (Moisture)	C (Compaction)	Factorial Group	f_c (in/hr)	f_o (in/hr)	k	min 15	min 30	min 60	min 120
NCDC2C	-	+	3	0.0	19.0	6.4	1.3	1.1	0.9	0.6
OCDC1A	-	+	3	0.8	3.6	7.3	1.8	1.3	1.1	0.8
OCDC1B	-	+	3	2.8	9.5	5.9	1.3	0.9	0.7	0.6
OCDC1C	-	+	3	0.6	2.5	4.0	1.3	1.1	0.9	0.7
OCDC2A	-	+	3	0.5	2.9	5.1	1.5	1.3	0.9	0.7
OCDC2B	-	+	3	0.4	1.7	3.0	0.8	0.6	0.6	0.4
OCDC2C	-	+	3	0.3	1.6	1.2	1.3	1.0	0.8	0.6
OCDC3A	-	+	3	0.1	1.1	5.2	0.0	0.0	0.0	0.0
OCDC3B	-	+	3	0.1	1.4	2.3	0.0	0.0	0.0	0.0
OCDC3C	-	+	3	0.2	0.7	2.1	0.0	0.0	0.0	0.0
NCDN1A	-	-	4	6.2	37.3	4.6	2.0	1.9	1.6	1.0
NCDN1B	-	-	4	0.1	17.6	15.9	2.0	1.3	0.8	0.5
NCDN1C	-	-	4	0.2	4.9	19.1	2.8	2.0	1.4	0.8
NCDN2A	-	-	4				2.3	1.8	1.5	1.3
NCDN2B	-	-	4	0.6	9.7	12.2	2.5	2.3	1.9	1.6
NCDN2C	-	-	4	0.6	7.9	10.7	0.8	0.4	0.3	0.2
OCDN1A	-	-	4	14.9	31.6	2.6	5.5	4.5	3.8	3.6
OCDN1B	-	-	4	21.5	21.5	-6.2	22.3	18.9	16.8	15.8
OCDN1C	-	-	4	20.1	20.1	-10.0	32.0	29.0	26.5	25.3
OCDN2A	-	-	4	10.8	16.4	4.9	4.5	3.3	2.5	2.3
OCDN2B	-	-	4	5.0	13.2	10.6	4.5	3.6	2.8	2.6
OCDN2C	-	-	4	5.2	10.8	10.4	2.0	1.4	1.1	0.8
OCDN3A	-	-	4	0.7	7.0	17.1	7.3	6.3	5.8	5.5
OCDN3B	-	-	4	2.2	5.3	3.7	8.0	6.3	5.8	5.3
OCDN3C	-	-	4	2.0	6.0	5.5	13.8	13.1	11.5	11.3
OCDN4A	-	-	4	24.1	43.0	7.6	27.8	22.6	22.9	21.8
OCDN4B	-	-	4	14.7	57.8	18.2	27.5	23.1	22.6	22.7
OCDN4C	-	-	4	3.3	8.9	9.4	26.8	23.1	20.8	18.0

group statistics	f_c (in/hr)	f_o (in/hr)	k	min 15	min 30	min 60	min 120
1 average	0.2	1.6	4.3	1.5	1.2	0.9	0.6
1 std error	0.1	0.8	3.3	0.7	0.5	0.4	0.3
1 number	18.0	18.0	18.0	18.0	18.0	18.0	18.0
2 average	0.4	4.0	6.9	3.8	2.8	2.1	1.5
2 std error	0.5	3.5	3.6	2.1	1.7	1.4	1.1
2 number	27.0	27.0	27.0	27.0	27.0	27.0	27.0
3 average	0.6	4.7	4.6	0.8	0.7	0.5	0.4
3 std error	0.4	2.5	1.1	0.3	0.2	0.2	0.1
3 number	15.0	15.0	15.0	15.0	15.0	15.0	15.0
4 average	7.8	18.8	8.0	10.8	9.1	8.3	7.8
4 std error	4.0	7.4	3.9	5.2	4.6	4.3	4.2
4 number	17.0	17.0	17.0	18.0	18.0	18.0	18.0

Table F-1. Factorial Analysis for Infiltration Test
Clay (Continued)

		f_c (in/hr)	f_o (in/hr)	k	min 15	min 30	min 60	min 120
overall averag		2.3	7.3	6.0	4.2	3.4	3.0	2.6
total obs		77.0	77.0	77.0	78.0	78.0	78.0	78.0
calc. polled S.E.		2.0	4.3	3.2	2.8	2.5	2.3	2.2
based on averages of replicates								
Moisture	M	-3.9	-9.0	-0.7	-3.1	-2.9	-2.9	-3.0
Compaction	C	-3.7	-8.2	-3.0	-6.1	-5.1	-4.5	-4.2
moisture x compaction	MC	3.5	5.9	0.4	3.8	3.4	3.3	3.2

Appendix G

Surface Runoff and Subsurface Flow Water Quality at Soil and Composted-Amended Soil Test Sites

Table G-1. Observed Water Quality of Collected Samples from Compost-Amended Soil and Soil Sites

Date	Site	tmt	type	PO4-P	Hydr P	TOT-P	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
			quantification limit	0.03	0.010	0.010	0.03	0.010	0.010	0.03	0.04	0.02	0.10	0.10	0.17	0.003	0.03	0.007	0.02
			detection limit	0.01	0.003	0.003	0.01	0.003	0.003	0.01	0.01	0.01	0.03	0.03	0.05	0.001	0.01	0.002	0.01
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
12/18/97	Urban Hort	precip	precip	ND	ND	TR	0.45	ND	0.03	0.91	0.61	0.22	ND	ND	TR	ND	0.23	0.01	0.02
12/18/97	Urban Hort	no-comp	lower	ND	ND	TR	0.02	ND	0.05	0.58	2.18	ND	2.07	ND	TR	0.01	6.44	0.01	0.03
12/18/97	Urban Hort	comp	lower	0.41	0.18	0.73	0.02	ND	0.69	1.81	0.66	2.59	11.16	ND	TR	0.07	24.07	0.01	0.05
12/18/97	Urban Hort	no-comp	lower	ND	ND	TR	0.02	ND	ND	0.68	1.49	0.07	0.88	ND	ND	0.01	9.10	0.01	0.03
12/18/97	Urban Hort	comp	lower	1.19	1.31	1.98	0.02	ND	0.03	1.83	1.51	0.41	1.31	ND	TR	0.01	16.27	0.01	0.03
12/18/97	Urban Hort	no-comp	upper	0.16	0.13	0.44	0.30	ND	0.50	1.68	1.61	0.62	48.69	ND	TR	0.10	5.13	0.01	0.03
12/18/97	Urban Hort	comp	upper	0.38	0.22	0.65	1.94	ND	0.30	2.24	0.87	0.37	0.57	ND	ND	0.00	1.34	0.01	0.02
12/18/97	Urban Hort	no-comp	upper	ND	ND	TR	0.11	ND	0.03	0.70	1.51	0.08	0.87	ND	ND	0.01	5.22	0.01	0.02
12/18/97	Urban Hort	comp	upper	0.62	0.50	0.80	0.26	ND	0.83	1.26	1.01	0.34	0.70	ND	TR	0.01	1.94	0.01	0.02
12/18/97	Woodmoor	no-comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Woodmoor	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Woodmoor	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Woodmoor	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Timbercrest	no-comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Timbercrest	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Timbercrest	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Woodmoor	precip	precip	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

Date	Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
			quantification limit	0.013	0.07	1.33	0.13	0.003	0.023	0.33	0.010	0.13	0.10	0.10	0.10	0.007	0.07	0.01
			detection limit	0.004	0.02	0.40	0.04	0.001	0.007	0.10	0.003	0.04	0.03	0.03	0.03	0.002	0.02	0.00
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
12/18/97	Urban Hort	precip	precip	ND	ND	1.69	TR	TR	ND	0.80	ND	TR	ND	0.38	TR	0.02	0.12	TR
12/18/97	Urban Hort	no-comp	lower	ND	1.20	2.76	3.36	0.02	TR	3.06	TR	TR	ND	0.20	0.12	0.01	11.54	0.01
12/18/97	Urban Hort	comp	lower	0.03	6.21	18.77	7.86	0.10	TR	2.33	0.02	0.73	ND	4.06	0.21	0.05	28.11	0.01
12/18/97	Urban Hort	no-comp	lower	ND	0.78	4.61	5.31	0.04	ND	3.40	TR	TR	ND	0.29	TR	0.02	9.12	TR
12/18/97	Urban Hort	comp	lower	0.05	3.61	2.86	5.63	0.87	ND	1.96	0.04	1.98	ND	1.68	0.14	0.04	16.38	0.01
12/18/97	Urban Hort	no-comp	upper	ND	10.85	3.22	6.91	0.04	ND	9.59	ND	0.44	ND	1.09	0.53	0.44	112.77	TR
12/18/97	Urban Hort	comp	upper	ND	0.24	4.22	0.51	0.01	ND	0.81	ND	0.65	ND	0.62	TR	0.04	1.74	TR
12/18/97	Urban Hort	no-comp	upper	ND	0.75	4.67	3.04	0.02	ND	2.31	ND	TR	ND	0.36	TR	0.05	6.06	TR
12/18/97	Urban Hort	comp	upper	TR	0.58	4.06	0.80	0.01	ND	2.97	TR	0.80	ND	0.66	TR	0.05	2.39	TR
12/18/97	Woodmoor	no-comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Woodmoor	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Woodmoor	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Woodmoor	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Timbercrest	no-comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Timbercrest	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Timbercrest	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12/18/97	Woodmoor	precip	precip	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

Urban Hort = (Center for) Urban Horticulture or CUH

Table G-1. Observed Water Quality of Collected Samples from Compost-Amended Soil and Soil Sites (Continued)

			quantification limit	0.03	0.010	0.010	0.03	0.010	0.010	0.03	0.04	0.02	0.10	0.10	0.17	0.003	0.03	0.007	0.02
			detection limit	0.01	0.003	0.003	0.01	0.003	0.003	0.01	0.01	0.01	0.03	0.03	0.05	0.001	0.01	0.002	0.01
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Site	tmt	type	PO4-P	Hydr P	TOT-P	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
1/5/98	Urban Hort	precip	precip	ND	ND	ND	0.22	ND	0.17	2.05	0.92	0.42	ND	ND	TR	ND	0.28	ND	TR
1/5/98	Urban Hort	no-comp	lower	ND	ND	TR	0.10	ND	ND	2.12	2.92	0.06	2.67	ND	ND	TR	5.49	ND	TR
1/5/98	Urban Hort	comp	lower	0.10	ND	0.47	0.02	ND	2.90	0.71	1.72	2.00	7.45	TR	TR	0.06	21.32	ND	0.04
1/5/98	Urban Hort	no-comp	lower	ND	ND	TR	0.07	ND	0.01	2.22	1.92	0.12	0.80	ND	ND	TR	6.88	ND	TR
1/5/98	Urban Hort	comp	lower	1.08	1.78	2.60	0.04	ND	ND	0.90	2.97	0.22	1.29	ND	ND	TR	15.76	ND	TR
1/5/98	Urban Hort	no-comp	upper	0.10	0.42	0.85	0.37	ND	0.66	0.76	1.53	0.82	69.00	ND	TR	0.16	6.47	TR	TR
1/5/98	Urban Hort	comp	upper	0.21	0.16	0.28	0.65	ND	0.32	1.53	0.77	0.45	0.81	ND	ND	TR	0.87	ND	TR
1/5/98	Urban Hort	no-comp	upper	0.03	ND	0.15	0.17	ND	0.05	1.04	1.90	0.20	1.69	ND	ND	TR	5.46	TR	TR
1/5/98	Urban Hort	comp	upper	1.17	2.04	2.77	0.03	ND	ND	1.17	1.92	0.10	1.03	ND	TR	TR	23.08	TR	0.04
1/5/98	Woodmoor	no-comp	lower	0.16	ND	0.21	0.68	ND	0.01	2.11	3.70	0.33	2.20	ND	ND	0.03	27.18	ND	0.04
1/5/98	Woodmoor	comp	lower	3.41	2.17	3.37	59.40	ND	2.42	118.00	181.00	75.50	2.47	TR	TR	0.26	189.58	ND	0.11
1/5/98	Woodmoor	no-comp	upper	0.08	1.04	1.59	0.08	ND	0.02	0.90	0.32	0.20	12.93	ND	ND	0.08	6.56	ND	TR
1/5/98	Woodmoor	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/5/98	Timbercrest	no-comp	lower	0.08	0.39	0.48	0.02	ND	3.66	3.51	1.47	4.16	9.13	ND	ND	0.09	16.01	ND	0.04
1/5/98	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/5/98	Timbercrest	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/5/98	Timbercrest	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/5/98	Woodmoor	precip	precip	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

			quantification limit	0.013	0.07	1.33	0.13	0.003	0.023	0.33	0.010	0.13	0.10	0.10	0.10	0.007	0.07	0.01
			detection limit	0.004	0.02	0.40	0.04	0.001	0.007	0.10	0.003	0.04	0.03	0.03	0.03	0.002	0.02	0.00
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
1/5/98	Urban Hort	precip	precip	ND	ND	1.68	0.06	TR	ND	0.74	ND	ND	ND	0.52	TR	ND	0.10	ND
1/5/98	Urban Hort	no-comp	lower	TR	1.39	1.67	2.95	0.04	ND	2.43	ND	TR	ND	0.24	TR	ND	11.12	ND
1/5/98	Urban Hort	comp	lower	0.03	4.16	15.98	6.98	0.08	ND	1.80	TR	0.47	ND	3.06	0.21	TR	20.80	ND
1/5/98	Urban Hort	no-comp	lower	ND	0.64	3.46	4.27	0.03	ND	2.71	ND	TR	ND	0.29	TR	ND	6.84	ND
1/5/98	Urban Hort	comp	lower	0.08	3.20	TR	5.74	0.75	ND	1.76	0.04	2.60	ND	1.26	TR	0.17	11.88	ND
1/5/98	Urban Hort	no-comp	upper	ND	15.54	2.81	9.51	0.04	ND	11.73	ND	0.85	ND	1.43	0.75	0.57	159.03	ND
1/5/98	Urban Hort	comp	upper	TR	0.34	2.33	0.37	TR	ND	0.78	ND	0.28	ND	0.54	TR	TR	1.99	ND
1/5/98	Urban Hort	no-comp	upper	ND	1.21	4.67	3.11	0.02	ND	2.32	ND	0.15	ND	0.45	TR	TR	7.85	ND
1/5/98	Urban Hort	comp	upper	0.09	5.22	2.99	8.12	1.00	ND	2.16	0.05	2.77	ND	1.51	0.16	TR	15.70	ND
1/5/98	Woodmoor	no-comp	lower	TR	2.81	4.51	6.84	0.24	ND	2.53	TR	0.21	ND	0.89	0.17	ND	10.34	ND
1/5/98	Woodmoor	comp	lower	0.05	6.40	283.22	69.67	12.59	ND	36.11	0.18	3.37	ND	65.19	0.77	TR	10.43	ND
1/5/98	Woodmoor	no-comp	upper	TR	6.21	TR	1.14	0.26	ND	0.76	ND	1.59	ND	0.38	0.18	TR	15.37	ND
1/5/98	Woodmoor	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/5/98	Timbercrest	no-comp	lower	ND	4.81	5.51	3.14	1.35	ND	2.24	ND	0.48	ND	4.30	0.22	ND	13.15	ND
1/5/98	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/5/98	Timbercrest	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/5/98	Timbercrest	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/5/98	Woodmoor	precip	precip	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

Table G-1. Observed Water Quality of Collected Samples from Compost-Amended Soil and Soil Sites (Continued)

			detection limit	0.03	0.010	0.010	0.03	0.010	0.010	0.03	0.04	0.02	0.10	0.10	0.17	0.003	0.03	0.007	0.02
			quantification limit	0.01	0.003	0.003	0.01	0.003	0.003	0.01	0.01	0.01	0.03	0.03	0.05	0.001	0.01	0.002	0.01
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Site	tmt	type	PO4-P	Hydr P	TOT-	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
2/20/98	Urban Hort	precip	precip	ND	ND	ND	0.10	ND	0.11	1.15	1.16	0.35	ND	ND	ND	ND	0.22	TR	TR
2/20/98	Urban Hort	no-comp	lower	0.05	ND	ND	0.08	ND	ND	1.54	1.36	0.01	0.65	ND	ND	0.01	9.11	ND	TR
2/20/98	Urban Hort	comp	lower	0.29	ND	0.54	0.06	ND	0.04	4.61	0.32	0.92	10.17	ND	TR	0.07	24.29	TR	0.05
2/20/98	Urban Hort	no-comp	lower	0.01	4.25	4.60	0.12	ND	ND	4.58	0.45	0.01	TR	ND	ND	0.01	19.43	TR	0.03
2/20/98	Urban Hort	comp	lower	1.68	ND	ND	0.10	ND	0.01	2.00	2.08	0.09	TR	ND	ND	0.01	12.01	ND	TR
2/20/98	Urban Hort	no-comp	upper	0.78	0.61	0.95	3.72	ND	0.02	6.71	4.28	0.71	40.42	ND	ND	0.09	4.86	TR	TR
2/20/98	Urban Hort	comp	upper	0.95	0.58	1.08	6.99	ND	0.09	9.33	1.51	0.80	ND	ND	ND	TR	1.25	TR	TR
2/20/98	Urban Hort	no-comp	upper	0.15	0.42	0.87	0.02	ND	0.41	2.02	1.26	0.18	TR	ND	ND	0.01	5.83	TR	TR
2/20/98	Urban Hort	comp	upper	1.91	1.98	2.85	0.41	ND	0.13	3.93	2.43	0.11	1.37	ND	ND	0.02	12.66	TR	0.03
2/20/98	Woodmoor	no-comp	lower	ND	ND	TR	0.35	ND	0.01	2.85	3.07	0.16	1.37	ND	ND	0.05	37.55	ND	0.04
2/20/98	Woodmoor	comp	lower	2.20	5.14	6.00	43.90	ND	ND	90.00	ND	10.17	4.47	TR	TR	0.26	131.87	TR	0.10
2/20/98	Woodmoor	no-comp	upper	ND	ND	ND	0.20	ND	0.09	2.07	1.71	0.35	1.58	ND	ND	0.02	13.81	ND	TR
2/20/98	Woodmoor	comp	upper	1.56	3.82	4.32	27.36	ND	ND	47.60	19.53	4.75	4.56	ND	TR	0.19	52.03	TR	0.06
2/20/98	Timbercrest	no-comp	lower	0.07	0.31	0.70	0.02	ND	0.80	3.34	1.38	4.33	15.45	ND	ND	0.12	41.02	TR	0.05
2/20/98	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
2/20/98	Timbercrest	no-comp	upper	0.02	ND	ND	ND	ND	.1.063	1.46	2.25	2.11	2.26	ND	ND	0.02	8.54	TR	TR
2/20/98	Timbercrest	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
2/20/98	Woodmoor	precip	precip	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

			detection limit	0.013	0.07	1.33	0.13	0.003	0.023	0.33	0.010	0.13	0.10	0.10	0.10	0.007	0.07	0.01
			quantification limit	0.004	0.02	0.40	0.04	0.001	0.007	0.10	0.003	0.04	0.03	0.03	0.03	0.002	0.02	0.00
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
2/20/98	Urban Hort	precip	precip	ND	TR	1.93	0.07	TR	ND	0.58	ND	ND	ND	0.58	TR	ND	ND	ND
2/20/98	Urban Hort	no-comp	lower	ND	0.35	2.36	4.78	TR	ND	3.53	ND	ND	ND	0.18	TR	ND	10.04	ND
2/20/98	Urban Hort	comp	lower	0.03	5.74	18.52	8.11	0.09	ND	2.09	TR	0.54	ND	2.26	0.30	TR	27.50	ND
2/20/98	Urban Hort	no-comp	lower	0.04	8.37	2.75	7.07	TR	ND	2.01	TR	4.60	ND	1.19	TR	ND	17.33	ND
2/20/98	Urban Hort	comp	lower	ND	0.36	2.54	7.01	0.02	ND	3.68	ND	ND	ND	0.30	TR	ND	8.29	ND
2/20/98	Urban Hort	no-comp	upper	ND	9.43	3.73	5.80	0.12	ND	10.05	ND	0.95	ND	2.17	0.57	0.39	94.79	ND
2/20/98	Urban Hort	comp	upper	TR	0.06	3.96	0.37	TR	ND	1.22	ND	1.08	ND	1.16	TR	TR	TR	ND
2/20/98	Urban Hort	no-comp	upper	ND	0.39	3.72	3.09	TR	ND	1.99	ND	0.87	ND	0.46	TR	TR	4.32	ND
2/20/98	Urban Hort	comp	upper	0.07	2.95	2.95	4.69	0.02	ND	1.95	TR	2.85	ND	1.17	TR	TR	11.00	ND
2/20/98	Woodmoor	no-comp	lower	TR	9.26	5.39	7.68	2.31	ND	2.30	TR	TR	ND	0.88	0.24	TR	9.69	ND
2/20/98	Woodmoor	comp	lower	0.05	5.93	240.68	47.00	8.13	ND	23.25	0.09	6.00	TR	31.15	0.46	0.11	14.32	TR
2/20/98	Woodmoor	no-comp	upper	TR	1.58	3.96	2.94	0.21	ND	2.17	ND	ND	ND	0.78	TR	0.96	6.96	ND
2/20/98	Woodmoor	comp	upper	0.05	4.75	158.10	18.05	2.62	ND	10.68	0.05	4.32	TR	7.78	0.28	0.22	11.98	ND
2/20/98	Timbercrest	no-comp	lower	TR	8.89	5.69	4.31	0.56	ND	2.21	ND	0.70	ND	4.90	0.32	TR	18.38	ND
2/20/98	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
2/20/98	Timbercrest	no-comp	upper	TR	1.33	4.49	1.27	0.06	ND	2.86	ND	ND	ND	2.39	TR	ND	4.14	ND
2/20/98	Timbercrest	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
2/20/98	Woodmoor	precip	precip	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

Table G-1. Observed Water Quality of Collected Samples from Compost-Amended Soil and Soil Sites (Continued)

			quantification limit	0.03	0.010	0.010	0.03	0.010	0.010	0.03	0.04	0.02	0.10	0.10	0.17	0.003	0.03	0.007	0.02
			detection limit	0.01	0.003	0.003	0.01	0.003	0.003	0.01	0.01	0.01	0.03	0.03	0.05	0.001	0.01	0.002	0.01
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Site	tmt	type	PO4-P	Hydr P	TOT-P	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
3/15/98	Urban Hort	precip	precip	ND	ND	ND	0.16	ND	0.10	0.53	0.65	0.27	ND	ND	ND	ND	0.19	ND	ND
3/15/98	Urban Hort	no-comp	lower	ND	ND	ND	0.03	ND	ND	0.20	0.54	ND	TR	ND	ND	TR	9.74	ND	TR
3/15/98	Urban Hort	comp	lower	0.21	0.14	0.45	0.07	ND	0.04	3.02	0.10	0.73	5.32	ND	TR	0.04	18.18	ND	0.12
3/15/98	Urban Hort	no-comp	lower	ND	ND	ND	0.02	ND	0.00	0.35	0.69	ND	ND	ND	ND	TR	10.58	ND	TR
3/15/98	Urban Hort	comp	lower	1.14	1.59	1.77	0.06	ND	ND	2.00	0.40	0.03	TR	ND	ND	TR	8.79	ND	TR
3/15/98	Urban Hort	no-comp	upper	0.53	0.70	0.51	3.34	ND	1.61	5.96	1.44	1.34	7.36	ND	ND	0.09	4.23	ND	0.07
3/15/98	Urban Hort	comp	upper	0.73	0.46	0.65	3.28	ND	1.40	5.04	2.76	0.89	1.69	ND	ND	0.01	1.09	ND	TR
3/15/98	Urban Hort	no-comp	upper	0.11	ND	0.22	0.01	ND	1.13	0.74	0.86	0.23	2.08	ND	ND	0.02	5.40	ND	ND
3/15/98	Urban Hort	comp	upper	1.16	1.01	1.50	0.07	ND	2.41	2.99	1.13	0.51	1.95	ND	ND	0.02	3.53	ND	0.07
3/15/98	Woodmoor	no-comp	lower	ND	ND	TR	0.43	ND	ND	2.20	2.15	0.03	TR	ND	ND	0.05	40.15	ND	TR
3/15/98	Woodmoor	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
3/15/98	Woodmoor	no-comp	upper	0.03	ND	0.30	0.03	ND	0.01	0.58	2.54	0.45	8.22	ND	ND	0.07	14.75	ND	TR
3/15/98	Woodmoor	comp	upper	0.69	1.54	2.99	19.10	ND	ND	34.20	16.08	0.28	0.73	ND	TR	0.07	69.85	ND	0.04
3/15/98	Timbercrest	no-comp	lower	0.02	0.13	0.35	ND	ND	0.28	1.74	0.61	4.15	6.67	ND	ND	0.07	29.70	ND	0.14
3/15/98	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
3/15/98	Timbercrest	no-comp	upper	0.02	0.25	TR	0.04	ND	0.12	1.79	0.46	0.22	2.73	ND	ND	0.02	1.58	ND	TR
3/15/98	Timbercrest	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
3/15/98	Woodmoor	precip	precip	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

			quantification limit	0.013	0.07	1.33	0.13	0.003	0.023	0.33	0.010	0.13	0.10	0.10	0.10	0.007	0.07	0.01
			detection limit	0.004	0.02	0.40	0.04	0.001	0.007	0.10	0.003	0.04	0.03	0.03	0.03	0.002	0.02	0.00
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
3/15/98	Urban Hort	precip	precip	TR	0.24	ND	0.07	TR	ND	0.35	0.05	ND	ND	0.26	ND	TR	TR	ND
3/15/98	Urban Hort	no-comp	lower	ND	0.18	TR	5.40	TR	ND	4.30	TR	ND	ND	0.13	ND	TR	9.22	ND
3/15/98	Urban Hort	comp	lower	0.02	4.51	14.65	6.28	0.06	ND	1.70	0.22	0.45	ND	1.51	TR	TR	9.12	ND
3/15/98	Urban Hort	no-comp	lower	ND	0.12	1.51	6.44	TR	ND	3.35	ND	ND	ND	0.13	TR	TR	5.16	ND
3/15/98	Urban Hort	comp	lower	0.02	4.51	TR	3.28	0.07	ND	1.02	0.04	1.77	ND	0.45	ND	TR	0.62	ND
3/15/98	Urban Hort	no-comp	upper	TR	3.05	1.73	1.78	0.08	ND	3.73	0.30	0.51	ND	0.64	TR	0.32	1.48	ND
3/15/98	Urban Hort	comp	upper	TR	1.36	5.07	0.60	0.06	ND	0.58	TR	0.65	ND	0.83	ND	0.16	1.58	ND
3/15/98	Urban Hort	no-comp	upper	TR	1.65	TR	3.26	0.04	ND	2.05	TR	0.22	TR	0.44	TR	TR	6.92	ND
3/15/98	Urban Hort	comp	upper	0.02	4.53	TR	1.26	0.58	ND	2.71	0.19	1.50	TR	0.65	TR	0.13	3.38	ND
3/15/98	Woodmoor	no-comp	lower	TR	16.51	4.17	8.39	4.74	ND	2.32	TR	TR	TR	0.56	TR	0.12	7.11	ND
3/15/98	Woodmoor	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
3/15/98	Woodmoor	no-comp	upper	0.01	10.50	1.64	3.11	0.74	ND	1.37	TR	0.30	ND	0.32	TR	TR	10.72	ND
3/15/98	Woodmoor	comp	upper	0.03	3.97	117.24	27.21	3.20	ND	7.70	TR	2.99	TR	2.16	TR	TR	4.23	ND
3/15/98	Timbercrest	no-comp	lower	TR	4.63	3.37	3.14	0.11	ND	1.46	0.12	0.35	TR	3.16	TR	TR	5.96	ND
3/15/98	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
3/15/98	Timbercrest	no-comp	upper	ND	1.63	TR	0.61	0.03	ND	0.57	TR	TR	ND	0.33	ND	TR	3.83	ND
3/15/98	Timbercrest	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
3/15/98	Woodmoor	precip	precip	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

Table G-1. Observed Water Quality of Collected Samples from Compost-Amended Soil and Soil Sites (Continued)

			quantification limit	0.03	0.010	0.010	0.03	0.010	0.010	0.03	0.04	0.02	0.10	0.10	0.17	0.003	0.03	0.007	0.02
			detection limit	0.01	0.003	0.003	0.01	0.003	0.003	0.01	0.01	0.01	0.03	0.03	0.05	0.001	0.01	0.002	0.01
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Site	tmt	type	PO4-P	Hydr P	TOT-P	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
4/15/98	Urban Hort	precip	precip	0.39	ND	0.41	0.29	ND	ND	0.97	0.76	0.64	ND	ND	ND	ND	0.47	ND	TR
4/15/98	Urban Hort	no-comp	lower	0.17	0.08	0.15	0.95	ND	0.00	1.04	0.16	0.01	ND	ND	ND	TR	9.66	ND	TR
4/15/98	Urban Hort	comp	lower	0.35	0.26	0.44	0.09	ND	0.54	2.62	0.15	0.34	1.69	ND	TR	0.03	24.34	TR	0.04
4/15/98	Urban Hort	no-comp	lower	0.19	0.02	0.25	0.23	ND	0.21	0.37	0.66	0.07	ND	ND	ND	TR	21.90	TR	TR
4/15/98	Urban Hort	comp	lower	1.78	5.57	3.15	0.44	ND	4.39	3.20	5.30	2.35	TR	ND	ND	0.01	15.38	TR	0.04
4/15/98	Urban Hort	no-comp	upper	0.61	0.83	0.72	0.88	ND	3.29	1.26	1.46	0.89	15.87	ND	ND	0.05	2.97	TR	TR
4/15/98	Urban Hort	comp	upper	0.88	0.70	1.15	3.74	ND	4.93	4.03	1.86	1.03	TR	ND	ND	0.01	2.03	TR	TR
4/15/98	Urban Hort	no-comp	upper	0.26	0.08	0.20	0.32	ND	0.83	0.80	0.57	0.17	TR	ND	ND	0.01	5.92	TR	TR
4/15/98	Urban Hort	comp	upper	1.09	0.85	1.32	0.35	ND	3.65	0.92	1.55	0.70	ND	ND	ND	TR	7.38	TR	TR
4/15/98	Woodmoor	no-comp	lower	0.18	ND	0.20	0.46	ND	ND	0.65	0.53	0.24	TR	ND	ND	0.01	6.69	ND	TR
4/15/98	Woodmoor	comp	lower	1.14	1.54	2.39	8.98	ND	ND	15.46	9.00	0.64	TR	ND	TR	0.03	64.51	TR	0.05
4/15/98	Woodmoor	no-comp	upper	0.18	ND	0.21	0.95	ND	ND	2.22	3.24	0.03	TR	ND	ND	0.06	56.78	TR	0.05
4/15/98	Woodmoor	comp	upper	0.84	0.84	1.41	6.79	ND	1.17	13.16	12.88	2.02	ND	ND	TR	0.03	49.18	ND	0.04
4/15/98	Timbercrest	no-comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
4/15/98	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
4/15/98	Timbercrest	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
4/15/98	Timbercrest	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
4/15/98	Woodmoor	precip	precip	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

			quantification limit	0.013	0.07	1.33	0.13	0.003	0.023	0.33	0.010	0.13	0.10	0.10	0.10	0.007	0.07	0.01
			detection limit	0.004	0.02	0.40	0.04	0.001	0.007	0.10	0.003	0.04	0.03	0.03	0.03	0.002	0.02	0.00
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
4/15/98	Urban Hort	precip	precip	ND	TR	2.44	0.10	TR	ND	0.44	ND	0.41	ND	0.49	TR	TR	TR	TR
4/15/98	Urban Hort	no-comp	lower	ND	0.08	2.50	5.16	0.02	ND	3.58	ND	0.15	ND	0.31	TR	ND	8.73	TR
4/15/98	Urban Hort	comp	lower	0.02	1.23	18.62	7.57	0.02	ND	1.80	TR	0.44	ND	1.56	TR	TR	11.75	TR
4/15/98	Urban Hort	no-comp	lower	ND	0.07	3.40	12.84	0.02	ND	5.93	ND	0.25	ND	0.42	TR	ND	14.27	TR
4/15/98	Urban Hort	comp	lower	0.05	3.41	4.17	4.49	0.03	ND	10.91	TR	3.15	ND	3.69	TR	TR	15.10	TR
4/15/98	Urban Hort	no-comp	upper	TR	3.71	4.49	2.50	0.02	ND	6.35	ND	0.72	ND	1.30	0.25	0.32	39.00	TR
4/15/98	Urban Hort	comp	upper	TR	0.13	5.50	0.55	0.04	ND	0.95	ND	1.15	ND	1.36	TR	0.21	0.87	TR
4/15/98	Urban Hort	no-comp	upper	TR	0.36	3.38	3.12	ND	ND	1.12	TR	0.20	ND	0.51	TR	TR	3.44	TR
4/15/98	Urban Hort	comp	upper	0.02	0.19	5.36	1.12	0.03	ND	4.74	ND	1.32	ND	1.13	TR	0.14	0.62	TR
4/15/98	Woodmoor	no-comp	lower	ND	0.22	2.51	0.56	TR	ND	0.38	ND	0.20	ND	0.48	TR	TR	0.98	TR
4/15/98	Woodmoor	comp	lower	TR	2.92	79.25	22.50	1.95	ND	4.16	TR	2.39	ND	3.04	0.33	ND	6.92	TR
4/15/98	Woodmoor	no-comp	upper	TR	23.55	6.29	10.66	4.15	ND	2.25	TR	0.21	ND	1.04	0.35	0.16	11.26	TR
4/15/98	Woodmoor	comp	upper	TR	1.00	84.21	18.17	1.34	ND	5.09	TR	1.41	ND	3.89	0.23	0.45	5.36	TR
4/15/98	Timbercrest	no-comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
4/15/98	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
4/15/98	Timbercrest	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
4/15/98	Timbercrest	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
4/15/98	Woodmoor	precip	precip	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

Table G-1. Observed Water Quality of Collected Samples from Compost-Amended Soil and Soil Sites (Continued)

			quantification limit	0.03	0.010	0.010	0.03	0.010	0.010	0.03	0.04	0.02	0.10	0.10	0.17	0.003	0.03	0.007	0.02
			detection limit	0.01	0.003	0.003	0.01	0.003	0.003	0.01	0.01	0.01	0.03	0.03	0.05	0.001	0.01	0.002	0.01
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Site	tmt	type	PO4-P	Hydr P	TOT-P	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
5/28/98	Urban Hort	precip	precip	0.07	0.00	TR	TR	ND		2.41	1.34	0.43	ND	ND	ND	TR	0.94	TR	TR
5/28/98	Urban Hort	no-comp	lower	0.46	0.41	0.61	0.01	ND	3.01	3.12	5.74	0.82	1.34	ND	ND	0.01	5.13	TR	TR
5/28/98	Urban Hort	comp	lower	1.73	1.85	2.59	1.51	ND	11.50	8.76	13.05	1.42	TR	ND	ND	0.02	10.44	TR	TR
5/28/98	Urban Hort	no-comp	lower	0.73	0.78	0.98	0.05	ND	8.78	3.86	1.97	0.58	ND	ND	ND	0.01	19.91	TR	TR
5/28/98	Urban Hort	comp	lower	1.60	2.87	1.77	1.38	ND	2.08	7.05	2.19	0.95	ND	TR	ND	ND	6.66	TR	TR
5/28/98	Urban Hort	no-comp	upper	0.38	0.35	0.60	1.96	ND	1.39	6.99	4.94	0.53	2.56	ND	ND	0.02	3.31	TR	TR
5/28/98	Urban Hort	comp	upper	5.24	6.34	8.16	19.10	ND	17.01	31.14	17.80	2.79	TR	ND	ND	0.04	16.36	TR	TR
5/28/98	Urban Hort	no-comp	upper	0.51	0.47	0.58	0.13	ND	3.48	7.62	2.94	0.50	ND	ND	ND	0.01	5.29	TR	TR
5/28/98	Urban Hort	comp	upper	2.55	2.88	4.18	2.59	ND	2.29	13.07	16.04	1.66	ND	ND	ND	TR	22.14	TR	TR
5/28/98	Woodmoor	no-comp	lower	ND	ND	ND	0.03	ND	ND	0.69	3.68	6.75	TR	ND	ND	0.02	11.75	TR	TR
5/28/98	Woodmoor	comp	lower	1.23	1.45	1.88	ND	ND	ND	3.58	0.37	3.51	ND	ND	TR	0.02	60.47	TR	0.05
5/28/98	Woodmoor	no-comp	upper	ND	TR	TR	0.07	ND	ND	1.65	1.50	2.91	ND	TR	ND	0.04	63.40	TR	0.05
5/28/98	Woodmoor	comp	upper	1.56	1.33	1.87	0.04	ND	ND	3.38	2.20	3.95	ND	TR	TR	0.02	60.76	TR	0.05
5/28/98	Timbercrest	no-comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5/28/98	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5/28/98	Timbercrest	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5/28/98	Timbercrest	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5/28/98	Woodmoor	precip	precip	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

			quantification limit	0.013	0.07	1.33	0.13	0.003	0.023	0.33	0.010	0.13	0.10	0.10	0.10	0.007	0.07	0.01
			detection limit	0.004	0.02	0.40	0.04	0.001	0.007	0.10	0.003	0.04	0.03	0.03	0.03	0.002	0.02	0.00
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
5/28/98	Urban Hort	precip	precip	ND	TR	3.81	0.22	ND	ND	0.58	ND	TR	ND	0.78	TR	ND	TR	ND
5/28/98	Urban Hort	no-comp	lower	TR	0.43	12.69	1.90	ND	ND	4.78	ND	0.61	ND	1.49	TR	0.18	4.66	ND
5/28/98	Urban Hort	comp	lower	0.02	0.24	40.54	3.45	ND	ND	1.97	ND	2.59	ND	2.85	TR	TR	3.47	ND
5/28/98	Urban Hort	no-comp	lower	TR	TR	6.92	7.37	ND	ND	5.83	ND	0.98	ND	1.18	TR	ND	12.92	ND
5/28/98	Urban Hort	comp	lower	0.02	0.36	12.62	1.78	0.01	ND	1.34	ND	1.77	ND	1.67	TR	TR	2.48	ND
5/28/98	Urban Hort	no-comp	upper	TR	0.69	16.03	1.33	TR	ND	5.14	ND	0.60	ND	1.52	TR	0.28	7.83	ND
5/28/98	Urban Hort	comp	upper	0.02	0.18	48.14	4.16	0.52	ND	2.26	ND	8.16	ND	4.74	TR	0.40	1.77	ND
5/28/98	Urban Hort	no-comp	upper	TR	0.11	11.73	2.10	ND	ND	1.65	ND	0.58	ND	1.03	TR	0.12	2.08	ND
5/28/98	Urban Hort	comp	upper	0.05	0.33	45.87	3.70	0.11	ND	8.84	ND	4.18	ND	3.79	TR	0.12	3.55	ND
5/28/98	Woodmoor	no-comp	lower	ND	0.17	5.11	1.37	TR	ND	3.69	ND	ND	ND	8.23	TR	0.17	3.53	ND
5/28/98	Woodmoor	comp	lower	TR	0.12	44.11	20.25	0.06	ND	2.86	ND	1.88	ND	4.99	TR	ND	5.26	ND
5/28/98	Woodmoor	no-comp	upper	TR	0.31	7.18	11.33	9.26	ND	2.15	TR	TR	ND	3.89	0.25	TR	11.99	ND
5/28/98	Woodmoor	comp	upper	TR	0.12	45.33	20.38	0.06	ND	2.93	ND	1.87	ND	5.07	0.25	TR	5.28	ND
5/28/98	Timbercrest	no-comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5/28/98	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5/28/98	Timbercrest	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5/28/98	Timbercrest	comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5/28/98	Woodmoor	precip	precip	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

Table G-1. Observed Water Quality of Collected Samples from Compost-Amended Soil and Soil Sites (Continued)

			quantification limit	0.03	0.010	0.010	0.03	0.010	0.010	0.03	0.04	0.02	0.10	0.10	0.17	0.003	0.03	0.007	0.02
			detection limit	0.01	0.003	0.003	0.01	0.003	0.003	0.01	0.01	0.01	0.03	0.03	0.05	0.001	0.01	0.002	0.01
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Site	tmt	type	PO4-P	Hydr P	TOT-	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
6/26/98	Urban Hort	precip	precip	TR	TR	TR	ND	ND	0.01	1.36	1.21	0.31	ND	ND	ND	TR	0.17	ND	ND
6/26/98	Urban Hort	no-comp	lower	1.35	0.80	1.46	0.87	ND	10.50	3.40	8.43	1.33	0.38	ND	ND	0.02	5.72	ND	ND
6/26/98	Urban Hort	comp	lower	6.56	6.38	7.85	ND	ND	14.50	15.12	18.50	2.84	ND	ND	ND	0.03	18.16	ND	ND
6/26/98	Urban Hort	no-comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
6/26/98	Urban Hort	comp	lower	8.42	8.66	9.66	5.53	ND	74.20	11.22	30.17	12.35	ND	ND	ND	TR	139.53	ND	ND
6/26/98	Urban Hort	no-comp	upper	1.51	1.14	1.54	0.34	ND	4.50	2.40	11.74	1.06	0.78	ND	ND	0.02	5.17	ND	ND
6/26/98	Urban Hort	comp	upper	6.99	6.36	8.20	ND	ND	11.60	2.63	16.40	3.01	ND	ND	ND	0.02	9.36	ND	ND
6/26/98	Urban Hort	no-comp	upper	3.77	3.72	4.49	1.62	ND	11.85	4.79	11.45	1.39	ND	ND	ND	0.01	10.04	ND	ND
6/26/98	Urban Hort	comp	upper	4.93	4.74	5.99	0.04	ND	7.63	6.16	17.29	2.23	ND	ND	ND	0.01	11.11	ND	ND
6/26/98	Woodmoor	no-comp	lower	ND	ND	ND	0.03	ND	3.69	1.37	0.24	3.48	ND	ND	ND	0.06	84.05	ND	ND
6/26/98	Woodmoor	comp	lower	0.84	0.94	0.97	0.25	ND	0.12	1.69	1.81	1.50	TR	ND	ND	0.01	20.12	ND	ND
6/26/98	Woodmoor	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
6/26/98	Woodmoor	comp	upper	1.08	1.80	2.02	ND	ND	0.34	2.15	2.51	1.54	ND	ND	TR	0.01	54.38	ND	ND
6/26/98	Timbercrest	no-comp	lower	0.33	0.21	0.30	1.00	ND	1.55	1.00	5.38	3.17	ND	ND	ND	0.02	6.22	ND	ND
6/26/98	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
6/26/98	Timbercrest	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
6/26/98	Timbercrest	comp	upper	124.80	15.49	125.22	360.00	ND	1.68	479.42	ND	223.00	1.28	ND	ND	0.21	74.05	ND	ND
6/26/98	Woodmoor	precip	precip	0.04	ND	ND	0.18	ND	0.24	0.38	1.32	0.53	ND	ND	ND	TR	0.80	ND	ND

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

			quantification limit	0.013	0.07	1.33	0.13	0.003	0.023	0.33	0.010	0.13	0.10	0.10	0.10	0.007	0.07	0.01
			detection limit	0.004	0.02	0.40	0.04	0.001	0.007	0.10	0.003	0.04	0.03	0.03	0.03	0.002	0.02	0.00
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Date	Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
6/26/98	Urban Hort	precip	precip	ND	ND	5.50	ND	ND	ND	0.52	ND	TR	ND	0.44	ND	TR	ND	TR
6/26/98	Urban Hort	no-comp	lower	ND	ND	16.83	1.59	ND	ND	7.76	ND	1.46	ND	1.65	ND	0.41	0.70	ND
6/26/98	Urban Hort	comp	lower	ND	ND	54.99	5.06	ND	ND	2.75	ND	7.85	ND	4.22	ND	TR	3.24	ND
6/26/98	Urban Hort	no-comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
6/26/98	Urban Hort	comp	lower	ND	ND	41.50	16.81	2.19	ND	13.48	ND	9.66	ND	14.17	ND	0.13	11.96	TR
6/26/98	Urban Hort	no-comp	upper	ND	ND	22.90	1.57	ND	ND	6.00	ND	1.54	ND	1.52	ND	0.35	2.75	ND
6/26/98	Urban Hort	comp	upper	ND	ND	48.74	3.24	ND	ND	2.29	ND	8.20	ND	4.08	ND	0.37	0.89	ND
6/26/98	Urban Hort	no-comp	upper	ND	ND	30.90	1.84	ND	ND	2.94	ND	4.49	ND	1.91	ND	0.17	0.80	ND
6/26/98	Urban Hort	comp	upper	ND	ND	50.04	2.47	ND	ND	3.44	ND	5.99	ND	3.32	ND	0.13	1.73	ND
6/26/98	Woodmoor	no-comp	lower	ND	ND	14.90	14.28	ND	ND	4.65	ND	ND	ND	4.43	ND	ND	18.21	TR
6/26/98	Woodmoor	comp	lower	ND	ND	10.08	2.57	ND	ND	4.16	ND	0.97	ND	2.07	ND	TR	4.35	TR
6/26/98	Woodmoor	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
6/26/98	Woodmoor	comp	upper	ND	ND	26.13	14.97	ND	ND	4.05	ND	2.02	ND	3.34	ND	TR	5.17	TR
6/26/98	Timbercrest	no-comp	lower	ND	ND	10.39	0.44	ND	ND	1.95	ND	0.30	ND	3.34	ND	0.12	0.89	ND
6/26/98	Timbercrest	comp	lower	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
6/26/98	Timbercrest	no-comp	upper	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
6/26/98	Timbercrest	comp	upper	ND	0.09	361.08	11.23	ND	ND	13.97	ND	125.22	ND	356.25	ND	0.14	6.25	TR
6/26/98	Woodmoor	precip	precip	ND	ND	3.88	ND	ND	ND	1.32	ND	ND	ND	0.45	ND	0.19	ND	ND

ND = below detection limit, TR = between detection and quantification limits, NS = no solution collected

Table G-2. Particle Size and Toxicity Analyses of Water Samples

			Particle Size (µm) by Percentile			
Sample Location	**Sample Date**	**Sample Type**	**10th Percentile**	**50th Percentile**	**90th Percentile**	**Toxicity (% light reduction)**
Rainfall	February 20, 1998	Precipitation	na	na	na	22
	April 4, 1998	Precipitation	na	na	na	36
	March 15, 1998	Precipitation	2.32	13.15	31.0	23
	April 20, 1998	Precipitation	2.15	7.42	51.5	5
	May 28, 1998	Precipitation	1.75	16.82	78.7	24
	June 30, 1998	Precipitation	10.15	52.08	85.9	na
UH-1 (CUH, UW, Alderwood soil A)	January 4, 1998	Surface	1.21	3.23	41.4	33
		Subsurface	1.55	3.95	18.5	10
	February 20, 1998	Surface	na	na	na	39
		Subsurface	3.24	14.07	27.2	15
	March 15, 1998	Surface	1.25	3.05	36.9	29
		Subsurface	2.07	8.01	40.1	21
	April 20, 1998	Surface	1.54	4.03	38.3	22
		Subsurface	na	na	na	19
	May 28, 1998	Surface	1.67	3.39	46.1	na
		Subsurface	1.95	15.39	87.2	12
	June 30, 1998	Surface	1.63	17.96	48.2	19
UH-2 (CUH, UW, Alderwood soil A, plus Cedar Grove compost)	January 4, 1998	Surface	1.81	6.85	29.6	25
		Subsurface	1.53	4.35	25.9	10
	February 20, 1998	Surface	2.63	23.5	97.5	29
		Subsurface	1.67	4.99	20.5	17
	March 15, 1998	Surface	3.79	15.51	47.3	31
		Subsurface	1.81	5.22	27.6	18
	April 20, 1998	Surface	2.52	9.19	38.5	18
		Subsurface	2.92	14.3	53.5	10
	May 28, 1998	Subsurface	3.57	18.85	98.0	2
	June 30, 1998	Surface	2.36	27.11	56.3	nd
		Subsurface	5.04	25.78	87.2	nd
UH-5 (CUH, UW, Alderwood soil B)	January 4, 1998	Surface	2.26	6.30	25.7	9
		Subsurface	2.45	7.39	18.4	19
	February 20, 1998	Surface	2.30	7.95	27.1	21
		Subsurface	2.61	8.08	28.0	nd
	March 15, 1998	Surface	3.24	12.48	34.0	17
		Subsurface	6.19	20.78	80.2	14
	April 20, 1998	Surface	4.42	15.85	45.1	25
		Subsurface	3.86	19.25	47.3	17
	May 28, 1998	Surface	2.89	8.22	37.3	13
	June 30, 1998	Surface	na	na	na	nd
		Subsurface	3.62	18.14	46.9	na

Table G-2. Particle Size and Toxicity Analyses of Water Samples (Continued)

			Particle Size (μm) by Percentile			
Sample Location	**Sample Date**	**Sample Type**	**10th Percentile**	**50th Percentile**	**90th Percentile**	**Toxicity (% light reduction)**
CUH, UW, Alderwood soil B, plus GroCo compost (UH-6)	January 4, 1998	Surface	2.31	9.32	21.8	48
		Subsurface	3.82	12.19	25.9	35
	February 20, 1998	Surface	2.21	7.01	31.2	18
		Subsurface	2.23	8.79	43.6	nd
	March 15, 1998	Surface	4.31	13.95	52.5	12
		Subsurface	2.45	8.92	32.4	1
	April 20, 1998	Surface	3.81	15.77	44.4	12
	May 28, 1998	Surface	2.17	11.29	44.4	18
	June 30, 1998	Surface	2.59	24.02	54.1	6
Timbercrest, Alderwod soil C (TC – no compost)	January 4, 1998	Subsurface	2.07	8.78	29.6	32
	February 20, 1998	Surface	1.57	5.17	33.9	13
		Subsurface	2.06	7.43	33.5	na
	March 15, 1998	Surface	5.48	27.45	50.9	na
		Subsurface	4.27	30.98	60.9	9
	June 30, 1998	Surface	5.77	11.51	46.1	nd
		Subsurface	3.61	28.67	49.4	4
Woodmoor, Alderwood soil D, with Cedar Grove compost (WM – Compost)	January 4, 1998	Subsurface	1.94	16.1	44.8	97
	February 20, 1998	Surface	2.67	14.39	45.9	23
		Subsurface	1.58	5.88	19.3	26
	March 15, 1998	Surface	2.19	17.46	88.2	9
		Subsurface	4.64	23.94	75.5	15
	April 20, 1998	Surface	na	na	na	1
		Subsurface	6.95	19.35	58.5	2
	May 28, 1998	Surface	3.32	15.48	35.3	nd
		Subsurface	8.57	28.45	74.1	na
	June 30, 1998	Surface	2.59	16.14	46.0	nd
		Subsurface	3.42	31.32	49.5	nd
Woodmore, Alderwood soil D (WM – No Compost)	February 20, 1998	Surface	na	na	na	74
		Subsurface	4.31	10.86	27.2	3
	April 20, 1998	Surface	na	na	na	12
		Subsurface	2.82	8.53	26.4	11
	May 28, 1998	Surface	8.78	47.32	117.6	11
		Subsurface	2.89	13.33	36.9	12

Table G-3. Comparison of Individual Test Plot Surface Runoff with Subsurface Flow Water Quality Data (significant differences, at $\alpha \leq 0.1$ are shown in bold)

Description		PO4-P	TP	NH4-N	NO3-N	TN	Cl	SO4-S	Al	Ca	Cu	Fe	K
group 1	average	0.02	0.01	0.02	0.59	1.63	1.36	1.17	2.50	5.06	0.01	1.48	2.50
Surface runoff	st dev	0.00	0.01	0.03	0.67	0.23	1.27	1.34	0.33	4.92	0.01	0.21	2.82
soil C	COV	0.00	1.41	1.41	1.13	0.14	0.93	1.15	0.13	0.97	1.41	0.14	1.13
Timbercrest	min	0.02	0.00	0.00	0.12	1.46	0.46	0.22	2.26	1.58	0.00	1.33	0.50
	max	0.02	0.01	0.04	1.06	1.79	2.25	2.11	2.73	8.54	0.01	1.63	4.49
	count	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
group 2	average	0.05	0.53	0.01	0.54	2.54	1.00	4.24	11.06	35.36	0.01	6.76	4.53
Subsurface flows	st dev	0.04	0.25	0.01	0.37	1.13	0.54	0.13	6.21	8.00	0.00	3.01	1.64
soil C	COV	0.79	0.47	1.41	0.68	0.45	0.55	0.03	0.56	0.23	0.00	0.45	0.36
Timbercrest	min	0.02	0.35	0.00	0.28	1.74	0.61	4.15	6.67	29.70	0.01	4.63	3.37
	max	0.07	0.70	0.02	0.80	3.34	1.38	4.33	15.45	41.02	0.01	8.89	5.69
	count	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
ratio of group 2 to group 1 averages		2.25	105.00	0.50	0.91	1.56	0.73	3.64	4.43	6.99	2.00	4.57	1.82
Kurskall-Wallis probability that averages are the same:		0.32	0.12	0.68	1.00	0.44	1.00	0.12	0.12	0.12	0.32	0.12	0.44

Description		PO4-P	TP	NH4-N	NO3-N	TN	Cl	SO4-S	Al	Ca	Cu	Fe	K
group 3	average	0.58	0.80	1.56	1.71	3.68	3.86	0.85	26.38	4.59	0.00	6.18	7.84
Surface runoff	st dev	0.48	0.37	1.47	1.62	2.75	3.78	0.28	26.48	1.20	0.01	5.83	8.23
soil A	COV	0.82	0.46	0.94	0.95	0.75	0.98	0.33	1.00	0.26	1.25	0.94	1.05
CUH (UW)	min	0.10	0.44	0.30	0.02	0.76	1.44	0.53	0.78	2.97	0.00	0.00	1.73
	max	1.51	1.54	3.72	4.50	6.99	11.74	1.34	69.00	6.47	0.01	15.54	22.90
	count	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
group 4	average	0.29	0.32	0.29	1.94	1.71	3.05	0.32	1.02	7.33	0.00	0.52	5.62
subsurface flows	st dev	0.50	0.55	0.42	3.94	1.23	3.01	0.54	1.04	2.08	0.00	0.55	6.40
soil A	COV	1.71	1.72	1.44	2.03	0.72	0.99	1.69	1.01	0.28	1.71	1.07	1.14
CUH (UW)	min	0.00	0.00	0.01	0.00	0.20	0.16	0.00	0.00	5.13	0.00	0.00	0.50
	max	1.35	1.46	0.95	10.50	3.40	8.43	1.33	2.67	9.74	0.01	1.39	16.83
	count	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
ratio of group 4 to group 3 averages		**0.50**	**0.40**	**0.19**	1.13	0.47	0.79	**0.38**	**0.04**	**1.60**	0.67	**0.08**	0.72
Kurskall-Wallis probability that averages are the same:		**0.083**	**0.047**	**0.025**	0.14	0.18	0.57	**0.063**	**0.009**	**0.015**	0.59	**0.041**	0.18

Table G-3. Comparison of Individual Test Plot Surface Runoff with Subsurface Flow Water Quality Data (significant differences, at a £ 0.1 are shown in bold) (Continued)

Description		Mg	Mn	Na	S	Zn	Si	10th size	50th size	90th size	toxicity
group 1	average	0.94	0.05	1.72	1.36	0.00	3.99	3.53	16.31	42.40	13.00
Surface runoff	st dev	0.47	0.02	1.62	1.46	0.00	0.22	2.76	15.75	12.02	na
soil C	COV	0.50	0.47	0.94	1.07	1.41	0.06	0.78	0.97	0.28	na
Timbercrest	min	0.61	0.03	0.57	0.33	0.00	3.83	1.57	5.17	33.90	13.00
	max	1.27	0.06	2.86	2.39	0.00	4.14	5.48	27.45	50.90	13.00
	count	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00
group 2	average	3.73	0.34	1.84	4.03	0.00	12.17	3.17	19.21	47.20	9.00
Subsurface flows	st dev	0.83	0.32	0.53	1.23	0.00	8.78	1.56	16.65	19.37	na
soil C	COV	0.22	0.95	0.29	0.31	0.00	0.72	0.49	0.87	0.41	na
Timbercrest	min	3.14	0.11	1.46	3.16	0.00	5.96	2.06	7.43	33.50	9.00
	max	4.31	0.56	2.21	4.90	0.00	18.38	4.27	30.98	60.90	9.00
	count	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00
ratio of group 2 to group 1 averages		3.96	7.44	1.07	2.96	2.00	3.05	0.90	1.18	1.11	0.69
Kurskall-Wallis probability that averages are the same:		0.12	0.12	1.00	0.12	0.32	0.12	1.00	0.44	1.00	0.32

Description		Mg	Mn	Na	S	Zn	Si	10th size	50th size	90th size	toxicity
group 3	average	4.20	0.04	7.51	1.38	0.38	59.66	1.46	6.33	42.18	28.40
Surface runoff	st dev	3.21	0.04	2.95	0.47	0.10	62.80	0.22	6.51	4.88	8.11
soil A	COV	0.77	1.02	0.39	0.34	0.26	1.05	0.15	1.03	0.12	0.29
CUH (UW)	min	1.33	0.00	3.73	0.64	0.28	1.48	1.21	3.05	36.90	19.00
	max	9.51	0.12	11.73	2.17	0.57	159.03	1.67	17.96	48.20	39.00
	count	7.00	7.00	7.00	7.00	7.00	7.00	5.00	5.00	5.00	5.00
group 4	average	3.59	0.01	4.21	0.60	0.09	8.00	2.20	10.36	43.25	15.40
subsurface flows	st dev	1.55	0.02	1.75	0.67	0.16	3.93	0.73	5.34	30.61	4.62
soil A	COV	0.43	1.32	0.42	1.11	1.83	0.49	0.33	0.52	0.71	0.30
CUH (UW)	min	1.59	0.00	2.43	0.13	0.00	0.70	1.55	3.95	18.50	10.00
	max	5.40	0.04	7.76	1.65	0.41	11.54	3.24	15.39	87.20	21.00
	count	7.00	7.00	7.00	7.00	7.00	7.00	4.00	4.00	4.00	5.00
ratio of group 4 to group 3 averages		0.86	0.27	**0.56**	**0.43**	**0.23**	0.13	**1.51**	1.64	1.03	**0.54**
Kurskall-Wallis probability that averages are the same:		0.95	0.14	**0.018**	**0.064**	**0.012**	0.34	**0.05**	0.22	0.46	**0.021**

Table G-3. Comparison of Individual Test Plot Surface Runoff with Subsurface Flow Water Quality Data (significant differences, at $\alpha \leq 0.1$ are shown in bold) (Continued)

Description		PO4-P	TP	NH4-N	NO3-N	TN	Cl	SO4-S	Al	Ca	Cu	Fe	K
group 5	average	2.20	2.88	5.10	5.09	7.99	6.00	1.33	0.45	4.61	0.01	0.33	16.85
surface runoff	st dev	2.74	3.63	6.59	6.69	10.53	7.63	1.10	0.63	6.00	0.01	0.47	21.60
soil A and CG	COV	1.25	1.26	1.29	1.31	1.32	1.27	0.82	1.40	1.30	0.81	1.42	1.28
CUH (UW)	min	0.21	0.28	0.00	0.09	1.53	0.77	0.37	0.00	0.87	0.00	0.00	2.33
	max	6.99	8.20	19.10	17.01	31.14	17.80	3.01	1.69	16.36	0.02	1.36	48.74
	count	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
group 6	average	1.38	1.87	0.25	4.32	5.24	4.93	1.55	5.12	20.11	0.02	3.16	26.01
subsurface flows	st dev	2.35	2.75	0.56	6.07	5.07	7.59	0.96	4.68	5.06	0.01	2.61	15.51
soil A and CG	COV	1.71	1.47	2.20	1.41	0.97	1.54	0.62	0.91	0.25	0.50	0.83	0.60
CUH (UW)	min	0.10	0.44	0.00	0.04	0.71	0.10	0.34	0.00	10.44	0.00	0.00	14.65
	max	6.56	7.85	1.51	14.50	15.12	18.50	2.84	11.16	24.34	0.03	6.21	54.99
	count	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
ratio of group 6 to group 5 averages		0.63	0.65	**0.05**	0.85	0.66	0.82	1.16	**11.31**	**4.36**	**2.50**	**9.56**	1.54
Kurskall-Wallis probability that averages are the same:		0.25	0.34	**0.029**	0.65	0.66	0.23	0.75	**0.071**	**0.003**	**0.025**	**0.063**	0.11

Description		PO4-P	TP	NH4-N	NO3-N	TN	Cl	SO4-S	Al	Ca	Cu	Fe	K
group 7	average	0.18	0.34	0.13	0.99	2.15	1.51	0.23	0.79	5.52	0.01	0.75	4.78
Surface runoff	st dev	0.19	0.32	0.11	1.30	2.72	0.84	0.14	0.92	0.29	0.01	0.59	3.73
soil B	COV	1.06	0.95	0.90	1.31	1.26	0.56	0.63	1.16	0.05	1.10	0.79	0.78
CUH (UW)	min	0.00	0.01	0.01	0.03	0.70	0.57	0.08	0.00	5.22	0.00	0.11	0.50
	max	0.51	0.87	0.32	3.48	7.62	2.94	0.50	2.08	5.92	0.01	1.65	11.73
	count	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
group 8	average	0.16	0.98	0.09	1.50	2.01	1.20	0.14	0.29	14.63	0.01	1.67	3.78
subsurface flows	st dev	0.29	1.82	0.08	3.57	1.86	0.68	0.22	0.43	6.49	0.02	3.30	1.84
soil B	COV	1.88	1.86	0.94	2.38	0.93	0.57	1.55	1.49	0.44	1.92	1.98	0.49
CUH (UW)	min	0.00	0.00	0.02	0.00	0.35	0.45	0.00	0.00	6.88	0.00	0.03	1.51
	max	0.73	4.60	0.23	8.78	4.58	1.97	0.58	0.88	21.90	0.04	8.37	6.92
	count	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
ratio of group 8 to group 7 averages		0.88	2.88	0.67	1.52	0.93	0.79	**0.63**	0.36	**2.65**	1.67	2.24	0.79
Kurskall-Wallis probability that averages are the same:		0.37	0.87	0.63	0.11	0.63	0.63	**0.078**	0.22	**0.004**	0.78	0.52	0.52

Table G-3. Comparison of Individual Test Plot Surface Runoff with Subsurface Flow Water Quality Data (significant differences, at $\alpha \leq 0.1$ are shown in bold) (Continued)

Description		Mg	Mn	Na	S	Zn	Si	10th size	50th size	90th size	toxicity
group 5	average	1.40	0.09	1.27	1.90	0.17	1.27	2.62	16.43	53.84	20.80
surface runoff	st dev	1.60	0.19	0.71	1.75	0.17	0.70	0.73	8.79	26.35	12.13
soil A and CG	COV	1.14	2.11	0.56	0.92	0.99	0.55	0.28	0.53	0.49	0.58
CUH (UW)	min	0.37	0.00	0.58	0.54	0.00	0.03	1.81	6.85	29.60	1.00
	max	4.16	0.52	2.29	4.74	0.40	1.99	3.79	27.11	97.50	31.00
	count	7.00	7.00	7.00	7.00	7.00	7.00	5.00	5.00	5.00	5.00
group 6	average	6.47	0.05	2.06	2.79	0.01	14.86	2.76	12.25	52.12	9.67
subsurface flows	st dev	1.69	0.04	0.37	1.09	0.02	10.63	1.38	8.89	33.54	7.17
soil A and CG	COV	0.26	0.86	0.18	0.39	1.83	0.72	0.50	0.73	0.64	0.74
CUH (UW)	min	3.45	0.00	1.70	1.51	0.00	3.24	1.53	4.35	20.50	1.00
	max	8.11	0.10	2.75	4.22	0.05	28.11	5.04	25.78	98.00	18.00
	count	7.00	7.00	7.00	7.00	7.00	7.00	6.00	6.00	6.00	6.00
ratio of group 6 to group 5 averages		**4.62**	0.55	**1.62**	1.46	**0.06**	**11.72**	1.05	0.75	0.97	**0.46**
Kurskall-Wallis probability that averages are the same:		**0.003**	0.61	**0.064**	0.14	**0.028**	**0.002**	0.78	0.27	0.58	**0.098**

Description		Mg	Mn	Na	S	Zn	Si	10th size	50th size	90th size	toxicity
group 7	average	2.95	0.01	1.91	0.54	0.03	5.11	3.02	10.16	33.84	17.00
Surface runoff	st dev	0.42	0.02	0.46	0.24	0.05	2.20	0.88	3.91	7.91	6.32
soil B	COV	0.14	1.20	0.24	0.45	1.58	0.43	0.29	0.39	0.23	0.37
CUH (UW)	min	2.10	0.00	1.12	0.36	0.00	2.08	2.26	6.30	25.70	9.00
	max	3.26	0.04	2.32	1.03	0.12	7.85	4.42	15.85	45.10	25.00
	count	6.00	6.00	6.00	6.00	6.00	6.00	5.00	5.00	5.00	5.00
group 8	average	7.22	0.02	3.87	0.58	0.00	10.94	3.78	13.88	43.48	12.75
subsurface flows	st dev	2.99	0.02	1.64	0.48	0.01	4.68	1.73	7.12	27.27	8.10
soil B	COV	0.41	1.13	0.42	0.81	2.09	0.43	0.46	0.51	0.63	0.64
CUH (UW)	min	4.27	0.00	2.01	0.13	0.00	5.16	2.45	7.39	18.40	1.00
	max	12.84	0.04	5.93	1.19	0.02	17.33	6.19	20.78	80.20	19.00
	count	6.00	6.00	6.00	6.00	6.00	6.00	4.00	4.00	4.00	4.00
ratio of group 8 to group 7 averages		**2.44**	1.14	**2.03**	1.08	**0.13**	**2.14**	1.25	1.37	1.28	0.75
Kurskall-Wallis probability that averages are the same:		**0.004**	0.68	**0.016**	0.42	**0.042**	**0.037**	0.46	0.46	0.62	0.54

Table G-3. Comparison of Individual Test Plot Surface Runoff with Subsurface Flow Water Quality Data (significant differences, at a £ 0.1 are shown in bold) (Continued)

Description		PO4-P	TP	NH4-N	NO3-N	TN	Cl	SO4-S	Al	Ca	Cu	Fe	K
group 9	average	1.92	2.77	0.54	2.42	4.21	5.91	0.81	0.72	11.69	0.04	1.97	15.97
surface runoff	st dev	1.47	1.82	0.92	2.66	4.33	7.37	0.82	0.77	8.37	0.03	2.23	21.93
soil B and GroCo	COV	0.77	0.66	1.72	1.10	1.03	1.25	1.02	1.07	0.72	0.90	1.13	1.37
CUH (UW)	min	0.62	0.80	0.03	0.00	0.92	1.01	0.10	0.00	1.94	0.00	0.00	0.50
	max	4.93	5.99	2.59	7.63	13.07	17.29	2.23	1.95	23.08	0.09	5.22	50.04
	count	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
group 10	average	2.41	2.99	1.08	11.53	4.03	6.37	2.34	0.39	30.63	0.03	2.21	9.24
subsurface flows	st dev	2.66	3.10	2.02	27.68	3.75	10.60	4.49	0.62	48.16	0.03	1.89	14.81
soil B and GroCo	COV	1.10	1.04	1.87	2.40	0.93	1.66	1.91	1.58	1.57	0.94	0.86	1.60
CUH (UW)	min	1.08	0.00	0.02	0.00	0.90	0.40	0.03	0.00	6.66	0.00	0.00	0.50
	max	8.42	9.66	5.53	74.20	11.22	30.17	12.35	1.31	139.53	0.08	4.51	41.50
	count	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
ratio of group 10 to group 9 averages		1.26	1.08	2.02	4.76	0.96	1.08	2.90	0.54	2.62	0.85	1.12	0.58
Kurskall-Wallis probability that averages are the same:		0.85	0.95	0.90	0.48	0.95	0.75	0.95	0.74	0.41	0.74	0.80	0.34

Description		PO4-P	TP	NH4-N	NO3-N	TN	Cl	SO4-S	Al	Ca	Cu	Fe	K
group 11	average	0.06	0.42	0.27	0.02	1.48	1.86	0.79	4.56	31.06	0.01	8.43	3.91
surface runoff	st dev	0.08	0.67	0.39	0.04	0.72	1.11	1.20	5.78	26.79	0.00	9.36	2.88
soil D	COV	1.30	1.58	1.46	1.58	0.48	0.59	1.52	1.27	0.86	0.00	1.11	0.74
Woodmoor	min	0.00	0.00	0.03	0.00	0.58	0.32	0.03	0.00	6.56	0.01	0.31	0.50
	max	0.18	1.59	0.95	0.09	2.22	3.24	2.91	12.93	63.40	0.01	23.55	7.18
	count	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
group 12	average	0.07	0.09	0.39	0.00	1.70	2.63	1.50	0.74	24.66	0.01	5.79	4.34
subsurface flows	st dev	0.09	0.11	0.24	0.01	0.98	1.33	2.94	0.99	15.02	0.01	7.04	1.13
soil D	COV	1.37	1.26	0.60	1.37	0.58	0.51	1.95	1.34	0.61	0.91	1.22	0.26
Woodmoor	min	0.00	0.00	0.03	0.00	0.65	0.53	0.03	0.05	6.69	0.00	0.17	2.51
	max	0.18	0.21	0.68	0.01	2.85	3.70	6.75	2.20	40.15	0.01	16.51	5.39
	count	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
ratio of group 12 to group 11 averages		1.17	0.20	1.47	0.17	1.15	1.41	1.91	0.16	0.79	0.60	0.69	1.11
Kurskall-Wallis probability that averages are the same:		0.82	0.34	0.40	0.31	0.60	0.25	0.68	0.52	0.75	0.13	0.47	0.75

Table G-3. Comparison of Individual Test Plot Surface Runoff with Subsurface Flow Water Quality Data (significant differences, at a £ 0.1 are shown in bold) (Continued)

Description		Mg	Mn	Na	S	Zn	Si	10th size	50th size	90th size	toxicity
group 9	average	3.17	0.25	3.83	1.75	0.08	5.48	2.90	13.56	41.40	19.00
surface runoff	st dev	2.62	0.39	2.39	1.28	0.06	5.63	0.92	6.01	12.58	14.90
soil B and GroCo	COV	0.83	1.56	0.63	0.73	0.75	1.03	0.32	0.44	0.30	0.78
CUH (UW)	min	0.80	0.00	1.95	0.65	0.00	0.62	2.17	7.01	21.80	6.00
	max	8.12	1.00	8.84	3.79	0.14	15.70	4.31	24.02	54.10	48.00
	count	7.00	7.00	7.00	7.00	7.00	7.00	6.00	6.00	6.00	6.00
group 10	average	6.39	0.56	4.88	3.32	0.05	9.53	2.83	9.80	33.97	12.33
subsurface flows	st dev	4.91	0.81	5.12	4.91	0.07	6.06	0.86	2.08	8.95	19.63
soil B and GroCo	COV	0.77	1.43	1.05	1.48	1.42	0.64	0.30	0.21	0.26	1.59
CUH (UW)	min	1.78	0.01	1.02	0.30	0.00	0.62	2.23	8.42	25.90	1.00
	max	16.81	2.19	13.48	14.17	0.17	16.38	3.82	12.19	43.60	35.00
	count	7.00	7.00	7.00	7.00	7.00	7.00	3.00	3.00	3.00	3.00
ratio of group 10 to group 9 averages		2.02	2.25	1.27	1.90	0.61	1.74	0.98	0.72	0.82	0.65
Kurskall-Wallis probability that averages are the same:		0.11	0.44	0.57	0.75	0.33	0.25	0.80	0.30	0.30	0.30

Description		Mg	Mn	Na	S	Zn	Si	10th size	50th size	90th size	toxicity
group 11	average	5.84	2.92	1.74	1.28	0.23	11.26	8.78	47.32	117.60	32.33
surface runoff	st dev	4.78	3.90	0.65	1.49	0.42	3.01	na	na	na	36.09
soil D	COV	0.82	1.33	0.38	1.16	1.84	0.27	na	na	na	1.12
Woodmoor	min	1.14	0.21	0.76	0.32	0.00	6.96	8.78	47.32	117.60	11.00
	max	11.33	9.26	2.25	3.89	0.96	15.37	8.78	47.32	117.60	74.00
	count	5.00	5.00	5.00	5.00	5.00	5.00	1.00	1.00	1.00	3.00
group 12	average	4.97	1.46	2.24	2.21	0.06	6.33	3.34	10.91	30.17	8.67
subsurface flows	st dev	3.71	2.08	1.19	3.37	0.08	4.01	0.84	2.40	5.84	4.93
soil D	COV	0.75	1.42	0.53	1.53	1.36	0.63	0.25	0.22	0.19	0.57
Woodmoor	min	0.56	0.00	0.38	0.48	0.00	0.98	2.82	8.53	26.40	3.00
	max	8.39	4.74	3.69	8.23	0.17	10.34	4.31	13.33	36.90	12.00
	count	5.00	5.00	5.00	5.00	5.00	5.00	3.00	3.00	3.00	3.00
ratio of group 12 to group 11 averages		0.85	0.50	1.29	1.72	0.26	**0.56**	0.38	0.23	0.26	0.27
Kurskall-Wallis probability that averages are the same:		0.60	0.35	0.12	0.60	0.58	**0.047**	0.18	0.18	0.18	0.26

Table G-3. Comparison of Individual Test Plot Surface Runoff with Subsurface Flow Water Quality Data (significant differences, at $\alpha \le 0.1$ are shown in bold) (Continued)

Description		PO4-P	TP	NH4-N	NO3-N	TN	Cl	SO4-S	Al	Ca	Cu	Fe	K
group 13	average	1.26	2.41	8.55	0.38	16.57	9.28	3.07	1.14	54.09	0.02	1.47	78.44
surface runoff	st dev	0.36	1.30	12.94	0.55	21.26	8.45	1.53	2.28	4.93	0.02	2.23	58.34
soil D and Cedar Grove	COV	0.29	0.54	1.51	1.46	1.28	0.91	0.50	2.00	0.09	1.27	1.52	0.74
compost	min	0.84	1.41	0.00	0.00	2.15	2.20	1.54	0.00	49.18	0.00	0.00	26.13
Woodmoor	max	1.56	4.32	27.36	1.17	47.60	19.53	4.75	4.56	60.76	0.05	4.75	158.10
	count	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
group 14	average	1.35	2.81	13.28	0.03	27.68	2.80	3.96	1.14	69.24	0.02	2.24	93.53
subsurface flows	st dev	0.59	2.21	20.83	0.06	41.99	4.21	4.31	2.22	46.31	0.02	2.80	102.08
soil D and Cedar Grove	COV	0.44	0.79	1.57	2.00	1.52	1.51	1.09	1.94	0.67	1.27	1.25	1.09
compost	min	0.84	0.97	0.00	0.00	1.69	0.00	0.64	0.00	20.12	0.00	0.00	10.08
Woodmoor	max	2.20	6.00	43.90	0.12	90.00	9.00	10.17	4.47	131.87	0.05	5.93	240.68
	count	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
ratio of group 14 to group 13 averages		1.07	1.17	1.55	0.08	1.67	**0.30**	1.29	1.00	1.28	1.00	1.53	1.19
Kurskall-Wallis probability that averages are the same:		0.88	0.77	0.66	0.32	0.77	**0.083**	0.56	0.44	0.39	1.00	0.77	0.77

Description		PO4-P	TP	NH4-N	NO3-N	TN	Cl	SO4-S	Al	Ca	Cu	Fe	K
group 15	average	0.06	0.06	0.18	0.09	1.22	1.00	0.40	0.00	0.41	0.00	0.04	2.64
rainfall	st dev	0.13	0.14	0.15	0.09	0.70	0.30	0.14	0.00	0.30	0.00	0.08	1.67
	COV	2.11	2.61	0.84	0.94	0.58	0.30	0.35	na	0.73	2.83	1.98	0.63
	min	0.00	0.00	0.00	0.00	0.38	0.61	0.22	0.00	0.17	0.00	0.00	0.20
	max	0.39	0.41	0.45	0.24	2.41	1.34	0.64	0.00	0.94	0.01	0.24	5.50
	count	8.00	8.00	8.00	7.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00

Table G-3. Comparison of Individual Test Plot Surface Runoff with Subsurface Flow Water Quality Data (significant differences, at a £ 0.1 are shown in bold) (Continued)

Description		Mg	Mn	Na	S	Zn	Si	10th size	50th size	90th size	toxicity
group 13	average	17.89	1.01	5.69	5.02	0.17	6.95	2.86	15.34	42.40	6.50
surface runoff	st dev	2.22	1.24	3.44	1.98	0.21	3.36	0.40	0.88	6.15	11.00
soil D and Cedar Grove	COV	0.12	1.24	0.61	0.39	1.26	0.48	0.14	0.06	0.15	1.69
compost	min	14.97	0.00	2.93	3.34	0.00	5.17	2.59	14.39	35.30	1.00
Woodmoor	max	20.38	2.62	10.68	7.78	0.45	11.98	3.32	16.14	46.00	23.00
	count	4.00	4.00	4.00	4.00	4.00	4.00	3.00	3.00	3.00	4.00
group 14	average	23.08	2.54	8.61	10.31	0.03	7.71	5.13	21.25	50.35	9.67
subsurface flows	st dev	18.27	3.84	9.78	13.94	0.05	4.53	3.20	11.45	23.06	14.15
soil D and Cedar Grove	COV	0.79	1.51	1.14	1.35	1.93	0.59	0.62	0.54	0.46	1.46
compost	min	2.57	0.00	2.86	2.07	0.00	4.35	1.58	5.88	19.30	1.00
Woodmoor	max	47.00	8.13	23.25	31.15	0.11	14.32	8.57	31.32	74.10	26.00
	count	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	3.00
ratio of group 14 to group 13 averages		1.29	2.52	1.51	2.05	0.17	1.11	1.79	1.39	1.19	1.49
Kurskall-Wallis probability that averages are the same:		0.39	0.77	1.00	0.56	0.14	1.00	0.29	0.29	0.29	0.33

Description		Mg	Mn	Na	S	Zn	Si	10th size	50th size	90th size	toxicity
group 15	average	0.07	0.00	0.67	0.49	0.03	0.04	4.09	22.37	61.78	18.50
rainfall	st dev	0.07	0.00	0.30	0.15	0.07	0.05	4.05	20.18	25.31	9.04
	COV	0.97	0.83	0.45	0.31	2.41	1.20	0.99	0.90	0.41	0.49
	min	0.00	0.00	0.35	0.26	0.00	0.00	1.75	7.42	31.00	5.00
	max	0.22	0.00	1.32	0.78	0.19	0.12	10.15	52.08	85.90	24.00
	count	8.00	8.00	8.00	8.00	8.00	8.00	4.00	4.00	4.00	4.00

Table G-4. Comparisons of Surface Runoff and Subsurface Flow Quality for Soil Sites Compared to Sites with Soil and Compost (significant differences, at a £ 0.1 are shown in bold)

Description		PO4-P	TP	NH4-N	NO3-N	TN	Cl	SO4-S	Al	Ca	Cu	Fe	K
group 1	average	0.27	0.49	0.65	0.96	2.47	2.40	0.68	10.86	11.53	0.01	4.64	5.41
surface runoff	st dev	0.37	0.48	1.09	1.32	2.31	2.50	0.73	19.16	16.93	0.01	6.31	5.57
soil-only	COV	1.36	0.99	1.67	1.38	0.94	1.04	1.07	1.76	1.47	0.84	1.36	1.03
	min	0.00	0.00	0.00	0.00	0.58	0.32	0.03	0.00	1.58	0.00	0.00	0.50
	max	1.51	1.59	3.72	4.50	7.62	11.74	2.91	69.00	63.40	0.01	23.55	22.90
	count	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
group 2	average	1.88	2.73	4.09	3.01	8.43	6.69	1.51	0.71	18.36	0.02	1.22	30.19
surface runoff	st dev	1.89	2.48	7.45	4.68	12.19	7.37	1.36	1.16	20.93	0.03	1.81	40.49
soil and compost	COV	1.00	0.91	1.82	1.56	1.45	1.10	0.90	1.63	1.14	1.20	1.48	1.34
	min	0.21	0.28	0.00	0.00	0.92	0.77	0.10	0.00	0.87	0.00	0.00	0.50
	max	6.99	8.20	27.36	17.01	47.60	19.53	4.75	4.56	60.76	0.09	5.22	158.10
	count	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
ratio of group 2 to group 1 averages		**6.89**	**5.60**	6.27	3.13	**3.42**	2.78	**2.23**	**0.07**	1.59	**3.61**	**0.26**	**5.58**
Kurskall-Wallis probability that averages are the same:		**0.00**	**0.00**	0.17	0.21	**0.007**	0.11	**0.035**	**0.002**	0.66	**0.018**	**0.011**	**0.026**

Description		PO4-P	TP	NH4-N	NO3-N	TN	Cl	SO4-S	Al	Ca	Cu	Fe	K
group 3	average	0.17	0.48	0.23	1.18	1.88	2.18	0.95	1.74	16.66	0.01	2.81	4.64
subsurface flows	st dev	0.33	1.05	0.30	2.98	1.31	2.04	1.87	3.59	12.26	0.01	4.50	3.86
soils only	COV	1.97	2.19	1.32	2.52	0.70	0.93	1.96	2.07	0.74	1.57	1.60	0.83
	min	0.00	0.00	0.00	0.00	0.20	0.16	0.00	0.00	5.13	0.00	0.00	0.50
	max	1.35	4.60	0.95	10.50	4.58	8.43	6.75	15.45	41.02	0.04	16.51	16.83
	count	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
group 4	average	1.78	2.51	3.47	6.17	9.75	5.02	2.39	2.40	35.12	0.02	2.58	34.49
subsurface flows	st dev	2.19	2.68	10.36	17.48	20.56	8.07	3.40	3.71	39.76	0.02	2.30	55.80
soil and compost	COV	1.23	1.07	2.99	2.83	2.11	1.61	1.42	1.55	1.13	0.89	0.89	1.62
	min	0.10	0.00	0.00	0.00	0.71	0.00	0.03	0.00	6.66	0.00	0.00	0.50
	max	8.42	9.66	43.90	74.20	90.00	30.17	12.35	11.16	139.53	0.08	6.21	240.68
	count	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
ratio of group 4 to group 3 averages		**10.47**	**5.25**	15.29	5.21	**5.18**	2.30	**2.51**	1.38	**2.11**	**4.07**	0.92	**7.44**
Kurskall-Wallis probability that averages are the same:		**0.00**	**0.00**	0.54	0.11	**0.012**	0.94	**0.004**	0.98	**0.057**	**0.002**	0.60	**0.003**

Table G-4. Comparisons of Surface Runoff and Subsurface Flow Quality for Soil Sites Compared to Sites with Soil and Compost (significant differences, at a £ 0.1 are shown in bold) (Continued)

Description		Mg	Mn	Na	S	Zn	Si	10th size	50th size	90th size	toxicity
group 1	average	3.91	0.75	3.81	1.10	0.20	25.63	2.94	12.49	44.81	24.07
surface runoff	st dev	3.22	2.20	3.29	0.90	0.26	43.73	2.17	12.71	23.16	16.87
soil-only	COV	0.82	2.92	0.86	0.81	1.29	1.71	0.74	1.02	0.52	0.70
	min	0.61	0.00	0.57	0.32	0.00	1.48	1.21	3.05	25.70	9.00
	max	11.33	9.26	11.73	3.89	0.96	159.03	8.78	47.32	117.60	74.00
	count	20.00	20.00	20.00	20.00	20.00	20.00	13.00	13.00	13.00	14.00
group 2	average	5.75	0.36	3.25	2.54	0.14	4.17	2.79	14.97	46.06	16.27
surface runoff	st dev	7.03	0.69	2.73	2.05	0.15	4.40	0.73	6.29	17.80	13.60
soil and compost	COV	1.22	1.93	0.84	0.81	1.07	1.06	0.26	0.42	0.39	0.84
	min	0.37	0.00	0.58	0.54	0.00	0.03	1.81	6.85	21.80	1.00
	max	20.38	2.62	10.68	7.78	0.45	15.70	4.31	27.11	97.50	48.00
	count	18.00	18.00	18.00	18.00	18.00	18.00	14.00	14.00	14.00	15.00
ratio of group 2 to group 1 averages		1.47	0.47	0.85	**2.30**	0.68	**0.16**	0.95	1.20	1.03	0.68
Kurskall-Wallis probability that averages are the same:		0.70	0.88	0.82	**0.01**	0.96	**0.003**	0.26	0.11	0.44	0.20

Description		Mg	Mn	Na	S	Zn	Si	10th size	50th size	90th size	toxicity
group 3	average	5.04	0.41	3.38	1.34	0.05	8.88	3.10	12.93	40.91	12.54
subsurface flows	st dev	2.91	1.14	1.70	2.00	0.10	4.75	1.28	7.35	22.29	5.98
soils only	COV	0.58	2.81	0.50	1.50	2.22	0.53	0.41	0.57	0.54	0.48
	min	0.56	0.00	0.38	0.13	0.00	0.70	1.55	3.95	18.40	1.00
	max	12.84	4.74	7.76	8.23	0.41	18.38	6.19	30.98	87.20	21.00
	count	20.00	20.00	20.00	20.00	20.00	20.00	13.00	13.00	13.00	13.00
group 4	average	10.13	0.80	4.61	4.67	0.03	11.20	3.50	14.45	47.38	10.33
subsurface flows	st dev	10.91	1.95	5.71	7.28	0.05	8.12	2.18	9.47	25.97	11.46
soil and compost	COV	1.08	2.43	1.24	1.56	1.78	0.73	0.62	0.66	0.55	1.11
	min	1.78	0.00	1.02	0.30	0.00	0.62	1.53	4.35	19.30	1.00
	max	47.00	8.13	23.25	31.15	0.17	28.11	8.57	31.32	98.00	35.00
	count	18.00	18.00	18.00	18.00	18.00	18.00	13.00	13.00	13.00	12.00
ratio of group 4 to group 3 averages		**2.01**	1.97	1.37	**3.48**	0.63	1.26	1.13	1.12	1.16	0.82
Kurskall-Wallis probability that averages are the same:		**0.075**	0.15	0.31	**0.001**	0.45	0.55	1.00	0.82	0.61	0.24

Figure G-1. Particle size for all precipitation samples.

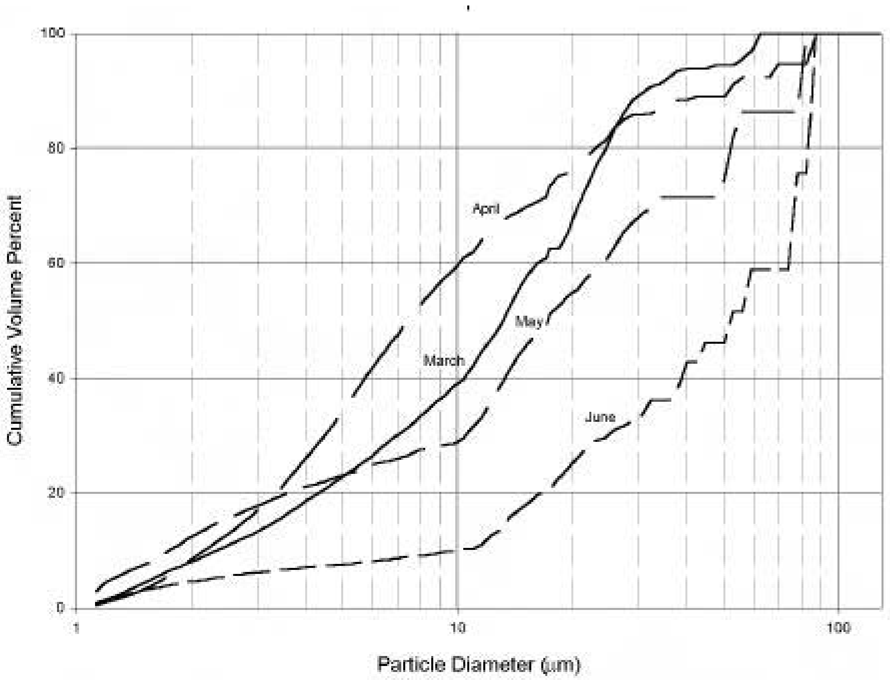


Figure G-2. Timbercrest, Alderwood soil C only, subsurface sample, January 4, 1998.

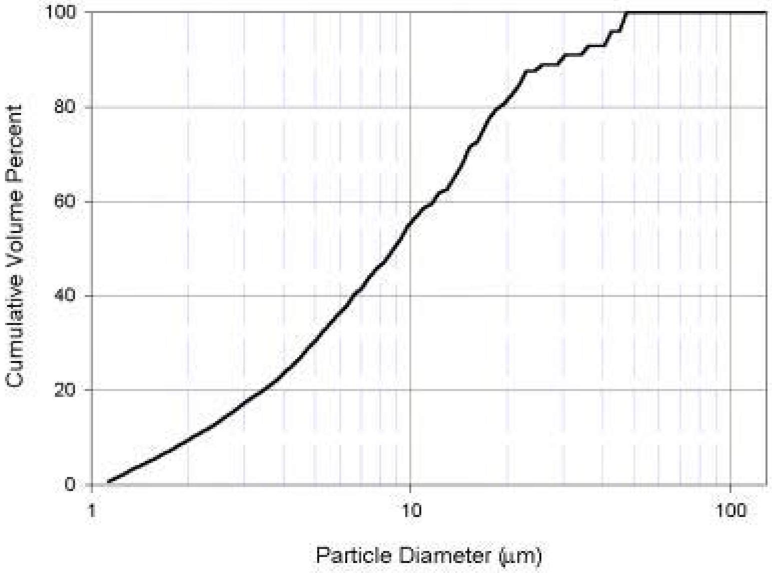


Figure G-3. Timbercrest, Alderwood soil C only, February 20, 1998.

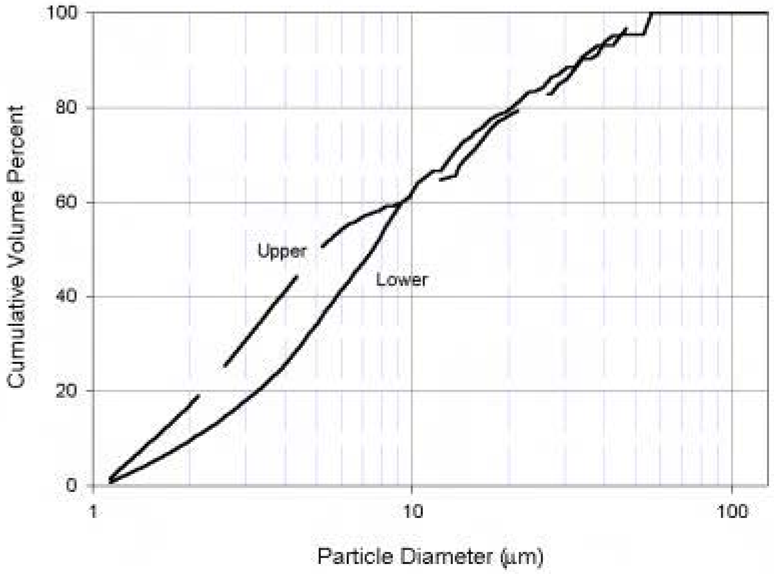


Figure G-4. Timbercrest, Alderwood soil C only, March 15, 1998.

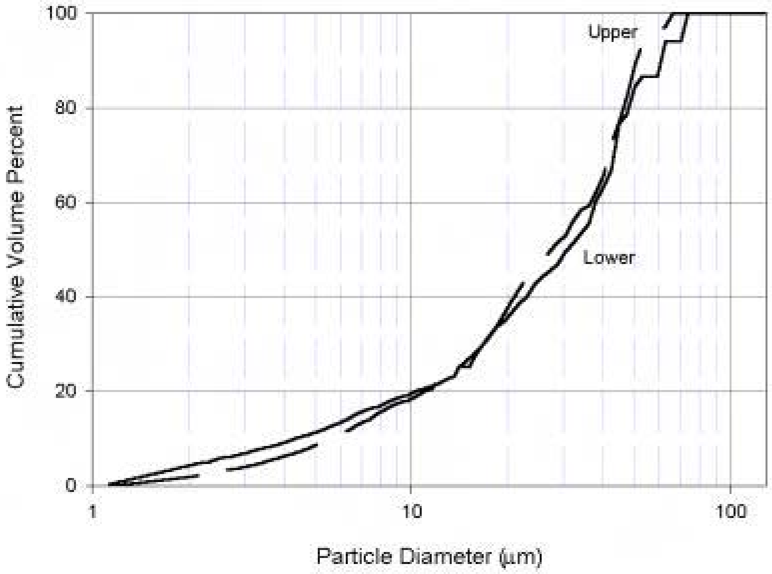


Figure G-5. Timbercrest, Alderwood soil C only, June 1998.

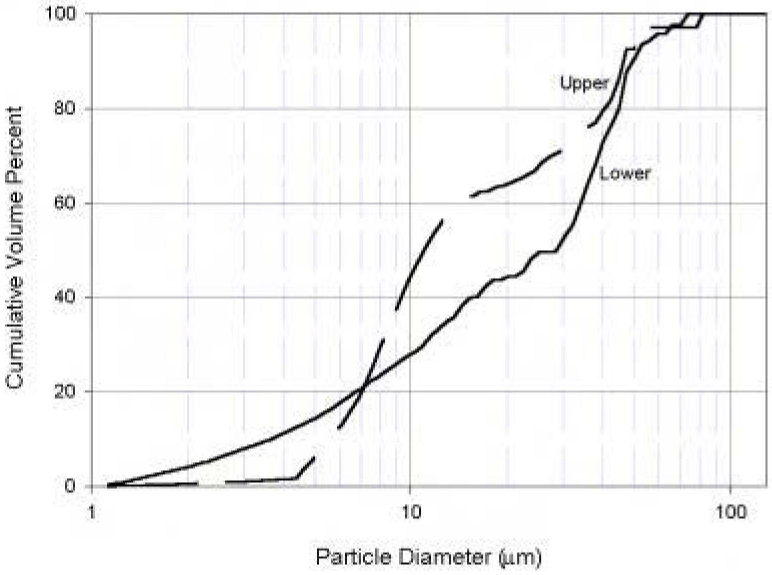


Figure G-6. Urban Horticulture (UW), Alderwood soil A only, surface runoff, April 17, 1998.

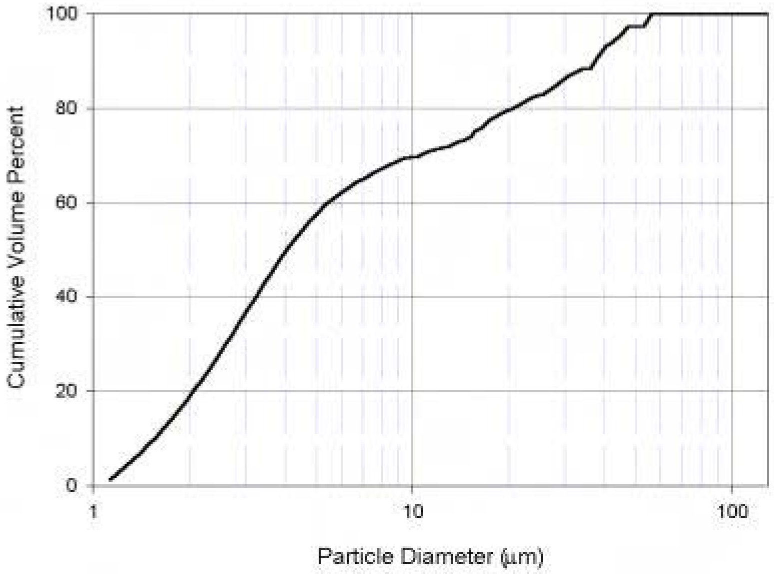


Figure G-7. Urban Horticulture (UW), Alderwood soil A only, June, 1998.

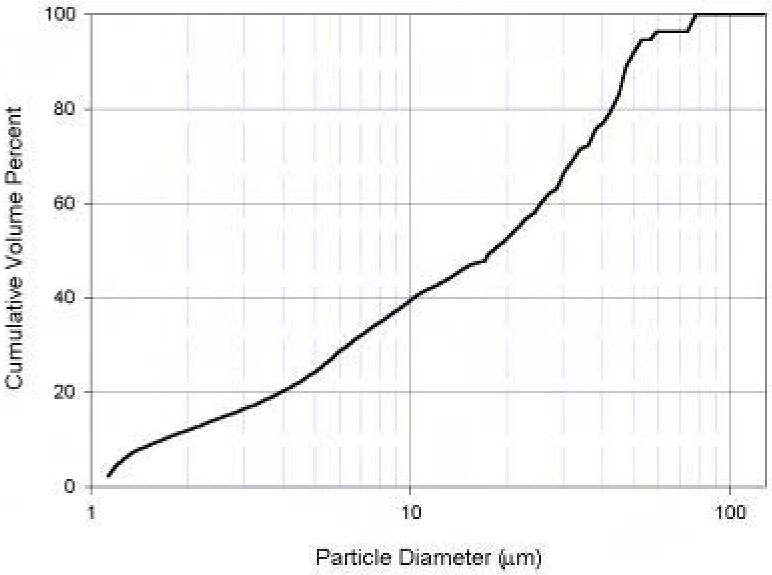


Figure G-8. Urban Horticulture (UW), Alderwood soil A only, February 20, 1998.

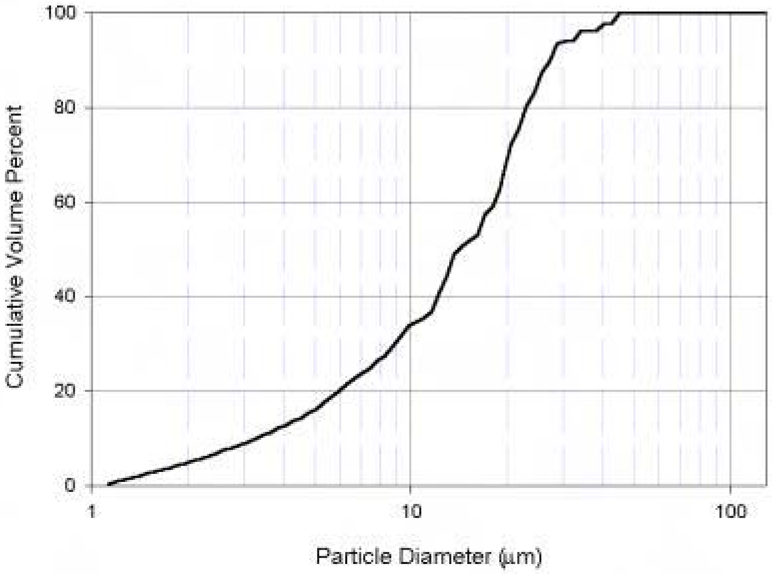


Figure G-9. Urban Horticulture (UW), Alderwood soil A only, January 4, 1998.

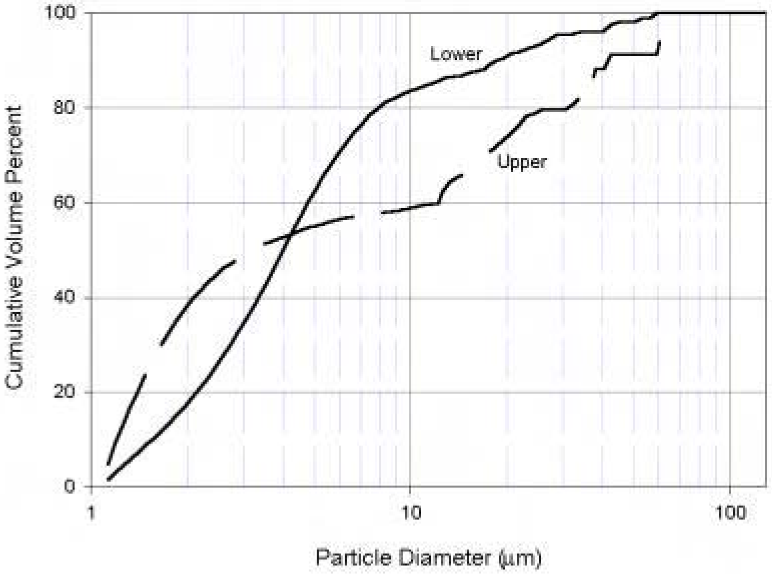


Figure G-10. Urban Horticulture (UW), Alderwood soil A only, March 15, 1998.

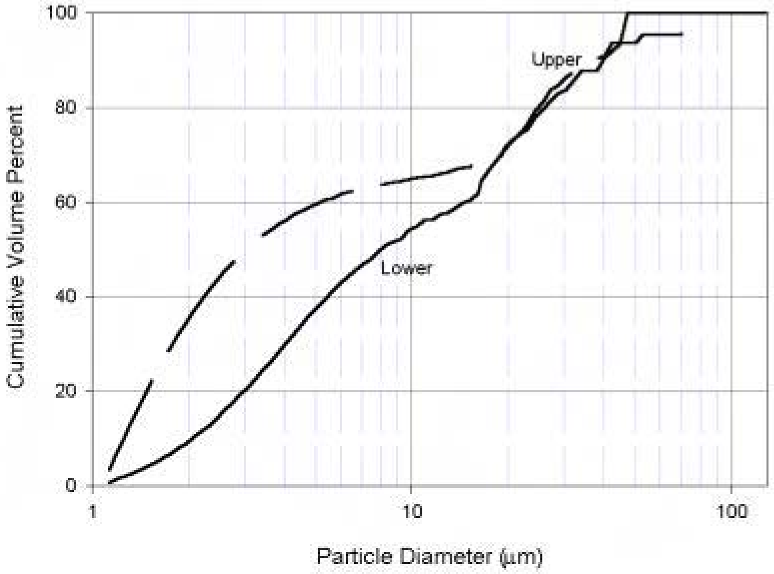


Figure G-11. Urban Horticulture (UW), Alderwood soil A only, May 28, 1998

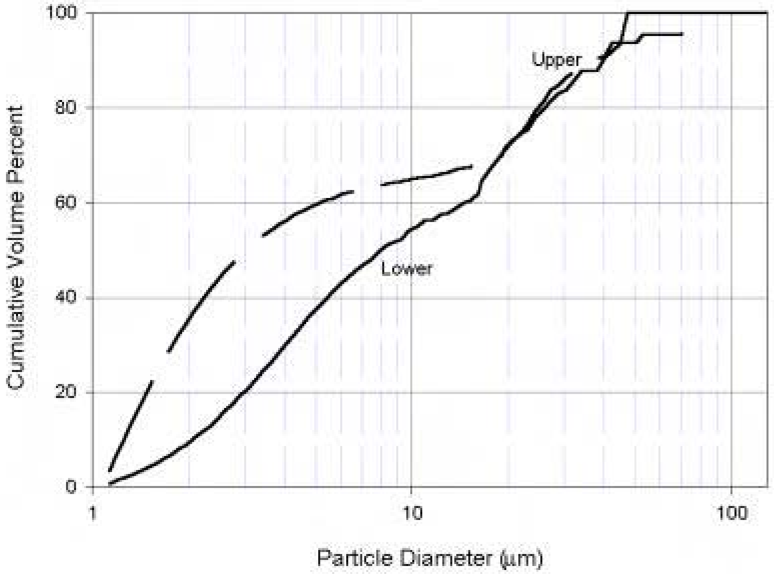


Figure G-12. Urban Horticulture (UW), Alderwood soil A and compost, subsurface flow sample, May 28, 1998.

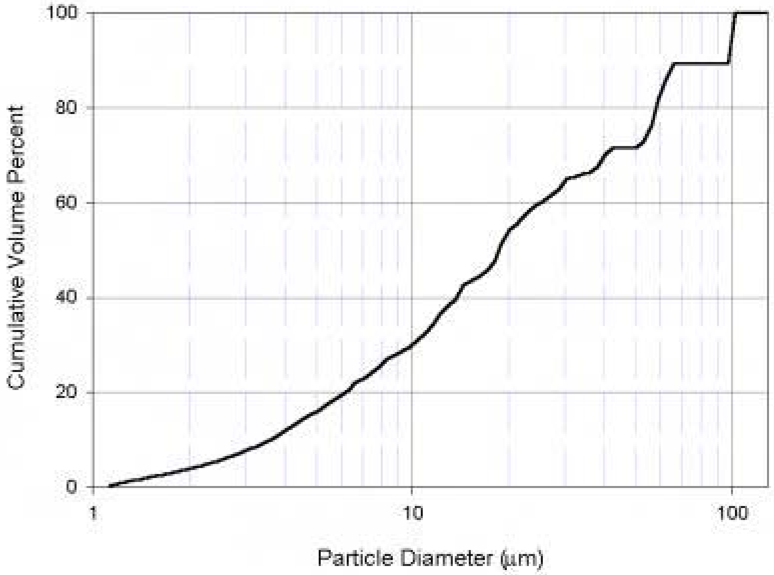


Figure G-13. Urban Horticulture (UW), Alderwood soil A and compost, January 4, 1998.

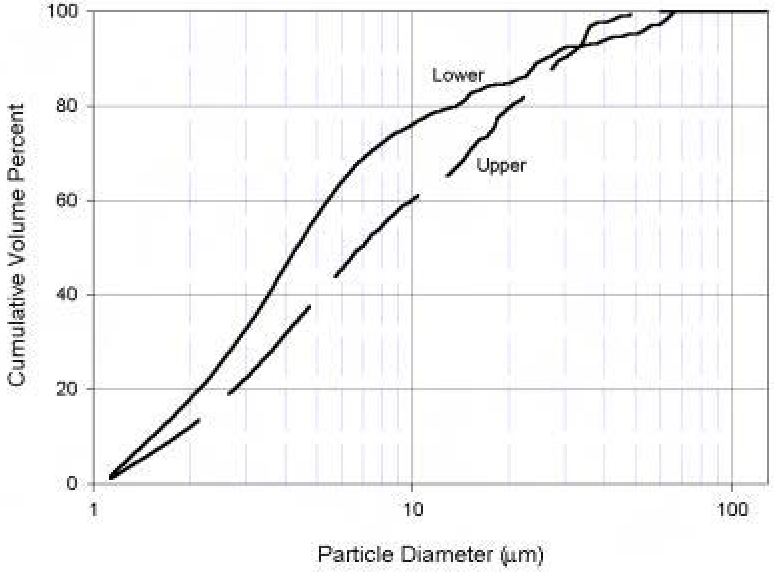


Figure G-14. Urban Horticulture (UW), Alderwood soil A and compost, February 20, 1998.

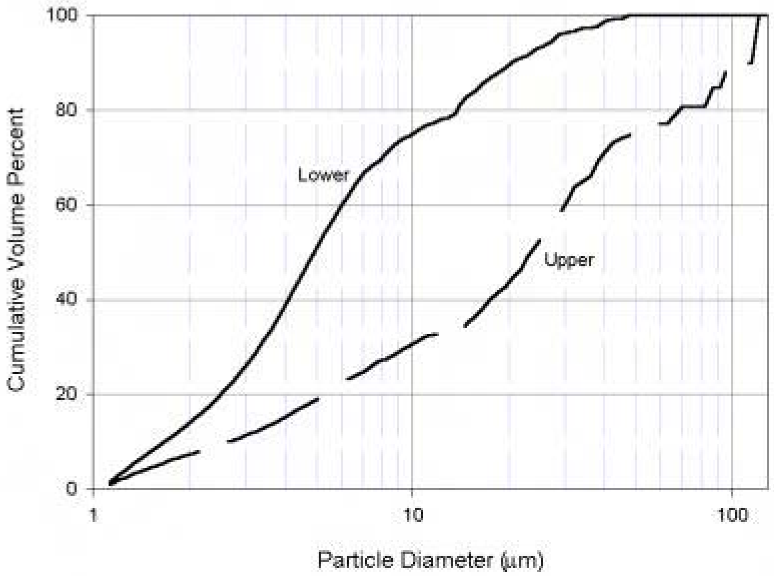


Figure G-15. Urban Horticulture (UW), Alderwood soil A and compost, March 15, 1998.

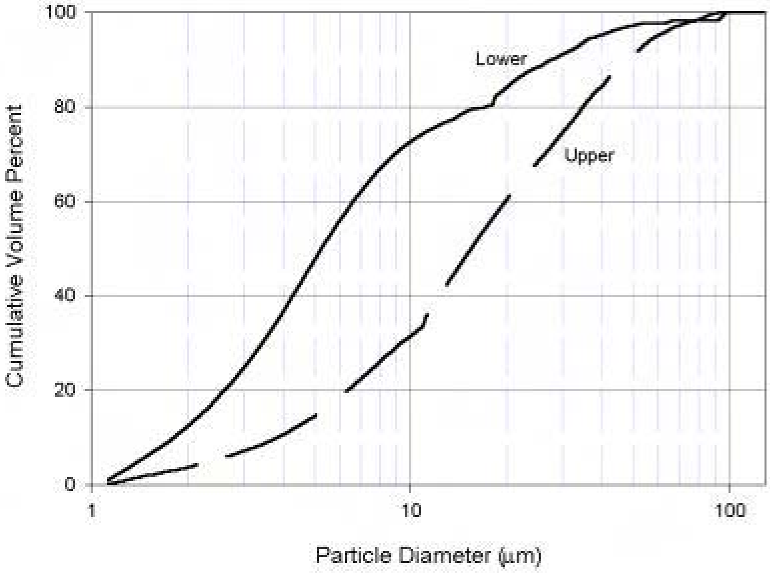


Figure G-16. Urban Horticulture (UW), Alderwood soil A and compost, April 17, 1998.

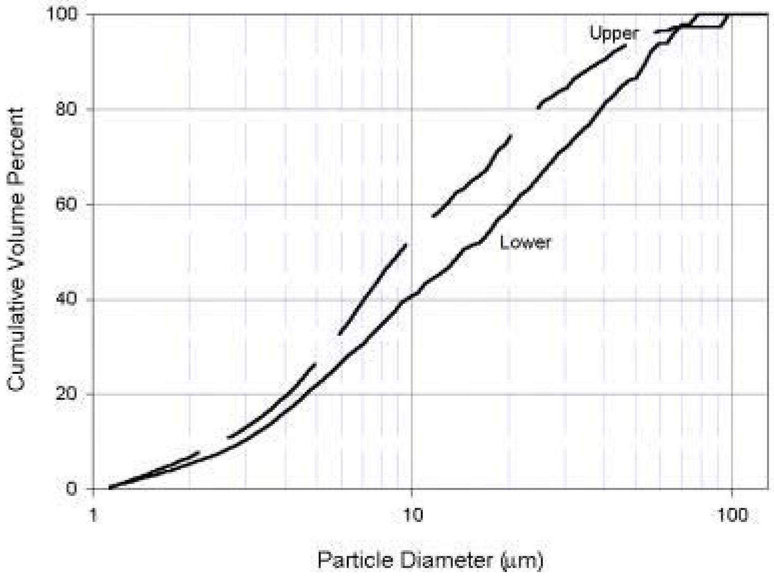


Figure G-17. Urban Horticulture (UW), Alderwood soil A and compost, June 1998

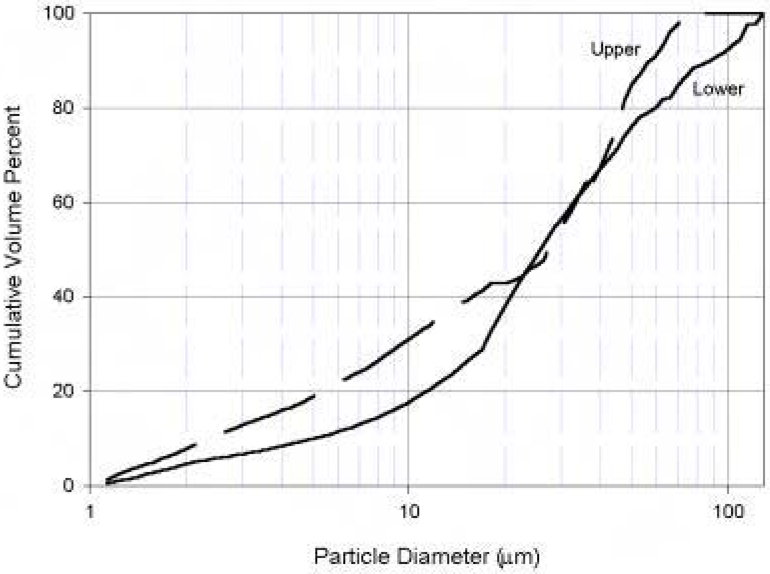


Figure G-18. Urban Horticulture (UW), Alderwood soil B only, surface runoff, May 28, 1998.

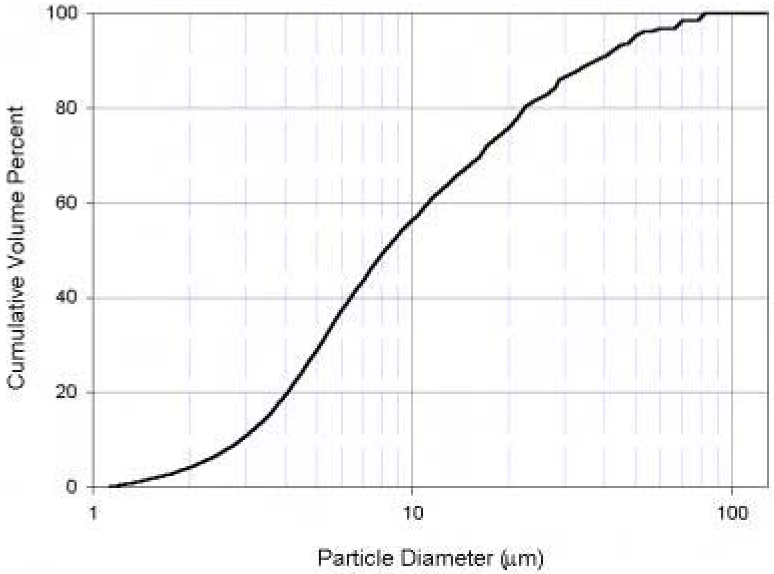


Figure G-19. Urban Horticulture (UW), Alderwood soil B only, surface runoff, June, 1998.

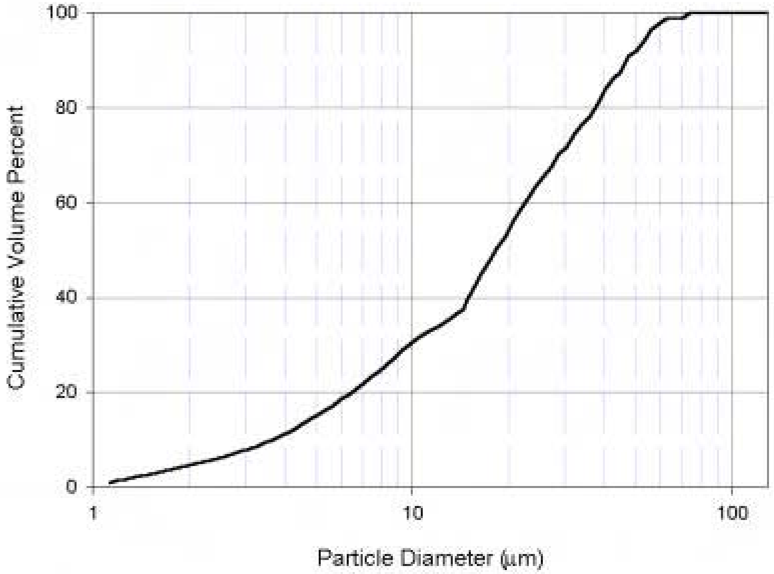


Figure G-20. Urban Horticulture (UW), Alderwood soil B only, January 4, 1998.

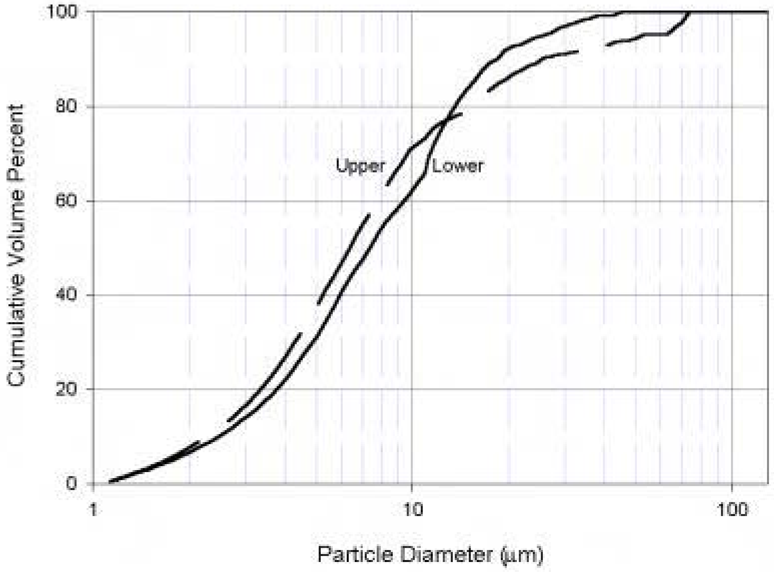


Figure G-21. Urban Horticulture (UW), Alderwood soil B only, February 20, 1998.

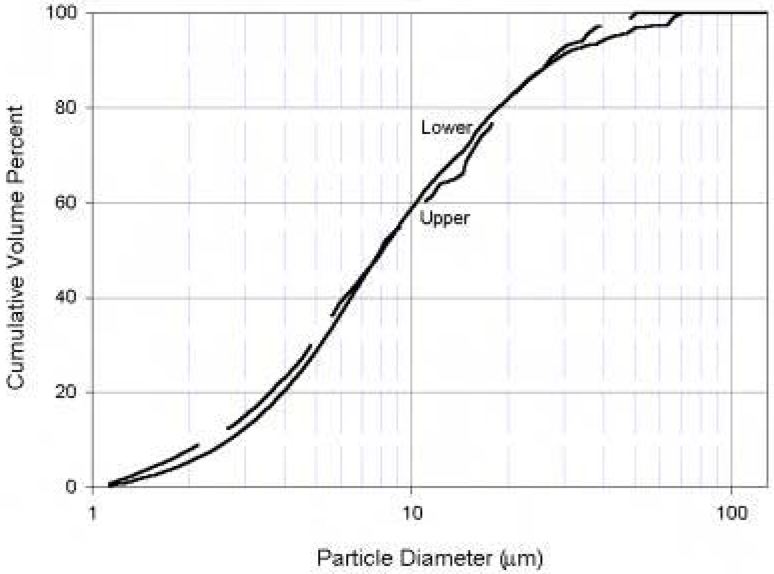


Figure G-22. Urban Horticulture (UW), Alderwood soil B only, March 15, 1998.

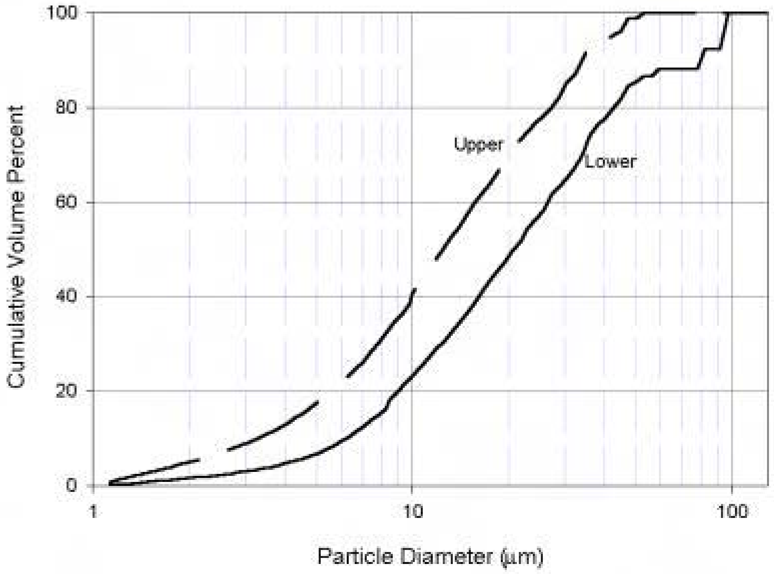


Figure G-23. Urban Horticulture (UW), Alderwood soil B only, April 17, 1998.

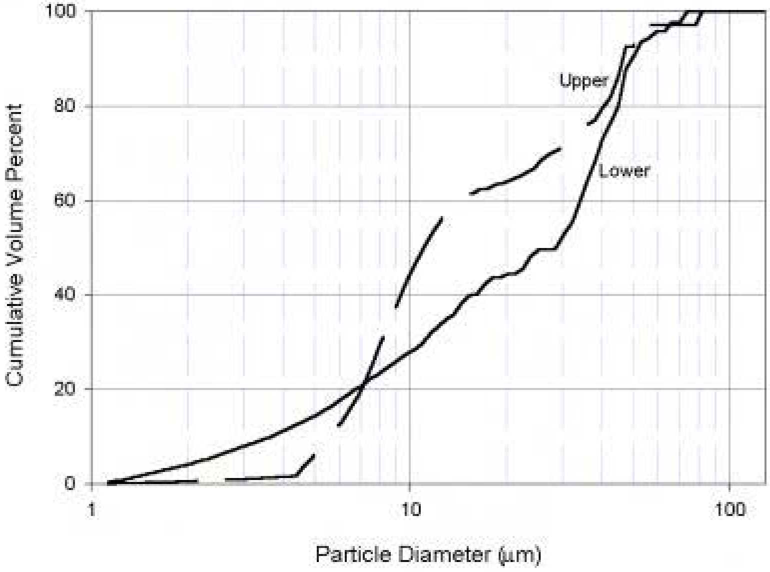


Figure G-24. Woodmoor, Alderwood soil D only, March 15, 1998.

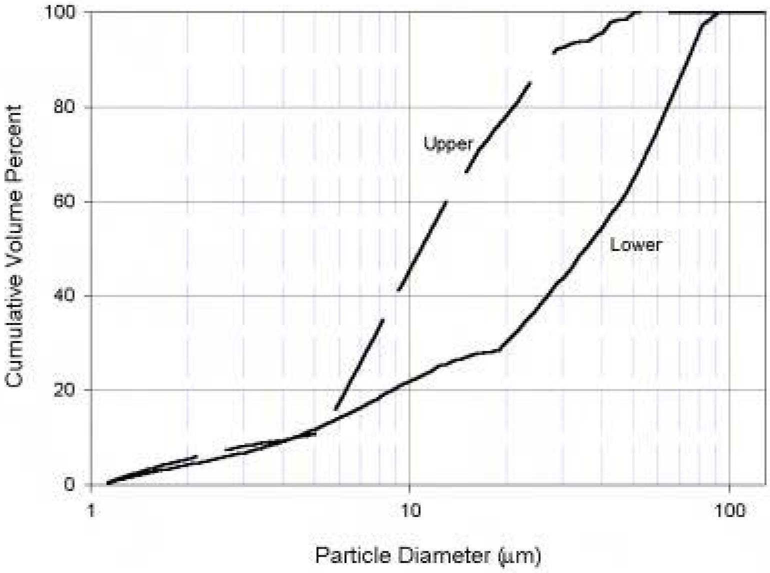


Figure G-25. Woodmoor, Alderwood soil D only , subsurface flow, April 15, 1998.

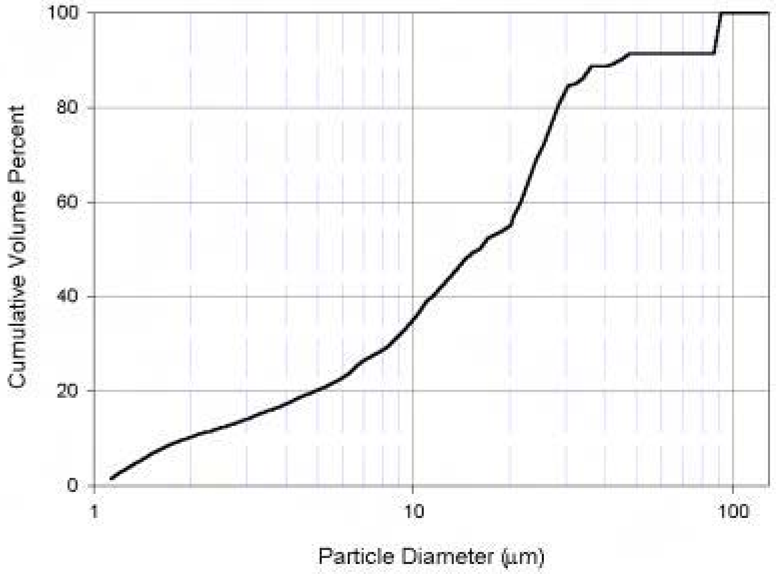


Figure G-26. Woodmoor, Alderwood soil D with compost, subsurface flow, January 4, 1998.

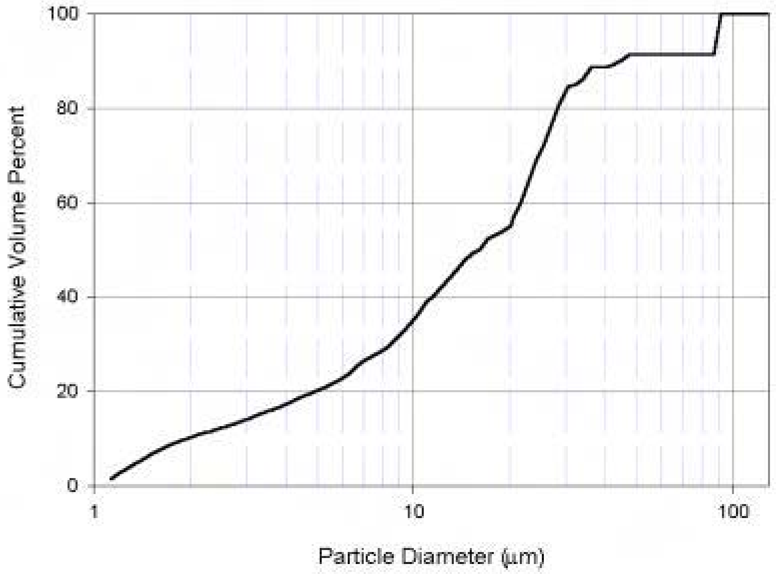


Figure G-27. Woodmoor, Alderwood soil D with compost, March 15, 1998.

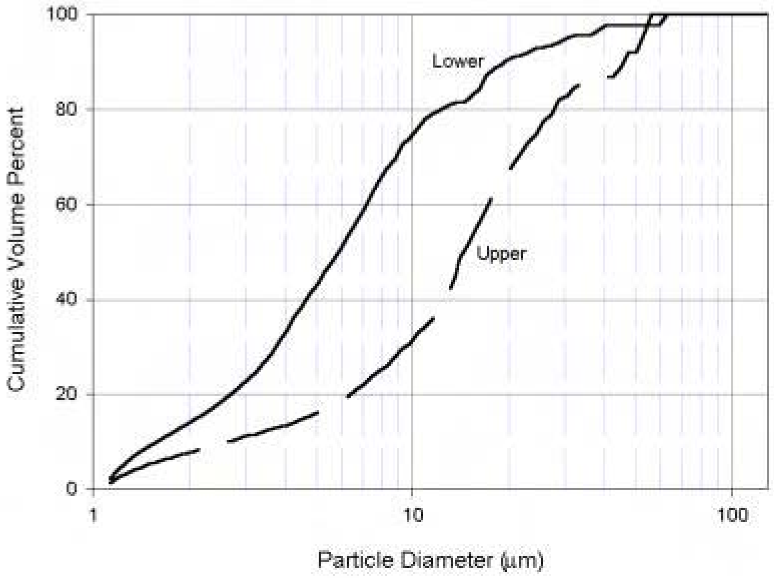


Figure G-28. Woodmoor, Alderwood soil D with compost, May 28, 1998.

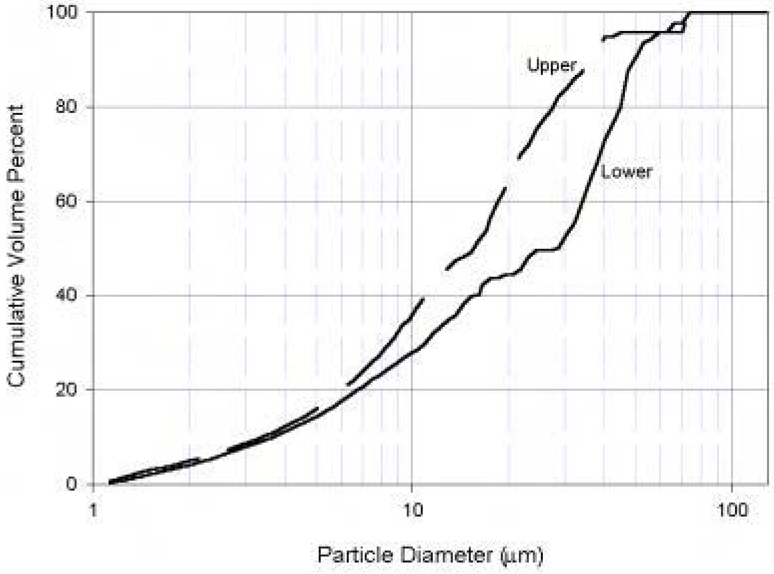
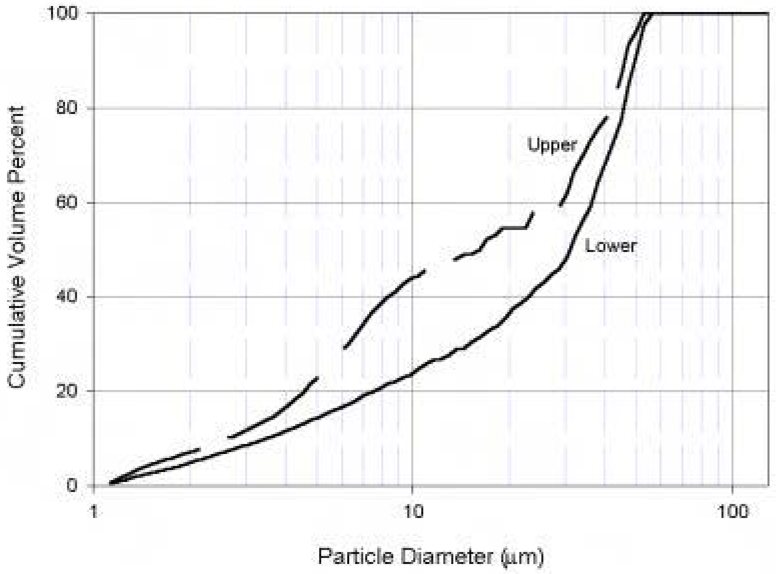


Figure G-29. Woodmoor, Alderwood soil D with compost, June 1998.



Appendix H

Collection Periods, Rainfall and Runoff Amounts, and Pollutant Discharges at Soil and Compost-Amended Soil Test Sites

Table Appendix H-1. Collection periods, rainfall and runoff (in mm) for the CUH sites.

					Total Runoff				Subsurface Runoff				Surface Runoff			
Period	Collection Started	Collection Finished	Time Period	Rain-fall	Plot 1	Plot 2	Plot 5	Plot 6	Plot 1	Plot 2	Plot 5	Plot 6	Plot 1	Plot 2	Plot 5	Plot 6
			– days –	—— mm ——												
1	971205-08:05	971217-12:30	12.2	46.2	29.5	21.1	37.7	23.6	29.0	20.9	25.5	23.5	0.47	0.22	12.1	0.12
2	971217-12:45	980103-12:10	17.0	34.5	38.6	30.8	33.9	26.8	38.4	30.6	28.7	22.4	0.18	0.27	5.2	4.4
3	980104-12:40	980218-16:20	45.2	288	221	236	246	251	217	233	176	130	3.2	2.9	69.7	121
4	980218-16:55	980314-17:15	24.0	79.6	64.8	66.1	64.4	61.7	64.4	65.5	48.0	61.6	0.41	0.60	16.4	0.06
5	980314-17:15	980414-18:30	31.1	65.4	33.4	31.6	36.3	0.27	33.2	31.1	25.6	0.15	0.29	0.49	10.7	0.12
6	980414-18:30	980527-12:20	42.7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
7	980527-12:20	980625-17:15	29.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
total	971205-08:05	980625-17:15	202.4	514	387	385	418	363	382	381	304	238	4.6	4.4	114	125

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-2. Collection periods and phosphate-P (mg/liter) concentrations for the CUH sites.

					Total Runoff				Subsurface Runoff				Surface Runoff			
Period	Collection Started	Collection Finished	Time Period	Rain-fall	Plot 1	Plot 2	Plot 5	Plot 6	Plot 1	Plot 2	Plot 5	Plot 6	Plot 1	Plot 2	Plot 5	Plot 6
			– days –	—— mg PO_4-P/liter ——												
1	971205-08:05	971217-12:30	12.18	0.00	n.d.	n.d.	n.d.	n.d.	0.00	0.41	0.00	1.19	0.16	0.38	0.00	0.62
2	971217-12:45	980103-12:10	16.98	0.00	n.d.	n.d.	n.d.	n.d.	0.00	0.10	0.00	1.08	0.10	0.21	0.03	1.17
3	980104-12:40	980218-16:20	45.15	0.00	n.d.	n.d.	n.d.	n.d.	0.05	0.29	0.01	1.68	0.78	0.95	0.15	1.91
4	980218-16:55	980314-17:15	24.01	0.00	n.d.	n.d.	n.d.	n.d.	0.00	0.21	0.00	1.14	0.53	0.73	0.11	1.16
5	980314-17:15	980414-18:30	31.05	0.39	n.d.	n.d.	n.d.	n.d.	0.17	0.35	0.19	1.78	0.61	0.88	0.26	1.09
6	980414-18:30	980527-12:20	42.74	0.07	n.d.	n.d.	n.d.	n.d.	0.46	1.73	0.73	1.60	0.38	5.24	0.51	2.55
7	980527-12:20	980625-17:15	29.20	0.02	n.d.	n.d.	n.d.	n.d.	1.35	6.56	n.d.	8.42	1.51	6.99	3.77	4.93

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-3. Collection periods and phosphate-P fluxes (mg/m^2 for CUH sites.

					Total Runoff				Subsurface Runoff				Surface Runoff			
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**Plot 1**	**Plot 2**	**Plot 5**	**Plot 6**	**Plot 1**	**Plot 2**	**Plot 5**	**Plot 6**	**Plot 1**	**Plot 2**	**Plot 5**	**Plot 6**
			– days –	mg PO_4-P/m^2												
1	971205-08:05	971217-12:30	12.2	0.00	0.07	8.57	0.00	28.0	0.00	8.49	0.00	28.0	0.07	0.08	0.00	0.07
2	971217-12:45	980103-12:10	17.0	0.00	0.02	3.18	0.15	29.4	0.00	3.12	0.00	24.2	0.02	0.06	0.15	5.16
3	980104-12:40	980218-16:20	45.2	0.00	13.8	70.9	12.3	450	11.3	68.2	1.58	220	2.53	2.70	10.7	231
4	980218-16:55	980314-17:15	24.0	0.00	0.22	13.9	1.77	70.4	0.00	13.4	0.00	70.36	0.22	0.44	1.77	0.07
5	980314-17:15	980414-18:30	31.1	25.3	5.88	11.2	7.75	0.40	5.70	10.7	4.94	0.27	0.18	0.43	2.81	0.13
total	**971205-08:05**	**980414-18:30**	**130.4**	**25.3**	**20.0**	**107.7**	**22.0**	**578.4**	**17.01**	**104.0**	**6.5**	**342.3**	**3.02**	**3.71**	**15.5**	**236.1**

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-4. Collection periods and total P (mg/liter) concentrations for theCUH sites.

					Total Runoff				Subsurface Runoff				Surface Runoff			
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**Plot 1**	**Plot 2**	**Plot 5**	**Plot 6**	**Plot 1**	**Plot 2**	**Plot 5**	**Plot 6**	**Plot 1**	**Plot 2**	**Plot 5**	**Plot 6**
			– days –	mg P/liter												
1	971205-08:05	971217-12:30	12.18	0.01	n.d.	n.d.	n.d.	n.d.	0.01	0.73	0.01	1.98	0.44	0.65	0.01	0.80
2	971217-12:45	980103-12:10	16.98	0.00	n.d.	n.d.	n.d.	n.d.	0.01	0.47	0.01	2.60	0.85	0.28	0.15	2.77
3	980104-12:40	980218-16:20	45.15	0.00	n.d.	n.d.	n.d.	n.d.	0.00	0.54	0.00	4.60	0.95	1.08	0.87	2.85
4	980218-16:55	980314-17:15	24.01	0.00	n.d.	n.d.	n.d.	n.d.	0.00	0.45	0.00	1.77	0.51	0.65	0.22	1.50
5	980314-17:15	980414-18:30	31.05	0.41	n.d.	n.d.	n.d.	n.d.	0.15	0.44	0.25	3.15	0.72	1.15	0.20	1.32
6	980414-18:30	980527-12:20	42.74	0.01	n.d.	n.d.	n.d.	n.d.	0.61	2.59	0.98	1.77	0.60	8.16	0.58	4.18
7	980527-12:20	980625-17:15	29.20	0.01	n.d.	n.d.	n.d.	n.d.	1.46	7.85	n.a.	9.66	1.54	8.20	4.49	5.99

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-5. Collection periods and total P fluxes (mg/m^2) for the CUH sites.

					Total Runoff				Subsurface Runoff				Surface Runoff			
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**Plot 1**	**Plot 2**	**Plot 5**	**Plot 6**	**Plot 1**	**Plot 2**	**Plot 5**	**Plot 6**	**Plot 1**	**Plot 2**	**Plot 5**	**Plot 6**
			– days –		mg P/m^2											
1	971205-08:05	971217-12:30	12.2	0.32	0.4	15.3	0.3	46.5	0.20	15.2	0.18	46.4	0.21	0.14	0.08	0.10
2	971217-12:45	980103-12:10	17.0	0.00	0.4	14.5	1.0	70.3	0.27	14.4	0.20	58.1	0.15	0.08	0.80	12.2
3	980104-12:40	980218-16:20	45.2	0.00	3.1	130	60.6	944	0.00	127	0.00	600	3.08	3.07	60.6	344
4	980218-16:55	980314-17:15	24.0	0.00	0.2	30.1	3.7	109	0.00	29.7	0.00	109	0.21	0.39	3.67	0.09
5	980314-17:15	980414-18:30	31.1	26.9	5.1	14.1	8.5	0.6	4.85	13.6	6.40	0.48	0.21	0.57	2.12	0.16
total	**971205-08:05**	**980414-18:30**	**130.4**	**27.2**	**9.2**	**204**	**74.0**	**1171**	**5.32**	**199**	**6.8**	**814**	**3.86**	**4.25**	**67.3**	**357**

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-6. Collection periods and nitrate-N (mg/liter) concentrations for the CUH sites.

					Total Runoff				Subsurface Runoff				Surface Runoff			
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**Plot 1**	**Plot 2**	**Plot 5**	**Plot 6**	**Plot 1**	**Plot 2**	**Plot 5**	**Plot 6**	**Plot 1**	**Plot 2**	**Plot 5**	**Plot 6**
			– days –		mg NO_3/liter											
1	971205-08:05	971217-12:30	12.18	0.03	n.d.	n.d.	n.d.	n.d.	0.05	0.69	0.00	0.03	0.50	0.30	0.03	0.83
2	971217-12:45	980103-12:10	16.98	0.17	n.d.	n.d.	n.d.	n.d.	0.00	2.90	0.01	0.00	0.66	0.32	0.05	0.00
3	980104-12:40	980218-16:20	45.15	0.11	n.d.	n.d.	n.d.	n.d.	0.00	0.04	0.00	0.01	0.02	0.09	0.41	0.13
4	980218-16:55	980314-17:15	24.01	0.10	n.d.	n.d.	n.d.	n.d.	0.00	0.04	0.00	0.00	1.61	1.40	1.13	2.41
5	980314-17:15	980414-18:30	31.05	0.00	n.d.	n.d.	n.d.	n.d.	0.00	0.54	0.21	4.39	3.29	4.93	0.83	3.65
6	980414-18:30	980527-12:20	42.74	n.d.	n.d.	n.d.	n.d.	n.d.	3.01	11.5	8.78	2.08	1.39	17.0	3.48	2.29
7	980527-12:20	980625-17:15	29.20	0.01	n.d.	n.d.	n.d.	n.d.	10.5	14.5	n.d.	74.2	4.50	11.6	11.9	7.63

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-7. Collection periods and total nitrate-N fluxes (mg/m^2) for the CUH sites.

					Total Runoff				Subsurface Runoff				Surface Runoff			
Period	Collection Started	Collection Finished	Time Period	Rain-fall	Plot 1	Plot 2	Plot 5	Plot 6	Plot 1	Plot 2	Plot 5	Plot 6	Plot 1	Plot 2	Plot 5	Plot 6
			– days –	mg NO$_3$-N/m^2												
1	971205-08:05	971217-12:30	12.2	1.48	1.81	14.5	0.32	0.83	1.57	14.4	0.00	0.73	0.23	0.06	0.32	0.10
2	971217-12:45	980103-12:10	17.0	5.80	0.12	88.8	0.45	0.00	0.00	88.8	0.20	0.00	0.12	0.09	0.25	0.00
3	980104-12:40	980218-16:20	45.2	30.8	0.07	9.1	28.4	17.2	0.00	8.85	0.00	1.30	0.07	0.26	28.4	15.9
4	980218-16:55	980314-17:15	24.0	7.88	0.67	3.33	18.6	0.15	0.00	2.49	0.14	0.00	0.67	0.85	18.5	0.15
5	980314-17:15	980414-18:30	31.1	0.00	1.04	19.1	14.2	1.1	0.07	16.7	5.30	0.66	0.97	2.43	8.86	0.44
total	**971205-08:05**	**980414-18:30**	**130.4**	**46.0**	**3.7**	**135**	**62.0**	**19.3**	**1.64**	**131**	**5.6**	**2.7**	**2.06**	**3.69**	**56.3**	**16.6**

n.d. = precipitation and runoff not recorded for this data period
* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-8. Collection periods and total N (mg/liter) concentrations for the CUH sites.

					Total Runoff				Subsurface Runoff				Surface Runoff			
Period	Collection Started	Collection Finished	Time Period	Rain-fall	Plot 1	Plot 2	Plot 5	Plot 6	Plot 1	Plot 2	Plot 5	Plot 6	Plot 1	Plot 2	Plot 5	Plot 6
			– days –	mg N /liter												
1	971205-08:05	971217-12:30	12.2	0.91	n.d.	n.d.	n.d.	n.d.	0.58	1.81	0.68	1.83	1.68	2.24	0.70	1.26
2	971217-12:45	980103-12:10	17.0	2.05	n.d.	n.d.	n.d.	n.d.	2.12	0.71	2.22	0.90	0.76	1.53	1.04	1.17
3	980104-12:40	980218-16:20	45.2	1.15	n.d.	n.d.	n.d.	n.d.	1.54	4.61	4.58	2.00	6.71	9.33	2.02	3.93
4	980218-16:55	980314-17:15	24.0	0.53	n.d.	n.d.	n.d.	n.d.	0.20	3.02	0.35	2.00	5.96	5.04	0.74	2.99
5	980314-17:15	980414-18:30	31.1	0.97	n.d.	n.d.	n.d.	n.d.	1.04	2.62	0.37	3.20	1.26	4.03	0.80	0.92
6	980414-18:30	980527-12:20	42.7	2.41	n.d.	n.d.	n.d.	n.d.	3.12	8.76	3.86	7.05	6.99	31.14	7.62	13.07
7	980527-12:20	980625-17:15	29.2	1.36	n.d.	n.d.	n.d.	n.d.	3.40	15.12	n.d.	11.22	2.40	2.63	4.79	6.16

n.d. = precipitation and runoff not recorded for this data period
* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-9. Collection periods and total N fluxes (mg/m) for the UW sites.

					Total Runoff				Subsurface Runoff				Surface Runoff			
Period	Collection Started	Collection Finished	Time Period	Rain-fall	Plot 1	Plot 2	Plot 5	Plot 6	Plot 1	Plot 2	Plot 5	Plot 6	Plot 1	Plot 2	Plot 5	Plot 6
			– days –	mg N/m ^{2}												
1	971205-08:05	971217-12:30	12.2	41.9	17.5	38.3	25.7	43.1	16.7	37.8	17.3	42.9	0.79	0.49	8.44	0.15
2	971217-12:45	980103-12:10	17.0	70.7	81.5	22.1	69.1	25.4	81.4	21.7	63.7	20.2	0.13	0.42	5.39	5.15
3	980104-12:40	980218-16:20	45.2	331	357	1100	947	735	335	1074	806	261	21.8	26.6	141	474
4	980218-16:55	980314-17:15	24.0	41.9	15.5	201	29.10	123	13.00	198	17.0	123	2.46	3.04	12.1	0.18
5	980314-17:15	980414-18:30	31.1	63.1	34.7	83.3	18.0	0.59	34.3	81.3	9.52	0.48	0.37	1.99	8.49	0.11
total	**971205-08:05**	**980414-18:30**	**130.4**	**549**	**506**	**1445**	**1088**	**928**	**480**	**1412**	**913**	**448**	**25.5**	**32.5**	**175**	**480**

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-10. Collections, rainfall and runoff for Woodmoor sites.

					Total		Subsurface		Surface	
Period	Collection Started	Collection Finished	Time Period	Rain-fall	WM cont	WM comp	WM cont	WM comp	WM cont	WM comp
			– days –	mm						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	27.2	16.5	12.5	13.2	12.5	3.3	0
3	980103-14:00	980218-18:40	46.2	250	268	212	174	189	93.8	23.1
4	980218-18:40	980314-14:15	23.8	68.1	53.2	51.9	38.8	51.8	14.4	0.1
5	980314-14:15	980414-20:50	31.3	76.2	68.8	60.2	56.4	60.2	12.4	0
6	980414-20:50	980527-15:00	42.8	54.6	16.7	12.0	15.5	12.0	1.2	0
7	980527-15:00	980625-14:10	29.0	33.8	5.4	1.0	4.4	1.0	1.0	0
total	**971205-09:20**	**980625-14:10**	**202**	**510**	**429**	**350**	**303**	**327**	**126**	**23.2**

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-11. Collection periods and phosphate-P (mg/liter) concentrations for the Woodmoor site.

Period	Collection Started	Collection Finished	Time Period	Rain-fall	Total WM cont	Total WM comp	Subsurface WM cont	Subsurface WM comp	Surface WM cont	Surface WM comp
			– days –	mg PO_4-P/liter						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	n.d.	n.d.	0.16	3.41	0.08	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	n.d.	n.d.	0.00	2.20	0.00	1.56
4	980218-18:40	980314-14:15	23.8	n.d.	n.d.	n.d.	0.00	n.d.	0.03	0.69
5	980314-14:15	980414-20:50	31.3	n.d.	n.d.	n.d.	0.18	1.14	0.18	0.84
6	980414-20:50	980527-15:00	42.8	n.d.	n.d.	n.d.	0.00	1.23	0.00	1.56
7	980527-15:00	980625-14:10	29.0	0.04	n.d.	n.d.	0.00	0.84	n.d.	1.08

n.d. = precipitation and runoff not recorded for this data period
* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-12. Collection periods and phosphate-P fluxes (mg/m^2) for the Woodmoor site.

Period	Collection Started	Collection Finished	Time Period	Rain-fall	Total WM cont	Total WM comp	Subsurface WM cont	Subsurface WM comp	Surface WM cont	Surface WM comp
			– days –	mg PO_4/m^2						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	2.35	42.7	2.11	42.7	0.25	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	0.00	452	0.00	416	0.00	36.1
4	980218-18:40	980314-14:15	23.8	n.d.	0.36	0.07	0.00	n.d.	0.36	0.07
5	980314-14:15	980414-20:50	31.3	n.d.	12.4	68.7	10.1	68.7	2.25	0.00
6	980414-20:50	980527-15:00	42.8	n.d.	0.00	14.7	0.00	14.7	0.00	0.00
7	980527-15:00	980625-14:10	29.0	33.8	0.00	0.85	0.00	0.8	n.d.	0.00
total	**971205-09:20**	**980625-14:10**	**202**	**510**	**15.1**	**579**	**12.2**	**543**	**2.86**	**36.1**

n.d. = precipitation and runoff not recorded for this data period
* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-13. Collection periods and total-P (mg/liter) concentrations for the Woodmoor site.

					Total		Subsurface		Surface	
Period	Collection Started	Collection Finished	Time Period	Rain-fall	WM cont	WM comp	WM cont	WM comp	WM cont	WM comp
			– days –	mg P/liter						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	n.d.	n.d.	0.21	3.37	1.59	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	n.d.	n.d.	0.01	6.00	0.00	4.32
4	980218-18:40	980314-14:15	23.8	n.d.	n.d.	n.d.	0.01	n.d.	0.30	2.99
5	980314-14:15	980414-20:50	31.3	n.d.	n.d.	n.d.	0.20	2.39	0.21	1.41
6	980414-20:50	980527-15:00	42.8	n.d.	n.d.	n.d.	0.00	1.88	0.01	1.87
7	980527-15:00	980625-14:10	29.0	0.00	n.d.	n.d.	0.00	0.97	n.d.	2.02

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-14. Collection periods and total-P fluxes (mg/m^2) for the Woodmoor site.

					Total		Subsurface		Surface	
Period	Collection Started	Collection Finished	Time Period	Rain-fall	WM cont	WM comp	WM cont	WM comp	WM cont	WM comp
			– days –	mg P/m^2						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	8.0	42.2	2.7	42.2	5.2	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	1.2	1235	1.2	1135	0.0	99.8
4	980218-18:40	980314-14:15	23.8	n.d.	4.5	n.d.	0.3	n.d.	4.3	0.3
5	980314-14:15	980414-20:50	31.3	n.d.	13.9	144.1	11.3	144.1	2.6	0.0
6	980414-20:50	980527-15:00	42.8	n.d.	0.0	22.6	0.0	22.6	0.0	0.0
7	980527-15:00	980625-14:10	29.0	0.00	0.0	1.0	0.0	1.0	n.d.	0.0
total	**971205-09:20**	**980625-14:10**	**202**	**0.00**	**27.6**	**1445**	**16**	**1345**	**12**	**100**

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-15. Collection periods and nitrate-N (mg/liter) concentrations for the Woodmoor site.

					Total		Subsurface		Surface	
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**WM cont**	**WM comp**	**WM cont**	**WM comp**	**WM cont**	**WM comp**
			– days –	mg NO_3-N/liter						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	n.d.	n.d.	0.01	2.42	0.02	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	n.d.	n.d.	0.01	0.00	0.09	0.00
4	980218-18:40	980314-14:15	23.8	n.d.	n.d.	n.d.	0.00	n.d.	0.01	0.00
5	980314-14:15	980414-20:50	31.3	n.d.	n.d.	n.d.	0.00	0.00	0.00	1.17
6	980414-20:50	980527-15:00	42.8	n.d.	n.d.	n.d.	0.00	0.00	0.00	0.00
7	980527-15:00	980625-14:10	29.0	0.24	n.d.	n.d.	3.69	0.12	n.d.	0.34

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-16. Collection periods and nitrate-N fluxes (mg/m^2) for the Woodmoor site.

					Total		Subsurface		Surface	
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**WM cont**	**WM comp**	**WM cont**	**WM comp**	**WM cont**	**WM comp**
			– days –	mg NO_3-N/m^2						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	0.19	30.3	0.12	30.3	0.07	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	10.7	0.00	2.27	0	8.45	0.00
4	980218-18:40	980314-14:15	23.8	n.d.	0.09	0.00	0.00	n.d.	0.09	0.00
5	980314-14:15	980414-20:50	31.3	n.d.	0.00	0.00	0.00	0.00	0.00	0.00
6	980414-20:50	980527-15:00	42.8	n.d.	0.00	0.00	0.00	0.00	0.00	0.00
7	980527-15:00	980625-14:10	29.0	8.21	16.3	0.12	16.33	0.12	n.d.	0.00
total	**971205-09:20**	**980625-14:10**	**202**	**8.2**	**27.3**	**30.4**	**18.7**	**30.4**	**8.6**	**0.0**

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-17. Collection periods and total N (mg/liter) concentrations for the Woodmoor site.

					Total		Subsurface		Surface	
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**WM cont**	**WM comp**	**WM cont**	**WM comp**	**WM cont**	**WM comp**
			– days –	—	—	—	mg N/liter	—	—	—
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	n.d.	n.d.	2.11	118	0.90	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	n.d.	n.d.	2.85	90.0	2.07	47.6
4	980218-18:40	980314-14:15	23.8	n.d.	n.d.	n.d.	2.20	n.d.	0.58	34.2
5	980314-14:15	980414-20:50	31.3	n.d.	n.d.	n.d.	0.65	15.5	2.22	13.2
6	980414-20:50	980527-15:00	42.8	n.d.	n.d.	n.d.	0.69	3.58	1.65	3.38
7	980527-15:00	980625-14:10	29.0	0.38	n.d.	n.d.	1.37	1.69	n.d.	2.15

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-18. Collection periods and nitrate-N fluxes (mg/m) for the Woodmoor site.

					Total		Subsurface		Surface	
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**WM cont**	**WM comp**	**WM cont**	**WM comp**	**WM cont**	**WM comp**
			– days –	—	—	—	mg N/m^2	—	—	—
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	30.7	1477	27.8	1477	3.0	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	691	18123	497	17023	194	1100
4	980218-18:40	980314-14:15	23.8	n.d.	93.8	3.4	85.5	n.d.	8.3	3.4
5	980314-14:15	980414-20:50	31.3	n.d.	64.2	930	36.7	930	27.4	0.0
6	980414-20:50	980527-15:00	42.8	n.d.	12.6	43.0	10.6	43.0	1.9	0.0
7	980527-15:00	980625-14:10	29.0	12.7	6.1	1.7	6.1	1.7	n.d.	0.0
total	**971205-09:20**	**980625-14:10**	**202**	**510**	**898**	**20578**	**663**	**19475**	**235**	**1103**

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-19. Collections, rainfall and runoff for Timbercrest sites.

					Total***		Subsurface		Surface	
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall****	**TC cont**	**TC comp**	**TC cont**	**TC comp**	**TC cont**	**TC comp**
			– days –	mm						
1	971205-10:30	971217-15:20	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-15:20	980103-15:30	17.0	27.2	12.3	11.8	8.9	11.8	3.5	0
3	980103-15:30	980218-19:50	46.2	250	**>45**	**>45**	**>45**	**>45**	**>45**	8.5
4	980218-19:50	980314-11:40	23.7	68.1	**>45**	**>45**	**>45**	**>45**	8.6	0
5	980314-11:40	980414-21:45	31.4	76.2	**>45**	**>45**	**>45**	**>45**	9.2	0
6	980414-21:45	980527-16:20	42.8	54.6	22.3	9.6	21.4	9.6	0.9	0
7	980414-21:45	980625-15:20	71.7	33.8	10.9	0.8	10.7	0.8	0.2	0
total	**971205-10:30**	**980625-15:20**	**202.2**	**510**	**>180**	**>157**	**>175**	**>157**	**>67**	**8.5**

n.d. = precipitation and runoff not recorded for this data period
* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes
** = Rainfall at the Timbercrest site was generated with data from the Woodmoor site
*** = fluxes calculated by bottle collections, not tipping buckets; values over 45 mm indicate overflowing

Table Appendix H-20. Collection periods and phosphate-P (mg/liter) concentrations for the Timbercrest site.

					Total		Subsurface		Surface	
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**WM cont**	**WM comp**	**WM cont**	**WM comp**	**WM cont**	**WM comp**
			– days –	mg PO_4-P/liter						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	n.d.	n.d.	0.08	n.d.	n.d.	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	n.d.	n.d.	0.07	n.d.	0.02	n.d.
4	980218-18:40	980314-14:15	23.8	n.d.	n.d.	n.d.	0.02	n.d.	0.02	n.d.
5	980314-14:15	980414-20:50	31.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
6	980414-20:50	980527-15:00	42.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
7	980527-15:00	980625-14:10	29.0	n.d.	n.d.	n.d.	0.33	n.d.	n.d.	125

n.d. = precipitation and runoff not recorded for this data period
* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-21. Collection periods and phosphate-P fluxes (mg/m^2) for the Timbercrest site.

					Total		**Subsurface**		**Surface**	
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**WM cont**	**WM comp**	**WM cont**	**WM comp**	**WM cont**	**WM comp**
			– days –	mg PO$_4$/m^2						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	0.66	n.d.	0.66	n.d.	n.d.	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	**>3.87**	**n.d.**	**>3.15**	**n.d.**	**>0.72**	n.d.
4	980218-18:40	980314-14:15	23.8	n.d.	**>1.02**	**n.d.**	**>0.86**	**n.d.**	0.16	n.d.
5	980314-14:15	980414-20:50	31.3	n.d.	**n.d.**	**n.d.**	**n.d.**	**n.d.**	n.d.	n.d.
6	980414-20:50	980527-15:00	42.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
7	980527-15:00	980625-14:10	29.0	n.d.	3.51	3.74	3.51	n.d.	n.d.	3.74
total	**971205-09:20**	**980625-14:10**	**202**	n.d.	**>9.06**	**3.74**	**>8.18**	**0.00**	**>0.88**	**3.74**

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-22. Collection periods and total-P (mg/liter) concentrations for the Timbercrest site.

					Total		**Subsurface**		**Surface**	
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**WM cont**	**WM comp**	**WM cont**	**WM comp**	**WM cont**	**WM comp**
			– days –	mg P/liter						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	n.d.	n.d.	0.48	n.d.	n.d.	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	n.d.	n.d.	0.70	n.d.	0.00	n.d.
4	980218-18:40	980314-14:15	23.8	n.d.	n.d.	n.d.	0.35	n.d.	0.01	n.d.
5	980314-14:15	980414-20:50	31.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
6	980414-20:50	980527-15:00	42.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
7	980527-15:00	980625-14:10	29.0	n.d.	n.d.	n.d.	0.30	n.d.	n.d.	125

n.d. = precipitation and runoff not recorded for this data period

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-23. Collection periods and total-P fluxes (mg/m^2) for the Timbercrest site.

					Total		Subsurface		Surface	
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**WM cont**	**WM comp**	**WM cont**	**WM comp**	**WM cont**	**WM comp**
			– days –	mg ^{2}						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	>4.25	0.00	>4.25	0.00	0.00	0.00
3	980103-14:00	980218-18:40	46.2	n.d.	>31.4	n.d.	>31.4	0.00	0.00	0.00
4	980218-18:40	980314-14:15	23.8	n.d.	>15.6	n.d.	>15.5	0.00	>0.06	0.00
5	980314-14:15	980414-20:50	31.3	n.d.	n.d.	n.d.	0.00	0.00	0.00	0.00
6	980414-20:50	980527-15:00	42.8	n.d.	n.d.	n.d.	0.00	0.00	0.00	0.00
7	980527-15:00	980625-14:10	29.0	n.d.	3.22	n.d.	3.22	0.00	0.00	3.76
total	**971205-09:20**	**980625-14:10**	**202**	**n.d.**	**>54.5**	**0.00**	**>54.5**	**0.00**	**>0.06**	**3.76**

n.d. = precipitation and runoff not recorded for this data period
* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-24. Collection periods and nitrate-N (mg/liter) concentrations for the Timbercrest site.

					Total		Subsurface		Surface	
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**WM cont**	**WM comp**	**WM cont**	**WM comp**	**WM cont**	**WM comp**
			– days –	mg NO $_3$-N/liter						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	n.d.	n.d.	3.66	n.d.	n.d.	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	n.d.	n.d.	0.80	n.d.	1.06	n.d.
4	980218-18:40	980314-14:15	23.8	n.d.	n.d.	n.d.	0.28	n.d.	0.12	n.d.
5	980314-14:15	980414-20:50	31.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
6	980414-20:50	980527-15:00	42.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
7	980527-15:00	980625-14:10	29.0	n.d.	n.d.	n.d.	1.55	n.d.	n.d.	1.68

n.d. = precipitation and runoff not recorded for this data period
* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-25. Collection periods and nitrate-N fluxes (mg/m^2) for the Timbercrest site.

Period	Collection Started	Collection Finished	Time Period	Rain-fall	Total WM cont	Total WM comp	Subsurface WM cont	Subsurface WM comp	Surface WM cont	Surface WM comp
			– days –	mg $_3$-N/m^2						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	32.4	n.d.	32.4	0.00	0.00	0.00
3	980103-14:00	980218-18:40	46.2	n.d.	>83.8	n.d.	>35.9	0.00	>47.8	0.00
4	980218-18:40	980314-14:15	23.8	n.d.	>13.7	n.d.	>12.6	0.00	1.02	0.00
5	980314-14:15	980414-20:50	31.3	n.d.	n.d.	n.d.	0.00	0.00	0.00	0.00
6	980414-20:50	980527-15:00	42.8	n.d.	n.d.	n.d.	0.00	0.00	0.00	0.00
7	980527-15:00	980625-14:10	29.0	n.d.	16.6	n.d.	16.6	0.00	0.00	0.05
total	**971205-09:20**	**980625-14:10**	**202**	**n.d.**	**>146**	**n.d.**	**>97.6**	**0.00**	**>48.9**	**0.05**

n.d. = precipitation and runoff not recorded for this data
* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-26. Collection periods and total N (mg/liter) concentrations for the Timbercrest site.

Period	Collection Started	Collection Finished	Time Period	Rain-fall	Total WM cont	Total WM comp	Subsurface WM cont	Subsurface WM comp	Surface WM cont	Surface WM comp
			– days –	mg N/liter						
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	n.d.	n.d.	3.51	n.d.	n.d.	n.d.
3	980103-14:00	980218-18:40	46.2	n.d.	n.d.	n.d.	3.34	n.d.	1.46	n.d.
4	980218-18:40	980314-14:15	23.8	n.d.	n.d.	n.d.	1.74	n.d.	1.79	n.d.
5	980314-14:15	980414-20:50	31.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
6	980414-20:50	980527-15:00	42.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
7	980527-15:00	980625-14:10	29.0	n.d.	n.d.	n.d.	1.00	n.d.	n.d.	479

n.d. = precipitation and runoff not recorded for this data
* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Table Appendix H-27. Collection periods and nitrate-N fluxes (mg/m^2) for the Timbercrest site.

					Total		Subsurface		Surface	
Period	**Collection Started**	**Collection Finished**	**Time Period**	**Rain-fall**	**WM cont**	**WM comp**	**WM cont**	**WM comp**	**WM cont**	**WM comp**
			– days –				mg	2		
1	971205-09:20	971217-14:10	12.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2	971217-14:10	980103-14:00	17.0	n.d.	31.1	n.d.	31.1	0.00	0.00	0.00
3	980103-14:00	980218-18:40	46.2	n.d.	>216	n.d.	>150	0.00	>65.7	0.00
4	980218-18:40	980314-14:15	23.8	n.d.	>93.6	n.d.	>78.3	0.00	15.4	0.00
5	980314-14:15	980414-20:50	31.3	n.d.	n.d.	n.d.	0.00	0.00	0.00	0.00
6	980414-20:50	980527-15:00	42.8	n.d.	n.d.	n.d.	0.00	0.00	0.00	0.00
7	980527-15:00	980625-14:10	29.0	n.d.	10.7	14.4	10.7	0.00	0.00	14.4
total	**971205-09:20**	**980625-14:10**	**202**	**n.d.**	**>351**	**>14.4**	**>270**	**0.00**	**81.09**	**>14.4**

n.d. = precipitation and runoff not recorded for this data

* = data reported as yymmdd-hh:mm, where yy = year, mm = month,
dd = day, hh = hour, and mm = minutes

Appendix I
Water Quality Criteria

The EPA (1986) has published guidelines for how their criteria are to be applied: “criteria present scientific data and guidance of the environmental effects of pollutants which can be useful to derive regulatory requirements based on consideration of water quality impacts.” Being criteria, they are not legal standards but are indicative of problems that may occur if they are exceeded. However, many states have adopted most of the EPA criteria as enforceable standards. In most cases, the EPA’s criteria are contained in the individual state’s standards. Appropriate water quality criteria is dependent on use classifications.

The following table list typical state water quality criteria for several toxicants (from *Toxic Pollutant Criteria Applicable to State Waters*, Code of Alabama 335-6-10.07). The public water supply and swimming criteria are not shown below.

	Aquatic Life Criteria		Human Life Criteria
	freshwater acute	freshwater chronic	fish consumption only
Arsenic +3	360 µg/L	190 µg/L	-
Arsenic	-	-	(1)
Cadmium	(2)	(2)	-
Chromium +3	(2)	(2)	(3)
Chromium +6	16	11	(3)
Lead	(2)	(2)	-
Mercury	2.4	0.012	(3)
Zinc	(2)	(2)	5,000 µg/L

footnotes:

(1) dependent on cancer potency and bioconcentration factors.
(2) criteria dependent on water hardness.
(3) dependent on reference doses and bioconcentration factors that are developed by the EPA and used by the states.

The Environmental Protection Agency (in *Quality Criteria for Water 1986*, EPA 440/5-86-001) recommends that the acute aquatic life criteria are for one-hour average concentrations that are not to be exceeded more than once every three years, while chronic criteria are for four-day averages that are also not to be exceeded more than once every three years.

If a large percentage of instantaneous observations exceed a criterion, it is apparent, using basic statistical theory, that the observed values are not unique and that longer duration concentrations (such as the one-hour averages and the four-day averages) would also be highly likely to exceed the criterion. Therefore, the frequent exceedences reported in this report are very likely to exist at least for the durations appropriate for the various criteria.

The EPA (in *Quality Criteria for Water 1986*) uses an acceptable exceedence frequency of once per three years because they feel that three years is the average amount of time that it would take an unstressed ecosystem to recover from a pollution event in which exposure to a metal exceeds the criterion. This assumes that a population of organisms exists in adjacent unaffected areas that can recolonize the affected receiving waters. The EPA (also in *Water Quality Criteria*) recommends that total recoverable forms of the metals be compared to the criteria because acid soluble methods have not been approved.

Water Quality Criteria for the Protection of Fish and Wildlife

The following summaries present water quality criteria to protect fish and wildlife resources. Most of this material is from the EPA's *Water Quality Criteria* (1986).

Ammonia

This discussion on the effects of ammonia on aquatic life is a summary from the U.S. EPA's *Quality Criteria for Water, 1986* (EPA 1986). The criteria were published in the Federal Register (50 F.R. 30784, July 29, 1985). The ammonia criteria are only for the protection of aquatic life, as no criteria have been developed for the protection of human health (consumption of contaminated fish or drinking water). The water quality criteria is for general guidance only and do not constitute formal water quality standards. However, the criteria reflect the scientific knowledge concerning the effects of the pollutants and are recommended EPA acceptable limits for aquatic life.

All concentrations used in the water quality criteria report are expressed as un-ionized ammonia (NH_3) because NH_3, not the ammonium ion (NH_4^+), has been demonstrated to be the principal toxic form of ammonia. The amount of the total ammonia (usually expressed as NH_3, but is really a mixture of ionized and un-ionized ammonia forms) that is un-ionized is a function of pH. At low pH values, most of the ammonia is ionized (the ammonium ion, NH_4^+), while at high pH values, most of the ammonia is un-ionized. Therefore, ammonia at high pH values creates more of a problem than similar total ammonia concentrations at low pH values. The un-ionized ammonia concentrations can be calculated, if the pH values are known.

The data used in deriving the EPA criteria are predominantly from flow-through tests in which ammonia concentrations were measured. Ammonia was reported to be acutely toxic to freshwater organisms at concentrations (uncorrected for pH) ranging from 0.53 to 22.8 mg/L NH_3 for 19 invertebrate species representing 14 families and 16 genera and from 0.083 to 4.60 mg/L NH_3 for 29 fish species from 9 families and 18 genera. Among fish species, reported 96-hour LC5O values ranged from 0.083 to 1.09 mg/L for salmonids and from 0.14 to 4.60 mg/L NH_3 for nonsalmonids. Reported data from chronic tests on ammonia with two freshwater invertebrate species, both daphnids, showed effects at concentrations (uncorrected for pH) ranging from 0.304 to 1.2 mg/L NH_3, and with nine freshwater fish species, from five families and seven genera, ranging from 0.0017 to 0.612 mg/L NH_3.

Concentrations of ammonia acutely toxic to fishes may cause loss of equilibrium, hyper-excitability, increased breathing, cardiac output and oxygen uptake, and, in extreme cases, convulsions, coma, and death. At lower concentrations, ammonia has many effects on fishes, including a reduction in hatching success, reduction in growth rate and morphological development, and pathologic changes in tissues of gills, livers, and kidneys.

Several factors have been shown to modify acute NH_3 toxicity in fresh water. Some factors alter the concentration of un-ionized ammonia in the water by affecting the aqueous ammonia equilibrium, and some factors affect the toxicity of un-ionized ammonia itself, either ameliorating or exacerbating the effects of ammonia. Factors that have been shown to affect ammonia toxicity include dissolved oxygen concentration, temperature, pH, previous acclimation to ammonia, fluctuating or intermittent exposures, carbon dioxide concentration, salinity, and the presence of other toxicants.

The most well-studied of these is pH; the acute toxicity of NH_3 has been shown to increase as pH decreases. However, the percentage of the total ammonia that is un-ionized decreases with decreasing pH. Sufficient data exist from toxicity tests conducted at different pH values to formulate a relationship to describe the pH-dependent acute NH_3 toxicity. The very limited amount of data regarding effects of pH on chronic NH_3 toxicity also indicates increasing NH_3 toxicity with decreasing pH, but the data are insufficient to derive a broadly applicable toxicity/pH relationship. Data on temperature effects on acute NH_3 toxicity are limited and somewhat variable, but indications are that NH_3 toxicity to fish is greater as temperature decreases. There is no information available regarding temperature effects on chronic NH_3 toxicity.

Examination of pH and temperature-corrected acute NH_3 toxicity values among species and genera of freshwater organisms showed that invertebrates are generally more tolerant than fishes, a notable exception being the fingernail clam. There is no clear trend among groups of fish; the several most sensitive tested species and genera include representatives from diverse families (Salmonidae, Cyprinidae, Percidae, and Centrarchidae). Available chronic toxicity data for freshwater organisms also indicate invertebrates (cladocerans, one insect species) to be more tolerant than fishes, again with the exception of the fingernail clam. When corrected for the presumed effects of temperature and pH, there is also no clear trend among groups of fish for chronic toxicity values. The most sensitive species, including representatives from five families (Salmonidae, Cyprinidae, Ictaluridae, Centrarchidae, and Catostomidae), have chronic values ranging by not much more than a factor or two. Available data indicate that differences in sensitivities between warm and coldwater families of aquatic organisms are inadequate to warrant discrimination in the national ammonia criterion between bodies of water with “warm” and “coldwater” fishes; rather, effects of organism sensitivities on the criterion are most appropriately handled by site-specific criteria derivation procedures.

Data for concentrations of NH_3 toxic to freshwater phytoplankton and vascular plants, although limited, indicate that freshwater plant species are appreciably more tolerant to NH_3 than are invertebrates or fishes. The ammonia criterion appropriate for the protection of aquatic animals will therefore in all likelihood be sufficiently protective of plant life.

The procedures described in the *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms and their uses should not be affected unacceptably if:

(1) the 1-hour* average concentration of un-ionized ammonia (in mg/L NH_3) does not exceed, more often than once every 3 years on the average, the numerical values summarized in the following table, if Salmonids and other sensitive coldwater species are absent:

One-Hour Averaged Maximum Allowable Concentrations for Total Ammonia (mg/L NH_3), For Concurrent pH and Temperature Conditions

pH	0°C	5°C	10°C	15°C	20°C	25°C	30°C
6.50	35	33	31	30	29	29	20
6.75	32	30	28	27	27	26	18.6
7.00	28	26	25	24	23	23	16.4
7.25	23	22	20	19.7	19.2	19.0	13.5
7.50	17.4	16.3	15.5	14.9	14.6	14.5	10.3
7.75	12.2	11.4	10.9	10.5	10.3	10.2	7.3
8.00	8.0	7.5	7.1	6.9	6.8	6.8	4.9
8.25	4.5	4.2	4.1	4.0	3.9	4.0	2.9
8.50	2.6	2.4	2.3	2.3	2.3	2.4	1.81
8.75	1.47	1.40	1.37	1.38	1.42	1.52	1.18
9.00	0.86	0.83	0.83	0.86	0.91	1.01	0.82

(*An averaging period of 1 hour may not be appropriate if excursions of concentrations to greater than 1.5 times the average occur during the hour; in such cases, a shorter averaging period may be needed.)

(2) the 4-day average concentration of un-ionized ammonia (in mg/L NH_3) does not exceed, more often than once every 3 years on the average, the average* numerical values summarized in the following table, if Salmonids and other sensitive coldwater species are absent:

Four-Day Averaged Maximum Allowable Concentrations for Total Ammonia ($mg/L\ NH_3$), for Concurrent pH and Temperature Conditions

pH	0°C	5°C	10°C	15°C	20°C	25°C	30°C
6.50	2.5	2.4	2.2	2.2	2.1	1.46	1.03
6.75	2.5	2.4	2.2	2.2	2.1	1.47	1.04
7.00	2.5	2.4	2.2	2.2	2.1	1.47	1.04
7.25	2.5	2.4	2.2	2.2	2.1	1.48	1.05
7.50	2.5	2.4	2.2	2.2	2.1	1.49	1.06
7.75	2.3	2.2	2.1	2.0	1.98	1.39	1.00
8.00	1.53	1.44	1.37	1.33	1.31	0.93	0.67
8.25	0.87	0.82	0.78	0.76	0.76	0.54	0.40
8.50	0.49	0.47	0.45	0.44	0.45	0.33	0.25
8.75	0.28	0.27	0.26	0.27	0.27	0.21	0.16
9.00	0.16	0.16	0.16	0.16	0.17	0.14	0.11

(*Because these criteria are nonlinear in pH and temperature, the criterion should be the average of separate evaluations of the formulas reflective of the fluctuations of flow, pH, and temperature within the averaging period; it is not appropriate in general to simply apply the formula to average pH, temperature, and flow.)

The extremes for temperature (0 and 30°C) and pH (6.5 and 9) given in the above summary tables are absolute. It is not permissible with current data to conduct any extrapolations beyond these limits. In particular, there is reason to believe that appropriate criteria at $pH > 9$ will be lower than the plateau between pH 8 and 9 shown above. Total ammonia concentrations equivalent to critical un-ionized ammonia concentrations are shown in these tables for receiving waters where salmonids and other sensitive coldwater species are absent. Reported EPA ammonia criteria values for salmonids and coldwater species are the same for temperatures up to 15°C. For warmer conditions, the total ammonia criteria are about 25% less.

The recommended exceedence frequency of 3 years is the EPA’s best scientific judgment of the average amount of time it will take an unstressed system to recover from a pollution event in which exposure to ammonia exceeds the criterion. A stressed system, for example, one in which several outfalls occur in a limited area, would be expected to require more time for recovery. The resilience of ecosystems and their ability to recover differ greatly, however, and site-specific criteria may be established if adequate justification is provided.

Nitrates

This discussion on the effects of nitrates on aquatic life and human health is a summary from the U.S. EPA’s *Quality Criteria for Water*, 1986 (EPA 1986). These criteria have been previously published by the EPA (*Quality Criteria for Water*, July 1976, PB-263943). These water quality criteria guidance documents do not constitute a national standard.

Two gases (molecular nitrogen and nitrous oxide) and five forms of nongaseous, combined nitrogen (amino and amide groups, ammonium, nitrite, and nitrate) are important in the nitrogen cycle. The amino and amide groups are found in soil organic matter and as constituents of plant and animal protein. The ammonium ion either is released from proteinaceous organic matter and urea, or is synthesized in industrial processes involving atmospheric nitrogen fixation. The nitrite ion is formed from the nitrate or the ammonium ions by certain microorganisms found in soil, water, sewage, and the digestive tract. The nitrate ion is formed by the complete oxidation of ammonium ions by soil or water microorganisms; nitrite is an intermediate product of this nitrification process. In oxygenated natural water systems, nitrite is rapidly oxidized to nitrate. Growing plants assimilate nitrate or ammonium ions and convert them to protein. A process known as denitrification takes place when nitrate containing soils become anaerobic and the conversion to nitrite, molecular nitrogen, or nitrous oxide occurs. Ammonium ions may also be produced in some circumstances.

Among the major point sources of nitrogen entering water bodies are municipal and industrial wastewaters, septic tanks, and feed lot discharges. Nonpoint sources of nitrogen include farm-site fertilizer and animal wastes, lawn fertilizer, sanitary landfill leachatte, atmospheric fallout, nitric oxide and nitrite discharges from automobile exhausts and other combustion processes, and losses from natural sources such as mineralization of soil organic matter (NAS 1972). Water reuse systems in some fish hatcheries employ a nitrification process for ammonia reduction; this may result in exposure of the hatchery fish to elevated levels of nitrite (Russo, *et al*. 1974).

For fingerling rainbow trout, *Salmo gairdneri*, the respective 96-hour and 7-day LC5O toxicity values were 1,360 and 1,060 mg/L nitrate nitrogen in fresh water (Westin 1974). Trama (1954) reported that the 96-hour LC5O for bluegills, *Lepomis macrochirus*, at 20^{o}C was 2,000 mg/L nitrate nitrogen (sodium nitrate) and 420 mg/L nitrate nitrogen (potassium nitrate). Knepp and Arkin (1973) observed that largemouth bass, *Micropterus salmoides* and channel catfish, *Ictalurus punctatus*, could be maintained at concentrations up to 400 mg/L nitrate without significant effect upon their growth and feeding activities.

Nitrite forms of nitrogen were found to be much more toxic than nitrate forms. As an example, the 96-hour and 7-day LC5O values for chinook salmon were found to be 0.9 and 0.7 mg/ L nitrite nitrogen in fresh water (Westin 1974). Smith and Williams (1974) tested the effects of nitrite nitrogen and observed that yearling rainbow trout, *Salmo gairdneri*, suffered a 55 percent mortality after 24 hours at 0.55 mg/L; fingerling rainbow trout suffered a 50 percent mortality after 24 hours of exposure at 1.6 mg/L; and chinook salmon, *Oncorhynchus tshawytscha*, suffered a 40 percent mortality within 24 hours at 0.5 mg/L. There were no mortalities among rainbow trout exposed to 0.15 mg/L nitrite nitrogen for 48 hours. These data indicate that salmonids are more sensitive to nitrite toxicity than are other fish species, e.g., minnows, *Phoxinus laevis*, that suffered a 50 percent mortality within 1.5 hours of exposure to 2,030 mg/L nitrite nitrogen, but required 14 days of exposure for mortality to occur at 10 mg/L (Klingler 1957), and carp, *Cyprinus carpio*, when raised in a water reuse system, tolerated up to 1.8 mg/L nitrite nitrogen (Saeki 1965).

The EPA concluded that (1) levels of nitrate nitrogen at or below 90 mg/L would have no adverse effects on warmwater fish (Knepp and Arkin 1973); (2) nitrite nitrogen at or below 5 mg/L should be protective of most warmwater fish (McCoy 1972); and (3) nitrite nitrogen at or below 0.06 mg/L should be protective of salmonid fishes (Russo, *et al*. 1974; Russo and Thurston 1975). These levels either are not known to occur or would be unlikely to occur in natural surface waters. Recognizing that concentrations of nitrate or nitrite that would exhibit toxic effects on warm- or coldwater fish could rarely occur in nature, restrictive criteria are not recommended.

Phosphate

This discussion on the effects of phosphate on aquatic life and human health is a summary from the U.S. EPA's *Quality Criteria for Water*, 1986 (EPA 1986). These criteria have been previously published by the EPA (*Quality Criteria for Water*, July 1976, PB-263943). These water quality criteria guidance documents do not constitute a national standard.

Phosphorus in the elemental form is very toxic (having an EPA marine life criteria of 0.10 µg/L) and is subject to bioaccumulation in much the same way as mercury. Phosphate forms of phosphorus are a major nutrient required for plant nutrition. In excessive concentrations, phosphates can stimulate plant growth. Excessive growths of aquatic plants (eutrophication) often interfere with water uses and are nuisances to man. Generally, phosphates are not the only cause of eutrophication, but there is substantiating evidence that frequently it is the key element of all of the elements required by freshwater plants (generally, it is present in the least amount relative to need). Therefore, an increase in phosphorus allows use of other already present nutrients for plant growth. In addition, of all of the elements required for plant growth in the water environment, phosphorus is the most easily controlled by man.

Phosphates enter waterways from several different sources. The human body excretes about one pound per year of phosphorus compounds. The use of phosphate detergents increases the per capita contribution to about 3.5 pounds per year of phosphorus compounds. Some industries, such as potato processing, have wastewaters high in phosphates. Many non-point sources (crop, forest, idle, and urban lands) contribute varying amounts of phosphorus compounds to watercourses. This drainage may be surface runoff of rainfall, effluent from agricultural tile lines, or return flow from irrigation. Cattle feedlots, birds, tree leaves, and fallout from the atmosphere all are contributing sources.

Evidence indicates that: (1) high phosphorus compound concentrations are associated with accelerated eutrophication of waters, when other growth-promoting factors are present; (2) aquatic plant problems develop in reservoirs and other standing waters at phosphorus values lower than those critical in flowing streams; (3) reservoirs and lakes collect phosphates from influent streams and store a portion of them within consolidated sediments, thus serving as a phosphate sink; and (4) phosphorus concentrations critical to noxious plant growth vary and nuisance growths may result from a particular concentration of phosphate in one geographical area but not in another. The amount or percentage of inflowing nutrients that may be retained by a lake or reservoir is variable and will depend upon: (1) the nutrient loading to the lake or reservoir; (2) the volume of the euphotic zone; (3) the extent of biological activities; (4) the detention time within a lake basin or the time available for biological activities; and (5) the discharge from the lake.

Once nutrients are discharged into an aquatic ecosystem, their removal is tedious and expensive. Phosphates are used by algae and higher aquatic plants and may be stored in excess of use within the plant cells. With decomposition of the plant cell, some phosphorus may be released immediately through bacterial action for recycling within the biotic community, while the remainder may be deposited with sediments. Much of the material that combines with the consolidated sediments within the lake bottom is bound permanently and will not be recycled into the system.

Although a total phosphorus criterion to control nuisance aquatic growths is not presented, the EPA believes that the following rationale to support such a criterion, which currently is evolving, should be considered.

Total phosphate concentrations in excess of 100 µg/L (expressed as total phosphorus) may interfere with coagulation in water treatment plants. When such concentrations exceed 25 µg/L at the time of the spring turnover on a volume-weighted basis in lakes or reservoirs, they may occasionally stimulate excessive or nuisance growths of algae and other aquatic plants. Algal growths cause undesirable tastes and odors to water, interfere with water treatment, become aesthetically unpleasant, and alter the chemistry of the water supply. They contribute to eutrophication.

To prevent the development of biological nuisances and to control accelerated or cultural eutrophication, total phosphates as phosphorus (P) should not exceed 50 µg/L in any stream at the point where it enters any lake or reservoir, nor 25 µg/L within the lake or reservoir. A desired goal for the prevention of plant nuisances in streams or other flowing waters not discharging directly to lakes or impoundments is 100 µg/L total P (Mackenthun 1973). Most relatively uncontaminated lake districts are known to have surface waters that contain from 10 to 30 µg/L total phosphorus as P (Hutchinson 1957).

The majority of the Nation's eutrophication problems are associated with lakes or reservoirs and currently there are more data to support the establishment of a limiting phosphorus level in those waters than in streams or rivers that do not directly impact such water. There are natural conditions, also, that would dictate the consideration of either a more or less stringent phosphorus level. Eutrophication problems may occur in waters where the phosphorus concentration is less than that indicated above and, obviously, such waters would need more stringent nutrient limits. Likewise, there are those waters within the Nation where phosphorus is not now a limiting nutrient and where the need for phosphorus limits is substantially diminished.

It is evident that a portion of that phosphorus that enters a stream or other flowing waterway eventually will reach a receiving lake or estuary either as a component of the fluid mass, as bed load sediments that are carried downstream, or as floating organic materials that may drift just above the stream's bed or float on its water's surface. Superimposed on the loading from the inflowing waterway, a lake or estuary may receive additional phosphorus as fallout from the atmosphere or as a direct introduction from shoreline areas.

Another method to control the inflow of nutrients, particularly phosphates, into a lake is that of prescribing an annual loading to the receiving water. Vollenweider (1973) suggests total phosphorus (P) loadings, in grams per square meter of surface area per year, that will be a critical level for eutrophic conditions within the receiving waterway for a particular water volume. The mean depth of the lake in meters is divided by the hydraulic detention time in years. Vollenweider's data suggest a range of loading values that should result in oligotrophic lake water quality:

Mean Depth/Hydraulic Detention Time (meters/year)	Oligotrophic or Permissible Loading (grams/meter/year)	Eutrophic or Critical Loading (grams/meter/year)
0.5	0.07	0.14
1.0	0.10	0.20
2.5	0.16	0.32
5.0	0.22	0.45
7.5	0.27	0.55
10.0	0.32	0.63
25.0	0.50	1.00
50.0	0.71	1.41
75.0	0.87	1.73
100.0	1.00	2.00

There may be waterways where higher concentrations, or loadings, of total phosphorus do not produce eutrophication, as well as those waterways where lower concentrations or loadings of total phosphorus may be associated with populations of nuisance organisms. Waters now containing less than the specified amounts of phosphorus should not be degraded by the introduction of additional phosphates

It should be recognized that a number of specific exceptions can occur to reduce the threat of phosphorus as a contributor to lake eutrophication:

1. Naturally occurring phenomena may limit the development of plant nuisances.
2. Technological or cost effective limitations may help control introduced pollutants.
3. Waters may be highly laden with natural silts or colors which reduce the penetration of sunlight needed for plant photosynthesis.
4. Some waters physical features of steep banks, great depth, and substantial flows contribute to a history of no plant problems.
5. Waters may be managed primarily for waterfowl or other wildlife.
6. In some waters, nutrients other than phosphorus (such as nitrogen) is limiting to plant growth; the level and nature of such limiting nutrient would not be expected to increase to an extent that would influence eutrophication.
7. In some waters, phosphorus control cannot be sufficiently effective under present technology to make phosphorus the limiting nutrient.

Dissolved Solids, Conductivity, and Chlorides

This discussion on the effects of total dissolved solids, chlorides, and conductivity on aquatic life and human health is a summary from the U.S. EPA's *Quality Criteria for Water*, 1986 (EPA 1986). These criteria have been previously published by the EPA (*Quality Criteria for Water*, July 1976, PB-263943). The water quality criteria guidance documents do not constitute a national standard, but do reflect the scientific knowledge concerning the effects of these pollutants on receiving waters.

Total dissolved solids, chlorides, and conductivity observations are typically used to indicate the magnitude of dissolved minerals in the water. The term total dissolved solids (or dissolved solids) is generally associated with freshwater and refers to the inorganic salts, small amounts of organic matter, and dissolved materials in the water (Sawyer 1960). Salinity is an oceanographic term, and although not precisely equivalent to the total dissolved salt content, it is related (Capurro 1970). Chlorides (not chlorine) are directly related to salinity because of the constant relationship between the major salts in sea water. Conductivity is a measure of the electrical conductivity of water and is also generally related to total dissolved solids, chlorides, or salinity. The principal inorganic anions (negatively charged ions) dissolved in fresh water include the carbonates, chlorides, sulfates, and nitrates (principally in groundwaters); the principal cations (positively charged ions) are sodium, potassium, calcium, and magnesium.

All species of fish and other aquatic life must tolerate a range of dissolved solids concentrations in order to survive under natural conditions. Studies in Saskatchewan found that several common freshwater species survived 10,000 mg/L dissolved solids, that whitefish and pikeperch survived 15,000 mg/L, but only the stickleback survived 20,000 mg/L dissolved solids. It was concluded that lakes with dissolved solids in excess of 15,000 mg/L were unsuitable for most freshwater fishes (Rawson and Moore 1944). The 1968 NTAC Report also recommended maintaining osmotic pressure levels of less than that caused by a 15,000 mg/L solution of sodium chloride.

Indirect effects of excess dissolved solids are primarily the elimination of desirable food plants and other habitat-forming plants. Rapid salinity changes cause plasmolysis of tender leaves and stems because of changes in osmotic pressure. The 1968 NTAC Report recommended the following limits in salinity variation from natural to protect wildlife habitats:

Natural Salinity (parts per thousand)	Variation Permitted (parts per thousand)
0 to 3.5 (freshwater)	1
3.5 to 13.5 (brackish water)	2
13.5 to 35 (seawater)	4

Temperature

This discussion on the effects of temperature is a summary from the U.S. EPA's *Quality Criteria for Water*, 1986 (EPA 1986). These criteria have been previously published by the EPA (*Quality Criteria for Water*, July 1976, PB-263943). The water quality criteria guidance documents do not constitute a national standard, but do reflect the scientific knowledge concerning the effects of these pollutants on receiving waters.

Water temperature affects many beneficial uses, including industrial and domestic water supplies and recreation. The effects of temperature on aquatic life are of the most concern, however, and the water quality criteria were developed to protect the most sensitive aquatic organisms from stress associated with elevated temperatures. Since essentially all of the aquatic organisms are cold blooded, the temperature of the water regulates their metabolism and their ability to survive and reproduce. Temperature, therefore, is an important physical parameter which to some extent regulates many of the beneficial uses of water. The Federal Water Pollution Control Administration in 1967 called temperature "a catalyst, a depressant, an activator, a restrictor, a stimulator, a controller, a killer, one of the most important and most influential water quality characteristics to life in water."

The suitability of water for total body immersion is greatly affected by temperature. In temperate climates, dangers from exposure to low temperatures is more prevalent than exposure to elevated water temperatures. Depending on the amount of activity by the swimmer, comfortable temperatures range from 20^{o} C to 30^{o} C. Short durations of lower and higher temperatures can be tolerated by most individuals. For example, for a 30-minute period, temperatures of 10^{o} C or 35^{o} C can be tolerated without harm by most individuals (NAS 1974).

Temperature also affects the self-purification phenomenon in water bodies and therefore the aesthetic and sanitary qualities that exist. Increased temperatures accelerate the biodegradation of organic material both in the overlying water and in bottom deposits which makes increased demands on the dissolved oxygen resources of a given system. The typical situation is exacerbated by the fact that oxygen becomes less soluble as water temperature increases. Thus, greater demands are exerted on an increasingly scarce resource which may lead to total oxygen depletion and obnoxious septic conditions.

Temperature changes in water bodies can alter the existing aquatic community. The dominance of various phytoplankton groups in specific temperature ranges has been shown. For example, from 20^{o} C to 25^{o} C, diatoms predominated; green algae predominated from 30^{o} C; to 35^{o} C and blue-greens predominated above 35^{o} C (Cairns

1956). Likewise, changes from a coldwater fishery to a warm-water fishery can occur because temperature may be directly lethal to adults or fry, or cause a reduction of activity, or limit their reproduction (Brett 1969).

Upper and lower limits for temperature have been established for many aquatic organisms. Considerably more data exist for upper, as opposed to lower limits. Tabulations of lethal temperatures for fish and other organisms are available (Jones 1964; FWPCA 1967; NAS 1974). Factors such as diet, activity, age, general health, osmotic stress, and even weather contribute to the lethality of temperature. The aquatic species and exposure time are considered the critical factors (Parker and Krenkel 1969).

The effects of sublethal temperatures on metabolism, respiration, behavior, distribution and migration, feeding rate, growth, and reproduction have been summarized by De Sylva (1969). Another study has illustrated that inside the tolerance zone, there is a more restrictive temperature range in which normal activity and growth occur and yet an even more restrictive zone in which normal reproduction will be occur (Brett 1960).

De Sylva (1969) has summarized available data on the combined effects of increased temperature and toxic materials on fish. These data indicate that toxicity generally increases with increased temperature and that organisms subjected to stress from toxic materials are less tolerant of temperature extremes.

The tolerance of organisms to extremes of temperature is a function of their genetic ability to adapt to thermal changes within their characteristic temperature range, the acclimation temperature prior to exposure, and the time of exposure to the elevated temperature (Coutant 1972). True acclimation to changing temperatures requires several days (Brett 1941). Organisms that are acclimated to relatively warm water, when subjected to reduced temperatures that under other conditions of acclimation would not be detrimental, may suffer significant mortality caused by thermal shock (Coutant 1972).

Through the natural changes in climatic conditions, the temperatures of water bodies fluctuate daily, as well as seasonally. These changes do not eliminate indigenous aquatic populations, but affect the existing community structure and the geographic distribution of species. Such temperature changes are necessary to induce the reproductive cycles of aquatic organisms and to regulate other life factors (Mount 1969).

In open waters elevated temperatures may affect periphyton, benthic invertebrates, and fish, in addition to causing shifts in algal dominance. Trembley (1960) studies of the Delaware River downstream from a power plant concluded that the periphyton population was considerably altered by the discharge.

The number and distribution of bottom organisms decrease as water temperatures increase. The upper tolerance limit for a balanced benthic population structure is approximately 32^{o} C. A large number of these invertebrate species are able to tolerate higher temperatures than those required for reproduction (FWPCA 1967).

In order to define criteria for fresh waters, Coutant (1972) cited the following as definable requirements:

1. Maximum sustained temperatures that are consistent with maintaining desirable levels of productivity.
2. Maximum levels of metabolic acclimation to warm temperatures that will permit return to ambient winter temperatures should artificial sources of heat cease.
3. Time-dependent temperature limitations for survival of brief exposures to temperature extremes, both upper and lower.
4. Restricted temperature ranges for various states of reproduction, including (for fish) gametogenesis, spawning migration, release of gametes, development of the embryo, commencement of independent feeding (and other activities) by juveniles, and temperatures required for metamorphosis, emergence, or other activities of lower forms.
5. Thermal limits for diverse species compositions of aquatic communities, particularly where reduction in diversity creates nuisance growths of certain organisms, or where important food sources (food chains) are altered,
6. Thermal requirements of downstream aquatic life (in rivers) where upstream flow reductions of a coldwater resource will adversely affect downstream temperature requirements.

To provide a safety factor, so that none, or only a few, organisms will perish, it has been found experimentally that a criterion of 2° C below maximum temperature is usually sufficient (Black 1953). To provide safety for all the organisms, the temperature causing a median mortality for 50 percent of the population should be calculated and reduced by 2° C in the case of an elevated temperature.

Maximum temperatures for an extensive exposure (e.g., more than 1 week) must be divided into those for warmer periods and winter. Other than for reproduction, the most temperature sensitive life function appears to be growth (Coutant 1972). Coutant (1972) has suggested that a satisfactory estimate of a limiting maximum weekly mean temperature may be an average of the optimum temperature for growth and the temperature for zero net growth.

Because of the difficulty in determining the temperature of zero net growth, essentially the same temperature can be derived by adding to the optimum temperature (for growth or other physiological functions) a factor calculated as onethird of the difference between the ultimate upper lethal temperature and the optimum temperature (NAS 1974).

Since temperature tolerance varies with various states of development of a particular species, the criterion for a particular location should be calculated for the most important life form likely to be present during a particular month. One caveat in using the maximum weekly mean temperature is that the limit for short-term exposure must not be exceeded. Example calculations for predicting the summer maximum temperatures for short-term survival and for extensive exposure for various fish species are presented in Table I-1. These values use data from EPA's Environmental Research Laboratory (ERL) in Duluth.

Table I-1. Maximum Weekly Average Temperatures for Growth, and Short-Term Maxima for Survival for Juveniles and Adults During the Summer (Centigrade and Fahrenheit)

Species	Growth[a]	Maxima[b]
Bluegill	32 (90)	35 (95)
Channel catfish	32 (90)	35 (95)
Largemouth bass	32 (90)	34 (93)

a - Calculated using optimum temperature for growth: maximum weekly average temperature for growth = optimum temperature + 1/3 (ultimate lethal temperature - optimum temperature).

b - Based on acclimation temperature, at the maximum weekly average temperature, needed for summer growth, minus 2° C.

The winter maximum temperature must not exceed the ambient water temperature by more than the amount of change a specimen acclimated to a discharge temperature can tolerate. Such a change could occur by a cessation of the source of heat or by the specimen being driven from an area by high flows, pollutants, or other factors. However, there are inadequate data to estimate a safety factor for the "no stress" level from cold shocks (NAS 1974).

Coutant (1972) has reviewed the effects of temperature on aquatic life reproduction and development. Reproductive events are noted as perhaps the most thermally restricted of all life phases assuming other factors are at or near optimum levels. Natural short-term temperature fluctuations appear to cause reduced reproduction of fish and invertebrates.

There are inadequate data available quantifying the most temperature sensitive life stages among various aquatic species. Uniform elevation of temperature a few degrees, but still within the spawning range, may lead to advanced spawning for spring spawning species and delays for fall spawners. Such changes may not be detrimental, unless asynchrony occurs between newly hatched juveniles and their normal food source. Such asynchrony may be most pronounced among anadromous species, or other migrants, who pass from the warmed area to a normally chilled, unproductive area. Reported temperature data on maximum temperatures for spawning and embryo survival have been summarized in Table I-2 (from ERL-Duluth 1976).

Table I-2. Maximum Weekly Average Temperatures for Spawning and Short-Term Maxima for Embryo Survival During Spawning Season (Centigrade and Fahrenheit)

Species	Spawning[a]	Survival[b]
Bluegill	25 (77)	34 (93)
Channel catfish	27 (81)	29 (84)
Largemouth bass	21 (70)	27 (81)
Threadfin shad	18 (64)	34 (93)

a - The optimum, or mean of the range, of spawning temperatures reported for the species (ERL-Duluth 1976).
b - The upper temperature for successful incubation and hatching reported for the species (ERL-Duluth 1976).

The recommended EPA criteria is in two main parts. The second part is also broken down into four subparts. This detail is needed to account for the differences in temperature tolerance for various aquatic organisms. The EPA criteria are as follows:

For any time of year, there are two upper limiting temperatures for a location (based on the important sensitive species found there at that time):

1. One limit consists of a maximum temperature for short exposures that is time dependent and is given by the species specific equation (example calculated values are shown on Table I-1 under the "maxima" column):

$$\text{Temperature} = (1/b)[\log(\text{time}) - a] - 2^{o}\ C$$

where: Temperature is ^{o} C,
exposure time is in minutes,
a= intercept on the "y" or logarithmic axis of the line fitted to experimental data and which is available for some species from Appendix Il-C, National Academy of Sciences 1974 document.
b= slope of the line fitted to experimental data and available for some species from Appendix Il-C, of the National Academy of Sciences 1974 document.

2. The second value is a limit on the weekly average temperature that:

a. In the cooler months (mid-October to mid-April in the north and December to February in the south) will protect against mortality of important species if the elevated plume temperature is suddenly dropped to the ambient temperature, with the limit being the acclimation temperature minus 2^{o} C when the lower lethal threshold temperature equals the ambient water temperature (in some regions this limitation may also be applicable in summer). or

b. In the warmer months (April through October in the north and March through November in the south) is determined by adding to the physiological optimum temperature (usually for growth) a factor calculated as one-third of the difference between the ultimate upper lethal temperature and the optimum temperature for the most sensitive important species (and appropriate life state) that normally is found at that location and time. (Some of these values are given in Table I-1 under the "growth" column). or

c. During reproductive seasons (generally April through June and September through October in the north and March through May and October through November in the south) the limit is that temperature that meets site specific requirements for successful migration, spawning, egg incubation, fry rearing, and other reproductive functions of important species. These local requirements should supersede all other requirements when they are applicable. or

d. There is a site-specific limit that is found necessary to preserve normal species diversity or prevent appearance of nuisance organisms.

Heavy Metals

Many of the heavy metal criteria are defined in terms of water hardness, as elevated water hardness levels have been demonstrated in many laboratory experiments to lessen the toxic effects of these metals. The following tables summarize the applicable criteria, associated with various values of hardness:

Freshwater Aquatic Life Criteria (µg/L)

hardness	Cadmium		Chromium(+3)	
mg/L	acute	chronic	acute	chronic
25	0.82	0.38	560	67
42	1.5	0.57	850	100
54	2.0	0.70	1050	125
63	2.3	0.79	1190	140
74	2.8	0.90	1360	160
84	3.2	0.99	1500	180
90	3.5	1.0	1590	190
98	3.8	1.1	1710	200
110	4.4	1.2	1880	220
120	4.8	1.3	2020	240
140	5.7	1.5	2290	270

Freshwater Aquatic Life Criteria (µg/L) (Cont.)

hardness	Lead		Zinc	
mg/L	acute	chronic	acute	chronic
25	14	0.54	36	33
42	27	1.1	56	51
54	37	1.5	69	63
63	45	1.8	79	72
74	56	2.2	91	82
84	65	2.5	100	91
90	71	2.8	110	97
98	80	3.1	115	100
110	92	3.6	130	115
120	100	4.0	140	120
140	125	4.9	160	140

Hexavalent chromium (Cr^{+6}) and mercury aquatic life problems are not effected by hardness, with the following criteria used to protect aquatic life from exposure to these two metals:

Mercury acute criterion: 2.4 µg/L
Mercury chronic criterion: 0.012 µg/L
Chromium +6 acute criterion: 16 µg/L
Chromium +6 chronic criterion: 11 µg/L

As noted above, the EPA suggests that these aquatic life criteria should not be exceeded more than once every three years. The acute criteria is for a one-hour average, while the chronic criteria is for a four-day average.

Water Quality Criteria for the Protection of Human Health

The following discussion is mostly from the EPA's *Water Quality Criteria* (1986). It summarizes applicable water quality criteria for the protection of human health through both drinking water and fish consumption pathways.

Nitrates

In quantities normally found in food or feed, nitrates become toxic only under conditions in which they are, or may be, reduced to nitrites. Otherwise, at "reasonable" concentrations, nitrates are rapidly excreted in the urine. High intake of nitrates constitutes a hazard primarily to warmblooded animals under conditions that are favorable to reduction to nitrite. Under certain circumstances, nitrate can be reduced to nitrite in the gastrointestinal tract which then reaches the bloodstream and reacts directly with hemoglobin to produce methemoglobin, consequently impairing oxygen transport.

The reaction of nitrite with hemoglobin can be hazardous in infants under three months of age. Serious and occasionally fatal poisonings in infants have occurred following ingestion of untreated well waters shown to contain nitrate at concentrations greater than 10 mg/L nitrate nitrogen (N) (NAS 1974). High nitrate concentrations frequently are found in shallow farm and rural community wells, often as the result of inadequate protection from barnyard drainage or from septic tanks (USPHS 1961; Stewart, *et al*. 1967). Increased concentrations of nitrates also have been found in streams from farm tile drainage in areas of intense fertilization and farm crop production (Harmeson, *et al*. 1971). Approximately 2,000 cases of infant methemoglobinemia have been reported in Europe and North America since 1945; 7 to 8 percent of the affected infants died (Walton 1951; Sattelmacher 1962). Many infants have drunk water in which the nitrate nitrogen content was greater than 10 mg/L without developing methemoglobinemia. Many public water supplies in the United States contain levels that routinely exceed this amount, but only one U.S. case of infant methemoglobinemia associated with a public water supply has ever been reported (Virgil, *et al*. 1965). The differences in susceptibility to methemoglobinemia are not yet understood, but appear to be related to a combination of factors including nitrate concentration, enteric bacteria, and the lower acidity characteristic of the digestive systems of very young mammals. Methemoglobinemia systems and other toxic effects were observed when high nitrate well waters containing pathogenic bacteria were fed to laboratory mammals (Wolff, *et al*. 1972). Conventional water treatment has no significant effect on nitrate removal from water (NAS 1974).

Because of the potential risk of methemoglobinemia to bottlefed infants, and in view of the absence of substantiated physiological effects at nitrate concentrations below 10 mg/L nitrate nitrogen, this level is the criterion for domestic water supplies. Waters with nitrite nitrogen concentrations over 1 mg/L should not be used for infant feeding. Waters with a significant nitrite concentration usually would be heavily polluted and probably bacteriologically unacceptable.

Dissolved Solids, Conductivity, and Chlorides

Excess dissolved solids are objectionable in drinking water because of possible physiological effects, unpalatable mineral tastes, and higher costs because of corrosion or the necessity for additional treatment.

The physiological effects directly related to dissolved solids include laxative effects principally from sodium sulfate and magnesium sulfate and the adverse effect of sodium on certain patients afflicted with cardiac disease and women with toxemia associated with pregnancy. One study was made using data collected from wells in North Dakota. Results from a questionnaire showed that with wells in which sulfates ranged from 1,000 to 1,500 mg/L, 62 percent of the respondents indicated laxative effects associated with consumption of the water. However, nearly one-quarter of the respondents to the questionnaire reported difficulties when concentrations ranged from 200 to 500 mg/L (Moore 1952). To protect transients to an area, a sulfate level of 250 mg/L should afford reasonable protection from laxative effects.

As indicated, sodium frequently is the principal component of dissolved solids. Persons on restricted sodium diets may have an intake restricted from 500 to 1,000 mg/day (National Research Council 1954). The portion ingested in water must be compensated by reduced levels in food ingested so that the total does not exceed the allowable intake. Using certain assumptions of water intake (*e.g*., 2 liters of water consumed per day) and the sodium content of food, it has been calculated that for very restricted sodium diets, 20 mg/L sodium in water would be the maximum, while for moderately restricted diets, 270 mg/L sodium would be the maximum. Specific sodium levels for entire water supplies have not been recommended by the EPA, but various restricted sodium intakes are recommended because: (1) the general population is not adversely affected by sodium, but various restricted sodium intakes are recommended by physicians for a significant portion of the population, and (2) 270 mg/L of sodium is representative of mineralized waters that may be aesthetically unacceptable, but many domestic water supplies exceed this level. Treatment for removal of sodium in water supplies is also costly (NAS 1974).

A study based on consumer surveys in 29 California water systems was made to measure the taste threshold of dissolved salts in water (Bruvold, *et al*. 1969). Systems were selected to eliminate possible interferences from other taste-causing substances besides dissolved salts. The study revealed that consumers rated waters with 320 to 400 mg/L dissolved solids as "excellent" while those with 1,300 mg/L dissolved solids were "unacceptable." A "good" rating was registered for dissolved solids less than 650 to 750 mg/L. The 1962 U.S. Public Health Service Drinking Water Standards recommended a maximum dissolved solids concentration of 500 mg/L, unless more suitable supplies were unavailable.

Specific constituents included in the dissolved solids in water may cause mineral tastes at lower concentrations than other constituents. Chloride ions have frequently been cited as having a low taste threshold in water. Data from Ricter and MacLean (1939) on a taste panel of 53 adults indicated that 61 mg/L NaCl was the median level for detecting a difference from distilled water. At a median concentration of 395 mg/L chloride, a salty taste was identified. Lockhart, *et al*. (1955) when evaluating the effect of chlorides on water used for brewing coffee, found threshold taste concentrations for chloride ranging from 210 mg/L to 310 mg/L, depending on the associated cation. These data indicate that a level of 250 mg/L chlorides is a reasonable maximum level to protect consumers of drinking water.

The EPA criteria for chlorides and sulfates in domestic water supplies is 250 mg/L to protect human welfare.

Heavy Metals

There are also established toxic pollutant criteria for human health protection. These criteria are for carcinogens and non-carcinogens and are established for the consumption of both water and fish and for the consumption of fish only. The equations used by many states to calculate these criteria require that a reference dose and a bioconcentration factor be known for mercury and chromium. A cancer potency factor and a bioconcentration factor is also needed for arsenic, a recognized carcinogen. A risk level of 10^{-5} assumes one increased cancer case per 100,000 people associated with this pollutant and fish consumption. The reference doses and bioconcentration factors are now given by the State of Alabama, for example, in their water quality criteria (Chapter 335-6-10, Appendix A). These values are given by the EPA for 10^{-5}, 10^{-6}, and 10^{-7} risk levels (in *Quality Criteria for Water 1986*). The following list shows these criteria for human health criteria protection for fish consumption only:

Arsenic: 0.175 μg/L (calculated using pg. 39, EPA 1986 values for 10^{-5} risk levels)
Chromium(+3): 3433 mg/L (calculated using pg. 95, EPA 1986 and Alabama values)
Mercury: 0.146 μg/L (calculated using pg. 177, EPA 1986 and Alabama values)
Zinc: 5 mg/L

Appendix J
Quality Control Analysis of Internal Standards

Table J-1 Values, Measured Values and Percent Recovery for Internal Standards

		quantification limit	0.03	0.010	0.03	0.010	0.03	0.04	0.02	0.10	0.10	0.17	0.003	0.03	0.007	0.02
		detection limit	0.01	0.003	0.01	0.003	0.01	0.01	0.01	0.03	0.03	0.05	0.001	0.01	0.002	0.01
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
sampling	Date	QA/QC measure	PO4-P	TOT-P	NH4-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
1	12/18/97	QA/QC known value	3.50	10.00	2.00	7.50	24.00	25.00	8.30	5.00	5.00	5.00	5.00	5.00	5.00	5.00
2	1/5/98	QA/QC known value	3.50	10.00	2.00	7.50	24.00	25.00	8.33	5.00	5.00	5.00	5.00	5.00	5.00	5.00
3	2/20/98	QA/QC known value	3.50	10.00	2.00	7.50	6.32	25.00	8.33	5.00	5.00	5.00	5.00	5.00	5.00	5.00
4	3/15/98	QA/QC known value	3.50	10.00	2.12	7.30	24.00	25.00	8.30	5.00	5.00	5.00	5.00	5.00	5.00	5.00
5	4/15/98	QA/QC known value	3.50	1.50	2.00	7.30	2.00	25.00	8.30	5.00	5.00	5.00	5.00	5.00	5.00	5.00
6	5/28/98	QA/QC known value	3.50	1.50	2.00	7.30	2.00	25.00	8.30	5.00	5.00	5.00	5.00	5.00	5.00	5.00
7	6/26/98	QA/QC known value	3.50	10.00	2.12	7.30	2.00	25.00	8.30	5.00	5.00	5.00	5.00	5.00	5.00	5.00
1	12/18/97	QA/QC measured value	3.45	10.96	2.09	7.35	23.50	25.30	8.27	4.90	4.97	4.94	5.00	4.91	4.92	4.93
2	1/5/98	QA/QC measured value	3.50	10.74	2.02	7.64	23.10	24.92	8.43	4.91	5.05	5.00	5.01	4.95	5.01	5.01
3	2/20/98	QA/QC measured value	3.60	10.12	2.01	7.66	5.97	26.60	8.60	4.99	5.01	5.03	5.00	5.07	5.02	5.02
4	3/15/98	QA/QC measured value	3.46	10.74	2.02	7.29	23.10	23.90	8.22	4.91	4.98	4.92	4.92	4.91	4.92	4.91
5	4/15/98	QA/QC measured value	3.36	1.42	1.97	7.50	2.08	25.49	8.24	4.92	4.85	4.92	4.88	4.96	4.95	4.95
6	5/28/98	QA/QC measured value	3.36	1.42	1.97	7.50	1.96	25.49	8.24	4.90	4.86	4.94	4.89	4.91	4.98	4.93
7	6/26/98	QA/QC measured value	3.49	10.01	2.07	7.65	1.96	23.65	8.43	4.90	4.86	4.94	4.89	4.91	4.98	4.93
1	12/18/97	QA/QC recovery (%)	99	110	105	98	98	101	100	98	99	99	100	98	98	99
2	1/5/98	QA/QC recovery (%)	100	107	101	102	96	100	101	98	101	100	100	99	100	100
3	2/20/98	QA/QC recovery (%)	103	101	101	102	94	106	103	100	100	101	100	101	100	100
4	3/15/98	QA/QC recovery (%)	99	107	95	100	96	96	99	98	100	98	98	98	98	98
5	4/15/98	QA/QC recovery (%)	96	95	99	103	104	102	99	98	97	98	98	99	99	99
6	5/28/98	QA/QC recovery (%)	96	95	99	103	98	102	99	98	97	99	98	98	100	99
7	6/26/98	QA/QC recovery (%)	100	100	98	105	98	95	102	98	97	99	98	98	100	99
		Average Recovery	99	102	99	102	98	100	100	98	99	99	99	99	99	99
		Minimum Recovery	96	95	95	98	94	95	99	98	97	98	98	98	98	98
		Maximum Recovery	103	110	105	105	104	106	103	100	101	101	100	101	100	100
		Standard Deviation	2.4	6.2	3.0	2.2	3.0	4.1	1.6	0.7	1.7	0.9	1.1	1.2	0.8	0.8

Table J-1. Values, Measured Values and Percent Recovery for Internal Standards (Continued)

		quantification limit	0.013	0.07	1.33	0.13	0.003	0.023	0.33	0.010	0.13	0.10	0.10	0.10	0.007	0.07	0.01
		detection limit	0.004	0.02	0.40	0.04	0.001	0.007	0.10	0.003	0.04	0.03	0.03	0.03	0.002	0.02	0.00
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
sampling	Date	QA/QC measure	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
1	12/18/97	QA/QC known value	5.00	5.00	50.00	5.00	5.00	5.00	5.00	5.00	10.00	5.00	5.00	5.00	5.00	5.00	5.00
2	1/5/98	QA/QC known value	5.00	5.00	50.00	5.00	5.00	5.00	5.00	5.00	10.00	5.00	5.00	5.00	5.00	5.00	5.00
3	2/20/98	QA/QC known value	5.00	5.00	50.00	5.00	5.00	5.00	5.00	5.00	10.00	5.00	5.00	5.00	5.00	5.00	5.00
4	3/15/98	QA/QC known value	5.00	5.00	50.00	5.00	5.00	5.00	5.00	5.00	10.00	5.00	5.00	5.00	5.00	5.00	5.00
5	4/15/98	QA/QC known value	5.00	5.00	50.00	5.00	5.00	5.00	5.00	5.00	10.00	5.00	5.00	5.00	5.00	5.00	5.00
6	5/28/98	QA/QC known value	5.00	5.00	50.00	5.00	5.00	5.00	5.00	5.00	10.00	5.00	5.00	5.00	5.00	5.00	5.00
7	6/26/98	QA/QC known value	5.00	5.00	50.00	5.00	5.00	5.00	5.00	5.00	10.00	5.00	5.00	5.00	5.00	5.00	5.00
1	12/18/97	QA/QC measured value	4.97	4.91	49.96	4.93	4.93	4.96	4.98	4.92	10.96	4.90	4.88	4.94	4.93	4.91	4.77
2	1/5/98	QA/QC measured value	4.96	4.95	49.53	5.00	4.99	4.97	4.93	5.00	10.74	5.00	5.06	5.02	5.02	4.94	4.62
3	2/20/98	QA/QC measured value	5.00	5.00	50.21	5.03	5.01	5.03	5.02	5.01	10.12	5.00	5.13	5.09	5.00	5.03	5.06
4	3/15/98	QA/QC measured value	4.93	4.88	49.52	4.92	4.92	4.95	4.85	4.93	9.88	4.91	4.82	4.94	4.94	4.89	4.70
5	4/15/98	QA/QC measured value	4.89	4.93	49.32	4.94	4.93	4.96	4.88	4.97	9.76	4.93	4.95	4.93	4.97	4.92	5.13
6	5/28/98	QA/QC measured value	4.88	4.91	49.20	4.92	4.91	4.92	4.84	4.96	10.97	4.96	5.05	4.91	4.95	4.92	5.13
7	6/26/98	QA/QC measured value	4.88	4.91	49.20	4.92	4.91	4.92	4.84	4.96	10.97	4.96	5.05	4.91	4.95	4.92	5.13
1	12/18/97	QA/QC recovery (%)	99	98	100	99	99	99	100	98	110	98	98	99	99	98	95
2	1/5/98	QA/QC recovery (%)	99	99	99	100	100	99	99	100	107	100	101	100	100	99	92
3	2/20/98	QA/QC recovery (%)	100	100	100	101	100	101	100	100	101	100	103	102	100	101	101
4	3/15/98	QA/QC recovery (%)	99	98	99	98	98	99	97	99	99	98	96	99	99	98	94
5	4/15/98	QA/QC recovery (%)	98	99	99	99	99	99	98	99	98	99	99	99	99	98	103
6	5/28/98	QA/QC recovery (%)	98	98	98	98	98	98	97	99	110	99	101	98	99	98	103
7	6/26/98	QA/QC recovery (%)	98	98	98	98	98	98	97	99	110	99	101	98	99	98	103
		Average Recovery	99	99	99	99	99	99	98	99	105	99	100	99	99	99	99
		Minimum Recovery	98	98	98	98	98	98	97	98	98	98	96	98	99	98	92
		Maximum Recovery	100	100	100	101	100	101	100	100	110	100	103	102	100	101	103
		Standard Deviation	1.0	0.8	0.8	0.9	0.8	0.7	1.5	0.7	5.4	0.8	2.2	1.3	0.7	0.9	4.6

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Infiltration through Disturbed Urban Soils and Compost-Amended Soil Effects on Runoff Quality and Quantity

Project Summary

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This project examined a common, but poorly understood, problem associated with land development and the modifications made to soil structure. Development tends to reduce rainfall infiltration and increase runoff. The project was divided into two tasks:

1) testing infiltration rates of impacted soils, and

2) enhancing soils by amending with compost to increase infiltration and prevent runoff .

The first task examined more than 150 infiltration tests in disturbed, urban soils and compared these data with site conditions. A complete factorial experiment fully examined the effects, and interactions, of soil texture, soil moisture, and compaction. In addition, age since development was briefly examined. Compaction

had dramatic effects on infiltration rates through sandy soils and was generally just as important as soil moisture at sites with predominately clayey soils. Moisture levels had little effect on infiltration rates at sandy sites. Because of the large amounts of variability in the infiltration rates found, it is important that engineers obtain local data to estimate the infiltration rates associated with local development practices.

The second task examined the benefits of adding a large amount of compost to a glacial till soil at the time of development. The compost-amended soils significantly increased infiltration rates, but also increased concentrations of nutrients in the surface runoff. The overall mass of nutrient discharges will more than likely decrease when using compost, although the collected data did not always support this hypothesis. The sorption and ion-exchange properties of the compost reduced the concentration of many cations and toxicants in the infiltrating water, but nutrient concentrations significantly increased. In addition, the compost-amended test plots produced superior turf, with little or no need for establishment or maintenance fertilization.

This Project Summary was developed by EPA's National Risk Management Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Field Studies on Infiltration Capabilities of Disturbed Urban Soils

Prior research (Pitt 1987) examined runoff losses from paved and roofed surfaces in urban areas and showed significant losses at these surfaces during the small and moderate sized events of most interest for water quality evaluations. Earlier research also found that disturbed urban soils did not behave as predicted by stormwater models.

Early unpublished double-ring infiltration tests conducted by the Wisconsin Department of Natural Resources (DNR) in Oconomowoc, Wisconsin, indicated highly variable infiltration rates for soils that were generally sandy (Natural Resources Conservation Service (NRCS) A/B hydrologic group soils) and dry. The median initial rate was about 75 mm/hr (3 in/hr), but ranged from 0 to 600 mm/hr (0 to 25 in/hr). The median final rate also had a value of about 75 mm/hr (3 in/hr) after at least two hours of testing, but ranged from 0 to 400 mm/hr (0 to 15 in/hr). Many infiltration rates actually increased with time during these tests. In about 1/3 of the cases, the observed infiltration rates remained very close to zero, even for these sandy soils. Areas that experienced substantial disturbances or traffic (such as school playing fields), and siltation (as in some grass swales) had the lowest infiltration rates. It was hoped that more detailed testing could explain some of the large variations observed.

The first major task of this project was to attempt to explain much of the variation observed in previous infiltration tests of disturbed urban soils. About 150 individual double-ring infiltration tests were conducted for this study in the Birmingham, Alabama area. These tests were separated into eight categories of soil conditions (comprising a full factorial experiment). Factors typically considered to cause infiltration rate variations are texture and moisture. These tests examined texture and moisture, plus soil compaction (as measured by a cone penetrometer and by site history). It was also hoped that age since disturbance and cover conditions could also be incorporated to help explain some of the infiltration variations, but these conditions were unevenly represented at the test sites and did not allow for a complete statistical examination.

Infiltration Mechanisms

Infiltration rainfall losses on pervious surfaces are controlled by three mechanisms, the initial entry of the water through the soil/plant surface (percolation), followed by movement of the water through the vadose (unsaturated) zone, and finally, depletion of the soil-water storage capacity. Overall infiltration is the least of these three rates, and the surface runoff rate is assumed to be the excess of the rainfall intensity greater than the infiltration rate. The infiltration rate typically decreases during the rain. Storage capacity is recovered when the movement of the water through the soil is faster than the percolation rate, which usually takes place after the rainfall has ended.

The surface entry rate of water may be affected by the presence of a thin layer of silts and clay particles at the surface of the soil and vegetation. These particles may cause a surface seal that would decrease a normally high infiltration rate. The movement of water through the soil depends on the characteristics of the underlying soil. Water cannot enter soil faster than it is being transmitted away, so this movement rate affects the overall infiltration rate. The depletion of available storage capacity in the soil also affects the overall infiltration rate. This storage capacity depends on the thickness, moisture content, and porosity of the soil. Many factors, i.e., texture, root development, structure, and presence of organic matter, affect the porosity of soil.

The infiltration of water into the surface soil is responsible for the largest abstraction (loss) of rainwater in natural areas. Once the infiltration capacity of the soil has been reached, most of the rain will become surface runoff. The infiltration capacity of most soils allows low intensity rainfall to totally infiltrate, unless the soil voids become saturated or the underlying soil is much more compact than the top layer. Intense rainfalls generate substantial runoff because the infiltration capacity of the upper soil layer is surpassed, even though the underlying soil might be very dry.

The classical assumption is that the infiltration capacity of a soil is highest at the very beginning of a storm and decreases with time. The moisture content of the soil, whether it is initially dry or still wet from a recent storm, will have a great affect on the infiltration capacity of certain soils. One of the oldest and most widely used infiltration equations was developed by Horton (1939). This equation was used in this study to compare the measured equation parameters with published literature values. The equation is as follows:

$$f = fc + (fo - fc)e-kt$$

where:
f= infiltration capacity (in/hr),
fo = initial infiltration capacity (in/hr),
fc = final capacity (in/hr),
k = empirical constant (hr-1)

The Horton equation assumes that the rainfall intensity is greater than the infiltration capacity at all times and that the infiltration rate decreases with time. The capacity of the soil decreases as the time of the storm increases because the pores in the soil become saturated with water and do not allow water to continuously infiltrate through the surface. The Horton equation's major drawback is that it does not consider storage availability in the soil after varying amounts of infiltration have occurred, but only considers infiltration as a function of time.

It is recommended that fc, fo, and k be obtained through field data, but these parameters are rarely measured locally. More commonly, they are determined through calibration of relatively complex stormwater drainage models, or by using published values. The use of published values in place of reliable field data is a cause of much concern.

Field Studies on Compost-Amended Soils

This second project task examined the benefits of using compost as a soil amendment to improve the infiltration capacity and pollutant retention capacity of disturbed urban soils. Currently, due to their wide distribution and inherent stability, most residential housing developments in the Seattle, Washington area are sited on the Alderwood soil series, which is characterized by a compacted subsurface layer that restricts vertical water flow. When disturbed and particularly when disturbed with cut and fill techniques as with residential or commercial development, uneven water flow patterns develop due to restricted permeability. This contributes to excessive overland flow, especially during storm events, and transport of dissolved and suspended particulate to receiving waters.

Research has demonstrated compost's effectiveness in improving the soil physical properties of porosity and continuity of macropores which influence soil-water relationships. Compost's chemical properties can also be valuable in some cases, such as in complexing potentially harmful trace metals including copper, lead, and zinc.

The University of Washington's (UW) College of Forest Resources (CFR) examined the effectiveness of using compost as a soil amendment to increase surface water infiltration and to reduce the quantity and/or intensity of surface runoff and subsurface flow from land development projects. In addition, runoff and subsurface flow was evaluated for dissolved nutrients and other constituents.

The CFR utilized the existing Urban Water Resource Center (UWRC) project site at the UW's Center for Urban Horticulture (CUH) for conducting the study. The CFR also used the UWRC design of large plywood beds for containing soil and soil-compost mixes. Additional sites of a similar design were constructed at public schools.

These test plots at the CUH were developed and tested previously during a study conducted for the city of Redmond, Washington. The following paragraphs summarize some of the findings and conclusions from that earlier study, conducted when the test plots were newly constructed:

The earlier project specifically examined the use of compost as an amendment to Alderwood series soil to increase water-holding capacity, reduce peak flow runoff, and decrease phosphorus in both surface runoff and subsurface flows. Seven 2.4 x 9.8 m (8 x 32 ft) beds were constructed out of plywood lined with plastic and filled with

Alderwood subsoil or mixtures of soil and compost. Surface and subsurface flow samples were obtained over the period from March 7 to June 9, 1995, during a series of seven simulated rainfall events. To create different antecedent soil moisture conditions, some storm events were quickly followed by another event. Simulated rainfall was applied at total amounts ranging from 19 to 62.4 mm (0.76 to 2.46 in.) per storm, with rainfall intensities ranging from 7.4 to 16 mm (0.29 to 0.63 in/hr). Compost amendments had the following effects on physical water properties:

Water-holding capacity of the soil was nearly doubled with a 2:1 compost:soil amendment.

Water runoff rates were moderated with the compost amendment, with the compost-amended soil showing greater lag time to peak flow at the initiation of a rainfall event and greater base flow in the interval following a rainfall event.

Runoff from the compost-amended soil had 24% lower average total P concentration (2.05 vs 2.54 mg/L) compared to the Alderwood soil that did not receive compost.

Soluble-reactive P was 9% lower in the compost-amended soil (1.09 vs 1.19 mg/L) compared to the Alderwood soil that did not receive compost amendment.

Nitrate-nitrogen was 17% higher in the compost-amended soil (1.68 vs 1.39 mg/L) compared to the Alderwood soil that did not receive compost amendment.

This earlier study highlighted the promise of organic amendments to improve water-holding capacity and runoff quality of Alderwood soils converted to turfgrass during urban development and was the basis for this current study. This study examined some of these same test plots at the CUH several years after their initial establishment, and during natural rains, to see if their behavior is substantially different with age. In addition, new test sites were established at two school locations for comparison.

Methodology and Test Site Descriptions

Sampling and Test Site Descriptions

Infiltration Tests in Disturbed Urban Soils

Birmingham, Alabama, the location of many of the test sites for disturbed urban soils, receives about 1400 mm (54 in.) of rain and about 110 separate rain events per year. Typical antecedent, dry periods range from about 2 to 5 days and it is unusual to go more than 10 days without recorded rainfall. The driest months are October and November, averaging 66 and 91 mm (2.6 and 3.6 in.), respectively, while March is the wettest month averaging 160 mm (6.3 in.) of rainfall. Snow is rare, with snowfalls of 130 mm (5 in.) or more occurring about once every 10 years. The growing season (temperature > 28° F) is at least 243 days per year in 5 out of 10 years. Average daily maximum temperatures are about 90° F in the summer months (June through August) and about 55° F in the winter months (December through February). Average daily minimum temperatures are about 65 to 70° F in the summer and about 34° F in the winter. The extreme recorded temperatures in Birmingham have ranged from about 0 to 110° F. Many of the sandy soil tests were located near Mobile, Alabama, where the rainfall averages about 250 mm (10 in.) more than in Birmingham.

Compost-Amended Soil and Soil Only Test Sites

The field study sites for testing the benefits of compost-amended soils were all located in the Seattle, Washington area. Seattle is relatively wet, receiving about 890 mm (35 in.) of rain a year; however, the typical rain intensity is quite low. Many of the tests were conducted at the existing test beds located at the UW's CUH demonstration site. Additional tests were conducted at newly established test sites at the Timbercrest High School and at the Woodmoor High School in Northern King County, Washington. The high school sites were characterized as having poorly-sorted and compacted glacial till soils of the Alderwood soil series. The three sites typified the problem areas for urban runoff in the region and represented development on glacial till soils in watersheds with water bodies of high quality. The three sites represent three replications of control and compost-amended soils for this study.

The CFR utilized the existing CUH site and associated UW facilities. The system included two different Alderwood glacial till soils that were transported to the site, and several mixtures of the glacial till soils and compost mixtures readily available in the Seattle area. Two plots each of glacial till-only soil and 2:1 mixtures of soil:compost were studied. The soil-compost mixture rates were also the same for the Timbercrest and Woodmoor sites, using Cedar Grove compost. The two composts used at the CUH sites were Cedar Grove and GroCo. The GroCo compost-amended soil at the CUH test site is a sawdust/municipal waste mixture (3:1 ratio, by volume) that is composted in large windrows for at least 1 year. The Cedar Grove compost is a yard waste compost that is also composted in large windrows.

Measurement of Infiltration Rates in Disturbed Urban Soils (Task1)

Experimental Design

A series of 153 double ring infiltrometer tests were conducted in disturbed urban soils in the Birmingham, and Mobile, Alabama, areas. The tests were organized in a complete 23 factorial design to examine the effects of soil moisture, soil texture, and soil compactness on water infiltration through historically disturbed urban soils. Turf age was also examined, but insufficient sites were found to thoroughly examine the effects of age on infiltration rates. Ten sites were selected representing a variety of desired conditions (compaction and texture) and numerous tests were conducted at each test site area. Moisture and soil texture conditions were determined by standard laboratory soil analyses. Compaction was measured in the field using a cone penetrometer and confirmed by the site history. Moisture levels were increased using long-duration surface irrigation before most of the saturated soil tests. From 12 to 27 replicate tests were conducted in each of the eight experimental categories in order to measure the variations within each category for comparison to the variation between the categories.

The expectation was that soil infiltration was related to the time since the soil was disturbed by construction or grading operations (turf age). In most new developments, compact soils are expected to be dominant, with reduced infiltration compared to pre-construction conditions. In older areas, the soil may have recovered some of its infiltration capacity due to root structure development and soil insects or other digging animals. Soils with a variety of times since development, ranging from current developments to those about 50 years old, were included in the sampling program. However, because these sites were poorly distributed in representation to the other primary test conditions, these effects were not directly determined. The Wisconsin DNR and the University of Wisconsin have conducted some soil infiltration tests on loamy soils to examine the effects of age of urbanization on soil infiltration rates. Their preliminary tests have indicated that several decades may be necessary before compacted loam soils recover to conditions similar to pre-development conditions.

Infiltration Rate Measurements

The infiltration test procedure included several measurements. Before a test was performed, the compaction of the soil was measured with the DICKEY-john Soil Compaction Tester Penetrometer and a sample was obtained to analyze moisture content. TURF-TEC Infiltrometers were used to measure the soil infiltration rates. These small devices have an inner ring about 64 mm (2.5 in.) in diameter and an outer ring about 110 mm (4.25 in.) in diameter.

The water depth in the inner compartment starts at 125 mm (5 in.) at the beginning of the test, and the device is pushed into the ground 50 mm (2 in.). The rings are secured in a frame with a float in the inner chamber and a pointer next to a stop watch. These units are smaller than standard double-ring infiltrometers, but their ease of use allowed many tests under a wide variety of conditions to be conducted. The use of three infiltrometers placed within a meter from each other also enabled better infiltration-rate site variability to be determined than if one larger unit was used.

Both the inner and outer compartments were filled with clean water by first filling the inner compartment and allowing it to overflow into the outer compartment. As soon as the measuring pointer reached the beginning of the scale, the timer was started. Readings were taken every five minutes for a duration of two hours. The two hour test duration was chosen to replicate the typical two hour rain durations and the expected time needed to reach saturation conditions. The instantaneous infiltration rates were calculated by noting the drop of water level in the inner compartment over the 5 min time period.

Tests were recorded on a field observation sheets and contained information such as: relative site information, testing date and time, compaction data, moisture data, and water level drops over time, with the corresponding calculated infiltration rate for the 5-minute intervals. All measurements are taken in natural soils in the field (leaving the surface sod in place), with no manipulation besides possibly increasing the moisture content before “wet” soil tests are conducted (if needed). At each site location, a field sample was obtained for a soil classification. The compaction of the test areas was obtained by pushing a DICKEYjohn Soil Compaction Tester Pentrometer into the ground and recording the readings from the gauge. For these tests, compact soils are defined as a reading of greater than 300 psi at a depth of three in., while uncompacted soils have readings of less than 300 psi. Compaction was confirmed based on historical use of the test site location.

Moisture values relating to dry or wet conditions are highly dependent on soil texture and are mostly determined by the length of antecedent dry period before the test. Soil moisture is determined in the laboratory using the ASTM D 2974-87 method. For typical sandy and clayey soil conditions at the candidate test areas, the dry soils have moisture contents ranging from 5 to 20% (averaging 13%) water, while wet soils have moisture contents ranging from 20 to 40% (averaging 27%) water.

The actual infiltration test procedure follows several basic steps. Whenever a test was performed, the compaction of the area was measured with the DICKEYjohn Soil Compaction Tester Penetrometer and a sample was obtained to analyze the moisture content. Then, three TURF-TEC Infiltrometers were pushed into the turf. This was accomplished by pushing down on the handles and twisting slightly until the saturn ring is level with the surrounding turf.

Soil Moisture Measurements

The moisture condition at each test site was an important test factor. The weather occurring during the testing enabled most site locations to produce a paired set of dry and wet tests. The dry tests were taken during periods of little rain, which typically extended for as long as two weeks with no rain and with sunny, hot days. The saturated tests were conducted through artificial soaking of the ground, or after prolonged rain. The soil moisture was measured in the field using a portable moisture meter (for some tests) and in the laboratory using standard soil moisture methods (for all tests). The moisture content was defined as the ratio of the weight of water to the weight of solids in a given volume of soil. This was obtained using ASTM method D 2974-87, by weighing the soil sample with its natural moisture content and recording the mass. The sample was then oven dried and its dry weight recorded. Saturated conditions occurred for most soils with soil moisture contents greater than about 20%.

Soil Texture Measurements

The texture of the samples were determined by ASTM standard sieve analyses to verify the soil conditions estimated in the field and for comparison to the NRCS soil maps. The sieve analysis used was the ASTM D 422-63 Standard Test Method For Particle Size Analysis of Soils for the particles larger than the No. 200 sieve, along with ASTM D 2488-93 Standard Practice for Description and Identification of Soils (Visual - Manual Procedure). The sample was prepared based on ASTM 421 Practice for Dry Preparation of Soil Samples for Particle Size Analysis and Determination of Soil Constants. The procedure requires a representative dry sample of the soil to be tested. After the material was dried and weighed, it was then crushed to allow a precise sieve analysis. The sample was then treated with a dispersing agent (sodium hexametaphosphate) and water at the specified quantities. The mixture was then washed over a No. 200 sieve to remove all soil particles smaller than the 0.075 mm openings. The sample was then dried again and a dry weight obtained. At that point, the remaining sample was placed in a sieve stack containing No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, No. 200 sieves, and the pan. The sieves were then placed in a mechanical shaker and allowed to separate onto their respective sieve sizes. The cumulative weight retained on each sieve was then recorded.

The designation for the sand or clay categories follows the Unified Soil Classification System, ASTM D 2487. Sandy soils required that more than half of the material be larger than the No. 200 sieve, and more than half of that fraction be smaller than the No. 4 sieve. Similarly, for clayey soils, more than half of the material is required to be smaller than the No. 200 sieve.

Soil Compaction Measurements

The extent of compaction at each site was measured using a cone penetrometer before infiltration testing. Soils, especially clayey soils, are obviously more spongy and soft when wet as compared to extremely dry, hard conditions. Because the cone penetrometer measurements are sensitive to moisture, measurements were not made for saturated conditions and the degree of soil compaction was also determined based on the history of the specific site (especially the presence of parked vehicles, unpaved lanes, well-used walkways, etc.). Compact soils were defined as having a reading of greater than 300 psi at a depth of three in. Other factors that were beyond the control of the experiments, but also affect infiltration rates, include bioturbation by ants, gophers and other small burrowing animals, worms, and plant roots.

Soil/Compost Test Site Characterization (Task 2)

Plot Establishment

Plots were planted using a commercial turfgrass mixture during the Spring, 1994, season for the CUH sites and in the fall of 1997 for the Timbercrest and Woodmoor sites. The soil and compost for this study was mixed on an asphalt surface with a bucket loader and hauled and dumped into the plot bays. A system of collection buckets to allow sampling of both surface runoff and subsurface flows at intervals ranging from 15 minutes to longer was located at the CUH site, along with a tipping bucket rain gage. Similar setups were also installed at the two high school locations for these experiments.

Fertilizer was added to all plots during plot establishment (16-4-8 N-P2O5-K2O) broadcast spread over the study bays at the rate of 0.024 kg fertilizer/m2 (0.005 lb fertilizer/ft2) as recommended on the product's label. The initial application resulted in an application of 0.010 kg (0.023 lb) of elemental phosphorus (P) as orthophosphate (PO4-) per plot, or 0.00043 kg P/m2 (0.000087 lb P/ft2). This resulted in an application of 0.091 kg (0.20 lb) of elemental nitrogen (N) as ammonium (NH4+) and nitrate (NO3-) (undetermined distribution) per plot, or 0.0039 kg N/m2 (0.00080 lb N/ft2). Due to the poor growth of turf on the control plots, and in order to simulate what would have likely been done anyway on a typical residential lawn, an additional application of 0.024 kg/m2 (0.005 lb/ft2) was made to the CUH control plots on May 25, 1995.

Characterization of Compost-Amended Soils

The study design for this phase of the research was a randomized complete block design, with four blocks of two treatments. Treatments included the following:

(1) control turf plots with Alderwood soil-only, and
(2) compost-amended turf plots with a 2:1 soil:compost mixture.

The four blocks were tested at the three locations, with one block each at Timbercrest and Woodmoor High School, and two blocks at the CUH facility. The blocks are differentiated by differences in the native soil characteristics. Differences in the physical and chemical parameters of the infiltrating water during this study were examined using nonparametric comparison tests, augmented with exploratory data analyses procedures.

Soil and soil/compost mixture samples were taken 1 month after the initiation of the study and analyzed by the CFR analytical labs for the following parameters:

1) total carbon (C),
2) total N,
3) gravimetric water holding capacity (field capacity) moisture,
4) volumetric water holding capacity (field capacity) moisture,
5) total porosity,
6) bulk density,
7) particle density,
8) particle size analysis, and
9) soil structure.

Total C and N, which are considered to be the primary measures of soil productivity in these soils, were determined using an automated CHN analyzer. Bulk density was estimated using a coring device of known volume (bulk density soil sampler). The core was removed, oven dried, and weighed. Bulk density was calculated as the oven dry weight divided by the core volume. Particle density was determined by using a gravimetric displacement. A known weight of soil or soil/compost mixture was placed in a volumetric flask containing water. The volume of displacement was measured and particle density was calculated by dividing the oven dry weight by displaced volume.

Gravimetric water holding capacity was determined using a soil column extraction method that approximates field capacity by drawing air downward through a soil column. Soil or soil/compost mixture was placed into 50 ml syringe tubes and tapped down (not compressed directly) to achieve the same bulk density as the field bulk density measured with coring devices. The column was saturated by drawing 50 ml of water through the soil column, then brought to approximate field capacity by drawing 50 ml of air through the soil or soil/compost column.

Volumetric water holding capacity was calculated by multiplying gravimetric field capacity by the bulk density.

Particle size distribution was determined both by sieve analysis and sedimentation analysis for particles less than 0.5 mm in size. Due to the light nature of the organic matter amendment, particle size analysis was sometimes difficult, and possibly slightly inaccurate. Soil structure was determined using the feel method and comparing soil and soil/compost mixture samples to known structures.

Before any runoff tests were conducted, background soil samples were analyzed. The relative concentrations and mass of nutrients and metal species in the soil and compost is of interest, as is the mass movement into and out of the soil. Additionally, because some nutrients interact strongly with several soil metals, determining these elements and relative amounts is useful in making inferences about nutrient and metal retention or loss in runoff. Another important aspect is the possibility of establishing a concentration gradient in the soil profile.

Flow Measurements at Field Test Sites

The design for the test bay system developed by the UWRC (Harrison, et al. 1997) was used to enclose soil-compost mixes and collect surface and subsurface runoff. These systems consist of enclosed bays with tipping buckets attached to data recorders. Similar systems were constructed and used at Timbercrest and Woodmoor high schools.

Glacial till soil was added to the bays and compacted before adding compost. Cedar Grove compost was added at a 2:1 soil:compost rate and rototilled into the soil surface. Particular attention was placed on simulating a compacted glacial till layer to represent natural field conditions. Once installed, all bays were cropped with perennial ryegrass. Separate surface runoff and subsurface flow collectors were installed within each bay. Collection basins were equipped with tipping buckets to record flow over time, every 15 min. Each tip of the bucket was calibrated for each site and checked on a regular basis to give rates of surface and subsurface runoff from all plots.

Double-ring infiltration tests, based on ASTM method D 3385, were performed. However, due to the small size of the plots and the potential for destruction of the plots by installation of large rings, the small ring was 7.5 cm in diameter and the large ring was 14 cm in diameter. The rings were driven into the soil to a maximum depth of 7.5 cm. Measurements were taken on surface infiltration only.

The Timbercrest High School and WoodMoor High School field sites in Northern King County, Washington were located on poorly-sorted, compacted Glacial Till soils of the Alderwood soil series. Sampling installations included in-situ installations. Surface runoff and subsurface flows were collected from bucket tips during 7 separate intervals.

There were several problems with flow monitoring and water sampling at the sites, especially at the new test sites. At Timbercrest, the very high water table and the pressure on the sealed container that was supposed to exclude surface water from entering the collector box, caused the tipping buckets to function improperly. Thus, they were removed and collection bottles were substituted that did not record flow versus time. Problems were not as severe at the Woodmoor site, and samples were collected versus time for the duration of the study. At the CUH site, tipping buckets did not record during the last two time periods. However, during each of the 5 to 6 fully monitored time periods at each site, many individual rains were included in the data.

Both surface runoff and subsurface flow were separately collected following the seven rainfall periods during the months of December 1997 through June 1998. Surface runoff and subsurface flows were collected monthly from the surface and subsurface collection basins. At the beginning of the project, to help establish the new turf, a typical lawn herbicide/fertilizer combination was broadcast spread over the study bays at the rate recommended on the product label.

Samples were collected in polypropylene bottles and immediately placed in cold storage on-site. Subsurface flow samples were collected in a similar manner. Sample times varied depending on antecedent moisture conditions and amount of flow generated by simulated rainfall. All water samples were immediately taken to the analytical lab and stored at 4°C until analysis.

Analytical Measurements and Procedures

Selected laboratory noncritical measurement were made to supplement the above critical physical measurements. These included periodic particle size analyses and toxicity screening analyses, plus nutrient and heavy metal analyses at the compost-amended test sites. The following list shows these measurements that were also conducted on the samples collected from the Seattle area tests:
Acid hydrolyzable P, Chlorine (Cl), nitrite (NO2), NO3, PO4- – P, sulfate (SO4), Total arsenic (As), boron (B), barium (Ba), calcium (Ca), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), magnesium (Mg), potassium (K), manganese (Mn), N, sodium (Na), nickel (Ni), P, lead (Pb), sulfer (S), selenium (Se), and zinc (Zn)

All work was done in accordance with UW analytical laboratory QA/QC procedures. In addition, most of the surface runoff and subsurface flow samples were also screened for toxicity (using the Azur Microtox procedure) and analyzed for particle sizes (using a Coulter counter) at UAB's Department of Civil and Environmental Engineering laboratory.

Conclusions

This project evaluated a widespread problem, decreased infiltration due to disturbed soils, and a potential solution, soil amendment with compost. The elements associated with the problem of disturbing natural soils during land development were examined over a wide variety of site conditions (soil texture, age, moisture, and compaction) and at several locations. A large number of infiltration tests were conducted to identify the factors significantly affecting infiltration parameters. In addition, the project also examined a potential solution, amending soils with large amounts of compost, to reduce the problems associated with altering the surface and subsurface hydrology during development. The benefits of compost amendment were measured at special test plots exposed to typical developmental construction practices.

Infiltration Rates in Disturbed Urban Soils (Task 1)

The initial exploratory analyses of the data showed that sandy soils were mostly affected by compaction, with little change due to moisture levels. However, the clayey soils were affected by a strong interaction of compaction and moisture. The variations of the observed infiltration rates in each category were relatively large, but four soil conditions were found to be distinct, as shown in Table 1. The data from each individual test were fitted to the Horton equation, but the resulting equation coefficients were relatively imprecise (Table 2) and it may not matter which infiltration model is used, as long as the uncertainty is considered in the evaluation. Therefore, when modeling runoff from urban soils, it may be best to assume relatively constant infiltration rates throughout an event, and to utilize Monte Carlo procedures to describe the observed random variations about the predicted mean value, possibly using the time-averaged infiltration rates and coefficient of variation (COV) values shown in Table 3.

Very large errors in soil infiltration rates can easily be made if published soil maps and most available models are used for disturbed urban soils, as these tools ignore compaction. Knowledge of compaction (which can be mapped using a cone penetrometer, or estimated based on expected activity on grassed areas) can be used to much more accurately predict stormwater runoff quantity.

In most cases, the mapped soil textures were similar to what was actually measured in the field. However, important differences were found during many of the 153 tests. Table 1 showed the 2-hr averaged infiltration rates and their COV in each of the four major groupings. Although these COV values can be generally high (up to 1.5), they are much less than if compaction was ignored. The results of the factorial analysis indicated that the best models were separated by the soil texture. For more accurate modeling, it is recommended that site specific data be obtained. Once the texture, moisture and compaction of the soil are known, a model can be developed. The high variations within each of these categories makes it difficult to identify legitimate patterns, implying that average infiltration rates within each event may be most suitable for predictive purposes. The remaining uncertainty can probably best be described using Monte Carlo components in runoff models.

The measured infiltration rates during these tests were all substantially larger than expected, but comparable to previous standard double-ring infiltrometer tests in urban soils. Other researchers have noted the general over-predictions of ponding by infiltrometers compared to actual observations during natural rains. In all cases, these measurements are suitable to indicate the relative effects of soil texture, compaction, and moisture of infiltration rates, plus the measured values can be directly used to predict the infiltration rates that may be expected from stormwater infiltration controls that utilize ponding. Additional research is needed in other urban areas to measure site specific effects of these soil conditions on infiltration rates.

Water Quality and Quantity Effects of Amending Soils with Compost (Task 2)

There was a substantial difference in appearance of amended and unamended plots. There was insufficient grass growth in the unamended plots, even following initial establishment fertilization. The compost-amended plots were very attractive and needed no fertilization. In fact, the initial establishment fertilization may not have been necessary based on studies at the University of Washington of growing turfgrass in similar compost-amended soils without inorganic fertilization. Besides fertilizer applications, other external sources of nutrients to the test plots included wildlife (especially geese that were noted to selectively graze the compost-amended plots).

Application of compost material similar to that used during these studies would be possible by applying 4 in. of compost onto the surface of an soil and tilling to a total depth of 30 cm (12 in.), including the compost amendment 20 cm (8 in.) into the soil). This mixing would probably need to be thorough and deep to achieve the conditions of this study. However,

Table 1. Infiltration Rates for Significant Groupings of Soil Texture, Moisture, and Compaction Conditions

Group	Number of tests	Average infiltration rate, mm/hr (in/hr)	COV
noncompacted sandy soils	36	414 (16.3)	0.4
compact sandy soils	39	64 (2.5)	0.2
noncompacted and dry clayey soils	18	220 (8.8)	1.0
all other clayey soils (compacted and dry, plus all saturated conditions)	60	20 (0.7)	1.5

Table 2. Observed Horton Equation Parameter Values for Sandy and Clayey Soils

	f_o mm/hr (in/hr)		f_c mm/hr (in/hr)		k (1/min)	
	mean	range	Mean	range	mean	range
Observed noncompacted sandy soils	990 (39)	110–3700 (4.2–146)	381 (15)	10–635 (0.4–25)	9.6	1.0–33
Observed compact sandy soils	381 (15)	3–2200 (0.1–86)	46 (1.8)	3–240 (0.1–9.5)	11	1.8–37
Observed dry noncompacted clayey soils	460 (18)	64–1500 (2.5–58)	170 (6.6)	3–610 (0.1–24)	8.8	-6.2–19
Observed for all other clayey soils (compacted and dry, plus all saturated conditions)	86 (3.4)	0–1200 (0–48)	10 (0.4)	-15–170 (-0.6–6.7)	5.6	0–46

Table 3. Soil Infiltration Rates for Different Categories and Storm Durations - mean [COV]

	15 minutes mm/hr (in/hr)	30 minutes mm/hr (in/hr)	60minutes mm/hr (in/hr)	120 minutes mm/hr (in/hr)
Sand, Non-compacted	582 (22.9) [0.4]	495 (19.5) [0.4]	429 (16.9) [0.4]	414 (16.3) [0.4]
Sand, Compacted	170 (6.7) [0.2]	120 (4.9) [0.2]	97 (3.8) [0.2]	64 (2.5) [0.2]
Clay, Dry Non-compacted	323 (12.7) [1.0]	244 (10.8) [1.0]	240 (9.6) [1.0]	220 (8.8) [1.0]
All other clayey soils (compacted and dry, plus all saturated conditions)	46 (1.8) [1.5]	25 (1.3) [1.5]	25 (1.0) [1.5]	20 (0.7) [1.5]

this may not be possible with most existing equipment.

The results of this study clearly show that amending soil with compost alters soil properties known to affect water relations of soils, i.e., the water holding capacity, porosity, bulk density, and structure, as well as increasing soil C and N, and probably other nutrients as well. The mobilization of these constituents probably led to observed increases in P and N compounds in surface runoff compared to unamended soil plots.

Results of the earlier tests (Harrison, et al. 1997) were somewhat different than obtained from the current tests. Some of these differences were likely associated with the age of the test plots, plus different rainfall conditions, and other site characteristics. The results of the earlier study clearly showed that compost amendment is likely an effective means of decreasing peak flows from all but the most severe storm events, even following very wet, antecedent conditions. The increases in water holding capacity with compost amendment showed that storms up to 20 mm (0.8 in.) total rainfall would be well buffered in amended soils and not result in significant peak flows, whereas without the amendment, only a 10 mm (0.4 in.) rainfall storm would be similarly buffered.

This study found that the infiltration rate increased by 1.5 to 10.5 times after amending the soil with compost, compared to unamended sites. There were mixed results with surface runoff results. Two of the older CUH test plots appeared to have no effect, the Woodmoor site had a ratio of 5.6 reduced runoff and the Timbercrest site had no reported runoff. Because the older CUH sites did not show any runoff improvements in these test while the new Timbercrest and Woodmoore sites did, further study should determine, if possible, the limits of effectiveness of compost amendment, i.e. age or decay rate, and a maintenance/reapplication schedule.

If a significant percentage of disturbed glacial till soils were amended with compost as described in this report, it would have a significant beneficial effect on watershed hydrology. The absolute amount depends on many factors, but it is clear that compost amendment is an excellent means of retaining runoff on-site and reducing the rate of runoff from all but the most intense storm events, especially during the early critical years following development.

One drawback is that the concentrations of many pollutants increased in the surface runoff, especially associated with leaching of nutrients from the compost. The surface runoff from the compost-amended soils had greater concentrations of almost all constituents, compared to the surface runoff from the soil-only test sites. The only exceptions were some cations (Al, Fe, Mn, Zn, Si), and toxicity, which were all lower in the surface runoff from the compost-amended soil test sites. The concentration increases in the surface runoff and subsurface flows from the compost-amended soil test site were quite large, typically in the range of 5 to 10 times greater. Subsurface flow concentration increases for the compost-amended soil test sites were also common and about as large. The only exceptions being for Fe, Zn, and toxicity. Toxicity tests indicated reduced toxicity with filtration at both the soil-only and at the compost-amended test sites, likely due to the sorption or ion exchange properties.

When the decreased surface flow quantities were considered in conjunction with the increased surface runoff concentrations, it was found that all of the surface runoff mass discharges were reduced by large amounts (to 2 to 50 percent of the unamended discharges). However, many of the subsurface flow mass discharges are expected to increase, especially for ammonia, phosphate, total phosphorus, nitrates, and total nitrogen. The large phosphorus and nitrogen compound concentrations found in surface runoff and subsurface flows at the compost-amended soil sites decreased significantly during the time of the tests (about 6 months). The older CUH test sites also had lower nutrient concentrations than the new sites, but still had elevated concentrations when compared to the soil-only test plots.

In conclusion, adding large amounts of compost to marginal soils enhanced many desirable soil properties, including improved water infiltration (and attendant reduced surface runoff), increased fertility, and significantly enhanced aesthetics of the turf. The need for continuous fertilization to establish and maintain the turf is reduced, if not eliminated, at compost-amended sites. Unfortunately, the compost also increased the concentrations of many nutrients in the runoff, especially when the site was newly developed but with increased infiltration of the soil, the nutrient mass runoff would be significantly decreased. Further research is needed to determine the optimum amount of compost amendment to benefit urban soils without the associated problems of leaching nutrients.

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The complete report, entitled "Infiltration through Disturbed Urban Soils and Compost-Amended Soil Effects on Runoff Quality and Quantity", EPA#/000/x/000/000 will be posted on U.S. Environmental Protection Agency, Office of Research and Development Web-site at: http://www.epa.gov and available from the National Technical Information Service (Order No. PB00-XXX XXX/AS; Cost:$XX.00, subject to change):

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