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SUMMARY

Rates of water entry were measured for 11 soil series representing many of the soils in parts of Nebraska where urban growth is most intensive.

The wetting procedure in making the tests is critical and a 24 hour wetting time as usually recommended is not adequate for all soils if the percolation test is made during a dry season.

Rates of water entry differed among soils even though a large amount of variation was evident within the same soil series. Differences in rate among holes at two different depths were not consistent even though it appeared that in some soils the rate beneath a clay pan was greater than in the clay pan. Rates of water entry measured at the same sites in spring when the soils were near field capacity were not different from those determined during the dry season of the preceding year indicating that the longer wetting period used was adequate.

Statistical analysis showed a highly significant negative relationship between both clay content and bulk density and rates of water entry. No significant statistical relationship between sand content and rate of water entry in the soils was evident. Lack of significance was attributed to the fact that the soils studied either contained very little sand, or the effect was masked by the very compact nature of the soils that contained appreciable amounts of sand, such as those formed in glacial till of Kansan Age. Linear regression coefficients were found to be highly significant when clay content or bulk density were compared with rate of water entry and prediction equations were calculated. A summary of the use of rate of water entry or percolation test data to plan the size of an absorbing field for a septic tank is presented.

Rates of Water Entry into the Subsoil of Several Soil Series in Nebraska

David T. Lewis[1]

INTRODUCTION

Absorption of water by the soil has been used for many years to estimate ability of a soil at a given site to absorb effluent from the seepage field of a septic tank sewage disposal system. Such measurements are usually called "percolation tests."

Although the "perc test" has been criticized as an unsound scientific tool (3, 15), it is still the most widely used means of predicting a soil's absorption capacity.

Perhaps the main reason that favors the percolation test is its simplicity (5). It is relatively easy to dig a hole to a specified depth, put some gravel in the bottom of the hole, fill the hole with water and measure the drop in water in the hole over a specified time. Perhaps the test is too simple, for unless other things about the site are considered, the results can be misleading (10).

RATES OF WATER ENTRY AND SUCCESS OF THE SEPTIC TANK SYSTEM

The Manual of Septic Tank Practice (13) specifies the area of soil absorbing surface needed based on the rate of water entry obtained for the soil (Fig. 1). Huddleston and Olson (6) have also recommended certain designs of seepage fields based on rates of water entry obtained from the soil in which the seepage field is to be established.

Several people have cautioned against relying solely on rates of water entry data for this purpose, however. Bouma (3) concluded that rates from percolation tests are too variable to rely on and has proposed an alternate method. Winneberger (15), after eight years of studying rates from percolation tests and the failure of septic tank systems, concluded that the rate obtained was too dependent on the method used to make it, inherently extremely variable, and consequently of little use in predicting the success or failure of a septic tank system. He also found that soils with rates as rapid as 4 minutes per

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[1] Assistant Professor of Agronomy, University of Nebraska. The author wishes to recognize and express his gratitude to Mr. Loyal Quandt, Mr. Paul A. Bartlett, and Mr. Ronald Hoppes of the Soil Conservation Service for their help in locating sites and to Dr. Robert Grossman and Mr. Robert Jordan of the Soils Investigation Unit of the Soil Conservation Service for determining bulk density values of the soils studied.

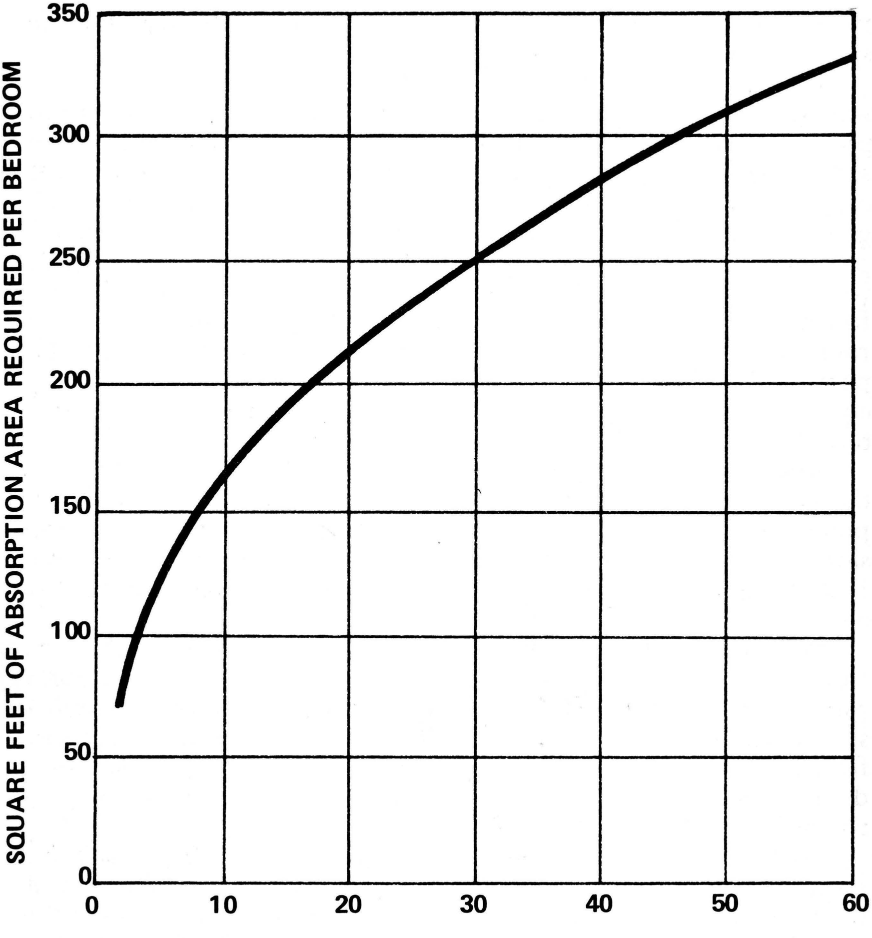

Figure 1. Absorption area requirements for private residences (from Manual of Septic Tank Practice).

inch [15 inches (37.5 cm) per hour] had effluent absorbance rates as slow as 1200 minutes per inch [.05 inches (.125 cm) per hour] after a period of a few months of absorbing effluent. He concluded that the short term ability of soil to accept fresh water is not related to its long term ability to accept sewage.

Several people have reported that the ability of a soil to absorb fresh water declined with time. Allison (1) used a system of sterile water and soil to show that the plugging of the soil that occurred was due to anaerobic organisms and the products they produced. Similar results were shown by McCalla (9) and Avnimelech and Nevo (2). Jones and Taylor (8) found that in sands, plugging of soil pores took place in a distance of less than 1.6 inches (4 cm) in the soil from the soil-liquid interface.

Thomas *et al.* (12) described two phases of soil plugging. The first was an aerobic phase in which soil particles were coated with iron and phosphate. Other products from soaps and detergents (9) also coat soil particles during this phase. Plugging pores slows the movement of oxygen to where it cannot keep up with the demand of aerobic organisms, and the system becomes anaerobic. The second phase of soil plugging is initiated when anaerobic respiration produces organic compounds which further plug the soil pores. Thomas *et al.* (12) found that air drying caused the ability of the soil to absorb effluent to rapidly recover to near its original rate. If the soil is given a rest periodically, the ability of the soil to absorb effluent will be nearly equivalent to its ability to absorb fresh water as measured on a short term basis.

Aside from plugging the soil pores, other factors can determine the success of the system. The Manual of Septic Tank Practice (13) points out that septic tanks need to be cleaned periodically to keep sludge from building up to the point where it enters the seepage field. If sludge gets into the drainage tile, the entire system plugs up rapidly and the system fails.

Weibel *et al.* (14) pointed out that the sewage content affects the working of the septic tank system. They specifically warned against putting large amounts of grease or ground garbage into the system. A system can easily be overloaded. The absorbing area of the seepage field is usually designed based on average amounts of sewage produced. This average is usually determined by the number of bedrooms in a house (13,15).

Mellen (10) has pointed out that the amount of water the soil in a seepage field must absorb is about half sewage effluent. The rest of the water comes from normal rainfall and runoff water crossing the area. Consequently, the system designed to absorb the liquid sewage from a home may be only about half as large as it should be to absorb all the water with which the seepage field may come in contact. He emphasizes that curtain drains are needed around the seepage field as described in the Manual of Septic Tank Practice (13). Mellen further pointed out that seasonal high water tables may not be noted when the percolation test is made and that layers of impermeable rock may be a few inches below the bottom of a percolation test hole. Both of these factors can cause the failure of a septic tank system but not be measured by a percolation test. Others also have pointed this out (4, 7).

Therefore, percolation test data alone are not a very sound basis for predicting success or failure of a septic tank system. As Winneberger (15) pointed out, there is no substitute for scientific evaluation of soils and care in the construction of the septic tank system.

This is not to say that percolation rates are not useful. In spite of obvious shortcomings, the rate of water entry, or percolation test, is still the best method available to obtain a relatively rapid indication of how fast a soil will absorb water. If a soil won't absorb fresh water, it won't absorb effluent. The percolation rate should be taken as another factor about the soil to consider when judgments are made first as to whether or not a septic tank system has a chance to succeed, and second, how large an area and what type of seepage field is required. If the rate of water entry is used as described here, and if the rate of water entry is measured with the same care as any other scientific measurement, then the measurement can provide a useful bit of information to help predict how well the soil at a given site will support a septic tank sewage disposal system.

Water absorption data are still widely used by state departments of health and other organizations to indicate suitability of a site for installation of a septic tank sewage disposal system. For this reason rates of water entry for several soil series in Nebraska were determined and related to some major physical properties of the soils. Since soil series are shown on soil maps, the data will add to the usefulness of soil maps made in Nebraska as guides for planning sites for septic tank sewage disposal.

SOILS STUDIED

Rates of water entry were determined for 11 soil series representing 6 soil families in Nebraska. Most soils studied were in areas of the state where pressures of urban expansion are most intense. Soils studied and a brief description of them are:

1. **Sharpsburg:** A moderately well drained soil developed in brown loess of Peoria Age. The subsoil is light silty clay with a moderate to strong subangular blocky structure. Sharpsburg soils are located in southeastern Nebraska, principally in Saunders, Lancaster, Cass, and Otoe Counties.
2. **Marshall:** a well drained soil developed in brown loess of Peoria Age. The subsoil is silty clay loam with a moderate subangular blocky structure. Marshall soils are located principally in the eastern part of Saunders County and in Douglas, Sarpy, and Cass Counties.
3. **Monona:** a well drained soil much like Marshall except that it contains more silt and less clay. In Nebraska Monona soils are located between areas of Marshall soil and the bottomland soils along the Missouri River.
4. **Holdrege:** a well drained soil developed in brown loess of Peoria Age. Holdrege soils are similar in texture to Marshall but are located in south central Nebraska and as a consequence are much drier. The Holdrege has a lime zone at a depth of about 30 inches (75 cm).

5. Keith: a well drained soil much like Holdrege except it is a little more dry and the lime zone is a little more shallow. Keith soils are found in southwestern Nebraska and in the Panhandle.

6. Wymore: a somewhat poorly drained soil developed in gray, mottled loess of Peoria Age. Wymore soils have a silty clay subsoil with moderate to strong subangular blocky structure. In Nebraska these soils are located principally in Lancaster, Gage, Johnson, Otoe, and Nemaha Counties.

7. Pawnee: a moderately well drained soil developed in firm, compact glacial till of Kansan Age. These soils have a clay subsoil that rests upon gray, mottled, limey clay loam glacial till. Pawnee soils are located throughout southeastern Nebraska on gentle slopes where the overlying loess has been stripped away by erosion.

8. Burchard: a well drained soil developed in firm, compact glacial till of Kansan Age. Burchard soils are located near Pawnee on slightly steeper slopes. As a consequence, they are not so deeply developed as the Pawnee soils, have a clay loam subsoil, and have limey glacial till at depths of 24-30 inches (60–75 cm).

9. Shelby: soils much like the Burchard except the till beneath the soil profile is not limey. Burchard, Pawnee, and Shelby soils are close together on the landscape in many parts of southeastern Nebraska.

10. Morrill: a well drained soil developed in reddish brown colored footslope deposits of Illinoian Age. Since these are a mixture of gravity and water lain deposits, Morrill soils are in many places composed of strata including thin layers of medium sized and coarse sand. In other places these strata are absent and the soil profile is clay loam in texture throughout its depth.

11. Mayberry: a well drained soil developed in reddish brown colored footslope deposits of Illinoian Age. These soils have a subsoil that is clay in texture and in many places is relatively deep. Mayberry and Morrill soils are common throughout southeastern Nebraska and are usually on sideslopes with loessal soils upslope and soils formed in glacial till downslope from them.

The particle size distribution and bulk density of each horizon of the soil series studied with the exception of Shelby are shown in Appendix Table 1. Shelby soils were not sampled because of their close resemblance to Burchard soils.

PROCEDURE

Three sites that represented typical soils for each series were located. The sites were all in grass vegetation and had been for some time. Six holes were dug with a 6-inch post hole digger at each site (Figure 2). Three holes were 2 feet (60 cm) deep and 3 were 5 feet (150 cm) deep. The two depths were used to determine whether or not the rate of water entry would be different if taken at different

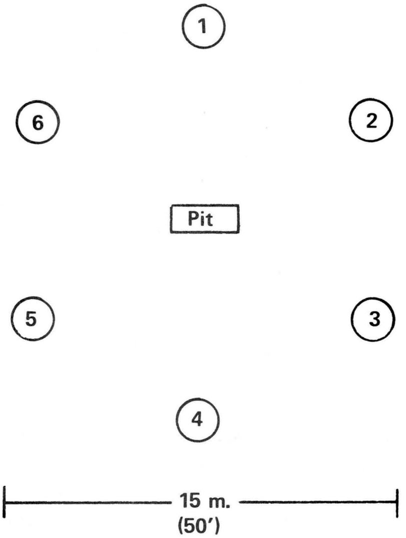

Figure 2. Plan of a soil site for the determination of the percolation rate. Holes 2, 5, and 6 are two feet (60 cm) deep, and holes 1, 3, and 4 are five feet (150 cm) deep.

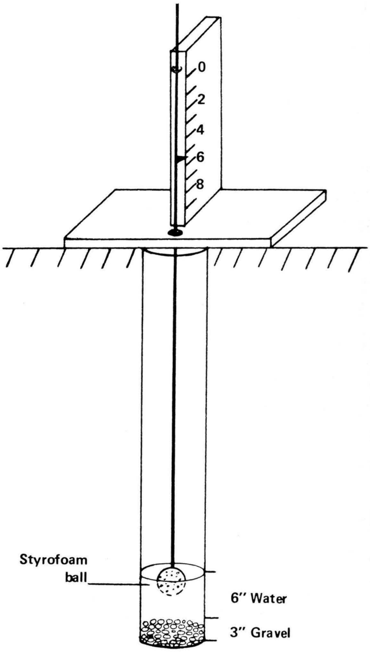

Figure 3. Diagram of the device used to measure rate of water entry into soil.

depths in the soil profile since no specified depth other than less than 5 feet (150 cm) is usually recommended.

After the holes were dug, the sides were carefully prepared with a small hoe-like device to correct any sealing caused during digging. All loose material was carefully removed from the bottom of the hole and 3 inches of pea gravel put into the hole to protect the bottom from sealing with sediment. The holes were filled with water in the morning, kept filled through the day, and left filled in the evening.

The next morning the holes were again filled with water and maintained at near full level for 4 hours. The water level was then lowered to 6 inches (15 cm) above the gravel. A float measuring device (Fig. 3) was installed and measurement of drop from the 6 inch (15 cm) head of water began. This was continued over a minimum of a 4 hour period, and longer if a declining rate was observed. An attempt was made to keep the head of water at a minimum of 5 inches (12.5 cm) throughout the time of measurement. The time required for water to drop from 6 to 5 inches (15 to 12.5 cm) was recorded each time and water was carefully added to bring the water level back to the original 6 inch (15 cm) head. Where drop occurred rapidly, this was not always possible, but the water level was never allowed to drop more than 3 inches (7.5 cm) before additional water was added. If the rate was relatively constant at the end of 4 hours, the last reading was taken as the rate of water entry. In some of the soils where the rate was extremely slow, no measureable drop in head occurred during the 4 hour period. In these cases, the holes were covered and left overnight to be read again the following morning.

The 24 hours of wetting the soil was not adequate in every case. In some cases soils that contained about 45 percent clay maintained very rapid rates for several days when rates were measured in August. One site of Pawnee soils required five continuous days of wetting before holes at 2 feet (60 cm) depth showed a constant rate of water entry. This was due to the large number of cracks that form in dried soils that contain considerable amounts of montmorillonite clays. Hill (5) described a similar phenomenon. Rates of water entry for sites read in July, August, and September were determined again the following spring when the soil was near its field capacity. Rates obtained did not differ greatly from those obtained during drier periods. Therefore, it appeared that our modified wetting procedure was adequate.

The point emphasized here is that cracks, worm holes, rodent burrows, and other voids in the soil, if in contact with the free water in the hole (11) can cause very rapid rates of water entry where the rates do not agree with soil properties. If the rate of water entry is to represent the soil, great care must be taken to adequately soak the soil to close any cracks caused by drying, or relocate the hole if a rodent burrow is encountered. A means to approximate what the rate should be to determine whether or not the rate obtained is representative of the soil will be discussed later.

RESULTS

Rates of water entry obtained for each soil studied are given in Table 1. These values represent averages from three sites, with three holes at each depth per site. Considerable variability between holes only a few feet apart at each site was noted (Table 3). The high variation of such determination has been described by several others (4, 5, 6, 7, 11, 15). Coefficients of variation as high as 230 were reported by Derr *et al.* (4). The coefficient of variation of 33 obtained for our data also implies considerable variation within experimental units, but not so much as has been reported elsewhere. Perhaps one reason for the relatively low variation is that each site was located in what represented the model concept of each soil series studied.

Although considerable variation existed, there were significant differences between rates of water entry from many of the soil series studied. However, as pointed out by Derr *et al.* (4) significant differences were noted primarily between soils having very slow rates and those with much faster rates. For example, at the 2 foot (60 cm) depth, the rates for the Morrill and Sharpsburg soils were the same at the 5% level of probability as those for the Mayberry and Wymore

Table 1. Percolation rates of each soil studied.

Soil	Percolation rate	
	in/hr	min/in
	60 cm (2 ft)	
Holdrege	7.89	7.6 [a]
Marshall	6.72	8.9
Monona	6.61	9.1
Keith	5.75	10.4
Morrill	2.01	29.9
Sharpsburg	1.43	42.0
Shelby	0.70	85.7
Burchard	0.70	85.7
Pawnee	0.33	181.8
Wymore	0.14	428.6
Mayberry	0.03	2000.0
	150 cm (5 ft)	
Keith	13.89	4.3
Holdrege	13.44	4.5
Morrill	4.66	12.9
Marshall	4.44	13.5
Monona	3.36	17.9
Sharpsburg	2.72	22.1
Wymore	1.21	49.6
Mayberry	0.44	136.4
Pawnee	0.17	352.9
Burchard	0.12	500.0
Shelby	0.10	600.0

[a] Lines indicate the grouping of mean values according to Duncan's Multiple Range Test.

soils. However, at the 20% level of probability, the rates for Sharpsburg and Morrill were different.

The rates noted at the two depths were not different statistically. However, in some of the soils the differences between the depths were quite large. For example, the Wymore soil had an average rate of 1.21 inches (3.1 cm) per hour at the five foot (150 cm) depth and a rate of 0.14 inches (0.36 cm) per hour at the 2 foot (60 cm) depth. In other words, the rate of 5 feet (150 cm) was almost nine times greater than the rate at 2 feet. This difference is probably due to the much higher clay content at 2 feet (60 cm) than at 5 feet (150 cm).

Other soils showed an opposite relationship, however. Rates of water entry for soils in Kansan glacial till (Pawnee, Burchard, Shelby) were lower deep in the profile because of the dense, compact nature of the underlying material. Rates for Marshall and Monona soils were also lower in the deeper holes probably because of the massive nature of the loess and the presence of moderate structure at the 2 foot (60 cm) depth. The difference in rates of water entry implies that the nature of the soil profile must be known before recommending adjustment of depth of a seepage bed to avoid slowly permeable layers. A deeper burial of the seepage bed might help in Wymore soils, but certainly would not in Pawnee soils.

Table 2. Correlation and regression coefficients for the soil separates and bulk density vs percolation rate.

Test	Linear correlation coefficient (r)	Linear regression coefficient (r^2)
Clay at 2 ft.	−0.85 [a]	0.72 [a]
Sand at 2 ft.	−0.19 N.S.	0.036 N.S.
B.D. at 2 ft.	−0.79 [a]	0.62 [a]
Clay at 5 ft.	−0.85 [a]	0.72 [a]
Sand at 5 ft.	−0.04 N.S.	0.002 N.S.
B.D. at 5 ft.	−0.69 [a]	0.48 [a]

Regression equations

34.01 − 22.74 (Bulk density g/cm^3 at 2′) = percolation rate.
36.08 − 23.11 (Bulk density g/cm^3 at 5′) = percolation rate.

19.06 − 0.44 (Clay content at 2′) = percolation rate.
20.35 − 0.53 (Clay content at 5′) = percolation rate.

[a] Indicates a highly significant relationship.

The largest amount of variation in rate of water entry within any soil series studied was in the Morrill soils. As presently recognized, these soils have a wide range in properties and are often made up of fine and coarse textured layers. If a coarse textured layer contacted the free water in the hole, rates of water entry were relatively fast. However, a coarse textured layer, as pointed out by Miller and Gardner (11), acts as an impediment to movement of water in the soil if it has finer material between it and the free water. Therefore, the rates of water entry in the Morrill soil ranged from near 0 to 8.5 inches (0–21.3 cm) per hour.

The relationship between certain soil physical properties and rates of water entry at the 2 and 5 foot (60 and 150 cm) depths were determined from samples taken from a pit near the test holes (Fig. 2).

Table 3. Rate of water entry with its standard deviation at 2 and 5 foot depths.

Soil Series	Percolation rate (in/hr) Average		Percolation rate (in/hr) Standard deviation	Percolation rate (in/hr) Average		Percolation rate (in/hr) Standard deviation
	60 cm (2 ft)			150 cm (5 ft)		
Sharpsburg	1.43	±	0.76	2.72	±	0.99
Marshall	6.72	±	2.00	4.44	±	1.62
Monona	6.61	±	1.21	3.36	±	0.75
Holdrege	7.89	±	0.90	13.44	±	2.70
Keith	5.75	±	1.38	13.89	±	2.42
Wymore	0.14	±	0.14	1.21	±	0.71
Pawnee	0.33	±	0.32	0.17	±	0.28
Morrill	2.01	±	2.44	4.66	±	3.02
Mayberry	0.03	±	0.05	0.44	±	0.62
Shelby	0.70	±	0.46	0.10	±	0.10
Burchard	0.70	±	0.94	0.12	±	0.13

Highly significant negative correlations of both clay content and bulk density with rate of water entry at both 2 and 5 ft. (60 and 150 cm) were obtained. Sand content did not affect the rates. However, in some soils the sand content has been shown an important factor (Derr *et al.*, 1969). Equations based on these data were calculated (Table 2). With these equations and the clay content and/or bulk density of the soil layer where the rate of water entry is measured, one can judge approximately what the rate of water entry should be. If it is more rapid than calculations show, the soil probably is not adequately wetted, or there are voids such as rodent burrows in contact with the free water level. If the soil series is known (from the soil map) and the site is located in one of the soil series studied, the rate of water entry can be estimated to be within the standard deviation for the series (Table 3).

APPENDIX

Appendix Table 1. Particle size distribution and bulk density (1/3 bar) of the soils for which percolation rates were determined.

Horizon	Sand	Silt	Clay	Textural class	Bulk density
	%	%	%		(g/cm^3)
			SHARPSBURG		
			Site #1		
A1	7.6	60.1	32.3	SiCL	---
A3	7.5	55.1	37.4	SiCL	1.24
B1	4.4	56.0	39.6	SiCL	1.30
B21	2.8	55.6	41.6	SiC	1.39[a]
B22	3.3	60.3	36.4	SiCL	1.35
B3	9.0	58.3	32.7	SiCL	1.30
C	2.4	67.3	30.3	SiCL	1.20[a]
			Site #2		
A1	3.3	65.8	30.9	SiCL	---
B1	3.7	60.8	35.5	SiCL	1.36
B21	2.2	59.9	37.9	SiCL	1.32[a]
B22	2.4	57.9	39.7	SiCL	1.38
B31	4.4	56.8	38.8	SiCL	1.40
B32	3.5	62.3	35.2	SiCL	1.40
C	2.9	63.7	33.4	SiCL	1.17[a]
			Site #3		
Ap	4.7	62.4	32.9	SiCL	---
B1	2.0	57.8	40.2	SiC	1.29
B21	1.9	55.5	42.6	SiC	1.34[a]
B22	2.5	59.0	38.5	SiCL	1.42
B3	2.8	62.5	34.7	SiCL	1.47
C	3.2	65.5	31.3	SiCL	1.32[a]

[a] Denotes horizons at the depths at which percolation tests were made.

Appendix Table 1 continued. Particle size distribution and bulk density (1/3 bar) of the soils for which percolation rates were determined.

Horizon	Sand	Silt	Clay	Textural class	Bulk density
	%	%	%		(g/cm^3)
			MARSHALL		
			Site #1		
Ap	4.5	65.3	30.2	SiCL	---
B2	4.7	64.4	30.9	SiCL	1.30
B31	5.0	66.1	28.9	SiCL	1.22[a]
B32	3.6	69.1	27.3	SiCL	1.35
C	3.3	66.0	30.7	SiCL	1.38[a]
			Site #2		
Ap	3.0	63.6	33.4	SiCL	---
B2	2.9	62.8	34.3	SiCL	1.19
B31	3.9	60.2	35.9	SiCL	1.23[a]
B32	3.2	62.8	34.0	SiCL	1.26
C	3.1	64.4	32.5	SiCL	1.32[a]
			Site #3		
Ap	2.7	60.0	37.3	SiCL	---
B2	3.7	56.2	40.1	SiC	1.24
B31	4.0	60.8	35.2	SiCL	1.21[a]
B32	3.4	62.3	34.3	SiCL	1.20
Clca	3.6	63.3	33.1	SiCL	1.33
C2	3.3	66.3	30.4	SiCL	1.35[a]
			MONONA		
			Site #1		
Ap	2.5	65.5	32.0	SiCL	---
B2	2.5	60.1	37.4	SiCL	1.21[a]
B3	2.2	62.7	35.1	SiCL	1.21
C1	1.7	64.8	33.5	SiCL	1.25[a]
C2	3.2	70.5	26.3	SiL	1.27[a]
			Site #2		
Ap	2.5	70.9	26.6	SiL	---
B2	1.6	69.8	28.6	SiCL	1.22[a]
B3	3.3	64.0	32.7	SiCL	1.17
C	3.5	68.1	28.4	SiCL	1.31[a]
			Site #3		
Ap	2.2	68.2	30.8	SiCL	---
B1	3.4	67.0	69.6	SiCL	1.21
B2	3.6	65.8	30.6	SiCL	1.24[a]
B3	2.7	65.6	31.7	SiCL	1.15
C	4.1	68.2	27.7	SiCL	1.24[a]

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[a] Denotes horizons at the depths at which percolation tests were made.

Appendix Table 1 continued. Particle size distribution and bulk density (1/3 bar) of the soils for which percolation rates were determined.

Horizon	Sand	Silt	Clay	Textural class	Bulk density
	%	%	%		(g/cm^3)
HOLDREGE					
Site #1					
A1	16.4	62.4	21.2	SiL	1.25
B2t	14.4	58.4	27.2	SiL	1.26[a]
B3	14.7	61.0	24.3	SiL	1.24
C	18.3	63.8	18.2	SiL	1.23[a]
Site #2					
A1	16.9	62.0	21.1	SiL	---
A3	16.5	60.9	22.6	SiL	1.22
B2t	15.2	58.3	26.5	SiL	1.22
B31	13.8	62.9	23.5	SiL	1.39[a]
B32	20.2	55.9	23.9	SiL	1.33
C	22.9	59.7	17.4	SiL	1.21[a]
Site #3					
A1	17.0	63.1	19.5	SiL	---
A3	15.8	58.8	25.4	SiL	1.23
B2t	18.1	58.6	23.8	SiL	1.25
B3	19.2	50.1	30.7	SiCL	1.26[a]
C1	27.2	48.8	24.0	L	1.28
C2	27.8	56.5	15.7	SiL	1.23[a]
KEITH					
Site #1					
A1	27.5	54.0	18.5	SiL	---
A3	17.9	56.2	25.8	SiL	1.21
B2t	20.0	51.6	28.4	SiCL	1.29
B3	21.0	49.9	29.1	SiCL	1.21[a]
C1	20.0	55.3	24.7	SiL	1.26
C2	24.4	54.4	20.2	SiL	1.21[a]
Site #2					
A1	26.6	52.7	20.7	SiL	---
A3	20.0	55.7	23.7	SiL	1.18
B2t	19.4	55.0	25.6	SiL	1.19
B3t	16.4	59.0	24.6	SiL	1.29[a]
C1	28.4	47.5	24.1	L	1.27
C2	21.2	56.4	22.4	SiL	1.18[a]
Site #3					
A1	19.3	58.8	21.9	SiL	---
A3	22.4	49.9	27.7	CL	1.21
B2t	22.3	48.4	28.8	CL	1.23
B3t	16.7	55.2	28.1	SiCL	1.19[a]
C1	13.2	59.2	27.6	SiCL	1.27
C2	15.6	65.2	19.3	SiC	1.18[a]

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[a] Denotes horizons at the depths at which percolation tests were made.

Appendix Table 1 continued. Particle size distribution and bulk density (1/3 bar) of the soils for which percolation rates were determined.

Horizon	Sand	Silt	Clay	Textural class	Bulk density
	%	%	%		(g/cm³)
			WYMORE		
			Site #1		
Ap	3.4	61.9	34.8	SiCL	---
B21t	2.3	48.5	49.2	SiC	1.33
B22t	3.1	51.2	45.7	SiC	1.43[a]
B3ca	2.8	61.0	36.2	SiCL	1.47
C1	5.6	63.6	30.8	SiCL	1.42
C2	2.8	67.6	29.6	SiCL	1.33[a]
			Site #2		
Ap	3.9	64.1	32.0	SiCL	---
B1	2.5	56.5	41.0	SiC	---
B21t	2.4	53.4	44.2	SiC	1.35
B22t	2.3	55.1	42.6	SiC	1.38[a]
B3ca	2.9	53.4	43.7	SiC	1.35
C	2.3	64.0	33.7	SiCL	1.30[a]
			Site #3		
Ap	2.3	53.9	43.8	SiC	---
B21t	2.2	48.0	48.8	SiC	1.36
B22t	1.4	54.9	43.8	SiC	1.41[a]
B3ca	2.8	54.8	42.4	SiC	1.45
C1	2.4	66.3	31.3	SiCL	1.45
C2	2.0	67.5	30.5	SiCL	1.47[a]
			MORRILL		
			Site #1		
Ap	17.9	46.8	35.3	SiCL	---
B1	26.1	39.5	34.9	CL	1.37
B2	28.6	36.5	34.9	CL	1.46[a]
B3	39.3	33.9	26.8	L	1.45
IIC	65.6	16.6	17.8	SL	1.62[a]
			Site #2		
Ap	41.6	34.5	23.9	L	---
B21t	39.4	37.1	23.5	L	1.49
B22t	41.5	34.1	24.4	L	1.47
B3	42.6	33.0	24.4	L	1.44[a]
C1	37.4	37.2	25.4	L	1.50
IIC2	61.7	22.2	16.1	SL	1.50
IIIC3	33.7	36.8	30.5	CL	1.43
IVC4	81.1	10.9	8.1	LS	---
VC5	21.9	51.0	27.1	CL	1.44[a]
			Site #3		
Ap	7.7	58.7	33.6	SiCL	---
B1	6.0	53.7	40.3	SiC	1.31
B21	6.1	55.9	38.0	SiCL	1.39[a]
B22	7.0	55.1	37.9	SiCL	1.44
B23	7.3	53.4	39.3	SiCL	1.49
B3	8.2	54.6	37.2	SiCL	1.51[a]

[a] Denotes horizons at the depths at which percolation tests were made.

Appendix Table 1 continued. Particle size distribution and bulk density (1/3 bar) of the soils for which percolation rates were determined.

Horizon	Sand	Silt	Clay	Textural class	Bulk density
	%	%	%		(g/cm³)
			MAYBERRY		
			Site #1		
Ap	11.8	50.8	37.4	SiCL	---
B21	10.6	46.5	42.9	SiC	1.40
B22	11.6	47.0	41.4	SiC	1.43[a]
B31	11.7	47.4	40.9	SiC	1.45
B32	12.6	49.5	37.9	SiCL	1.46
C	20.0	45.5	34.5	SiCL	1.51[a]
			Site #2		
Ap	11.1	51.4	37.5	SiCL	---
B21	14.0	42.2	43.8	SiC	1.42
B22	13.5	42.6	43.9	SiC	1.47[a]
B3	13.8	41.0	45.2	SiC	1.43
C1	10.8	41.7	47.5	SiC	1.40
C2	12.4	40.3	47.3	SiC	1.41[a]
			Site #3		
Ap	9.3	50.1	40.6	SiC	---
B1	9.5	47.7	42.8	SiC	1.40
B21	12.6	42.2	45.2	SiC	1.51[a]
B22	15.0	42.0	43.0	SiC	1.58
IIB3	23.5	33.4	43.1	C	1.57
IIC	26.3	31.6	42.1	C	1.61[a]
			BURCHARD		
			Site #1		
Ap	29.7	36.2	34.1	CL	---
AB	25.4	36.5	38.1	CL	1.35
B2t	25.4	33.5	41.2	C	1.43[a]
B3t	26.0	34.8	39.2	CL	1.47
C	26.0	38.4	35.6	CL	1.58[a]
			Site #2		
A1	23.2	42.2	34.6	CL	---
B1	21.5	35.6	42.9	C	1.32
B2t	19.6	36.1	44.3	C	1.39[a]
B3	16.2	45.8	38.0	SiCL	1.38
C1	12.8	50.0	37.2	SiCL	1.35
IIC2	8.9	61.3	29.9	SiCL	1.47[a]
			Site #3		
Ap	35.9	31.0	32.1	CL	---
B2	27.8	32.3	39.9	CL	1.47
B3ca	25.2	35.4	39.4	CL	1.56[a]
C	25.0	38.1	36.9	CL	1.64[a]

[a] Denotes horizons at the depths at which percolation tests were made.

Appendix Table 1 continued. Particle size distribution and bulk density (1/3 bar) of the soils for which percolation rates were determined.

Horizon	Sand	Silt	Clay	Textural class	Bulk density
	%	%	%		(g/cm³)
			PAWNEE		
			Site #1		
A11	24.2	48.7	27.1	CL	1.25
A12	25.0	44.1	30.9	CL	1.30
B1	22.5	37.2	40.3	C	1.33
B21t	19.9	36.3	43.8	C	1.48[a]
B22t	25.9	33.1	41.0	C	1.54
B23t	29.4	33.9	36.7	CL	1.67
C1ca	29.9	36.9	33.2	CL	1.66
C2	30.3	36.9	32.8	CL	1.67[a]
C3	30.4	38.5	31.1	CL	---
			Site #2		
A1	25.3	42.5	32.2	CL	---
B1	26.0	39.6	34.4	CL	1.36
B21t	24.9	37.3	37.8	CL	1.51[a]
B22t	28.1	35.1	36.8	CL	1.60
B3t	26.8	32.5	40.7	C	1.50
C	24.4	34.7	40.9	C	1.56[a]
			Site #3		
A1	20.6	43.7	35.7	CL	---
AB	23.2	24.9	41.9	C	1.34
B21t	22.0	29.6	48.4	C	1.43[a]
B22t	23.3	31.8	44.9	C	1.46
B3	25.7	34.5	39.8	CL	1.50
C1	24.2	32.8	43.0	C	1.53[a]

[a] Denotes horizons at the depths at which percolation tests were made.

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