# CORRELATION OF SOIL PROPERTIES, PERCOLATION TESTS, AND SOIL SURVEYS IN DESIGN OF SEPTIC TANK DISPOSAL FIELDS IN EATON, GENESEE, INGHAM AND MACOMB COUNTIES, MICHIGAN

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ABSTRACT

CORRELATION OF SOIL PROPERTIES, PERCOLATION TESTS, AND SOIL SURVEYS IN DESIGN OF SEPTIC TANK DISPOSAL FIELDS IN EATON, GENESEE, INGHAM AND MACOMB COUNTIES, MICHIGAN

by Delbert Lewis Mokma

The mean percolation rate increases as the soil profile texture becomes coarser. The rates vary from .85 inches per hour on the clay soils to 15.6 inches per hour on the sand soils.

Percolation tests should be made early in the year when the soil most limits the operation of the septic tank disposal field or after adequate presoaking. Better presoaking techniques are needed to obtain reliable percolation measurements, especially after the soils begin to dehydrate in the summer season.

The required minimum length of presoak should be at least eight hours and twenty-four hours seems a reasonably practical requirement. It commonly takes more than twenty-four hours of presoak to completely rehydrate the soils after they have begun to dehydrate.

The average percolation rates are at a minimum during February, March, and April. At this time the rates for Miami,

Celina, Conover, and Brookston are about equal but during August, September, and October the rates of these soils are in the following decreasing order: Miami > Celina > Conover > Brookston.

The seasonal variability in percolation rates of the well-drained sandy loam over loam soils was very similar to that for the well-drained loam soil, Miami, Apparently the loam textured lower story controls their percolation rates.

There does not appear to be seasonal variations in the percolation rate, due to the soil moisture variations, of the coarse textured soils, Graycalm and Oshtemo, but there are variations in the rates for the finer textured Hillsdale, Miami, and St. Clair soils.

It appears unnecessary to require percolation tests on the well-drained loamy sand soils. This is probably true also of the well-drained sand soils.

The percolation rates determined by the Health Department method were greater than the permeabilities determined by the Uhland core method at the 30-36 inch depth.

The presence of a garbage disposal unit in the home has an adverse effect on the performance of the septic tank disposal fields.

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By

Delbert Lewis Mokma

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# INTRODUCTION

Since World War II there has been a steady increase in the number of people moving from the cities and large communities to the rural areas several miles from these highly populated areas in the United States. This movement has not evaded Michigan and will continue to increase in the future. Since the population density in these rural areas is not great enough to justify the expense of public sewers, the residents must depend on septic tank disposal fields to dispose of their sewage. The health and comfort of the residents of a community depends on the safe and prompt disposal of the human excreta and other domestic wastes. For these purposes the satisfactory operation of the septic tank and its disposal field are essential. Some of the existing systems are not functioning properly.

The major factor in the operation of the septic tank disposal field is the soil in which it is located. The size of the disposal field is usually determined mainly by one or more percolation tests made on the proposed site of the disposal field. Soil maps are now becoming more important in the design of the disposal fields. The purpose of this study has been to correlate soil properties, percolation tests, and soil surveys in the design of septic tank disposal fields and evaluate, in so far as possible, the performance of existing systems in various soils.

Percolation test results recorded by engineers were obtained from the Eaton, Genesee, Ingham, and Macomb County Health Departments. These were plotted on the existing soil maps to compare the various soil series and to evaluate their sewage effluent absorption capacities. In addition percolation tests were made on five different soils at two month intervals to study the seasonal variability of their percolation tests. Core samples from horizons of each of the five soils were taken into the laboratory to compare the Uhland core method and the health department method of percolation tests as methods of evaluating sites for septic tank disposal fields. Finally sixty-seven septic tank disposal fields in Macomb County currently in use were studied to evaluate their performance in the various soils under different conditions of load, age, and seasonal variations.

# LITERATURE REVIEW

The soil properties which affect the operation of septic tank disposal fields have been discussed in detail by Bender (1961) and Olson (1964a). From their work and that of Clayton et al (1959), Weibel et al (1955), Ehlers and Steel (1958), Huddleston and Olson (1963), and the Public Health Service (1958) there appears to be six factors which must be evaluated to interpret soil maps for septic tank disposal systems. These factors are percolation rate, depth of water table, depth of bedrock or impermeable layers, soil slope, contamination hazards, and qualities of the disposable materials.

Morris et al (1962) have concluded from their study on the use of soil maps for septic tank disposal field design that a correlation of the existing percolation tests must be made with all of the soil types found in the county. If they based the percolation rate for a soil type on six or more holes on each of five or more sites, the confidence limits for the mean percolation rate were raised to 95 percent from 30 percent for six or more holes on an individual site. Olson (1964a) concluded from a similar study that percolation tests had their greatest value for the design of a septic tank disposal field when they were correlated with soil maps and soil properties. Bartelli (1962) has suggested a range of percolation rates for soils with a specific range of properties. This was based on percolation tests run on several key soil types.

Morris et al (1962), Seglin (1965), and Witwer (1965) found a very good correlation between the permeability maps obtained by interpretation of the soil maps and from the percolation tests made by the health department.

Soil survey maps can commonly be used to predict if a soil will have an intermittent high water table if artificial drainage has not been provided. Hutchinson and Arno (1965) found percolation tests in the summer to be misleading on two poorly drained soils. The rates obtained during the summer were rapid, but during the winter and spring months the water table was only a few inches below the surface of the ground. The septic tanks on these soils only worked during the summer and fall when the depth of the water table was greatest.

Bendixen (1962), Cain and Beatty (1965), Morris (1962) and Thomas et al (1960) found the percolation test failed to recognize soils with intermittent high water tables and abnormal soil conditions such as dry weather cracking, root channels, small animal burrows, and frozen ground.

Morris et al (1962) in reviewing the existing septic tank disposal fields in areas where the soil types were known, found that the systems on soils which were predicted from soil surveys to have satisfactory percolation rates were functioning properly after at least one year of use.

Huddleston and Olson (1963) found the water from wells in an area of soils, which had very little filtering capacity for septic tank effluent, to be contaminated.

Morris (1963) and Morris et al (1962) concluded from their studies that soil maps were most valuable in reviewing large areas of land which are proposed for new subdivision development. The soil maps were of little value for predicting the suitability of an individual site for a septic tank disposal field because the scale of the soil maps was too small to allow the necessary accuracy for location of the site. Clayton et al (1959) stated that care must be taken in locating the disposal field near soil boundaries without careful on site investigation. He cited two cases where a soil scientist helped a land owner locate the septic tank disposal field in more porous material on his lot after the owner had run percolation tests on a proposed site and found them to be too slow for adequate drainage. McGauhey and Winneberger (1964) and Bendixen (1962) found there was a wide variation in replicate percolation tests on the same site only a few feet apart. Cain and Beatty (1965) found a wide variation in the techniques used in running the percolation tests. Often the tests were run improperly.

Krynine (1941) concluded that when water is added to dry soil the particles will expand but due to imperfect elasticity, the original size of the particle may not be reached. Baver (1963) found that most clays require one to three days to swell to their original size but others took almost a week. Marshall (1959) concluded from his study of water and soil that the swelling of clay is a slow process and it may be some months after a wet season begins before the cracks close up even when water is freely available. Franzmeier et al (1964) found it took eight to ten days of soaking before percolation rates of replicate treatments agreed.[1] Weibel et al (1955) found the percolation rate decreased rapidly during the first four hours of soaking and less rapidly during the next four hours. They also found the percolation rates were significantly slower the second day after an overnight saturation. They suggested a longer testing period or an overnight saturation in order to obtain equilibrium percolation rates. Anonymous (1958) concluded from a similar study that percolation rates should be determined 24 hours after the water was first added to the hole to insure that the soil had sufficient time to swell and approach the condition it would be in during the wettest part of the year. McGauhey and Winneberger (1964) obtained a slower percolation rate when using septic tank effluent than when using clear water in their percolation tests. The short-term

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[1]D. P. Franzmeier, P. R. Basher, S. J. Ross, Jr. (1964) Soil percolation rates during sustained testing. Soil conservation Service, U. S. Dept. Agr. Mimeo.

percolation rate was greater than a long-term percolation rate when using clear water in both tests.

The Housing and Home Finance Agency (1951) found that repeated percolation tests on the same laboratory samples for sixteen months reduced the percolation rate to about 20 percent of their original rate.

Baver (1963) stated it takes more water to form continuous water films in a dry soil than in a wet soil. Therefore it would take a longer time for a dry soil to reach saturation than a moist soil. The movement of water in the large pores may be influenced by the resistance due to entrapped soil air.

Nelson and Muckenhirn (1941) found that the infiltration rate is ordinarily at its maximum when water is first added to the soil and then as the pore space becomes full and swelling takes place, it decreases until a more or less stable minimum is reached. This minimum is the field percolation rate or the rate at which water will flow through the soil profile. Swartzendruber (1960) found the water flow through a soil profile to be controlled mainly by the permeability of the least permeable soil horizon.

The Public Health Service (1958) found no correlation between percolation rate and test hole size. Clayton _et al_ (1959) found no relationship between the percolation rate and the vegetative cover.

In comparing the Uhland core method and the health department method of percolation test, Clayton _et al_ (1959) obtained a better correlation between the health department method and the performance of septic tank disposal fields than with the Uhland core method. The health department method examines a larger volume of soil and is less liable to sampling error than the Uhland core method (Marshall, 1959). According to Clayton _et al_ (1959) and Weibel _et al_ (1955) neither the Uhland core method nor the health department method of measuring soil permeability give all the answers but they supplement each other and support the belief of Robinson _et al_ (1955) that a thorough knowledge of the soil properties is necessary to adequately design a septic tank disposal field. Because the Uhland core method does not measure the lateral movement of water or effluent in the soil, it is not a good method on which to base the design of the disposal system. The lateral movement is the most important in the disposal field because the bottom of the trench becomes clogged first and shows very little tendency to become unclogged during a rest period according to McGauhey and Winneberger (1964). The sides of the trench did not clog as rapidly as the bottom of the trench and regained their original percolation rate in a two or three hour rest period. For this reason they recommended using narrow trenches in the disposal fields rather than wide trenches.

The major factor which limited the functioning of the septic tank disposal field was found by McGauhey and Winneberger (1964) to be soil clogging by chemical, physical, and biological means. This clogging occurs much faster under anaerobic conditions than under aerobic conditions (Jones and Taylor, 1965). In anaerobic conditions a black color due to ferrous sulfide appeared after two weeks of ponding in sand columns. This black color disappeared within a few hours after air was allowed to enter the system. Jones and Taylor (1965) suggested that the rate of clogging, as it affected the initial percolation rate, be used in evaluating soils for septic tank disposal fields.

Wooding (1963) and Weibel et al (1955) do not recommend the flushing of the brine from water softners into the disposal system. The brine did not affect the performance of the septic tank but the effluent containing the brine caused the soil aggregates to be broken down and the soil pores to become sealed shut. This phenomenon, they reported, did not occur with the detergent soaps used in the household.

Huddleston (1965) found septic tank disposal field failures where there was heavy and lengthy use of the systems and where the volumes of effluent were too great for the slowly permeable soils to absorb. Sanitary engineers found that most of the disposal fields which had failed were located on soils with high water tables or on soils which had slow percolation rates (Bender, 1961). Failures also occurred on soils located on slopes greater than 10 percent, soils which were shallow to bedrock, soils which had a cemented layer near the surface, and soils which were located near streams and were periodically flooded. Jones and Taylor (1965) found disposal fields on well-drained soils had failed to function properly when the disposal field was designed from the initial percolation rate rather than from the equilibrium percolation rate. The Housing and Home Finance Agency (1951) found systems which received ground garbage in addition to the usual sewage had more failures than those receiving only sewage.

## SOILS AND METHODS

### Percolation Tests by Kinds of Soils in Several Michigan Counties

Available percolation test data records were obtained from the Eaton, Genesee, Ingham and Macomb County Health Departments. These data were plotted on the soil maps made since 1962 in these four counties to determine the respective mapping units. The data were then tabulated by the soil series named as the predominant soil in each mapping unit. In Macomb County the Health Department had also made an independent survey in which the soil had been identified on some lots where septic tank disposal fields had been installed and percolation tests had been made. These data were initially separated into two groups, the percolation tests made before June 1 and those made after May 30. This separation was selected because in June the potential evapotranspiration commonly exceeds the precipitation (Foth and Jacobs, 1964) in Michigan and soils dry out. Later percolation tests on soils where sufficient tests had been made at various dates were summarized by months to see what differences were apparent with dates of measurements.

## Seasonal Variability of Percolation Rates on Five Sites

The following method was devised from procedures suggested by several workers (Public Health Service (1958), Shepard *et al* (1963), Housing and Home Finance Agency (1956), Bendixen (1962), Coulter *et al* (1960), Kiker (1948), and Olson 1964b). Six holes were dug in an area the size of a possible septic tank disposal field. A post-hole auger was used to dig the holes. The holes were seven inches in diameter and extended to a depth of 36 inches. The sides of the holes were scarified to remove any smeared or compacted soil. All loose soil was then removed from the bottom of the holes. About two inches of gravel was placed in the bottom of the holes to prevent silting. A galvanized stove pipe which was four inches in diameter and had several one-inch holes near the bottom end was inserted in each seven inch hole and steadied by means of wooden wedges. The water was poured into the stove pipes to avoid the washing of the soil from the sides of the hole when water was added to the hole. The top of the stove pipe also provided a reference point from which to measure the water levels in the hole at various times. The test holes were filled with water to a depth of twelve inches above the gravel. Repeated water level measurements were made from the beginning of the soak period to the time an equilibrium percolation rate was obtained. Most measurements were taken when the water level was 4 to 8 inches above the gravel.

The percolation tests were run at two month intervals three times in 1965 beginning in May. They were again run in March or April in 1966 to obtain percolation rates when the soil was approximately at field capacity before beginning to dry out in the spring.

This seasonal variability was studied on five different well-drained soils; St. Clair loam, Miami sandy loam, Hillsdale sandy loam, Oshtemo loamy sand, and Graycalm loamy sand. These soils were chosen because of the variation of texture of their profiles. Two sites were located on the St. Clair soil, one in an alfalfa field and the other in a grass sod across the road, in order to study the effects of vegetation on the percolation tests.

The five soils studied were described according to the procedures discussed in the Soil Survey Manual (Soil Survey Staff, 1951) except that the International Society Color Council - National Bureau of Standards (ISCC-NBS, Kelly and Judd, 1955) color names are used.

## Soil Profile Descriptions

### St. Clair Loam

Vegetation: grass

Physiography and relief: The soil was located on a gently rolling moraine (3% slope) near the top of the ridge.

Ground Water: deep

Moisture: moist

Stoniness: none

Location: NW1/4 of NE1/4 of NE1/4 of NW1/4 of Sec. 9, T7N, R4W. Dallas Township, Clinton County, Michigan

| Horizon | Depth (Inches) | Description |
|---|---|---|
| $A_1$ | 0-5 | Loam; dark grayish yellowish brown (10YR 3/2); moderate, medium, granular; friable; mildly alkaline (pH 7.5); abrupt, smooth boundary. |
| $A_2$ | 5-8 | Clay loam; light yellowish brown (10 YR 6/3); weak, medium, platy to weak, medium, subangular blocky; friable; mildly alkaline (pH 7.6); abrupt, wavy boundary. |
| $B_{21t}$ | 8-14 | Clay; moderate yellowish brown (10YR5/4) with some light yellowish brown (10YR6/3) and grayish yellowish brown (10YR4/2) coatings; moderate, medium, subangular blocky to moderate, fine, angular blocky; firm; mildly alkaline (pH 7.5); clear, wavy boundary. |
| $B_{22t}$ | 14-18 | Clay; moderate yellowish brown (10YR4/4) with yellowish grayish brown (10YR4/2) coatings; moderate, medium, angular blocky; firm; moderately alkaline (pH 8.0); clear, wavy boundary. |
| $BC_t$ | 18-26 | Clay; yellowish grayish brown (10YR5/3) with light brownish gray (10YR5/1), grayish yellowish brown (10YR5/2) and grayish yellowish brown (10YR4/2) coatings; moderate, medium, angular blocky; firm; calcareous; clear, wavy boundary. |
| C | 26-44 | Silty clay; moderate yellowish brown (10YR5/4) with light brownish gray (10YR 6/1) coatings and dark yellowish brown (10YR3/3) spots; weak to moderate, coarse, angular blocky; firm; calcareous. |

Miami Sandy Loam

Vegetation: grass

Physiography and Relief: The soil was located on a moraine (10% slope).

Ground Water: deep

Moisture: moist

Stoniness: none

Location: NE1/4 of SE1/4 of SE1/4 of Sec. 3, T5N, R2W. DeWitt Township, Clinton County, Michigan

| Horizon | Depth (Inches) | Description |
|---|---|---|
| $A_p$ | 0-11 | Sandy loam; dark yellowish brown (10YR 3/4); weak, fine and medium, granular; friable; slightly acid (pH 6.2); abrupt, smooth boundary. |
| $B_{11}$ | 11-14½ | Sandy loam; moderate yellowish brown (10YR5/4-4/4); weak, medium to coarse, platy breaking to weak, medium, subangular blocky; peds show thin patches of clay skins and are vesicular where clay skins do not occur; friable; slightly acid (pH 6.2); clear, smooth boundary. |
| $B_{12}$ | 14½-19 | Sandy loam; moderate yellowish brown (10YR5/4); moderate, medium, subangular blocky; nearly continuous clay skins on ped surfaces; firm; slightly acid (pH 6.2); clear, smooth boundary. |
| $B_{21t}$ | 19-29 | Sandy loam; moderate yellowish brown (10YR 4/4); weak, medium, prismatic breaking to moderate, medium, blocky, continuous clay skins on ped surfaces; firm; slightly acid (pH 6.2); diffuse boundary. |
| $B_{22t}$ | 29-39 | Sandy clay loam; moderate yellowish brown (10YR4/4); moderate, medium, blocky; nearly continuous clay skins on ped surfaces; firm; slightly acid (pH 6.2); clear, smooth boundary. |

| Horizon | Depth (Inches) | Description |
|---|---|---|
| $B_3$ | 39-43 | Loam; moderate yellowish brown (10YR 4/4); weak, medium, subangular blocky; common, fine, faint mottles of strong brown; slightly firm; moderately alkaline (pH 8.0); clear, smooth boundary. |
| $C_1$ | 43-52 | Loam; moderate yellowish brown to dark yellowish brown (10YR4/3 to 3/4); weak, coarse, subangular blocky; few, distinct, coarse mottles of grayish brown; friable; calcareous; gradual, smooth boundary. |
| $C_2$ | 52-63 | Loam; moderate yellowish brown (10YR5/4-4/4) and light brownish gray (10YR5/1-6/1); weak, coarse, platy; common, fine, mottles of strong brown; slightly firm; calcareous. |

## Hillsdale Sandy Loam

Vegetation: alfalfa

Physiography and Relief: The soil was located on a gently rolling moraine (3-4% slope) on a west slope.

Ground Water: deep

Moisture: moist

Stoniness: none

Location: NE1/4 of SE1/4 of NW1/4 of Sec. 24, T1N, R1W. Leslie Township, Ingham County, Michigan

| Horizon | Depth (Inches) | Description |
|---|---|---|
| $A_p$ | 0-9 | Sandy loam; grayish yellowish brown (10YR4/2); weak, medium, granular; friable; slightly acid (pH 6.5); abrupt, smooth boundary. |
| $A_2$ | 9-13 | Sandy loam; moderate yellowish brown (10YR5/4); weak, medium, platy to weak, fine, subangular blocky; friable; slightly acid (pH 6.0); clear, smooth boundary. |

| Horizon | Depth (Inches) | Description |
|---|---|---|
| $B_1$ | 13-17½ | Sandy loam; moderate yellowish brown (10YR5/4) with few moderate yellowish brown (10YR4/3) clay coatings; moderate, fine, subangular blocky; friable; slightly acid (pH 6.2); gradual, wavy boundary. |
| $B_{21t}$ | 17½-29 | Sandy loam; moderate yellowish brown (10YR5/4) with moderate brown (7.5YR4/4) clayey coatings, moderate, medium, subangular blocky; friable; strongly acid (pH 5.0); clear, wavy boundary. |
| $B_{22t}$ | 29-38 | Sandy loam; light brown (7.5YR5/6) with some medium brown (7.5YR4/4) clayey coatings; moderate, medium, subangular blocky; friable; medium acid (pH 5.5); abrupt, irregular boundary. |
| $B_3$ | 38-58 | Sandy loam; light brown (7.5YR6/6) with few moderate yellowish brown (10YR4/4) clay coatings; weak, fine, subangular blocky; friable; medium acid (pH 5.5); abrupt, irregular boundary. |
| C | 58-72 | Sandy loam; grayish yellowish brown (10YR 5/3); massive; friable; neutral (pH 7.0). |

## Oshtemo Loamy Sand

Vegetation: grass

Physiography and Relief: The soil was located on a level outwash plain.

Ground Water: deep

Moisture: moist

Stoniness: none

Location: SE1/4 of SW1/4 of SE1/4 of SE1/4 of Sec. 24, T5N, R2W. DeWitt Township, Clinton County, Michigan.

| Horizon | Depth (Inches) | Description |
|---|---|---|
| $A_p$ | 0-10 | Loamy sand; dark grayish yellowish brown (10YR3/2); very weak, fine, granular; very friable; medium acid (pH 5.7); abrupt, smooth boundary. |
| $A_2$ | 10-20 | Loamy sand; moderate brown (7.5YR4/4); massive; very friable; slightly acid (pH 6.0); abrupt, smooth boundary. |
| $B_{21}$ | 20-31 | Loamy sand; moderate brown (5YR3/4); very weak, fine, subangular blocky; very friable; neutral (pH 6.5); clear, wavy boundary. |
| $B_{22t}$ | 31-44 | Gravelly sandy loam; moderate brown (5YR3/4-4/4); weak, fine, subangular blocky; slightly firm; neutral (pH 7.0); abrupt, wavy boundary. |
| C | 44-60 | Sand and gravel; grayish yellowish brown (10YR5/3); single-grain; loose; calcareous. |

Graycalm Loamy Sand

Vegetation: grass

Physiography and Relief: The soil is located on a level outwash plain along the Looking Glass River.

Ground Water: deep

Moisture: moist

Stoniness: none

Location: SE1/4 of NW1/4 of SW1/4 of Sec. 31, T6N, R1W. Victor Township, Clinton County, Michigan.

| Horizon | Depth (Inches) | Description |
|---|---|---|
| $A_p$ | 0-9 | Loamy sand; dark yellowish brown (10YR 3/3); weak, medium, granular; very friable; strongly acid (pH 5.0); abrupt, smooth boundary. |

| Horizon | Depth (Inches) | Description |
|---|---|---|
| $B_{ir}$ | 9-20 | Loamy sand; strong yellowish brown (10YR 5/6); weak, fine, granular; very friable; slightly acid (pH 5.6); clear, smooth boundary. |
| $A_2$ | 20-37 | Sand; moderate yellowish brown (10YR5/4); weak, fine, granular; loose; slightly acid (pH 6.2); clear, wavy boundary. |
| $B_2$-$A_2$ | 37-51 | Loamy sand; grayish yellowish brown (10YR5/3) $B_2$ horizons separated by moderate yellowish brown (10YR5/4) $A_2$ horizons; weak, fine, granular; loose; slightly acid (pH 6.0); clear, smooth boundary. |
| $B_{22}$ | 51-57 | Sand/ and gravel; moderate brown (7.5YR4/4); weak, medium subangular blocky; friable; neutral (pH 6.5); clear, smooth boundary. |
| C | 57-72 | Sand; light grayish yellowish brown (10YR6/3); single-grained; loose; calcareous. |

## Mechanical Analyses

After the samples were allowed to air dry in the laboratory, they were sieved through a 20 mesh (2 mm) screen, with light crushing to disperse the coarse aggregates but not to break the primary particles. The material greater than 2 mm and less than 2 mm were weighed and the greater than 2 mm was calculated as a percentage of the total on the air dry basis.

To 10 grams of the less than 2 mm material, in a 600 ml beaker, 50 ml of 6% hydrogen peroxide and 2 drops of glacial acetic acid were added. The samples were allowed to remain over night, and after heating and the foaming had stopped, 12 ml of 30% hydrogen peroxide were added and heated again. This was repeated until the decomposition of organic matter was essentially complete.

Calcareous samples were treated with 150 ml of 0.5N HCl after the hydrogen peroxide treatment and allowed to stand overnight. An additional 50 ml of 0.5N HCl were added to assure the complete removal of carbonates.

The samples were washed on Buchner funnels using Whatman no. 50 filter paper with 5 small increments of 0.1N HCl. This was followed by distilled water to remove the excess hydrochloric acid as indicated by the $AgNO_3$ test for Cl on the leachate. Next the samples were transferred to square shaker bottles made up to about 275 ml and titrated with 0.1 N NaOH to the end point with phenolphthalein. 1 ml of 0.1 N NaOH was added in excess. They were shaken for 24 hours with a retitration of 0.1 N NaOH midway through the shaking.

The suspensions were then transferred to sedimentation cylinders by washing them through a 300 mesh (.05 mm) sieve to remove the sand fraction.

The volume in the sedimentation cylinder was made up to 1000 ml with distilled water and allowed to equilibrate with the atmosphere in a constant temperature room.

After the suspensions reached room temperature, they were stirred. While stirring a 25 ml aliquot of the total suspension was removed at a depth of 5 cm. This sample was oven dried and weighed. It represented the silt plus clay in the sample.

After the suspensions had stood for 2 minutes and 20 seconds, a 25 ml aliquot was again removed from a depth of 5 cm. This sample was oven dried and represented the fine silt and clay.

After the suspensions were again redispersed and allowed to stand for 3 hours and 50 minutes, another 25 ml aliquot was taken at the 5 cm depth. This was oven dried and represented the clay fraction $<$ .002 mm, in the sample.

The sand fraction was oven dried and then transferred into the top sieve (1 mm) of the nest in a mechanical shaker. They were shaken for 15 minutes after which the respective sand fractions were weighed.

The St. Clair, Hillsdale, Oshtemo, and Graycalm samples were run in duplicate and the percentages reported are averages of the two determinations. The Miami values are based on single determinations.

Table 1. Mechanical analyses of the horizons of St. Clair.

| | | Gravel | Sand (mm) | | | | | Silt (mm) | | Clay (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Horizon | Depth | > 2.0 | 2.-1. | 1.-.5 | .5-.25 | .25-.1 | .1-.05 | .05-.02 | .02-.002 | < .002 | Texture |
| $A_1$ | 0-5 | 2.1 | 1.4 | 3.5 | 5.7 | 11.8 | 8.1 | 9.9 | 33.8 | 25.9 | Loam |
| $A_2$ | 5-8 | 2.8 | 1.2 | 2.4 | 4.2 | 10.9 | 7.3 | 8.5 | 32.5 | 33.2 | Clay Loam |
| $B_{21t}$ | 8-14 | .7 | .6 | 1.5 | 2.9 | 6.9 | 5.6 | 6.8 | 29.7 | 46.1 | Clay |
| $B_{22t}$ | 14-18 | 4.3 | .9 | 1.6 | 2.8 | 6.6 | 5.0 | 7.0 | 30.9 | 45.5 | Clay |
| $BC_t$ | 18-26 | 3.7 | .6 | 1.4 | 2.7 | 6.5 | 4.7 | 7.1 | 30.5 | 46.7 | Clay |
| $C_1$ | 26-35 | 2.9 | .3 | 1.4 | 2.7 | 6.4 | 5.0 | 5.7 | 34.6 | 44.0 | Silty Clay |
| $C_2$ | 35-44 | 3.9 | .5 | 1.7 | 3.0 | 6.9 | 4.7 | 7.6 | 32.4 | 43.5 | Silty Clay |

Table 2. Mechanical analyses of the horizons of Miami.

| Horizon | Depth | Gravel(mm) | Sand (mm) | | | | | Silt (mm) | | Clay(mm) | Texture |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | > 2.0 | 2.-1. | 1.0-.5 | .5-.25 | .25-.1 | .1-.05 | .05-.02 | .02-.002 | < .002 | |
| $A_p$ | 0-11 | 5.3 | 2.0 | 5.7 | 6.6 | 32.2 | 17.6 | 10.7 | 17.5 | 7.7 | Sandy Loam |
| $B_{11}$ | 11-14½ | 4.8 | 2.5 | 6.0 | 7.8 | 25.3 | 15.7 | 11.6 | 22.5 | 8.6 | Sandy Loam |
| $B_{12}$ | 14½-19 | 7.6 | 2.3 | 5.5 | 6.7 | 25.4 | 13.9 | 10.6 | 19.1 | 16.5 | Sandy Loam |
| $B_{21t}$ | 19-29 | 3.4 | 2.2 | 5.2 | 7.1 | 24.3 | 14.4 | 9.1 | 18.0 | 19.7 | Sandy Loam |
| $B_{22t}$ | 29-39 | 5.4 | 2.5 | 4.7 | 6.7 | 22.6 | 14.3 | 9.5 | 17.3 | 22.4 | Sandy Clay Loam |
| $B_3$ | 39-43 | 6.1 | 2.0 | 4.7 | 6.0 | 20.2 | 14.2 | 10.6 | 19.7 | 22.6 | Loam |
| $C_1$ | 43-52 | 5.3 | 1.9 | 3.0 | 3.6 | 17.0 | 12.6 | 11.5 | 27.2 | 23.2 | Loam |
| $C_2$ | 52-63 | 6.1 | 2.5 | 4.3 | 4.8 | 21.8 | 13.7 | 11.0 | 22.1 | 19.8 | Loam |

Table 3. Mechanical analyses of the horizons of Hillsdale.

| Horizon | Depth | Gravel(mm) | Sand (mm) | | | | | Silt (mm) | | Clay(mm) | Texture |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $>2.0$ | 2.-1. | 1.-.5 | .5-.25 | .25-.1 | .1-.05 | .05-.02 | .02-.002 | $<.002$ | |
| $A_p$ | 0-9 | 6.4 | 3.3 | 8.7 | 17.0 | 29.3 | 13.3 | 8.8 | 8.8 | 6.0 | Sandy Loam |
| $A_2$ | 9-13 | 5.3 | 2.0 | 6.6 | 12.6 | 26.6 | 14.1 | 9.1 | 21.7 | 7.2 | Sandy Loam |
| $B_1$ | 13-17½ | 5.6 | 1.9 | 5.9 | 12.3 | 22.3 | 22.0 | 6.8 | 18.2 | 10.7 | Sandy Loam |
| $B_{21t}$ | 17½-29 | 7.6 | 2.2 | 6.9 | 14.2 | 30.2 | 15.8 | 5.7 | 11.2 | 13.7 | Sandy Loam |
| $B_{22t}$ | 29-38 | 11.5 | 2.9 | 7.0 | 14.0 | 29.5 | 14.2 | 5.0 | 10.7 | 16.6 | Sandy Loam |
| $B_3$ | 38-58 | 13.0 | 2.5 | 6.1 | 15.5 | 37.5 | 16.6 | 4.3 | 6.4 | 10.6 | Sandy Loam |
| C | 58-72 | 13.9 | 2.7 | 7.2 | 13.7 | 30.2 | 17.0 | 9.0 | 10.6 | 9.5 | Sandy Loam |

Table 4. Mechanical analyses of the horizons of Oshtemo.

| | | Gravel(mm) | Sand (mm) | | | | | Silt (mm) | | Clay(mm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Horizon | Depth | > 2.0 | 2.-1. | 1.-.5 | .5-.25 | .25-.1 | .1-.05 | .05-.02 | .02-.002 | < .002 | Texture |
| $A_p$ | 0-10 | 14.6 | 5.3 | 23.4 | 36.4 | 16.5 | 3.2 | 3.6 | 8.7 | 5.1 | Loamy Sand |
| $B_1$ | 10-20 | 16.1 | 5.7 | 20.8 | 31.7 | 18.0 | 3.7 | 6.2 | 9.5 | 4.5 | Loamy Sand |
| $B_{21}$ | 20-31 | 15.1 | 7.4 | 22.1 | 33.1 | 10.9 | 10.1 | 2.6 | 8.9 | 5.1 | Loamy Sand |
| $B_{22t}$ | 31-44 | 35.9 | 7.5 | 23.9 | 29.9 | 17.8 | 2.8 | 1.3 | 4.5 | 12.5 | Gravelly Sandy Loam |
| C | 44-60 | 29.1 | 13.9 | 35.3 | 30.8 | 13.1 | 1.8 | 0.4 | 3.5 | 2.7 | Sand and Gravel |

Table 5. Mechanical analyses of the horizons of Graycalm.

| | | Gravel(mm) | Sand (mm) | | | | | Silt (mm) | | Clay(mm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Horizon | Depth | > 2.0 | 2.-1. | 1.-.5 | .5-.25 | .25-.1 | .1-.05 | .05-.02 | .02-.002 | < .002 | Texture |
| $A_p$ | 0-9 | 6.7 | 5.0 | 13.1 | 33.2 | 27.1 | 6.5 | 4.2 | 5.8 | 5.0 | Loamy Sand |
| $B_{ir}$ | 9-20 | 4.0 | 3.1 | 6.3 | 21.3 | 28.5 | 25.1 | 4.5 | 7.4 | 3.4 | Loamy Sand |
| $A_2$ | 20-37 | 1.9 | 1.0 | 5.4 | 45.6 | 39.1 | 5.7 | 0.7 | 1.7 | 0.8 | Sand |
| $B_2$-$A_2$ | 37-51 | 21.6 | 8.3 | 16.0 | 21.6 | 33.7 | 5.0 | 1.6 | 3.7 | 10.4 | Loamy Sand |
| $B_2$ | 51-57 | 28.6 | 15.1 | 30.5 | 33.1 | 12.7 | 2.4 | 1.9 | 1.5 | 2.7 | Sand and Gravel |
| C | 57-72 | 6.7 | 1.7 | 7.2 | 43.2 | 41.2 | 3.8 | 1.1 | 1.4 | 0.6 | Sand |

## Permeabilities of Core Method

Six three-inch core samples were taken from each of the horizons sampled in each of the five soils. The permeability was determined on these cores for each horizon as follows. A one inch high aluminum ring was attached to the top of each core and the joint was made waterproof with masking tape. The cores were placed in water overnight to allow them to become saturated. Distilled water was added to each core by means of a siphon and a constant head of about one-half inch was maintained. After the core began dripping, the water was collected in a flask for one hour or until approximately 500 milliliters of water had passed through, whichever took the shortest length of time.

The cores were then placed in an oven and dried at 105$^{\circ}$C overnight. The average bulk density of each horizon was determined.

## Performance of Septic Tank Disposal Fields

In 1961 the Macomb County Health Department in cooperation with the Soil Conservation Service had made a special survey in which a soil scientist identified the soil on lots where septic tank disposal fields had been installed and percolation tests had been made. This survey included the completion of the following questionnaire. In 1965 the questionnaire was again taken around to each site by several students from Ferris State College.

## SOIL SURVEY QUESTIONNAIRE

1. How many persons live in your home?
2. How many children under 5 years of age?
3. Do you have a garbage disposal unit?
4. When was it installed (year)?
5. Do you have a mechanical dishwasher?
6. When was it installed (year)?
7. Do you have a clothes washer?
8. It is an automatic?
9. Is all or a major portion of your laundry done outside the home?
10. When doing your laundry in your machine, do you try and do it all in 1 or 2 days?
11. How many days a week do you operate your machine?
12. How many loads a week do you wash (approximately)?
13. Do you check the septic tank at least once each year to see if it needs cleaning?
14. How many times has your septic tank been cleaned?
15. Was the tank cleaned because you were having trouble with drainage?
16. Has your septic tank or tile field given you any trouble?
17. Is your sump pump in the basement connected to the septic tank?
18. Do all of the drains work satisfactorily during periods of heavy rainfall or when you are using your clothes washer?
19. Are all of the drains carrying sanitary wastes connected to the septic tank?
20. Has any work been done on the septic tank-tile field system since it was installed?
21. System appears to be working satisfactorily?
22. System inspected and approved by this department?
23. Percolation Rate?
24. The number of feet of tile?

To completely evaluate the performance of the septic tank disposal fields, the load on the systems had to be estimated. The Public Health Service (1958) and New York State (1962) estimated the quantity of sewage for a single-family dwelling to be 75 gallons per person per day. Weibel et al (1949) estimated the quantity of sewage to be equal to the amount of water used by the family. Several workers (MacKichan and Kammerer (1961), Senate Select Committee on National Water Resources (1960), Weibel et al (1949), and MacKichan (1957) estimated the water used by a person to be from 50 to 60 gallons per day. The latter estimates include water for a conventional type clothes washer but not the increase in water used by the automatic clothes washer or a garbage disposal unit. An automatic clothes washer requires between 27 and 48 gallons of water for one complete cycle (Burgess(1964b) and Anonymous (1964)). The average required water usage is 35 gallons per load. The size of the tile field should be increased 35 percent above the minimum for the use of a garbage disposal unit according to Anonymous (1964).

The quantity of sewage also depends on the age of the person according to Weibel et al (1949). The quantity from a child under 5 years of age was estimated to be one-half that from an older person.

An automatic dishwasher requires from 7 to 15 gallons of water per load with the average between 8 and 10 gallons per load, according to Burgess (1964a).

The total quantity of sewage entering each system was estimated in gallons per week from the following values. The volume of water used per person per day was 60 gallons. The automatic clothes washer used 35 gallons per load while the conventional clothes washer used 15 gallons for six loads. The automatic dishwasher used an additional 30 gallons per day. The estimated volume of water used by the garbage disposal unit was 35 percent of the volume of the load due to the other factors.

To compare the performance of the septic tank disposal fields from one site to another, it was necessary to relate the load on the system to the design of the system under the different conditions. This was done by dividing the estimated load on the system by the length of the tile in the disposal field. This allowed the various systems located on the same soil series to be compared with each other. The smaller the value, the more likely the system will work unless there is interference due to an intermittent high water table.

The estimated load of the septic tank disposal field for a home with four persons over 5 years of age and one person less than 5 years old, an automatic clothes washer which washes 5 loads per week, and an automatic dishwasther is 1890+175+210=2275 gallons per week. If the tile length of the disposal field is 750 feet, the estimated load to tile length ratio would be about 3.0.

# RESULTS AND DISCUSSION

## Percolation Tests by Kinds of Soils in Several Michigan Counties

### Seasonal Variability

The Health Department percolation test data for the soil series in Eaton, Genesee, Ingham, and Macomb are arranged according to the profile texture and natural drainage in Table 6. This table is divided into two segments. Table 6A includes the percolation tests made before June 1 of each year while Table 6B includes the tests made after May 30 of each year. The averages or means of the percolation tests made in the latter part of the year (after May 30) are greater than those made in the earlier part of the year (before June 1). The variability in the percolation rate for the same soil series, as shown by the standard deviation (the ± values), is greater for the tests made after May 30 than for those made before June 1. This indicates the soil conditions may not be as uniform during the latter part of the year as during the earlier part of the year.

As shown in Table 7, on only five of the soils which had percolation tests made on them before June 1 and after May 30 was the probability greater than 1 percent that the difference between tests made before June 1 and those made

Table 6A. Summary of percolation tests before June 1 by soil series (as shown on the soil maps made since 1962 or as identified recently by a soil scientist in Eaton, Genesee, Ingham and Macomb Counties).

| Profile Texture | Natural Drainage: Well and Moderately Well (a) | Natural Drainage: Imperfectly (b) | Natural Drainage: Poorly (c) |
|---|---|---|---|
| Clay 1 | | | Hoytville .85±.74 (9)* |
| Clay loam 1.5 | | | |
| Sandy Loam over Clay 3/1 | | | |
| Loam 2.5 | Miami 1.94 ± 1.44 (300)<br>Celina 2.14 ± 1.22 (395)<br>Sisson 2.81 ± 1.86 (8)<br>Tuscola 3.45 ± 2.76 (28) | Conover 2.24 ± 2.26 (446) | Brookston 2.31±1.76 (36) |
| Sandy Loam over Loam 3/2 | Owosso 2.04 ± 1.17 (28)<br>Kendallville 1.9 ± 1.14 (5) | Metamore 6.8 ± 2.64 (5) | |
| Sandy Loam 3 | 4502**2.1 ± 1.7 (7) | | |
| Loamy Sand over Loam 4/2 | Metea 8.74 ± 4.41 (6) | Imp. dr. Metea 8.96 ± 5.92 (5) | |
| Loamy Sand 4 | Spinks 6.94 ± 6.15 (65)<br>Boyer 9.61 ± 5.32 (89)<br>Oshtemo 11.71 ± 4.08 (7) | Imp. dr. Spinks 7.75 ± 5.26 (7)<br>Wasepi 12.58 ± 15.02 (18)<br>7092 5.84 ± 3.73 (5) | Gilford 2.61 ± 1.49 (11) |
| Sand over Loam 5/2 | | | |
| Sand 5 | | | |

*The numbers given for each soil series are, in the order given: (1) the average or mean value of the percolation tests (inches per hour), (2) the standard deviation of the average or mean value, (3) the number of tests on each soil, in parenthesis.

**This soil has a loam upperstory.

Table 6B. Summary of percolation tests after May 30 by soil series (as shown on the soil maps made since 1962 or as identified recently by a soil scientist in Eaton, Genesee, Ingham and Macomb Counties).

| Profile Texture | Natural Drainage: Well and Moderately Well (a) | Natural Drainage: Imperfectly (b) | Natural Drainage: Poorly (c) |
|---|---|---|---|
| Clay 1 | | Nappanee 1.44 ± .95 (8)* | Hoytville 2.21±3.84 (15) |
| Clay Loam 1.5 | | Aboite 3.62 ± 3.26 (25) | |
| Sandy Loam over Clay 3/1 | | | Wauseon 4.7±5.49 (9) |
| Loam 2.5 | Miami 4.05 ± 6.21 (294)<br>Celina 2.42 ± 2.12 (412)<br>Sisson 4.94 ± 2.88 (39)<br>Tuscola 4.55 ± 6.04 (62)<br>Ockley 1.92 ± 1.09 (7) | Conover 2.54 ± 1.7 (693)<br>Kibbie 4.95 ± 4.26 (33) | Bookston 4.17±4.06 (63)<br>Colwood 3.94±2.7 (30)<br>Westland 5.78±2.93 (12) |
| Sandy Loam over Loam 3/2 | Owosso 5.26 ± 4.72 (174)<br>Kendallville 2.1 ± 1.61 (18) | Metamora 3.93 ± 2.61 (48) | Berville 1.24±1.52 (5) |
| Sandy Loam 3 | Fox 2.0 ± .84 (13) | Locke 5.61 ± 4.26 (9) | Sebewa 2.64±1.77 (10) |
| Loamy Sand over Loam 4/2 | | Imp. dr. Metea 2.43 ± 2.42 (11)<br>7582 5.78 ± 4.94 (5) | |
| Loamy Sand 4 | Spinks 7.73 ± 4.51 (41)<br>Boyer 6.54 ± 4.44 (63)<br>Perrien 4.11 ± .72 (12)<br>Oshtemo 16.51 ± 8.8 (10) | Wasepi 17.96 ± 14.05 (32)<br>7092 11.12 ± 10.0 (47)<br>7141 4.55 ± 1.25 (21) | Gilford 6.19±12.25 (14) |
| Sand over Loam 5/2 | 2021 7.52 ± 4.0 (8) | | |
| Sand 5 | Oakville 7.61 ± 2.78 (17) | Tedrow 10.8 ± 5.85 (5)<br>AuGres 15.61 ± 8.15 (6) | Granby 5.65 ± 9.86 (8) |

*The numbers given for each soil series are, in the order given: (1) the average or mean value of the percolation tests (inches per hour), (2) the standard deviation of the average or mean value, (3) the number of tests on each soil in parenthesis.

Table 7. The probability that differences between the means of the percolation tests made before June 1 and the means of those made after May 30 are due to chance.

| Profile Texture | Natural Drainage: Well and Moderately Well (c) | | Imperfectly (b) | | Poorly (c) | |
|---|---|---|---|---|---|---|
| Clay | | | | | Hoytville | .16 |
| Loam | Miami | $<.01$ | Conover | .01 | Brookston | $<.01$ |
| | Celina | $<.01$ | | | | |
| | Sesson | $<.01$ | | | | |
| | Tuscola | $<.01$ | | | | |
| Sandy Loam over Loam | Owosso | $<.01$ | Metamora | .01* | | |
| | Kendallville | .75 | | | | |
| Loamy sand over Loam | | | Imp. dr. Metea | .01 | | |
| Loamy Sand | Spinks | 45 | Wasepi | $<.01$ | Gilford | .28 |
| | Boyer | $<.01$ | 7092 | .01 | | |
| | Oshtemo | $<.01$ | | | | |

*The values underlined indicate the mean percolation rate for the tests made after May 30 was less than the mean for those made before June 1.

after May 30 would exceed the difference between the means purely by chance. Only Kendallville and Spinks had a probability greater than 33 percent that the difference would be due to chance. Three soils had significantly lower percolation rates during the latter part of the year than during the first part of the year. Two of these three soils were imperfectly drained and had only 5 observations on them during the early part of the year. These soils may be influenced by an intermittent high water table. The third soil Boyer, is in the "4a" management group and for this coarse textured soil group it does not appear to be too important when the percolation test is made. The percolation rate of Oshtemo is significantly greater during the latter part of the year, while that of Boyer is significantly less and that of Spinks is not significantly greater or less during the latter part of the year than during the earlier part of the year. Apparently the minimum presoaking of 4 hours prescribed by the Health departments is not sufficient to eliminate the effect of seasonal variations of soil moisture on the percolation tests.

The average or mean soil percolation rates for the various months of the year have been plotted in Figure 1 for the loam textured soils, Miami, Celina, Conover, and Brookston. These soils were formed in well, moderately well, imperfectly and poorly drained situations, respectively. In January and February the soils are continuing to rehydrate as shown by the greater percolation rate in those months than the rates for the same soils in March and April when the rates are the lowest. The clays have become completely hydrated and the water tables are at their highest levels during March and April. The percolation rates begin to increase in May as the amount of moisture in the soils begin to decrease as the spring rains cease and the vegetation begins to grow rapidly. The increase continues through September after which they begin to decrease with cessation of the growing season and rehydration of the soils. In October the precipitation again commonly exceeds potential evapotranspiration (Foth and Jacobs, 1964). Similar results are seen in Figure 2 for the 4a and 4b management groups.

The seasonal variability of the percolation rates of the 3/2a management group soils, including the Kendallville and Owosso series, is shown by the curve in Figure 3. They are almost exactly the same as the curve for the Miami series, Figure 1. This would indicate that the percolation rate of these soils is controlled by the loam textured understory rather than the sandy loam upperstory.

Figures 1, 2, and 3 also show that the technique being used to obtain an equilibrium percolation rate is not adequate to eliminate the effects of seasonal variations in the moisture content of the soil.

Figure 1. Variability in percolation rates during the year for Miami, Celina, Conover, and Brookston series.

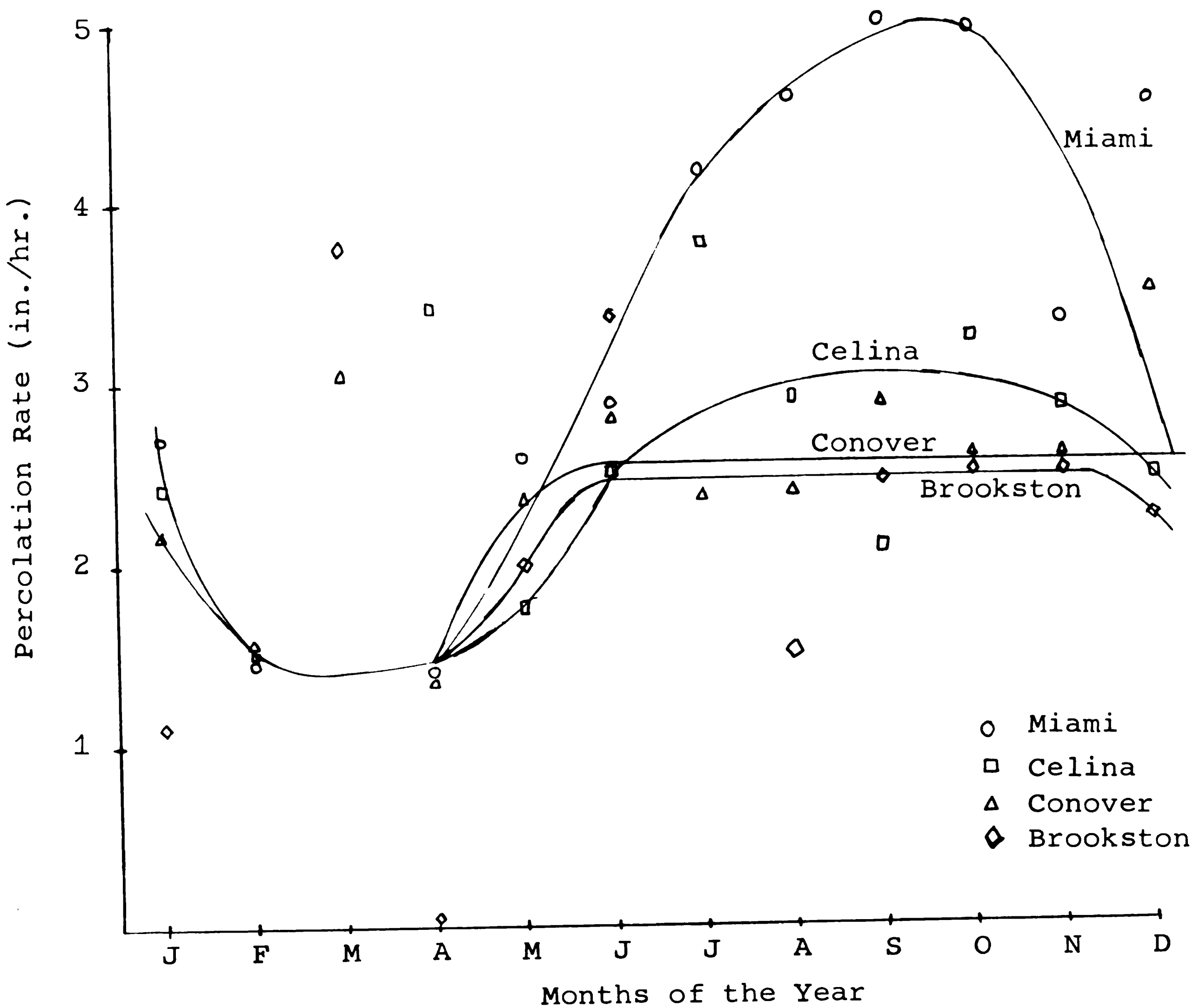


Figure 2. Variability in percolation rates during the year for the 4a and 4b soil management groups.

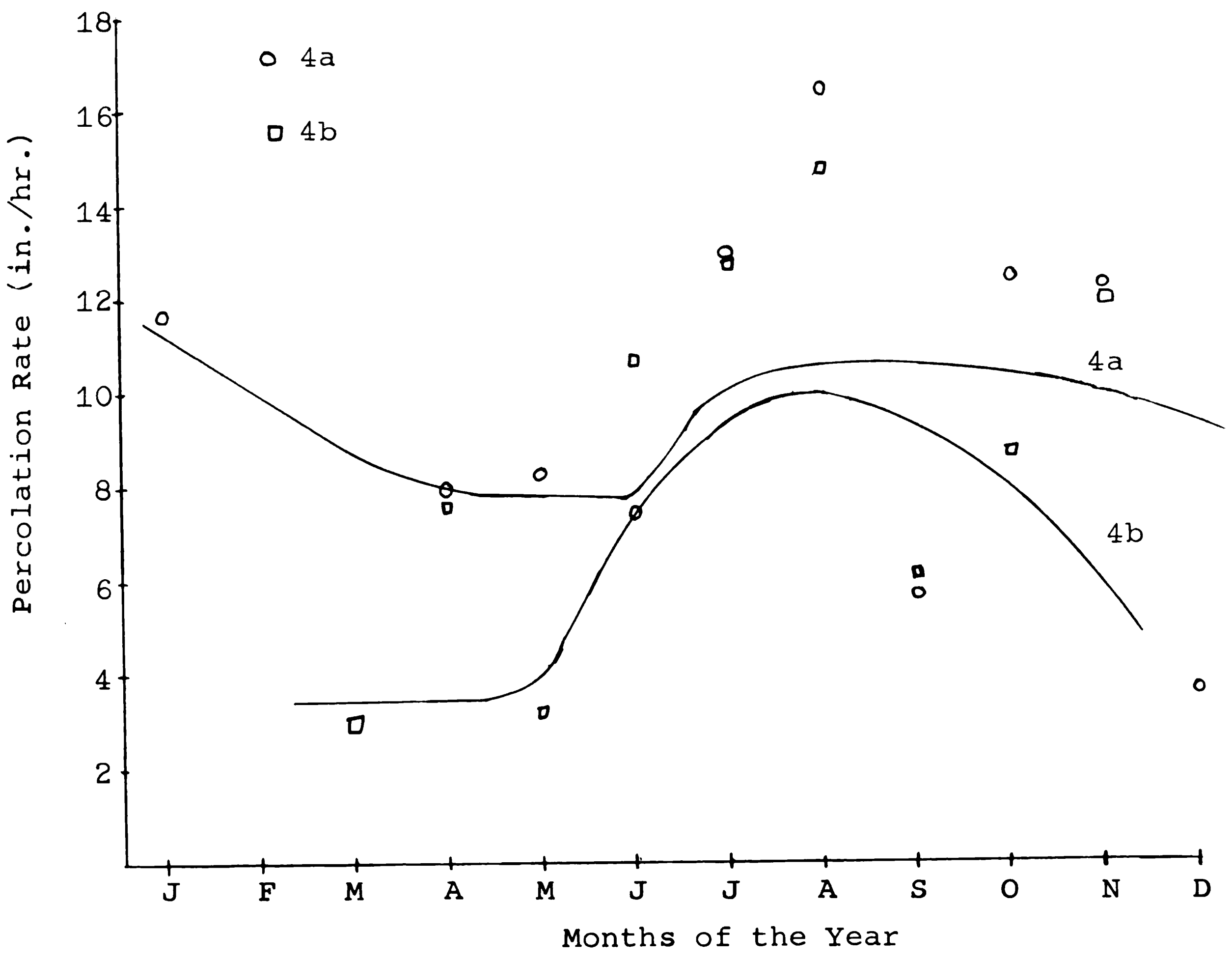
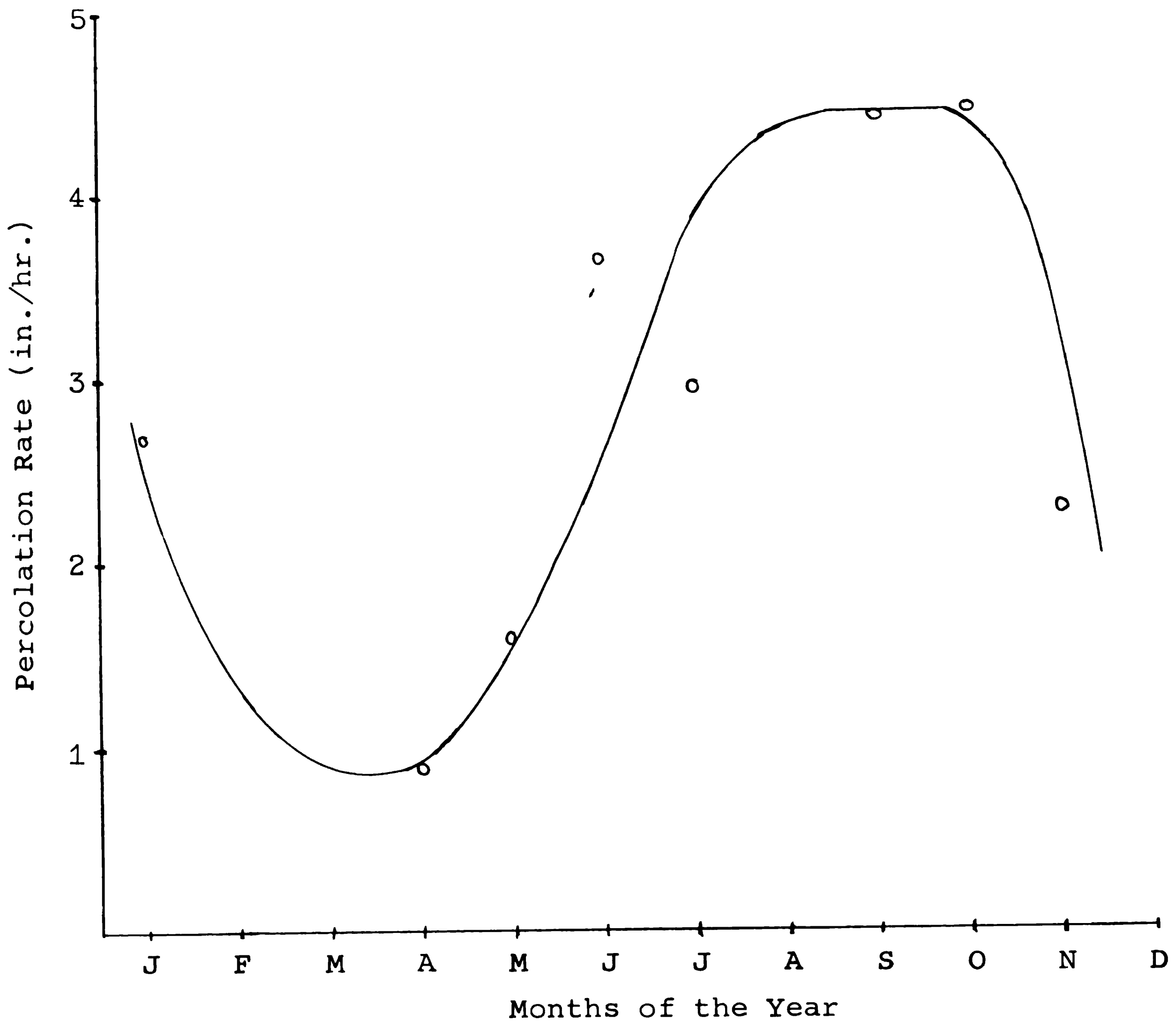


Figure 3. Variability in percolation rates during the year for the $\frac{3}{2}$a soil management group.



## Soil Properties

To understand relationships between soil properties and percolation rates let us look again at the data available before June 1 in the areas studied to date, Table 6. As the texture of the profile becomes coarser (clay to sand), the mean percolation rate increases for the well and moderately well (a), imperfectly (b), and poorly (c) drained soils. In the latter part of the year the soils, especially the finer textured soils, are cracked due to dry weather. These cracks may not swell completely shut during the presoak, therefore the percolation rate is more nearly equal to that of the coarser textured soils. The coarse textured soils do not contain a sufficient amount of clay to cause much cracking, therefore there is no large increase in the percolation rate.

The well-drained soils formed in sandy loam over loam materials (Kendallville and Owosso) have percolation rates similar to those of the well-drained loam textured soils. This substantiates the previously stated theory that the percolation rate of the sandy loam over loam soils is controlled by the loam textured understory. This also agrees with Swartzendruber (1960) that the percolation rate is controlled by the permeability of the least permeable horizon.

The well-drained soil formed in loamy sand over loam textured materials, Metea, has a mean percolation rate similar to the well-drained loamy sand textured soils. The lateral movement in the Metea may increase the percolation rate over that of the loam textured soils.

The loam textured soil groups have small variations between the mean percolation rates of the well (Miami), moderately well (Celina), imperfectly (Conover), and poorly (Brookston) drained soils. One would predict this if there were no effect of an intermittent high water table in the latter three soils.

There is a significant difference between the mean percolation rates of most of the well-drained soils as shown in Table 8. This table also indicates the well-drained sandy loam over loam soils (Kendallville and Owosso) have percolation rates similar to well-drained loam soils (Miami and Celina). The well-drained loamy sand over loam soil (Metea) has a percolation rate more similar to the well-drained loamy sand soils (Boyer, Spinks and Oshtemo).

There are less significant differences between the means of the imperfectly drained soils than the means of the well-drained soils as shown in Table 8. This may be the influence of the fluctuating water table. The mean of Conover was significantly different from the means of the other imperfectly drained soils. The other imperfectly drained soils tend to have similar means but no two are very similar.

The mean for Hoytville was not similar to the means of Brookston or Gilford but the means of Brookston and Gilford tended to be similar.

Table 8. The probability that differences between the means of the percolation tests, made before June 1, for different soil series are due to chance.

| Natural Drainage | | Celina | Sisson | Tuscola | Owosso | Kendallville | Metea | Boyer | Spinks | Oshtemo |
|---|---|---|---|---|---|---|---|---|---|---|
| Well and Mod. Well | Miami | .02 | .16 | <.01 | .68 | .94 | <.01 | <.01 | <.01 | <.01 |
| | Celina | | .28 | .01 | .65 | .63 | <.01 | <.01 | <.01 | <.01 |
| | Sisson | | | .41 | .24 | .25 | <.01 | <.01 | <.01 | <.01 |
| | Tuscola | | | | .01 | .03 | .02 | <.01 | <.01 | <.01 |
| | Owosso | | | | | .80 | <.01 | <.01 | <.01 | <.01 |
| | Kendallville | | | | | | <.01 | <.01 | <.01 | <.01 |
| | Metea | | | | | | | .64 | .35 | .20 |
| | Boyer | | | | | | | | <.01 | .19 |
| | Spinks | | | | | | | | | <.01 |

| Natural Drainage | | Metamora | Imp.Dr. Metea | Imp. Dr. Spinks | Wasepi | 7092 | Miami | Celina | Brookston |
|---|---|---|---|---|---|---|---|---|---|
| Imperfectly | Conover | <.01 | <.01 | <.01 | <.01 | .03 | .03 | .37 | .82 |
| | Metamora | | .45 | .69 | <.01 | <.01 | | | |
| | Imp. Dr. Metea | | | .66 | .27 | .30 | | | |
| | Imp. Dr. Spinks | | | | .02 | .46 | | | |
| | Wasepi | | | | | .09 | | | |

| Natural Drainage | | Hoytville | Gilford | Miami | Celina |
|---|---|---|---|---|---|
| Poorly | Brookston | <.01 | .58 | .22 | .57 |
| | Hoytville | | <.01 | | |

Comparison of Soil Management Groups

In Table 9 the percolation rate data obtained before June 1 annually are arranged according to the soil management groups based on profile textures and natural drainage classes. The proportion of total observations on the soils in each management group that exceeds the various minimum percolation rates cited (2, 1.5, 1.3, and 1 inch per hour) are given. These values were chosen because the various health departments use these for guides in the design of the septic tank disposal fields.

For the well and moderately well drained sandy loam over loam textured soils, the percent of individual tests equal to or greater than any given minimum percolation rate are slightly lower than those for similar loam textured soils. The percent of individual tests equal to or greater than any given minimum percolation rate are considerably greater for the well-drained loamy sand, "a" group, than for the well-drained loam and sandy loam over loam groups. This agrees with the higher average or mean percolation rate for the respective 4a compared to the 2.5a and 3/2a groups.

For the loam textured soils, 2.5 group, the percent of individual tests equal to or greater than a given percolation rate increases as the natural drainage goes from well and moderately well, a, to imperfectly, b, to poorly, c. This is also indicated by the average or mean percolation rate for the respective groups. This may be the result of the more

Table 9. Mean percolation rates before June 1 and their variabilities on various soil management groups with 10 or more observations.

| Profile Texture | Min. Perc. Rate | Well & Mod. Well (a) | | | Imperfectly (b)** | | | Poorly (c)** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Loam | 1.0 | 2.12 | 91.5 | 100* | 2.42 | 95.8 | 89.5 | 2.92 | 92.7 | 91.7 |
| 2.5 | 1.3 | 2.12 | 70.3 | 65.8 | 2.42 | 79.3 | 76.3 | 2.92 | 82.9 | 75.0 |
| | 1.5 | 2.12 | 66.1 | 57.9 | 2.42 | 68.9 | 60.5 | 2.92 | 80.5 | 66.7 |
| | 2.0 | 2.12 | 47.3 | 52.6 | 2.42 | 47.8 | 36.8 | 2.92 | 63.4 | 66.7 |
| Sandy Loam | 1.0 | 1.99 | 84.8 | 83.3 | | | | | | |
| over Loam | 1.3 | 1.99 | 63.6 | 83.3 | | | | | | |
| 3/2 | 1.5 | 1.99 | 63.6 | 83.3 | | | | | | |
| | 2.0 | 1.99 | 45.5 | 50.0 | | | | | | |
| Loamy Sand | 1.0 | 8.62 | 98.8 | 100 | 9.21 | 97.1 | 88.9 | 2.61 | 90.9 | 100 |
| 4 | 1.3 | 8.62 | 97.5 | 100 | 9.21 | 91.2 | 88.9 | 2.61 | 81.8 | 100 |
| | 1.5 | 8.62 | 95.7 | 100 | 9.21 | 91.2 | 88.9 | 2.61 | 72.7 | 100 |
| | 2.0 | 8.62 | 94.4 | 100 | 9.21 | 88.2 | 88.9 | 2.61 | 63.6 | 100 |

*The numbers given for each soil management group are, in the order given: (1) the average or mean values of the percolation tests, (2) the percent of individual tests with a percolation rate equal to or greater than the minimum percolation rate for that line, and (3) the percent of areas with a mean percolation rate equal to or greater than the minimum percolation rate for that line.

**These soils are not usually suitable for septic tank disposal fields because of seasonably high water tables.

percolation tests made during January and February on the imperfectly and poorly drained soils when the soil is continuing to rehydrate. The poorly drained soils had a greater percentage of percolation tests made during January and February than did the imperfectly drained soils.

For the loamy sand textured soils, "4" groups, the percent of individual tests equal to or greater than a given percolation rate decreases as the natural drainage goes from group a to group b to group c.

All but nine of the percolation tests on the 4a soil management group had a percolation rate of 2 inches per hour or greater. Only two observations had a percolation rate less than 1 inch per hour. All of the areas of the soils in the 4a management group had an average or mean percolation rate greater than 2 inches per hour. This indicates it is not necessary to require percolation tests to be run on the soils in the 4a management group if an on site investigation confirms the soil in the area of the proposed septic tank disposal field is one of those in the 4a group. This would probably also be true of the 5a group of soils.

Only one area of soils in the 3/2a and 2.5a management groups had an average or mean percolation rate less than 1 inch per hour. But only 50 percent of the areas of these soils had average or mean percolation rates greater than 2 inches per hour.

The similarities between the percent of observations which have a percolation rate equal to or greater than a minimum percolation rate and the percent of areas which have a mean percolation equal to or greater than a minimum percolation rate indicate the randomness of the percolation tests. The only soil management group which does not have this similarity is the 4c group which has only 11 observations located in two areas.

## Seasonal Variability of Percolation Rates on Five Sites

The seasonal variabilities of the percolation rates of St. Clair, Miami, Hillsdale, Oshtemo, and Graycalm are shown in Figures 4, 5, 6, 7, and 8, respectively. For St. Clair the percolation rate decreases rapidly during the first four hours and then less rapidly for the next four hours, Figure 4. The percolation tests made in July and August required a greater period of time to reach an equilibrium percolation rate than the percolation tests made during May and June. It appears the presoak period should be a minimum of 8 hours and that the period should increase during the latter part of the year.

The percolation tests made during July and August on St. Clair had a considerably greater percolation rate after an overnight delay in adding water to the holes. During this period of time it appears the clays dehydrate and must be rehydrated again before an equilibrium percolation rate is reached. When holes were dug for percolation tests in April, the St. Clair was found to have a perched water table at about

Figure 4. Seasonal variation in percolation rates of St. Clair.

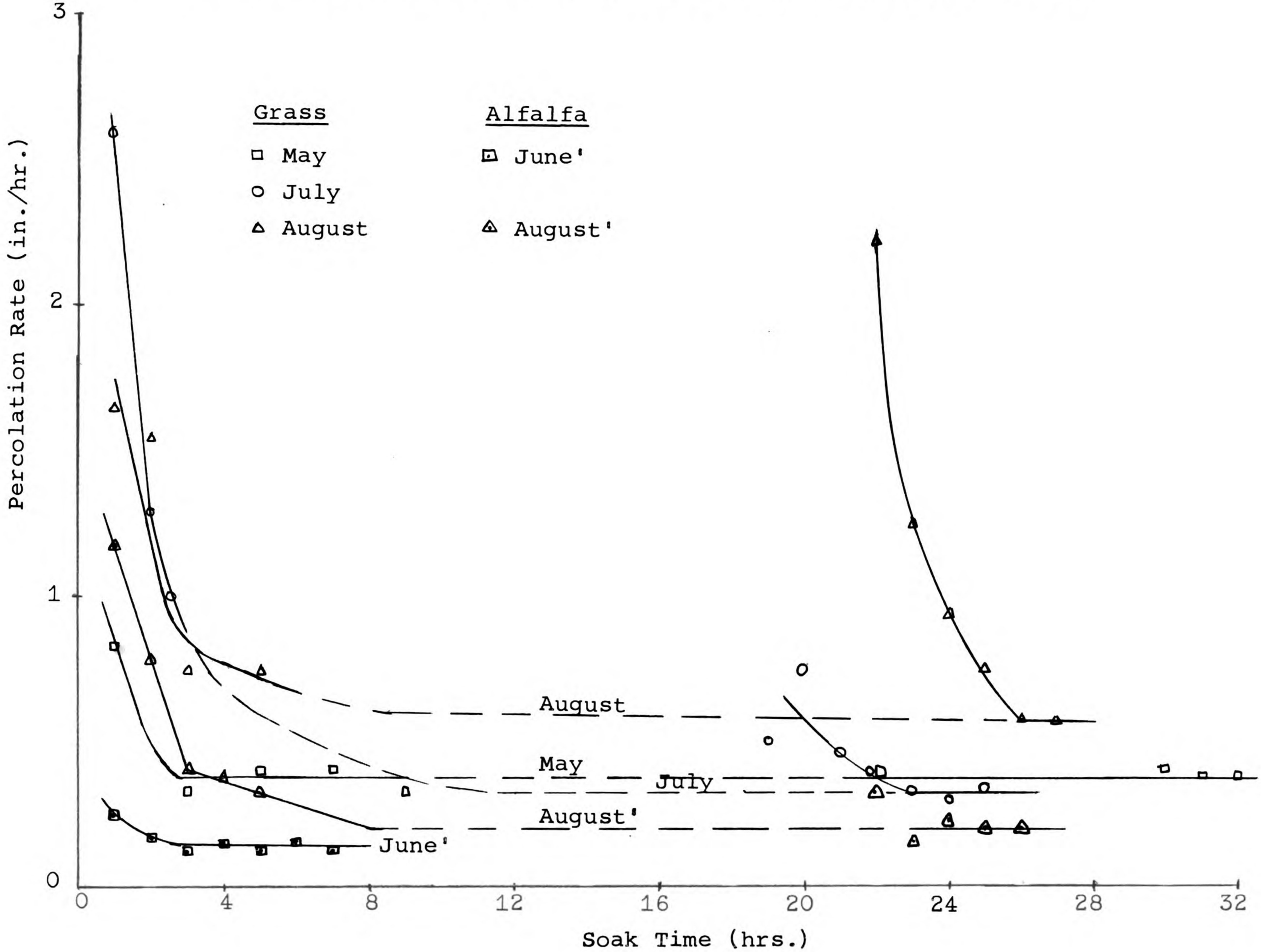


Figure 5. Seasonal variation in percolation rates of Miami.

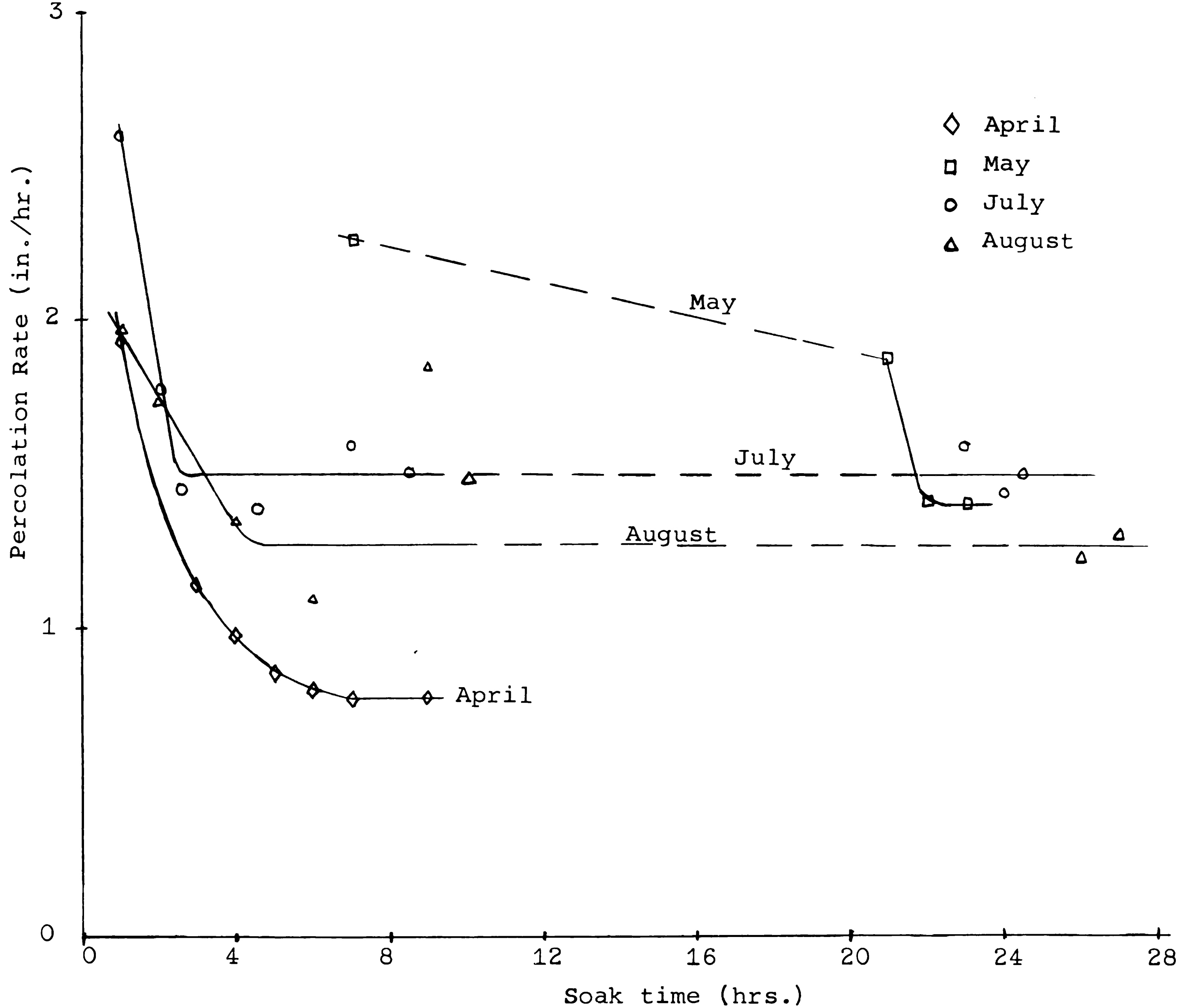


Figure 6. Seasonal variation in percolation rates of Hillsdale.

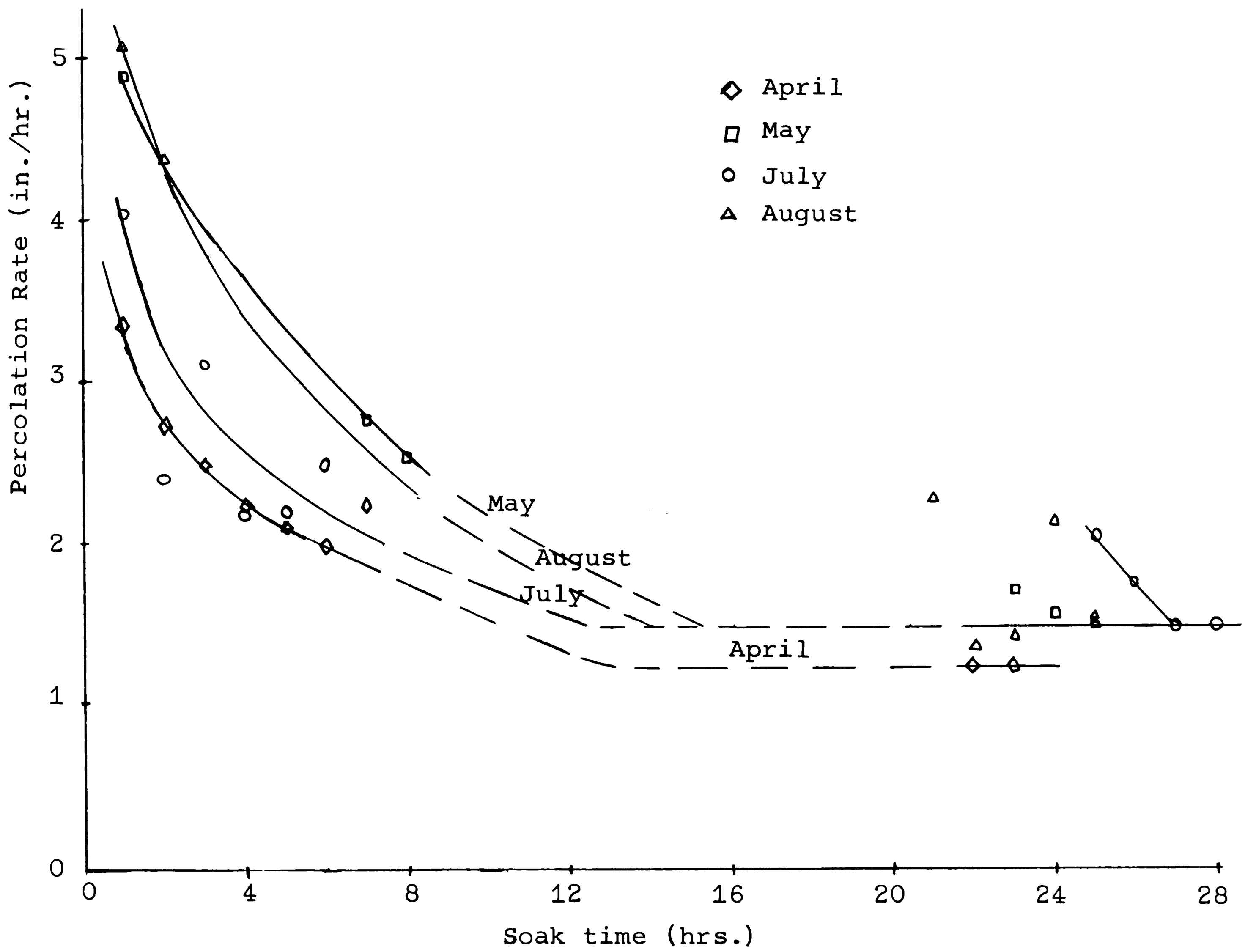


Figure 7. Seasonal variation in percolation rates of Oshtemo.

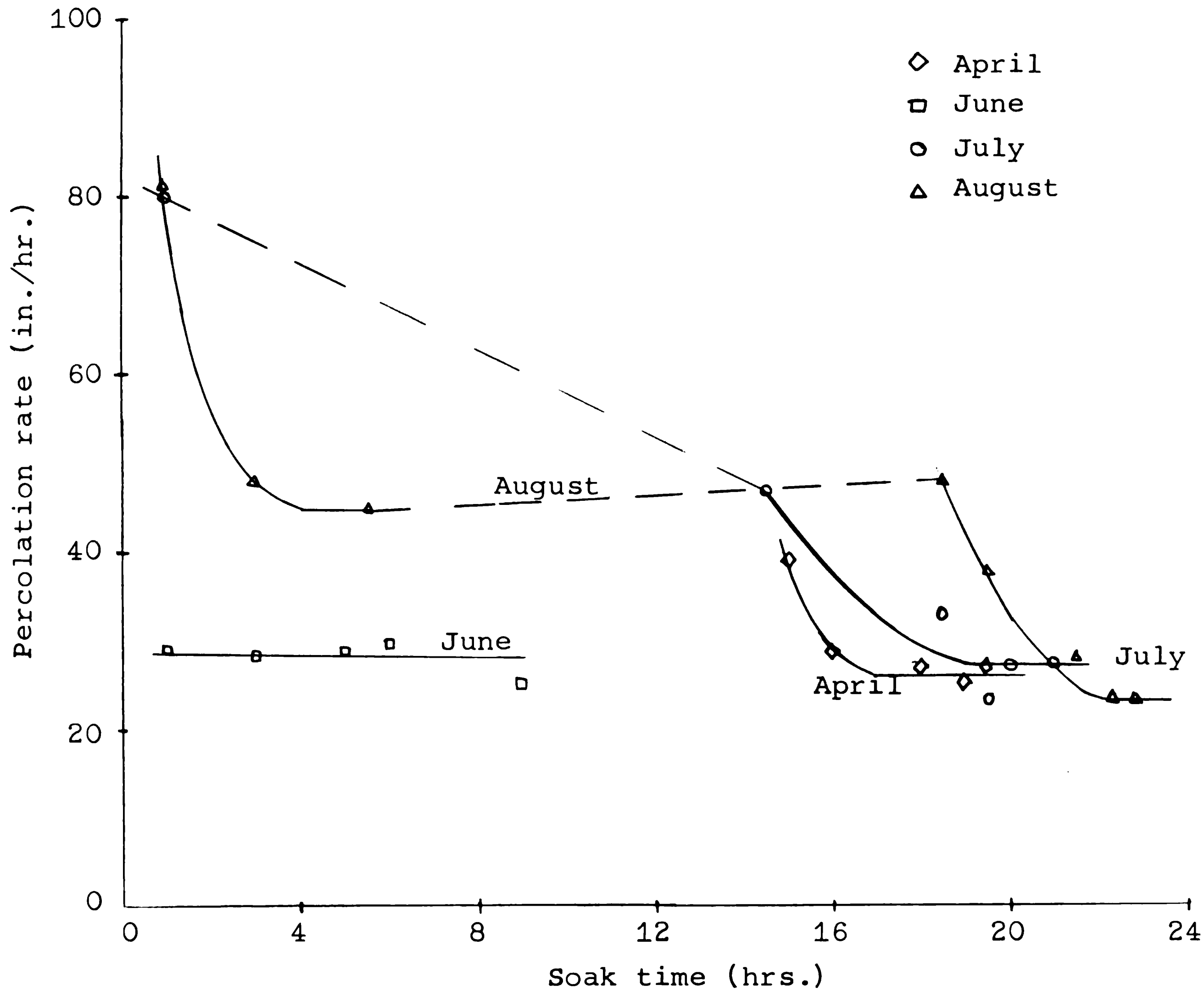
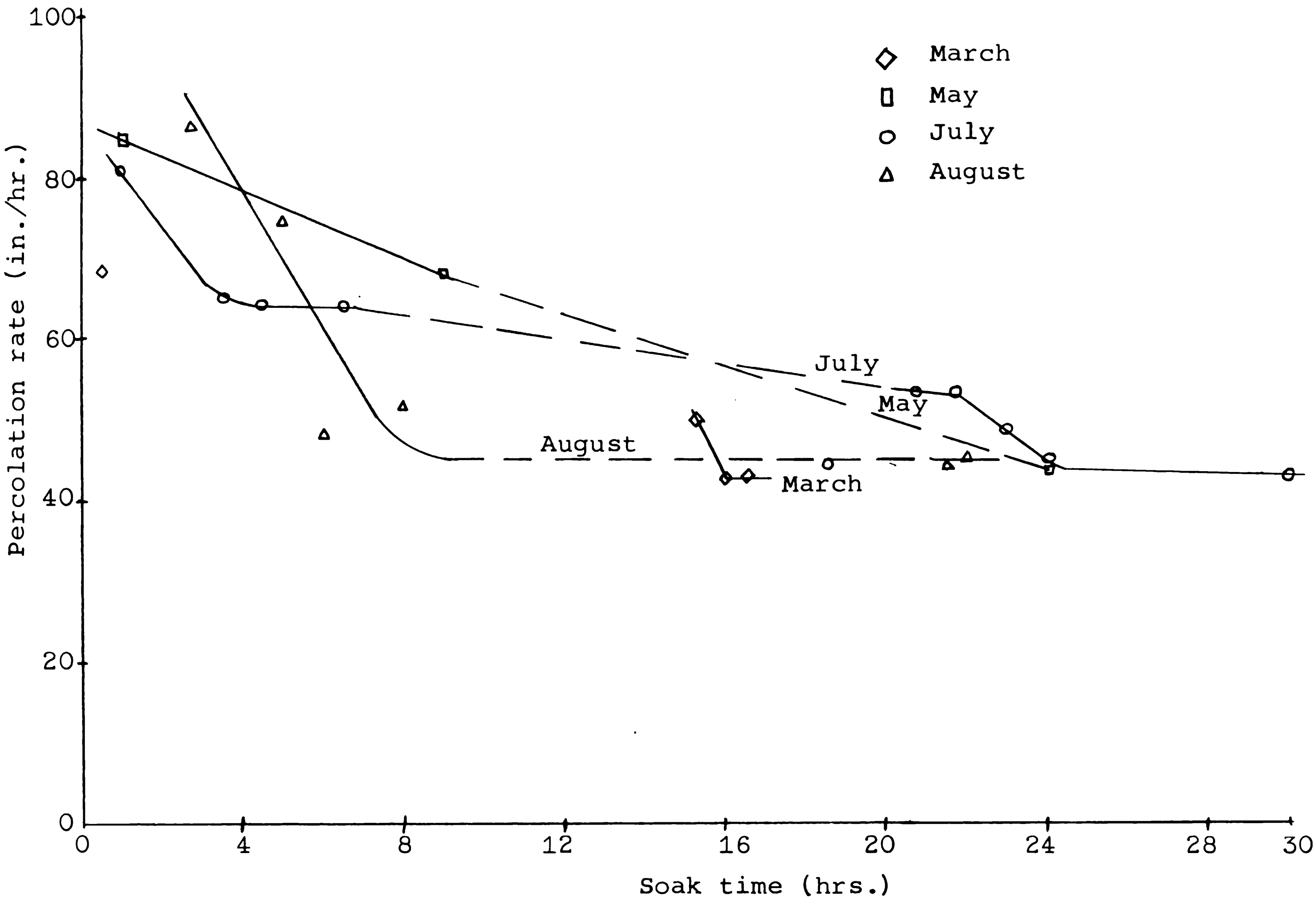


Figure 8. Seasonal variation in percolation rates of Graycalm.



19 inches. The equilibrium percolation rates increased with time as the tests were made from May to July to August. Apparently 24 hours of soak was not sufficient to rehydrate the clays completely.

Marshall (1959) found swelling of the clay to be a slow process and it may take several months for the cracks to close up after a wet season begins and water is freely available. Franzmeier et al (1964) found it took 8 to 10 days of soaking to achieve reproducible percolation rates.[2]

The equilibrium percolation rates for the tests made in the alfalfa field were lower than the equilibrium rates for the tests made in the grass sod. This difference may be due to the deep alfalfa roots compacting the subsoil as they grow, but the percolation rate would be considerably greater after the roots die because of the channels formerly occupied. This does not agree with Clayton et al (1959) who found vegetation did not influence the percolation rates.

The minimum length of the soak period for Miami appeared to be the same as that for the St. Clair (8 hours), Figure 5. The percolation tests made during April and May required this length of time, but those made during July and August required only approximately 4 hours of soak to reach an equilibrium percolation rate.

The May and July percolation tests exhibited the dehydration phenomenon which occurred in the July and August tests

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[2] Op. cit.

made on St. Clair. The equilibrium percolation rate for the April test was considerably less than the rates for the tests made during May, July, and August. This indicates the soil may not rehydrate within 24 hours.

The minimum length of the soak period appears to be greater for the Hillsdale (16 hours), Figure 6, than for the St. Clair and Miami. The percolation tests made during May and July also exhibited the dehydration effect during the overnight period when no water was added. The equilibrium rate for the test made during April was less than the equilibrium rates for the tests made during May, July, and August, which were identical. The difference was not as great as that of the Miami. This may be due to the lower clay content of the Hillsdale than the Miami.

The time required to obtain the equilibrium rate for the Oshtemo did not appear to be closely related to the soak time but it appeared to be more closely related to the amount of water added to the holes or the moisture content of the soil. The tests which were begun late in the afternoon and continued through the following day had curves, Figure 7, which were similar to the curve for the test which was made during August when the test was begun in the morning and continued until the following morning.

There was very little difference in the equilibrium rates for the tests made at any month of the year. The Oshtemo soil has a very low clay content, so the effect of dehydration of the clay is not apparent.

The equilibrium rate of the Graycalm also appeared to be more a function of the amount of water added to the holes or the moisture content of the soil than the time of soaking. There is no similarity between the individual curves for the percolation tests made during different months of the year, Figure 8. Again there was very little difference between the equilibrium rates obtained from the tests made at the different months. The Graycalm soil also has a very low clay content so the dehydration effect is not apparent.

The equilibrium percolation rates for Oshtemo and Graycalm are about 26 and 44 inches per hour, respectively. If the effluent flows through the soil at this rate, there may be contamination of wells nearby.

## Permeabilities by Core Method

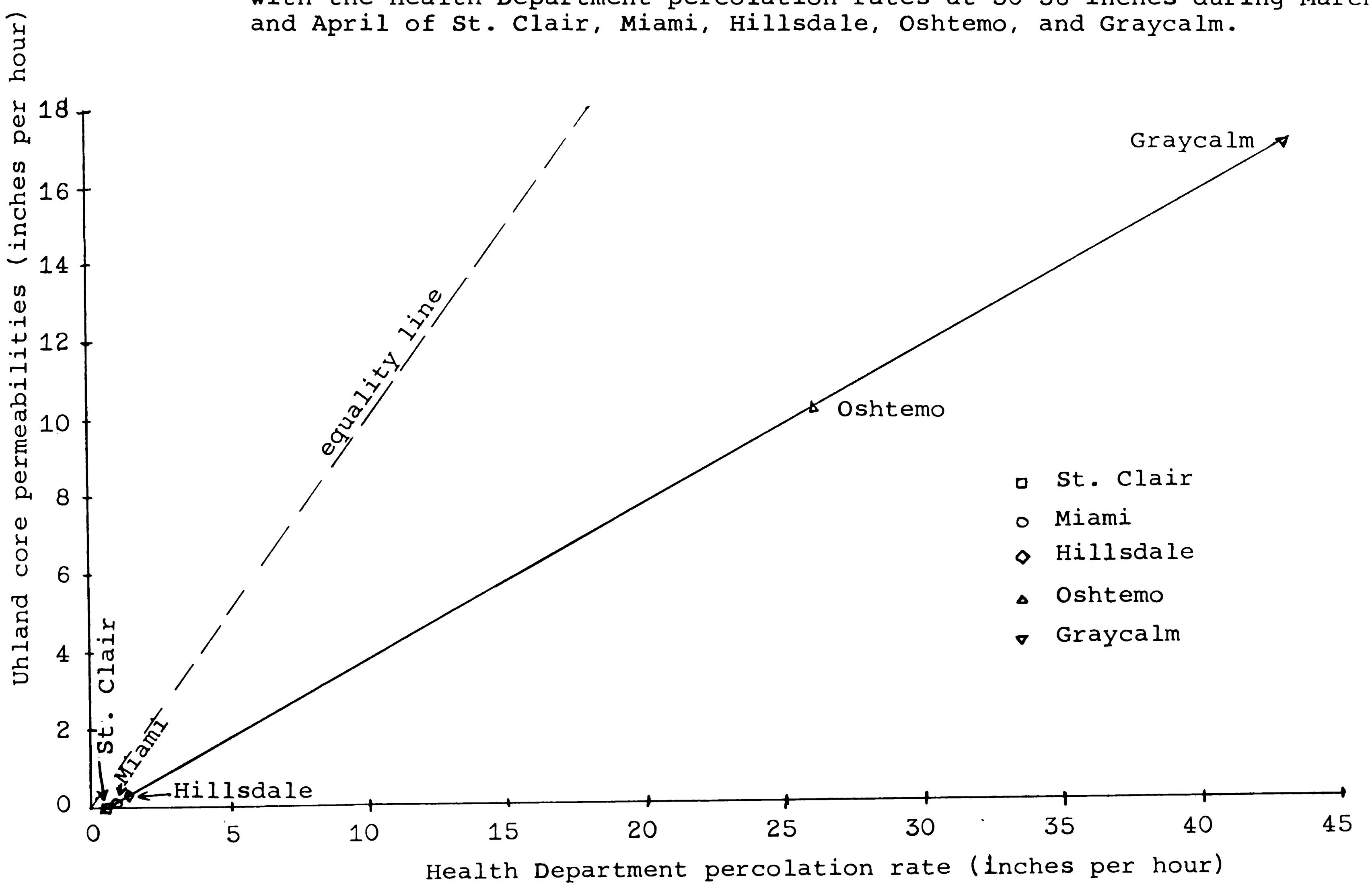
The percolation rates as determined by the Health Department method on the five soils studied were greater in all cases than the permeability of the least permeable horizon as determined by the Uhland core method for the cores taken within the depth at which the percolation rates were measured in the field as shown in Table 10 and Figure 9. There appears to be a straight line relationship between the permeabilities at about 30-36 inch depth as determined by the Uhland core method and the percolation rates at the 30-36 inch depth as determined

Table 10. Comparison of percolation rates by the Health Department method, permeability rates by the Uhland core method, and the bulk densities of five, well-drained soils.

| Soil Series | Permeability Rates by Uhland Core Method depth (in.) | rate (in./hr.) | | Percolation Rate by Health Department Method at 30-36 in. depth (in./hr.) | | Bulk Density |
|---|---|---|---|---|---|---|
| St. Clair | 0-3 | 5.13 | Grass | April | 0.0* | 1.06 |
| | 5-8 | 1.16 | Grass | May | 0.39 | 1.45 |
| | 9-12 | 0.36 | Grass | July | 0.30 | 1.48 |
| | 14-17 | 0.55 | Grass | August | 0.58 | 1.41 |
| | 20-23 | 0.29 | Alfalfa | June | 0.16 | 1.59 |
| | 27-30 | 0.01 | Alfalfa | August | 0.20 | 1.68 |
| | 35-38 | 0.02 | | | | 1.76 |
| Miami | 11-14 | 0.84 | | | | 1.57 |
| | 15-18 | 0.68 | | April | 0.78 | 1.62 |
| | 20-23 | 0.54 | | May | 1.41 | 1.62 |
| | 30-33 | 0.17 | | July | 1.43 | 1.63 |
| | 39-42 | 0.07 | | August | 1.37 | 1.67 |
| | 44-47 | 0.09 | | | | 1.75 |
| | 53-56 | 0.05 | | | | 1.91 |
| Hillsdale | 1-4 | 1.07 | | | | 1.59 |
| | 10-13 | 0.57 | | April | 1.25 | 1.66 |
| | 16-19 | 0.33 | | May | 1.50 | 1.75 |
| | 22-25 | 0.16 | | July | 1.50 | 1.74 |
| | 32-35 | 0.24 | | August | 1.50 | 1.68 |
| | 44-47 | 0.52 | | | | 1.66 |
| Oshtemo | 1-4 | 4.72 | | April | 26.2 | 1.56 |
| | 26-29 | 11.95 | | June | 22.6 | 1.58 |
| | 33-35 | 10.30 | | July | 21.9 | 1.56 |
| | 37-40 | 10.32 | | August | 22.4 | 1.60 |
| Graycalm | 2-5 | 4.32 | | | | 1.60 |
| | 12-15 | 8.78 | | March | 43.2 | 1.60 |
| | 24-27 | 15.12 | | May | 44.6 | 1.60 |
| | 36-39 | 17.03 | | July | 44.4 | 1.60 |
| | 43-46 | 18.87 | | August | 44.2 | 1.62 |

*Perched water table was at 19.38 inches.

Figure 9. Comparison of the Uhland core permeabilities of horizons at 30-36 inches with the Health Department percolation rates at 30-36 inches during March and April of St. Clair, Miami, Hillsdale, Oshtemo, and Graycalm.



by the Health Department method for the five soils studied, Figure 9. The percolation rates for Oshtemo and Graycalm are about 2.5 times greater than their permeabilities. Miami and Hillsdale, Table 10, have a percolation rate about 5.5 times greater than their permeabilities. St. Clair has a percolation rate about 25 times greater than its permeability. These differences may be due to the lateral movement which occurs in the percolation test but not in the cores.

For naturally well-drained soils the Uhland core and the Health Department methods may give adequate data to use in the design of septic tank disposal fields. For the soils with intermittent high water tables, these methods are very inadequate. The water table has no effect on the observed percolation rate unless it is present at the time of measurement, yet it determines whether a disposal field will function properly during the wettest part of the year.

It was not possible to obtain an undisturbed core sample of the C horizon (sand and gravel) of the Oshtemo. The permeability of that horizon should be considerably greater than the values given in Table 10 for the horizons above the C horizon of Oshtemo. The depth of the C horizon was quite variable over this site. This variability may be of considerable importance. If the disposal field should be placed in the C horizon, contamination of the well waters nearby may occur.

The comparison of the bulk density of the horizons, Table 10, with the permeability of the core samples for a profile shows that the permeability decreases as the bulk density increases. In the Miami the bulk density increases and the permeability decreases below the 39 inch depth where the texture changes from sandy clay loam to loam. In the Hillsdale and Oshtemo soils the bulk density increases from the surface to the B horizon and below the B horizon the bulk density decreases. This is the result of the increase in clay content of the B horizon. There is essentially no change in the bulk density of the horizons of the Graycalm. The bulk density increases with depth in the St. Clair and Miami with the C horizons the most dense.

The bulk density is considerably greater for the C horizons in the St. Clair and Miami soils. This may be due to the high carbonate content of these horizons.

## Performance of Septic Tank Disposal Fields

In the special survey made by the Macomb County Health Department there was only one septic tank disposal field located on the well and moderately well drained soils which was not functioning satisfactorily as shown in Table 11. This failing system was located on Oakville, a soil in the 5a soil management group. The estimated load to tile length ratio for this system was less than several other systems on finer textured soils. The trouble with the system may be due

Table 11. Comparison of the performance of existing septic tank disposal fields, profile textures, estimated load/tile length ratios, and ages of the disposal fields located on well and moderately well drained soils.

| Profile Texture | Soil Series | Performance | Estimated Load / Tile Length Ratio | Age of Field (years) |
|---|---|---|---|---|
| Loam | Miami | S | 14.5 | 6 |
| | Miami | S | 7.2 d | 6 |
| Loamy Sand | Spinks | S | 12.6 d | 6 |
| | Bronson | S | 12.0 g | 9 |
| | Spinks | S | 8.7 g | 5 |
| | Oshtemo | S | 6.3 | 5 |
| | Boyer | S | 5.7 | 7 |
| | Spinks | S | 3.4 | 6 |
| Sand | Oakville | F | 8.6 dg | 8 |

S - satisfactory; F - failure
d - the home has an automatic dishwasher
g - the home has a garbage disposal unit
dg - the home has both an automatic dishwasher and a garbage disposal unit

to the home having both an automatic dishwasher and a garbage disposal unit. Another factor is the age of the system; it is one of the oldest installations. Coulter et al (1960) found that septic tank disposal fields located on Plainfield, a soil also in the 5a soil management group, began to fail four years after their installation. Some of the other sewage disposal systems had either an automatic dishwasher or a garbage disposal unit but not both and they were all functioning satisfactorily.

There were several septic tank disposal field failures on the imperfectly drained soils as shown in Table 12 and on the poorly drained soils in Table 13. If one assumes adequate artificial drainage has been supplied these may be of interest. However, the intermittent high water table may complicate interpretations of these observations.

The imperfectly drained soils may be divided into two groups. One group includes the soils developed in clay, clay loam, loam, and sandy loam over loam materials. The critical value for the estimated load to tile length ratio appears to be around 3.0. One of the systems located on the loamy soil, Kibbie, had an estimated load to tile length ratio considerably greater than 3.0 and was functioning satisfactorily after being in operation six years. The percolation rate for this site was greater than that for the other Kibbie sites. This could indicate that the disposal field may be composed of more permeable material.

Table 12. Comparison of the performance of existing septic tank disposal fields, profile textures, estimated load/tile length ratios, and ages of the disposal fields located on imperfectly drained soils.

| Profile Texture | Soil Series | Performance | Estimated Load / Tile Length Ratio | Age of Field (years) |
|---|---|---|---|---|
| Clay | Nappanee | F | 3.8 | 6 |
| | Nappanee | F | 3.7 | 8 |
| | Nappanee | S | 3.0 | 5 |
| | Nappanee | S | 1.9 | 5 |
| | Nappanee | S | .8 | 6 |
| Clay Loam | Blount | S | 2.5 | 7 |
| | Blount | S | 1.9 | 9 |
| Loam | Kibbie | S | 8.3 | 6 |
| | Conover | S | 3.1 | 7 |
| | Conover | F | 2.7 | 7 |
| | Kibbie | S | 2.3 d | 7 |
| Sandy Loam over Loam | Macomb | S | 2.0 | 8 |
| Sandy Loam over Clay | Rimer | S | 10.3 | 5 |
| | Rimer | S | 7.9 | 5 |
| | Rimer | S | 6.7 | 5 |
| Sandy Loam | Matherton | F | 8.8 d | 7 |
| | Matherton | Q | 7.6 g | 8 |
| | Matherton | S | 4.1 | 9 |
| Loamy Sand | Imp. Dr. Spinks | F | 17.1 g | 5 |
| | Brady | F | 16.5 | 7 |
| | Tedrow | S | 14.1 g | 9 |
| | Brady | F | 13.2 | 5 |
| | Tedrow | F | 13.2 g | 6 |
| | Tedrow | S | 12.1 | 5 |
| | Tedrow | S | 10.4 | 6 |
| | Imp. Dr. Spinks | S | 10.3 g | 5 |
| | Tedrow | S | 9.2 | 6 |
| | Tedrow | F | 7.9 | 6 |
| | Brady | S | 6.4 | 6 |
| | Wasepi | F | 6.2 | 8 |
| | Imp. Dr. Spinks | S | 3.9 | 6 |

S - satisfactory; F - failure; Q - questionable
d - the home has an automatic dishwasher
g - the home has a garbage disposal unit

Table 13. Comparison of the performance of existing septic tank disposal fields, profile textures, estimated load/tile length ratios, and ages of the disposal fields located on poorly drained soils.

| Profile Texture | Soil Series | Performance | Estimated Load / Tile Length Ratio | Age of Field (years) |
|---|---|---|---|---|
| Clay | Paulding | S | 5.5 | 6 |
| (> 55%) | Paulding | S | 2.4 | 6 |
| | Paulding | F | 2.1 | 5 |
| Clay | Hoytville | Q | 7.2 g | 5 |
| (< 55%) | Hoytville | S | 6.9 | 9 |
| | Hoytville | F | 5.7 | 8 |
| | Hoytville | S | 4.0 | 5 |
| | Hoytville | F | 3.7 | 5 |
| | Hoytville | S | 3.7 | 5 |
| | Hoytville | F | 3.5 | 5 |
| | Hoytville | F | 3.3 g | 5 |
| | Hoytville | S | 1.6 | 5 |
| | Hoytville | S | 1.1 | 7 |
| Sandy Loam | Wauseon | Q | 12.3 | 9 |
| over Clay | Wauseon | Q | 6.6 | 9 |
| | Wauseon | F | 6.4 | 6 |
| | Wauseon | Q | 1.6 | 6 |
| Clay Loam | Pewamo | F | 9.8 | 5 |
| | Pewamo | Q | 4.0 | 5 |
| Loam | Brookston | S | 9.7 d | 5 |
| | Colwood | S | 8.7 | 6 |
| | Brookston | S | 8.2 | 6 |
| | Colwood | S | 3.8 | 6 |
| | Colwood | F | 3.8 | 6 |
| | Colwood | F | 3.7 | 9 |
| | Colwood | S | 1.1 | 6 |
| Loamy Sand | Gilford | S | 7.7 d | 9 |

S - satisfactory; F - failure; Q - questionable
d - the home has an automatic dishwasher
g - the home has a garbage disposal unit

The second group includes the soils developed from sandy loam over clay, sandy loam, and loamy sand materials. The critical estimated load to tile length ratio appears to be about 8.0. All of the systems located on Rimer (sandy loam over clay) were functioning satisfactorily even though they have relatively high estimated load to tile length ratios. Apparently there is sufficient lateral movement through the sandy loam portion of the profile of these soils for the systems to function satisfactorily. These systems are only five years old and this may also account for their satisfactory performance.

These are very preliminary observations but if they are true, they suggest that the design of systems on the finer soils need to be more conservative.

The septic tank disposal fields located on the poorly drained soils were with one exception located on soils developed from clay, sandy loam over clay, clay loam, and loam materials as shown in Table 13. The systems on the clay, sandy loam over clay, and clay loam soils appear to be functioning similarly. These soils appear to have a critical estimated load to tile length ratio of 2. There were three systems located on Hoytville (clay, $< 55\%$) which were functioning properly even though their ratio was greater than 2. Two of these systems were only five years old and this could explain their satisfactory performance. The percolation rate determined for the soil of the third system was considerably greater than that for the other sites located on Hoytville soils. This may indicate the disposal field may be composed of more permeable material than the other systems located on Hoytville.

Two of the systems on the loam textured soils failed to function satisfactorily. These two systems had lower estimated load to tile length ratios than four of the other five systems which were functioning satisfactorily. One of the two failing systems is nine years old while the other is six years old and this could account for their failures. The behavior of the septic tank disposal fields on these soils may be due to the intermittent high water tables which are present in them. From these data it is not possible to determine a critical value for the estimated load to tile length ratio, but it appears to be greater than 2 which was estimated for the finer textured, poorly-drained soils discussed above.

It was not possible to determine a critical value for the estimated load to tile length ratio for the poorly-drained, loamy sand soil, Gilford because only one septic tank disposal field was located on it and the system was functioning satisfactorily.

Of the eleven septic tank disposal systems which had ground garbage added to them in addition to the sewage, only four of them were functioning satisfactorily. Two of the four systems were located on well-drained, loamy sand soils.

The other two were located on imperfectly drained loamy sand soils. One on each of the two soil management groups was only five years old while the other was seven years old. The Housing and Home Finance Agency (1951) also found, that the septic tank disposal field which received ground garbage in addition to sewage had more failures than those which received only sewage.

Only two of the seven septic tank disposal systems which included an automatic dishwasher were not functioning satisfactorily. One of these two systems also received ground garbage in addition to the sewage. Apparently the automatic dishwasher does not have as great an adverse effect on the septic tank disposal system as does the garbage disposal unit.

The estimated load to tile length ratios for the imperfectly and poorly drained soils are lower than that for the well drained soils of the same textural profile. This is an indication the natural drainage conditions were not adequately supplemented.

## CONCLUSIONS

1. Percolation rates should be obtained early in the year when the soil most limits the operation of septic tank disposal fields or after adequate presoaking. It may not be possible to completely rehydrate the soils in a length of time that is feasible to require in a percolation test. It commonly takes longer than twenty-four hours.

2. Better presoaking techniques are needed to obtain reliable percolation measurements especially after the soils begin to dehydrate in the summer season. The required minimum length of the presoak should be at least eight hours and twenty-four hours seems a reasonably practical requirement. The longer the presoak, the more reliable the percolation test will be.

3. It appears unnecessary to require percolation tests on the well-drained loamy sand soils. This is probably true also of the well-drained sand soils which were not tested in these studies.

4. The percolation rates are at a minimum during February, March, and April. At this time the rates for Miami, Celina, Conover, Brookston are about equal but during August, September, and October the rates of the soils are in the following decreasing order: Miami > Celina > Conover > Brookston.

5. The seasonal variability in percolation rates of the well-drained sandy loam over loam soils (3/2a group) was very similar to that for the well-drained loam soil, Miami. The loam textured lower story of the former soil apparently controls its percolation rate. The seasonal variability of percolation rates of the well-drained loamy sand soils was less than that for the above soils.

6. There does not appear to be seasonal variations in the percolation rate due to the soil moisture variation for the coarse textured soils, Graycalm and Oshtemo, but there are variations in the rates for the finer Hillsdale, Miami and St. Clair soils.

7. The percolation rates by the Health Department method were greater than the permeabilities by the Uhland core method at the 30-36 inch depth.

8. Garbage disposal units have a considerable adverse effect on the performance of the septic tank disposal fields.

## LITERATURE CITED


Anonymous. 1958. Private sewage disposal system--special service article. J. Milk and Food Tech. 21:194-196.

Anonymous. 1964. If you plan to install a septic tank. Sunset. 132:110.

Bartelli, L. J. 1962. Use of soil information in urban-fringe areas. J. Soil and Water Cons. 17:99-103.

Baver, L. D. 1963. Soil Physics. John Wiley and Sons. New York. Pp. 224-298.

Bender, W. H. 1961. Soils suitable for septic-tank filter fields--a soil map can help you. Bul. 243. Soil Cons. Serv., U. S. Dept. Agr., Washington, D. C.

Bendixen, T. W. 1962. Use and interpretation of field percolation tests for sanitary engineering application. Paper presented at 1962 annual meeting of American Society for Testing and Materials. U. S. Dept. of Health, Ed., and Welfare. Robert A. Taft. San. Engr. Center. Cincinnati.

Burgess, C. 1964a. Choosing and using your automatic dishwasher. Mich. State Univ. Ext. Bul. E-388.

Burgess, C. 1964b. Choosing and using your automatic washer. Mich. State Univ. Ext. Bul. E-392.

Cain, J. M. and Beatty, M. T. 1965. Disposal of septic tank effluent in soils. Jour. of Soil and Water Cons. 20:101-105.

Clayton, J. W., Kennedy, H., Porter, H. C., and Devereux, R. E. 1959. Soils make a difference--use of soil survey in designing sewage disposal systems. Virginia Agr. Exp. Sta. Bul. 509.

Coulter, J. B., Bendixen, T. W. and Edwards, A. B. 1960. Study of Seepage beds. Report to the Federal Housing Administration. Pub. Health Serv. Robert A. Taft. San. Engr. Center. Cincinnati.

Ehlers, V. M. and Steel, E. W. 1958. Municipal and Rural Sanitation. McGraw Hill. New York.

Foth, H. D., and Jacobs, H. S. 1964. Laboratory Manual for Introductory Soil Science. Wm. C. Brown Co., Iowa.

Housing and Home Finance Agency 1951. Septic tanks--their use in sewage disposal. Housing Research Paper 18. Washington, D. C.

Housing and Home Finance Agency. 1956. Septic tank soil absorption systems for dwellings. Construction Aid No. 5. Division of Housing Research. Washington, D. C.

Huddleston, J. H. 1965. Soil survey interpretation for sub-surface sewage disposal in Broome County, New York. M. S. Thesis. Cornell University.

Huddleston, J. H. and Olson, G. W. 1963. Urban soil survey of the village of Whitney Point, New York: an example study showing the direct application of soil survey toward solution of a villages' sewage disposal problems. Agronomy Department, Cornell University. (Mimeo)

Hutchinson, F. E. and Arno, J. R. 1965. Soil surveys for urban use in Maine. J. Soil and Water Cons. 20:85-88.

Jones, J. H. and Taylor, G. S. 1965. Septic tank effluent percolation through sands under laboratory conditions. Soil Sci. 99:301-309.

Kelly, K. L. and Judd, D. B. 1955. The ISCC-NBS method of designating colors and a dictionary of color names. National Bureau of Standards Circular 553. U. S. Govt. Ptg. Off., Washington, D. C.

Kiker, J. E., Jr. 1948. Subsurface sewage disposal. Florida Eng. and Ind. Exp. Sta. Bul. 23.

Krynine, D. P. 1941. Soil Mechanics--its Principle and Structural Application. McGraw-Hill. New York. Pp. 37-40.

MacKichan, K. A. 1957. Estimated use of water in the United States, 1955. Geo. Sur. Cir. No. 398. Washington, D. C.

MacKichan, K. A. and Kammerer, J. C. 1961. Estimated use of water in the United States, 1960. Geo. Sur. Cir. No. 456. Washington, D. C.

Marshall, T. J. 1959. Relations between water and soil. Technical Communication No. 50. Commonwealth Bureau of Soils. Harpenden.

McGauhey, P. H. and Winneberger, J. H. 1964. Causes and prevention of failure of septic tank percolation systems. Federal Housing Adm. Pub. No. 533. Washington, D. C.

Morris, J. G. 1963. Health official says soil survey "One of the most useful tools." Soil Cons. 29:110-112.

Morris, J. G., Newbury, R. L. and Bartelli, L. J. 1962. For septic tank design soil maps can substitute for percolation test. Pub. Works Mag. 93:106-107.

Nelson, L. B. and Muckenhirn, R. J. 1941. Field percolation rates of four Wisconsin soils having different characteristics. J. Am. Soc. Agron. 33:1028-1036.

New York State. 1962. Sewage disposal system for the home. Part III. Bul. No. 1. New York State.

Olson, G. W. 1964a. Application of soil survey to problems of health, sanitation, and engineering. Cornell University Agr. Exp. Sta. Mem. 387.

Olson, G. W. 1964b. Using soil surveys for problems of the expanding population in New York State. Cornell Ext. Bul. 1123.

Olson, G. W., Huddleston, J. H., Austin, R. M., Winkelblech, C. S. and Barber, O. C. 1965. Designs of seepage fields for subsurface sewage disposal in soils of Broome County, New York. Agron. Mim. 65-20. Dept. of Agron., Cornell Univ.

Public Health Service. 1958. Manual of septic-tank practice. Public Health Serv. Pub. 526. Washington, D. C.

Robinson, G. H., Porter, H. C., and Obenshain, S. S. 1955. The use of soil survey information in an area of rapid urban development. Soil Sci. Soc. Amer. Proc. 19: 502-504.

Seglin, L. L. 1965. Comparability of soil survey and percolation test data. J. Soil and Water Cons. 20:167-168.

Senate Select Committee on National Water Resources. Future water requirements for municipal use. U. S. Congress. Committee Report No. 7. Washington, D. C.

Shephard, W. F., Amundson, G., and Sheldon, W. 1963. Questions and answers about home sewage disposal. Michigan Dept. of Health and Michigan State Univ. Coop. Ext. Serv. Misc. Series Cir. E-9.

Soil Survey Staff. 1951. Soil Survey Manual. U. S. Dept. Agr. Handbook 18. U. S. Govt. Ptg. Off., Washington, D. C.

Swartzendruber, D. 1960. Water flow through a soil profile as affected by the least permeable layer. J. Geophys. 65:4037-4042.

Thomas, H. A., Jr., Coulter, J. B., Bendixen, T. W., and Edwards, A. B. 1960. Technology and economics of household sewage disposal systems. J. Water Pollution Control Federation. 32:113-141.

Weibel, S. R., Bendixen, T. W., and Coulter, J. B. 1955. Study on household sewage disposal systems. Part III. U. S. Dept. of Health, Ed., and Welfare. Pub. Health Serv. Robert A. Taft. San. Engr. Center. Cincinnati.

Weibel, S. R., Straub, C. P., and Thoman, J. R. 1949. Study on household sewage disposal systems. Part I. Federal Security Agency. Pub. Health Serv. Environmental Health Center.

Witwer, D. B. 1965. In Pennsylvania: soil survey use in a suburban county. J. Soil and Water Cons. 20:88-90.

Wooding, N. H., Jr. 1963. Home sewage disposal: the septic-tank system. Pennsylvania Ag. Ext. Spec. Cir. 59.