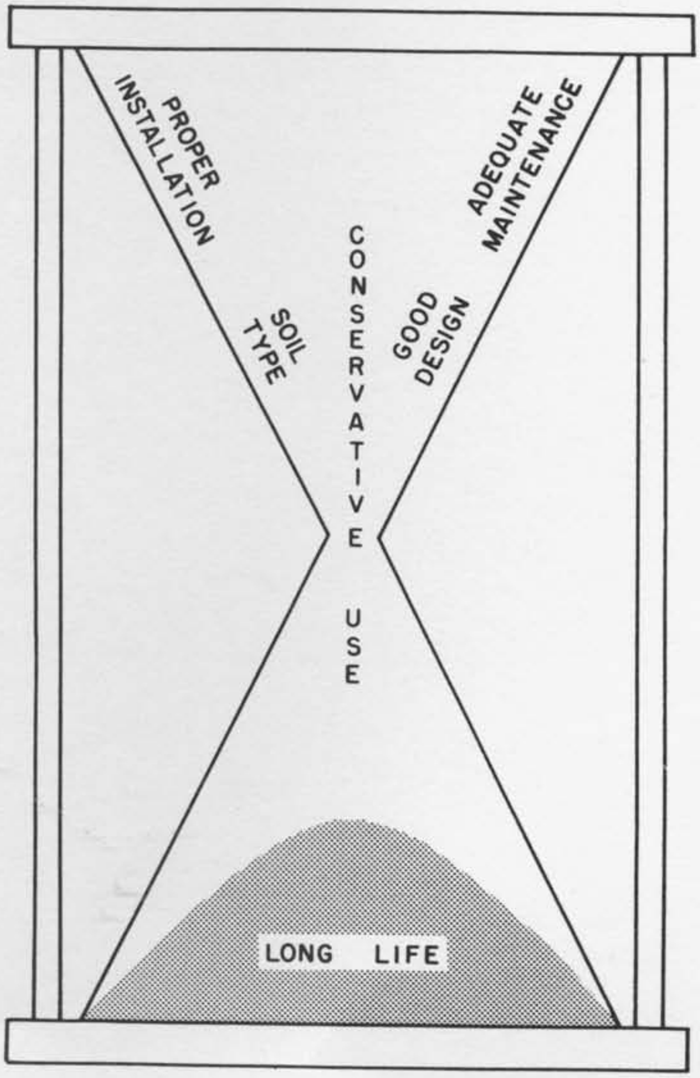
Longevity of septic systems in Connecticut soils



D. E. Hill
C. R. Frink

Bulletin 747
June 1974

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION • NEW HAVEN

ACKNOWLEDGEMENTS

The inventory of 2845 septic systems involving the collection of 8 different facts about each is no small task. For the inventory of the failing systems we are indebted to Mr. Richard Mihm, Science Department, Glastonbury High School, who guided the initial search of town records by honors students Terry Crowley, Court Donovan, Margie Flynn, Sally Parshley, and Mark Schneider.

We are indebted to many town officials and their staff in Glastonbury who made our task easier, notably: Richard Coppa, Frank Richardson and Mary Cooper of the Health Department; David MacArthur and Betty Perrin of the Assessor's Office; and Bernard Dion, Building Inspector.

We also thank the Glastonbury Town Plan and Zoning Commission for the base map and the US Soil Conservation Service for the composite soil survey map.

Finally, our special thanks to Carol Evans who capably assisted in the basic inventory, map interpretation, and data processing.

LONGEVITY OF SEPTIC SYSTEMS IN CONNECTICUT SOILS

David E. Hill and Charles R. Frink

INTRODUCTION

If a septic system design is based on accurate soil information, and the system is properly installed, used and maintained, it can serve its owner well, perhaps for decades.

Many septic systems, however, are doomed to failure by inadequate design, poor installation and the stresses placed upon them by misuse and improper maintenance. Little factual information is available, however, on the rate or extent of such failures.

For more than a decade, soil scientists and sanitary engineers have held that soil properties influenced not only the percolation rates used for design (Olson, 1964; Hill, 1966; Derr, Matelski, and Peterson, 1969) but also the performance of the systems after installation (Longwell and Springer, 1966; Huddleston and Olson, 1968; Mokma and Whiteside, 1972).

Other scientists have discussed the limitations of the percolation test (McGauhey and Winneberger, 1964) and have proposed other methods of evaluation of soil for septic design (Morris, Newbury, and Bartelli, 1962; Healy and Laak, 1972; Bouma et al., 1972).

Despite this effort devoted to testing and design, few have examined the longevity of systems actually used by homeowners. The only report that has come to our attention is a recent summary of the longevity of septic systems in Fairfax County, Virginia. In this report, Clayton (1973) expressed his amazement that systems, properly installed, lasted not 10 to 15 years as the records of failure suggested, but indeed twice as long when the successful systems were taken into account.

Since we have long been interested in evaluating soils for waste disposal, we examined the longevity of septic systems in a Connecticut town. Our objectives were six-fold:

- To develop a system for evaluating longevity of septic systems.

- To determine if systems installed in different soils have different longevities.

- To evaluate the effectiveness of repairs.

- To evaluate earlier changes in Connecticut's Health Codes.

- To determine if present interpretations of soil for septic systems are meaningful and correct.

- To identify problems that remain and to develop tactics that may solve them.

METHODS

The Sample

The study area was Glastonbury, Connecticut, a town of about 22,000 people located near the center of the state. It was especially suited for this study since it straddles the boundary between the Connecticut River Lowlands and the Eastern Highlands and includes representatives of about 70% of the dominant soil types found in Connecticut. A second important reason for choosing Glastonbury was the availability of Town Health Department records of post-1960 septic system failures that required repairs. These records, although dating back only 13 years, allowed us to infer failure rates before 1960 as we shall describe.

Although the study was town-wide, we excluded streets in the west central and north western sections where sewers were installed during 1968-1970. Also excluded were Main Street and the New London Turnpike where commercial buildings and old residences predominated. Little information was available on longevity of domestic septic systems in these areas because early records were scarce.

We make no claim that this is a random sample of septic systems installed in various soil types in Connecticut. For example, as the population increased in Glastonbury, houses were developed on the highlands as choice lots on the sandy lowlands became scarcer and land became costlier. Hence, our sample contains many older systems located in the lowlands and younger systems located in the highlands. Moreover, although the reporting requirement was established in 1960, its efficiency was undoubtedly low until the permit system became well known. Thus, some systems may have been repaired by the homeowner without a permit from the Health Department.

Finally, the leaching fields of septic systems vary in size depending on the percolation rate of the soil: coarse-textured soils require less area than do fine-textured soils. Hence, our results compare the longevity of systems installed in different soils with varying rather than uniform-sized leaching fields.

Despite these qualifications, however, we believe the data reveal many previously unknown factors affecting the longevity of septic tank systems.

The Inventory

Data collection was begun by several Glastonbury High School honors students. They painstakingly examined the records in the Town Health Department and recorded information about the 493 septic systems that had failed since 1960. The project eventually grew beyond the resources of even this enthusiastic group so data collection was continued by the staff of this Station. All information on each system was ultimately recorded on punch cards as follows:

- Failure or success
- Date of initial use
- Date of repair or complaint
- Longevity
- Soil type
- Percolation rate
- Multiple failure (where appropriate)
- Coded street address.

Failures. A "failure" was defined as a system that required enlargement of the leaching field or installation of a new one. Repairs of broken pipes and replacement of the septic tank or distribution box were not recorded as "failures". Failures that require permits for repair are recorded in the logs of the Health Department.

Often systems that have chronic problems during unfavorable weather are called to the attention of the Town Health Department. A separate record of these "complaints" is kept by the Health Director. About half of the complaints ultimately end in repair of the system. About 40% of the complaints are caused by ground water "drowning" the leaching field and are repaired by draining water away from the leaching field. These repairs do not require permits and would have been overlooked if only the repair files were examined. The remaining 10% were due to mechanical failures and were not recorded as "failures".

Successes. A "success" was defined as a system that operates satisfactorily or is endured by the owner without repair throughout the year. The Town Assessor's files were examined to determine and locate all homes with "successes" in the study area. The successes undoubtedly include some that failed before 1960 and were repaired. If failure rates before 1960 resembled those after 1960, 85 out of 1300 systems failed before 1960. We will treat the matter of these missing observations in more detail later.

Initial Use. The date of initial use was obtained from the Building Inspector's Office which issues certificates of occupancy (CO) for new houses. The date the certificate is issued closely corresponds to the initial occupancy of the house. When a CO was not available, we used the Building Permit (BP) data. The BP date reveals the approximate time that construction of the house began, but does not indicate when the house was occupied. To correct for this time lag, we drew a random sample of 100 house lots that had both BP and CO dates. Since the median interval between BP and CO dates was 5 months, we estimated the CO date by adding 5 months to the BP date when a CO was lacking.

Repairs and Complaints. The dates of repair or complaint are recorded in the appropriate files. We noted earlier that many complaints end in repair for which a permit is granted. In these cases we used the complaint date instead of the repair date to indicate the onset of failure.

Longevity. We defined the longevity of "failures" as the calculated age between the CO date and the repair or complaint date. Occupancy was assumed to be continuous. Although the Assessor's files showed that most houses in the study changed ownership at least once, the vast majority were vacant less than 1-month.

The longevity of "successes" was defined as the time between the CO date and July 1973. The longevities of systems installed during 1973 were not calculated. Many houses built before 1944 had neither BP nor CO dates. We simply identified these as pre-1944 houses and excluded them from calculations of longevity.

Although the reporting system was initiated in 1960, it was not in full operation until 1961. Hence, we have used the period 1961-1973 for our calculations of longevity.

Soil Type. The base map used had a 1:1,000 scale and was titled "Plan of Development, Town of Glastonbury - 1970". This map, prepared by Brown, Donald, and Donald Planning Services for the Town Planning Commission, shows all property lines on the Town Assessor's aerial maps of 1970. Lots subdivided and developed through 1973 were drawn on the map. Each house lot on the map was identified with the assessor's plot number.

An inventory of soils in Glastonbury was published in the Hartford County Soil Survey (Shearin and Hill, 1962). A composite of the published survey sheets prepared by the Soil Conservation Service was reproduced at the same scale as the map of the town on stable transparent Mylar. Because distortion of the aerial photographs, although slight, was amplified somewhat by increasing the scale, identification of the soil type on the soil map overlay corresponding to house lots on the base map required "fitting" to roads and other landmarks.

Although soil boundaries on the map bisected about 25% of the house lots, only half of those boundaries were between contrasting soils. The other boundaries separated different slopes. We assumed that most houses and their septic systems on lots less than one acre lie in the front half of the lot; hence, the soil type of the front half of the lot was assigned to the septic system. On large and irregular lots we located the house on the aerial photograph and recorded its position on the base map. No attempt was made to verify the soil type by site inspection. We assumed that the soil boundaries were correct within the errors reported in an earlier study of the accuracy of soil mapping (Hill, 1973).

Other Data. The remaining entries on the punch cards require little explanation. Where percolation tests had been conducted, the results were recorded as minutes per inch. Some systems have failed more than once since 1960 and were noted on the cards as MULT. Finally, the address, coded by street and house number, was entered to identify the card.

RESULTS AND DISCUSSION

We will analyze the data in two ways, first, comparing the number of failures with the number of successes to estimate longevity, and then examining the failures to learn causes of failure.

Longevity on All Soils

The failures and successes of 2845 systems are shown in Table 1. The systems that began operation each year can be called year-classes and form the vertical columns. The age of all systems form age-classes, which are shown in the horizontal rows. The 13-year record of failures during 1961-1973 is shown to the right of the diagonal line across the table.

To estimate longevity, we determined the average failure rate of all systems in each of the age classes during the 13-year span. Thus, counting horizontally from 1961 to 1973, we find that 11 systems or 0.9% of 1232 one-year-old systems failed. For the two-year-old systems, 18 of 1224 or 1.5% installed between 1960 and 1972 failed. The columns on the right summarize the 13-year average for systems up to 18 years of age.

The cumulative failure rate is shown in the extreme right column of Table 1. The calculations were continued through age-class 26 but are more variable since fewer years of record are available. Now we ask how this may be used to predict the longevity of septic tanks. The data are plotted on probability paper in Figure 1 and, with the exception of the first few years, follow a straight line. The goodness of fit to the straight line was determined by linear regression analysis after transformation of the cumulative percentages to probits (Bliss, 1967) which then are a linear function of the age-classes. The straight line accounts for nearly all the variability: the correlation coefficient $r^2 = 0.988$. Hence, if the past is any guide to the future, we expect these septic systems to continue failing at the rate shown by the slope of the line in Figure 1. This line intersects the 50% probability ordinate at 26.7 years; thus, half the systems should fail after this period of time.

The data can also be analyzed by year-classes, although we are hampered by ignorance of early failures of systems installed before 1960. To reconstruct this record of early failures, we proceeded as follows. If 0.9% of one-year old systems fail as shown in the right-hand column of Table 1, then in 1960, 0.9% of the 96 systems installed, or 0.86 systems, should have failed in one year. Similar calculations were applied for all systems back in 1944. New totals for failures were

TABLE 1. The rates of failure of septic systems

Age (Yrs)	*Pre '44*	*'44*	*'45*	*'46*	*'47*	*'48*	*'49*	*'50*	*'51*	*'52*	*'53*	*'54*	*'55*	*'56*	*'57*	*'58*	*'59*
1																	
2																1	1
3																	2
4																	
5														2	1		
6														4		1	
7												1		2	1	1	2
8										1		4	4	2	3	3	1
9									1		1			2	1	1	4
10									3		1			3	3	2	5
11								1		2		2	2	3	2		3
12								1	1	1	1	3	1		2	4	5
13										1	1		2	6	5	1	4
14								2	2	4	1	1	4	3	1	2	2
15						1		1			2		2	5	5	1	
16						1		1	1	1	1	1	3	2	1		
17			1		1		2	1		2	5	1	5	3			
18				1				2	2	4	1	3	1				
19								1	1	2	1	1					
20				1		1	3	1	2	2	1						
21		1				2	2	4	1								
22			1	1		2	2	3	3								
23								3									
24		1		1			2										
25				1	2	2											
26					1												
Failures	120	3	2	5	4	9	11	21	17	20	16	17	24	37	25	17	29
Total	462	10	4	8	13	39	38	56	69	69	81	75	118	142	138	87	108
% Failure	26	30	50	62	31	23	29	38	25	29	20	23	20	26	18	20	27

obtained, and the resulting percentages plotted as in Figure 1. Since this is an average rate across all year-classes, the resulting plot showed more scatter which we attribute to differences in weather, rainfall and the like. However, a straight line still fit the data well ($r^2 = 0.941$) and gave the same predicted half-life of 26.7 years. Had the failure rate been drastically different before 1960, this fit would not have been obtained.

Two features of Figure 1 invite further comment. First, if we project a line through the first 3 points representing failures during the first 3 years, its slope is very steep compared to the slope of the line projected through the points representing older age-classes. The rate of failure of very young systems then appears to be greater than the rate of failure after 3 years. In fact, these points were omitted from the statistical analysis because of this discrepancy. Second, this figure includes all soils but we suspect that failure rates are different on different soils.

in the town of Glastonbury, Connecticut.

'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	*Failures 13-Year Span*	*Total Systems 13-Year Span*	*Failure, %*	*Cumulative Failure, %*
		2		2		2	1			1	3			11	1232	0.9	0.9
			1		1	3	6	1	4	1	1			18	1224	1.5	2.4
1		2		1	1	2		1	1	1				12	1266	1.0	3.4
1			1	1		1		3						7	1279	0.5	3.9
	1	2	3	1	1	1	2	1						13	1348	1.0	4.9
2	1			1	2	1								12	1392	0.9	5.8
1	1	1	4	1	3	1								18	1375	1.3	7.1
2	4	4	4	2										33	1357	2.4	9.5
3	1	3	1											17	1327	1.3	10.8
2	2	1	2											21	1303	1.6	12.4
3		1												18	1268	1.4	13.8
1														20	1218	1.6	15.4
3														23	1162	2.0	19.4
														22	1116	2.0	19.4
														17	1033	1.6	21.0
														12	933	1.3	22.3
														21	850	2.5	24.8
														14	722	1.9	26.7
														6*	580	1.0	27.7
														11	462	2.4	30.1
														10	387	2.6	32.7
														12	306	3.9	36.6
														3	237	1.3	37.9
														4	168	2.4	40.3
														5	112	4.5	44.8
														1	74	1.4	46.2
19	10	16	16	9	8	11	9	6	5	3	4	–	–				
96	85	94	106	104	93	111	93	135	98	69	74	66	104				
20	12	17	15	9	9	10	10	4	5	4	5	0	0				

**Data below not for full 13-year span.*

Longevity in Different Soil Groups

Since many soil types have few systems, we classified all soils into 5 groups: those formed in well drained and moderately well drained soils in (1) terraces of stratified sand and gravel, (2) loose glacial till, (3) compact glacial till with "hardpan" within 3 feet of the surface, (4) soils with bedrock at shallow depth, and (5) all poorly drained and very poorly drained soils. The data in Table 1 were sorted into these five groups and analyzed by plotting on probability paper as before. The resulting fitted straight lines are shown in Figure 2. Differences among all five groups were statistically significant either in slope or position of the line. However, systems installed in poorly drained soils were intermediate between those in stratified sand and gravel (SG) and those in loose glacial till (LT) and were omitted from the graph for clarity. The results are summarized in Table 2 as the cumulative failures after 5, 10, 15, and 20 years and the extrapolated number of years for half of the systems to fail, i.e. the half-life. Expressing this in different terms for all soils, a newly installed system has about 1 chance in 17 of failing within the first 5 years, 1 chance in 9 of failing within 10 years, 1 chance

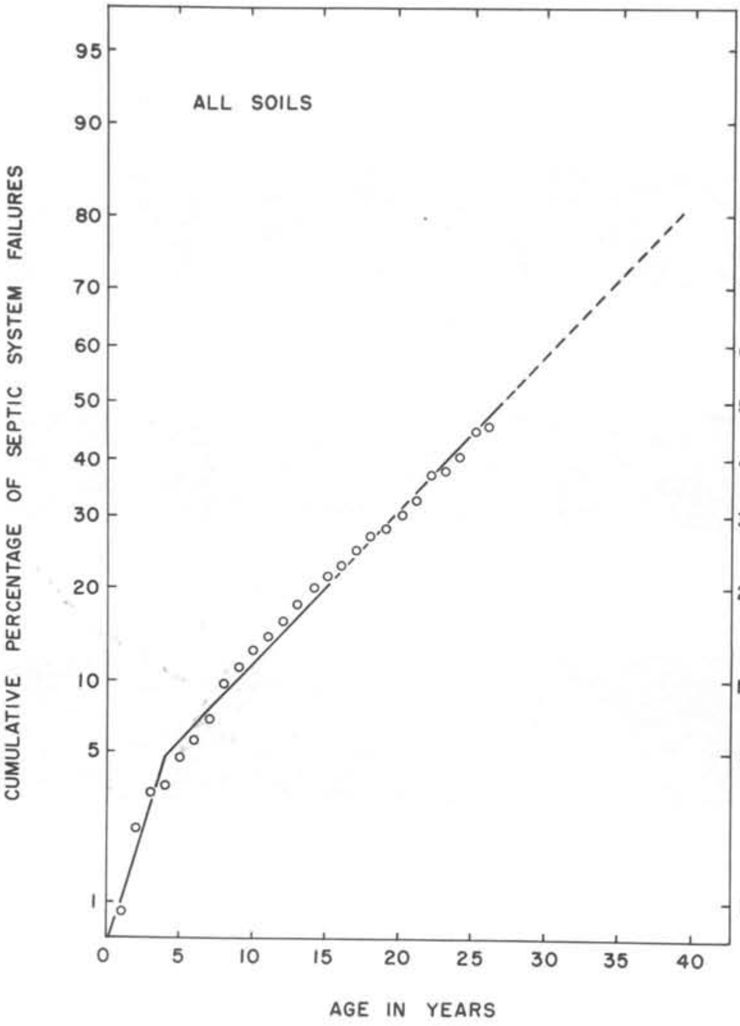


FIGURE 1. Rate of failure of septic systems in all soils. Dashed line projects failure rate beyond 26 years.

in 5 of failing within 15 years, 1 chance in 3 of failing within 20 years and 1 chance in 2 of failing after 27 years.

Looking at the results for the various soil groups, we see that in the first 5 years the failure of systems in stratified sand and gravel is less than in any other soil group. Only 1 in 30 failed. On the other hand, about 1 in 8 of all systems installed in compact glacial till failed within the first 5 years. This large percentage is due to a large number of very early failures, a subject we shall treat in more detail later. When very early failures are discounted, however, we note that systems installed in compact glacial till have the longest projected half-life, while those in loose glacial till have the shortest.

It can be noted from Figure 2, however, that the cumulative percentage of failures in compact glacial till is distinctly higher than the percentage of failures on loose glacial till up to 10 years of age and the remaining soil groups up to 20 years of age.

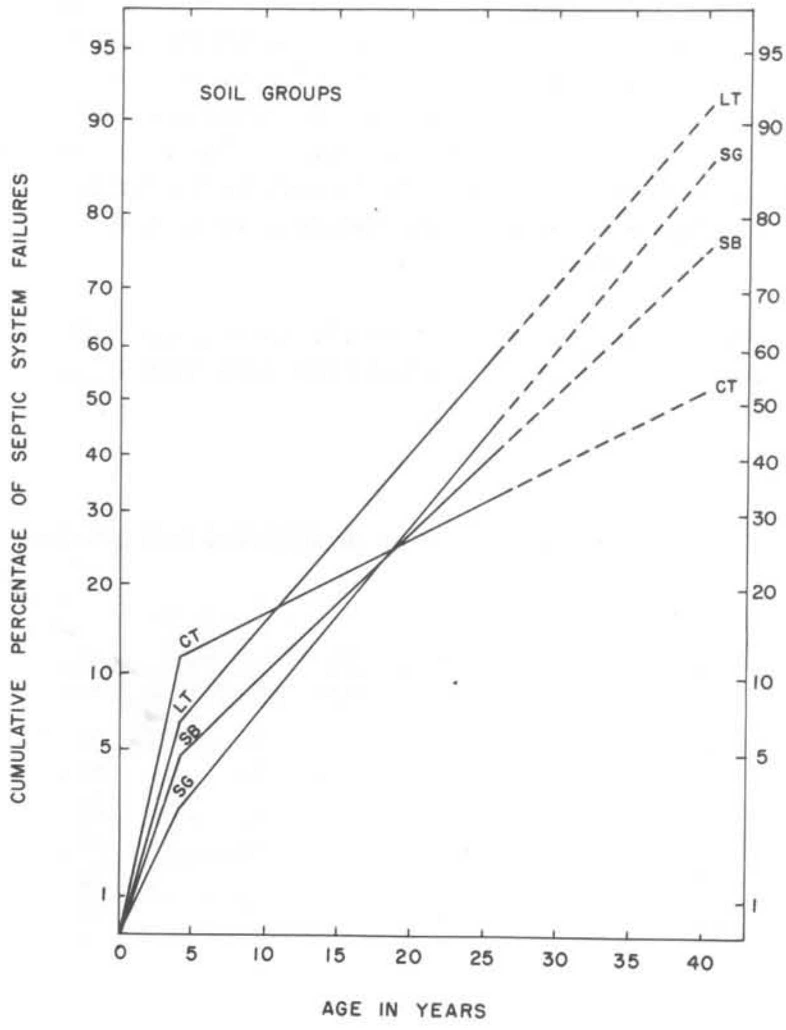


FIGURE 2. Rate of failure of septic systems in each soil group. Dashed line projects failure rate beyond 26 years.

LT = loose glacial till;
SG = stratified sand and gravel;
SB = shallow soils over bedrock;
CT = compact glacial till.

Thus, this analysis reveals two distinct problems: 1) early failure in systems installed in compact glacial till, and 2) a significantly shorter half-life for systems in loose glacial till. Having established reasonable estimates of longevity, we now examine the failures to determine their causes.

Premature Failure

Examination of Table 1 revealed that 31 systems or 2.0% of the 1523 systems installed since 1958 failed after less than 2 years. Table 2 revealed that a large percentage of these very early failures were associated with compact glacial till. To evaluate the causes of these premature failures we sought more detailed records on these systems. Recall that we eliminated the systems that failed because of known mechanical problems such as tilted and broken distribution boxes, broken pipes, and insufficient cover material, among others. The 31 that remained appeared to have problems related to the soil or to high ground water levels. Half of these systems were repaired by adding to the leaching field and half required ground water control. Only 1 failed a second time. We found more detailed records on 20 of the 31 systems that failed prematurely. With few exceptions, these systems were installed between June and November when water tables are normally low. Further, there was no record of ground water being observed when the percolation test and on-site inspection were performed. Percolation tests and on-site observations in deep pits during the wet spring months would probably have reduced the number of early failures especially in those systems installed in compact glacial till where perched water tables are common during the early spring. We must acknowledge, however, that an occasional spring occurs when perched water tables do not appear and that on-site testing would have to rely on other criteria such as the mottling of soil colors which would reveal high ground water levels during normal years.

Short Half-Life

Table 2 revealed that the shortest half-life occurs in loose glacial till. Over 80% of the percolation tests taken in loose glacial till had rates less than 5 min/in

TABLE 2. Longevity of septic systems installed in different soil groups.

	Sample size	*% Cumulative failure*				*Half-life (Years)*
		5-Year	*10-Year*	*15-Year*	*20-Year*	
All soils	2845	6	11	20	31	27
Stratified sand and gravel	1608	3	8	16	28	27
Loose glacial till	491	8	15	27	42	23
Compact glacial till	278	12	16	21	26	38
Shallow to bedrock	333	5	10	17	27	29
Poorly drained soils	129	7	14	23	36	25
Miscellaneous soils	6	–	–	–	–	–

TABLE 3. Rates of second failures.

	Year of Repair																	
Age	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	Total 2nd Failure	Total Repaired	Failure, %	Cumulative Failure, %
1						1	1			1			1		4	493	0.8	0.8
2								1			1	1			3	453	0.7	1.5
3				1							2				3	385	0.8	2.3
4															0	326	0.0	2.3
5			1	1			1	2							5	257	1.9	4.2
6						1									1	197	0.5	4.7
7			1	1		1									3	151	2.0	6.7
8			2												2	123	1.6	8.3
9		1		1	1										3	93	3.2	11.5
10																	0.0	11.5
11																	0.0	11.5
12																	0.0	11.5
2nd Failure	0	1	4	4	1	3	2	3	0	1	3	1	1	0	24			
Total Repairs	5	10	19	18	15	26	30	28	46	60	69	59	68	40	493			
Failure, %	0	10	21	22	7	12	7	11	0	2	4	2	2	0				

and required the smallest leaching area. Fully 95% of the rates in stratified sand and gravel were equally as fast. If we equate percolation rates with performance, then their performance should be approximately equal. Obviously they are not equal because Table 2 shows that their half-lives differ by 4 years. Why then are they different? The basic difference between the two soil groups is particle and pore size distribution. There is little mixing of different particle sizes in stratified sand and gravel. In glacial till, sand, silt and clay are usually mixed. Silt and clay may become smeared on the exposed surfaces of trenches, beds, and pits during excavation especially if the soil is wet. We can speculate that smeared surfaces of the leaching system prepared when soils are wet will contribute to earlier failure. Further, some soils that we normally associate with loose glacial till have a compact layer at a depth below 3 to 4 feet. Systems installed in these soils may flood with perched ground water causing early failure. Improvement in the longevity of systems installed in loose glacial till would require either greater care in preparation of soil surfaces exposed in trenches, beds, or pits to avoid smearing, or restrictions on installation when soil moisture contents are very high. Alternatively, increased design capacity irrespective of percolation test results could be required.

Effectiveness of Repair

We tested the effectiveness of repair by examining the longevity of the 493 systems that failed as recorded in Table 1. In effect, we treat them as new systems in Table 3 where the "year of initial use" becomes the "year of repair". Although we

TABLE 4. Failures of systems placed in use before and after 1961.

	1944–1960		*1961–1973*	
Soil Group	*Number of failures*	*Percent failures*	*Number of failures*	*Percent failures*
Stratified sand and gravel	164	26	33	5
Loose glacial till	52	32	30	11
Compact glacial till	18	16	14	12
Poorly drained soils	7	23	8	9
Shallow to bedrock soils	35	20	12	9
Miscellaneous soil types	0	0	0	0
Averages		25		8

consider them "new" systems, most are systems with added leaching area. To estimate the failure rate of repairs we determined the average rate of second failures for each age class. For example, from 1961 to 1973, 4 or 0.8% of 493 systems failed again during the first year. The columns on the right summarize the 13-year average. The cumulative average shows that 4% of the repaired systems fail after 5 years and nearly 12% fail after 10 years. Although we can extrapolate with less confidence beyond 10 years because the population of second failures is small, we estimate the half-life of first repairs to be about 21 years. Thus, repaired systems have a half-life that is 6 years less than new systems.

Now, we have another population of 24 systems that were repaired for a second time. Of these, 4 have failed a third time. The second repairs are too recent and few in number for analysis, but we can comment on the soils in which they are installed.

Among soil groups, 14 or 0.9% of all systems in stratified sand and gravel, failed twice; 4 or 0.8% failed in loose glacial till and 6 or 2.2% failed in compact glacial till. Moreover, 4 of 7 (Table 3) first repairs of systems that failed within 2 years were in compact till. Clearly, first repairs have been less effective in compact glacial till than in other soil groups.

We also know that 20 of the 24 systems that failed a second time were installed before 1961 when design requirements were one-third of current requirements. Repairs of pre-1961 systems did not always increase their size to 1961 minimum standards. In many lots, there was insufficient area to accomodate the 1961 design standards. Thus one might expect that second failures should proceed at a faster rate than first failures, and they do. Repairs of pre-1961 systems on lots that can accomodate the 1961 design capacity should improve the longevity of the repaired systems.

Design Changes

The design of septic leaching fields was substantially altered in 1961 to increase their size. To illustrate, if the soil percolation rate was faster than 5 min/in the requirement was 25 sq ft of absorptive area per person before 1961 (Conn. Dept. Health - 1958). Thus, a household of 5 required 125 sq ft of leaching field. Under present regulations a soil with the same percolation rate now requires 375 sq ft of effective leaching area for a household with 3 bedrooms or less (Conn. Dept. Health, 1964). Thus, requirements essentially tripled. Has this had an effect on the performance of septic system leaching fields?

To evaluate the effectiveness of the increased requirements, we divided the septic systems into two age groups; those that were placed in use between 1944 and 1960 and those in use after 1960. Table 4 shows that of the systems installed before 1961 in soils developed on stratified sand and gravel terraces, loose glacial till, and poorly drained soils, 23 to 32% failed. Records of percolation tests revealed that 95% of these soils had rates less than 5 min/in and would have required the smallest leaching area. On the other hand, 16% of the systems installed in compact glacial till before 1961 ended in failure. The percolation test data revealed that 75% of the successful systems in compact glacial till had percolation rates that required at least a doubling of the minimum leaching area. Of the systems that failed in this soil group, 90% had percolation rates faster than 5 min/in thus requiring the minimum leaching area. Percolation rates faster than 5 min/in are not consistent with known rates in compact glacial till although small inclusions of more permeable soil materials in the compact till are known.

From the pre-1961 data, it appears that many failures were due to inadequately designed systems. The new codes of 1961 increased leaching area requirements and an analysis of the post-1961 data of Table 4 shows the percent failures are significantly lower in each soil group. This, of course, is a natural consequence of fewer failures in a younger population. It is important to note, however, that the ranking of the systems has changed in comparison to the ranking before 1961.

Before 1961, systems installed in compact glacial till were failing much slower than the average, while those in loose till were failing much faster. After 1961, systems installed in stratified sand and gravel showed the greatest improvement and were the only group failing at less than the average rate. Thus, increasing the size of leaching fields in 1961 improved systems installed in stratified sand and gravel more than in any other soil group.

Since our earlier analysis (Fig. 1) indicated that there were no detectable differences in overall rates of failure before and after 1961, this conclusion seems contradictory. We again examined the systems installed on stratified sand and gravel to determine if this change could be detected by a different analysis. If the population is divided into age classes of uniform size before and after 1961, and compared by linear regression, the slope of the line for the post-1961 samples is about 10 percent less. However, this change was not statistically significant. Hence, we conclude that any improvements due to design changes are modest at best and cannot yet be confirmed by statistical analysis.

Weather

Septic systems often fail temporarily during late winter and early spring thaws and during prolonged rain. All operating drainfields have biological and chemical crusts that coat the soil in contact with the leaching field. This crust filters the effluent as it passes into the soil. The permeability of these crusts is usually less than the soil and causes a reservoir of effluent to build up in the leaching system beneath the surface. Meanwhile, drainage of large soil pores beyond the crust continues (Bouma, 1972). A temporary failure occurs when the large soil pores surrounding the drainfield become fully saturated with rain or melt water. The drainfield then becomes completely filled with effluent and either retards flow of wastes from the house or erupts on the surface of the ground. Cessation of the rain or complete thawing of the frost table allows the large soil pores to drain and effluent once again flows through the filtering crust into the smaller pores. Thickening of the biochemical crust usually reduces its permeability. When the permeability of the thickening crust becomes low enough failure results because water cannot pass into the surrounding soil as fast as it is received from the house. Do prolonged rains and extended thaw favor thickening of the biochemical crust under anaerobic conditions, and lead to failure?

We can look to weather records to determine if failures during abnormally wet years produced abnormal numbers of failures or if abnormally dry years produced subnormal numbers of failures. During the 13-year period there were three unusual years of weather. Both 1965 and 1966 are remembered for their droughts, and 1972 was extremely wet. The numbers of repairs in each year since 1961 are shown in Table 5. There were 26 and 30 repairs in the dry years of 1965 and 1966, and 68 repairs in the wet year 1972. Although one could easily speculate that high rainfall caused failures, the total numbers of systems was also increasing and produced a greater number of failures.

The percentage failure must be compared around each of those specific years. The percentage varies little around the dry years of 1965 and 1966. Similarly the percentage in wet 1972 is only slightly higher than normal 1971 and less wet 1973. Evidently abnormally wet years do not hasten the demise of systems.

The effect of a dry year may be more subtle. Dry years do not appear to cause fewer failures, but high water tables may not be observed during dry years. Systems installed then do not have ground water control included in their design. When rainfall returns to normal the water table may rise above the base of the leaching field and cause the system to fail prematurely. To illustrate, Table 1 shows that 5 systems of year-class 1966 and 7 systems of year-class 1967 failed during the first two years. Virtually all of these systems were installed during dry

TABLE 5. Numbers of repairs and percent failure in each year since 1961.

Year	*Number of failures*	*Percent failures*	*Year*	*Number of failures*	*Percent failures*
1961	10	0.6	1968	46	1.9
1962	19	1.1	1969	60	2.4
1963	18	0.9	1970	69	2.6
1964	15	0.7	1971	59	2.2
1965	26	1.2	1972	68	2.5
1966	30	1.4	1973	40	1.4
1967	28	1.2			

1965 and 1966. Failure must have been due to a high water table because the repair of 8 of 12 required ground water control.

The effect of weather on the life expectancy of a septic tank system appears to be more complex than one might first imagine. Inspection of Table 1 shows that failures in year-class 1956 were more frequent, by far, than in any other year-class. Many of these systems were actually installed in the fall of 1955. The torrential rains of hurricane Diane in August and a continental storm in October 1955 are well remembered by the Southern New Englanders who endured their wrath. Over 22 inches of rain more than normal fell in the latter part of the year, saturating the soil for prolonged periods.

The greatest number of failures for any year-class occurring in systems installed during the wettest period on record seems more than coincidental. Excavation of drainfields in very wet soils produces soil faces that are smeared and puddled by bulldozer and back hoe. Smeared walls and bases of trenches, beds, and pits reduce the infiltrative capacity.

In the future, we shall look very closely at year-class 1972 for it too was a year of record rainfall (21 inches above normal). Hence, systems installed in 1972 were placed in very wet soil and conditions were ripe for smearing of soil faces during construction.

Soil Interpretative Ratings

Soil scientists rate the engineering properties of soils as slight, moderate, or severe for various uses including on-site sewage disposal. The rating classes are based upon severity of limitations imposed both by soil properties and by landscape characteristics. Definitions of the classes imply favorable performance provided limitations can be overcome by suitable treatments. For example, favorable properties for leaching fields in soils with slight limitations include rapid permeability, adequate depth to water table and bedrock, modest slope, few stones and boulders, and not flooded. Soils rated severe have slow permeabilities, shallow depths to bedrock and water table, steep slopes, extreme stoniness, and are prone to flooding. Installation of systems under these unfavorable conditions requires special design. Without it, in all probability, their performance would be poor.

The interpretative ratings are based on a national system in which each mapping unit is evaluated for up to 9 soil properties and landscape characteristics (SCS-1971). The rating class assigned to the mapping unit is the lowest rating for any 1 of the 9 properties evaluated. For example, the mapping unit Charlton fine sandy loam, 8-15% slope, may be rated slight for hydraulic conductivity rate, drainage class, depth to bedrock and stoniness but its slope has a moderate limitation. Thus, the overall rating for this mapping unit is moderate.

Heretofore, data have not been available to determine whether the rating scheme is consistent with actual performance. Hence, we examined the performance of Glastonbury's septic systems relative to each factor alleged to influence performance. Table 6 shows that performance was poorer in soils rated slight than in those rated severe, while performance in those rated moderate was generally intermediate. Although we realize that the age distribution of septic systems installed in Glastonbury is skewed toward older systems in soils with only slight limitations, it appears that the current rating of soils is not consistent with performance.

Why is this so? Remember that the rating system implies that limitations can be corrected by special design. Leaching fields installed in soils with slow permeability will be larger and those installed where ground water is known to be high will have ground water drains or fill added as an element of design. Hence

TABLE 6. Percent failure of septic systems in each rating class for several soil factors.

Soil Factor	*Rating Class*		
	Slight	*Moderate*	*Severe*
Saturated permeability	> 2.0 in/hr	0.8 – 2.0 in/hr	< 0.8 in/hr
% Failure	18	16	13
Drainage class	Excessively to well drained	Moderately well drained	Poorly and very poorly drained
% Failure	18	15	14
Slope	0 – 8%	8 – 15%	> 15%
% Failure	19	15	17
Depth to bedrock	> 72"	48 – 72"	< 48"
% Failure	18	*	16
Stoniness class	Non-stony and stony	Very stony	Extremely stony
% Failure	18	15	*

**Soil maps for Glastonbury do not identify areas that are moderately deep to bedrock or extremely stony.*

their performance should be better than those without special design features. We have already determined that systems installed in compact glacial till, although rated severe, have long half-lives (38 years) and their performance is satisfactory once past the critical early years.

Hence, in terms of longevity, the severe limitations were more than offset by improved design. On the other hand, failure to detect high ground water caused many early failures so the severe limitation still seems appropriate. In contrast, systems installed in loose glacial till are generally rated slight for all soil factors but their half-lives are 15 years less than those in compact till. We attribute this in part to inadequate design caused by difficulties of installations during wet weather that merit a change in the rating of these soils to moderate.

Thus, it appears that we can quantify the present interpretative ratings of slight, moderate and severe by including numerical estimates of early failures and predicted half-lives. The following class limits are proposed:

	Severity of limitations		
Performance criteria	*Slight*	*Moderate*	*Severe*
% failure in first 5-year span	< 5%	5–10%	> 10%
Half-life, Years	> 25	15–25	< 15

How would this affect Connecticut's current interpretive ratings? The only important change would occur in soils formed in loose till. Their overall rating of "slight" would be altered to "moderate" because the half-lives of soils in this group are less than 25 years. No Connecticut soils would be rated severe for half-life because no soil groups had half-lives less than 15 years, but the overall ratings for soils in compact till would remain severe. Although their half-life exceeds 25 years and would carry a "slight" rating, the fact that greater than 10% of systems fail within 5 years after installation places them in "severe".

Systems installed in soils with moderate or severe performance limitations may require special design requirements such as increased leaching area in loose till to compensate for smearing of silt and clay during excavation. They also may require special regulations governing collection of test data and installation of systems such as limiting percolation testing and evaluation of deep observation holes in early spring or restricting installation of systems when soils are very wet.

SUMMARY

An analysis of septic systems in Glastonbury, Connecticut revealed that 493 of 2845 systems failed since 1960. Examination of the failures of each age-class (population of systems one year old, two years old, etc.) for all systems revealed that the half-life for all systems is 27 years. There is a 6, 11, 20 and 31% chance that systems 5, 10, 15 and 20 years old respectively will fail.

After dividing the population into 5 soil groups, we identified two distinct problems; many early failures were in systems installed in compact glacial till and there was a short half-life for systems in loose glacial till. Half-lives ranged from 23 years in loose glacial till to 38 years in compact glacial till.

Testing the effectiveness of first repairs, we found that their rate of failure is greater than in initial installations and their half-life is 21 years or 6 years less than initial installations.

Requirements for drainfields increased almost three-fold in 1961. The increased requirements seem to have benefited systems installed in stratified sand and gravel most because they required the smallest leaching area under the old design criteria. There seems to be a modest 10% improvement in longevity of septic tanks in stratified sand and gravel after 1961 but we suspect that it is too early to determine the full impact of these design changes on longevity.

The effect of weather seems two-fold. The rate of failure of operating systems is not greater in wet years. Prolonged rains do, however, affect the longevity of systems installed in wet years. The fall of 1955 is well remembered for two epic storms which saturated Connecticut's soils with over 22 inches of rain. Systems installed late in 1955 had the greatest numbers of failures of all years. Systems installed in saturated soil are prone to smearing of silt and clay on the faces of the leaching system and thus to decreases in its permeability. Percolation tests and deep observations conducted during dry seasons may not detect maximum ground water levels.

The records of Glastonbury's septic systems reveal 1) premature failure of systems installed in compact glacial till, 2) high rates of failure in loose glacial till, 3) more frequent failures of repaired systems than the original installations, and 4) frequent failure of systems installed in very wet years. These findings suggest several corrective measures:

- Percolation testing in early spring when water tables are normally (but not always) highest should reduce numbers of premature failures due to "drowning" of the leaching field.
- Systems installed in loose glacial till apparently require either greater absorptive area irrespective of percolation test results or greater care in preparing the leaching system to avoid smearing of soil faces.
- Delay in installation and repair of systems in all soils with appreciable silt and clay until they fully drain should help minimize smearing.

- Repair of systems installed before 1961 may be more effective if the leaching area is increased to present standards where land is available.
- Leaching field sizes should be based on percolation tests, deep observations, and knowledge of soil type.

Finally, testing of the engineering rating system of soils for on-site sewage disposal revealed that the present ratings of slight, moderate and severe are not entirely consistent with performance. The short half-life of septic systems on loose glacial till suggests their rating be increased from slight to moderate. Furthermore, we propose that the interpretative ratings be quantified by including numerical estimates of early failures and predicted half-lives.

REFERENCES

1. Bliss, C.I. 1967. Statistics in Biology Vol. I. McGraw-Hill, New York, 558p.
2. Bouma, J. et al. 1972. Soil absorption of septic tank effluent. Univ. of Wisconsin. Extension Inf. Circ. 20. 235p.
3. Clayton, J.W. 1973. An analysis of septic tank survival data in Fairfax County, Virginia 1952-1972. Groundwater Jour. May-June 1973:29-32. National Water Well Assn.
4. Conn. State Dept. Health. 1958. Sewage disposal. Hartford, Conn. 31p.
5. Conn. State Dept. Health. 1964. Private subsurface sewage disposal. Hartford, Conn. 30p.
6. Derr, B.D., Matelski, R.P. and Peterson, G.W. 1969. Soil factors influencing percolation test performance. Soil Sci. Soc. Amer. Proc. 33:942-946.
7. Healy, K.A. and Laak, R. 1972. Factors affecting the percolation test. School of Engr. Rpt., Univ. of Conn. 25p.
8. Hill, D.E. 1966. Percolation testing for septic tank drainage. Conn. Agr. Exp. Sta. Bul. 678. 25p.
9. Hill, D.E. 1973. Inland wetland soils. Proc. Conn. Inland Wetland Conf. Inst. Water Resources, Univ. of Conn., 30-39.
10. Huddleston, J.H. and Olson, G.W. 1967. Soil survey interpretations for subsurface sewage disposal. Soil Sci. 104:401-409.
11. Longwell, T.J. and Springer, M.E. 1966. Percolation rates of soils aid in predicting suitability for septic tank disposal fields. Tenn. Farm and Home Science Prog. Rpt. 60:2-4.
12. McGauhey, P.H. and Winneberger, J.H. 1964. Causes and prevention of failure of septic-tank percolation systems. F.H.A. Tech. Studies Rpt. 533 66p.
13. Mokma, D.L. and Whiteside, E.P. 1972. Performance of septic tank disposal fields in representative Michigan soils. Mich. State Univ. Res. Rpt. 157. 15p.
14. Morris, J.G., Newbury, R.L. and Bartelli, L.J. 1962. For septic tank design, soil maps can substitute for percolation tests. Public Works. Feb.:106-107.
15. Olson, G.W. 1964. Application of soil survey to problems of health, sanitation, and engineering. Cornell Univ. Memoir 387. 77p.
16. Shearin, A.E. and Hill, D.E. 1962. Soil survey of Hartford County, Conn. U.S.D.A., SCS Series 1958, No. 14. 126p.
17. Soil Conservation Service. 1971. Guide for interpreting engineering uses of soils. Washington, D.C. 87p.

THE CONNECTICUT
AGRICULTURAL EXPERIMENT STATION
NEW HAVEN, CONNECTICUT 06504

Paul E Waggoner
Director

PUBLICATION
PENALTY FOR PRIVATE USE, $300

An Equal Opportunity Employer

POSTAGE PAID
U.S. DEPARTMENT OF
AGRICULTURE
AGR 101

U.S.MAIL