GUIDANCE FOR DESIGN
OF
LARGE-SCALE
ON-SITE WASTEWATER RENOVATION SYSTEMS

TABLE OF APPENDICES

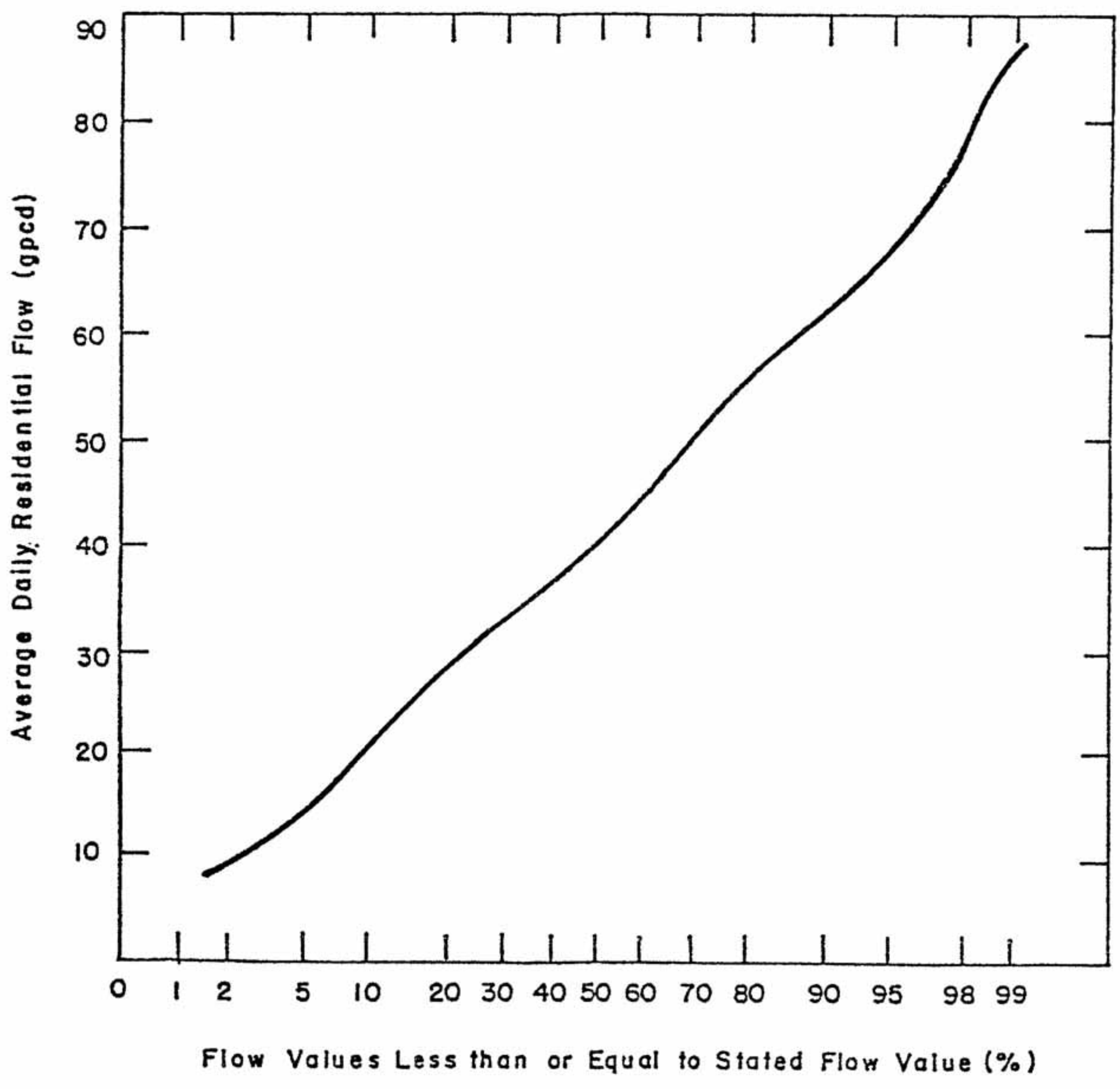
APPENDIX A

WASTEWATER FLOW DATA

From

SEEPAGE AND POLLUTANT RENOVATION
ANALYSIS FOR LAND TREATMENT, SEWAGE DISPOSAL SYSTEMS.
CT. DEPT. OF ENVIRONMENTAL PROTECTION
Healy, K.A. and R. May -1982

Frequency Distribution for Average Daily
Residential Water Use/Waste Flows



From: Healy, K.A. and R. May. 1982. Seepage and Pollutant Renovation - Analysis For Land Treatment, Sewage Disposal Systems. CT. Dept. of Environmental Protection

TABLE 5

Summary of Average Daily Residential Wastewater Flows

Study	No. of Residences	Duration of Study months	Wastewater Flow: Study Average gpcd	Wastewater Flow: Range of Individual Residence Averages gpcd
Linaweaver, et al.	22	-	49	36 - 66
Anderson and Watson	18	4	44	18 - 69
Watson, et al.	3	2-12	53	25 - 65
Cohen and Wallman	8	6	52	37.8 - 101.6
Laak	5	24	41.4	26.3 - 65.4
Bennett and Linstedt	5	0.5	44.5	31.8 - 82.5
Siegrist, et al.	11	1	42.6	25.4 - 56.9
Otis	21	12	36	8 - 71
Duffy	16	12	42.3	-
		Weighted Average	44	

From: Healy, K.A. and R. May 1982. Seepage and Pollutant Renovation - Analysis for Land Treatment, Sewage Disposal System. Connecticut Department of Environmental Protection.

TABLE 7

Residential Water Use by Activity[a]

Activity	Gal/use	Uses/cap/day	gpcd[b]
Toilet Flush	4.3 4.0 - 5.0	3.5 2.3 - 4.1	16.2 9.2 - 20.0
Bathing	24.5 21.4 - 27.2	0.43 0.32 - 0.50	9.2 6.3 - 12.5
Clothes washing	37.4 33.5 - 40.0	.29 0.25 - 0.31	10.0 7.4 - 11.6
Dish washing	8.8 7.0 - 12.5	0.35 0.15 - 0.50	3.2 1.1 - 4.9
Garbage Grinding	2.0 2.0 - 2.1	0.58 0.4 - 0.75	1.2 0.8 - 1.5
Miscellaneous	-	-	6.6 5.7 - 8.0
Total	-	-	45.6 41.4 - 52.0

[a] Mean and ranges
[b] gpcd may not equal gal/use multiplied by uses/cap/day due to difference in the number of study averages used to compute the mean and ranges shown.

From: Healy, K.A. and R. May 1982. Seepage and Pollutant Renovation - Analysis for Land Treatment, Sewage Disposal System. Connecticut Department of Environmental Protection.

TABLE 8

Typical Wastewater Flows from Commercial Sources

Source	Unit	Wastewater Flow Range (gpd/unit)	Wastewater Flow Typical (gpd/unit)
Airport	Passenger	2.1 - 4.0	2.6
Automobile Service Station	Vehicle Served	7.9 - 13.2	10.6
	Employee	9.2 - 15.8	13.2
Bar	Customer	1.3 - 5.3	2.1
	Employee	10.6 - 15.8	13.2
Hotel	Guest	39.6 - 58.0	50.1
	Employee	7.9 - 13.2	10.6
Industrial Building (excluding industry and cafeteria)	Employee	7.9 - 17.2	14.5
Laundry (Self Service)	Machine	475 - 686	580
	Wash	47.5 -52.8	50.1
Motel	Person	23.8 - 39.6	31.7
Motel with Kitchen	Person	50.2 - 58.1	52.8
Office	Employee	7.9 - 17.2	14.5
Restaurant	Meal	2.1 - 4.0	2.6
Rooming House	Resident	23.8 - 50.1	39.6
Store, Department	Toilet Room	423 - 634	528
	Employee	7.9 - 13.2	10.6
Shopping Center	Parking Space	0.5 - 2.1	1.1
	Employee	7.9 - 13.2	10.6

From: Healy, K.A. and R. May 1982. Seepage and Pollutant Renovation - Analysis for Land Treatment, Sewage Disposal System. Connecticut Department of Environmental Protection.

TABLE 9

Typical Wastewater Flows from Institutional Sources

Source	Unit	Wastewater Flow Range	Wastewater Flow Typical
		gpd/unit	gpd/unit
Hospital, Medical	Bed	132.0 - 251.0	172.0
	Employee	5.3 - 15.9	10.6
Hospital, Mental	Bed	79.4 - 172.0	106.0
	Employee	5.3 - 15.9	10.6
Prison	Inmate	79.3 - 159.0	119.0
	Employee	5.3 - 15.9	10.6
Rest Home	Resident	52.8 - 119.0	92.5
	Employee	5.3 - 15.9	10.6
School, Day:			
With Cafeteria, Gym, Showers	Student	15.9 - 30.4	21.1
With Cafeteria Only	Student	10.6 - 21.1	15.9
Without Cafeteria, Gym, Showers	Student	5.3 - 17.2	10.6
School, Boarding	Student	52.8 - 106.0	74.0

From: Healy, K.A. and R. May 1982. Seepage and Pollutant Renovation - Analysis for Land Treatment, Sewage Disposal System. Connecticut Department of Environmental Protection.

TABLE 10

Typical Waste Water Flows from Recreational Sources

Source	Unit	Wastewater Flow Range	Typical
		gpd/unit	
Apartment, Resort	Person	52.8	58.1
Cabin, Resort	Person	34.3 - 50.2	42.3
Cafeteria	Customer	1.1 - 2.6	1.6
	Employee	7.9 - 13.2	10.6
Campground	Person	21.1 - 39.6	31.7
Cocktail Lounge	Seat	13.2 - 26.4	19.8
Coffee Shop	Customer	4.0 - 7.9	5.3
	Employee	7.9 - 13.2	10.6
Country Club	Member Present	66.0 - 132.0	106.0
	Employee	10.6 - 15.9	13.2
Day Camp (no meals)	Person	10.6 - 15.9	13.2
Dining Hall	Meal Served	4.0 - 13.2	7.9
Dormitory, Bunkhouse	Person	19.8 - 46.2	39.6
Hotel, resort	Person	39.6 - 63.4	52.8
Laundromat	Machine	476.0 - 687.0	581.0
Store Resort	Customer	1.3 - 5.3	2.6
	Employee	7.9 - 13.2	10.6
Swimming Pool	Customer	5.3 - 13.2	10.6
	Employee	7.9 - 13.2	10.6
Theater	Seat	2.6 - 4.0	2.6
Visitor Center	Visitor	4.0 - 7.9	5.3

From: Healy, K.A. and R. May 1982. Seepage and Pollutant Renovation - Analysis for Land Treatment, Sewage Disposal System. Connecticut Department of Environmental Protection.

APPENDIX B

SOIL TEXTURAL CLASSIFICATION SYSTEM

U.S. Department of Agriculture
Natural Resources Conservation Service

APPENDIX B

U.S.D.A. SOIL TEXTURAL CLASSIFICATION SYSTEM

(1) Soil texture is a term commonly used to designate the proportionate distribution of different sized mineral particles in a soil material. The three basic sizes of soil mineral particles are the sand size, the silt size and the clay size. The sand size class is subdivided further into the subclasses of very coarse sand, coarse sand, medium sand, fine sand, and very fine sand. Individual particles, based on their size, are grouped into separates. These soil separates are classified by size into the groupings shown below:

Soil Separates	Diameter Limit in Millimeters:
Very coarse sand	2.00 - 1.00
Coarse sand	1.00 - 0.50
Medium sand	0.50 - 0.25
Fine sand	0.25 - 0.10
Very fine sand	0.10 - 0.05
Silt	0.05 - 0.002
Clay less than	0.002

(2) Major soil texture classifications and some of the characteristics which can be utilized in the field for identification of these soil texture groups is accomplished primarily by rubbing moist samples of soil material between the fingers and observing how the material feels.

(a) Sand - Sand feels extremely gritty and does not form a ribbon or ball when wet or moist. A sand is loose and single grained. The individual grains can readily be seen or felt.

(b) Loamy sand - Loamy sand feels extremely gritty and forms a weak ball that cannot be handled without breaking.

(c) Sandy loam - A sandy loam feels extremely gritty and slightly sticky. When moist, it forms a cast that will bear careful handling without breaking.

(d) Loam - A loam feels somewhat gritty, yet fairly smooth and slightly plastic. When moist, it forms a cast that may be handled quite freely without breaking. Loam forms only short ribbons about 0.25 inch to 0.50 inches in length.

(e) Silt loam - Silt loam lacks grittiness and feels extremely floury when moist or dry. When dry it may appear cloddy but the lumps can be readily broken. When moist it will form casts that can be freely handled without breaking. It will not form a ribbon but will give a broken appearance.

(f) Silt - Silt lacks grittiness and feels extremely floury when moist or dry. It will not ribbon and forms a weak ball that will tolerate careful handling without breaking.

(g) Sandy clay loam - sandy clay loam feels very gritty and sticky. When moist it forms a firm ball and may form a ribbon of one to two inches before it breaks.

(h) Clay loam - A clay loam feels very sticky with little or no grittiness. When moist it will form a ribbon that is about one to two inches long. The moist soil is plastic and will form a cast or ball that will bear much handling. When kneaded in the hand it does not crumble readily but tends to work into a heavy compact mass.

(i) Sandy clay - Sandy clay feels extremely sticky and very gritty. When moist and forms a firm ball and produces a ribbon that is over two inches in length before breaking.

(j) Silty clay - Silty clay feels both plastic and extremely sticky when moist and lacks any gritty feeling. It forms a firm ball and readily ribbons to over two inches in length before it breaks.

(k) Clay - A clay feels extremely sticky and is neither gritty nor floury. When moist it forms a ribbon over two inches in length before breaking. It will form a hard ball or cast which will not break when handled.

(l) Organic soils - Muck peat, and mucky peat are used in place of textural class names in organic soils. Muck is well-decomposed organic soil material; peat consists of raw un-decomposed organic soil material; and mucky peat designates materials intermediate in decomposition between muck and peat.

(3) Definitions of the soil texture classes according to distribution of size classes of mineral particles ≤ 2 millimeters in diameter are as follows[1]:

(a) Sands - 85 percent or more sand and the percentage of silt plus 1 1/2 times the percentage of clay is 15 or less.

1. Coarse sand - 25 percent or more very coarse and coarse sand and less than 50 percent any other single grade of sand.

2. Sand - 25 percent or more very coarse, coarse and medium sand, but less than 25 percent very coarse and coarse sand, and less than 50 percent either fine sand or very fine sand.

[1] The U.S. Department of Agriculture, Natural Resources Conservation Service "Soil Texture Triangle" shown on the following page provide a graphical means of classifying the fine soil (≤ 2 mm).fractions.

3. Fine sand - 50 percent or more fine sand; or less than 25 percent very coarse, coarse, and medium sand and less than 50 percent very fine sand.

4. Very fine sand - 50 percent or more very fine sand.

(b) Loamy sands - At the upper limit 85 to 90 percent sand and the percentage of silt plus 1 1/2 times the percentage of clay is 15 or more; at the lower limit 70 to 85 percent sand and the percentage of silt plus twice the percentage of clay is 30 or less.

1. Loamy coarse sand - 25 percent or more very coarse and coarse sand and less than 50 percent any other single grade of sand.

2. Loamy sand - 25 percent or more very coarse, coarse, and medium sand and less than 50 percent either fine sand or very fine sand.

3. Loamy fine sand - 50 percent or more fine sand; or less than 50 percent very fine sand and less than 25 percent very coarse, coarse, and medium sand.

4. Loamy very fine sand - 50 percent or more very fine sand.

(c) Sandy loams - 20 percent or less clay and 52 percent or more sand and the percentage of silt plus twice the percentage of clay exceeds 30; or less than 7 percent clay, less than 50 percent silt, and between 43 and 52 percent sand.

1. Coarse sandy loam - 25 percent or more very coarse and coarse sand and less than 50 percent any other single grade of sand.

2. Sandy loam - 30 percent or more very coarse, coarse, and medium sand, but less than 25 percent very coarse and coarse sand, and less than 30 percent either fine sand or very fine sand.

3. Fine sandy loam - 30 percent or more fine sand and less than 30 percent very fine sand; or between 15 and 30 percent very coarse, coarse, and medium sand; or more than 40 percent fine and very fine sand, at least half of which is fine sand, and less than 15 percent very coarse, coarse, and medium sand.

4. Very fine sandy loam - 30 percent or more very fine sand; or more than 40 percent fine and very fine sand, at least half of which is very fine sand, and less than 15 percent very coarse, coarse, and medium sand.

(d) Loam - 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand.

(e) Silt loam - 50 percent or more silt and 12 to 27 percent clay; or 50 to 80 percent silt and less than 12 percent clay.

(f) Silt - 80 percent or more silt and less than 12 percent clay.

(g) Sandy clay loam - 20 to 35 percent clay, less than 28 percent silt, and 45 percent or more sand.

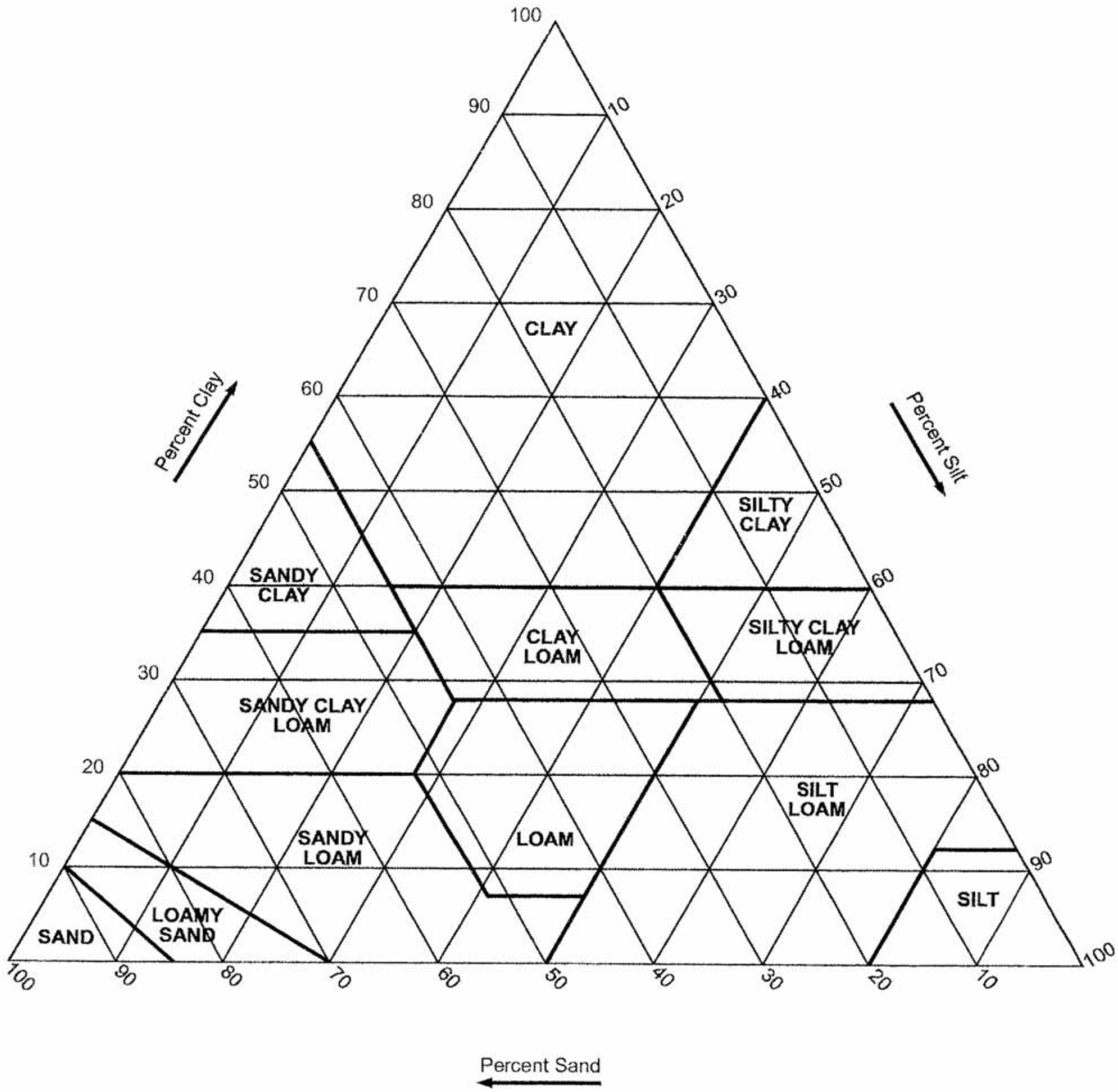
(h) Clay loam - 27 to 40 percent clay and 20 to 45 percent sand.

(i) Silty clay loam - 27 to 40 percent clay and less than 20 percent sand.

(j) Sandy clay - 35 percent or more clay and 45 percent or more sand.

(k) Silty clay - 40 percent or more clay and 40 percent or more silt.

(l) Clay - 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.



TEXTURE TRIANGLE

(Fine Earth Texture Classes)

From: U.S. Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center Field Book for Describing and Sampling Soils, Version 1.1 5/13/98

APPENDIX C

SELECTING HYDRAULIC CONDUCTIVITY VALUES FOR DESIGN

APPENDIX C

SELECTING HYDRAULIC CONDUCTIVITY VALUES FOR DESIGN

As stated in Section VI, estimating hydraulic conductivity (K) is a difficult task involving testing and measurement, tempered by reasonable judgement. When performing a hydraulic capacity analysis, or selecting a value for long term acceptance rate (LTAR), a value in the lower 50 percentile of the range of K values should be used and certainly should not exceed the geometric mean hydraulic conductivity (K_g). On the other hand, when computing travel time, a conservative value from the high end of the range of K values should be used.

It is quite likely that the K values, obtained as discussed in Section VI, will differ from the actual K values of the in-situ soils because the K values obtained actually represent a relatively few localized samples in a universe of samples needed to represent the entire soil deposit. For example, the mean value of a set of K sample data points is not equivalent to the mean K of the entire soil deposit under investigation, and it is virtually impossible to physically determine the true mean K value. However, statisticians have developed methods for determining how close the mean of a set of samples approaches the true mean. One such method, as presented in Lin (1986), was used to prepare Figure QC-1. This Figure provides an estimate of the number of samples required in order to have 90% confidence that the calculated mean is within 10% of the true mean. It requires knowledge of the coefficient of variation (C_v) of the sample set. Where C_v is unknown, a reasonable initial value of C_v can be made from results obtained from initial laboratory testing of a relatively small number of samples. Once the initial value of C_v is determined, the number of samples required to provide the 90% confidence level can be obtained from Figure QC-1. The number of samples required for any further testing can then be based on the C_v determined from the preceding sample set.

It should be remembered that errors caused by using values of K that differ significantly from actual in-situ values could be very difficult and costly to remedy once the SWAS is constructed and placed into operation. Therefore, consideration should be given to applying reasonable safety factors to the values of K determined by localized field tests or laboratory tests of soil samples. The magnitude of the safety factor selected should be based on the type of SWAS to be used.

Cedergren (1989) indicates that the K value defined by Darcy's Law is a statistical average factor that represents a definite cross-section of soil. When determined by the careful experimental testing of a given mass of soil, it is representative of the volume of soil tested. To be useful in practical problems it is usually necessary to estimate the K of extensive soil deposits from tests on limited volumes of soil. As a rule, the larger the mass represented by a test, the more reliable the results; however, tests on comparatively minute specimens can be extremely valuable when applied carefully and with the proper regard for limitations inherent to all such determinations. Cedergren (ibid.) further states that " A sound approach to every seepage and drainage situation requires the greatest possible care in assigning permeabilities [hydraulic conductivities] and other physical data as realistically as possible and the use of reasonable care in carrying out the appropriate theoretical or mathematical solution."

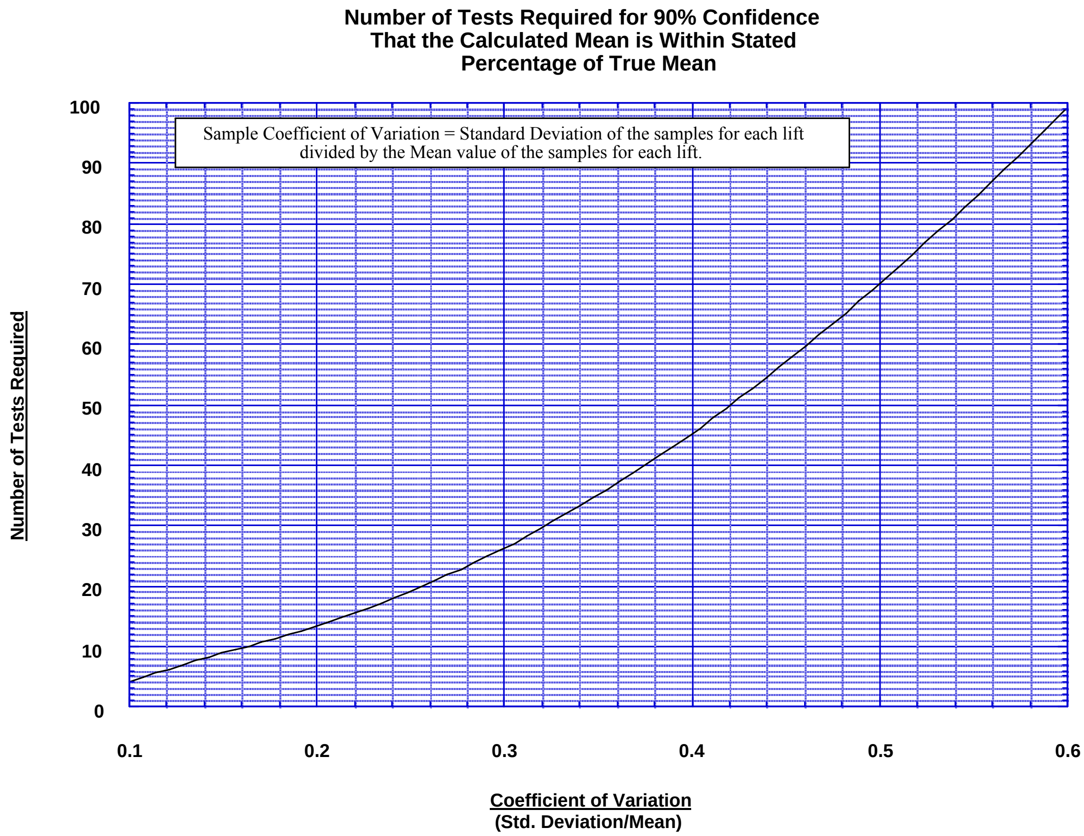


Figure QC-1

Thus, one should make reasonable use of the tools available to assist in assigning realistic K values. One of these tools is the application of simple statistics to the range of K values obtained from tests on soil samples, or from a limited number of field tests.

The use of basic statistical methods has been made somewhat "user friendly" by the availability of numerous dedicated statistical programs for use on desktop and laptop computers. In addition, there are also several spreadsheet and data analysis/graphics program packages available for such computers that are capable of performing statistical analysis. Also, many hand-held electronic calculators have statistical analysis functions programmed into their static memory. Thus, the use of basic statistical methods for analysis of K data and determining the necessary statistical parameters is no longer an involved or difficult task.

When working with transformed variables, as is required when computing the statistics for the values of K determined in the field or laboratory[1], it is necessary to observe the laws of logarithms in making such calculations. Microsoft™Excel™ spreadsheets have been prepared to illustrate the calculation of the statistical parameters such as geometric mean (X_m), standard deviation of geometric mean (s_g), 95% Confidence Interval about the Geometric Mean, and the calculations for determining possible outliers. The computations in these spreadsheets conform to the laws of logarithms.

[1] Recall that K values can be defined by a lognomal distribution.

These laws are:

$Log_a(X * Y) = Log_a X + Log_a Y$ *[Note:* $Log_a (X+Y) \neq Log_a X + Log_a Y$*]*

$Log_a(X/Y) = Log_a X - Log_a Y$ *[Note:* $Log_a X / Log_a Y \neq Log_a (X-Y)$*]*

$Log_a X^n = n Log_a X$, where n is a real number. *(Note that* $Log_a X^n \neq (Log_a X)^n$*]*

By combining these laws, we can find the Log of $A^p B^q C^r / D^s E^t$ = p Log A +q Log B + r Log C- s Log D - t Log E. (Spiegel, and Stephens 1999).

The two spreadsheets (Table 1 and Table 2) included in the Appendix make use of natural logarithms because many statistical computer programs use natural logarithms (Ln, = Log to the base e, where e = 2.7183, a mathematical constant) rather than common logarithms (Log_{10} or Log to the base 10). Mathematicians and statisticians normally use natural logs because it simplifies many formulae. (It should be noted that the base used for logarithms affects the values of the logs, but nothing else. Provided the correct anti-log is used to return to the natural (arithmetic) scale, it does not matter which base is used.)

These spreadsheets are provided as an example on how spreadsheets using Excel™, or other spreadsheet and database programs that have statistical functions similar to Excel™, can be used to obtain values for statistical parameters using a lognormal distribution. Tables 1 and 2 show the results before and after removal of the only value determined to be an outlier.

Outliers

Outliers are extreme values of data points that appear to be inconsistent with the trend established by the majority of the data. While extreme values may or may not be outliers, any outliers are always extreme (or relatively extreme) values in the sample set. When no explanations can be found for such inconsistency, outliers should be discarded to eliminate bias from statistical evaluations. Outliers can sometimes be detected by visual examination of plots of the data points, but this can be a subjective decision. There are also procedures available for statistically detecting outliers (Barnett and Lewis-1984; Snedecor and Cochran-1989).

Snedecor and Cochran (1989) state that "A major error in an experiment greatly distorts the mean of (statistical) treatment involved. By inflating the error variance, it affects conclusions about other (statistical) treatments as well. The principal safeguards are vigilance in carrying out the operations, the measurements, and the recording, plus eye examination of the data before analysis. If a figure in the data looks suspicious, an inquiry about this observation should be made. Sometimes the inquiry shows a mistake and also reveals the correct value for the observation, which is then used in the statistical analysis. Sometime it is certain that a gross error was made, but there is no way of finding the correct value. In this event, omit the erroneous observation and use the analysis for data with one missing value. In such cases, check that the source of the gross error did not affect other observations also."

Before omitting any suspicious value (an "outlier") a good faith effort should be made to determine if there is a reasonable explanation of why the value in question differs extremely from other values in the data set. For example, a value for K believed to be an "outlier" may be incorrect because of errors made in selection of sampling locations, sampling procedures, testing procedures, recording of data, or inputting incorrect data into the statistical data processing procedure.

Many statistical procedures are based on the assumption that the data are random in nature. While it is quite difficult to assure that a true random set of samples are obtained, care should be taken not to subjectively select the sampling locations because of the desired end results. A subjective selection might consist of including a sample taken in a small inclusion of soil having a relatively high K value in a body of soil that otherwise can be expected to have a much lower mean K value. A sample knowingly taken from a small, localized deposit of relatively clean sand in a glacial till soil is an example of a subjective selection.

In the case of tube samples, an error might involve using too great a force to push the tube into the soil, thus possibly altering the soil structure and density. Laboratory tests are prone to errors in measurement and technique, even though care is taken in performing the test. Incorrect recording of the laboratory measurement data, such as by misplacement of a decimal point, will contribute an incorrect data point. If such an error is detected by reviewing the measurement data, its correction would provide a valid data point and the test results would not be an outlier. Other errors might occur from a tube sample that contains a worm or decomposed root hole, or a large pebble that would yield a test K value that is not characteristic of the soil deposit.

A common source of error is incorrectly inputting a data point into a hand-held calculator used to derive statistical data from the sample set. If the calculator does not have the ability to recall and display the data points entered, it is difficult to detect such an error unless all of the data are carefully re-entered to check the results of the first data entry. (It is much better to input the data into a computer program capable of statistical calculations that will display, and provide a hard copy of, the data entered so that such errors can be detected visually.)

If all of these possible sources of error have been investigated and discounted, then a method for identifying and dealing with outliers should be used. There are a number of statistical methods available for identifying outliers; many of the more robust methods are given in Barnett and Lewis (ibid). The following method is based on a statistical procedure presented in Barnett and Lewis (ibid) for the case where only the mean and standard deviation of samples are known (i.e. the true mean and standard deviation of the whole universe of values representing the entire soil mass are unknown).

If a set of data is ordered from low to high: X_L, X_2 ... X_H, and the mean (X_m) and standard deviation (s) are calculated, suspected extreme high and low outliers can be tested by the following procedure:

First, calculate the T Score Statistic:

$$\textbf{T score for a high value} = T_H = (X_H - X_m)/s$$
$$\textbf{T score for a low value} = T_L = (X_m - X_L)/s.$$

Second, compare the value of T with the critical value from Figure No. 2 "Critical Values of T at a 5% level of significance" included in this Appendix. If the calculated T is larger than the critical value from Figure No. 2 for the degrees of freedom of the sample set (Degrees of Freedom = N-1, where N = number of sample values in the sample set), then X_H or X_L is an outlier at a 5% level of significance.

This method assumes that the data are normally distributed. However, as previously discussed in Section VI, normal distribution can be assumed by transforming values of K to values of Ln K and calculating the geometric mean and standard deviation from the geometric mean. These values can then be used in calculating the T-score, where the geometric mean = X_m and the standard deviation from the geometric mean = s_g.

[Barnett and Lewis (ibid) state that if X is a log-normal random variable, a test for any outlier in a log-normal sample can be made by taking the logarithms of the observations and apply an appropriate normal sample test to the transformed sample. Davis (1971) states that: "As long as we work with the data in its transformed state, all of the statistical procedures that are appropriate for ordinary variables are applicable to log transformed variables.]

The preceding Barnett and Lewis (ibid) equations can be used for lognormal K data by transforming them to logarithmic equations, as follows:

$$\text{Ln } T_H = (\text{Ln } K_H - \text{Ln } X_m) - \text{Ln } s_g$$
$$\text{Ln } T_L = (\text{Ln } X_m - \text{Ln } K_L) - \text{Ln } s_g$$

Where:

Ln T_H = Ln of the T score statistic for the highest value of K
Ln T_L = Ln of the T score statistic for the lowest value of K
K_H = Highest value of K
K_L = Lowest value of K
X_m = Geometric Mean K
S_g = Standard Deviation of the Geometric Mean

After obtaining the anti-logs of the Lns of T_H and T_L, the remainder of the procedure is as given on the previous page.

Examples of the calculation for outliers using the method of Barnett and Lewis (ibid.) discussed above are shown in the spreadsheets (Table No. 1 and Table No. 2) included in this Appendix. The approval of the Department should be obtained before using a method for identifying outliers that differs from the cited method.

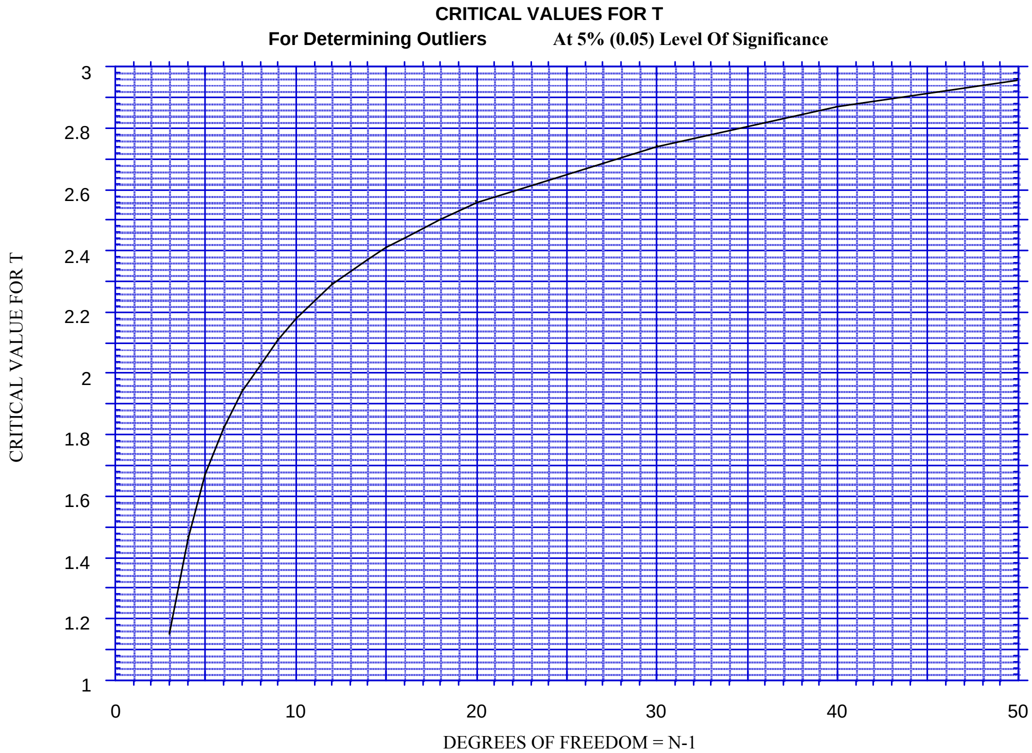


Figure No.2

Selecting K Values for Calculating Hydraulic Capacity and Travel Time

In calculations involving site hydraulic capacity, the mean value of the saturated horizontal hydraulic conductivity of the soil deposit in which the water will travel is needed. However, we cannot determine the mean value of the entire deposit because we have only a limited number of samples that supposedly represent the entire deposit. Thus, we can only estimate the mean value within probable confidence limits determined by the application of statistics.

The procedure recommended by the Department for determining the K value to be used for hydraulic capacity calculations is to calculate the geometric mean of the K samples, determine the 95% confidence interval of that mean, and use the lower interval limit as the design K for hydraulic capacity calculations. A 95% confidence level for a mean value X_m, calculated from a random sample of N values of X, means that we are 95% confident of the probability that the true mean of the variable X (in our case, X = K), will fall within the upper and lower 95% confidence limits (that is, within the 95% confidence interval).

Examples of the calculation for the lower limit of a 95% confidence interval for the geometric mean of lognormal distributed data are shown in the spreadsheets (Table No. 1 and Table No. 2) included in this Appendix. Row 57 in Table No. 1 shows the calculated lower limit of the 95% confidence interval (10.3 ft/day) before discarding the outlier K value of 2.1 ft/day calculated in row 74. Row 56 in Table No. 2 shows the calculated lower limit of the 95% confidence interval (11.3 ft/day) after discarding the outlier K value of 2.1 ft/day. Thus, K = 11.3 ft/day should be used for hydraulic capacity analysis.

The statistical expression for a 95% Confidence Level is as follows:

$$\mathbf{X_m - (t_{(1-\alpha/2)} \times s_g/N^{0.5}) < True\ Geometric\ Mean < X_m + (t_{(1-\alpha/2)} \times s_g/N^{0.5})}$$ **where**

X_m = Sample Geometric Mean
t = Student's t value for n Degrees of Freedom (N-1),
α = 1- the specified Confidence Level expressed as a decimal (i.e. 1.00-0.95),
$t_{(1-\alpha/2)}$ = the Student's t value at $1-\alpha/2$ for n degrees of Freedom (two tailed t value)
s_g = Standard Deviation of the Sample Geometric Mean, and,
N = The number of sample values.

Rewriting this expression in logarithmic form, and solving for the high end and low end of the 95% confidence interval

High end of the 95% Confidence Interval = $[\mathrm{Ln}\ (X_m)] + [\mathrm{Ln}\ (t_{(1-\alpha/2)} \times \mathrm{Ln}\ (s_g)/N^{0.5})]$

Low end of the 95% Confidence Interval = $[\mathrm{Ln}\ (X_m)] - [\mathrm{Ln}\ (t_{(1-\alpha/2)} \times \mathrm{Ln}\ (s_g)/N^{0.5})]$

The antilog of the two intervals will provide the values of K at the high end and low end of the 95% Confidence Interval for the geometric mean K.

Use of the calculated geometric mean K for travel time computations is not appropriate. The travel time will depend upon the ground water velocity and the "horizontal" distance to a point of concern, such as a drinking water well or surface water body. The average linear ground water velocity is calculated from the soil hydraulic conductivity and porosity,[2] and the hydraulic gradient of the water table. However, it should be noted that pathogens might travel faster than the average linear ground water velocity. Those pathogens that have not been adsorbed to a soil particle may be traveling with the ground water through some of the larger micropores and perhaps through macropores, where the ground water velocities are higher than the average velocities. Therefore, the K value used for travel time calculations must be greater than the geometric mean value of K.

Variations in K values of naturally deposited soils will occur depending upon how these deposits were formed. Stratified drift deposits consist of sorted sediments (layers of sand and gravel and lesser amounts of silt and clay) deposited by glacial meltwaters. Thus, for stratified drift aquifers, it is not unlikely that several high values of K, significantly higher than the geometric mean value of a number of sample values of K, may represent a continuous layer of relatively coarse-grained soil lying between other layers of less coarse-grained soils. Ground water flowing in the coarse-grained layer will travel at a faster rate than the ground water in the less coarse-grained layers. In this case, a conservative approach would be to select a K value near the high end of the range of K values as representative of a coarse-grained soil layer when computing horizontal travel times.

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[2] It is important that a realistic value of porosity be used in such calculations. Ranges of values of porosities can be found in: Table 3 in Melvin, R. L., V. de Lima, and B. D. Stone. (1992) and Appendix B in Walton, W. C. (1991). It is recommended that the lower end of the range of porosity given in these references be used for travel time computations.

On the other hand, glacial till deposits consist of non-stratified, non-sorted, intermingled clay, silt, sand and boulders transported and deposited by glacial ice. Thus, it is less likely that the highest values of K would represent a continuous layer (continuous path) of coarse-grained soils and a K value between the geometric mean and high-end values of K is considered to be appropriate when computing horizontal travel time through a glacial till soil deposit. However, it should be noted that each soil horizon, or layer, through which the ground water will flow must be analyzed separately for travel time.

In the case of fill type systems, it is likely that each layer of fill will consist of truckloads of granular soil that have been mixed during loading, unloading and placement of the fill material. In this case, the high-end values of K are considered unlikely to represent a continuous layer of coarser-grained soils and each layer can be considered in a manner similar to that of a glacial till soil given above.

Accordingly, it is suggested that a K value equal to the 95th percentile value of K values of coarse-grained strata be used in computing horizontal travel time in deposits of stratified drift, and a K value equal to the third quartile value of K be used in computing horizontal travel time in glacial till. The method of determining the 95th percentile value and third quartile values for K is shown on the spreadsheets included in this Appendix. The spreadsheets also indicate the method of solving for K_m, s_g, and C_v using logarithms.

Where the Applicant's Consultant does not wish to follow the procedures discussed herein for selecting K values for hydraulic capacity and travel time computations, the Department will require that a conservative low value for K be used to calculate hydraulic capacity and a conservative high value for K be used in travel time computations. Thus, the K value for hydraulic capacity should be selected near the low end of the range of K values and the K value for travel time computations should be selected near the high end of the range of the K values for the soil in question.

	A	B	C	D	E	F
1	**TABLE No. 1**					
2	**Statistics for Values of K, ft/d (Before Removal of Outliers)**					
3						
4	**K**	**Ln K**	**EXCEL Statistical**	**Statistical**	**Antilog (EXP)**	**Parameter**
5	ft/day		**Function**	**Parameter**	**of Parameter LN**	**Value**
6	24.1	3.18221	= LN(B6)	Natural Log (LN) of K		
7	26.1	3.26194	.			
8	10.2	2.32239	.			
9	2.1	0.74194	.			
10	22.4	3.10906	.			
11	12.7	2.54160	.			
12	19.2	2.95491	.			
13	13.5	2.60269	.			
14	18.4	2.91235	.			
15	9.2	2.21920	.			
16	35.2	3.56105	.			
17	34.7	3.54674	.			
18	12.0	2.48491	.			
19	4.6	1.52606	.			
20	10.4	2.34181	.			
21	11.2	2.41591	.			
22	24.0	3.17805	.			
23	11.3	2.42480	.			
24	9.0	2.19722	.			
25	31.0	3.43399	.			
26	14.2	2.65324	.			
27	12.8	2.54945	.			
28	6.7	1.90211	.			
29	12.5	2.52573	.			
30	11.5	2.44235	.			
31	46.1	3.83081	.			
32	7.7	2.04122	.			
33	10.5	2.35138	.			
34	5.1	1.62924	.			
35	12.2	2.50144	.			
36	10.6	2.36085	= LN(B36)			
37						
38		2.57247	=AVERAGE(B6:B36)	= Mean of LNs = Geomean = X_m	=EXP(B38)	13.1
39		2.50144	= MEDIAN(B6:B36)	= Median of LNs	=EXP(B39)	12.2
40		0.64923	= STDEV(B6:B36)	= Std. Dev. Of Geomean = s	=EXP(B40)	1.91
41		31	= COUNT(B6:B36)	= The number of values of K		
42						
43						
44		2.33210	QUARTILE (array, quart)= QUARTILE(B6:B36, 1)	=1st Quartile Value of K	= EXP(B44)	10.3
45		2.50144	QUARTILE (array, quart)= QUARTILE(B6:B36, 2)	=2nd Quartile Value of K	= EXP(B45)	12.2
46		3.03199	QUARTILE (array, quart)= QUARTILE(B6:B36, 3)	=3rd Quartile Value of K	= EXP(B46)	**20.7**
47						

49 **CALCULATE 95% CONFIDENCE INTERVAL FOR GEOMETRIC MEAN**

51 31 = B41, which returns the N, the Number of Values
52 5.57 = SQRT(B51), which returns the Square Root of N
53 2.042 = TINV(0.05,30), which returns the value of Student's t for 95% Confidence and N-1 Degrees of Freedom.
54 [Where the input value 0.05 = (100-% Confidence)/100.]
55 13.1 =EXP(B38) =Mid value of interval, which is the Geometric Mean calculated in cell B38
56 **16.6** = EXP(B38+B53*B40/B52), which returns the high end of the 95% interval
57 **10.3** = EXP(B38-B53*B40/B52), which returns the Low end of the 95% interval

59 Thus, we are 95% confident that the true geometric mean K lies within the interval 10.3 to 16.6.

61 **CHECK VALUES OF K FOR POSSIBLE OUTLIERS**
62 (Using procedure given in Barnett and Lewis*)

64 3.83081 = MAX(B6:B36), which returns the LN of Highest Value of K_H
65 0.60911 = (B31-B38)-B40, which returns the LN of the T statistic for Highest K Value = (LN(X_H)-LN (X_m))-LN(s)
66 **1.84** = EXP(B65), which returns the value of the T statistic for Highest K Value
67 0.74194 = MIN(B6:B36), which returns the LN of Lowest Value of K = K_L
68 1.18131 =(B38-B9)-B40, which returns the LN of the T statistic for Lowest K Value = (LN(X_m)-LN(X_L)-LN(s)
69 **3.26** = EXP(B68), which returns the value of the T statistic for Lowest K Value
70 2.74 = Critical Value of T for N-1 Degrees of Freedom, Input from Figure No. 2

73 Since T statistic for Highest K value of 46.1 is less than Critical Value of T, 46.1is not an outlier
74 Since T statistic for lowest K value of 2.1 is greater than Critical Value of T, 2.1 is an outlier

76 Therefore, the procedure shown in this spreadsheet should be repeated for all values of K except for
77 K = 2.1, which should be discarded.

79 * Reference: Barnett, V. and T. Lewis. 1984. Outliers in Statistical Data. John Wiley & Sons, New York, NY
80 Pages 216-223 and 250-251.

82 **CALCULATE 95% PERCENTILE VALUE OF K**

84 3.55389 = PERCENTILE(B6:B36, 0.95), which returns the LN of the 95 Percentile Value of K
85 **34.9** = EXP(B84), which returns the 95 Percentile Value of K

87 **CALCULATE COEFFICIENT OF VARIATION, C_v**

89 -1.92324 = B40-B38, which returns the LN of C_v (Cv= Std. Dev.of Geomentric Mean/Geometric Mean)
90 **0.15** = EXP(B89), which returns the value of the Coefficient of Variation, C_v, expressed as a decimal.

	A	B	C	D	E	F
1			TABLE No. 2			
2			Statistics for Values of K, ft/d (After Removal of Low End Outlier)			
3						
4	**K**	**Ln K**	**EXCEL Statistical**	**Statistical**	**Antilog (EXP)**	**Parameter**
5	ft/day		**Function**	**Parameter**	**of Parameter LN**	**Value**
6	24.1	3.18221	= LN(B6)	Natural Log (LN) of K		
7	26.1	3.26194	.			
8	10.2	2.32239	.			
9	22.4	3.10906	.			
10	12.7	2.54160	.			
11	19.2	2.95491	.			
12	13.5	2.60269	.			
13	18.4	2.91235	.			
14	9.2	2.21920	.			
15	35.2	3.56105	.			
16	34.7	3.54674	.			
17	12.0	2.48491	.			
18	4.6	1.52606	.			
19	10.4	2.34181	.			
20	11.2	2.41591	.			
21	24.0	3.17805	.			
22	11.3	2.42480	.			
23	9.0	2.19722	.			
24	31.0	3.43399	.			
25	14.2	2.65324	.			
26	12.8	2.54945	.			
27	6.7	1.90211	.			
28	12.5	2.52573	.			
29	11.5	2.44235	.			
30	46.1	3.83081	.			
31	7.7	2.04122	.			
32	10.5	2.35138	.			
33	5.1	1.62924	.			
34	12.2	2.50144	.			
35	10.6	2.36085	= LN(B35)			
36						
37		2.63349	=AVERAGE(B6:B35)	= Mean of LNs = Geomean =mX	=EXP(B37)	13.9
38		2.51358	= MEDIAN(B6:B35)	= Median of LNs	=EXP(B38)	12.3
39		0.56270	= STDEV(B6:B35)	= Std. Dev. Of Geomean = s	=EXP(B39)	1.76
40		30	= COUNT(B6:B35)	= The number of values of K		
41						
42						
43		2.34420	QUARTILE (array, quart)= QUARTILE(B6:B36, 1)	= 1st Quartile Value of K	= EXP(B43)	10.4
44		2.51358	QUARTILE (array, quart)= QUARTILE(B6:B36, 2)	= 2nd Quartile Value of K	= EXP(B44)	12.3
45		3.07052	QUARTILE (array, quart)= QUARTILE(B6:B36, 3)	= 3rd Quartile Value of K	= EXP(B45)	**21.6**
46						

CALCULATE 95% CONFIDENCE INTERVAL FOR GEOMETRIC MEAN

30 = B40, which returns the N, the Number of Values
5.48 = SQRT(B50), which returns the Square Root of N
2.042 = TINV(0.05,30), which returns the value of Student's t for 95% Confidence and N-1 Degrees of Freedom.
[Where the input value 0.05 = (100-% Confidence)/100.]
13.9 =EXP(B37) =Mid value of interval, which is the Geometric Mean calculated in cell B38
17.2 = EXP(B37+B52*B39/B51), which returns the high end of the 95% interval
11.3 = EXP(B37-B52*B39/B51), which returns the Low end of the 95% interval

Thus, we are 95% confident that the true geometric mean K lies within the interval 10.3 to 16.6.

CHECK VALUES OF K FOR POSSIBLE OUTLIERS
(Using procedure given in Barnett and Lewis*)

3.83081 = MAX(B6:B35), which returns the LN of Highest Value of K_H
0.63462 = (B30-B37)-B39, which returns the LN of the T statistic for Highest K Value = (LN (X_H)-LN (X_m))-LN(s)
1.89 = EXP(B64), which returns the value of the T statistic for Highest K Value
1.52606 = MIN(B6:B35), which returns the LN of Lowest Value of K = K_L
0.54473 =(B37-B66)-B39, which returns the LN of the T statistic for Lowest K Value = (LN(X_m)-LN(X_L)- LN(s)
1.72 = EXP(B67), which returns the value of the T statistic for Lowest K Value
2.70 = Critical Value of T for a 5% level of significance and N-1 Degrees of Freedom (Input from Figure No. 2)

Since T statistic for Highest K value of 46.1 is less than Critical Value of T, 46.1 is not an outlier
Since T statistic for lowest K value of 4.6 is less than Critical Value of T, 2.1 is not an outlier
Therefore, the statistical parameters calculated in this table are OK for use in hydraulic capacity and travel time calculations.

* Reference: Barnett, V. and T. Lewis. 1984. Outliers in Statistical Data. John Wiley & Sons, New York, NY
Pages 216-223 and 250-251.

CALCULATE 95% PERCENTILE VALUE OF K

3.55461 = PERCENTILE(B6:B36, 0.95), which returns the LN of the 95 Percentile Value of K
35.0 = EXP(B84), which returns the 95 Percentile Value of K

CALCULATE COEFFICIENT OF VARIATION, C_v

-2.07079 = B40-B38, which returns the LN of C_v (Cv= Std. Dev.of Geomentric Mean/Geometric Mean)
0.13 = EXP(B89), which returns the value of the Coefficient of Variation, C_v , expressed as a decimal.

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APPENDIX D

U.S. --METRIC CONVERSION FACTORS

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					LENGTH		
in	Inches	25.4	millimeters	mm	mm	millimeters	0.039	Inches	in
ft	feet	0.3048	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	Miles (statute)	1.61	kilometers	km	km	kilometers	0.621	Miles (statute)	mi
		AREA					AREA		
in^2	square inches	645.2	millimeters squared	cm^2	mm^2	millimeters squared	0.0016	square inches	in^2
ft^2	square feet	0.0929	meters squared	m^2	m^2	meters squared	10.764	square feet	ft^2
yd^2	square yards	0.8361	meters squared	m^2	m^2	meters squared	1.1960	square feet	ft^2
ac	acres	0.4046	hectare	ha	ha	hectare	2.4711	acres	ac
		MASS (weight)					MASS (weight)		
oz	Ounces (avdp)	28.35	grams	g	g	grams	0.0353	Ounces (avdp)	oz
lb	Pounds (avdp)	0.454	kilograms	kg	kg	kilograms	2.205	Pounds (avdp)	lb
		VOLUME					VOLUME		
fl oz	fluid ounces (US)	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces (US)	fl oz
gal	Gallons (liq)	3.785	liters	liters	liters	liters	0.264	Gallons (liq)	gal
ft^3	cubic feet	0.0283	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
	Note: Volumes greater than 1000 L are shown in m^3								
		VELOCITY					VELOCITY		
ft./s	feet per second	0.3048	meters/second	m/s	m/s	meters/second	3.2808	feet per second	ft./s
ft./d	feet per day	0.3048	meters/day	m/d	m/d	meters/day	3.2808	feet per day	ft./d
ft./d	feet per day	0.35278 x 10^{-3}	centimeters/s	cm/s	cm/s	centimeters/s	2834.6	feet per day	ft./d
		FLOW RATE					FLOW RATE		
ft^3/s	cubic feet per sec.	2.8317 x 10^{-2}	cubic meters/sec	m^3/s	m^3/s	cubic meters/sec.	35.3147	cubic feet per sec.	ft^3/s
gal/d	gallons per day	4.3808 x 10^{-5}	liters per second	L/s	L/s	liters per second	22,831	gallons per day	gal/d
Gal/d	Gallons per day	3.785 x 10^{-3}	Cubic meters/day	m^3/d	m^3/d	cubic meters /day	264.20	Gallons per day	Gal/d
gal/m	gallons per min.	6.3083 x 10^{-2}	liters per second	L/s	L/s	liters per second	15.8521	gallons per min.	gal/m
gal/d	gallons per min.	6.3095 x 10^{-5}	cubic meters/sec.	m^3/s	m^3/s	cubic meters/sec.	15,849	gallons per min.	gal/m
		LOADING RATE					LOADING RATE		
gal/d/ft^2	gal/day/sq ft	4.075	centimeters/day	cm/d	cm/d	centimeters/day	0.2454	gal/day/sq ft.	gal/d/ft^2
		TEMPERATURE					TEMPERATURE		
^{o}F	Fahrenheit	5/9 (^{o}F-32)	Celsius	^{o}C	^{o}C	Celsius temperature	9/5 ^{o}C+32	Fahrenheit	^{o}F

* SI = Système International (International System [of Units]).

APPENDIX E

GLOSSARY

Note: The Glossary contains definitions and discussions of terms contained in "Guidance for Design of Large-Scale On-Site Wastewater Renovation Systems" as well as terms contained in many of the published articles referenced in the various sections therein.

Abiotic	Pertaining to or characterized by the absence of living organisms.
Ablation Till	Loose, permeable till deposited during the final meltdown of glacial ice. Lenses of crudely sorted sands and gravel are common.
Absorbent	A substance that is capable of absorbing another substance.
Absorption	To take a substance in through pores or interstices. The process by which one substance is taken into and included within another substance, as the absorption of water by soil or nutrients by plants.
Acid	A substance which increases the concentration of hydronium ion in solution. A proton donor.
Actinomycetes	A group of microorganisms with characteristics intermediate between simple bacteria and fungi.
Adsorption	The adhesion of a substance to the surface of a solid or liquid. The increased concentration of molecules or ions at a surface, including exchangeable cations and anions on soil particles.
Adsorption Isotherm	A graph of the quantity of a given chemical species bound to an absorption complex, at a fixed temperature, as a function of the concentration of the species in a solution that is in equilibrium with the complex.
Aerobic Bacteria	Bacteria that require free elemental oxygen for their growth. Strict aerobes utilize the elemental oxygen for their terminal electron acceptor.
Aerobic(Oxic) Conditions -	where molecular oxygen is present at greater than 0.4 mg/L.
Aggregate Soils	Many fine particles held in a single mass or cluster. Natural soil aggregates, such as granules, blocks, or prisms, are called peds. Clods are aggregates produced by tillage or logging.
Ammonification	The decomposition of organic compounds e.g. proteins, by microorganisms with the release of ammonia. Also, the change from organic nitrogen to the ammonium form.
Amorphous	Lacking definite form (e.g.: shapeless; lacking organization; lacking distinct crystalline structure)

Amphoteric	Having the characteristics of an acid and a base and capable of reacting chemically either as an acid or a base.
Anaerobic Bacteria	Strict anaerobes use "chemically bound" oxygen rather than free elemental oxygen, which is toxic to such organisms. They use carbon, nitrogen or sulfur compounds as their terminal electron acceptor.
Anaerobic Conditions	Where molecular oxygen is present at less than 0.4 mg/L and NO_X-N is present at less than 0.2 mg/L.
Anaerobic Digestion	The process of decomposing organic matter in sewage by anaerobic bacteria.
Anaerobic Respiration	Respiration under anaerobic conditions in which a terminal electron acceptor other than oxygen is involved, the more common acceptor molecules being carbonate, sulfate and nitrate.
Anion	An atom that is negatively charged because of a gain in electrons.
Anion Exchange Capacity	The sum total of exchangeable anions that a soil can adsorb. Expressed as milliequivalents per 100 grams of soil or other adsorbing material (such as clay).
Anoxic Zone	An anoxic zone provides the environment necessary for facultative, heterotrophic bacteria to use nitrates in place of oxygen in their respiratory process.
Anoxic Conditions	Where D.O. is less than 0.4 mg/L and NO_X-N is greater than 0.5 mg/L.
Antibiotic	A chemical substance produced by certain molds and bacteria which inhibits the growth of or kills other microorganisms.
Antimicrobial	Capable of destroying or suppressing the growth of microorganisms.
Anthropogenic	of, relating to, or involving the impact of humans on nature.
Antigen	Certain compounds of microbial cells that can incite production of a specific antibody and that can combine with that antibody. Also, any substance that the body regards as foreign or dangerous for which an antibody is produced.

Anisotrophic	A condition where the hydraulic conductivity varies with the direction of measurement at a point in a geologic formation.
Antibodies	specific blood serum proteins, which bind to the antigens of microbial cells. Also, blood protein made in lymphoid tissue in response to the presence of antigens.
Aquifer	A water-bearing stratum of permeable rock, sand, or gravel.
Aquic conditions	Conditions where the soils are saturated and chemically reduced.
Arithmetic Mean	The average, calculated by dividing the sum of all values by the number of values to be averaged.
Artifact	A structure or substance not normally present but produced by an external agent or action.
Assimilation	The conversion of nutritive material into protoplasm.
Asymptomatic	Neither causing nor exhibiting symptoms of disease. Presenting no subjective evidence of disease.
Autoclave	A strong, pressurized, steam-heated vessel, as for laboratory experiments, sterilization, or cooking.
Autotrophic Bacteria	Microorganisms that use inorganic materials (carbon dioxide or carbonates) as a source of nutrients. Autotrophic bacteria utilize inorganic compounds entirely to produce an organic end product. Inorganic salts furnish the building blocks, as well as the energy.
Available Moisture Capacity	The moisture content of the soil in excess of the wilting point that can be taken up by plants at rates significant to their growth.
Bacillus	Any rod shaped bacterium.
Bacteriophage	A submicroscopic virus that can infect and destroy bacterial cells. (Also, see Coliphage)
Bacteria Respiration	The oxidative process occurring within living cells by which the chemical energy of organic molecules is released in a series of metabolic steps involving the consumption of oxygen and the liberation of carbon dioxide and water.

Bar	A unit of pressure; the pressure exerted by the entire atmosphere on one square centimeter is approximately one bar. Normal atmospheric pressure (at sea level) is 1.013 bars or 1,013 millibars, which is equivalent to 29.92 inches or 760 millimeters.
Base	A substance that increases the concentration of hydroxide ion in solution and reacts with an acid to produce a salt and water. A proton acceptor.
Basal Till	Any compact glacial till, deposited beneath the ice, nearly impervious to water.
Bedrock	A solid and continuous body of rock, with or without fractures or faults, and including weathered bedrock overlying solid bedrock.
Bentonite	A chemically altered volcanic ash that consists primarily of the clay mineral montmorillonite. The bentonite has a charge of 70-90 meq/gram.
Biodegradable	capable of being decomposed by biological processes.
Biofilm	a matrix of polysaccharide polymer produced externally by bacteria for attachment to surfaces, protection from environmental attack, and enhanced nutrient capture. It is normally a slimy material that is insoluble in water and most acids. Bacteria produce from 30 to 100 times their own weight in biofilm and, if external pressures are placed on a biofilm, it responds first by tightening or compacting, and shortly thereafter by producing larger amounts of exopolymers as a defense mechanism.
Biomat (Biocrust)	A growth of a biological or zoogleal layer at the soil interface of a subsurface soil absorption system. This growth forms a clogging layer of only a few cm in thickness. The biomat consists of wastewater solids, microorganisms, mineral precipitates, and the detritus remaining after decomposition of organic matter. The permeability and thickness of the biomat depends to a great extent upon the type of soil, wastewater loading rate, and wastewater quality (strength). Also referred to as clogging zone or clogging mat.
Biosolids	The residues of wastewater treatment. Formerly called sewage sludge.
Bioturbation	Disturbances of soils by animals or plants.

BOD (Biochemical Oxygen Demand)	The amount of oxygen required to maintain aerobic conditions during decomposition.
Bulk Density (Soil)	The mass of dry soil per unit bulk volume. The bulk volume is determined before drying to a constant weight at 105°C.
Calcareous Soil	A soil containing enough calcium carbonate (commonly combined with magnesium carbonate) to effervesce visibly when treated with cold, dilute hydrochloric acid.
Capillary attraction	A liquid's movement over or retention by a solid surface due to the interaction of adhesive and cohesive forces.
Capillary fringe	A zone just above the water table that is maintained in an essentially saturated state by capillary forces of lift.
Capsid	protein coat of a virus.
Capsule	Compact layer of polysaccharide exterior to the cell wall in some bacteria.
Cation	An atom that is positively charged because of loss of one or more electrons.
Cation Exchange	The interchange between a cation in solution and another cation on the surface of any surface-active material such as a clay colloid or organic colloid.
Cation Exchange Capacity (CEC)	CEC is a measure of the chemical reactivity of the soil and is generally an indication of the effectiveness of the soil in adsorbing cationic contaminants from wastewater. The adsorption occurs as a result of the attraction of the positively charged cations by negative charges that exist on the surfaces of clay minerals, hydrous aluminum and iron oxides, and organic matter. CEC is the sum total of exchangeable cations that a soil can absorb; sometimes referred to as total-exchange, base-exchange capacity, or cation-absorption capacity. Expressed in milliequivalents per 100 grams of exchanger. (Also defined as the total charge on the surfaces of the soil system.)
Chemisorption	To take up and chemically bind (a substance) onto the surface of a substance.

Chroma	The aspect of color in the Munsell color system by which a sample appears to differ from a gray of the same lightness or brightness and that corresponds to saturation of the perceived color. The relatively purity or saturation of a color, or its intensity of distinctive hue as related to grayness. Chroma is one of the 3 variables of soil color defined within the Munsell system of classification.
Class (Biology)	A taxonomic category ranking below a phylum or division and above an order.
Clay	Soil material that contains 40% or more clay, less than 45% sand, and less than 40% silt. Plastic when wet and hardens when heated. Mineral soil particles less than 0.0002 in dia. consisting primarily of hydrated silicates of aluminum.
Coagulate, coagulation	To cause transformation of dissolved suspended or colloidal matter in solution into a soft, semisolid, or solid mass for the purpose of precipitation (removal) of the matter from the liquid in which it is contained.
COD (Chemical Oxygen Demand)	A measure of the oxygen equivalent of that portion of organic matter that is susceptible to oxidation by a strong chemical agent.
Cocci	Bacteria having a spherical or spheroidal shape.
Cohesion	The force holding a solid or liquid together, owing to the attraction between like molecules.
Coliform	Bacteria that commonly inhabit the intestines of human beings and other vertebrates.
Coliphages	Bacteriophages-viruses that infect the Escherichia Coli (E Coli) bacterium. They resemble human enteric viruses such as poliovirus and Hepatitis A virus in size, shape and composition.
Colloids (colloidal matter)	Particles ranging from molecular dimensions to less than 1μ in diameter.
Confined Space	OSHA defines a confined space as being large enough for a person to enter, having a restricted means of entry or exit, and not designed for human occupancy.
Contaminant (in Water)	An undesirable constituent in the water or wastewater that may directly or indirectly affect human or environmental health.

Cryptosporidium — A protozoan parasite that can live in the intestines of humans and animals. *Cryptosporidium parvum* is a species of *Cryptosporidium* known to infect humans, causing the gastrointestinal disease known as cryptosporidiosis.

Cyst — A small capsule-like sac that encloses certain microorganisms in their dormant or larval stage. A resting stage formed by some bacteria and protozoa in which the whole cell is surrounded by a protective layer. The infectious stage of *Giardia*, and some other protozoan parasites, that has a protective wall, which enables it to survive in water and other environments.

Denaturation — Any process in which the molecular structure of a substance, especially that of a protein or nucleic acid, is artificially altered in order to eliminate or modify one or more of its characteristic chemical, physical, or biological properties. Inactivation of viruses occurs by denaturation of the viral protein coat.

Denitrification — The reduction of nitrates to nitrogen gas. A two-step sequential process that usually takes place only under anoxic conditions. Organic matter must be available to the denitrifying bacteria. In the first step, nitrate is reduced to nitrite. In the second step, the nitrite is reduced to nitrogen gas, N_2, which is released to the atmosphere. For denitrification to occur, nitrification of ammonia must first take place.

Denitrification may be carried out heterotrophically by common facultative bacteria, for example species of Pseudonomonas, Alcaligenes, Paracoccus, Bacillus, Propionibacterium, etc. These organisms metabolize compounds for carbon and energy."

Design Flow — The daily flow rate that an on-site wastewater renovation system is designed to accommodate on a sustained basis while satisfying all permit discharge limitations and treatment and operational requirements. The design flow incorporates peaking and safety factors to ensure sustained, reliable operation.

Dessicate, Dessication — To dry out thoroughly, to make dry and lifeless.

Desorption — The process of removal of a previously adsorbed substance.

Diffuse Double Layer — A heterogeneous system that consists of a solid surface having a net electrical charge, together with an ionic swarm

	under the influence of the solid and in a solution phase that is in direct contact with the surface of the solid. The electrical double layer consisting of a charged-particle surface (usually negatively charged) and a surrounding sheath of ions of charge opposite to that of the particle surface.
Disinfection	A reduction in the concentration of pathogens to non-infectious levels.
DNA	Deoxyribonucleic Acid. A nucleic acid that carries the genetic information in the cell and is capable of self-replication and synthesis of RNA. DNA consists of two long chains of nucleotides twisted into a double helix. The sequence of nucleotides determines individual hereditary characteristics. Also see RNA.
D.O.	Dissolved Oxygen
Domestic Wastewater	Wastewater from residential buildings or from non-residential buildings, but not including manufacturing process water, cooling water, wastewater from water softening equipment, commercial laundry wastewater, dry cleaning wastewater, blow-down from heating or cooling equipment, water from cellar or roof drains or surface water from roofs, paved surfaces, or yard drains.
Domestic Well	A self-supplied ground water source for household water.
Domestic Well Water	Untreated ground water collected from domestic wells.
Drumlim	An elongated or oval hill of glacial drift.
Effective porosity	that portion of the total porosity that contributes significantly to fluid flow.
Effective Size, (d_{10})	The percent by weight of the soil particles that pass the No. 10 standard mesh sieve.
Electrical Double Layer	See Diffuse Double Layer.
Electron	A stable, negatively charged subatomic particle.
Electron Acceptor	A substance being reduced. A substance that accepts electrons during an oxidation-reduction reaction; an oxidant.
Electron Donor	A substance being oxidized. A substance that donates electrons in an oxidation-reduction reaction; a reductant.

Eluviation	Leaching. The process of removing nutrients and inorganics out of the A horizon of soils. The removal of soil material in suspension (or in solution, as in leaching) from a layer or layers of soil.
Elution	Extraction of one material from another, as by washing out adsorbed material i.e.: The removal of virus from soil by washing with a liquid.
Endemic	Prevalent in or peculiar to a particular locality, region, or people. Native to or confined to a certain region.
Endogenous	Produced or originating from within.
Energy release	Energy is released by oxidation reactions. Organic matter in wastewaters is stabilized by oxidation. Bacteria and other microorganisms in waste stabilization systems do not oxidize matter by the direct addition of oxygen, but rather by the indirect scheme of hydrogen removal and addition of water. The hydrogen eventually reacts with oxygen, carbon, nitrogen or sulfur.
Enteric bacteria	General term for a group of bacteria that inhabit the intestinal tract of humans and other animals. Among this group are pathogenic bacteria such as S*almonella* and *Shigella.*
Enterovirus	A virus that infects cells of the intestinal tract.
Enzyme	Protein within or derived from a living organism that functions as a catalyst to promote specific reactions. Complex proteins which act as organic catalysts to speed up the rate of hydrolysis of complex organic compounds and the rate of oxidation of simple compounds. Capable of action outside or inside the cell. Certain of the enzymes are secreted by the cell and are known as extracellular enzymes. Others are associated with the protoplasm of the cell and perform their function within the cell: These are known as intracellular enzymes. Enzymes are proteinaceous in character.
Epidemiology	The branch of medicine that deals with the study of the causes, distribution, and control of disease in populations.
Equivalent Spherical Diameter of Particle	The diameter of a sphere that has a volume equal to the volume of the particle.
Etiology	The branch of medicine that deals with the causes or origins of disease. The cause or origin of a disease or

	disorder as determined by medical diagnosis i.e.: The causal relationship between a virus and the specific disease.
Etiologic Agent	Something that causes disease.
Eukaryote	A single-celled or multicellular organism whose cells contain a distinct membrane-bound nucleus.
Eutrophic	Nutrient -rich.
Evaporation	The change from a liquid state to a vapor state. With respect to soil systems, it is the process by which molecules of water at the surface of moist soils acquire enough energy through solar radiation to escape to the atmosphere.
Evapotranspiration	The process by which water in the land surface, soil and vegetation is converted into the vapor state and returned to the atmosphere. It consists of evaporation from water, soil, vegetative and other surfaces and transpiration by vegetation.
Excystation	The release of the internal contents of cysts or oocysts. The mechanism by which ingested Cryptosporidium oocysts cause human and animal infection.
Exogenous	produced or originating from without.
Extracellular	Located or occurring outside a cell or cells.
Facultative Bacteria	Facultative bacteria can use most aerobic and anaerobic mechanisms, and also can use "chemically bound" oxygen, carbon, nitrogen or sulfur as their hydrogen acceptor. They will use the hydrogen acceptor yielding the greatest energy. Thus, facultative bacteria will not use carbon as their hydrogen acceptor when dissolved oxygen is present.
Failure (SSAS)	When a subsurface soil absorption system (SSAS) does not properly contain or treat wastewater or causes or threatens to cause the discharge of partially treated wastewater onto the ground surface or into adjacent ground water or surface water.
Family (Biology)	A taxonomic category of related organisms ranking below an order and above a genus. A family usually consists of several genera.
Fecal Contamination	Contamination derived from the feces of humans and other animals. Includes bacteria, viruses and parasites.

Fermentation	The metabolic process in which the final electron acceptor is an organic compound.
Field Moisture Capacity (Field Capacity)	The quantity of water held in a soil by capillary action after the gravitational or free water has been allowed to drain. Expressed as a moisture percentage, dry weight basis.
Fill Material	An approved soil material, meeting specific particle size (gradation) requirements, placed on an existing soil horizon and used as part of the soil system to provide treatment of septic tank effluent. Does not include soil material used to contain or cover a subsurface wastewater absorption system (SWAS).
Filtrate	The liquid that has passed through a filter.
Floc	A flocculent mass formed in a fluid through precipitation or aggregation of suspended particles.
Flocculation	Gentle mixing to promote the aggregation of discrete suspended particles of small size into larger particulate matter (“floc”) to enhance removal of particulates by settling in clarification processes.
Formula Weight	The sum of all the atomic weights in the chemical formula under consideration. If the molecular formula is used, the formula weight is called the molecular weight.
Fragipan	a loamy, brittle subsurface horizon low in porosity and content of organic matter and low or moderate in clay but high in silt or very fine sand. A fragipan appears cemented and restricts roots. When dry, it is hard or very hard and has a higher bulk density than the horizon or horizons above. When moist, it tends to rupture suddenly under pressure rather than deform slowly. This horizon is mottled, slowly or very slowly permeable to water, and usually shows occasional or frequently bleached cracks forming polygons.
Genus	A taxonomic category ranking below a family and above a species and generally consisting of a group of species exhibiting similar characteristics. In taxonomic nomenclature the genus name is used, either alone or followed by a Latin adjective or epithet, to form the name of a species.
Geometric Mean	The average of a set of numbers covering a wide range that do not fit a normal distribution. The geometric mean is calculated by converting each of the numbers in the set to a log value, adding up all log values and dividing by the

	number of samples. The geometric mean is the anti-log of the sum of the log values. Also referred to as the log mean.
Giardia Lamblia	A single celled flagellated protozoan of the genus Giardia that may be parasitic in the intestines of vertebrates including human beings and most domestic animals. Can cause a gastrointestinal disease called giardiasis.
Glacial Drift	Pulverized and other rock material transported by glacial ice and then deposited. Also the sorted and unsorted material deposited by streams flowing from glaciers.
Glaciofluvial Deposits	Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and occur as kames, eskers, deltas and outwash plains.
Glacial Outwash	Gravel, sand, and silt, commonly stratified, deposited by melt water as it flows from the glacial ice.
Glacial Till	Unsorted, non-stratified glacial drift consisting of clay, silt, sand and boulders, intermingled in any proportion, transported and deposited by glacial ice.
Gleyed soil	In the B and C soil horizons, a soil matrix with grayish to bluish hues, indicating soils with pores filled with water (saturated) for prolonged periods, caused by leaching of iron from the soil. Usually indicates a poorly or very poorly drained soil.
Graywater	Wastewater generated from non-toilet plumbing fixtures. i.e. discharge from sinks, basins, dishwashers, bathtubs, or showers, etc.
Hardpan	A hardened soil layer, in the lower A or in the B horizon, caused by cementation of soil particles with organic matter or with materials such as silica, sesquioxides or calcium carbonate.
Helminth	A worm, especially a parasitic roundworm or tapeworm.
Heterotroph	a microorganism that is unable to use carbon dioxide as its sole source of carbon and requires one or more organic compounds.
Heterotrophic Bacteria	Those bacteria which can only utilize organic matter for energy. Most microorganisms are heterotrophic.

Horizontal Travel Time	The time that a water volume requires to travel in a horizontal direction through an aquifer from a fecal contamination source to a point of concern.
Hue (Soils)	The dominant spectral color, one of the three variables of soil color defined within the Munsell system of classification.
Humus	The well decomposed, more or less stable part of the organic matter in soil.
Hydration	The physical binding of water molecules to ions, molecules, particles or other matter.
Hydraulic Conductivity	A measure of the ease of flow through a porous media such as soil. The constant of proportionality, K, in the Darcy law of fluid flow through porous media. K is a function of the porous media, the soil moisture tension, and the fluid properties, and has units of velocity. It can also be defined as the one-dimensional flow rate through a unit area at a unit hydraulic gradient.
Hydraulic Head	The elevation of a free surface of water above or below a reference datum. Also see Pump Heads.
Hydrolysis	Decomposition of a chemical compound by reaction with water, such as the dissociation of a dissolved salt or the catalytic conversion of starch to glucose. The chemical reaction of a compound with water, whereupon the anion from the compound combines with the hydrogen from the water and the cation from the compound combines with the hydroxyl from the water to form an acid and a base.
Hydrophobic	Repelling, tending not to combine with, or incapable of dissolving in water.
Illuviation	The process of deposition in an underlying soil layer of colloids, soluble salts, and mineral particles leached out of an overlying soil layer
Immobilization	The conversion of an element from the inorganic to the organic form in microbial or plant tissue, thus rendering the element not readily available to other organisms or plants.
Indicator Microorganisms	viruses and bacteria that may be non-pathogenic but are associated with fecal contamination and are transmitted through the same pathways as pathogenic viruses and bacteria.

Infectious Units	Either a single virus particle or a stable viral clump that is infectious for a living host system.
Infiltration	The entry into soil of water made available at the ground surface. The downward entry of water into the soil.
Infiltrometer	A device by which the rate and amount of water infiltration into the soil is determined.
Ion	An atom or a group of atoms that has acquired a net electric charge by gaining or losing one or more electrons. If an atom loses an electron, it becomes a positively charged ion termed a cation. If an atom gains an electron, it becomes a negatively charged ion termed an anion.
Isoelectric Point	The pH at which the electrical charge of an amphoteric particle becomes neutral.
Isotherm	See Absorption Isotherm.
Isotrophic	A condition where the hydraulic conductivity is independent of the direction of measurement at a point in a geologic formation.
Karst, Karstic	An area of irregular limestone in which erosion has produced fissures, sink holes, underground streams and caverns.
Kjeldahl Nitrogen	A term that reflects the technique used in determining the sum total of organic nitrogen and ammonium.
Labile	Constantly undergoing or likely to undergo change; unstable: a labile compound.
Lipid	Any of a group of organic compounds, including the fats, oils, waxes, sterols, and triglycerides, that are insoluble in water but soluble in common organic solvents, are oily to the touch, and together with carbohydrates and proteins constitute the principal structural material of living cells.
Land Treatment and Disposal	A system which utilizes soil materials for the treatment of domestic sewage and disposes of the effluent by percolation into the underlying soil and mixing with the ground water.
Latent	Present or potential but not evident or active.

Leach (Leaching)	To cause water or another liquid to percolate through something. The removal of materials in solution from the soil.
Limiting Horizon	Any horizon that limits the ability of the soil to provide treatment or disposal of septic tank effluent. Includes seasonal high water table, bedrock, hydraulically restricted or excessively coarse soil horizons and soil substrata.
Loam	As a soil textural class, soil material that contains 7% to 27% clay, 28% to 50% silt, and less than 52% sand.
Loamy	Intermediate in texture and properties between fine-textured and coarse-textured soils.
Loamy Sand	As a soil textural class, soil material that contains 70% to 90% sand, the remainder being silt and clay.
Longitudinal Dispersion	the spreading in the direction of ground water flow.
Lyse	To undergo or cause to undergo lysis.
Lysis	The dissolution or destruction of cells, such as blood cells or bacteria.
Lysimeter	A device for collection of liquid percolating through soil under controlled conditions.
Mass Transport	The distribution of contaminants in the subsurface via advection, dispersion and diffusion processes.
Mesophilic Bacteria	An organism whose optimum temperature for growth falls in an intermediate range of approximately 15° to 40° C.
Macrophyte	A macroscopic plant.
Macropore	Large soil pores, generally having a minimum diameter between 30 and 100 micrometers (μm), from which water drains readily by gravity.
Male Specific Coliphage	Viruses that attack coliform bacteria through the hair-like appendages extending from the cell walls of the bacteria. Designated as MS-Coliphage, or F^+ Coliphage.
Matric Potential	Attractive forces of soil particles for water and water molecules for each other.

Metabolism	The physical and chemical processes occurring within a living cell or organism that are necessary for the maintenance of life. In metabolism some substances are broken down to yield energy for vital processes while other substances, necessary for life, are synthesized.
Methemoglobin	A brownish-red crystalline organic compound formed in the blood when hemoglobin is oxidated either by decomposition of the blood or by the action of various oxidizing drugs or toxic agents. It contains iron in the ferric state and cannot function as an oxygen carrier.
Methemoglobinemia	A condition in which ferrous iron in hemoglobin is oxidized in the presence of nitrites to ferric iron, which converts hemoglobin (the blood pigment that carries oxygen from the lungs to tissue) to methemoglobin which is incapable of binding molecular oxygen. This condition prevents hemoglobin from carrying oxygen throughout the body and is particularly harmful to infants less than 6 months old because their stomachs are not yet acidic enough to prevent the growth of denitrifying bacteria that convert nitrate to nitrite.
Micrometer (µm)	One-millionth of a meter. (1 µm)
Microorganisms	An organism of microscopic or submicroscopic size, especially a bacterium or protozoan. Living organisms to small to be seen by the naked eye (<0.1 mm.); includes microscopic algae, bacteria, fungi, protozoans, and viruses. Also referred to as microbes.
Microfauna	Protozoa, nematodes and arthropods generally <200 micrometers long.
Microflora	Bacteria, fungi, algae, and viruses.
Micropore	Relatively small soil pore, generally found within structural aggregates and having a diameter <30 micrometers.
Mineral	A naturally occurring substance which has definite physical properties and chemical composition.
Mineral soil	A soil consisting predominantly of, and having its properties determined predominantly by, mineral matter. Usually contains less than 20% organic matter, but may contain an organic surface layer up to 30 cm thick.

Mineralize, Mineralization	To convert from an organic to a mineral substance. The conversion of a compound from an organic form to an inorganic form as a result of microbial decomposition.
Moderately-coarse texture	Consisting predominantly of coarse particles. In soil textural classification, it includes all the sandy loams except the very fine sandy loam.
Moderately-fine texture	Consisting predominantly of intermediate-size soil particles or with relatively small amounts of fine or coarse particles. In soil textural classification, it includes clay loam, sandy clay loam, and silty clay loam.
Mole (Chemistry)	An amount of a substance whose mass in grams numerically equals the formula weight of the substance.
Molal Solution	A solution containing one mole of solute in 1,000 grams of solvent.
Molar Solution	A solution that contains one mole of solute per liter of solution.
Molecular Weight	The sum of the atomic weights of all the atoms in a molecule.
Monosaccharide	A carbohydrate that cannot be decomposed by hydrolysis. Also called simple sugar.
Morphology	The branch of biology that deals with the form and structure of organisms without consideration of function. b. The form and structure of an organism or one of its parts. Also used in soil science to describe the form and structure of soils.
Motile, Motility	Moving or having the power to move spontaneously. Movement of a microbe under its own power.
Mottling, mottles	Spots or blotches of different color or shades of color, with both high and low chroma, interspersed with the dominant color of a soil. Redoximorphic features.
Munsell System (soil color)	A system of classifying soil color consisting of an alpha-numeric designation of hue, value and chroma, together with a descriptive color name, such as “strong brown”.
Nanometer (nm)	1×10^{-9} m (0.001 µm) One billionth of a meter.
Nemotode	An unsegmented, usually microscopic roundworm.

Nitrate-Nitrogen	The nitrogen in nitrates. 10 mg/l nitrate-nitrogen = 45 mg/l nitrate.
Nitrification	The transformation of ammonia nitrogen to nitrates.
Nitrogen Fixation -	The formation of ammonia from free atmospheric nitrogen.
NOx-N	Chemical compounds containing oxygen and nitrogen (nitrogen oxides), such as nitrites (NO_2-N), nitrates (NO_3-N), nitric oxide (NO), and nitrous oxide (N_2O).
Nutrient	Any substance that is assimilated by organisms and promotes growth.
Obligate	An adjective referring to an environmental factor (for example, oxygen) that is always required for growth. An organism that can grow and reproduce only by obtaining carbon and other nutrients from a living host.
Obligate Bacteria	Bacteria able to exist or survive only in a particular environment or by assuming a particular role. (Example: Nitrifying bacteria which use inorganic nitrogen compounds, rather than organic compounds, to supply their energy needs. Carbon compounds such as CO_2 are used for cellular synthesis reactions but not for energy producing reactions.
Oligotrophic	Lacking in nutrients, nutrient poor.
Oocyst	The infectious stage of *Cryptosporidium parvum* and some other coccidian parasites. An oocyst has a protective shell-like wall that facilitates its survival in water and other environments. The encysted stage in the life cycle of some protozoa. A metabolically dormant protective phase often exhibited by parasitic protozoa.
Order	A taxonomic category of organisms ranking above a family and below a class.
Organic matter	Chemical substances of basically carbon structure.
Organic soil material	soil containing 12 to 18 percent or more organic carbon by dry weight, depending upon the clay content.
Organic Nitrogen	Nitrogen combined in organic molecules, such as proteins and amino acids.
Ova	A reproductive cell, an egg.

Oxidation-Reduction

A chemical reaction in which one substance is reduced and another is oxidized.

Reduction is a chemical transformation involving a gain of electrons to an atom, molecule or ion. Usually, reduction involves the loss of oxygen; gain of hydrogen; or an increase in the proportion of a metal in a compound. Oxidation is a chemical transformation involving a loss of electrons from an atom, molecule or ion. Usually, oxidation involves the gain of oxygen; loss of hydrogen; or an increase in the proportion of a nonmetal in a compound.

An oxidizing agent oxidizes or acquires electrons from another material and is itself reduced. Reducing agents contribute electrons and are themselves oxidized. Electrons transfer from reducing agents to oxidizing agents. Energy is released by oxidation reactions. The chemical scheme of oxidation is believed to be the same for all microorganisms whether plant or animal. The differences between aerobic, facultative, and anaerobic bacteria lie in their mechanisms of hydrogen oxidation.

Organic matter in wastewaters is stabilized by oxidation. Bacteria and other microorganisms in waste stabilization systems do not oxidize matter by the direct addition of oxygen, but rather by the indirect scheme of hydrogen removal and addition of water. The hydrogen eventually reacts with oxygen, carbon, nitrogen or sulfur.
The growth and survival of microorganisms depends upon their ability to obtain energy from the system. Energy is required for the production of new protoplasm, for motility, and just to remain alive. Microorganisms obtain their energy from the metabolism of organic and inorganic compounds. The energy level of the organic matter being metabolized is reduced while the energy level of the cellular material is increased.

Removal of hydrogen from organic matter results in its oxidation, while addition of hydrogen to organic matter results in its reduction. In aerobic biological systems oxygen is the ultimate hydrogen acceptor. In anaerobic biological systems the hydrogen acceptors include any oxidized organic matter, nitrates, nitrites, sulfates and carbon dioxide.

Oxygen Reduction Potential (ORP)

A metal (gold or platinum) electrode immersed in water with a redox reaction occurring, or at least containing redox

	reaction products, will develop a potential related to the reaction.
	Practical oxidation-reduction potential (ORP) measurement is simply the voltage measured between a metal ORP electrode and a reference electrode. ORP is measured in millivolts (mV), typically ±1000 mV.
	Oxidizing chemicals have the ability to accept electrons; reducing chemicals have the ability to donate electrons. When present in a solution, the presence of an oxidizer will raise the ORP (oxidation/reduction potential), while a reducer's presence will lower the ORP.
Pans	Horizons or layers, in soils, that are strongly compacted, hardened, or very high in clay content. A natural subsurface soil layer of low or very low permeability, with a high concentration of small particles, and differing in certain physical and chemical properties from the soil immediately above or below the pan.
Pandemic	Epidemic over a wide geographic area: i.e. pandemic influenza.
Parasite	An organism that lives in or on another organism (the host) and gains benefit at the expense of the host. An organism that grows, feeds, and is sheltered on or in a different organism while contributing nothing to the survival of its host.
Pathogens	Microorganisms that cause disease. They include a few types of bacteria, viruses, protozoa and other organisms.
Pathogenesis	The development of a diseased or morbid condition.
Pathogenicity	Capable of causing disease.
Ped	The arrangement or grouping of individual soil particles into aggregates or clusters. A unit of soil structure such as an aggregate, crumb, prism, block, or granule, formed by natural processes (in contrast with a clod, which is formed artificially)
Pedology	The scientific investigation of soils.
Pedon	The smallest volume of a soil body which displays the normal range of variations in properties of a soil. A three-dimensional body of soil with lateral dimensions large enough to permit the study of horizon shapes and relations.

Percolation	The downward movement of excess water through soil; the water may or may not fill all of the soil pores.
Permeability	A measure of the rate of flow of a liquid or gas through a porous media. Permeability is a function of the porous media only, as compared to hydraulic conductivity, which is a function of both the porous media and the fluid (liquid or gas). Permeability has dimensions of $[L^2]$.
PFU	Plaque forming units. The presence of plaques, in an otherwise dense growth of bacteria susceptible to destruction by the selected virus, indicates that bacteria at the plaque locations have been destroyed and thus the presence of viable viruses.
pH (Soil)	The negative logarithm (base 10), of the hydrogen ion activity of a soil at a specified moisture content or soil-water ratio. The hydrogen ion activity in a soil solution is an index of soil acidity. A soil with a $pH<7$ is an acid soil.
Phosphates	Compounds of phosphorus and oxygen which occur in many forms, often combined with other elements such as sodium, calcium and potassium.
Phreatic Surface	The surface of the ground water, the water table.
Piezometer -	A device so constructed and sealed as to measure the static (hydraulic) head at a point in the subsurface.
Plaques	Small, clear, circular areas on a lawn of growing cells (monolayer) which result from the virus-induced deaths of groups of cells. The number of plaques indicated the concentration of virus particles.
Plinthic	Containing plinthite
Plinthite	An iron-rich, humus poor mixture of clay with quartz and other minerals. It commonly occurs as dark red redox concentrations that usually form platy, polygonal or reticulate patterns.
Polysaccharide	Any of a class of carbohydrates, such as starch and cellulose, consisting of a number of monosaccharides joined together.
Pore space	Portion of soil bulk volume occupied by soil pores.

Porosity	Volume of pores in a soil sample divided by the bulk volume of the sample.
Pump Heads	The head of water on the suction side of the pump is the static suction head. The height to which a pump must raise a liquid is the static discharge head. The head required to overcome the friction and form losses in a piping system at a given flow rate is the system head. The velocity head is the kinetic head imparted to the pumped liquid. The total head on a pump is the sum of all the various heads defined herein, expressed in similar units.
Precipitate	To cause (a solid substance) to be separated from a solution.
Predation	The capture of prey as a means of maintaining life.
Protein.	Any of a group of complex organic molecules that contain carbon, hydrogen, oxygen, nitrogen, and usually sulfur and are composed of one or more chains of amino acids. Proteins are fundamental components of all living cells and include many substances, such as enzymes, hormones, and antibodies, necessary for the proper functioning of an organism, including growth and repair of tissues.
Proton	A stable, positively charged subatomic particle.
Protoplasm	The living substance of a cell. The term usually refers to the substance enclosed by the cytoplasmic membrane, the protoplasm outside the nucleus of a cell.
Protozoa	Microscopic, usually single-celled microorganisms that live in water and are relatively large in comparison to other microorganisms. Protozoa eat bacteria and many are parisitic.
Recalcitrant	Resistant to microbial attack
Receiving layer	The natural soil under and around an effluent disposal area, beyond the biomat interface, which receives and provides additional treatment of the percolating wastewater before it reaches the ground water.
Redox Reactions	See Oxidation-Reduction.

Redoximorphic Features	Features formed by the process of reduction, translocation and/or oxidation of iron and manganese oxides. Can be categorized as redox depletions and redox concentrations (low and high chroma mottles, respectively) and a gleyed matrix.
Reduction	See Oxidation-Reduction.
Refractory	Resistant to treatment.
Regolith	The layer of loose rock resting on bedrock, constituting the surface of most land. Approximately equivalent to the term "soil".
Respiration	The oxidative process occurring within living cells by which the chemical energy of organic molecules is released in a series of metabolic steps involving the consumption of oxygen and the liberation of carbon dioxide and water. Also, any of various analogous metabolic processes by which certain organisms, such as fungi and anaerobic bacteria, obtain energy from organic molecules.
Respirometer	An instrument for measuring the degree and nature of respiration.
Restrictive layer	A soil horizon that restricts the downward flow of water and is uncharacteristic of the soil layers above and below, such as a layer of soil with a consistence of firm or very firm, cemented horizons, or stratified layers of silt, loam or clay within the soil profile.
Risk	A compound measure describing the probability of an adverse event occurring and the severity of such an event. An evaluation of the health risks posed by the use of on-site wastewater disposal systems requires knowledge of (1) the presence of agents that cause disease, (2) the dose response characteristics of the agent involved, and (3) the manner in which the agent comes into contact with susceptible individuals. The risk of infection is defined as a mathematical probability of infectivity from a given dose or exposure
Risk Assessment	The process of making estimates that particular adverse events will occur in a given time period. There are four steps in a formal risk assessment: (1) hazard identification, (2) dose-response determination, (3) exposure assessment, and (4) risk characterization.

Risk Evaluation	A social value judgement as to what level of risk is acceptable.
RNA	Ribonucleic acid. A polymeric constituent of all living cells and many viruses. The structure and base sequence of RNA are determinants of protein synthesis and the transmission of genetic information.
Salt	A compound produced when an acid reacts with a base. Usually water is also produced. Salts are composed of anions and cations.
Sand	As a soil textural class, soil that contains 85% or more (by weight) of particle sizes between 0.05 and 2.0 mm.
Coarse Sand	Contains 25% or more (by weight) of soil that has a particle size between 0.5 and 2.0 mm.
Fine Sand	Contains 50% or more (by weight) of soil that has a particle size between 0.10 and 0.25 mm.
Sandy Loam	As a soil textural class, soil that contains silt and clay and between 43% and 52% (by weight) of sand.
Saprolite	Highly weathered (rotten) bedrock. Soft, partially decomposed rock rich in clay and remaining in its original place.
Saturated Zone	The soil zone in which all easily drained voids between soil particles are temporarily or permanently filled with water.
Saturated Hydraulic Conductivity	The hydraulic conductivity when all of the soil pores are filled with water.
Seasonal high water table	The upper limit of the seasonally high saturated zone.
Seep	To pass slowly through small openings or pores; ooze.
Self-supplied water	Water withdrawn from a source by a user rather than being obtained from a public water supply system.
Septage	The waste content found in a septic tank.
Serology	The medical science that deals with serums (clear yellowish fluids obtained by separating whole blood into its solid and liquid components).
Serotype	A group of closely related microorganisms distinguished by a characteristic set of antigens.
Sesquioxides	Metallic (e.g. Fe, Al, Mn) oxides in clay minerals or in soils.
Silicate	Any of numerous compounds containing silicon, oxygen, and one or more metals and sometimes hydrogen.

Silt	Soil particle with a diameter between 0.002 and 0.05 mm. As a soil textural class, soil material that contains more than 80& or more silt and less than 12% clay.
Slime layer (Bacterial)	Diffuse layer of polysaccharide exterior to the cell wall of some bacteria.
Smectitic Soils	Soils containing clay minerals that swell on wetting and close the larger pores in the soil system.
Soil Aeration	The process by which air in the soil is replaced by air from the atmosphere. The rate of aeration depends largely on the volume and continuity of air-filled pores within the soil.
Soil aggregates	A group of soil particles cohering so as to behave mechanically as a unit.
Soil Bulk Density	The mass of solids divided by the total volume of solids and voids.
Soil, Silt.	Individual mineral particles that range in diameter from 0.002 mm to 0.05 mm. As a soil textural class, soil that is 80 percent or more silt and less than 12 percent clay.
Soil Catena	Related soils of about the same age, derived from similar parent material and occurring under similar climatic conditions, arranged into a sequence of increasing wetness.
Soil, Clay	Soil particle <0.002 mm in diameter. Naturally occurring inorganic matter, largely of secondary origin. As a soil textural class, soil that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.
Soil, coarse textured	Sand or loamy sand.
Soil, moderately coarse Textured	Sandy loam and fine sandy loam.
Soil, medium textured	Very fine sandy loam, loam, silt loam, or silt.
Soil, fine textured	Sandy clay, silty clay and clay.
Soil Horizon	A distinct layer of soil running approximately parallel to the soil surface, having distinct characteristics produced by soil-forming processes. Alphabetically designated, but not necessarily in alphabetical order, proceeding vertically through the soil profile from the soil surface downward.

O horizon	A soil horizon at the surface, formed from organic litter derived from plants and animals, which overlies mineral soils.
A horizon	A soil horizon formed at or near the surface, but within the mineral soil, having properties that reflect the influence of accumulating organic matter or the removal of soil material in suspension, alone or in combination. Also a plowed surface horizon most of which was originally part of the B-horizon. Commonly referred to as the topsoil.
E horizon	An eluvial, mineral soil horizon in which the main feature is loss off silicate clay, iron, or aluminum,, or some combination of these, leaving a concentration of sand and silt particles.
AB horizon	A transitional horizon between the A and B horizons.
B-horizon	A soil horizon immediately beneath an A, E, or O horizon characterized by a higher colloid (clay or humus) content. Commonly referred to as the subsoil. The alluviated B horizons are layers that are rich in deposited iron, aluminum and other minerals that were leached out of the A horizons.
B2 horizon	That part of the B horizon where the properties on which the B horizon is based are without clearly expressed subordinate characteristics indicating that the horizon is transitional to an adjacent overlying or underlying horizon.
Solum	The upper and most weathered part of the soil profile; the O, E and B horizons. The soil beneath the solum is defined as the substratum.
C-horizon	The unconsolidated mineral soil horizon than normally lies beneath the solum. This horizon is outside the zone of major biological activity and has been influenced only slightly by soil-forming processes. If the C horizon material is similar in properties to the soils in the solum, it is referred to as unaltered or slightly altered parent material.
Cd horizon	A dense, compact, brittle horizon which is nearly impervious to water. Commonly associated with basal till.
Soil Macropores	Large soil pores, generally having a minimum diameter between 30 and 100 micrometers (μm), from which water drains readily by gravity.

Soil, massive	Soil with no structural units, a coherent mass (not necessarily cemented).
Soil matrix	The natural soil material composed of both mineral and organic matter.
Soil matric potential	Portion of the total soil water potential due to the attractive forces between water and soil solids as represented through adsorption and capillarity.
Soil Micropore	Relatively small soil pore, generally found within structural aggregates and having a diameter <30 micrometers.
Soil Moisture	See Water Content.
Soil Moisture Tension	The equivalent negative pressure in the soil water.
Soil Morphology	The physical constitution, particularly the structural properties, of a soil profile as exhibited by the kinds, thickness, and arrangement of the horizons in the profile, and by the texture, structure, consistence and porosity of each horizon.
Soil Particle Size Descriptors	
D	Diameter of soil particles determined by a sieve or hydrometer analysis.
D_{10}	Diameter of particles such that 10%(by weight) of the sample is smaller than that size. Also referred to as the “effective size”.
D_{60}	Diameter of particles such that 60%(by weight) of the sample is smaller than that size.
C_u	Coefficient of Uniformity, the ratio of D_{60}/D_{10}.
Soil Profile	A vertical cross section of the undisturbed soil showing the characteristic soil horizontal layers or soil horizons that have formed as a result of the combined effects of parent material, topography, climate, biological activity, and time.
Soil Series	The basic unit of soil classification, consisting of soils, which are essentially alike in all major profile characteristics, although the texture of the A-horizon may vary somewhat.

Soil solution	Aqueous liquid phase of the soil and its solutes, consisting of ions dissociated from the surfaces of the soil particles and of other soluble materials.
Soil texture	The visual or tactile surface characteristics of soil. The distribution, on a percent by weight basis, of sand, silt, and clay.
Soil structure	The arrangement or grouping of individual soil particles into aggregates or clusters. The principal forms of soil structure are blocky (angular or sub-angular), columnar (prisms with rounded tops), granular, platy (laminated), and prismatic (vertical axis of aggregates longer than horizontal). Structure-less soils are either single grained (each grain by itself) or massive (the particles adhering without any regular cleavage, as in many hardpans).
Soil Water (soil moisture)	Water present in the soil pores in an unsaturated zone above the ground water table.
Soil water potential (total)	The amount of energy that must be expended to extract water from soil. The total potential of soil water consists of gravitational potential, matric potential, and osmotic potential.
Solum	The upper and most weathered part of the soil profile; the A and B horizons.
Solute	A substance dissolved in another substance.
Somatic Coliphage	Viruses that attack fecal coliform bacteria through their cell walls.
Sorb	To take up and hold, as by absorption or adsorption.
Sorption	The transfer of ions (molecules with positive or negative charges) from the solution phase (water) to the soil (solid phase). Sorption actually describes a group of processes, which include adsorption and precipitation reactions.
Species	A fundamental category of taxonomic classification, ranking below a genus or subgenus and consisting of related organisms capable of interbreeding. A collection of closely related strains sufficiently different from all other strains to be recognized as a distinct unit.

Specific Yield	The volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline in the water table.
Spore	A dormant, non-reproductive body formed by certain bacteria, protozoa and fungi in response to adverse environmental conditions. A small, usually single-celled, reproductive body that is highly resistant to desiccation and heat and is capable of growing into a new organism under favorable environmental conditions.
Sporocyst	A protective case containing spores of certain protozoans.
Sterilization	Free from live bacteria or other microorganisms.
Strain	A group of organisms of the same species, having distinctive characteristics but not usually considered a separate breed or variety.
Stratified Drift	Sorted sediments (layers of sand and gravel and lesser amounts of silt and clay) deposited by glacial meltwaters.
Streptobacilli	Bacilli arranged in chains of cells.
Streptococci	Cocci that divide in such a way that chains of cells are formed.
SWAS	Subsurface wastewater absorption system. Also referred to as a subsurface soil absorption system (SSAS).
Substrate	The material or substance on which an enzyme acts. Also, a surface on which an organism grows or is attached.
Supernatant	The clear fluid above a sediment or precipitate.
Symbiosis	Close prolonged associations between two or more different organisms of different species that may, but does not necessarily, benefit each member.
Taxonomy	The classification of organisms in an ordered system that indicates natural relationships.
Tensiometer	a device used to measure in situ the negative hydraulic pressure (or tension) with which water is held in the soil; a porous, permeable cup connected through a tube to a manometer or vacuum gage.
Terminal Acceptor	A chemical substance that accepts the hydrogen ion that has been removed from another substance during the

biological oxidation process. Strict aerobes utilize free dissolved oxygen as their ultimate hydrogen acceptor, while strict anaerobes use chemically bound oxygen, carbon, nitrogen or sulfur as their hydrogen acceptor. The facultative bacteria can use most of the above mechanisms, but will always use the hydrogen acceptor yielding the greatest energy. Also see Electron Acceptor.

Threshold Moisture Content	The minimum moisture condition, measured either in terms of moisture content or moisture stress, at which biological activity just becomes measurable.
Till	See Glacial Till.
Titer	The concentration of a substance in solution. Often expressed as the reciprocal of dilution. A solution diluted to 1:256 is said to have a titer of 256. The concentration of viruses in a given volume of liquid.
Tortuosity	The non-straight nature of soil pores.
Total Nitrogen	The sum total of Kjeldahl nitrogen, nitrites and nitrates.
Total Organic Carbon (TOC)	The organic carbon in water and wastewater that includes those organic compounds that can be oxidized by biological (BOD test) and chemical (COD test) processes and those organic compounds that do not respond to those processes. TOC tests convert organic carbon to CO_2, which is then measured.
Travel Time	The time of travel of a contaminant from the contaminant source to a point of concern.
Transpiration	A process by which plants transfer water from the root zone to the leaf surface, where it eventually evaporates into the atmosphere.
Transverse Dispersion	The spreading in the direction perpendicular to the ground water flow.
Ultraviolet (UV) Light	Electromagnetic radiation with a wavelength between 175 and 350 nm (nanometers)-shorter than visible light. Certain wavelengths absorbed by nucleic acids result in mutation and death.
Unsaturated Zone	The soil zone above the water table in which the soil pores are not all filled with water and the pressure is less than atmospheric.

Uniformity Coefficient	The ratio of the percent by weight of the soil particles that pass the No. 60 standard mesh sieve to the percent by weight of soil particles that pass the No. 10 sieve. (d_{60}/d_{10})
Vadose Zone	The vadose zone is that portion of the soil between the ground surface and the water table and includes the capillary fringe.
Valency	The number of hydrogen atoms that combine with, or replace, one atom of the element. Hydrogen has a valency of one.
Value (soil color)	The relative lightness or intensity of a color, one of the three variables of soil color defined within the Munsell system of classification.
London-Van der Waal Force	An atomic cohesive force, existing between all atoms. Generally considered to operate within distances on the order of atomic dimensions. In the case of colloidal particles, the aggregate effect of the attractive forces is to extend the range of effectiveness to the order of colloidal dimensions.
Virion	A complete viral particle, consisting of RNA or DNA surrounded by a protein shell and constituting the infective form of a virus.
Virus n., pl. viruses.	Any of various simple submicroscopic parasites of plants, animals, and bacteria that often cause disease and that consist essentially of a core of RNA or DNA surrounded by a protein coat. Viruses are unable to replicate without a host cell and are typically not considered living organisms, but are sometimes referred to as being on the "threshold of life".
Virulence (Viral)	The disease: infection ratio.
Volatilization	The evaporation or changing of a substance from a liquid to a vapor.
Wastewater	Water and human excretions or other waterborne wastes incidental to the occupancy of a residential building or a non-residential building but not including manufacturing process water, cooling water, wastewater from water softening equipment, commercial laundry wastewater, blowdown from heating or cooling equipment, water from cellar or floor drains or surface water from roofs, paved surfaces or yard drains.

Water Content (soil)	The unit volume of water in a unit bulk volume of the soil. Expressed as a percentage or decimal fraction. Also referred to as the soil moisture content.
Water Table	The upper surface of the ground water or that level in the ground where the water is at atmospheric pressure. The upper surface of a zone of saturation.
Water Table, perched	The water table of a saturated layer of soil, which is separated from an underlying saturated layer by an unsaturated layer.
Water Year	The period from October 1st of one calendar year to September 30th of the following calendar year.
Wild Viruses	Viruses recovered from the environment or from an infected individual.
Wilting Point	The minimum quantity of water in a given soil necessary to maintain plant growth. When the quantity of moisture falls below the wilting point, the leaves begin to drop and shrivel up.

APPENDIX F

PHOSPHORUS SORPTION ISOTHERM DETERMINATION

Phosphorus Sorption Isotherm Determination

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V.D. Nair, University of Florida

Introduction:

Phosphorus (P) retention by soils is an important parameter for understanding soil fertility problems, as well as for determining the environmental fate of P. The P adsorption capacity of a soil or sediment is generally determined by batch-type experiments in which soils or sediments are equilibrated with solutions varying in initial concentrations of P. Equations such as the Langmuir, Freundlich and Tempkin models have been used to describe the relationship between the amount of P adsorbed to the P in solution at equilibrium (Berkheiser et al., 1980; Nair et al., 1984).

Advantages of the batch technique include: the soil and solution are easily separated, a large volume of solution is available for analysis, and the methodology can be easily adapted as a routine laboratory procedure. Disadvantages include difficulties in measuring the kinetics of the sorption reaction and optimizing the mixing of solution and soil without particle breakdown (Burgoa et al. 1990). Despite the disadvantages, the batch technique has been, and still is, widely used to describe P sorption in soils and sediments.

Nair et al. (1984) noted that P sorption varies with soil/solution ratio, ionic strength and cation species of the supporting electrolyte, time of equilibration, range of initial P concentrations, volume of soil suspension to head space volume in the equilibration tube, rate and type of shaking, and type and extent of solid/solution separation after equilibration. Although most researchers use a similar basic procedure for measuring P adsorption, there is considerable variation observed among studies with regard to the above parameters. This variation often makes comparisons of results among studies difficult. Thus, Nair et al. (1984) proposed a standard P adsorption procedure that would produce consistent results over a wide range of soils. This procedure was evaluated, revised, tested among laboratories and was eventually proposed as a standardized P adsorption procedure. This procedure as described below is proposed as the standard procedure recommended by the SERA-IEG 17 group.

Equipment:

1. Shaker: End-over-end type
2. Filter Apparatus: Vacuum filter system using 0.45 or 0.2 μm filters
3. Equilibration tubes: 50 mL or other size to provide at least 50% head space
4. Spectrophotometer: Manual or automated system capable of measuring at 880 nm

Reagents:

1. Electrolyte: 0.01 M $CaCl_2$, unbuffered
2. Microbial inhibitor: Chloroform
3. Inorganic P solutions: Selected concentrations as KH_2PO_4 or NaH_2PO_4 (in 0.01 M $CaCl_2$ containing: 20 g/L chloroform)

Procedure:

1. Air-dry soil samples and screen through a 2 mm sieve to remove roots and other debris.
2. Add 0.5 to 1.0 g air-dried soil to a 50 mL equilibration tube.
3. Add sufficient 0.01 M $CaCl_2$ solution containing 0, 0.2, 0.5, 1, 5, and 10 mg P/L as KH_2PO_4 or NaH_2PO_4, to produce a soil: solution ratio of 1:25. The range of P values could vary from 0 to 100 mg P/L (0, 0.01, 0.1, 5, 10, 25, 50 and 100 mg P/L) and the soil/solution ratio could be as low as 1:10 depending on the sorbing capacity and the P concentrations of the soils in the study.
4. Place equilibration tubes on a mechanical shaker for 24 h at 25 ± 1 C.
5. Allow the soil suspension to settle for an hour and filter the supernatant through a 0.45 μm membrane filter.
6. Analyze the filtrate for soluble reactive P (SRP) on a spectrophotometer at a wavelength of 880 nm.

Calculations and Recommended Presentation of Results:

Two of the often used isotherms are the Langmuir and the Freundlich isotherms; the Langmuir having an advantage over the Freundlich in that it provides valuable information on the P sorption maximum, S_{max} and a constant k, related to the P bonding energy.

The Langmuir equation
The linearized Langmuir adsorption equation is:

$$C/S = 1/kS + C/S_{max}$$

where:

$S = S' + S_o$, the total amount of P retained, mg/kg
S' = P retained by the solid phase, mg/kg
S_o = P originally sorbed on the solid phase (previously adsorbed P), mg/kg
C = concentration of P after 24 h equilibration, mg/L
S_{max} = P sorption maximum, mg/kg, and
k = a constant related to the bonding energy, L/mg P.

The Freundlich equation
The linear form is: $\log S = \log K + n \log C$
where:
K is the adsorption constant, expressed as mg P/kg,
n is a constant expressed as L/kg, and
C and S are as defined previously.

A plot of log S against log C will give a straight line with log K as the intercept, and n as the slope.

Previously adsorbed P (also referred to as native sorbed P)
Adsorption data should be corrected for previously adsorbed P (S_o). For the calculation of previously sorbed P, Nair et al. (1984) used isotopically exchangeable P (Holford et al., 1974) prior to calculations by the Langmuir, Freundlich and Tempkin procedures. Other procedures used to calculate the previously adsorbed P include oxalate-extractable P (Freese et al., 1992; Yuan and Lavkulich, 1994), anion-impregnated membrane (AEM) technology (Cooperband and Logan, 1994) and using the least squares fit method (Graetz and Nair, 1995; Nair et al., 1998; Reddy et al., 1998). Sallade and Sims (1997) used Mehlich 1 extractable P as a measure of previously sorbed P.

Investigations by Villapando (1997) have indicated a good agreement among native sorbed P values estimated by the least squares fit method, oxalate extractions, and the AEM technology. At this point, it appears that selection of the method for determination of native sorbed P would depend on the nature of the soils in the study and reproducibility of the results.

The procedure for calculation of S_o using the least square fit method is based on the linear relationship between S' and C at low equilibrium P concentrations. The relationship can be described by

$$S' = K' C - S_o$$

Where

K'= the linear adsorption coefficient, and all other parameters are as defined earlier. (Note: It is recommended that the linear portion of the isotherm has an r^2 value 0.95 or better).

Equilibrium P Concentration
The “equilibrium P concentration at zero sorption” (EPC_0) represents the P concentration maintained in a solution by a solid phase (soil or sediment) when the rates of P adsorption and desorption are the same (Pierzynski et al., 1994). Values for EPC_0 can be determined graphically from isotherm plots of P sorbed vs. P in solution at equilibrium. From the calculations given above, EPC_0 is the value of C when S' = 0.

Comments:

The above procedure was developed to provide a standardized procedure with a fixed set of conditions that could be followed rigorously by any laboratory. The procedure uses a low and narrow range of dissolved inorganic P concentrations because these are the concentrations likely to be encountered in natural systems and because higher concentrations may result in precipitation of P solid phases. However, higher concentrations of P (up to 100 mg/L) and/or lower soil:solution ratios (1:10) have been used for isotherm determinations on soils and sediments (Mozaffari and Sims, 1994; Sallade and Sims, 1997; Nair et al., 1998; Reddy et al., 1998). A 0.01 M KC1 solution may be used as the background electrolyte to avoid precipitation of Ca in neutral and alkaline soils.

Toluene and chloroform have been shown to increase the dissolved P concentration in the supernatant, apparently due to lysis of microbial cells, and thus, some researchers do not try to inhibit microbial growth (Reddy et al., 1998).

Most adsorption studies are conducted under aerobic conditions, however, with certain studies it is more appropriate to use anaerobic conditions, as they more closely represent the natural environments of the soils or sediments. Reddy et al. (1998) preincubated sediment/soil samples in the dark at 25º C under a N_2 atmosphere, to create anaerobic conditions. Adsorption experiments were then conducted, performing all equilibrations and extractions in an O_2-free atmosphere.

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APPENDIX G

CONNECTICUT PUBLIC HEALTH CODE

REGULATIONS AND TECHNICAL STANDARDS
FOR SUBSURFACE SEWAGE DISPOSAL SYSTEMS

Page 27, Section IV - Design Flows
Pages 28-32, Section V – Septic Tanks

CONNECTICUT PUBLIC HEALTH CODE

Regulations and Technical Standards

for Subsurface Sewage Disposal Systems

Section 19-13-B100a (Building Conversions, Changes in Use, Additions)
Effective August 3, 1998

Section 19-13-B103 (Discharges 5,000 Gallons Per Day or Less)
Effective August 16, 1982

Technical Standards (Pursuant to Section 19-13-B103)
Effective August 16, 1982
Revised January 1, 1986
Revised January 1, 1989
Revised January 1, 1992
Revised January 1, 1994
Revised January 1, 1997
Revised January 1, 2000
Revised January 1, 2004

Section 19-13-B104 (Discharges Greater than 5,000 Gallons Per Day)
Effective August 16, 1982

State of Connecticut
Department of Public Health
Environmental Engineering Program
410 Capitol Avenue - MS #51SEW
P.O. Box 340308
Hartford, Connecticut 06134

www.dph.state.ct.us/BRS/Sewage/sewage_program.htm

January 2004

IV. DESIGN FLOWS

RESIDENTIAL BUILDINGS: 150 Gallons per Day per Bedroom

NON-RESIDENTIAL BUILDINGS and RESIDENTIAL INSTITUTIONS: Table No. 4 shall be used for determining the daily design flow from non-residential buildings and residential institutions unless specific water use data is available for the facility. Design flow based on metered flows must use a minimum 1.5 safety factor applied to all metered average daily water use.

TABLE NO. 4

SCHOOLS, PER PUPIL	**GALLONS PER DAY**
BASE FLOW (EXCLUDES KITCHEN & SHOWERS)	
HIGH SCHOOL	12
JR. HIGH/MIDDLE SCHOOL	9
KINDERGARTEN/ELEMENTARY SCHOOL	8
KITCHEN	3
SHOWERS	3 to 5
RESIDENTIAL	100
DAY CARE CENTER (NO MEALS PREPARED)	10
COMMERCIAL/INDUSTRIAL BUILDINGS, PER EMPLOYEE	
FACTORY (NO SHOWERS)	25
FACTORY (WITH SHOWERS)	35
OFFICE (AVERAGE 200 SQ.FT./PERSON-GROSS AREA)	20
SMALL RETAIL BUILDING-LESS THAN 2,000 SQ.FT.-GROSS AREA	20
LARGE RETAIL/COMMERCIAL BUILDING-SEE MISCELLANEOUS	
CAMPS	
RESIDENTIAL CAMPS (SEMI PERMANENT), PER PERSON	50
CAMPGROUND WITH CENTRAL SANITARY FACILITIES, PER PERSON	35
CAMPGROUND WITH FLUSH TOILETS (NO SHOWERS), PER PERSON	25
CAMPGROUNDS PER CAMP SPACE (WATER AND SEWER HOOK-UPS)	75
DAY CAMPS, PER PERSON	15
LUXURY CAMPS, PER PERSON	75
PICNIC PARKS (TOILET WASTES ONLY), PER PERSON	5
PICNIC PARKS WITH BATHHOUSES, SHOWERS, FLUSH TOILETS, PER PERSON	10
HEALTH CARE FACILITIES	
HOSPITALS, PER BED	250
REST HOMES, PER BED	150
CONVALESCENT HOMES, PER BED	150
INSTITUTIONS, PER RESIDENT	100
GROUP HOME, PER CLIENT (LARGE TUB/ON-SITE LAUNDRYING USE HIGHER FLOW)	100-150
RESTAURANTS	
RESTAURANTS (PUBLIC TOILETS PROVIDED), PER MEAL SERVED	10
TAKE OUT FOOD SERVICE/RESTAURANTS WITH NO PUBLIC TOILETS, PER MEAL SERVED	5
BARS AND COCKTAIL LOUNGES (NO MEALS) PER PATRON	5
RECREATIONAL FACILITIES	
SWIMMING POOLS, PER BATHER	10
INDOOR TENNIS COURTS, PER COURT	400
OUTDOOR TENNIS COURTS, PER COURT	150
THEATERS, SPORTING EVENTS, PER SEAT	3.5
CHURCHES	
WORSHIP SERVICE ONLY, PER SEAT	1
SUNDAY SCHOOL, PER PUPIL	2
SOCIAL EVENTS (MEALS SERVED) PER PERSON	5
MISCELLANEOUS	
AUTO SERVICE STATIONS, PER CARS SERVICED	5
BEAUTY SALON, PER CHAIR	200
BARBER SHOPS, PER CHAIR	50
DENTAL/MEDICAL OFFICES WITH EXAMINATION ROOMS, PER SQ. FT. OF GR. AREA	0.2
KENNEL DOG RUNS, PER RUN, ROOF MUST BE PROVIDED	25
LARGE RETAIL/COMMERCIAL BLDG., PER SQ. FT. OF GROSS AREA	0.1
LAUNDROMATS, PER MACHINE	400
MOTELS, PER ROOM, (NO FOOD SERVICE, KITCHENETTE OR LAUNDRY FACILITIES)	75
MOTELS, PER ROOM, (WITH KINCHENETTE BUT NO LAUNDRY FACILITIES)	100
MARINAS (BATHHOUSE-SHOWERS PROVIDED), PER BOAT SLIP	20

V. SEPTIC TANKS

A. General

1. Septic Tank Standards

All subsurface sewage disposal systems shall be provided with a septic tank. Such septic tank shall be made of concrete or other durable material approved by the Commissioner of Public Health.

a) Concrete Septic Tanks

All concrete septic tanks shall be produced with a minimum 4,000-psi concrete with 4 to 7 percent air entrainment. Concrete tanks must not be shipped until the concrete has reached the 4,000-psi compressive strength. Concrete septic tank construction shall conform to ASTM C 1227 with the following exceptions:

- There shall be no maximum liquid depth.
- The air space above the liquid level shall be a minimum of eight inches.
- Inspection ports over the compartment wall shall be optional.

b) Non-Concrete Septic Tanks

All non-concrete septic tanks shall meet all of the applicable requirements set forth in subsections 2, 3, and 4 of Standard V A regarding tank configuration, tank access, and tank cleaning. Non-concrete tanks shall be marked with the manufacturer's name and tank designation number. Non-concrete septic tanks shall be installed with strict adherence to the manufacturer's installation instructions in order to avoid tank damage or tank deformation. Proper bedding, backfill, and compaction shall be confirmed with each tank installation. Shallow groundwater conditions may prohibit installation of certain tanks due to tank design limitations or warranty restrictions. Tank bottoms located below maximum groundwater levels must be provided with anti buoyancy/floatation provisions (check with manufacturer). Manufacturers of non-concrete septic tanks shall file specifications and technical support documentation with the Commissioner of Public Health. The Commissioner of Public Health shall maintain a list of approved non-concrete septic tanks. The approved list as of the date of this revision has been provided in Appendix D.

2. Tank Configuration

All septic tanks shall contain an inlet baffle submerged for a depth of eight to eighteen inches and an outlet baffle (unless tank is provided with an approved outlet filter) submerged to a depth of at least ten inches, but no lower than 40 percent, of the liquid depth. The inlet baffle shall encompass not more than 48 square inches of liquid surface area. All baffles shall extend a minimum of five inches above the tank's liquid level and an air space of at least a 1/2-inch shall be provided above the baffle. The outlet invert of the septic tank shall be 3 inches lower than the inlet invert. Tanks must be installed with the inlet invert between 2 and 4 inches above the outlet invert. Inlet and outlet piping entering and exiting the septic tank shall be as level as possible with a pitch no greater than 1/4-inch per foot. The outlet invert of the tank shall be set at a higher elevation than the top of all leaching structures (except in a pump systems), or in the case of serial systems higher than the high-level overflow elevation of the upper most trench. All newly installed tanks shall have an approved non-bypass effluent filter at the outlet. The Commissioner of Public Health shall maintain a list of approved outlet filters. The approved list as of the date of this revision has been provided in Appendix B.

All septic tanks (except tanks in series) shall have two compartments with 2/3 of the required capacity in the first compartment (see Figure No. 4). The transfer port must be at mid-depth (opening in middle 25% of liquid depth). Inlet and outlet piping shall be sealed with a polyethylene gasket or rubber boot with stainless steel clamp. All septic tanks shall be manufactured with manhole covers or risers that have been placarded with notification of its two-compartment construction and a warning that "Entrance into the tank could be fatal". The minimum liquid depth of septic tanks shall be thirty-six inches.

Additional septic tank capacity over one thousand gallons may be obtained by utilizing two tanks in series. In no case may more than two septic tanks be placed in series. When two septic tanks are placed in series, each tank shall be of single compartment design; the volume of the first tank shall be twice the volume of the second; mid-depth baffles shall be provided at the connection of the two tanks; an outlet filter shall be provided for the outlet of the second tank (see Figure No. 5).

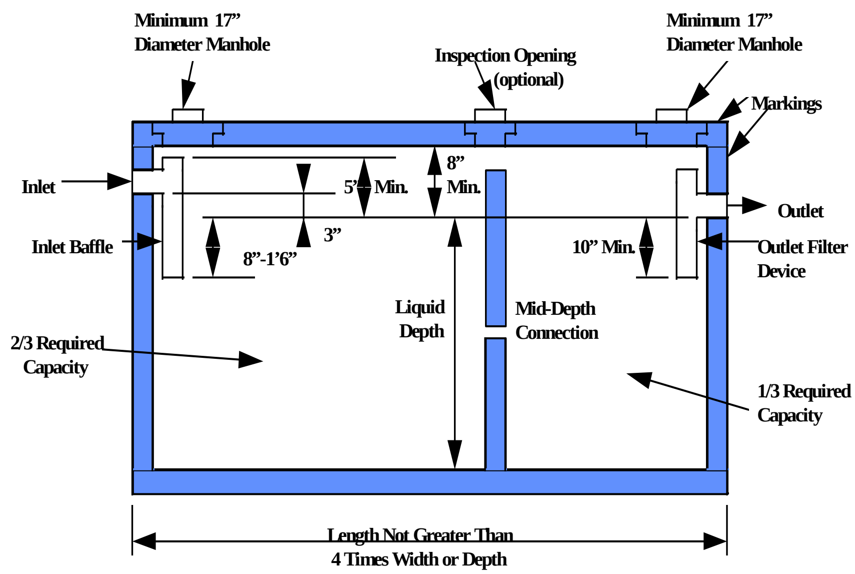


FIGURE NO. 4 - TYPICAL SEPTIC TANK

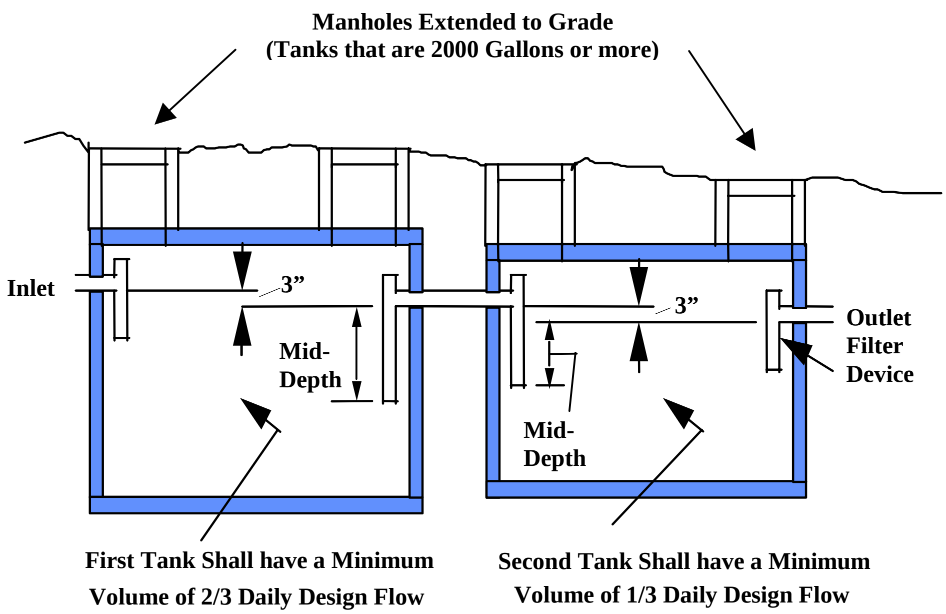
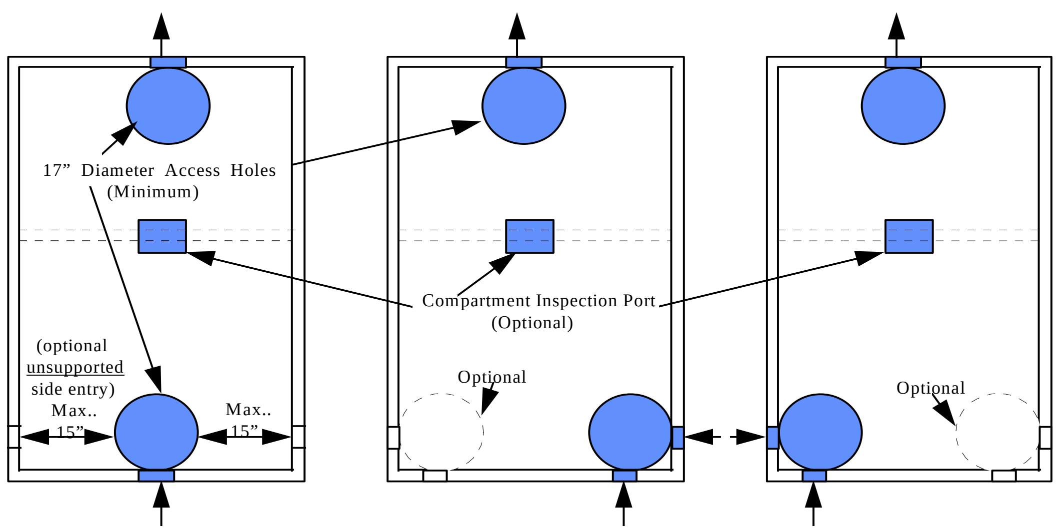


FIGURE NO. 5 - SEPTIC TANKS IN SERIES

3. Septic Tank Access

Septic tanks shall have removable covers or manholes to provide access to the tank for the purposes of inspection and cleaning. Cleanout manholes shall be located at a depth not greater than twelve inches below final grade level. Existing tanks that exceed the 12-inch depth shall be retrofitted with a cleanout riser(s) at the time of tank cleaning. New tanks and existing tanks deeper than 24 inches below finish grade shall be provided with large (24-inch minimum inside diameter) access risers over each manhole opening. Cleanouts shall consist of a minimum 17-inch inside diameter opening and shall be located directly over the inlet baffle and outlet filter. If a tank provides side inlets, the maximum distance between the interior wall surface and the cleanout manhole shall be 15 inches unless the pipe extension from the tank side to the cleanout manhole opening will be supported. Baffle extensions shall not have more than a 1/4-inch per foot pitch. All tank covers shall be stepped and be provided with handles consisting of 3/8-inch coated rebar or approved plastic handles. Below ground plastic handles and plastic riser covers cannot be used unless provisions are made to allow for manhole locating with a metal detector. On septic tanks of two thousand gallons or more, manholes shall extend to grade except for single-family residential buildings. Where covers are flush with or above grade, either the lid must weigh a minimum of 59 pounds or the cover shall be provided with a lock system to prevent unauthorized entrance. Tanks that exceed fifteen feet in length shall provide a minimum of three manholes. In any case, the overall length shall not be greater than four times either the width or the depth.



TYPE "C" TANK
CENTER ENTRY

TYPE "R" TANK
RIGHT ENTRY
(OPTIONAL)

TYPE "L" TANK
LEFT ENTRY
(OPTIONAL)

STANDARDIZED SEPTIC TANK TOP CONFIGURATIONS

4. Septic Tank Cleaning

Septic tanks shall be cleaned as often as necessary to prevent a buildup of sludge, grease and scum which will adversely effect the performance of the leaching system. In a properly functioning subsurface sewage disposal system, effluent should not backflow from the leaching system into the septic tank at the time of pumping. Such conditions indicate the leaching system is surcharged at that time. In these instances, further system evaluation is warranted. Inlet and outlet baffles shall be inspected for damage or clogging at the time of the tank pump out. When provided, outlet filters shall be properly cleaned, at the time of each tank pump out, by washing the filter waste into the septic tank or, if rinse water is not available, exchanged with a clean filter. All contaminated filters shall be treated as sewage and handled properly during the cleaning and/or exchange process.

5. Septic Tank Markings

Tank information (size, date manufactured, name of manufacturer and indication of limit of external loads/cover depths required by Section 13 of ASTM C 1227) shall be located on the top of the tank between the outlet access hole and outlet wall or on the vertical outlet wall between the top of the tank and the top of the outlet opening.

6. Performance Testing

When necessary due to installation concerns, testing for leakage will be performed using either a vacuum test or water-pressure test.

Vacuum Test: Seal the empty tank and apply a vacuum to 4 in. (50 mm) of mercury. The tank is approved if 90% of vacuum is held for 2 minutes.

Water-Pressure Test: Seal the tank, fill with water, and let stand for 24 hours. Refill the tank. The tank is approved if the water level is held for 1 hour.

7. Tank Abandonment

Abandonment of septic tanks, or hollow leaching structures, shall be performed in such a manner as to eliminate the danger of the structure inadvertently collapsing. The responsibility for abandonment lies with the property owner. When hollow structures are abandoned the chamber shall be emptied of all septage wastes, and the structure shall be filled with clean sand and gravel, or the structure shall be crushed and the area backfilled with clean soil.

B. Septic tank capacities

1. The minimum liquid capacity of septic tanks serving residential buildings shall be based on the number of bedrooms in the building. For three bedrooms or less, a 1000-gallon tank is required; and another 250-gallons shall be added for each additional bedroom above three.

2. The minimum liquid capacity of septic tanks serving non-residential buildings and residential institutions shall be equal to the 24-hour design flow (see Table No. 4). In no case shall a septic tank be installed with a liquid capacity of less than one thousand gallons. In cases of non-residential buildings that are subject to high peak sewage flows, the liquid capacity of the septic tank shall provide a minimum detention time of 2 hours under peak flow conditions. The required septic tank capacity shall be increased by a minimum of 50% at food service establishments and restaurants in instances of repairs of existing subsurface sewage disposal systems where it is determined that it is not feasible to install a grease interceptor tank or internal grease recovery unit.

3. Whenever more than 25 percent of the daily design flow from a building served will be pumped into the septic tank, the size of the tank shall be increased 50 percent beyond the minimum capacity required per Standard V B.

4. The liquid capacity of a septic tank shall be increased whenever a residential building contains a garbage grinder or large capacity bathtub in accordance with the following:

Garbage grinder:
Add 250 gallons to required capacity of the septic tank.

Large tub
100 to 200 gallon tub: Add 250 gallons to required capacity of the septic tank
Over 200 gallon tub: Add 500 gallons to required capacity of the septic tank.

C. Grease interceptor tanks

Grease interceptor tanks shall be provided for restaurants and food service establishments with design flows of 500 gallons per day or greater for new construction and repairs of existing subsurface sewage disposal systems where feasible. If it is determined that it is not feasible to install a grease interceptor tank on a food service/restaurant system repair, a mechanical grease recovery unit (GRU) is recommended to be retrofitted on the internal wastewater piping in the kitchen. If a grease interceptor tank or an internal GRU is not included in a food service/restaurant septic system repair, then the required septic tank capacity shall be increased by a minimum of 50% (see Standard V B).

Grease interceptor tanks shall receive wastewater from the kitchen waste lines only. Effluent discharged from the grease interceptor tank shall be directed to the inlet end of the septic tank. The capacity of grease interceptor tanks shall be a minimum of 1000 gallons and shall meet or surpass the 24-hour design flow. For restaurants and food service establishments with design flows of 2,000 gallons per day or greater, two grease interceptor tanks in series shall be provided. Such grease interceptor tanks shall have a combined liquid volume meeting or surpassing the 24-hour design flow. Grease interceptor tanks shall have inlet and outlet baffles that extend to a depth of six to twelve inches above the tank bottom (see Figure No. 6) and extend at least five inches above the liquid level. All manholes and cleanouts on grease interceptor tanks shall be extended to grade to facilitate cleaning. Grease interceptor tanks shall be provided with manhole covers that have been placarded with notification as to the danger of entering the tank due to noxious gases.

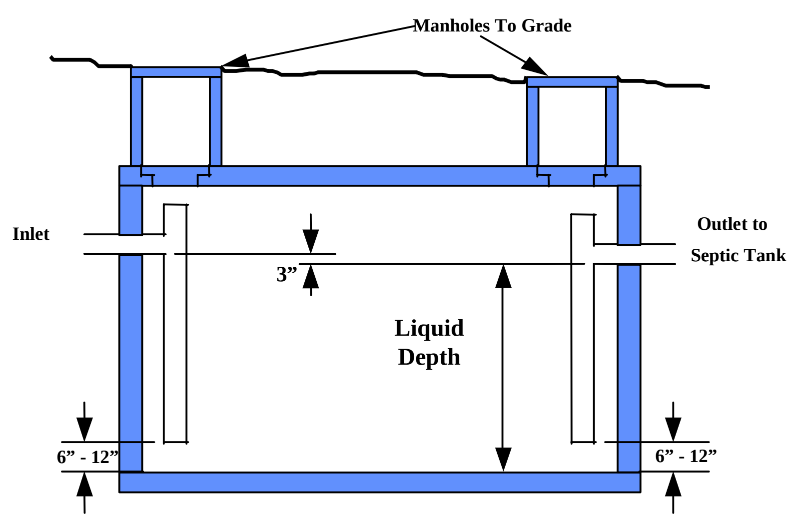


FIGURE NO. 6 - GREASE INTERCEPTOR TANK

Grease interceptor tanks can be single or two compartment tanks and shall be constructed out of concrete or other durable material approved by the Commissioner of Public Health. Concrete grease interceptor tanks shall meet all structural and access requirements for concrete septic tanks. This includes applicable configuration (pipe seals, inlet/outlet differential, etc) and access (riser sizes, stepped covers, etc) requirements consistent with the requirements for concrete septic tanks. Concrete grease interceptor tanks shall be marked with tank information (size, name of manufacturer, date manufactured, loading limits), and be subject to other applicable septic tank provisions (performance testing, cleaning, tank abandonment, etc). Non-concrete grease interceptor tanks shall also meet all of the requirements for concrete grease interceptor tanks excluding the structural and marking requirements. Non-concrete grease interceptor tanks must be approved by the Commissioner of Public Health. Non-concrete grease interceptor tanks shall be marked with the manufacturer's name and tank designation number.