ENVIRONMENTAL ENGINEERING AND SANITATION

Fourth Edition

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and synthetic nutrients received as well as light, temperature, water body size, and depth. The degree of eutrophication is indicated by the quantity of planktonic algae (phytoplankton), zooplankton, bacteria, fungi, and detritus; reduced water transparency or clarity (Secchi disc depth), dissolved oxygen in the water near the surface, and pH. Reduced dissolved oxygen may cause the release of hydrogen sulfide, ammonia, methane, iron, and manganese. Sunlight stimulates the growth of algae.

A young lake is said to be *oligotrophic*. It is usually relatively clear, high in dissolved oxygen, deep, and receives few nutrients, thereby supporting little plant and animal life. As nutrients increase, together with siltation due to the acts of man and nature, plant and animal life increases. The lake then begins to mature and is referred to as a balanced *mesotrophic* lake. The continued siltation and accumulation of organic matter begin to fill up the lake, making it shallower. This, together with proper nutrients, increases the growth of aquatic plants, particularly algae, and the lake becomes mature or *eutrophic* with low water transparency, large organic deposits colored brown or black, and often hydrogen sulfide odors. If there is an excess of nutrients, the algal growths greatly increase ("bloom"), die, and decay. The decay process uses up more oxygen to the point of there not being enough for other forms of aquatic life. As the growth and decay progresses, the lake fills with organic matter and silt to become a marsh and eventually, dry land.

The aging process or eutrophication of a lake normally takes place over hundreds of years. With the addition of the proper combination of nutrients, the aging process can be greatly accelerated.

The nutrients associated with eutrophication include phosphorus, nitrogen, and organic carbon, any one of which may be a limiting factor in algal growth. Phosphorus appears to be the most practical nutrient to control.[29] The source may be compounds discharged to the atmosphere and their precipitation, groundwater, lake sediment (internal regeneration of phosphorus), tributary and stream drainage, agricultural runoff, animal pastures and fertilizer, forest runoff, urban and suburban drainage, and domestic wastewater. Nitrate-nitrogen is more likely to infiltrate during heavy rains, whereas phosphate-phosphorus is more readily adsorbed on soil and transported with sediment.[30] The nitrogen, phosphorus, and carbon from land drainage alone have been found to be adequate to support algal growths at the nuisance level. The upgrading of wastewater treatment or a detergent phosphate ban *alone* will not, as a rule, reverse the aging process in a lake or pond water.[31] Other nonpoint sources of nutrients, including storm-water drainage from urban, suburban, and rural areas, must also be removed. If wastewater contributes more than 20 percent of the total phosphorus load to a water body, a detergent phosphorus

ban is believed likely to produce only a marginally detectable improvement in eutrophication related water quality.[32,33]

Lee, et al.,[34] concluded that phosphorus is a key element in controlling the growth of planktonic algae in fresh water and that nitrogen is generally the controlling element in marine waters. From 1970 to 1980, decreased phosphorus loadings in the Great Lakes have improved water quality. Stumm states that "the entire limnological community is united in the opinion that reduction of the supply of phosphate to receiving waters is the only cure against manmade eutrophication."[35] But for many bodies of water phosphorus from nonpoint sources will also have to be controlled if the water quality is to be restored to desirable levels. Randall, et al.,[36] found that eutrophication in a reservoir could not be controlled by reduction of point sources of phosphorus and biochemical oxygen demand alone. Over 85 percent of the nitrogen and phosphorus entering the reservoir came from storm-water runoff, mostly from urbanized areas. Sawyer[37] indicates that any lake having 0.01 mg/l inorganic phosphorus and 0.3 mg/l nitrogen can expect to have major algal blooms. Ahern and Weand[38] found that in general, higher phosphorus concentrations are associated with lower transparencies as measured with a Secchi disc. The desirable total phosphorus level in reservoir waters was 0.03 mg/l *total* phosphorus or less and, that based on transparency, there does not seem to be any reason to require phosphorus controls unless they can reduce phosphorus concentrations to 0.08 to 0.03 mg/l, and in some instances to 0.01 mg/l or less. Municipal wastewater treatment plant effluent should not exceed 1.0 mg/l on an average monthly basis.* Watershed land-use control is a major factor in the prevention of pollution, sediment transport, and eutrophication. See Control of Microorganisms and Chemical Examination (Phosphorus) and (Nitrates), Chapter 3.

SMALL WATERBORNE WASTEWATER DISPOSAL SYSTEMS

The number of households in the United States served by public sewers, septic tank or cesspool systems, or other means is shown in Table 4-3. With an estimated average occupancy of 3.0 persons per household in 1970, 2.7 in 1980, and 2.6 in 1990, a total of 58.5 million people were dependent on individual on-site facilities

*U.S. Great Lakes basin.

[32]G. Fred Lee and R. Anne Jones, "Detergent phosphate bans and eutrophication," *Environ. Sci. Technol.*, April 1986, pp. 330–331.

[33]Keith A. Booman and Richard I. Sedlak, "Phosphate detergents—a closer look," *J. Water Pollut. Control Fed.*, December 1986, pp. 1092–1100.

Table 4-3 Housing Units Served by Public Sewers and Individual Facilities

Sewage Disposal Facility	Number of Housing Units Served[a] 1970	1980	1987[b]
Public sewer	48,187,675	64,569,886	77,130,000
Septic tank or cesspool	16,601,792	20,597,165	24,769,000
Other means	2,904,375	1,602,338	752,000
Total housing units	67,693,842	86,769,389	102,651,000
Total population	203,302,031	226,542,203	243,300,000

Source: U.S. Census of Housing and Census Bureau.
[a]All units were not occupied.
[b]Estimated.

in 1970, 59.9 million in 1980, and 66.4 million in 1990. This represents 28.8 percent of the population in 1970, 26.4 percent in 1980, and 26.7 percent in 1990. At an estimated water usage of 50 gallons per capita per day, about 3 billion gallons of sewage is discharged each day to on-site sewage disposal systems and thence to the groundwater. It is apparent that there is a need for continued support and research for on-site sewage treatment and disposal facilities, in addition to municipal facilities.

The provision of running water in a dwelling or structure immediately introduces the requirement for sanitary removal of the used water. Where sewers are available, connection to the sewer will solve a major sanitation problem. Where sewers are not provided or anticipated, as in predominantly rural areas and many suburban areas, consideration must be given to the proposed method of collection, removal, treatment, and disposal of wastewater. With a suitable soil, the disposal of wastewater can be simple, economical, and inoffensive; but careful maintenance, in addition to proper design and construction, is essential for continued satisfactory operation. Where rock or groundwater is close to the surface or the soil is a tight clay, it would be well to investigate some other property. Sometimes the groundwater level can be lowered by the proper design and construction of curtain drains.

The common system for wastewater treatment and disposal at a private home in a rural area consists of a proper septic tank for the settling and treatment of the wastewater and a subsurface absorption system for the disposal of the septic tank overflow, provided the soil is satisfactory. The soil percolation test and soil characteristics are commonly used as a means for determining soil permeability or the capacity of a soil to absorb settled wastewater. This and the quantity of wastewater from a dwelling are the bases upon which a subsurface sewage disposal system is designed. Sand filters, elevated systems in suitable fill, evapotranspiration-absorption systems, evapotranspiration beds, aeration systems, stabilization ponds or lagoons, recirculating toilets, and various types of toilets and privies are used under certain conditions and where the soil is unsuitable. These are discussed later in this chapter.

Wastewater Characteristics

The composition of wastewater can be expected to vary considerably depending on the community and water use, industries served, infiltration, and whether the sewers are combined sewers or sanitary sewers. However, the wastewater from a residential community is fairly uniform. The characteristics of average domestic wastewater, septic tank effluent, septic tank gray water effluent, and septic tank black water effluent are given in Table 4-1.

The wastewater from water closet and latrine or aqua privy flushing is referred to as *black water*. All other domestic wastewater is referred to as *gray water*.

For all practical purposes, and from a public health standpoint, gray water should be considered sewage or wastewater and should be treated as such. Gray water can be expected to contain pathogens from the bathroom shower and wash basin, and from clothes washing, including baby diapers and clothing. Gray water is amenable for treatment in a septic tank and subsurface absorption system.

General Soil Characteristics

In its broadest sense, soil is made up of glacial deposits, and weathered, decayed, or broken-down rock containing varying amounts of organic material such as animal and plant wastes. Destruction of rock is accomplished by water and rainfall, wind, glacial ice, chemical or biochemical action, plant life, freezing and thawing, heat, and other forces to form soil. The soil may accumulate in place or may be transported by wind, water, or glacial ice. Soil that accumulates in place is representative of the rock from which it has been derived and the local flora and fauna. Soils may be divided, for reference purposes, into gravel, sand, silt, and clay, and, depending on which is predominant, into sandy loam, gravelly loam, silty loam, loam, clay loam, and clay, with and without large cobbles and stones. See Table 4-4. Silt feels smooth; clay is plastic when wet; cobbles are 75 to 250 mm in size, and stones are larger than 250 mm. Loam, for example, is soil that is 7 to 27 percent

Table 4-4 U.S. Department of Agriculture Size Limits for Soil Separates

Soil Separate	Size Range (mm)	Tyler Standard Sieve No.
Sand	2–0.05	10–270 mesh
Very coarse sand	2–1	10–16
Coarse sand	1–0.5	16–35
Medium sand	0.5–0.25	35–60
Fine sand	0.25–0.1	60–140
Very fine sand	0.1–0.05	140–270
Silt	0.25–0.002	—
Clay	<0.002	—

Source: *Design Manual, Onsite Wastewater Treatment and Disposal System*, U.S. EPA, Office of Water Program Operations, Washington, D.C., October 1980, pp. 367–374.

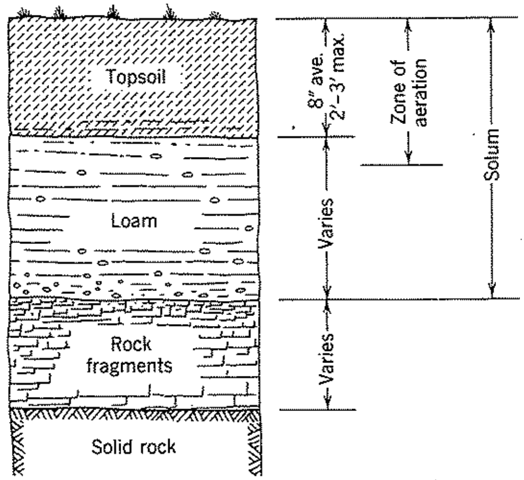

Figure 4-2 Typical earth formation.

lay by weight, 28 to 50 percent silt, and less than 52 percent sand. If the content of particles coarser than sand is as much as 15 percent, an appropriate modifier is added, for example, gravelly (USDA).

Figure 4-2 illustrates a typical earth formation with the top layer, or topsoil, as much as 2 or 3 ft deep, although on the average it will be about 6 to 8 in. or less. The topsoil is usually richer in humus (the organic portion of soil, decomposing plant or animal matter and their products). Clay loam and clay do not drain well and are usually considered unsuitable for the disposal of sewage and other wastewater by subsurface means. Some of the chemicals in clay soil can be displaced by salts, acids, and bases. This ion exchange process, for example, accounts for soil acidity and alkalinity, the friability of some clays, the binding of potassium and ammonium in soil, and the travel of nitrogen through soils.[39]

Soil Characteristics and Clues

The permeability of a soil, or the ability of the soil to absorb and allow water and air to pass through, is related to the chemical composition, color, texture, and granular structure of the soil. The soil texture refers to the proportion of clay, silt, and sand less than 2 mm in diameter, to its filtration capacity and permeability. The soil structure refers to the agglomeration or clumping of particles of clay, silt, and sand and the intervening cleavage planes indicating hydraulic conductivity and shrink/swell potential. The microbial population and root penetration modifies the properties of the soil as noted below. A lump of soil with good structure will break apart, with little pressure, along definite cleavage planes. Horizontal cleavage restricts vertical percolation and permits a perched water table to exist. Prismatic and columnar structure enhance vertical percolation, and blocky and granular structure

[39]Witold Rybezynski, Chongrak Polprasert, and Michael McGarry, *Low-Cost Technology Options for Sanitation*, International Development Research Centre, Ottawa, Canada, 1978, p. 22.

enhance both horizontal and vertical water flow.[40] If the color of the soil is yellow, brown, or red, it would indicate that air, and therefore water, passes through. However, if the soil is blue or grayish it would indicate a soil saturated for extended periods, and if mottled brown and red, it would indicate a fluctuating seasonal high water table or poor aeration, and therefore an intermittently saturated or tight soil that is probably unsuitable for subsurface absorption of wastewater. The absorption field and dwelling basement would probably be flooded at times if not drained. A grayish soil, however, may be suitable if drained, but is generally unsuitable. Magnesium and calcium tend to keep the soil loose, whereas sodium and potassium have the opposite effect. Sodium hydroxide, a common constituent of so-called septic tank cleaners, would cause a breakdown of soil structure with resultant smaller pore space and reduced soil permeability.

Role of Microorganisms and Macroorganisms

Aerobic oxidizing bacteria, that is, oxygen-loving bacteria, are found in the zone of aeration. This zone extends through the topsoil and into the upper zone of the subsoil, depending on the soil structure and texture. Earthworm, insect and small animal populations, root penetrations, soil moisture, and other factors also influence the extent of the zone of aeration. The topsoil may contain organic matter, minerals, air, water, supportive vegetative organisms such as bacteria, fungi in-cluding yeasts and molds, as well as protozoa, nematodes, actinomycetes, algae, rotifers, earthworms, insects, and larger animals. A gram of topsoil can be expected to contain millions of bacteria and other organisms. These organisms have the faculty of reducing complex organic matter to simpler forms through their life processes. Earthworms, fungal activity, and small animals play an important role together with other soil flora and fauna in keeping soil fertile and aerated.

Septic tank effluent, for example, which contains material in solution, colloidal state, and suspension, when discharged into or close to the topsoil will be acted upon by these organisms and reduced to "soil," as well as liquids and gases. This is accomplished provided the sewage is not discharged at too great a volume and concentration into the earth in the zone of aeration. A waterlogged soil impedes oxygen transfer and destroys the aerobic organisms, producing anaerobic conditions that tend to preserve the organic matter in septic tank effluent, thereby delaying its decomposition and increasing mechanical clogging of the liquid-soil interface with organic matter including slimes and sulfides. In addition, the nitrites in septic sewage are toxic to plants. Complete soil treatment of septic tank effluent requires that it be discharged into the unsaturated soil zone at an acceptable rate to fully utilize the treatment available through physical filtration, and chemical and biolog-ical degradation processes. Travel through 1 to 2 ft of unsaturated silty, sandy, or clay loam soil can be expected to remove practically all sewage microorganisms and protect the groundwater. However, soil conditions vary. Greater unsaturated soil depth is required in coarse granular soils.

[40]*Design Manual, Onsite Wastewater Treatment and Disposal Systems*, U.S. EPA, October 1980, pp. 367–381.

Maintenance of Soil Infiltrative Capacity

To assist in the maintenance of aerobic conditions, subsurface absorption fields are usually laid at depths of 24 to 30 in., although depths as great as 36 in. or more are sometimes used. The gravel around the open-joint tile or perforated pipe should extend up into the zone of aeration, usually within 8 to 12 in. of the ground surface.

McGauhey and Winneberger call attention to the recovery infiltrative capacity of trench sidewalls after resting a few hours; the need to have a permeable soil in the first instance; the insulating effect of impermeable lenses or strata to the downward percolation of water; the reduction of percolative capacity of soils containing colloids that swell; and the necessity for the groundwater table to be at a sufficient depth to permit the soil to drain during rest periods rather than water remaining suspended by surface tension and capillary phenomena.[41] The

> loss of infiltrative capacity is directly traceable to the organic fraction of sewage which leads to clogging of the soil surface by suspended solids, bacterial growth, and ferrous sulfide precipitation.

They report "conclusively that intermittent dosing and draining of the soil system is necessary to the maintenance of optimum infiltration rates." In a subsequent report, narrow trenches, 8 to 12 in. in width, and placement of the distributing line as high as possible are advised to provide a maximum effective sidewall surface area.[42] It has also been found that "Soil clogging can be delayed or altogether mitigated by reducing the applied mass loading rate of the total biochemical oxygen demand (carbonaceous plus nitrogenous) and total suspended solids either through lower hydraulic loading rates or reduced effluent concentrations."[43] Full loading (siphon chamber or pump) on an intermittent basis will promote even distribution of wastewater, resting, and maintenance of aerobic conditions in the trench and soil. Prolonged resting periods (several months to a year) will permit restoration of infiltrative capacity; but two absorption systems and a diversion gate or valve are needed to permit alternate use of each system. Laak[44] believes that soil seepage beds will function forever if the system is properly designed, constructed, and maintained. There is no evidence to suggest that soil clogging is irreversible.

Soil adsorptive capacity is an important consideration in the design of a septic tank system for the protection of the groundwater. Robeck, et al.,[45] advise that a soil must have a low permeability (effective size 0.1 to 0.3 mm) and some adsorptive capacity to allow organic material to be retained. A minimum soil organic content of 0.5 to 1 percent is suggested (found in practically all agricultural soil, together with some clay and silt, which add to the adsorptive capacity). Under such circumstances pathogenic and essential aerobic organisms, which are capable of degrading such food sources as detergents and other organic matter, are retained. A soil with low adsorption (coarse gravel) or a formation with solution channels, fractures, or fissures will permit pollution to travel long distances without purification. Careful consideration to these factors in the design of subsurface sewage disposal systems is necessary.

Hydrogen peroxide has been used on an experimental basis to restore and maintain the infiltrative capacity of clogged absorption systems, but its effectiveness is short-lived. The soil percolation capacity is greatly reduced. Use of hydrogen peroxide is not recommended.[46]

Site Investigation, Soil Profile, and Suitability

Prior to the construction of a sewage disposal system, subsurface explorations are necessary to determine the subsoil formation in a given area. An auger with an extension handle is often used in the investigation, but a backhoe should also be employed for deep test holes in large systems. The examination of road cuts, stream embankments, or building excavations provides useful information. Wells and well drillers' logs can also be used to obtain information on groundwater and subsurface conditions. In some areas subsoil strata vary widely within short distances and numerous borings are required in the selected site. Agricultural* and highway soil maps, if available, can give an indication of soil characteristics, provided the number and depth of the soil cores or test holes used to prepare the soil maps is representative of the soil strata and area to be used for the subsurface disposal of wastewater. Aerial photograph maps† are also very useful to experienced individuals. If the subsoil appears suitable (as judged by a study of soil maps and soil texture, and an investigation of the structure, color, and depth or thickness of permeable strata and their swelling characteristics), percolation tests should be made at points and elevations selected as typical of the area in which the disposal system is to be located to establish a settled sewage application rate for design purposes.

Like the soil percolation test (discussed later), soil maps and reports have limitations. The variability in soils and the map scale make impractical a prediction of soil characteristics and behavior on an individual plot for a subsurface soil absorption system. However, the soil survey map and report are extremely useful

41 P. H. McGauhey and John H. Winneberger, "Studies of the Failure of Septic-Tank Percolation Systems," *J. Water Pollut. Control Fed.*, May 1964, pp. 593–606.

42 P. H. McGauhey and John H. Winneberger, "Final Report on a Study of Methods of Preventing Failure of Septic-Tank Systems," Sanitary Engineering Research Laboratory, College of Engineering and School of Public Health, University of California, Berkeley, October 31, 1965.

43 Robert L. Siegrist and William C. Boyle, "Wastewater-Induced Soil Clogging Development," *J. Environ. Eng.*, June 1987, pp. 550–566.

44 Rein Laak, "Septic Tank and Leach Field Operation," *Wastewater Treatment Systems For Private Homes And Small Communities*, Paul S. Babiarz, Robert D. Hennigan, and Kevin J. Pilon, eds., Central New York Regional Planning and Development Board, Syracuse, N.Y., 1978, p. 23.

45 Gordon G. Robeck, et al., "Factors Influencing the Design and Operation of Soil Systems for Waste Treatment," *J. Water Pollut. Control Fed.*, August 1964, p. 971.

*See local Soil Conservation Service, USDA.

†ASCS Aerial Photography Field Office, Salt Lake City, Utah.

46 D. L. Hargett, et al., "Effects of Hydrogen Peroxide as a Chemical Treatment for Clogged Wastewater Absorption Systems," *On-Site Wastewater Treatment*, American Society of Agricultural Engineers 1985.

when supplemented by a field investigation of a specific site (including soil percolation tests) made by a qualified person.[47]

It is necessary to have at least 2 ft of suitable soil between the bottom of absorption trenches and leaching pits and the highest groundwater level, clay, rock, or other relatively impermeable layer. This helps ensure removal of most of the pathogenic viruses, bacteria, protozoa, and helminths in septic tank effluent before they reach the groundwater. Some agencies require a minimum of 3 or 4 ft. Seasonal groundwater levels can be determined by means of test holes, soil clues, piezometers, and rust accumulation on steel rods driven in the ground.

The design of leaching pits and cesspools is based on the ability of the soil found at the depth between 3 and 8 or 10 ft to absorb water. Sometimes pits are made 20 to 25 ft or more in depth, using prefabricated sections, in order to reach permeable soil. It is not known to what extent viruses, bacteria, protozoa, and metazoa are active in leaching pits and cesspools. Since relatively large quantities of sewage would be discharged in a small area, designs incorporating cesspools or leaching pits must take into consideration the soil texture and structure, direction and depth of groundwater flow, and the relative location of wells or springs with respect to their possible pollution. Cesspools and leaching pits should be prohibited in shale, coarse sand, gravel, and limestone areas or where groundwater is within 3 to 4 ft of the bottom, and avoided when shallow wells or springs are in the vicinity, unless adequate protecting distances and soils can be ensured.

Where the soil is relatively nonpermeable at shallow and deep depths, an alternate treatment and disposal system (discussed later) is needed in place of a conventional leaching system. Preferably, construction should be postponed in such situations until sewers are available.

It is extremely important while in the planning stage, before building construction is started, to consider:

1. The suitability of the soil to absorb settled sewage as determined by soil percolation tests, soil characteristics, and the type and size of the disposal system required. At least 4 to 5 ft of suitable soil should be available over clay, hardpan, rock, or groundwater for absorption trenches and 8 to 10 ft for leaching pits. The hydraulic conductivity of the soil below, around, and downgrade from the absorption system should permit adequate dispersal of the sewage effluent.
2. The area of land available for the sewage disposal system, and its adequacy for sewage disposal and water supply protection. This should include the location of existing and proposed on-site and off-site sewage disposal systems and underground sources of drinking water; type of well construction, underground strata, and depth of water-bearing source; slope of the groundwater table; and protecting distances between wells and sewage disposal systems.
3. The elevation of the sewage disposal units, the house sewer, the house drain, the first-floor level, and location of the lowest plumbing fixture. Sometimes the installation of a sewage pump, excavation at a greater depth, or the carting in of earth fill is made necessary because the slope of the ground surface, clay or rock level, and depth of the underground water are not considered in the planning stage. Earth fill will require careful selection and placement to achieve uniform density without compaction, stabilization for about 1 year, and testing for percolation since the original soil structure will have been changed.

[47]R. B. Brown, "Introduction to Soils and the Functioning of Onsite Sewage Systems," *3rd Annual National Environmental Health Association Mid-year Conference*, National Environmental Health Association, Denver, Co. , 1988, pp. 125–144.

4. The location of rock outcrops, hills, large trees, storm-water drains, watercourses, adjoining structures; also bathing beaches, shellfish-growing areas, and water supply intakes.
5. Surface and underground water drainage, including roof, cellar, and foundation drainage (this drainage must be excluded from the sewage disposal system to prevent the system becoming overloaded and waterlogged).
6. The average rainfall and temperature during the period of use.

Information on aquifer geology, well yields, well pump capacities, and static and pumping water levels will help determine the circle of influence and travel of underground pollution. All these factors should be carefully evaluated by a trained person before a decision is made and construction is started. The state and county sanitary or public health engineers and sanitarians are trained to give sound advice.

Travel of Pollution From Septic Tank Absorption Systems

Groundwater contamination potential from a septic tank leaching system is determined by the physical, chemical, and microbiological characteristics of the soil; the unsaturated soil depth to groundwater; the volume and strength of the septic tank effluent; and the biological slime or mat on the trench gravel, bottom, and sidewalls. The ability of the soil to remove or reduce the organic and inorganic contaminants is variable and determined by many factors. These include activity in the vegetation root zone to take up or break down chemical and organic substances. As the contaminants percolate downward and laterally, they may be volatilized, filtered, absorbed, attenuated, adsorbed, neutralized, hydrolized, changed, and broken down by aerobic and anaerobic microorganisms. (This latter role was discussed earlier.) See Role of Microorganisms and Macroorganisms, this chapter. There is some dilution of contamination, and the contamination that does reach the groundwater will usually travel very slowly as compared to surface water. It should be noted that the extent and health significance of groundwater contamination by a properly sited, designed, and constructed septic tank system is minimal. Concerns to be addressed include the persistence and potential transport of pathogenic viruses, bacteria, protozoa, and helminths, in addition to nitrates, phosphates, and household toxic cleaning compounds, particularly in granular coarse textured soils such as coarse sand and gravel.[48] The biological mat that forms in absorption field trenches further minimizes the travel of microorganisms. Because of their larger size, protozoa and helminths are not likely to travel significant distances compared to bacteria and viruses.

There are indications that 4 ft (122 cm) of unsaturated coarse grained sandy soil is not adequate to prevent bacteria from reaching saturated soils beneath on-site septic tank absorption trenches. However, no bacteria traveled beyond 3.6 ft (110 cm) in loamy sandy soil. The percentage of clay and silt particles, passing the U.S. Standard Sieve No. 200 with openings of 0.075 mm, and organic matter, appear

[48]Craig Cogger, "On-Site Septic Systems: The risk of groundwater contamination," *J. Environ. Health*, September/October 1988, pp. 12–16.

to be the major factors in bacteria retention by straining and adsorption, and in bacteria die-off.[49]

Studies show that unsaturated soil beneath absorption trenches will remove a high percentage of total dissolved solids, 5-day BOD, soluble organic carbon, ammonia nitrogen, iron, viruses, coliforms, fecal coliforms, and fecal streptococci from septic tank effluent. Phosphate (total PO_4-P) removal may or may not be high (removal or retention is dependent upon the type of soil). Nitrates will increase in the vicinity of the leaching system as ammonia, organic nitrogen, and nitrites convert to nitrates, but decrease downstream with microbial denitrification, distance, and dilution.[50]

Soils containing loam (clay, silt, and sand) will remove most of the phosphorus, soluble orthophosphates, and microorganisms in sewage effluent. If the absorption trenches are kept shallow (top of gravel about 8 to 12 in. from the ground surface) as recommended, the vegetative cover root system over the absorption field penetrates and takes up much of the nitrogen during the growing season, which coincides with maximum system use at summer vacation homes, resorts, and recreational areas. Moisture is also removed by capillarity and evapotranspiration. Hence, the danger of phosphates and nitrates traveling any significant distance through the soil (other than coarse-textured granular soils) to the groundwater table and contributing significant amounts of nutrients that might reach a lake or other impoundment and accelerate its eutrophication can be greatly minimized. This is particularly so when considered in relation to the phosphorus and nitrogen contribution from surface runoff, storm water, and wastewater discharges to lakes and streams. There are, however, some ecologically critical waters where even minimal amounts of phosphorus and/or nitrogen, regardless of source, should be avoided. But this may be impossible, as natural sources of nitrogen from precipitation and/or phosphorus from automobile exhaust, phosphorus and nitrogen from agricultural, uncultivated, and forest area, and storm-water overflows cannot in practice be eliminated. And even if minimized, there may still be sufficient amounts of nutrients reaching sensitive waters to cause algal growths and natural eutrophication, although it is hoped, at a slower rate.

Laboratory studies using nine types of soil indicate that passage through forty to fifty cm of an agricultural-type soil is very effective in removing viruses from water, with soils at pH below 7.0 to 7.5 best.[51] Culp concluded that although not well established, soil with reasonable amounts of silt and clay removes viruses within the first 2 ft.[52] Wellings, et al., reported virus travel of 5 ft in sandy soil

[49]Thomas C. Peterson and Robert C. Ward, "Bacterial retention in soils," *J. Environ. Health*, March/April 1989, pp. 196–200.
[50]T. Viraraghavan and R. G. Warnock, *J. Am. Water Works Assoc.*, November 1976, pp. 611–614.
[51]William A. Drewry and Rolf Eliassen, "Virus Movement in Groundwater," *J. Water Pollut. Control Fed.*, **40**, *8*, R271, (August 1968).
[52]Gordon Culp, *Summary of A "State-of-the-Art" Review of Health Aspects of Waste Water Reclamation for Ground Water Recharge*, Supplement to *Report of the Consulting Panel on Health Aspects of Wastewater Reclamation for Groundwater Recharge*, State of California, PB-268 540, U.S. Dept. of Commerce, National Technical Information Service, Springfield, Va., June 1976, p. 29.

spray irrigated with chlorinated activated sludge effluent and also travel to 6 and 20 ft-deep wells.[53] Slow sand filters dosed uniformly at standard loading rates removed 99 percent or more viruses from septic tank effluent over a 2-year period under controlled experimental conditions.[54] Sorber and his co-workers found that enteric viruses can be recovered in soils at considerable distances from their point of application.[55] It is apparent that the travel of pollution is not reduced to an exact science.

Travel of chemical pollution from other than septic tank absorption systems often presents a more serious problem in that the pollution may travel long distances, not be filtered in passage through the soil, and persist for long periods of time. Spills, leaking petroleum and other hazardous chemical storage tanks, lagoons, and old landfills are other examples. Millions of underground tanks are leaking. See Chapter 3: Travel of Pollution Through the Ground, Well Contamination—Cause and Removal, and Removal of Gasoline, Fuel Oil, and Other Organics in an Aquifer.

Soil Percolation Test

Background of the Soil Percolation Test

The suitability of soil for the subsurface disposal of sewage and other wastewater can be determined by a study of soil characteristics and the soil percolation test. The test is a measure of the relatively constant rate at which clear water maintained at a relatively constant depth (6 in.) will seep out of a standard size test hole (Ryon used a 12-in. square hole) that has been previously saturated; the bottom of the test hole is at the approximate depth of the proposed absorption system and greater than 2 ft above the seasonal high groundwater, rock, or tight soil. Henry Ryon first introduced this test in 1924 based on his investigation of subsurface disposal systems that had failed or were about to fail after 20 years of use in New York State.[56] He plotted the results of his tests, covering a wide range of soils, and developed "safe gallons per square foot per day subsurface irrigation rates." The soil percolation test developed by Ryon has been used throughout the world and, except for some refinements,* remains the only rational basis for the design of subsurface disposal systems. Ryon emphasized the importance of "taking care to wet the soil before pouring water in for the test if it appears dry," and that "the ground must be thoroughly wet before the test is made." *Saturation of the soil is essential* to compensate for soil swell, simulate wet conditions, and obtain repro-

*Two in. of gravel in the bottom of the test pit and reemphasis on prior soaking of the hole.
[53]F. M. Wellings, A. L. Lewis, and C. W. Mountain, "Virus Survival Following Wastewater Spray Irrigation of Sandy Soils," in *Virus Survival in Water and Wastewater Systems*, J. F. Malina, Jr., and B. P. Sagik, eds., Austin, Texas, Center for Research in Water Resources, 1974, pp. 253–260.
[54]*Management of Small Waste Flows*, PB-286 560, University of Wisconsin, National Technical Information Service, Springfield, Va., September 1978, p. C-55.
[55]Paper given at Environmental Engineering Division Conference, ASCE, Seattle, Wa., July 1976.
[56]Henry Ryon, *Notes on the Design of Sewage Disposal Works With Special Reference to Small Installations*, 1924, pp. 11–14; also *Notes on Sanitary Engineering*, Albany, N.Y., 1924, pp. 31–33.

ducible results, that is, a relatively constant rate of water drop in the test hole. The work done by Ryon was confirmed by the PHS in independent field tests and, in spite of its limitations, serves as the major basis for present-day design of subsurface absorption systems, adjusted for the automatic home clothes washer and garbage grinder disposal unit.[57]

The reliability of the soil percolation test is increased by scientific evaluation of soils maps by a qualified person (as noted in this Chapter General Soil Characteristics, and Site Investigation, Soil Profile, and Suitability). Special training and experience in soils is very helpful in properly interpretating the soils data.

Other investigators have studied the test to determine the effect of the shape of the test hole and the saturation of the soil on the percolation test. It has been found that the shape of the hole has no effect; size or diameter does affect results. However, it is again emphasized that *saturation of the soil is essential* to obtain reproducible results, that is, a constant rate of water drop in the test hole. This was recognized by Ryon and needs to be continually emphasized.

One of the main significant differences of opinion in connection with the soil percolation test is its interpolation to determine the allowable rate of septic-settled sewage application per square foot of leaching area. This rate is taken as a percentage of the actual volume of water a test hole accepts in 24 hours. Various investigators have stated that this rate should be 0.4 to 3.5 (Ryon), to 5.0 or 7.0 percent of the actual amount of water absorbed or accepted by the test hole. The rate is recorded in the minutes it takes the water level to drop 1 in.

The Percolation Test

Percolation tests and soils studies help to determine the acceptability of the site and establish the design size of the subsurface disposal system. The length of time required to carry out percolation tests will vary with different types of soil. The safest method is to make tests in holes that have been kept filled with water at least 4 hours, preferably overnight, except where the soil is clean sand or gravel. This is particularly desirable if the tests are to be made by an inexperienced person, and for some soils, such as those that swell on wetting, this precaution is necessary even if the person carrying out the test has had considerable experience. Percolation rates in such cases should preferably be calculated from test data obtained after the soil has had an opportunity to swell overnight. An adequate number of tests should be made to ensure a valid result.[15] Some agencies require that soil tests be made during the wet period of the year to minimize error.

The soil percolation test is performed as follows:

1. Dig a hole about 1 ft^2 (the EPA suggests a 6-in. diameter hole) and to the depth at which it is proposed to lay the drain tile or perforated pipe. Scrape the inside of the hole to remove all smooth or cemented patches. A good average depth is 24 to 30 in. About 2 in. of washed pea gravel should be placed in the bottom of the hole. See Figure 4-3.

[57]*Studies on Household Sewage Disposal Units*, PHS Pub. No. 397, Part I, 1949; Part II, 1950; Part III, 1954; DHEW, Cincinnati, Oh. *Manual of Septic-Tank Practice*, DHEW, PHS Pub. 526, Cincinnati, Oh., 1967.

[15]J. A. Salvato, *op. cit.*, p. 128.

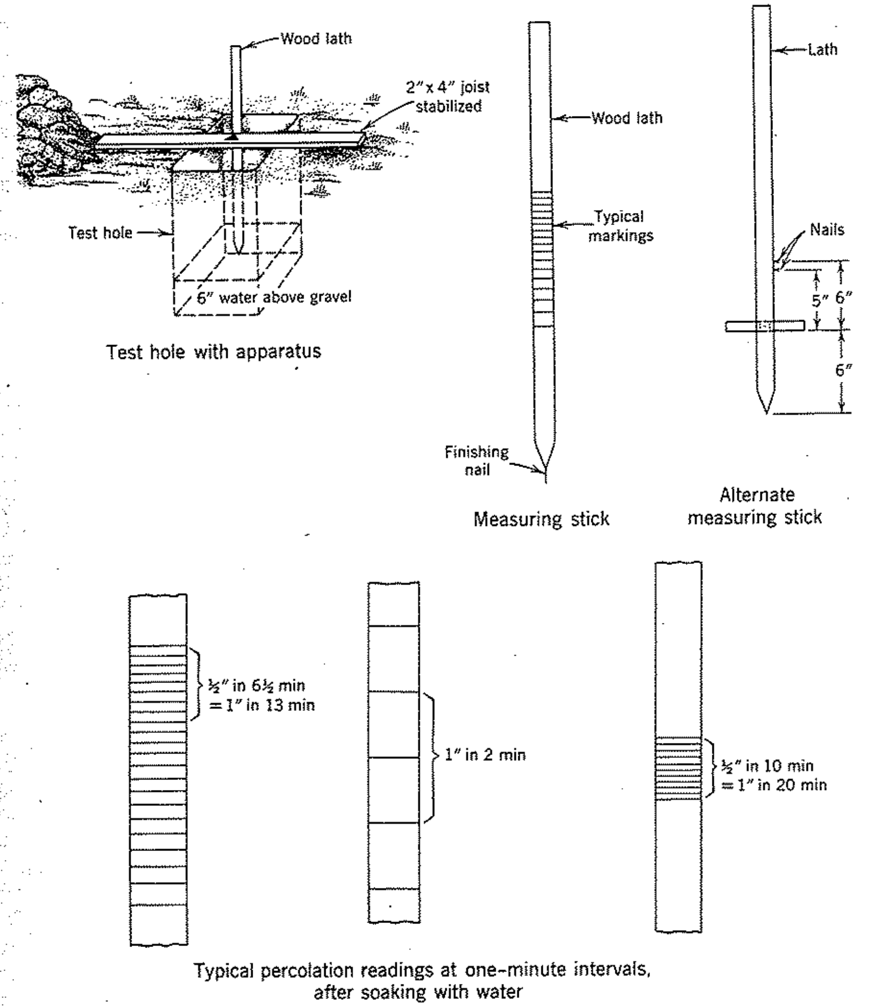

Figure 4-3 The soil percolation test. (Place 2 in. of gravel in bottom of test hole.)

2. Slowly pour about 12 in. of water on the gravel in the hole to prevent scour. If the soil is relatively tight, let the water soak for about 4 hours, adding more water as necessary, and proceed as explained in Step 3. If the soil is very absorbent, allow the water to seep away; if the soil contains clay or fine silt, soak overnight. Add another 8 in. of water in the hole and proceed as in Step 3. The test can be expedited by routinely having all test holes filled with water the night before the tests are made to allow ample time for soil swelling and saturation. Arrangement should be made to refill the holes. A 5-gal carboy, with a stopper and plastic tubing, filled with water could be inverted over the hole.

3. Measure the rate at which the water surface drops. This can be done by placing a piece of 2×4 across the hole, *being careful to anchor it in a firm position*. Then, using a point or line on the 2×4 as a reference (see Figure 4-3) for the remainder of the test, slide a pointed slat or similar measuring stick straight down until it just touches the water surface. Immediately read the exact time on your watch and draw a horizontal pencil line on the measuring stick using the point or line on the 2×4 as

a guide. Repeat the test at 1-min intervals, if the water level drops rapidly, or at 5- or 10-min intervals if the water level drops slowly. Observe the space between the pencil markings. Keep the depth of water in the hole at about 6 in. above gravel. When at least three spaces become relatively equal, between the 6- and 5-in. water depth in the test pit, the test is completed, since equilibrium conditions have been reached for all practical purposes. The percolation test result is recorded as the minutes it takes for the water level to drop 1 in.

4. With the aid of a ruler, measure the space between the *equal* pencil markings and reduce this to the number of minutes it takes for the water level to drop 1 in. This can be approximated closely with a ruler or can be computed. For example, if the interval between 5-min readings is $\frac{3}{8}$ in., the time for the water level to drop 1 in., is calculated as follows:

$$\frac{\frac{3}{8}\text{ in.}}{5\text{ min}} = \frac{1\text{ in.}}{x\text{ min}}, \quad \text{or } \tfrac{3}{8}x = 5, \quad \text{or } x = 13\tfrac{1}{3}, \text{ say } x = 15 \text{ min.}$$

Tests must be carefully made to minimize errors due to soil swelling, smearing, variations in soils characteristics, inaccurate readings, and water scour.

Make at least three tests for the average lot; six tests are preferable where soil is not relatively uniform. Consider the soil characteristics and excavate the test holes to a depth of 4 to 6 ft to ensure groundwater, rock, or tighter soil is not encountered. *Interpret the percolation tests results in the light of soil characteristics and soil clues as previously described.* Deeper borings may be indicated if clay or hardpan is encountered to determine the thickness of the soil horizons. Adjustments must be made if a lense of dense or impermeable material, that could cause a perched water table, or if a less permeable soil that could cause a mounded water table, is encountered.

5. Use Table 4-5 to determine the allowable rate of settled sewage application in gallons per day per square foot of bottom trench area (gpd/ft²) in an absorption trench system. Table 4-5 is applicable

Table 4-5 Interpretation of Soil Percolation Test

Time for Water to Fall 1 in. (min)	Allowable Rate of Settled Sewage Application (gpd/ft²)			
	U.S. PHS[a]	U.S. EPA[b]	GLUMR[c]	Ryon[g]
<1	5.0[d]	[b]	1.2	4.0 to 3.4
1	5.0[d]	1.2	1.2	3.3
2	3.5[d]	1.2	1.2	2.9
3	2.9[d]	1.2	1.2	2.7
4	2.5[d]	1.2	1.2	2.4
5	2.2[d]	1.2	1.2	2.2
6	2.0	0.8	0.9	
7	1.9	0.8	0.9	2.0
8	1.8	0.8	0.9	
9	1.7	0.8	0.9	
10	1.6	0.8	0.9	1.7
11	1.5	0.8	0.6	
12	1.4	0.8	0.6	
15	1.3	0.8	0.6	1.4
16	1.2	0.6	0.6	
20	1.1	0.6	0.6	1.1
25	1.0	0.6	0.6	
30	0.9	0.6	0.6	0.9
31	0.8	0.45	0.5	
35	0.8	0.45	0.5	
40	0.8	0.45	0.5	
45	0.7	0.45	0.5	0.7
46	0.7	0.45	0.45	
50	0.7	0.45	0.45	
60	0.6	0.45	0.45	0.4
61–120	[e]	0.2	[e]	0.2
>120	[e]	[e]	[e]	[f]

NOTE: Be guided by state and local regulations.

[a] USPHS, *Manual of Septic-Tank Practice*, PHS Pub. 526, HEW, Washington, D.C., 1967. Increase leaching area by 20 percent where a garbage grinder is installed and by additional 40 percent where a home laundry machine is installed. The required length of the absorption field may be reduced by 20 percent if 12 in. of gravel is placed under the distribution lateral, or by 40 percent if 24 in. of gravel is used, provided the bottom of the trench is at least 24 in. above the highest groundwater level. Superceded by the USEPA Manual.

[b] *Design Manual, Onsite Wastewater Treatment and Disposal Systems*, U.S. EPA, Cincinnati, Oh., October 1980. Soils with percolation rates <1 min/in. can be used if the soil is replaced with a suitably thick (>2 ft) layer of loamy sand or sand. Use 6 to 15 min/in. percolation rate.

Rates based on septic tank effluent from a *domestic* wastewater source are used to determine the required *trench* bottom area. Reduce application rate where applied BOD and TSS is higher than domestic sewage. Additional area credit may be given for sidewall trench area if more than 6 in. of gravel is placed below the distributor. The trench or bed bottom must be at least 2 to 4 ft above the seasonally high water table, bedrock, or clay soil.

The EPA and GLUMR application rates are lower than the U.S. PHS rates. The former recognize the importance of settled sewage retention in the unsaturated zone to obtain maximum purification before it reaches the groundwater and results in a larger disposal system.

[c] GLUMR, *Recommended Standards for Individual Sewage Disposal Systems*, Great Lakes-Upper Mississippi River Board of State Sanitary Engineers, 1980 Edition. Absorption trench or bed shall not be constructed in soils having a percolation rate slower than 60 min/in., or where rapid percolation may result in contamination of water-bearing formation or surface water. The percolation rate is for *trench* bottom area. For absorption *bed*, use application rate of 0.6 gpd/ft² for percolation rate up to 6 min/in., then use 0.45 gpd/ft². Trench or bed bottom, or seepage pit bottom, should not be less than 3 ft above highest groundwater level. Maximum trench width credit shall be 24 in. for design purposes, even if trench is wider.

[d] Reduce rate to 2.0 gpd/ft² where a well or spring water supply is downgrade; increase protective distance, and place 6 to 8 in. sandy soil on trench bottom below gravel and between gravel and sidewalls.

[e] Soil not suitable.

[f] See Small Wastewater Disposal Systems for Unsuitable Soils or Sites, this chapter.

[g] Henry Ryon, *Notes on Sanitary Engineering*, New York State, Albany, N.Y., 1924, p. 33. This is given for historical perspective, as are U.S. PHS rates.

only for typical residential sewage. For other applications adjust for organic loading, BOD, SS, COD, TKN, and grease in septic tank effluent.

An example will serve to illustrate how the soil test results are used.

Example

Number of bedrooms—3
Required septic tank—1000 gal liquid volume*
Average of soil tests for absorption field, from table = 0.9 gpd/ft^2 (1 in. in 30 min)
Estimated sewage flow at 150 gal per bedroom = 450 gpd
Required leaching area = 450/0.9, plus 60% for garbage grinder and clothes washer = 800 ft^2 (Using the U.S. PHS rate.)
The required area can be obtained by providing:

800/1.0 or 800 lineal ft of tile in trenches 12 in. wide, or
800/1.5 or 533 lineal ft of tile in trenches 18 in. wide, or
800/2.0 or 400 lineal ft of tile in trenches 24 in. wide, or
} Recommended widths

NOTE: No additional credit is given for bottom area for trenches wider than 2 ft; the trench may be wider. The required leaching area using the Great Lakes-Upper Mississippi River Board or EPA recommendation would be: 450/0.6 = 750 ft^2.

A variation of the soil percolation test is to observe the time for the water level to drop from a depth of 6 to 5 in. after saturation as shown in Figure 4-3. Repeat the test, adding water as necessary, and if the times recorded in subsequent tests are within 10 percent or $\frac{1}{16}$ in., use this time to determine the allowable rate of settled sewage application per square foot per day using Table 4-5. If the "times" vary by more than 10 percent, repeat the test until the times for two successive tests do not vary by more than 10 percent. With a tight soil, this method will take somewhat longer to perform than the first method. Some sanitary engineers and sanitarians prefer to continue the test until the times for the water to fall 1 in. are within 3 to 5 percent.

Many variations and refinements of the soil percolation test, including the use of a float gauge, inverted carboy as in a water cooler, and permeability test, have been proposed.[58-60] In any case, a sufficient number of soil tests should be made that will give information representative of the soil, as indicated by a relatively constant rate of water drop in the test hole. This will also make possible determination of an average percolation rate that can be used in design. A typical layout is shown in Figure 4-4.

Where a small rural real estate subdivision is under consideration, at least three holes per acre should be tested and soil borings made. More holes should be tested if the percolation results vary widely, say by more than 20 percent. If rock, clay, hardpan, or groundwater is encountered within 4 ft of the ground surface, the

*Assumes a home laundry machine and a garbage grinder are to be installed.

[58] *Manual of Septic-Tank Practice*, PHS Pub. 526, Washington, D.C., revised 1967, pp. 4–8, 75–76.

[59] John T. Winneberger, "Correlation of Three Techniques for Determining Soil Permeability," *J. Environ. Health*, September/October 1974, pp. 108–118. Also Rein Laak, *Wastewater Engineering Design for Unsewered Areas*, Ann Arbor Science Publishers, Inc., Ann Arbor, Mi., pp. 12–15.

[60] Michael E. Peterson, "Soil Percolation Tests," *J. Environ. Health*, January/February 1980, pp. 182–186.

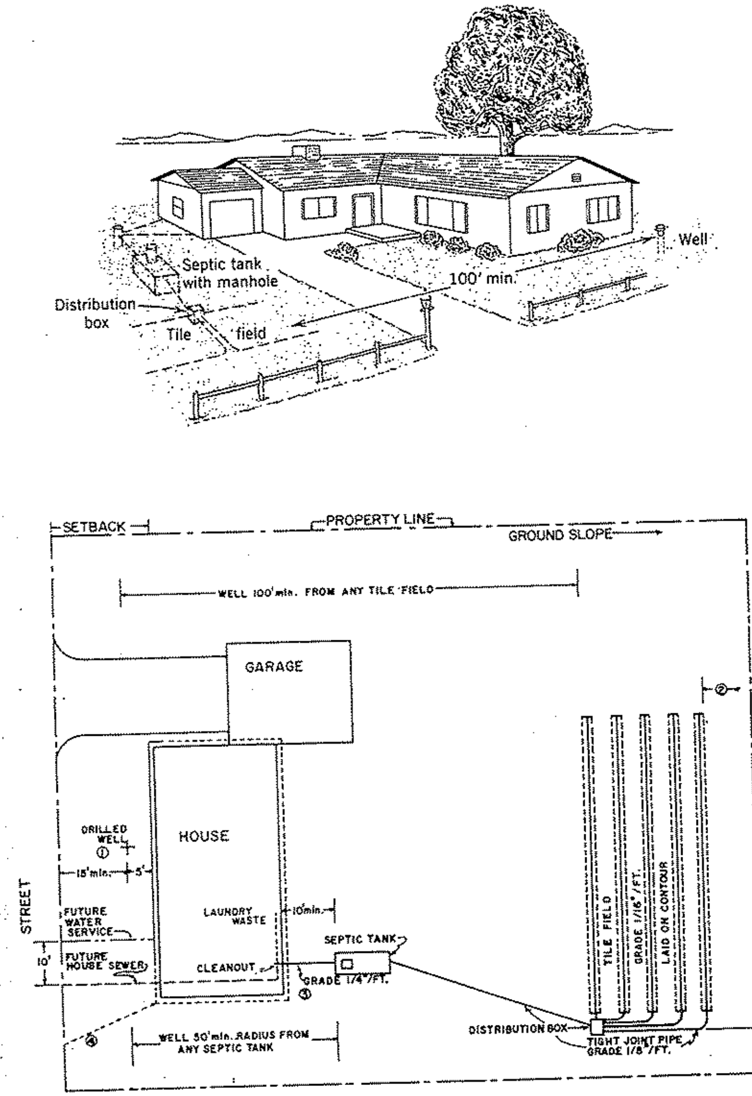

Figure 4-4 Typical private water supply and sewage disposal layouts.

Notes:
(1) Watertight footing drain within 25 ft of well. (2) Tile field to be 50 ft or more from any lake, swamp, ditch, or watercourse and 10 ft or more from any waterline under pressure. (3) Cast-iron pipe, lead caulked joints within 50 ft of any well. (4) Discharge footing, roof, and cellar drainage away from sewerage system and well. (5) Grade lot to drain surface runoff away from the subsurface absorption system.

property should be considered unsuitable for the disposal of sewage by means of conventional subsurface absorption fields. An alternative system may be considered. This calls for the exercise of trained professional judgment.

In special cases, where tighter soil is encountered just below the bottom of the test hole, interpretation of the results might require adjustment of the allowable sewage application to that based on the tighter soil.

It should be pointed out that the ill repute of septic tank absorption systems in some areas is due to improperly performed and interpreted soil percolation tests, high groundwater, poor construction, lack of maintenance, or abuse of the system, and to the use of septic tanks where they were never intended. Inadequate design, lack of inspection by regulatory agencies, and failure to consider soil color, texture, and structure may contribute to the problem.

Absorption systems should not be constructed on filled-in ground until it has been thoroughly settled or otherwise stabilized. Percolation tests should be made in fill after at least a 6-month, preferably 12-month, settling period and after complete stabilization of the soil. Percolation tests cannot be made in frozen ground. Soil tests in fill are not reliable as the soil structure, texture, moisture, and density will be quite variable. See Small Wastewater Disposal Systems for Unsuitable Soils or Sites, this chapter.

Where the ground is flat, provision should be made to drain surface water from off and around the absorption field to prevent the soil from becoming waterlogged. On steeply sloping ground, a surface water diversion ditch or berm should be provided above and around the absorption field to minimize water infiltration and prevent the absorption field from being washed out. This will also prevent silt and mud from washing into the trench during construction and coating the bottom with a relatively impervious film. It is also important to point out that the undesirable practice of walking in the bottom of trenches causes a compaction of the earth and a reduced percolation capacity. If this happens, rake the bottom to restore the original surface. Ensure that the trench bottom is on a slope of $\frac{1}{16}$ in. per ft or less.

Where leaching pits are permitted, the soil test is made in a test hole about 1 ft^2, where the soil profile changes, at a depth about one-half the proposed *effective depth* of the leaching pit, and at the bottom. Upon completion of the test, the hole should be extended an additional 2 to 3 ft to ensure that the soil at a greater depth is similar to that tested and that groundwater is not encountered. The test is made in the same manner as explained for an absorption system but at the greater depth. The results are interpreted in Table 4-5.

The design of septic tanks, subsurface absorption fields, and seepage pits is explained and illustrated in the discussion of these systems that follows.

Estimate of Sewage Flow

The sewage flow to be expected from a dwelling or other type of establishment is not constant each day. The day of the week, season of the year, habits of the people, water pressure, type and number of plumbing fixtures, and type of place or business maintained are some of the factors affecting the probable sewage flow. The design cannot be based on the minimum flow but must be based at least on

Table 4-6 A Fixture Basis of Estimating Sewage Flow

Type of Fixture	Gallons per Day per Fixture, Country Clubs[a]	Gallons per Hour per Fixture, Public Parks[b]	Gallons per Hour per Fixture (Average), Restaurants[c]
Shower	500	150	17
Bathtub	300	—	17
Washbasin	100	—	$8\frac{1}{2}$
Water closet	150	36	42 (flush valve) 21 (flush tank)
Urinal	100	10	21
Faucet	—	15	$8\frac{1}{2}$, 21 (hose bib)
Sink	50	—	17 (kitchen)

[a]John E. Kiker, Jr., "Subsurface Sewage Disposal," *Fla. Eng. Exp. Sta.*, Bull. No. 23 (December 1948).
[b]National Park Service.
[c]After M. C. Nottingham Companies, California.

the average maximum. Daily water-meter consumption figures from a similar type of establishment taken over an extended period of time, including weekends and maximum days, would be of value in arriving at a good average maximum daily flow estimate to be used in design. Caution must be used when interpreting quarterly, semi-annual, or annual meter readings, as averages derived from these figures will be low unless corrected for vacation periods, weekends and holidays, seasons of the year, etc. In the absence of actual figures, the per capita or unit estimated water flow given in Table 3-14 may be used as a guide.

Fixture bases of estimating sewage flow assume that all water used finds its way to the sewage disposal or treatment system. Adjustment should be made for lawn watering, car washing, etc. In one method, the total number of different types of fixtures is summarized. The sum of each type is multiplied by the usual flow from such a fixture per use or operation. The frequency of use per hour can be estimated for the type of establishment under study. Knowing the number of hours of daily operation, a rough estimate of the probable flow in gpd can be arrived at.

Another fixture basis of estimating sewage flow is given in Table 4-6. Although the fixtures refer to country clubs, public parks, and restaurants, they can be applied with modifications to similar types of establishments. The fixture bases of estimating sewage flow are useful in determining the required size drain or sewer line and also as a check on other methods. Fixture unit values in Table 4-7 can also be used with Figure 3-26 for the same purpose.

A third fixture unit basis of estimating sewage flow is that described in Chapter 3, Water Supply, using the probability curves developed by Hunter. These flows are somewhat high, being based on estimated peak discharge. An analysis made by Wyly[61] is based on the estimated average discharge. For two-bath houses with

[61]Robert S. Wyly, *Hydraulics of 6- and 8-inch Diameter Sewer Laterals*, Building Research Institute, BRAB, NAS-NRC, 2102 Constitution Ave., Washington, D.C., November 27, 1956.

Fixture or Group	Fixture Unit Value
Bathroom group consisting of a lavatory, bathtub or shower stall, and a water closet (direct flush, valve)	8
Bathroom group consisting of a lavatory, bathtub or shower stall, and a water closet (flush tank)	6
Bathtub with $1\frac{1}{2}$ trap	2
Bathtub with 2″ trap	3
Bidet with $1\frac{1}{2}$ trap	3
Combination sink and wash tray with $1\frac{1}{2}$ trap	3
Combination sink and wash tray with food waste grinder unit (separate $1\frac{1}{2}$ trap for each unit)	4
Dental unit or cuspidor	1
Dental lavatory	1
Drinking fountain	$\frac{1}{2}$
Dishwasher, domestic type	2
Floor drain	1
Kitchen sink, domestic type	2
Kitchen sink, domestic type with food waste grinder unit	3
Lavatory with $1\frac{1}{2}$ waste plug outlet	2
Lavatory with $1\frac{1}{4}$ or $1\frac{3}{8}$ waste plug outlet	1
Lavatory (barber shop, beauty parlor, or surgeon's)	2
Lavatory, multiple type (wash fountain or wash sink), per each equivalent lavatory unit	2
Laundry tray (1 or 2 compartments)	2
Shower stall	2
Showers (group) per head	3
Sink (surgeon's)	3
Sink (flushing rim type, direct flush valve)	8
Sink (service type with floor outlet trap standard)	3
Sink (service type with P trap)	2
Sink (pot, scullery, or similar type)	4
Urinal (1 flush valve)	8
Urinal ($\frac{3}{4}$ flush valve)	4
Urinal (flush tank)	4
Water closet (direct flush valve)	8
Water closet (flush tank)	4
Swimming pools, per each 1000-gal capacity	1
Unlisted fixture, $1\frac{1}{4}$ or less fixture drain or trap size	1
Unlisted fixture, $1\frac{1}{2}$ fixture drain or trap size	2
Unlisted fixture, 2 fixture drain or trap size	3
Unlisted fixture, $2\frac{1}{2}$ fixture drain or trap size	4
Unlisted fixture, 3 fixture drain or trap size	5
Unlisted fixture, 4 fixture drain or trap size	6

Source: *New York State Uniform Fire Prevention and Building Code*, Table I-903, Division of Housing and Community Renewal, New York, N.Y., January 1984, pp. 276, 277.

Note: Values for continuous or intermittent flow. For a continuous or intermittent flow into a drain, as from a pump, ejector, air-conditioning equipment or similar equipment, a fixture value of 2 shall be assigned for each gpm of flow at rated capacity. The total discharge flow in gpm for any single fixture, divided by 7.5, provides the fixture unit value for that particular fixture.

automatic dishwasher, clothes washer, and garbage grinder, for a total of 19 fixture units per home, the discharge may be 1.6 gpm for 1 home, 7.6 gpm for 5 homes, 15.2 gpm for 10 homes, 30.4 gpm for 20 homes, 76 gpm for 50 homes, and 152 gpm for 100 homes. See Peak Demand Estimates, Chapter 3.

The design flow and sewage application rate for subsurface absorption systems should take into consideration the strength of the septic tank effluent (BOD and TSS), in addition to the hydraulic loading.

House Sewer and Plumbing

The house or building sewer is that part of the building drainage system carrying sewage that extends from the septic tank or public sewer to a point 3 ft out from the foundation wall. That portion of the drainage system extending from the house sewer horizontally into the structure is the house or building drain. The recommended size of the sanitary drainage piping is given in Table 4-8, although the local plumbing or building code will govern, where one has been adopted. In general, the house drain and building sewer should be not less than 4-in. bell and spigot cast-iron pipe with lead-caulked or equal joints. Other plastic or composition pipe constructed of durable material and laid with tight joints is also used.

Increasing fittings with smooth joints should be used where the pipe size increases in diameter. Sewer lines should be laid in a straight line to the septic tank

Table 4-8 Maximum Permissible Loads for Sanitary Drainage Piping (in terms of fixture units)

Pipe Diameter, (in.)	Any Horizontal Fixture Branch	One Stack of 3 Stories or Less in Height	Stacks More Than 3 Stories in Height: Total for Stack	Total at One Story	Building Drain, and Building Drain Branches from Stacks, Slope (in./ft): $\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$
$1\frac{1}{4}$[a]	1	2	2	1	np	np	np	np
$1\frac{1}{2}$[a]	3	4	8	2	np	np	np	np
2[a]	6	10	24	6	np	np	21	26
$2\frac{1}{2}$[a]	12	20	42	9	np	np	24	31
3	20[b]	30[c]	60[c]	16[b]	np	np	27[b]	36[b]
4	160	240	500	90	np	180	216	250
5	360	540	1,100	200	np	390	480	575
6	—	960	1,900	350	np	700	840	1,000
8	—	—	3,600	600	1,400	1,600	1,920	2,300
10	—	—	5,600	1,000	2,500	2,900	3,500	4,200
12	—	—	—	—	3,900	4,600	5,600	6,700

Source: New York State Uniform Fire Prevention and Building Code, Division of Housing and Community Renewal, New York, N.Y., January 1984, p. 279.

[a] No water closets permitted.
[b] Not over two water closets permitted.
[c] Not over six water closets permitted.

where possible. If bends are necessary, use one or two 45 ells, as may be needed, and provide a cleanout. A manhole is sometimes preferable. A cleanout should also be provided at the end of the building drain in the basement and ahead of the septic tank when the tank is located 30 or more ft from the cleanout on the building drain. A cleanout may be provided on a buried sewer line by installing a tee fitting in the line with the vertical leg up and connecting to it a section of pipe extending to the ground surface. The fitting, sewer joints, and pipe extension should be encased in 6 in. of concrete. All cleanouts should have tight-fitting brass caps. See Figures 4-5 and 4-6.

Grease Trap

A grease trap, interceptor, or separator is a unit designed to remove grease and fat from kitchen wastes. Liquid wastes leaving properly designed and maintained units should not cause clogging of pipes nor have a harmful effect on the bacterial and settling action in a septic tank.

Grease traps are of the septic tank and commercial types. The commercial types are of questionable value, unless the unit and storage chamber are regularly cleaned, a repulsive chore in restaurants. In the septic tank type, use is made of the cooling, separating, and congealing effect obtained when the warm or hot, greasy liquid wastes from the kitchen mix with the cooler liquid standing in the tank. There is also a natural tendency, if mixing is not too rapid, for the warmer liquid to rise and the cooler liquid, from which grease has been separated, to settle and be carried out with the food particles. *A grease trap is unnecessary in the average private home*. The small quantity of fat and grease that does find its way into the kitchen

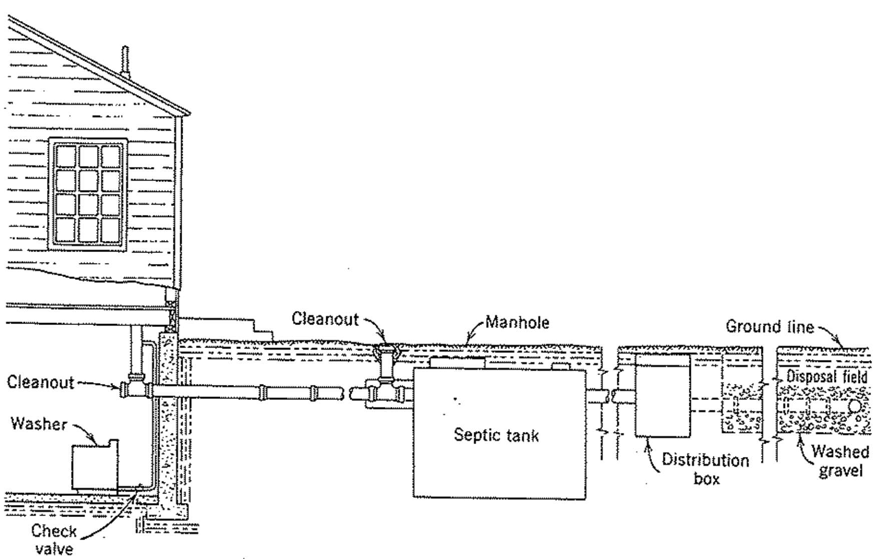

Figure 4-5 Section showing sewage disposal system.

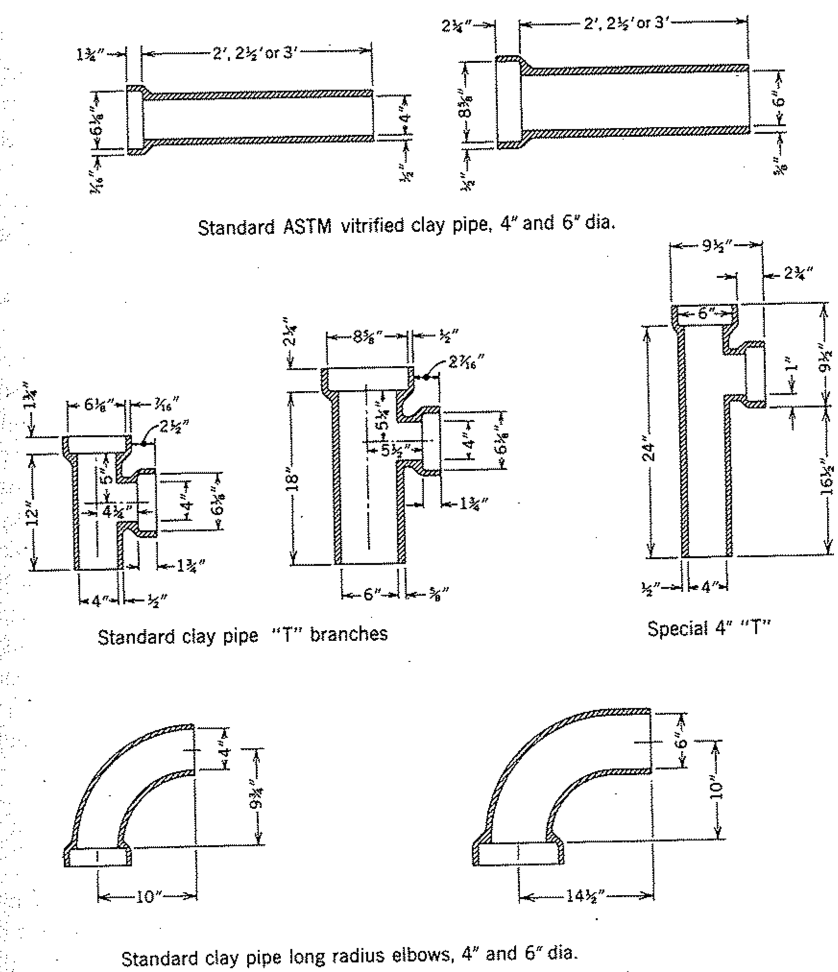

Figure 4-6 Details of some clay pipe fittings. (Cement mortar joints are unsatisfactory where sulfides are expected.)

drain is mixed with soaps and detergents and is difficult to separate. In any case, such small quantities would not be harmful when allowed to enter a proper size septic tank. Grease traps of the septic tank type should be provided, however, in restaurants and similar establishments where the quantity of grease and fats in liquid wastes is likely to be large. All grease traps should discharge into the building sewer ahead of the septic tank. Grease traps should be located within 20 or 30 ft from the plumbing fixtures served to prevent congealing and clogging of waste lines.

The capacity of the septic tank type of grease trap is made equal to the maximum volume of water used in a kitchen during a mealtime period. Garbage is not discharged to the sewer. The type of meals served and kitchen equipment used should be taken into consideration. A figure of $2\frac{1}{2}$- or 3-gal capacity per meal served during a mealtime is frequently used, and up to 5 gal where full meals are served. The tank should be located in a protected, accessible place outside the building, using the same precautions as for the septic tank. It should have a tight-fitting removable cover. Heavy cast iron and steel make satisfactory covers. When covers do not fit tightly, a silicon or rubber seal around the cover or a layer of clay soil over the cover may be necessary to eliminate odors. In another design basis, the tank capacity (gal) = the number of seats in dining room × wastewater per meal (5 gal) × storage factor (2 avg.) × hours open ÷ 2 × loading factor (1.0 avg.).[40]

The construction of several septic tank type grease traps is shown in Figure 4-7. Large tanks should have two compartments. Grease traps can be built on the job out of concrete or brick masonry, or can be prefabricated out of metal, concrete, or terra cotta, with inlet and outlet arrangements as shown in the sketches. Because of the greater capacity of septic tank type grease traps, they do not require cleaning as frequently as the commercial type. Nevertheless, they must be cleaned so as not to greatly reduce the liquid volume available for cooling of the greasy wastes entering and, of course, to prevent large quantities of grease being carried over to the septic tank. The frequency of cleaning should be determined at each establishment during operation, when the grease occupies one-half the liquid depth of the tank. Cleaning at monthly intervals may be sufficient, but experience should dictate the frequency. One person should be given this responsibility, and a supervisor should check to see that the job is done. Grease removed from a grease trap may be disposed of with the garbage, rendered and sold, or thoroughly buried as explained under Privies, Latrines, and Waterless Toilets, depending on local conditions and requirements. A minimum size for a grease trap is 750 gal.

Septic Tank

A septic tank is a watertight tank designed to slow down the movement of raw sewage and wastes passing through so that solids can separate or settle out and be broken down by liquefaction and anaerobic bacterial action. It does not purify the sewage, eliminate odors, or destroy all solid matter. The septic tank simply conditions the sewage so that it can be disposed of normally to a subsurface absorption system without prematurely clogging the system. Suspended solids removal is 50 to 70 percent; 5-day BOD removal is about 60 percent.

Recommended septic tank sizes based on estimated daily flows are given in Tables 4-9 and 4-10. The septic tank should have a liquid volume of not less than 750 gal. When a tank is constructed on the job, its liquid volume can be increased at a nominal extra cost, thereby providing capacity for possible future additional flow, garbage grinder, and sludge storage. A plastic sludge and gas deflector on the outlet as shown in Figure 4-8 is highly recommended.* Regulatory agencies are requiring a minimum 1000-gal septic tank in some instances.

*First suggested by Salvato in *Environmental Sanitation*, John Wiley & Sons, Inc., New York, 1958, p. 208.

[40]*Design Manual, Onsite Wastewater Treatment and Disposal Systems*, *op. cit.*, pp. 321–327.

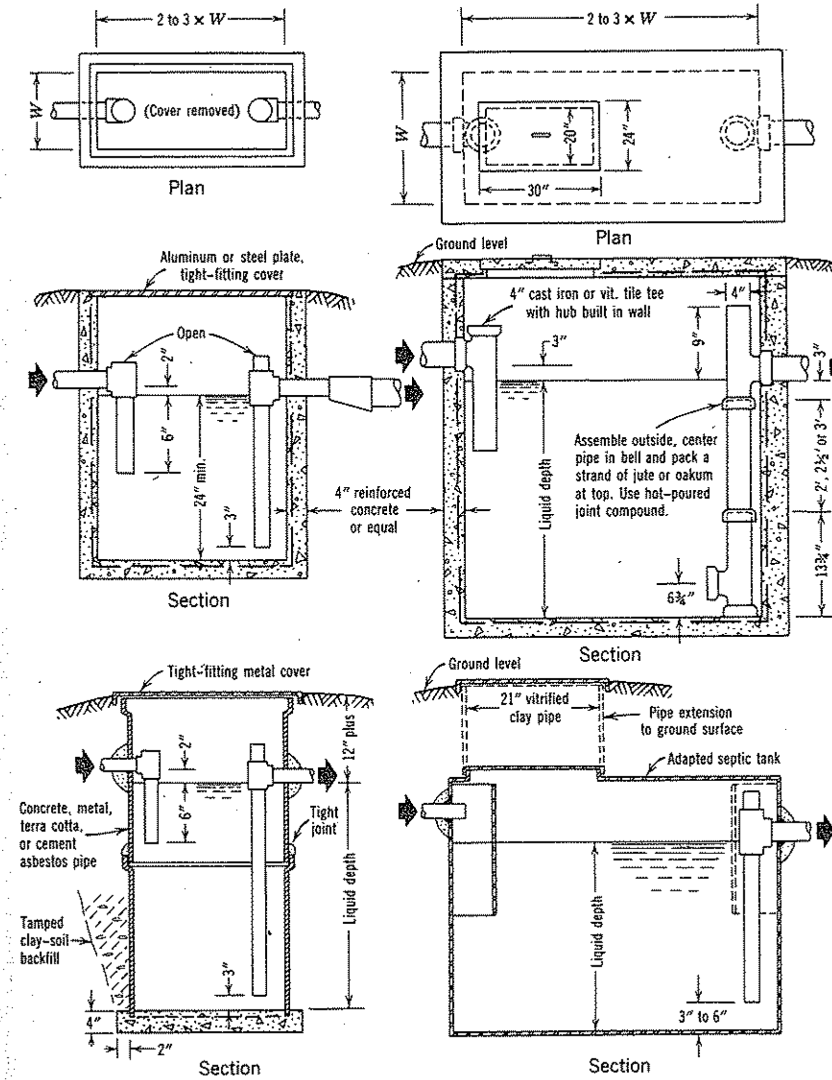

Figure 4-7 Grease trap details.
Manhole over the outlet is also recommended for large tank.

The detention time for large septic tanks** should not be less than 24 to 72 hours. Schools, camps, theaters, factories, and fairgrounds are examples of places where the total or a very large proportion of the daily flow takes place within a few hours. For example, if the total daily flow takes place over a period of 6 hours ($\frac{1}{4}$ of 24 hours), the septic tank should have a liquid volume equal to four times

**Inspect every 3 months and clean, if necessary. Measure inlet flows monthly and compare with design flow. Check annually BOD, SS, and pH for major changes.

Table 4-9 Water Supply and Sewerage Schedule (Use Combination of Headings that Fit Local Conditions)

Population: Bedrooms	Population: Persons	Septic Tank Minimum[b,c]: Sewage Flow (gpd)[a]	Septic Tank: Length (ft)	Septic Tank: Width (ft)	Septic Tank: Depth (ft)	Septic Tank: Volume (gal)	Tile Field Laterals[c,d]: No. Length (ft)	Tile Field Laterals: Trench Width (in.)
2 or less	4	300	7½	3½	4	750	(Determined by site and soil percolation test)	
3	6	450	9	4	4	1000		
4	8	600	11	4	4	1250		
5	10	750	10½	5	4	1500		

Population: Bedrooms	Population: Persons	Leaching Pit System[c,d]: No. Pits	Size	Depth	Water Supply—Well, Drilled[f]: Service[e]	Pump Size (gal/hr)	Pres. Tank (gal)
2 or less	4	(Determined by site and soil percolation test)			¾ in.	250	42
3	6				¾	300	82
4	8				1	360	82
5	10				1¼	450	120

Population: Bedrooms	Population: Persons	Sand Filter System[c,g]: Length (ft)	Width (ft)	Area (sq ft)	Chlorine Contact Tank[c]: Length (ft)	Width (ft)	Depth (in.)	Sump Pump Float Setting (gal)[c]
2 or less	4	21½	12	260	3	2	8	20
3	6	21	18	390	3	2	12	30
3	6	32½	12	390	3	2	12	30
4	8	30	18	520	3	2	16	40
4	8	43	12	520	3	2	16	40
5	10	36	18	650	3	2	20	50
5	10	54	12	650	3	2	20	50

[a] The design basis is 75 gal per person and 150 gal per bedroom.
[b] Includes provision for home garbage grinder and laundry machine. Larger than minimum size septic tank is strongly recommended.
[c] See detail drawings for construction specifications.
[d] Based on the results of soil percolation tests. Discharge all kitchen, bath, and laundry wastes through the septic tank, but *exclude* roof and footing drainage, surface and groundwater, and softener wastes.
[e] Use next larger diameter house service line if water is corrosive or hard, if service line is 50 to 100 ft long, if two bathrooms are provided, or flush valve is used for water closet. These pipe sizes are based on the use of brass or copper pipe; use next larger size if iron pipe is proposed.
[f] The minimum dependable well yield should be 3 to 7 gpm.
[g] Sand filter normally should not be used. Reserve for compelling circumstances to relieve an impending or existing public health hazard.

Table 4-10 Suggested Large Tank Dimensions

Gallons	Width (ft)	Length (ft)	Depth (ft)
1,000	4	9	4
1,250	4	11	4
1,500	5	10½	4
1,750	5	12	4
2,000	5	14	4
2,250	6	13	4
2,500	6	14½	4
2,750	6	16	4
3,000	6	17	4
3,250	6	15	5
3,500	6	16	5
3,750	6	17	5
4,000	7	16	5
5,000	7	19½	5
6,000	8	20½	5
7,000	8	24	5
8,000	8	23	6
10,000	8	28	6

Concrete Details:

1. Concrete for top and bottom 4-in. thick for 2000-gal tank or smaller and 6 in. for 2,000- to 10,000-gal tank.
2. Concrete for sides and ends 6-in. thick for 6000-gal tank or smaller and 8 in. for 6,000- to 10,000-gal tank.
3. Reinforce with ⅜-in. deformed rods 4 in. on center both ways for ordinary loading. Place rods 1 in. above bottom of top slab and 1 in. in from inside of tank for sides, ends, and bottom. Overlap ⅜-in. rods 15 in. where needed. Adjust steel for local conditions.
4. Concrete mix: 1 bag cement to 2¼ ft^3 sand to 3 ft^3 gravel with 5 gal water for moist sand.

the 6-hr flow to provide a detention equivalent to 24 hours over the period of actual use. The larger tank would minimize scouring of septic tank sludge and scum and carryover of solids into the absorption system.

Pumping of raw sewage, if required, directly into a septic tank will cause scour and carryover of solids and should be avoided. Pumping into an equalizing tank ahead of the septic tank is a possible solution, but it will require frequent maintenance. The problem can be avoided by pumping septic tank effluent from a sump to the soil absorption system.

If the septic tank is to receive ground garbage, its capacity should be increased by at least 50 percent. Some authorities recommend a 30 percent increase. Others recommend against garbage disposal to a septic tank.

Septic tanks can be constructed of good quality reinforced concrete on the job as explained in Figures 4-8 and 4-9 and Tables 4-9 and 4-10. Standard concrete block tanks, with cells filled with concrete, require two ½-in. cement plaster coats

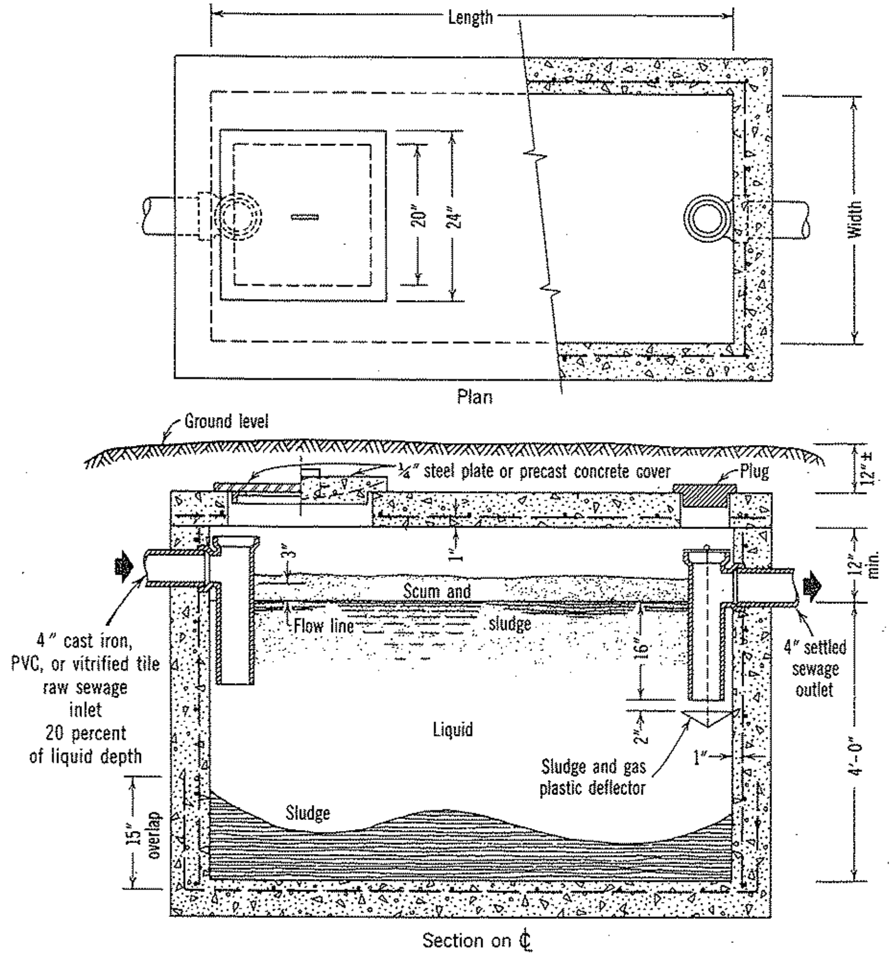

Figure 4-8 Details for small septic tanks. Recommended construction for small septic tanks:

Top—Reinforced concrete poured 3- to 4-in. thick with two 3/8-in. steel rods per ft, or equivalent, and a 20- × 20-in. manhole over inlet, or precast reinforced concrete 1-ft slabs with sealed joints.

Bottom—Reinforced concrete 4-in. thick with reinforcing as in "top" or plain poured concrete 6-in. thick.

Walls—Reinforced concrete poured 4-in. thick with 3/8-in. steel rods on 6-in. centers both ways, or equivalent; plain poured concrete 6-in. thick; 8-in. brick masonry with 1-in. cement plaster inside finish and block cells filled with mortar.

Concrete Mix—One bag of cement to $2\frac{1}{4}$ of sand to 3 ft^3 of gravel with 5 gal of water for moist sand. Use 1:3 cement mortar for masonry and 1:2 mortar for plaster finish. Gravel or crushed stone and sand shall be clean, hard material. Gravel shall be $\frac{1}{4}$ to $1\frac{1}{2}$ in. in size; sand from fine to $\frac{1}{4}$ in.

Bedding—At least 3 in. of sand or pea gravel, leveled.

Cover—Raised cover by means of collar if tank greater than 12 in. below ground.

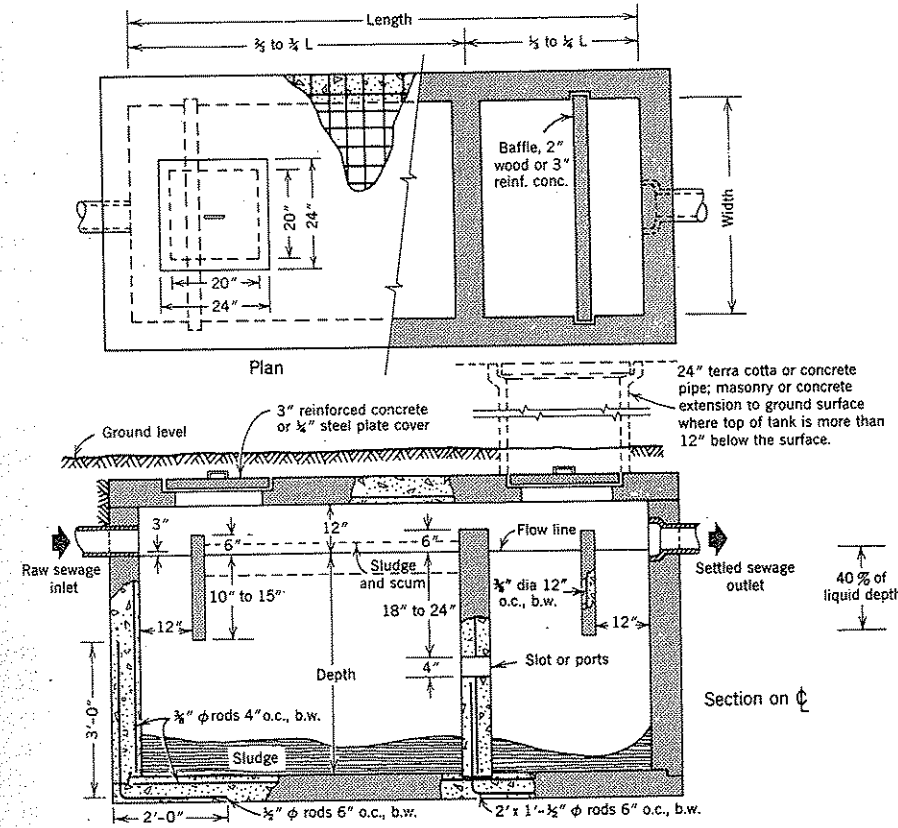

Figure 4-9 Details for large septic tanks. (See Table 4-10.)

on the inside to provide a smooth watertight finish. Precast-reinforced concrete and commercial tanks of metal, fiberglass, polyethylene, and other composition materials are also available. Since some metal tanks have a limited life, it is advisable that their purchase be predicated on their meeting certain minimum specifications. These should include a guaranteed 20-year minimum life expectancy, not less than 12- or 14-gauge metal thickness, thorough covering both inside and outside with a heavy, continuous, protective, acid-resistant coating and a minimum liquid capacity of 750 gal. Metal septic tanks manufactured in accordance with the Department of Commerce Commercial Standard, provided with a minimum 16- to 18-in. manhole, represent a great improvement over the ordinary metal tank. Large metal tanks, with a capacity greater than 1000 gal, should be 10 to 8 gauge metal. In any case, it should be kept in mind that metal tanks, especially the baffles and area above the waterline, have a limited life. Precast concrete baffles also have a limited life. Use rigid plastic tees. The bottom of the excavation for the septic tank should be carefully leveled at the proper elevation and well bedded on a layer of sand or pea gravel to prevent uneven settlement of the septic tank and breaks at the inlet and outlet lines.

The depth of septic tanks and the ratio of width to length recommended by most health departments are very similar. A liquid depth of 4 ft and a ratio of width to length of 1:2 or 1:3 is common. Depths as shallow as 30 in. and as deep as 6 ft have been found satisfactory. Compartmented tanks are somewhat more efficient. The first compartment should have 60 to 75 percent of the total volume. Open-tee inlets and outlets as shown in Figure 4-8 are generally used in small tanks, and high quality reinforced concrete baffled inlets and outlets as shown in Figure 4-9 are recommended for the larger tanks.[62] Precast open concrete tees or baffles have in some instances disintegrated or fallen off; vitrified clay, cast-iron, PVC, ABS, or PE tees should be used. Cement mortar joints are unsatisfactory. A better distribution of flow and detention is obtained in the larger tank with a baffle arrangement of preferably rigid acid-resistant plastic. A minimum 16-in. manhole over the inlet of a small tank, and a 20- to 24-in. manhole over both the inlet and outlet of a larger tank, constructed with a top slab poured monolithically with the sides, is preferred to a sectional slab top. The sectional slab top can, however, be more easily purchased or constructed on a flat surface over a plastic sheet with a minimum of form lumber. Joints will require a seal to prevent the entrance of surface water into the tank.

An efficient septic tank design should provide for a detention period longer than 24 hours; an outlet configuration with a gas baffle to minimize suspended solids carryover (see Figure 4-8); maximized surface area to depth ratio for all chambers (ratio more than 2); and a multichamber tank with interconnections similar to the outlet design (open-tee inlet and outlet).[63]

The elevation of the septic tank and the inlet should be selected and established with regard to the landscaping; elevations of sewers that discharge to the septic tank; elevation of dosing tank outlet pipe inverts where used; location available and elevation of the area selected for the disposal or treatment system; and the high-water level of groundwater and nearby watercourses, to ensure gravity flow, provided the topography makes this possible. On the other hand, if pumping is required it should be taken into consideration in the initial design, and every advantage taken of this necessity to reduce excavations and shorten and straighten lines. If pumping is required, an equalization tank ahead of the septic tank is necessary to prevent scour and carryover of solids.

Septic tank soil absorption systems in *continuous* operation are not likely to freeze. Studies near Ottawa, Canada, showed that winter operation did not pose any special problems,[64] and observations by the author in the Yukon Territory, Canada (1944), confirm this.[65]

Care of Septic Tank and Subsurface Absorption Systems

Proper maintenance of a properly designed and constructed septic tank system is the best assurance of satisfactory operation of a subsurface sewage disposal or treatment system and prevention of sudden replacement expenses.

A septic tank for a private home will generally require cleaning every 3 to 5 years depending on occupancy, but in any case it should be inspected once a year. If a garbage disposal unit is used, more frequent cleaning is needed. Septic tanks serving commercial operations should be inspected at least every 6 months. When the depth of settled sludge or floating scum approaches the depth given in Table 4-11, the tank needs cleaning.[63,66] Sludge accumulation in a normal home septic tank has been estimated at 69 to 80 l (18 to 21 gal) per person per year.[66,67] Reports of septage generated vary widely. The U.S. average has been estimated at 55 gal per capita per year.[68] The Ontario Ministry of the Environment set the permissible highest level of sludge at 0.45 m below the bottom of the outlet fitting. Gray water septic tank sludge was found to accumulate at the rate of 8.3 l (2.2 gal) per person per year, and black wastewater sludge at the rate of 65.7 l (17.4 gal) per person per year.[69] A long pole having a small board about 6 in.^{2} nailed to the bottom to make a plunger, with Turkish toweling wrapped around the lower 18 in. of the pole, can be used to measure the sludge depth and floating-scum thickness. The appearance of particles or scum in the effluent from a septic tank going through a distribution box is also an indication of the need for cleaning. Routine inspection and cleaning will prevent solids from being carried over and clogging the treatment or leaching systems. The larger the septic tank above the minimum, the less frequent the need for cleaning. A contractual arrangement for annual inspection and cleaning as needed and noted above is a good investment. Community cooperation in this regard should be encouraged. A maintenance district might be formed.

It is best to clean a septic tank during the dry months of the year. The groundwater level should be low (to prevent possible flotation of the tank) and bacterial adjustment will proceed faster in warm weather.

Septic tanks are generally cleaned by septic tank cleaning firms. They mix and

[62]*Manual of Septic-Tank Practice*, PHS Pub. No. 526 (1967), states that "the outlet device should generally extend to a distance below the surface equal to 40 percent of the liquid depth. For horizontal, cylindrical tanks, this should be reduced to 35 percent." The inlet should penetrate at least 6 in. below the liquid level but not greater than the outlet. The distance between the liquid line and underside of the tank (air space) should be approximately 20 percent of the liquid depth. In horizontal, cylindrical tanks, the area should be 15 percent of the total circle. Sludge accumulation $S = 17 + 7.5t$, in which S = sludge in gal per capita and t = years after cleaning.

[63]Rein Laak, "Multichamber Septic Tanks," *J. Environ. Eng. Div.*, ASCE, June 1980, pp. 539–546.

[64]T. Viraraghavan, "Temperature Effects on Onsite Wastewater Treatment and Disposal Systems," *J. Environ. Health*, July/August 1985, pp. 10–13.

[65]J. A. Salvato, "Sewage Disposal in the Near Arctic," *Water Works & Sewerage*, October 1945, and *Sewage Works J.*, September 1945.

[66]S. R. Wiebel, C. P. Straub, and J. R. Thoman, *Studies on Household Sewage Disposal Systems, Part I*, Report: Federal Security Agency, PHS, Environmental Health Center, Cincinnati, Oh., 1949.

[67]M. Brandes, *Accumulation Rate and Characteristics of Septic Tank Sludge and Septage*, Ontario Ministry of the Environment, Research Report W63, 1977, Toronto, Canada. Also *J. Water Pollut. Control Fed.*, May 1978, pp. 936–943.

[68]*EPA Handbook Septage Treatment and Disposal*, U.S. EPA, Cincinnati, Oh., October 1984, p. 18.

[69]M. Brandes, *Characteristics of Effluents from Separate Septic Tanks Treating Gray Water and Black Water from the Same House*, Ontario Ministry of the Environment, October 1977.

Table 4-11 Allowable Sludge Accumulation (in.)

Tank Capacity (gal)	Sludge Depth (in.) Tank Liquid Depth (in.) 30	36	48	60
250	4			
300	5	6		
400	7	9	10	
500	8	11	13	15
600	10	14	16	18
750	13	16	19	23
900	14	18	22	26
1000	14	18	23	28
1250		18	24	30

Source: Adapted from *Manual of Septic-Tank Practice,* PHS Pub. 526, DHEW, Cincinnati, Oh., 1967.
This Table assumes the outlet baffle or tee depth below the flow line is 40 percent of the tank liquid depth. *Clean the tank when the bottom of the scum layer builds up to within 3 in. of the bottom of the baffle or tee outlet, or when the sludge depth approaches the depth given in this table.* For example, a tank 48 in. deep with a capacity of 750 gal will require cleaning when the sludge depth reaches 19 in.

pump the entire contents, referred to as septage, out into a tank truck with special equipment. Care must be taken to prevent spillage and consequent pollution of the surrounding ground. Sludge sticking to the inside of a tank that has just been cleaned would have a seeding effect and assist in renewing the bacterial activity in the septic tank. The septic tank should not be scrubbed clean. This is a good time to inspect the inlet and outlet baffles for damage and possible replacement with PVC tees.

Do not enter the tank!

The use of septic tank cleaning solvents or additives containing halogenated hydrocarbon, aromatic hydrocarbon, toxic, or hazardous chemicals can cause carryover of solids and clogging of absorption field. The chemicals can also contaminate the groundwater. Such chemicals should not be permitted. The same precaution would apply to commercial and industrial sewage septic systems. Public education is also necessary.

The contents of the septic tank, called septage, should preferably be emptied into a sanitary sewer or wastewater treatment plant if prior approval is obtained. Disposal at a plant dumping station provided with bar racks, holding tank, pump, and aeration tank may be required prior to discharge to the wastewater treatment plant. Alternative methods[70] for the disposal of septage consists of ridge-and-furrow, spray irrigation, plow-furrow-cover, subsurface injection, and sanitary landfill under controlled conditions, with storage when necessary in colder climates when the ground is frozen to prevent runoff. Also possible are leaching lagoons in which the sludge is periodically removed, and disposal lagoons in which the sludge can be removed or allowed to dry for disposal in a sanitary landfill or covered over with 2 ft of earth. Septage treatment facilities include aerated lagoons, facultative lagoons, composting with dry organic matter for moisture control, chemical treatment using lime, chlorine,[71] alum, polyelectrolytes, and ferric chloride, and other proprietary processes. A permit is usually required for septage treatment and disposal.

[70] Ivan A. Cooper and Joseph W. Razek, *Alternative for Small Wastewater Treatment Systems*, U.S. EPA, EPA-625/4-77-011, October 1977, pp. 61–90.

Safety and Other Precautions

Excavations such as for septic tanks, trenches, privies, leaching pits, dry wells, pump wells, storage tanks, and cesspools can create a safety hazard to workers and passersby, especially children. No person should be permitted to work in a trench or pit 5 ft or more in depth that has sides or banks with slopes steeper than 45° unless the sides or banks are supported with sheeting or shoring. Any excavation in sand, silt, loam or clay 3 ft or more in depth needs sidewall protection to prevent cave-in; excavated material should be placed at least 24 in. back from the edges. Where the excavation is left unattended, a fence or a barricade should be placed around the opening, or the opening should be covered with properly supported 2-in. planking or $\frac{3}{4}$ exterior-grade plywood. If sheeting is used and extended 42 in. above the adjacent ground, other barricades are not usually necessary.[72]

An individual should not enter a septic tank, septic privy pit, pump well, manhole, storage tank, sludge digestion tank, or aqua privy tank that has been emptied, regardless of whether it is open or covered. Cases of asphyxiation and death have been reported due to the lack of adequate oxygen or presence of toxic gases in the emptied tank. If it should become necessary to inspect or make repairs, at least three strong individuals should be present. The tank should first be checked with a gas detector[73] for oxygen and toxic gases and thoroughly ventilated using a blower, which is kept operating. Then two persons should remain on top and the third makes the inspection or repairs wearing a full-body safety harness connected to a pulley supported by a tripod or other support so that he can be hauled out in case of trouble. The tank should not be left uncovered or unguarded as small children or pets could possibly fall in. See Safety, later in this chapter.

Certain chemicals should not be added to septic tank systems. The use of 1 gal of sulfuric acid to "unclog" a home septic tank system resulted in reaction with sulfides present and the release of toxic fumes (H_2S), which overcame three and

[71] W. C. Parsons, "County Develops Unique Plant to Treat Septage," *Public Works*, June 1987, pp. 76–77.
[72] See publications NBSIR 83-2693 and DHHS (NIOSH) 83-103, also state and local regulations.
[73] Ted Pettit and Herb Linn, *A Guide to Safety in Confined Spaces*, DHHS (NIOSH) Pub. No. 87-113, July 1987. Hazardous gas monitoring equipment is available to detect the presence of and measure the concentration of methane, hydrogen sulfide, and lack of oxygen. Check also liquid manure tanks. *Do not enter.*

killed two persons.[74] The mixing of household cleaning compounds such as chlorine bleach and ammonia, caustic soda (lye), or similar cleaners is dangerous as toxic gases such as chlorine are released. This can cause injury to the throat and lungs and possibly permanent damage and death. Soap, drain solvents, disinfectants, and similar materials used individually for household purposes are not harmful to septic tank operation unless used in large quantities. Organic solvents and cleaners, pesticides, and compounds containing heavy metals could contaminate the groundwater and well-water supplies. They should not be disposed of in a septic tank system. Exclude sanitary napkins, absorbent pads, and tampons.

There may be occasions when the level of the contents in a septic privy drops below the overflow level, or where the water level in an aqua privy drops below the bottom of the squat plate funnel and pipe. In such circumstances the use of special chemical compounds to promote liquification and/or control odors may be hazardous. The gases emitted may be explosive and may be ignited by a discarded match or lighted cigarette. It is safer to add water and mix the contents with a long pole.

Salt or brine from a household zeolite softening unit backwash wastewater, in amounts as little as 1.2 percent, temporarily retards the bacterial action in the septic tank and tends to build up in the sludge, but the salt is gradually flushed out as the sludge digests, rises, and falls. However, the salt (sodium) tends to cause swelling and clogging of clay loam soils due to soil structure breakdown. Therefore, it is not prudent to discharge brine waste to the septic tank. The calcium and magnesium in water to be softened replace the sodium in the zeolite filter media, and the sodium passes through with the treated water. The unit is regenerated by flushing a solution of common salt through the zeolite filter media and filtering to waste until there is no longer any salt in the filtered water, during which time the calcium and magnesium attached to the zeolite are replaced by the sodium in the salt, causing calcium and magnesium to also be flushed out with the chloride. The calcium and magnesium salts, released during regeneration and added to the wastewater entering the septic tank and then the absorption system, tend to keep the soils open, counteracting to some extent the action of the sodium in the regenerated water and the wastewater during regeneration. It appears that the detrimental effect of all the sodium would supersede the beneficial effect of the calcium and magnesium salts. If water softener wastewater is discharged to the septic tank, the area of the absorption system should be increased to handle an additional hydraulic load of about 75 gal per day.

High weeds, brush, shrubbery, and trees, although consumers of groundwater, should not be permitted to grow over an absorption system or sand filter system. It is better to crown the bed, seed the area to grass, and build up a lawn. Sunlight and exposure to wind is beneficial as it encourages evapotranspiration.

If trees are near the sewage disposal system, difficulty with roots entering poorly joined sewer lines can be anticipated. Lead-caulked cast-iron pipe, a sulfur base or bituminous pipe joint compound, mechanical clay pipe joints, copper rings over joints, and lump copper sulfate in pipe trenches have been found effective in resisting the entrance of roots into pipe joints. Roots will penetrate first into the gravel in absorption field trenches rather than into the pipe. About 2 to 3 lb of copper sulfate crystals flushed down the toilet bowl once a year will destroy roots the solution comes into contact with, but will not prevent new roots from entering. The application of the chemical should be done at a time, such as late in the evening, when the maximum contact time can be obtained before dilution. Copper sulfate will corrode chrome, iron, and brass, hence it should not be allowed to come into contact with these metals. Cast iron is not affected to any appreciable extent. Some time must elapse before the roots are killed and broken off. Copper sulfate in the recommended dosage will not interfere with operation of the septic tank.[75] The cutting or mechanical removal of roots in sewers tends to increase root growth and size, leading to more problems and sewer repair. The flooding of sewers with a copper sulfate solution or a foam containing copper sulfate can provide longer contact time with roots and should be more effective in their removal. Television scanning in 2 to 3 years may show the need for retreatment. An EPA registered herbicide, or a chemical foam, is also reported to be effective.[76]

Flooding of sewer lines with scalding water [(180 to 210°F) (82 to 99°C)] will kill roots subjected to a 30-min soak at 170°F (76°C). A portable steam generator is needed to reheat recirculated water to maintain the water temperature and compensate for heat loss. A temperature of 122°F (50°C) will kill most plant tissue.[77]

Hydrogen peroxide has been used to oxidize the sludge and organic growths in clogged distribution lines and trenches. If used, it should be handled with extreme care. Hydrogen peroxide is a strong oxidizing agent and potentially explosive. Its effectiveness is temporary and the soil percolation capacity is greatly reduced.[46]

Causes of Failure of Septic Tank System and Corrective Measures

Common causes of septic tank system failures are seasonal high groundwater; carryover of solids into the absorption field due to use of septic tank cleaning compounds, lack of routine cleaning of the septic tank, or outlet baffle disintegration or loss; leaking plumbing fixtures, especially water closets; excessive water use, connected roof and footing drains, and hydraulic overloading; uneven settlement of the septic tank, connecting pipe, or distribution box; and improper design and construction of the absorption system, including compaction and smearing of absorption trench bottom and sidewalls. One must avoid soil compaction, construction during wet weather, leaving trenches open during a rainstorm or snowstorm, or surface water drainage into open absorption trenches, and walking in trenches when leveling, and cleaning; raking should be done prior to placement of gravel.

[74] "Two dead, one critical from fumes inhalation," Endicott, N.Y., Associated Press, November 5, 1978.

[75] Don E. Bloodgood, "Tree Roots, Copper Sulfate, and Septic Tanks," *Water and Sewage Works*, May 1952, pp. 190–193.

[76] Tim Casey, "Removing Roots from a Sewer System," *Public Works*, September 1989, pp. 134–135.

[77] James T. Conklin, "Thermal Kill of Roots in Sanitary Sewers," *Deeds and Data*, Water Pollut. Control Fed., March 1977.

[46] D. L. Hargett, et al., *op. cit.*

Corrective measures, once the cause is identified, might include water conservation measures such as reduced water usage, low-flush toilets, low-flow shower heads, reduced water pressure, faucet aerators, spray taps, and use of commercial laundromat. In an emergency, consideration might be given to installation of a recirculating toilet, air-assist toilet, composting toilet, separation and reuse of grey water, and a holding tank. Other measures to consider are cleaning of septic tank and flushing out distribution lines (*do not empty tank if groundwater level is high—tank will float to surface*), and installation of additional leaching lines; installation of a separate absorption system and division box or gate for alternate use with the annual resting of existing system; lowering the water table with curtain drains; discontinuation of use of septic tank cleaning compounds; replace corroded or disintegrated baffles with terra cotta, cast-iron, ABS, or PVC tees; replace or relevel distribution box on a gravel footing extended below frost; clean septic tank every 3 years; and disconnect roof, footing, and area drains, or some combination of measures as applicable.

Use of Additives

Compounds that are supposed to make tank cleaning unnecessary may actually cause solids to be carried over into the absorption or treatment system and the penetration of fine solids into the soil infiltrative surface with resultant clogging. A grab sample collected from a septic tank serving a 60-unit trailer park showed a total solids concentration of 15,058 mg/l 1 day after a septic tank cleaner had been added. The effluent from the sand filter following the septic tank showed a total solids content of 1038 mg/l at the same time.*

Some septic tank cleaners (degreasing compounds) contain sodium or potassium hydroxide or sulfuric acid. Acids and bases are only temporarily effective in unclogging absorption trenches. Sodium hydroxide causes solids deflocculation and dispersion on and in the soil, with resultant sealing of the infiltrative surface. Others contain methylene chloride, trichloroethylene, methyl chloroform, trichloroethane, or orthodichloro-benzene, which are suspected of being carcinogenic. These and other toxic compounds may eventually reach the groundwater and endanger well-water supplies in the area. Their use is not advised and should be prohibited where the groundwater is a source of water supply.

Commercial compounds alleged to prevent septic tank system clogging and backup usually require regular application; weekly or monthly is not unusual. Temporary relief may be obtained, but the cost of the chemical on an annual basis could equal twice the cost of having a septic tank cleaned *annually*. Hydrogen peroxide applied to clogged distribution lines has been only temporarily effective; it destroys soil structure. Special bacteria and enzymes added to septic tanks to prevent or ameliorate failure of septic tank absorption systems have been of debatable effectiveness. They are not likely to contaminate nearby wells; organic solvent-type products can contaminate drinking water sources.[78]

*Author's experience.
[78]Richard R. Noss, "Septic System Cleaners," *J. Environ. Health*, March/April 1989, pp. 201–204.

A starter, such as yeast, added to a septic tank does not accelerate the digestion. The addition of 6 gal of digested sludge per capita to a new septic tank appears to have a beneficial seeding effect. A new septic tank does not need a starter or other additive to function. The sewage it receives contains the organisms necessary to initiate and promote anaerobic digestion. Slug doses of household chemicals, 4.8 l of liquid bleach, 9.5 l of liquid lysol, or 18.9 gms of "Drano" crystals to a 3780-l septic tank, was reported to not harm bacterial action.[79]

Division of Flow to Soil Absorption System

The overflow from a septic tank should be run to a distribution box to ensure equal division of the settled sewage flow to all the leaching pits or laterals comprising the disposal or treatment system. The distribution box should have a removable cover extended to the surface to simplify inspection of the septic tank effluent and flow distribution to the disposal or treatment system. *Outlets must leave the distribution box at exactly the same level.* Eccentric inserts for distribution box outlets are also available to balance the flow to each lateral. A gravel fill or footing under the box, extending below frost, will help keep the box level. A baffle is usually necessary in front of the inlet to break the velocity of the incoming sewage and permit equal distribution to the outlets. Bricks or blocks are very useful for this purpose. Details of distribution boxes are given in Figures 4-10 and 4-12. If the outlets are constructed about 6 in. above the bottom of the distribution box, the liquid collected will have the effect of breaking the incoming velocity of the settled sewage. In any case, it is important to place all outlets at the same level and obtain equal distribution of flow to each of the laterals. A $\frac{1}{8}$-in. mesh plastic basket screen over each outlet would prevent large particles of septic tank sludge from being carried into the absorption field. Backup would occur at the box without ruining the absorption field, signaling the need to replace the septic tank outlet baffle or clean the septic tank.

Serial distribution of sewage (Figure 4-11) by the use of tees and elbows is reported to have certain advantages over the use of distribution boxes.[62] It compensates for varying soils and absorptive capacity; it forces full use of a trench before overflow to the next and overcomes the hazard of overflow associated with the parallel system if one trench is overloaded due to uneven flow distribution from an improperly installed distribution box. However, greater expertise is needed in construction. This method of sewage distribution promotes creeping failure of the absorption system due to overloading of the beginning laterals and trenches, thereby promoting anaerobic conditions rather than aerobic. Drop manholes (Figure 4-12) or a dosing system (Figure 4-30) provide more reliable and balanced wastewater distribution on sloping ground.

On steep grades, special provision must be made for reducing the velocity of the sewage leaving the septic tank in order to get good distribution to the subsurface

[79]Mark A. Gross, "Laboratory and Field Studies Investigate Chemicals' Effects," *Small Flows*, West Virginia University, Morgantown, W. Va., June 1988, p. 4.
[62]*Manual of Septic-Tank Practice*, *op. cit.*

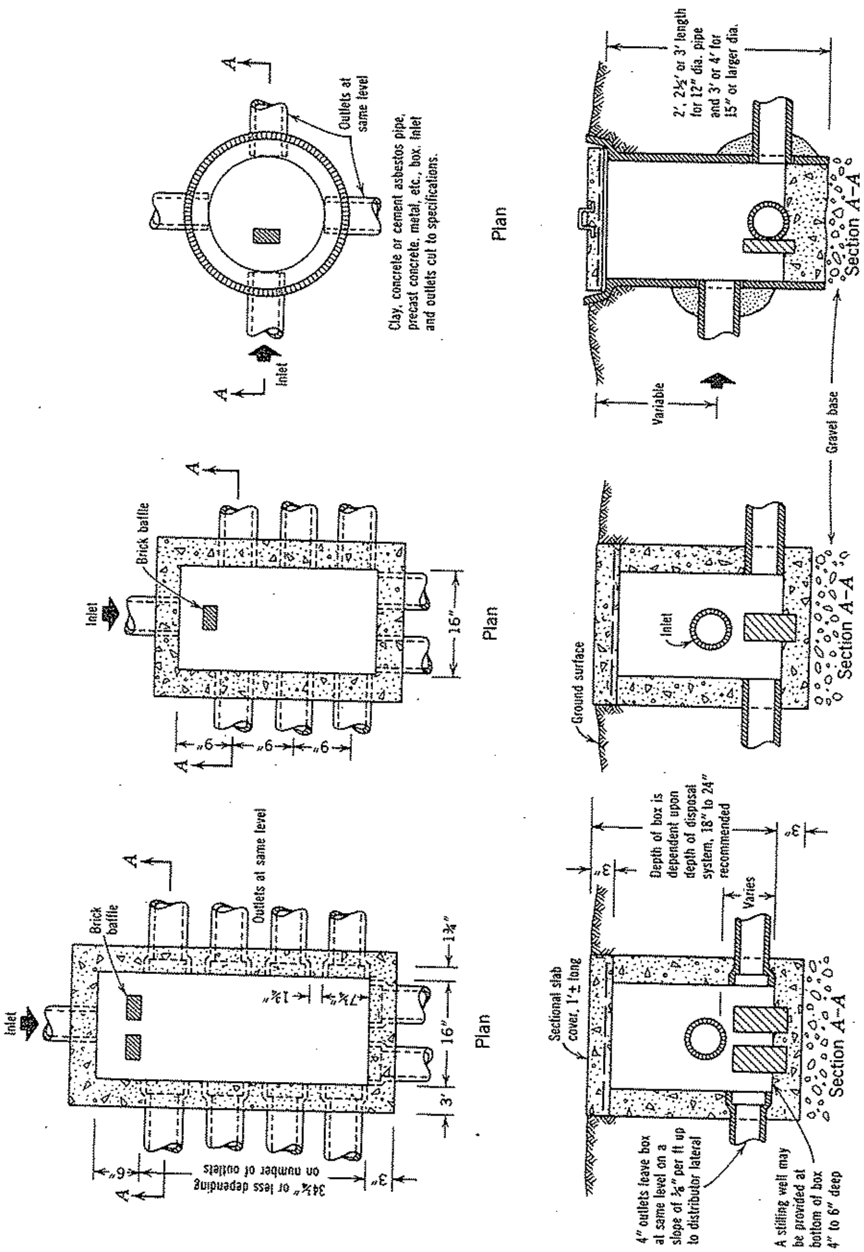

Figure 4-10 Distribution box details. (Bottom of gravel below frost; level box on 12 in. of well-stabilized gravel.) Vitrified clay tile and plastic distribution boxes better resist deterioration.

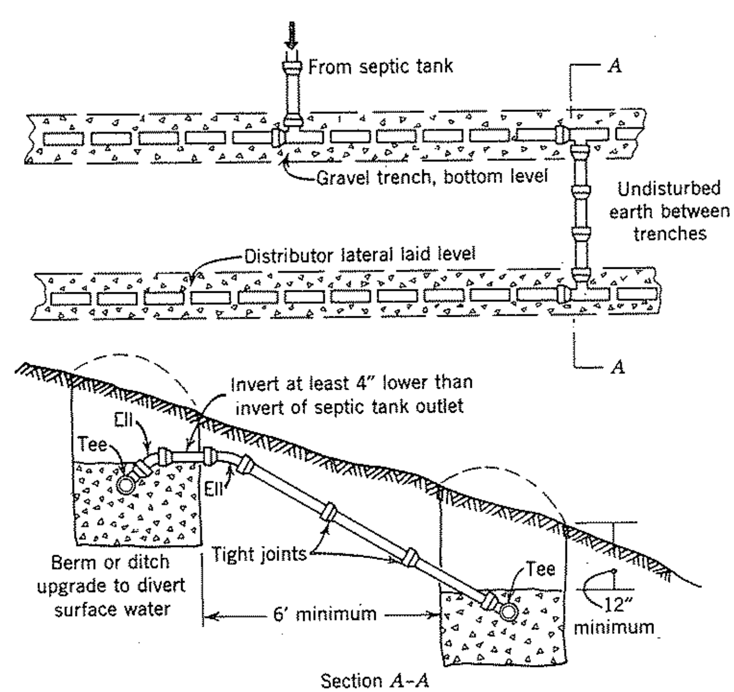

Figure 4-11 Serial distribution for sloping ground. (Adapted from U.S. PHS Pub. 526, DHEW, Washington, D.C., 1967.)

tile field or absorption system. Drop manholes are used for this purpose. The flow can be divided approximately in proportion to the length of the absorption system at each manhole. Drop-manhole details are shown in Figure 4-12.

A flow diversion box or two-port valve on the line leaving the septic tank to permit use of alternate absorption systems, say on a 6-month cycle, will promote maintenance of trench infiltrative capacity, aerobic conditions, and prolonged life if the septic tank is cleaned regularly (every 3 years). See Table 4-11.

Subsurface Soil Absorption Systems

The conventional subsurface absorption system following the septic tank is the absorption field or leaching pit. The cesspool is still used for raw sewage, although generally prohibited, and the dry well is used for the disposal of rainwater, footing, roof, and basement floor drainage. Where the soil is not suitable for subsurface disposal, a sand filter, evapotranspiration system, modified tile field system, aeration system, system in fill, mound system, stabilization pond, or some combination may be used. These systems are discussed later.

In all cases, it is again emphasized to avoid compaction of trench bottoms and soil where the absorption system is to be built. Smearing of trench bottoms and sidewalls must be removed. Construction must not take place during wet weather,

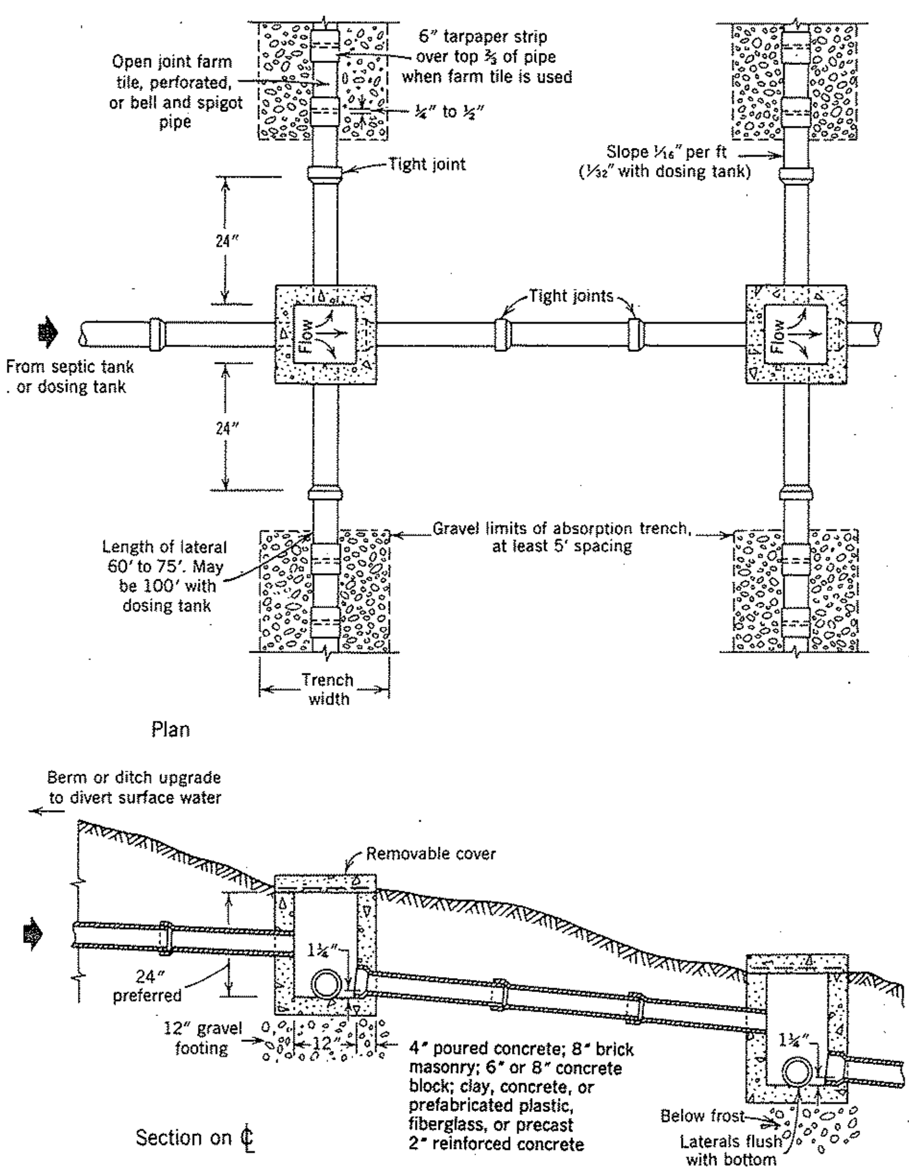

Figure 4-12 Drop-manhole details for absorption field on slopping ground.

or on wet soil; trenches must not be left open during a rainstorm or snowstorm; and surface water drainage must not be permitted to enter the trenches.

Absorption Field System

The soil percolation test and soil clues basis for the design of absorption systems were given earlier in this chapter. Design standards and details for absorption systems are shown in Figures 4-5, 4-11, 4-12, 4-13, and in Table 4-12.

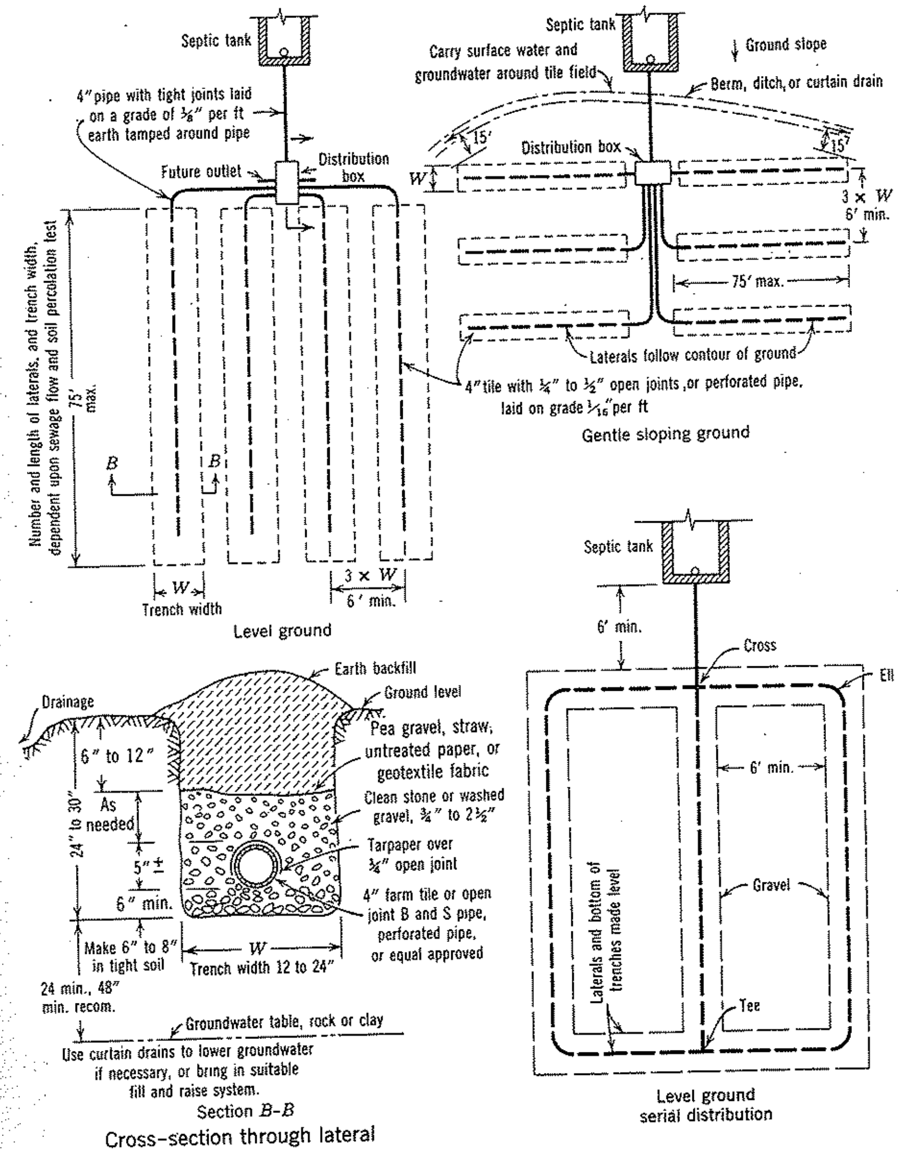

Figure 4-13 Arrangements and details for absorption field disposal systems. See local regulations.

The absorption field laterals should be laid in narrow trenches (18 to 24 in.), parallel to the contour and perpendicular to the groundwater flow, preferably not more than 24 in. below the ground surface, and spaced as shown in the illustrations, to provide dispersion of the septic tank effluent over a larger area, utilize the more absorbent topsoil, and promote the maintenance of aerobic conditions in the absorption trenches. The highest seasonal groundwater level should be at least 2 ft, and preferably 4 ft, below the bottom of trenches, depending on the capillarity and coarseness of the unsaturated soil beneath the trench, to maintain it unsaturated.

Table 4-12 Suggested Minimum Standards—Subsurface Sewage Disposal Systems

Item	Material	Size	Grade	Minimum Governing Distances: To Building or Property Line	To Well or Suction Line	To Water Service Line
Sewer to septic tank	Cast iron for 10′ from bldg. recommended.	4″ min. dia. recommended	$\frac{1}{4}$″ per ft max., $\frac{1}{8}$″ per ft min.	5′ or more recommended	25′ if cast-iron pipe, otherwise 50′	10′ hor.[a]
Septic tank	Concrete or other app'd matrl. Use a 1:2$\frac{1}{4}$:3 mix.	Min. 750 gal 4′ liquid depth, with min. 16″ M.H. over inlet.	Outlet 2″ below inlet.	10′	50′	10′
Lines to distribution box and disposal system	Cast iron, vit. clay, concrete, or composition pipe.	Usually 4″ dia. on small jobs.	$\frac{1}{8}$″ per ft; but $\frac{1}{16}$″ per ft with pump or siphon.	10′	50′	10′
Distribution box	Concrete, clay tile, masonry, coated metal, etc.	Min. 12″ × 12″ inside carried to the surface. Baffled.	Outlets at same level.	10′	100′	10′
Absorption field[b]	Clay tile, vit. tile, concrete, composition pipe, laid in washed gravel or crushed stone, $\frac{3}{4}$″ to 2$\frac{1}{2}$″ size, min. 12″ deep.	4″ dia., laid with open joint or perforated pipe. Depth of trench 24″ to 30″.	$\frac{1}{16}$″ per ft, but $\frac{1}{32}$″ per ft with pump or siphon.	10′ except when fill used, in which case 20′ required	100′	10′ (25′ from any stream; 50′ recommended)
Sand filter[b]	Clean sand, all passing $\frac{1}{4}$″ sieve with effective size of 0.30 to 0.60 mm and uniformity coefficient less than 3.5. Flood bed to settle sand.	Send 2-lb sample to health dept. for analysis 15 days before construction.	Laterals laid on slope $\frac{1}{16}$″ per ft; but $\frac{1}{32}$″ per ft with pump or siphon.	10′	50′	10′ (25′ from any stream; 50′ recommended)
Leaching or seepage pit[b]	Concrete block, clay tile, brick, fieldstone, precast.	Round, square, or rectangle	Line to pit $\frac{1}{8}$″ per ft.	20′	150′ plus in coarse gravel	20′ (50′ from any stream)
Chlorine contact-inspection tank.	Concrete, concrete block, brick, precast.	2′ × 4′ and 2′ liquid depth recommended	Outlet 2″ below inlet.	10′	50′	10′

Note: A slope of $\frac{1}{16}$″ per ft = 6.25′ per 100′ = 0.0052 ft per ft = 0.52 percent.
Note: All parts of disposal and treatment system shall be located above groundwater and *downgrade* from sources of water supply. The architect, builder, contractor, and subcontractor shall establish and verify all grades and check construction. Laundry and kitchen wastes shall discharge to the septic tank with other sewage. Increase the volume of the septic tank by 50 percent if it is proposed to also install a garbage grinder. No softening unit wastes, roof or footing drainage, surface water or groundwater shall enter the sewerage system. Where local regulations are more restrictive, they govern, if consistent with county and state regulations.

[a] Water service and sewer lines may be in same trench, if cast-iron sewer with lead-caulked joints is laid at all points 12″ below water service pipe; or sewer may be on dropped shelf at one side at least 12″ below water service pipe, provided sound sewer pipe is laid below frost with tight and root-proof joints which is not subject to settlement, superimposed loads, or vibration. Separate trenches are strongly recommended.
[b] *Manual of Septic-Tank Practice*, PHS Pub. 526 (1967), states that the leaching area should be increased by 20 percent where a garbage grinder is installed, and by 40 percent where a home laundry machine is also installed. It recommends that the gravel in the tile field extend at least 2″ above pipe and 6″ below the bottom of the pipe.

Where laterals must be laid at a greater depth, the gravel fill around the open joint or perforated lateral should extend at least to the topsoil and as shown in Figures 4-13 and 4-14 to promote aerobic conditions, evapotranspiration, and nitrogen and phosphorus removal. The sunny and open side of a slope is the preferred location for an absorption field to promote evapotranspiration, if there is a choice. After settlement and grading, the absorption field area should be seeded to grass. Permeable geotextile fabric may be used in place of pea gravel, straw, or untreated paper to prevent the infiltration of soil fill into the trench gravel.

Possible elevations of absorption field distribution laterals to stay 24 in. or more above seasonal high groundwater, bedrock, tight clay soil, or other natural barrier condition are shown in Figure 4-14.

When the total length of the laterals to provide the required leaching area is 500 to 1000 linear ft, a siphon or pump should be installed between the septic tank and absorption system to distribute the sewage to all the laterals. If the total required length of the laterals is 1000 to 3000 linear ft, the system should be divided into two or four sections with alternating feed to each section, or each two sections when four are provided. Where the total length of laterals required is greater than 3000 linear ft, it is advisable to investigate a secondary treatment process, although larger absorption systems can operate satisfactorily if the site and soil permeability are suitable to disperse the effluent and prevent groundwater mounding. Annual resting of sections is strongly recommended. In some instances flat topography makes it impossible to install siphons and still obtain distribution of settled sewage by gravity to all the laterals. In such cases, it would be necessary to install a sump and pump(s) or ejector(s); however, the design should permit gravity flow to the absorption system in case of pump failure, if possible. Dosing arrangements are discussed later.

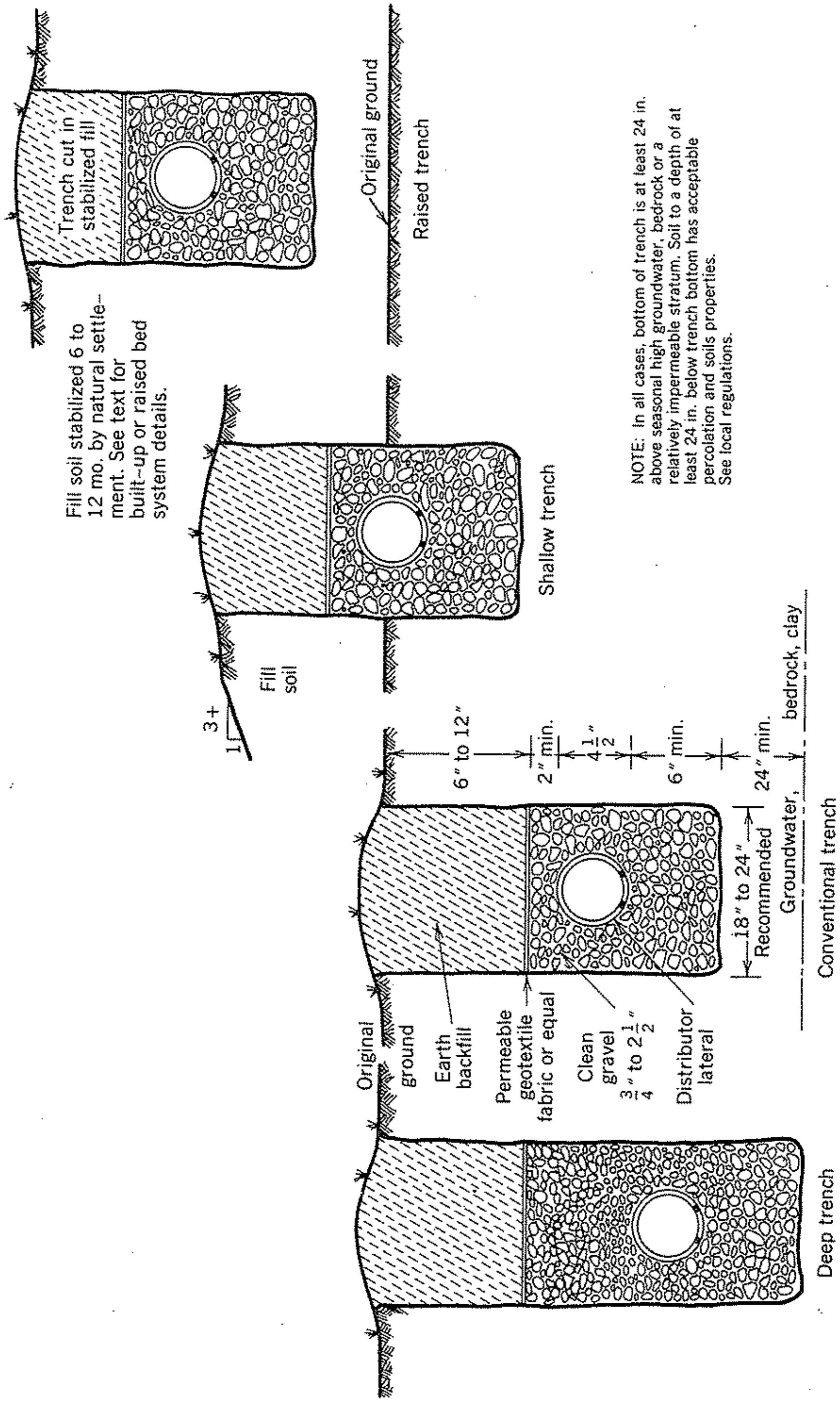

Figure 4-14 Possible distribution trench elevations to stay at least 24 in. above a limiting barrier condition.

Absorption field laterals must be laid on careful grades. *The bottom of trenches should be dug practically level, on the same grades as the laterals* to prevent the sewage running out at one end of a trench or onto the ground surface. Laterals for fields of less than 500 ft in total length, without siphon or pump dosing, should be laid on a slope of $\frac{1}{16}$ in./ft or 3 in./50 ft. When siphons or pumps are used, the laterals should be laid on a slope of 3 in./100 ft. Absorption fields for steep sloping ground are shown in Figures 4-11 and 4-12, and layouts for level and gently sloping ground are shown in Figures 4-13 and 4-15. Dosing, regardless of absorption field size, is recommended to ensure full distribution and use of the field, intermittent resting, and aerobic conditions.

The disposal of septic tank effluent in a bed, rather than in separated lateral trenches, can cause operational problems. Groundwater table mounding is more likely to develop beneath the bed, particularly where the soil percolation is marginal and subsoil hydraulic conductivity is low, with consequent backup or surface seepage of sewage. This would also occur if the subsoil vertical and horizontal trans-

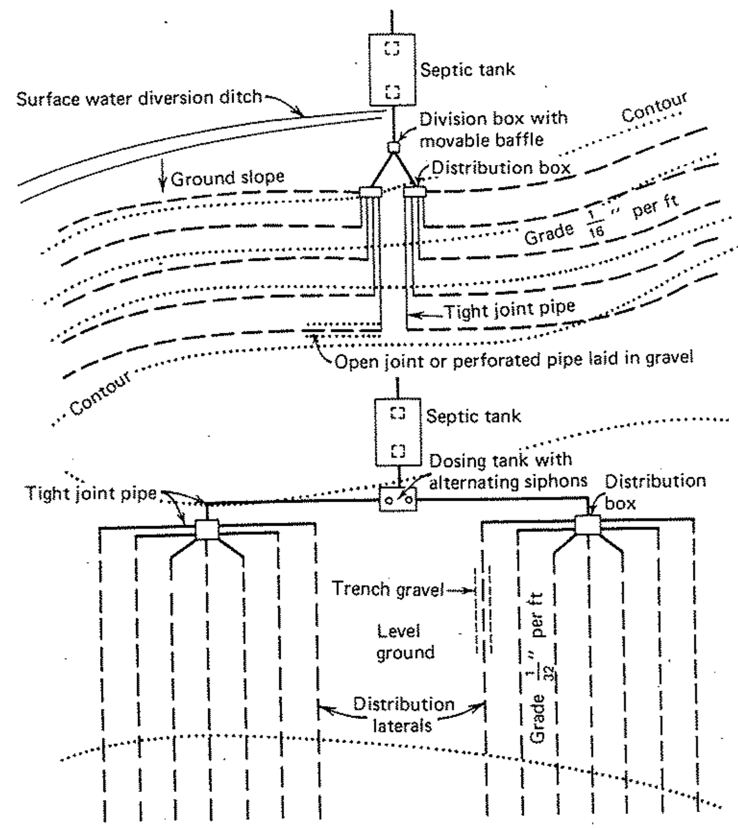

Figure 4-15 Absorption fields with division box, distribution box, and dosing tank. Lateral lengths: 75 ft max. for gravity flow, and 100 ft max. if dosing siphon or pump is used. See also Figure 4-12 for sloping ground.

missivity does not exceed the rate at which the sewage effluent infiltrates the absorption bed bottom and walls and percolates through the soil, and where the groundwater hydraulic gradient is relatively flat. It is recommended, and often required, that the bed area be twice that required for absorption trenches. In contrast, the use of lateral trenches and separated fields would permit dispersion and evapotranspiration of the effluent over a greater area, which would include a trench sidewall area. Similar precautions should be taken with large subsurface absorption systems, consisting of several fields or sections, to avoid their being located in a limited area and downgrade from one another.[80] In effect, water balance, soil permeability, transmissivity, and soils studies should be made over the total area impacted to ensure that the receiving soil has the capacity (hydraulic conductivity) to carry away and disperse the sewage effluent downward and laterally at a rate faster than it is applied, at all times of the year, without backup, surface seepage, or water mounding beneath or around the absorption field.

Leaching or Seepage Pit

Leaching pits, also referred to as seepage pits, are used for the disposal of settled sewage where the soil is suitable and a public water supply is used, or where private well-water supplies are at least 150 to 200 ft away, at a higher elevation and not likely to be affected. The bottom of the pit should be at least 2 ft, and preferably 4 ft, above the highest groundwater level and channeled or creviced rock. If this cannot be ensured, subsurface absorption fields should be used. In special instances, where public water supply is available, suitable soil is found at greater depths, and groundwater can be protected, pits can be dug 20 to 25 ft deep or more, using precast perforated wall sections. The soil percolation test is made at mid-depth, at changes in the soil profile, and at the bottom of the proposed leaching pit and interpreted for design purposes as explained earlier in this chapter and in Table 4-5. The effective leaching area provided by a pit is equal to the vertical wall area of the pit below the inlet. Credit is not usually given for the pit bottom. A leaching pit is usually round to prevent cave-in. If precast perforated units are not used, the wall below the inlet is drywall construction—that is, laid with open joints, without mortar. Field stones, cinder or stone concrete blocks, precast perforated wall sections, or special cesspool blocks are used for the wall construction. Concrete blocks are usually placed with the cell holes horizontal. Crushed stone or coarse gravel should be filled in between the outside of the leaching pit wall and the earth hole. Table 4-13 simplifies determination of the sizes of circular leaching pits. Sketches of leaching pits are given in Figures 4-16 and 4-17.

Since leaching pits concentrate pollution in a small area, their use should generally be avoided where the groundwater is a drinking water source.

[80]E. Jerry Tyler and James C. Converse, "Soil Evaluation and Design Selection for Large or Cluster Wastewater Soil Absorption Systems," in *On-Site Wastewater Treatment*, Proceedings of the Fourth National Symposium on Individual and Small Community Sewage Systems, American Society of Agricultural Engineers, St. Joseph, Mi., 1985, pp. 179–190.

Table 4-13 Sidewall Areas of Circular Seepage Pits (ft^2)[a]

Seepage[b] Pit Diameter (ft)	Thickness of Effective Layers Below Inlet (ft)									
	1	2	3	4	5	6	7	8	9	10
1	3.1	6	9	13	16	19	22	25	28	31
2	6.3	13	19	25	31	38	44	50	57	63
3	9.4	19	28	38	47	57	66	75	85	94
4	12.6	25	38	50	63	75	88	101	113	126
5	15.7	31	47	63	79	94	110	126	141	157
6	18.8	38	57	75	94	113	132	151	170	188
7	22.0	44	66	88	110	132	154	176	198	220
8	25.1	50	75	101	126	151	176	201	226	251
9	28.3	57	85	113	141	170	198	226	254	283
10	31.4	63	94	126	157	188	220	251	283	314
11	34.6	69	104	138	173	207	242	276	311	346
12	37.7	75	113	151	188	226	264	302	339	377

Source: *Design Manual. Onsite Wastewater Treatment and Disposal Systems*, U.S. EPA, October 1980, p. 237.

[a]Areas for greater depths can be found by adding columns. For example, the area of a 5-ft diameter pit, 15 ft deep is equal to 157 + 79, or 236 ft.

[b]Diameter of excavation.

Cesspool

Cesspools are covered, open-joint, or perforated walled pits that receive raw sewage. Their use is not recommended where the groundwater serves as a source of water supply. Many health departments prohibit the installation of cesspools. Pollution could travel readily to wells or springs used for water supply. Where cesspools are permitted, they should be located downgrade from sources of water supply and 200 to 500 ft away. Even 500 ft may not be a safe distance in a coarse gravel unless the water-bearing stratum is below the gravel and separated by a thick clay or hardpan stratum. On the other hand, lesser distances may be permitted where fine sand and no groundwater is involved. In all cases, the bottom of the cesspool should be at least 4 ft above the highest groundwater level.

The construction of a cesspool is the same as a leaching pit, shown in Figure 4-16. In some areas, such as where sand and gravel deposits are found, cesspools have been in common use for many years before requiring cleaning. Cleaning the cesspool will not restore it to full use since the space and soil behind the wall cannot be effectively cleaned. Heavy chlorination may be of value. Special cesspool (or septic tank, as previously noted) cleaning compounds may contain toxic or carcinogenic chemical compounds and should not be used. These compounds may persist for many years and contaminate the groundwater aquifer serving as the source of drinking water. The cesspool system can be made more efficient under such circumstances by providing a tee outlet, as shown in Figure 4-16, with the overflow discharging to an absorption field or leaching pit. A preferable alternative

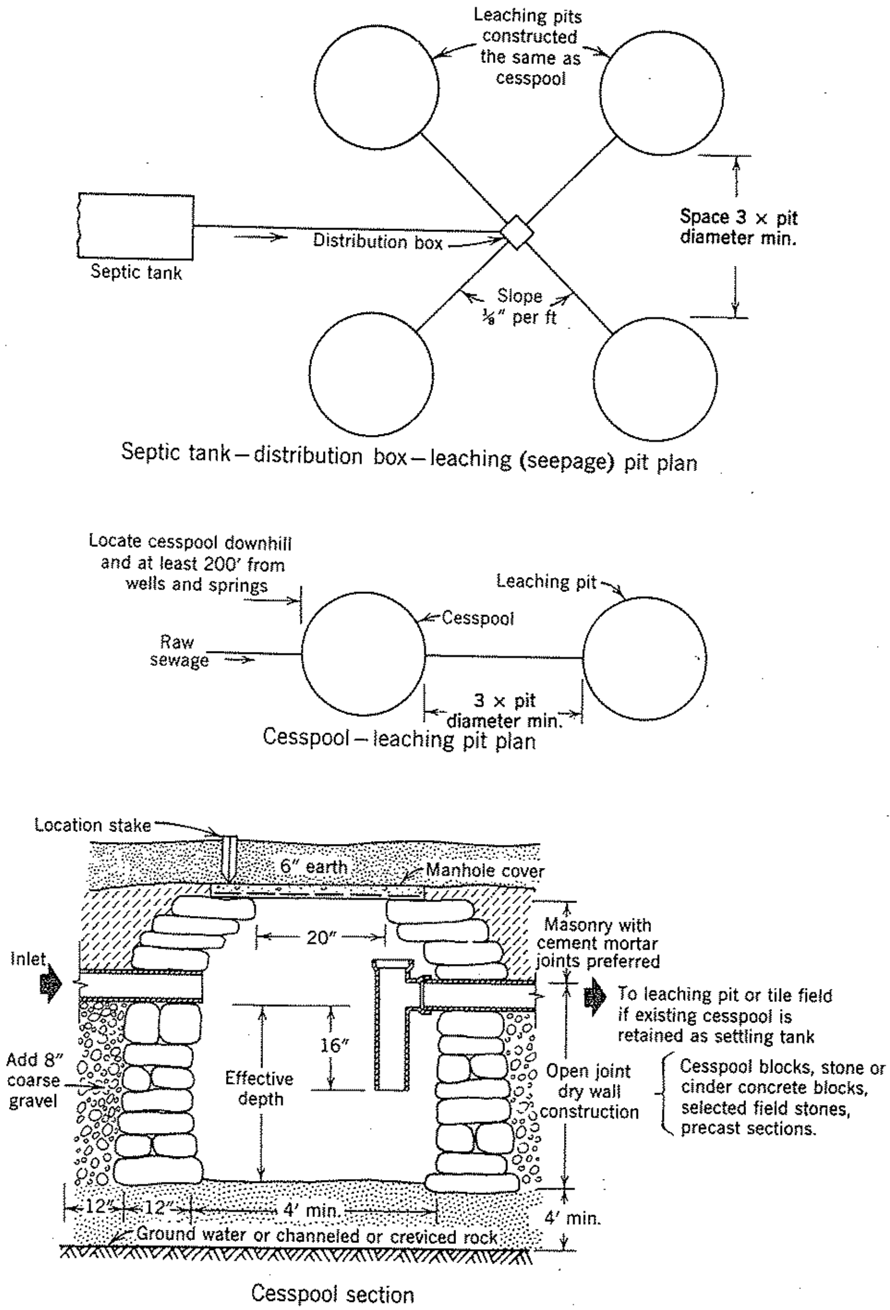

Figure 4-16 Leaching pit and cesspool details.

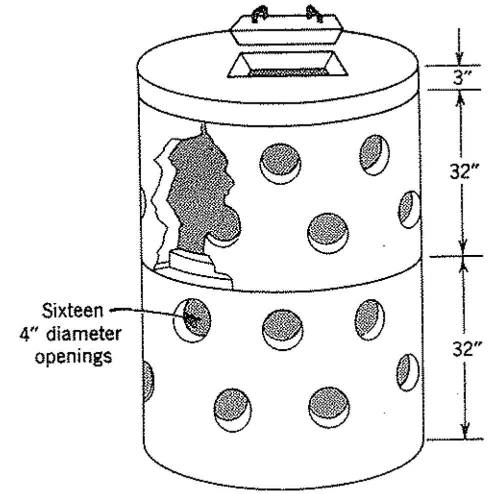

Figure 4-17 Precast leaching pit or dry well. (Courtesy of the Fort Miller Co., Inc., Fort Miller, N.Y.) Each section: 32 in. high, 4 ft inside diameter (available in larger sizes); 3 in. thick walls — place 8 in. coarse gravel all around; 250-gal volume; 1,100-lb weight. Cover weight: Approximately 400 lb. Manhole can be built up to grade using standard chimney blocks.

would be replacement of the cesspool with a septic tank followed by an absorption field.

Dry Well

A dry well is constructed in the same way as a leaching or seepage pit and with identical care. A dry well is used where the subsoil is relatively porous, for the underground disposal of clear rainwater, surface water, or groundwater collected in footing, roof, and basement floor drains and similar places. Footing, roof, or basement floor drainage should never be discharged to a private sewage disposal or treatment system as the septic tank and leaching system would be seriously overloaded, causing exposure of the sewage and premature failure of the leaching system. It is uneconomical and unnecessary to design the sewerage system for this additional flow. If the soil at a depth of 6 to 10 ft or more is tight clay, gravel- or stone-filled trenches about 3 ft deep may be more effective. Dry wells should not be used for the disposal of toilet, bath, laundry, or kitchen wastes. These wastes should be discharged through a septic tank. In some cases, footing and roof drainage may be discharged to a nearby watercourse, combined sewer, storm sewer, or roadside ditch rather than to dry wells, if permitted by local regulations.

Dry wells should be located at least 50 ft from any water well, 20 ft from any leaching portion of a sewage disposal system, and 10 ft or more from building foundations or footings.