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# The Class V Underground Injection Control Study

## Volume 5

## Large-Capacity Septic Systems

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# LARGE-CAPACITY SEPTIC SYSTEMS

The U.S. Environmental Protection Agency (USEPA) conducted a study of Class V underground injection wells to develop background information the Agency can use to evaluate the risk that these wells pose to underground sources of drinking water (USDWs) and to determine whether additional federal regulation is warranted. The final report for this study, which is called the Class V Underground Injection Control (UIC) Study, consists of 23 volumes and five supporting appendices. Volume 1 provides an overview of the study methods, the USEPA UIC Program, and general findings. Volumes 2 through 23 present information summaries for each of the 23 categories of wells that were studied (Volume 21 covers 2 well categories). This volume, which is Volume 5, covers Class V large-capacity septic systems.

## 1. SUMMARY

Large-capacity septic systems (LCSSs) are an onsite method for partially treating and disposing of sanitary wastewater. Only those septic systems having the capacity to serve 20 or more persons-per-day are included within the scope of the federal UIC regulations.

LCSSs do not utilize a single design but instead are designed for each site according to the appropriate state and/or local regulations. Many conventional LCSSs consist of a gravity fed, underground septic tank or tanks, an effluent distribution system, and a soil absorption system. LCSSs may also include grease traps, several small septic tanks, a septic tank draining into a well, connections to one large soil absorption system, or a set of multiple absorption systems that can be used on a rotating basis.

LCSSs are used by a wide variety of establishments, including residential (multi-unit housing) and non-residential (commercial, institutional, and recreational) facilities. The characteristics of the sanitary wastewater from these establishments vary in terms of biological loadings and flow (e.g., daily, seasonal). Generally, the injectate from LCSSs is characterized by high biological oxygen demand (BOD) and chemical oxygen demand (COD), nitrate, trace metals and other inorganics, limited trace organics, and biological pathogens.

Even with a fully functioning system, data indicate LCSS effluent may contain arsenic, fecal coliform, nitrate (as N), total nitrogen species (as N), and formaldehyde (in septic systems serving recreational vehicles) at concentrations above primary drinking water maximum contaminant levels (MCLs) or health advisory levels (HALs). The concentrations of aluminum, iron, manganese, and sodium may exceed secondary MCLs.

The effect of these constituents on USDWs depends in part on the characteristics of the injection zone. It is difficult to generalize about the injection zone for LCSSs because these systems have been constructed nationwide. Typically, LCSSs are located in well-drained soils; however, LCSSs have been located in areas with karst or fractured bedrock. The injectate from LCSSs receives partial treatment within the system (i.e., settling and biodegradation in the septic tank). However, attenuation occurs as the septic tank effluent travels through the soil media below the fluid distribution system, which is most commonly a leachfield. In particular, dissolved organic matter, pathogens, and some inorganic constituents can be attenuated in unsaturated soils below the soil absorption system.

The likelihood of ground water contamination resulting from LCSSs may be minimized by following best management practices (BMPs) relating to siting, design, construction and installation, and operation and maintenance. Careful siting and design of LCSSs are important because understanding site limitations can prevent future system failure. The construction and installation of the septic system is best left to professionals, so that the underlying soils are not damaged through compaction and the system is not constructed during periods of high moisture, both of which are likely to contribute to early system failure. Further, it is recommended that LCSSs be properly operated and maintained by conducting inspections and performing maintenance as appropriate, "resting" the soil absorption field, pumping the septic tank to remove solids as necessary, and limiting system loading (e.g., water conservation, reducing chemical use or addition). Owners or operators of LCSSs who follow such BMPs are likely to maximize the life of their system and lower the likelihood that their system would contaminate a USDW.

Nevertheless, contamination incidents caused by LCSSs have occurred. For example, in Racine, MO during 1992, two drinking water wells at a nearby church and school were contaminated by sewage from a LCSS, causing 28 cases of Hepatitis A. In Coconino County, AZ during 1989, failure of the leaching field (due to excessive flow) at a resort area resulted in approximately 900 cases of gastroenteritis. In Richmond Heights, FL during 1974, a drinking water well was contaminated by sewage from a nursery school, and resulted in approximately 1,200 cases of gastrointestinal distress. In addition, 24 other instances have been identified in which LCSSs failure and ground water contamination may have resulted. While there are surely other examples of LCSS failure across the U.S. beyond these known incidents, the prevalence of contamination cases appears low relative to the prevalence of these systems.

LCSSs are vulnerable to spills because any materials spilled or dumped down sinks, toilets, or floor drains connected to the sanitary waste system can enter the septic tank. Examples of the materials that may enter LCSSs include household cleaning products and wastes (e.g., cleaning solvents and spent solutions) that were either intentionally or accidentally spilled as well as chemicals dumped illicitly (e.g., waste oil). Once in the LCSS, these materials are not necessarily treated by the system and may be released to ground waters that may serve as USDWs. USDWs may also be vulnerable due to the large numbers of LCSSs operating nationwide. While the incremental effect associated with spills at each LCSS may be small, aggregating each of these spills may provide evidence of a broader contamination problem for USDWs.

According to anecdotal evidence, LCSSs are believed to be a frequently used onsite wastewater disposal option. Yet, until this study constructed the inventory model to estimate total numbers of LCSSs nationwide, no quantitative information on system prevalence was available. As discussed in Section 3.3, the inventory model estimated 353,400 LCSSs in the nation; with a 95 percent prediction interval, the range is 304,100 to 402,600.

In the future, the total number of systems is expected to increase as the population increases. USEPA found that construction and use of LCSSs will continue in areas where geological conditions are favorable and sewerage is not readily available or economically feasible. In addition, these systems will continue to be constructed because using LCSSs is an accepted and economically attractive practice. While some states are now encouraging owners of large systems to connect to municipal sewers (when such connections become available), there do not seem to be any states planning to ban LCSSs entirely.

USEPA also found that there are no consistent state definitions of regulations for LCSSs. While the 20 persons-per-day criterion is used to define systems subject to federal UIC regulation, states generally characterize large systems using flow definitions that range from 2,000 to 20,000 gallons-per-day (gpd). Regulation of LCSSs is also highly variable across states. Some states have stringent requirements for large systems. For example, Massachusetts and Minnesota both use 10,000 gpd as the cutoff for large systems and have strict requirements for siting, construction, and operation. Other states only require general construction permitting. For example, New Jersey and Iowa both use a 2,000 gpd threshold for large systems but only require that such systems meet specific construction standards. In addition, LCSSs may be regulated by local regulations that focus on enforcing state and/or county building and health ordinances.

## 2. INTRODUCTION

This volume focuses on LCSSs, which serve 20 or more individual users per day and receive, treat, and dispose of only sanitary waste (which includes wastewaters from kitchens, clothes washing machines, bathrooms, floor washing, etc.). For the most part, these systems are comprised of a septic tank and a subsurface fluid distribution system, such as a leachfield. However, for the purposes of this study, the LCSS category includes a variety of other septic system configurations, some of which are no longer commonly accepted by experts in the field as “best management practices” (e.g., seepage pits). These outdated septic system configurations are addressed in this volume because they are still in use at many locations across the U.S., even though they are no longer considered best management practice. In addition, large-capacity rapid filtration systems (i.e., septic systems where wastewater is applied to shallow basins in moderately to highly permeable soils) are also considered within the scope of this volume. While the construction specifications of most septic systems may not precisely fit the definition of a “well” as specified in 40 CFR §144.3 (“well means a bored, drilled, or driven shaft, or dug hole, whose depth is greater than the largest surface dimension”), LCSSs are within the scope of the federal UIC program.

In particular, “any septic tank ... or other well used by a multiple dwelling, community, or Regional system for the injection of wastes” is specifically included among the types of injection activities covered by the federal UIC regulations (see 40 CFR §144.1(g)(1)). Likewise, the existing UIC regulations in 40 CFR §146.5(e)(9) define Class V wells to include “septic system wells used to inject the waste or effluent from a multiple dwelling, business establishment, community or regional business establishment septic tank.” The regulations add that the “UIC requirements do not apply to single family residential septic system wells, nor to non-residential systems which are used solely for the disposal of sanitary waste and have the capacity to serve fewer than 20 persons a day.”

**What is a LCSS?**

As defined in the federal UIC program, large-capacity septic systems (LCSSs) are septic systems serving 20 or more persons per day and that are designed to receive, treat, and dispose of solely sanitary wastes. This size threshold is different than the flow definition (i.e., gallons per day) typically used by states.

Examples of LCSSs include systems serving industrial and commercial facilities, clusters of homes, apartment complexes, motels, churches, day care centers, schools, hospitals, casinos, and

The basis for this regulatory authority comes from the Safe Drinking Water Act (SDWA), in which Congress acknowledged that septic systems (regardless of the size and capacity of the system) pose risks to USDWs if improperly sited, managed, or operated. Congress, however, chose to differentiate between small and large-capacity septic systems because it believed that the larger volume of sanitary waste (and potentially wider range of contaminants) being disposed of in LCSSs posed sufficient risk to warrant special consideration. Special consideration was also warranted because LCSSs were typically designed and constructed as if they were only larger-scale individual septic systems, and often times, insufficient attention was paid to the impact of increased influent and effluent flow volumes on the operation and maintenance of these larger-scale systems. It should be noted, that State of Idaho staff found this to be true after many early community systems, which had been based on designs for individual systems, experienced hydraulic failure (Burnell, 1992). (System failure is defined as the direct or rapid movement of effluent from the soil absorption system to the saturated zone.)

Although most states, trade associations, and other organizations agree that there are important differences between small-scale and large-capacity septic systems, the threshold for determining which septic system is a LCSS is still debated by many. For example, many organizations commenting on Class V UIC revisions proposed on August 28, 1995 (60 FR 44652) suggested that the differentiation between large and small septic systems be based on wastewater flow rate or septic tank size. This definition would be similar to those established by many of the states (NSFC, 1997). These commenters believed that such a distinction would be more easily determined, and therefore more consistently applied, than the current 20 persons-a-day distinction.[1] Similar public comments were received on Class V UIC regulatory revisions proposed again on July 29, 1998 (63 FR 40586).

In addition, many states now recognize that LCSSs are different than small, individual home systems and these states have changed their UIC regulations or other state regulations governing septic systems to reflect this realization (NSFC, 1995a). However, the specific definition of a LCSS still varies significantly among states. Many states currently define LCSSs by a flow volume threshold, while others do not differentiate between small and large systems in their regulations. In states that do differentiate between small and large systems, the threshold for defining LCSSs varies significantly (USEPA, 1997b). For example:

- Oregon specifies minimum design standards applicable to any system that receives more than 2,500 gpd (OR Final Regulations, No date).

- Massachusetts has specific requirements for systems with flows greater than 2,000 gpd and stipulates additional requirements for any system that is used by more than one building or dwelling (MA Final Regulations, No date).

- Minnesota requires a state disposal system permit for any single or group sewage treatment system designed to treat an average daily flow greater than 10,000 gpd (MN Final Regulations, No date).

- Washington requires a waste discharge permit for septic systems with design capacities over 14,500 gpd (WA Final Regulations, No date).

The issue regarding which metric is most appropriate for distinguishing between small-scale and large-capacity septic systems has not yet been decided. USEPA will continue to evaluate this issue, along with other information presented in this volume, in the context of future rulemaking decisions for LCSSs.

Lastly, it is important to highlight what is not within the scope of this volume. Any septic system disposing solely of sanitary wastes but serving fewer than 20 individuals is not considered. In addition, septic tanks and leachfields (or other similar configurations) that are used by commercial or industrial establishments to dispose of wastes other than sanitary waste are not considered LCSSs. For example, any system serving 20 or more individuals that is used to dispose of industrial wastes is considered an "industrial well," and is not covered here. Similarly, systems receiving waste fluids from motor vehicle repair or maintenance activities are considered "motor vehicle waste disposal wells" and are not within the scope of this volume. This volume also does not consider cesspools, which receive raw sanitary waste without first passing through a septic tank.

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[1] Alyeska, 1995; American Gas Association, 1995; Department of Health and Human Services, 1995; Florida DEP, 1995; Hawaii DoH, 1995; Mississippi DEQ, 1995; Monsanto, 1995; Ohio EPA, 1995; Santa Clara Valley Water District, 1995; South Dakota DoNR, 1995; Texas Chemical Council, 1995; U.S. DoE, 1995; Washington Department of Ecology, 1995; Washington DoH, 1995; Westinghouse, 1995; Wyoming DEQ, 1995.

# 3. PREVALENCE OF WELLS

USEPA used three different methods to determine the number and patterns of use of LCSSs across the nation. First, a comprehensive review of existing literature was performed in order to examine historical data. Next, USEPA obtained state-specific data on LCSS usage through a survey of state and USEPA Regional programs that administer the UIC program. Finally, site surveys of designated census tracts across the country were performed in an effort to count LCSSs and model their numbers at a national level. Since existing state inventories may underestimate the actual number of LCSSs, the modeling effort was designed to provide a more accurate national picture of the prevalence of LCSSs. Discussion of these efforts and their findings follow.

## 3.1 Literature Search Findings

USEPA gathered many studies on LCSSs from a variety of sources, including federal, state, and local governments, universities, research institutes, and private companies. Five of these studies had information particularly relevant to the prevalence of LCSSs, although some of these studies are rather old and may not reflect today's conditions.

In the first of these studies, Canter (1987) found that, "intensive septic tank usage occurs in the east and southeast as well as the northern tier and northwest portions of the United States." The second study was conducted in Florida to determine the number of large-volume septic tank systems in the state. Large-volume was defined as those serving 20 or more people, having a daily flow of 1,000 gallons or more, or having a 1,650-gallon or larger tank. Data on the number of large systems and total systems were collected for each of the five counties selected as representative of the different population sizes and geographic locations. Then, the percentage of total systems that were large systems was applied to the other 62 counties to get an estimate of 42,886 LCSSs in the state. The author notes that this number is greater than the number of systems USEPA previously estimated to exist nationwide. According to the study, large systems tend to be found in coastal areas with moderate-to-high populations (Sherman, 1994).

In the third study, Snyder et al. (1994) examined septic systems located outside of Portland, Oregon and found that most septic systems consisted of a septic tank that discharged effluent to a cesspool. In 1985, there were about 2,571 of these commercial onsite wastewater disposal systems in a 39 square mile area east of Portland, Oregon (mid-Multnomah County area). This averages 66 systems per square mile; however, a sewering project in the area aims to eliminate all onsite systems by 2003. Another densely populated and unsewered area in the metropolitan area outside of Portland (southwestern Clark County) was estimated to contain 556 commercial onsite systems in 1985.

In the fourth study, Knape (1984) presented the results of an effort to identify large sewage disposal wells in Texas. In this study, large sewage disposal wells were defined as bored or dug holes in which the depth exceeds the diameter, and which are used for disposal of water-borne human wastes or effluent resulting from partial treatment of these wastes (i.e., via septic tanks) (Knape, 1984). This definition includes both Class V septic systems and Class V cesspools. Most of the 66 to 72 systems identified in the study are Class V septic systems; however, the exact number is unclear.

Finally, according to a 1980 report for the Federal Highway Administration (FHWA), septic tank systems were used for wastewater treatment at approximately 50 percent of the nation's 422 roadside rest areas. The FHWA noted that rest area septic tank systems are sized to handle up to 15,000 gpd (FHWA, 1980). In 1998, the FHWA indicated that the total number of rest areas along the U.S. Interstate system had increased to approximately 1,500 (ICF, 1998b). The FHWA, however, was unable to provide an estimate for how many of these rest areas have LCSSs or recreational vehicle (RV) dump stations that were serviced by septic tanks.

### 3.2 General Data Collection

For this study, data on the number of Class V LCSSs were collected through a survey of state and USEPA Regional UIC Programs. The survey methods are summarized in Section 4 of Volume 1 of the Class V Study.

USEPA found that because local officials document many LCSSs, states do not have accurate estimates of LCSSs. Many state officials responded to their uncertainty by over-estimating the numbers of LCSSs in their state. Estimation efforts are further complicated because the definition of LCSSs varies among states.[2] Based on state respondents' information, approximately 43,000 LCSSs can be documented but approximately 132,000 LCSSs are believed to exist nationwide. Table 1 lists the number of Class V LCSSs in each state, as determined from this survey. The table includes the documented number and estimated number of LCSSs in each state, along with the source and basis for any estimate, when noted by the survey respondents. If a state is not listed in Table 1, it means that the UIC Program responsible for that state indicated in its survey response that it did not have any Class V LCSSs.

### 3.3 Inventory Model

Because the accuracy of state inventories was found to be inadequate, USEPA constructed a model to estimate the number of LCSSs nationwide. Estimates were based on geologic, demographic, and other characteristics of a sample of census tracts. USEPA made assumptions based on geologic and demographic variables to choose the specific census tracts to include in this sample. For example, areas with very high population and housing density were thought less likely to contain septic systems (i.e., likely served by sanitary sewer systems).

Using these variables, USEPA chose 99 census tracts across the nation with varying geologic and demographic characteristics as representative of a national sample. Data were then gathered through site surveys in each tract and used to model the number of LCSSs nationwide. Overall, LCSSs were found in 88.9 percent of the tracts visited. LCSSs were less likely to be found in large, sewered urban areas and were more likely to be found in areas such as small towns and unincorporated developments where

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[2] As discussed in Section 2, many states use a flow volume threshold to define their large-capacity systems, which may vary from 1,000 to 20,000 gpd. The different definitions presented problems with how to correlate the federal definition of a large-capacity septic system with the various state definitions for inventory purposes.

access to sewers was impractical or costly. Geological variables were not good predictors of system existence. Septic systems were found in a wide variety of areas, with the largest percentage of systems located at churches (23 percent), commercial areas (15 percent), and restaurants (10 percent).

The model estimated the number of LCSSs using an equation with the following variables: households on septic systems; households per square mile in a tract; and percentage of the tract with poor soil drainage. The model estimated 353,400 LCSSs in the nation; with a 95 percent prediction interval, the range is 304,100 to 402,600. See Section 5 of Volume 1 of the Class V Study and Appendix C of the Class V Study for a complete description of the development and results of the statistical inventory model.

## Table 1. Inventory of Large-capacity Septic Systems in the U.S.

| State | Documented Number of Wells | Estimated Number of Wells | |
|---|---|---|---|
| | | Number | Source of Estimate and Methodology[1] |
| **USEPA Region 1** | | | |
| CT | 300 | 500-600 | Best professional judgement. |
| MA | Unknown | 800-1,000 | Best professional judgement. Systems with flows greater than 15,000 gpd are classified as sewage treatment effluent wells. |
| ME | 440 | NR | N/A |
| NH | 28,218 | 28,218 | N/A |
| RI | 90 | 90 | N/A |
| VT | 191 | > 1,000 | Best professional judgement. |
| **USEPA Region 2** | | | |
| NJ | 509 | NR | N/A |
| NY | 13 (NYSDEC and USEPA Region 2) | 5,000 (NYSDEC)<br>10,000 (USEPA Region 2) | Based on inspections and reviews of business directories. |
| PR | 634 | NR | N/A |
| VI | 0 | 500 | USEPA Region estimate based on review of inspection reports and business directory. |
| **USEPA Region 3** | | | |
| DE | 60 | 60 | N/A |
| MD | 32 | 3,450 | Best professional judgement based on limited survey data; 150 systems in each of 23 counties. |
| PA | 20 | > 20 | Best professional judgement. State believes a few more wells may exist. |
| WV | 717 | > 717 | Best professional judgement. |
| **USEPA Region 4** | | | |
| FL | Unknown | > 42,886 | Based on survey done in conjunction with *Class V Sewage Disposal System Research in the State of Florida*. (See Section 3.1.) |
| GA | 4 | >4 | No estimate provided, but state suspects that more wells may exist. |

## Table 1. Inventory of Large-capacity Septic Systems in the U.S. (continued)

| State | Documented Number of Wells | Estimated Number of Wells | |
|---|---|---|---|
| | | Number | Source of Estimate and Methodology[1] |
| MS | 430 | 2,050 | Best professional judgement; 25 systems in each of 82 counties. |
| SC | 814 | 814 | N/A |
| TN | 157 | NR | N/A |
| **USEPA Region 5** | | | |
| IL | 903 | 1,020 | Best professional judgement; 10 systems in each of 102 counties. |
| IN | 33 | NR | State cannot estimate because information is in paper files and DOH does not have resources to go through the files. |
| MI | 4 | NR | N/A |
| MN | 26 | 2,000-2,500 | Estimate based on systems documented in the food, beverage, and lodging program (tracking restaurants and hotels) and best professional judgement (state does not keep records of systems at other facilities). |
| OH | 389 | 5,000-21,000 | Assuming 200 permits issued in each of 25 years. This would equal 5,000 in addition to the 1997 inventory. An early 1990s average estimate for each district adds up to 21,000. |
| WI | 186 | 600 | N/A |
| **USEPA Region 6** | | | |
| NM | 228 | 228 | N/A |
| OK | 84 | 84 | N/A |
| TX | 545 | 545 | Based on database. |
| **USEPA Region 7** | | | |
| IA | 3 | >50-100 | USEPA Region 7 estimate based on requirement that all septic systems serving more than 25 people be permitted (this estimate does not include systems serving 20 to 25 people). |
| KS | 76 | Several hundred | Best professional judgement. |
| MO | 2,053 | 3,000 | Conservative estimate using best professional judgement based on number of systems that have not yet been inspected and inventoried. |
| NE | 356 | 356 | N/A |
| **USEPA Region 8** | | | |
| CO | 1 | NR | N/A |

## Table 1. Inventory of Large-capacity Septic Systems in the U.S. (continued)

| State | Documented Number of Wells | Estimated Number of Wells | |
|---|---|---|---|
| | | Number | Source of Estimate and Methodology[1] |
| MT | 0 | NR | USEPA Region and state do not track systems serving more than 20 people and thus cannot estimate. |
| ND | 289 | 350 | Best professional judgement and assuming that there are 20% more facilities than are documented. |
| UT | 120 | $120 | State personnel asked owners/operators whether their system(s) serves more than 20 people per day. |
| WY | 575 | >575 | No estimate provided, but state suspects actual number is higher than the number documented. |
| **USEPA Region 9** | | | |
| AZ | Unknown | Several hundred | Best professional judgement. |
| CA | 1,907 (USEPA Region 9)/<br>754 (counties) | 1,907 (USEPA Region 9)/<br>±3,587 (counties) | N/A (USEPA Region 9). Best professional judgement (counties). |
| HI | 1 | >1 | No estimate provided, but state suspects more may exist. |
| NV | 87 | >87 | No estimate provided, but state suspects more may exist. |
| **USEPA Region 10** | | | |
| AK | 2,123 | 2,123 | N/A |
| ID | 0 | 75 | USEPA Region 10 estimate based on conversation with state personnel. |
| OR | 200 | 500 | USEPA Region 10 estimate based on conversation with state personnel. Also, UIC staff estimates and UIC database. |
| WA | 445 | 1,000 | USEPA Region 10 estimate based on conversation with state personnel. |
| **All USEPA Regions** | | | |
| All states | 43,263 | ±131,638 | Total estimated number counts the documented number when estimate is NR. For the purpose of the estimated total, the "several hundred" reported in KS and AZ was assumed to be 300. |

[1] Unless otherwise noted, the best professional judgement is that of the state or USEPA Regional staff completing the survey questionnaire.

| | |
|---|---|
| N/A | Not available. |
| NR | Although USEPA Regional, state and/or Territorial officials reported the presence of the well type, the number of wells was not reported, or the questionnaire was not returned. |
| Unknown | Questionnaire completed, but number of wells is unknown. |

### 3.4 Factors Affecting the Use and Prevalence of LCSSs

Although the model did not show that geological variables were good predictors, soil conditions are believed to affect the use of LCSSs. Many soil types are not suitable for septic systems, and extreme geologic variables, such as presence of and depth to bedrock or high water tables, may effectively prohibit their use. Septic systems with drain fields are generally sited in areas containing shallow alluvial aquifers with interbedded layers of gravel, clay, and silt that meet minimum, acceptable percolation rates dictated by local building codes.

LCSSs are less likely to occur in large urban areas where sewers are available and less costly. Consistent with this assumption, housing density in the inventory model was inversely related to the presence of LCSSs. LCSSs are more likely to be found in areas where economic hardship is prevalent -- i.e., poorer areas that do not have infrastructure often use septic systems.

### 3.5 Future Use of LCSSs

In the future, the total number of systems is expected to increase as the population increases. USEPA found that construction and use of LCSSs will continue in areas where geological conditions are favorable and sewerage is not readily available or economically feasible. In addition, these systems will continue to be constructed because using LCSSs is an accepted and economically attractive practice. While some states are now encouraging owners of large systems to connect to municipal sewers (when such connections become available), there do not seem to be any states planning to ban LCSSs entirely.

## 4. WASTEWATER CHARACTERISTICS AND DISPOSAL PRACTICES

### 4.1 Septic Tank Effluent Characteristics

The wastewater of primary interest for this study is “septic tank effluent.” This is defined as the wastewater leaving the septic tank but before it percolates through a soil absorption system (e.g., a leachfield). USEPA defines this as the “point of injection” for the purpose of this study. Therefore, when available, data on the quality of septic tank effluent are presented to account for the settling and other treatment that occurs in the tank. In lieu of these data, however, information on the quality of “raw” or “untreated” sanitary waste – meaning the wastewater before it enters the septic tank – and in a few cases information on the quality of “septic system effluent” – meaning the wastewater that has percolated through a leachfield – is also presented to help characterize the fluids that may be released.

LCSSs are used by a wide variety of establishments, including residential (multi-unit housing) and non-residential (commercial, institutional, and recreational) facilities (MN Pollution Control Agency, 1984). All of these systems receive solely sanitary wastes by definition, and therefore, the types of potential pollutants tend to be similar. However, biological loadings, as well as daily, weekly, or seasonal flows, can vary greatly depending on the establishment served (MN Pollution Control Agency, 1984; USEPA, 1997b). For example, septic tank effluent from a large system serving an elementary school in Canada had higher levels of most constituents than typical household effluent, because the school's waste consisted primarily of blackwater (i.e., toilet waste), with very little dilution by grey water (i.e., wash water) (Harman, 1996). By comparison, septic systems serving restaurants often receive higher concentrations of solids and oils and grease, rather than black or grey water. (Some states require grease traps or other pretreatment methods prior to release to the septic system (USEPA, 1997b) in order to avoid clogging the system's infiltrative surface.)

Despite the variation in the types of establishments served, raw domestic wastewater typically consists of approximately 99.9 percent water (by weight) and 0.03 percent suspended solids. Table 2 differentiates three classes of untreated wastewater (i.e., weak, medium, and strong).

After biodegradation, retention, and clarification in a septic tank, the constituents of the effluent can be categorized into three major groups:

- Inorganics (e.g., nitrogen, phosphorus, sodium, chlorides, potassium, calcium, magnesium, sulfates, and ammonium, which oxidizes to nitrate in aerobic environments).

- Organics (e.g., parameters such as COD, BOD, and constituents such as dichloromethane, toluene, dichlorobenzene, bis(2-ethylhexyl)phthalate, trichloromethane and diethylphthalate) (USEPA, 1997b; Canter and Knox, 1985).

- Microorganisms (e.g., bacteria, viruses, and cysts).

Each of these categories is discussed in more detail below and is based on sampling data collected from more than 25 studies (representing more than 50 sites) conducted between 1974 and 1998.

## Table 2. Typical Composition of Untreated Domestic Wastewater

| Contaminants | Units | Concentrations | | |
|---|---|---|---|---|
| | | **Weak** | **Medium** | **Strong** |
| Biological Oxygen Demand (BOD), at 5-day, 20 degrees C | mg/l | 110 | 220 | 400 |
| Chemical Oxygen Demand (COD) | mg/l | 250 | 500 | 1,000 |
| Total Organic Carbon (TOC) | mg/l | 80 | 160 | 290 |
| Total Solids (TS) | mg/l | 350 | 720 | 1,200 |
| Total Dissolved Solids (TDS) | mg/l | 250 | 500 | 850 |
| Fixed | mg/l | 145 | 300 | 525 |
| Volatile | mg/l | 105 | 200 | 325 |
| Total Suspended Solids (TSS) | mg/l | 100 | 220 | 350 |
| Fixed | mg/l | 20 | 55 | 75 |
| Volatile | mg/l | 80 | 165 | 275 |
| Settleable solids | ml/l | 5 | 10 | 20 |
| Total Nitrogen (N) | mg/l | 20 | 40 | 85 |
| Organic N | mg/l | 8 | 15 | 35 |
| Free Ammonia ($NH_3$) | mg/l | 12 | 25 | 50 |
| Nitrate ($NO_3$) | mg/l | 0 | 0 | 0 |
| Nitrite ($NO_{2-}$) | mg/l | 0 | 0 | 0 |
| Total Phosphorous (TP) | mg/l | 4 | 8 | 15 |
| Organic | mg/l | 1 | 3 | 5 |
| Inorganic | mg/l | 3 | 5 | 10 |
| Alkalinity ($CaCO_3$) | mg/l | 50 | 100 | 200 |
| Chloride | mg/l | 30 | 50 | 100 |
| Sulfate | mg/l | 20 | 30 | 50 |
| Grease | mg/l | 50 | 100 | 200 |
| Total Coliform | #/100 ml | $10^6$-$10^7$ | $10^7$-$10^8$ | $10^8$-$10^9$ |
| Fecal Coliform | #/100 ml | – | $10^5$-$10^6$ | -- |
| Volatile Organic Compounds (VOCs) | mg/l | < 0.1 | 0.1 - 0.4 | > 0.4 |

Source: Metcalf and Eddy, 1991.

### 4.1.1 Inorganic Constituents

*Nitrogen*

While a wide range of inorganic constituents are potentially present in septic tank effluent, nitrogen poses the most significant threat of environmental degradation. Septic tank effluent contains a substantial quantity of nitrogen in the forms of ammonium and organic matter nitrogen. These nitrogen compounds are likely to oxidize to nitrate in unsaturated soils. Nitrate has long been recognized as a significant threat to ground water (USEPA, 1987). Nitrate from septic systems has been the subject of many studies, and is considered to be one of the most problematic contaminants in septic system effluent. The results of several LCSS sampling events found that septic tank effluent contained nitrates, nitrites, and total Kjeldahl nitrogen, as well as phosphorous, at the levels shown in Table 3.

**Table 3. Summary of Inorganic Wastewater Constituents for LCSSs**

| **Sites** | | **Total Nitrogen (mg/l)** | **Ammonium (mg/l)** | **Nitrate (mg/l)** | **Total Phosphorous (mg/l)** | **Flow (Lpcd)[1]** |
|---|---|---|---|---|---|---|
| Multiple Homes[2] | Westboro, WI | 57 | 44 | 6.4 | 8.1 | 136 |
| | Bend, OR | 41 | -- | -- | -- | 151 - 227 |
| | Glide, OR | 50 | 32 | 0.5 | -- | 182 |
| | Manila, CA | -- | -- | -- | -- | 151 - 216 |
| | College Station, TX | 29.5 | 24.7 | 0.2 | 8.2 | -- |
| Washington Multiple Home Systems[3] | Harbor County | 49 | -- | -- | 11.1 | 7,000 |
| | Nesika Bay | 33 | -- | -- | 10.3 | 1,375 |
| | Tolmie Park+ | 21 | -- | -- | 5.2 | 4,260 |
| | Farwell Estates | 25 | 23 | -- | 10.4 | 2,320 |
| | Galen Park | 28 | 25 | -- | 13.4 | 2,360 |
| | Riegel Heights | 33 | 31 | -- | 11.9 | 1,840 |
| Indian Casinos in Oregon and Washington[4] | Site 1 | 12.3 | 1 | 8.1 | -- | -- |
| | Site 2 | 130 | 65 | < 1.0 | -- | -- |
| Average | | 42.4 | 30.7 | 3.2 | 9.8 | 1977.5 |

[1] Lpcd is defined as liters per capita day.

[2] Adapted from Siegrist et al., 1983.

[3] Adapted from Siegrist et al., 1983.

Nitrogen compounds will usually oxidize to nitrate in the soil through the process of biological nitrification. This process often takes place in the aerobic environment just below the clogging mat of the soil absorption system. After organic nitrogen or ammonium has been oxidized to nitrate, denitrification, the process by which nitrate is converted to nitrogen gas or nitrous oxide, may also occur. This process requires an anaerobic environment, which may be found deeper in the soil, along with a supply of labile (unstable) organic carbon to act as an electron donor (Robertson and Cherry, 1995). Soil characteristics, such as texture and structure, will primarily influence the availability of oxygen in the subsurface, and therefore, the amount of denitrification that is likely to occur (Wall, 1991). Some studies have found that ground water in areas where properly operating septic systems were underlain by poorly drained soils had much lower nitrate concentrations than in comparable areas with well drained soils (Ritter and Churnside, 1984; Miller, 1972). Permeable soils immediately below a soil absorption system with poorly drained soils in the lower soil horizons would optimize conditions for reducing nitrate concentrations. With sufficient soil organic matter and available carbon, the denitrification process in the soil beneath septic systems can remove up to 90 percent of the nitrate from the wastewater (Eastburn and Ritter, 1984).

However, in an optimally functioning conventional soil absorption system with well drained soils, minimal denitrification can be expected, because aerobic (not anaerobic) conditions persist. This situation maximizes nitrification and minimizes denitrification (Reneau et al., 1989). There are several alternative systems designed to create conditions favorable for denitrification, because such conditions do not frequently occur naturally. Refer to Section 6.5.4 of this document for a more detailed discussion of denitrification systems.

Nitrate that is not denitrified will not adsorb because of its negative charge and will easily percolate to ground water (USEPA, 1992). Optimally designed and constructed septic systems depend on dilution of the effluent by ground water to reduce the concentration of nitrate to safe levels in the receiving aquifer. When effluent inputs to the receiving aquifer exceed that aquifer's maximum sustainable loading rate, ground water nitrate concentrations will exceed regulated limits (Bauman and Schafer, 1984). LCSSs, as a result of their high effluent flow rates, pose a greater threat to ground water by nitrate contamination when compared to small individual systems. The 1987 Class V UIC Report to Congress (RTC) states that cases of ground water contamination from, "nitrates produced by septic tank effluent are widespread throughout the nation" (USEPA, 1987). However, with proper siting, design and construction, and operation and maintenance, USEPA believes that septic systems are an effective, low-cost alternative for domestic waste management (USEPA, 1986).

### *Phosphorus*

Phosphorous is a nutrient commonly found in septic tank effluent. In contrast to nitrate, phosphorus is readily removed by interaction with soils and does not pose a significant threat to USDWs under optimal septic system operating conditions (USEPA, 1987).

Phosphorus, generally in the form of phosphates, is removed by adsorption or precipitation processes including physical adsorption, chemisorption, anion exchange, surface precipitation, and precipitation as separate solid phases (Reneau et al., 1989; Canter and Knox, 1984). Precipitation is the primary mechanism of phosphorus removal at the relatively high concentrations found in effluent. Precipitation depends on factors such as pH; concentrations of iron, aluminum, and calcium; competing anions; and reaction time. In acidic soils, phosphorus forms compounds with iron and aluminum, while in calcareous soils, phosphorus forms compounds with calcium. While these mechanisms effectively attenuate phosphorus in most soils, recent studies indicate that the attenuation potential of some soils may decline over long periods of time (Harman et al., 1996). This situation could increase phosphorus mobility and pose a contamination threat to ground water and nearby surface waters.

### *Other Inorganics*

Chloride, sulfate, sodium, potassium, and calcium are often found in septic tank effluent at concentrations significantly above background levels. These ions can contaminate USDWs if released at sufficiently high concentrations (USEPA, 1987). These contaminants are not considered to be harmful to human health unless consumed in great quantities (as discussed in Appendix D to the UIC Class V Study). In addition to these constituents, low levels of trace metals are also present in septic tank effluent.

Tables 4a and 4b demonstrate the interaction between tape water treatment (i.e., to make raw water drinkable) and trace metal and mineral concentrations in septic tank effluent, respectively. Table 4a highlights how the concentrations of select minerals in wastewater may increase after use. Table 4b presents the results of recent sampling conducted at LCSSs at Indian Casinos in Oregon and Washington (ICF, 1998a). However, many of the constituents noted in Tables 4a and 4b are either naturally present in untreated tap water or are added to untreated tap water as part of the treatment process.

Under optimal operating conditions, cations such as sodium, potassium, and calcium are attenuated by soils in significant quantities as a result of exchange reactions within the soil matrix. Their presence in a receiving aquifer will be limited provided unsaturated flow conditions prevail in the soil adsorption system.

Anions such as chloride and sulfate will behave similarly to nitrate in most soils. Because of their negative charge, they tend to pass readily through the soil matrix into the receiving aquifer even in unsaturated conditions.

## Table 4a. Typical Mineral Concentration Increases, Compared to Domestic Water Supplies (mg/l)

| Constituent | Range | |
|---|---|---|
| | Septic Tank Effluent | Municipal Wastewater |
| Anions | | |
| Bicarbonate | 100 - 200 | 50 - 100 |
| Carbonate | 2 - 20 | 0 - 10 |
| Chloride | 40 - 100 | 20 - 50 |
| Sulfate | 30 -60 | 15 - 30 |
| Cations | | |
| Calcium | 10 - 20 | 6 - 16 |
| Magnesium | 8 - 16 | 4 - 10 |
| Potassium | 10 - 20 | 7 - 15 |
| Sodium | 60 - 100 | 40 - 70 |
| Other Constituents | | |
| Aluminum | 0.2 - 0.3 | 0.1 - 0.2 |
| Boron | 0.1 - 0.4 | 0.1 - 0.4 |
| Fluoride | 0.2 - 0.4 | 0.2 - 0.4 |
| Manganese | 0.2 - 0.4 | 0.2 - 0.4 |
| Silica | 2 - 10 | 2 - 10 |
| Total Alkalinity | 60 - 120 | 60 - 120 |
| Total Dissolved Solids | 200 - 400 | 150 - 380 |

Source: Adapted from Crites and Tchobanoglous, 1998.

## Table 4b. Comparison of Analytical Results Characterizing Tap Water, Grey Water, and Effluent from Septic Tanks at Two Indian Casinos in Oregon and Washington[1] (mg/l)

| Parameters | Tap Water[2] | Average Grey Water[2] | Site #1 | Site #2 |
|---|---|---|---|---|
| Alkalinity, Total as CaC03 | -- | -- | 78 | 420 |
| Aluminum | -- | -- | 0.056 | 6.8 |
| Antimony | -- | -- | < 0.006 | < 0.06 |
| Arsenic | < 0.01 | < 0.01 | < 0.005 | < 0.005 |
| Barium | < 1 | < 1 | 0.031 | 1.7 |
| Beryllium | -- | -- | < 0.001 | < 0.01 |
| Cadmium | < 0.01 | < 0.01 | < 0.001 | < 0.02 |
| Calcium | -- | -- | 21 | 66 |
| Carb. Alkalinity (CO3) | -- | -- | < 2 | < 2 |
| Chloride | -- | -- | 39 | 69 |
| Chromium | < 0.05 | < 0.05 | 0.003 | 0.018 |

## Table 4b. Comparison of Analytical Results Characterizing Tap Water, Grey Water, and Effluent from Septic Tanks at Two Indian Casinos in Oregon and Washington[1] (mg/l)

| Parameters | Tap Water[2] | Average Grey Water[2] | Site #1 | Site #2 |
|---|---|---|---|---|
| Cobalt | -- | -- | < 0.005 | < 0.05 |
| Copper | 0.08 | 0.17 | 0.033 | 0.74 |
| Iron | 0.18 | 0.46 | 0.16 | 2.4 |
| Lead | < 0.01 | 0.03 | < 0.005 | < 0.05 |
| Magnesium | -- | -- | 7.8 | 5 |
| Manganese | < 0.05 | < 0.05 | 0.062 | 0.045 |
| Mercury | -- | -- | < 0.0002 | 0.0005 |
| Nickel | < 0.05 | < 0.05 | 0.012 | < 0.02 |
| Potassium | -- | -- | 16 | 25 |
| Selenium | < 0.01 | < 0.01 | < 0.005 | < 0.005 |
| Silver | < 0.05 | < 0.05 | < 0.001 | < 0.01 |
| Sodium | 8 | 75 | 52 | 85 |
| Sulfate (SO4) | -- | -- | 32 | 14 |
| Thallium | -- | -- | < 0.02 | < 0.2 |
| Total Phosphate as P | -- | -- | 12 | 36 |
| Vanadium | -- | -- | < 0.005 | < 0.05 |
| Zinc | 0.39 | 0.45 | 0.016 | 1.3 |

Source: [1] Adapted from ICF, 1998a.
[2] Adapted from Tyler et al., 1977.

### 4.1.2 Organic Constituents

The primary purpose of a septic tank is to reduce both the solids and organic carbon content of sanitary waste (through facultative and anaerobic decomposition in the bottom of the septic tank). It does this before releasing the effluent to the drainage field. If the system has been properly operated and maintained (and receiving only sanitary waste), then the effluent is likely to contain low levels of organic constituents. Table 5 summarizes data on the level of organic constituents both as septic tank influent and effluent for several sites, not all of which are known to be LCSSs. Table 6 presents data only on organic constituents, as measured by $BOD_5$, COD, and total oil and grease.

## Table 5. Comparison of Septic Tank Influent and Effluent Characteristics

| Source (effluent compartment) | Influent (Raw Domestic Sewage) | | | | | Effluent (Unfiltered from Tank) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Flow (Lpcd)[1] | BOD (mg/l) | TSS (mg/l) | Grease (mg/l) | pH | BOD (mg/l) | TSS (mg/l) | Grease (mg/l) | pH |
| Kreissl | 242 | 435 | 380 | 65 | -- | 218 | 114 | -- | -- |
| Lawrence Home1 | 117 | 241 | 200 | 21 | 7.5 | 224 | 130 | -- | -- |
| Lawrence Home2 | 185 | 146 | 126 | 16 | 7.2 | 124 | 70 | 8.5 | 7.2 |
| Otis et al. | 0 | 233 | 269 | -- | -- | 128 | 50 | -- | -- |
| U. Wisconsin | 0 | 343 | 259 | -- | -- | 158 | 51 | -- | -- |
| Bennett, ASAE | 168 | 278 | 396 | -- | 7.4 | 134 | -- | -- | -- |
| Ziebell, 1974 | 0 | 343 | 259 | -- | -- | 158 | 51 | -- | -- |
| Watson et al. Home1 | 295 | 542 | 363 | 95 | 8 | -- | -- | -- | -- |
| Watson et al. Home2 | 250 | 284 | 293 | 33 | 8 | -- | -- | -- | -- |
| Watson et al. Home3 | 91 | 479 | 473 | 66 | 8.3 | -- | -- | -- | -- |
| Watson et al. Home1 | 269 | 518 | 478 | 134 | 7.6 | -- | -- | -- | -- |
| Watson et al. Home2 | 193 | 356 | 360 | 41 | 8.2 | -- | -- | -- | -- |
| Watson et al. Home3 | 110 | 598 | 602 | 92 | 8.4 | -- | -- | -- | -- |
| Kreissl | 0 | 490 | 480 | 89 | -- | -- | -- | -- | -- |
| U. Wisconsin | 121 | 415 | 296 | 122 | -- | -- | -- | -- | -- |
| U. Wisconsin | 129 | 465 | 394 | 129 | -- | -- | -- | -- | -- |
| Carcich et al. | 121 | 330 | 310 | 81 | 7.8 | -- | -- | -- | -- |
| Comm. On Rural Water | 220 | 207 | 165 | -- | -- | -- | -- | -- | -- |
| Schmidt (two) | 151 | 400 | -- | -- | -- | 90 | -- | -- | -- |

## Table 5. Comparison of Septic Tank Influent and Effluent Characteristics (continued)

| | **Influent (Raw Domestic Sewage)** | | | | | **Effluent (Unfiltered from Tank)** | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Source (effluent compartment)** | **Flow (Lpcd)**[1] | **BOD (mg/l)** | **TSS (mg/l)** | **Grease (mg/l)** | **pH** | **BOD (mg/l)** | **TSS (mg/l)** | **Grease (mg/l)** | **pH** |
| Bounds, 1982-Grinders | 189 | 304 | 226 | 42 | 6.9 | -- | -- | -- | -- |
| Bounds, 1982-Step (one) | 189 | -- | -- | -- | -- | 118 | 52 | 16 | 6.9 |
| Metcalf & Eddy, 3rd. Ed. | 189 | 392 | 436 | 70 | 7.2 | -- | -- | -- | -- |
| PHS 2nd Series | -- | -- | -- | -- | -- | 178 | 111 | -- | 7.4 |
| PHS 3rd Series | -- | -- | -- | -- | -- | 92 | 112 | 19 | 7.5 |
| PHS 4th Series | -- | -- | -- | -- | -- | 151 | 128 | -- | 7.5 |
| Barshied | -- | -- | -- | -- | -- | 223 | 39 | -- | 7.1 |
| Ronayne, 1982 (two) | 208 | -- | -- | -- | -- | 217 | 146 | -- | -- |
| USEPA 1980 Onsite | 167 | -- | -- | -- | -- | 155 | 88 | -- | -- |
| Eastsound, WA--Bounds 1996 | -- | -- | -- | -- | -- | 214 | 117 | -- | – |
| Loon Lake, WA–Bounds 1996 | -- | -- | -- | -- | -- | 90 | 45 | -- | -- |
| Cagle, 1993, Placer CA (two) | -- | -- | -- | -- | -- | 160 | 73 | -- | -- |
| **Average** | **150.2** | **371.4** | **338.3** | **73.1** | **7.7** | **157.3** | **86.1** | **14.5** | 7.3 |

[1] Lpcd is defined as liters per capita day.

Source: Adapted from Bounds, 1997, Table 1 and 2,

## Table 6. Summary of Organic Parameters Data for LCSSs Effluent

| Site | | Biological Oxygen Demand (mg/l)[1] | Chemical Oxygen Demand (mg/l) | Total Solids (mg/l) | Total Suspended Solids (mg/l) | pH | Chloride (mg/l) | EC (umhos/cm) | Grease (mg/l) | Flow (Lpcd)[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| Multiple Homes[4] | Westboro, WI | 168 | 338 | 663 | 85 | 6.9 - 7.4 | 62 | 1,073 | -- | 136 |
| | Bend, OR | 157 | 276 | -- | 36 | 6.4 - 7.2 | -- | -- | 65 | 151-227 |
| | Glide, OR | 118 | 228 | 376 | 52 | 6.4 - 7.2 | -- | -- | 16 | 182 |
| | Manila, CA | 189 | 284 | 355 | 75 | 6.5 - 7.8 | -- | -- | 22 | 151-216 |
| | College Station, TX | -- | 266 | -- | -- | 7.4 | 1.8 | 3,204 | -- | -- |
| Washington Multiple Home Systems[4] | Harbor County | 164 | 359 | -- | 40 | 6.9 - 7.1 | -- | -- | -- | 7,000 |
| | Nesika Bay | 91 | 231 | -- | 34 | 6.8 - 7.1 | -- | -- | -- | 1,375 |
| | Tolmie Park+ | 46 | 102 | -- | 24 | 6.4 - 6.7 | -- | -- | -- | 4,260 |
| | Farwell Estates | 139 | 232 | -- | 34 | -- | -- | -- | -- | 2,320 |
| | Galen Park | 165 | 341 | -- | 102 | -- | -- | -- | -- | 2,360 |
| | Riegel Heights | 87 | 179 | -- | 26 | -- | -- | -- | -- | 1,840 |
| Indian Casinos in Oregon and Washington[5] | Site 1 | < 5 | 34 | -- | -- | -- | -- | -- | < 5 | -- |
| | Site 2[3] | 1,750 | 5,100 | -- | -- | -- | -- | -- | 84 | -- |
| **Average** | | **256.6** | **613.1** | **464.7** | **50.8** | **6.7** | **31.9** | **2,138.5** | **38.4** | **1,977.5** |

[1] BOD at 5-day, 20 degrees Celsius.

[2] Lpcd is defined as liters per capita day.

[3] These levels indicate that the grease trap is being short-circuited as elevated levels of oil and grease were detected in the septic tank effluent. Although the dishwasher flow has been rerouted to just after the grease trap, the distance that the kitchen waste travels prior to entering the grease trap is insufficient to allow the water to cool sufficiently to allow the oil and grease to be captured in the grease trap.

Source: [4] Adapted from Siegrist et al., 1983.
[5] Adapted from ICF, 1998a.

Although common household products contain organic chemicals, these constituents are rarely observed in domestic septic systems at concentrations exceeding regulated levels. The presence and subsequent detection of organic chemicals in septic tank effluent is a function of what organic containing materials are disposed of in the septic system. As discussed in Section 2, the system would be considered a motor vehicle waste disposal well if it receives waste fluids from vehicle repair, and considered an industrial waste disposal well if it receives industrial waste. For example, the system at a funeral home would be considered an industrial waste disposal well if it receives fluids from the embalming process, even if the system was designed as a septic tank and leachfield systems. The seven studies summarized below provide examples of where organic constituents have been observed at low, but detectable, concentrations in non-industrial systems.

In 1995, the National Funeral Home Directors Association (NFDA) conducted a study to gather information regarding the origin, nature, quantity, and fate of funeral home wastewater that was discharged to publicly owned treatment works (NFDA, 1995). The NFDA collected samples from five funeral homes. Separate samples of the total embalming wastewater and samples of 24-hour domestic wastewater flow were collected and analyzed (because the embalming wastewater was kept separate from the sanitary flow, USEPA was able to use the data characterizing the sanitary waste only; had the flow been combined, the data would no longer be representative of sanitary waste from a LCSS as defined in this study). All five samples were analyzed in accordance with established USEPA protocols for the following groups of parameters:

- 44 Volatile Organic Compounds
- 82 Acid/Base/Neutral Organics
- 21 Miscellaneous Organics (identified through the MSDS and literature review but not on the standard lists of analytes, including formaldehyde and various alcohols)

As shown below in Table 7, miscellaneous organic constituents were found only in trace concentrations (i.e., <1 mg/l) in the septic tank.

In principle, sanitary wastewater from funeral homes should be similar to that of conventional sanitary wastewater. However, the presence of formaldehyde and phenol, as shown in Table 7, is indicative of embalming wastes being disposed of in the septic tank and is not representative of typical sanitary waste. (Although the embalming waste was separated from the sanitary flow during sampling, this waste was routinely discharged to the septic tank prior to the study.) In addition, while these data are useful to show what constituents could enter the septic system, they are not representative of the quality of the effluent leaving the septic tank (i.e., some amount of degradation of the constituents will occur inside the septic tank).

### Table 7. Summary of Funeral Home Sanitary Waste[1] Characteristics (mg/l)

| Detected Constituents | Site A | Site B | Site C | Site D | Site E |
|---|---|---|---|---|---|
| Chloroform | 0.003 | 0.026 | 0.005 | 0.003 | 0.017 |
| Dichlorobromomethane | 0.002 | ND | ND | 0.002 | ND |
| Trichloroethylene | ND | 0.003 | ND | ND | ND |
| T-butyl alcohol | ND | 0.016 | ND | ND | 0.011 |
| Phenol | 0.88 | 0.035 | 0.14 | ND | 0.11 |
| Bis 2-ethylhexyl phthalate | 0.005 | 0.018 | ND | ND | ND |
| Diethyl phthalate | 0.008 | ND | ND | ND | ND |
| Di-n-octyl phthalate | ND | 0.003 | ND | ND | ND |
| Formaldehyde | 30 | 26 | 16 | ND | ND |
| 1,4-dichlorobenzene | ND | ND | ND | ND | 0.006 |
| Acetone | ND | ND | ND | ND | 0.006 |

Key: ND - not detected.

[1] The sampled waste was reportedly only sanitary waste separated from embalming fluids or any other wastewater considered an industrial waste. However, these results indicate that the septic tank sampled was contaminated beforehand with embalming waste and that the fluids analyzed may not be representative of solely sanitary waste.

Source: Adapted from NFDA, 1995.

In a study conducted by the Washington State Department of Health and the University of Washington, untreated domestic sewage was found to contain approximately 50 organic chemical compounds in excess of 0.001 mg/l (USEPA, 1987). The study found dichloromethane, toluene, dichlorobenzene, bis-2-ethylhexyl phthalate, and diethyl phthalate to be the most frequently detected synthetic organic compounds. These chemicals can originate from cleaning products, cosmetics, and other chemicals used in homes and businesses. Septic tanks alone, without further treatment, were found to be ineffective in treating these compounds (USEPA, 1987).

In another study, researchers identified trichloroethylene, a cleaning solvent, as one of the most common organic chemicals disposed in septic tanks and found in ground water (Canter and Knox, 1985).

In a fourth study conducted by the Minnesota Pollution Control Agency, cleansers, medical products and ointments, disinfectants, deodorizers, detergents, pesticides, hand soaps, shampoos, polishes, cosmetics, laundry products, textile coatings, paints, and paint/varnish strippers were identified as possible sources of organic chemicals in domestic wastewater. The Minnesota study noted that organic chemical compounds were likely present only at low levels in septic systems (MPCA, 1984).

In the fifth study, USEPA found that benzene, phenol, 2,4,6-trichlorophenol, 2-chlorophenol, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,1,1-trichloroethane, naphthalene, toluene, diethylphthalate, dimethlyphthalate, trichloroethylene, aldrin, and dieldrin can be present in household wastewater in measurable quantities as a result of the disposal of common household products. It was noted that other solvents may also be present depending on the locality and the frequency of product use (USEPA, 1980b). In some cases, particularly where LCSSs are poorly sited, designed and constructed, and operated and maintained, these chemicals may potentially contaminate USDWs.

In a sixth study on the disposal of sanitary wastes from recreational vehicles (RVs) in LCSSs at highway rest areas and parks, researchers determined that significant levels of formaldehyde were being introduced into the septic systems (Brown et al, 1982).[3] Table 8a presents data on RV wastewater characteristics. Specifically, researchers found that the average concentration of formaldehyde in RV wastewater from owners that used formaldehyde-based tank agents was 250 mg/l (standard deviation was 180 mg/l). The researchers also determined that the average concentration of formaldehyde across all RVs (including owners that did not use formaldehyde-based additives) was 170 mg/l (standard deviation of 250 mg/l). To characterize the septic tank effluent, the researchers collected samples of septic tank water from the second and/or third compartments of the LCSS at Wenberg State Park on three separate occasions, one sample from the distribution box just after the LCSS, and one sample from the drainfield. A second drainfield sample was also collected from Dash Point State Park. The results of these sampling events are presented in Table 8b.

Lastly, in 1980, researchers determined that RV blackwater contained on average 280 mg/l of formaldehyde (range of 30 mg/l to 960 mg/l with a standard deviation of 312 mg/l) (FHWA, 1980).

The first five studies highlight what constituents can enter a septic system but do not discuss assumed rates of constituent degradation that occur inside the septic tank. Similarly, the last two studies demonstrate that even when formaldehyde is present in wastewater, some degradation can be anticipated.

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[3] RVs typically employ 40 gallon holding tanks for sanitary waste (blackwater) and shower/cooking water (grey water); black and grey water can either be stored separately or commingled depending on the particular RV. To prevent the formation of offensive odors associated with these materials, RV owners use commercial products that contain chemical additives to inhibit microbial action. RV owners also use these products to aid in breaking down toilet tissue. Often times, these products contain formaldehyde, glutaraldehyde, para-formaldehyde, quaternary based compounds, or phenolic compounds as the active ingredient(s). Over time, newer, “greener” products have been introduced but have yet to capture significant market share, compared to formaldehyde-based products. These newer products rely on non-toxic chemicals such as sodium dodecylbenzenesulfonate, diethanolamine, bronopol, pine oil, bacteria, and/or enzymes (ICF, 1998b).

## Table 8a. Characteristics of RV Wastewater Entering Septic System (mg/l)

| Contaminants | Average Wastewater[1] | Black Wastewater[2,3,4] | Grey Wastewater[3,4] | Treated Wastewater[1] |
|---|---|---|---|---|
| BOD (5-day, 20°C) | 3,110 | 11,770 | 1,870 | 460 - 910 |
| COD | 8,230 | 11,680 - 14,660 | 2,400 - 3,220 | 1,240 - 1,880 |
| Total Solids | -- | 13,140 | 1,790 | -- |
| Total Dissolved Volatile Solids | -- | 9,280 | 1,220 | -- |
| Total Suspended Solids | 3,120 | 4,000 - 7,590 | 600 - 750 | -- |
| Volatile | 2,460 | 6,850 | 670 | -- |
| Organic N | -- | 1,000 | 37 | -- |
| Free Ammonia | -- | 1,000 | 180 | -- |
| Total Phosphorous | -- | 240 | 36 | -- |
| pH | -- | 8 | 7 | -- |
| Grease (ml/l) | -- | 729 | 310 | -- |
| Zinc | -- | 8 - 18 | 1 | -- |
| Phenol | -- | 1 | -- | -- |
| Formaldehyde | -- | 75 - 280 | -- | 5 |
| Flow (Lpcd) | 62 | 49 | 49 | -- |

Lpcd is defined as liters per capita day.

Source:
[1] Brown et al, 1982.
[2] Pearson, F. et al. 1984.
[3] Pearson, F. et al. 1980a.
[4] Pearson, F. et al. 1980b.

## Table 8b. Summary of Septic Tank Effluent Data from LCSSs Receiving Sanitary Wastes from RVs (mg/l)

| Location / Date | COD | $BOD_5$ | Formaldehyde |
|---|---|---|---|
| Wenberg -Vault #2 / 3-10-81 | 2,500 | -- | 5 |
| Wenberg - Vault #2 / 8-20-81 | 2,870 | 1,490 | 6.8 |
| Wenberg - Vault #3 / 8-20-81 | 2,870 | 1,430 | 8.7 |
| Wenberg- Dist. Box / 9-9-81 | 2,310 | 1,360 | 9.2 |
| Wenberg Drainfield / 9-9-81 | 1,240 | 460 | 4.8 |
| Dash Point Drainfield / 9-14-81 | 1,880 | 910 | 6 |
| Average RV Wastewater | 8,230 | 3,100 | 250/170* |
| Average Single Family Home | 300 | 150 | -- |

***** Formaldehyde additives/non-formaldehyde-based additives.

Source: Brown et al., 1982

### 4.1.3 Microbial Constituents

Pathogenic bacteria and viruses that can create health hazards if they reach drinking water supplies are present in any septic system, including LCSSs (USEPA, 1987). Most types of disease-causing microorganisms have been isolated in domestic sewage, including:

- Protozoa (*Giardia lamblia* and others);

C Bacteria (*Salmonella*, *Shigella*, pseudomonas, indicators such as coliform and fecal coliform, and others); and

C Viruses (polio viruses, hepatitis-A, Coxsackie viruses, Norwalk virus, and others).

These microorganisms can cause a variety of illnesses, ranging from diarrhea to typhoid fever. They range in size from relatively large protozoa, which are efficiently removed by filtration during passage through soils, to small viruses, which are capable of moving greater distances through soils under specific improper use conditions (Yates, 1987). The results of recent sampling conducted at two LCSSs at Indian Casinos in Oregon and Washington found that septic tank effluent from both sites contained fecal coliform (indicators of the presence of pathogens) at levels greater than 1,600 MPN/100 ml (ICF, 1998a). Table 9a and 9b present additional information on microbial constituents from septic tanks.

**Table 9a. Microorganism Concentration Found in Septic Tank Effluent and Untreated Wastewater and the Corresponding Infectious Dose**

| Organism | Concentration in Septic Tank Effluent and Raw Wastewater, MPN/100mL [1] | Infectious Dose, Number |
|---|---|---|
| **Bacteria** | | |
| Coliform, total | $10^{7} - 10^{9}$ | -- |
| Coliform, fecal | $10^{6} - 10^{8}$ | $10^{6} - 10^{10}$ [2] |
| *Clostridium perfringens* | $10^{3} - 10^{5}$ | $1 - 10^{10}$ |
| Enterococci | $10^{4} - 10^{5}$ | -- |
| Fecal streptococci | $10^{4} - 10^{6}$ | -- |
| *Pseudomonas aeruginosa* | $10^{3} - 10^{4}$ | -- |
| *Shigella* | $10^{0} - 10^{2}$ | 10 - 20 |
| *Salmonella* | $10^{2} - 10^{4}$ | -- |
| **Protozoa** | | |
| *Crytosporidium parvum* oocysts | $10^{1} - 10^{3}$ | 1 - 10 |
| *Entamoeba histolytica* cysts | $10^{-1} - 10^{1}$ | 10 - 20 |
| *Giardia lamblia* cysts | $10^{3} - 10^{4}$ | <20 |
| **Helminths** | -- | -- |
| Ova | $10^{1} - 10^{3}$ | 1 - 10 |
| *Ascaris lumbricoides* | -- | – |

## Table 9a. Microorganism Concentration Found in Septic Tank Effluent and Untreated Wastewater and the Corresponding Infectious Dose (continued)

| Organism | Concentration in Septic Tank Effluent and Raw Wastewater, MPN/100mL [1] | Infectious Dose, Number |
|---|---|---|
| **Viruses** | | |
| Enteric virus | $10^3$ - $10^4$ | 1 - 10 |
| Colliphage | $10^3$ - $10^4$ | -- |

[1] Most probable number per 100 mL, a statistical estimate of concentration.

[2] *Escherichia coli* (enteropathogenic).

Source: Adapted from Crites and Tchobanoglous, 1998.

## Table 9b. Bacteria Data From Five Septic Tanks

| Bacteria (per 100 mL) | Mean (Samples) | 95 Percent Confidence Interval of Mean | Range |
|---|---|---|---|
| Fecal streptococci | 3,800 (97) | 2,000 - 7,200 | <100 - 1,000,000 |
| Fecal coliforms | 420,000 (94) | 290,000 - 620000 | 500 - 18,000,000 |
| Total coliforms | 3,400,000 (91) | 2,600,000 - 4,400,000 | 150,000 - 40,000,000 |
| *Pseudomonas aeruginosa* | 10,000 (13) | 1,900 - 54,000 | 210 - 350,000 |
| Total bacteria (x $10^5$ per mL) | 34 (88) | 25 - 48 | 0.3 - 2,300 |
| pH | 7.3 (58) | 7.2 - 7.4 | 6.4 - 8.0 |
| Temperature in tank, °C | 17 (13) | 15 - 19 | 12 - 23 |

Source: Adapted from Ziebell et al., 1975.

Blood-borne pathogens are generally not very persistent outside the human body and would likely be consumed in the septic tank or leach field colloguing layer within a matter of days.[4] However, human pathogens (mainly protozoa, enteric bacteria, and viruses) introduced into soil through septic system effluent and land-applied sewage sludge can be conveyed to both surface water and ground water. At the 1998 Ground Water Protection Council annual forum, Mr. Michael Rapacz (MA Department of Environmental Protection) presented a paper with evidence that viruses can remain active for up to two-years of ground water transport. His paper is supported by other research, including an article in Ground Water which found that: (1) viruses could travel as fast, or faster than inorganic contaminants; and (2) the combination of the virus sorption processes and long survival times resulted in the presence of viable seed virus for more than nine months (DeBorde et al., 1998).

The transmission of waterborne diseases is influenced by the latency, persistence, and infective dose of the pathogen. Latency is the period of time between excretion of a pathogen and its becoming

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[4] The colloguing layer is also referred to as a clogging zone or mat. This is an organic mat about 5 mm thick, which is found at the liquid-soil interface, and is where you get deposition of suspended solids, bacterial buildup, and decomposition of organic material by bacterial action.

infective to a new host. No excreted viruses, bacteria, and protozoans have a latent period. Among the helminthes (intestinal worms), only a few have eggs or larvae passed in feces that are immediately infectious to humans. Persistence is measured by the length of time that a pathogen remains viable in the environment outside a human host. The transmission of persistent microorganisms can follow a long route, for example, through a wastewater treatment system, and still infect persons located remotely from the original host. In general, persistence increases from viruses, the least persistent, to protozoans, to bacteria, to helminthes having persistence measured in months. Infective dose is the number of organisms that must be ingested to result in disease. Usually, the minimum infective dose for viruses and protozoans is low and less than for bacteria, while a single helminth egg or larva can infect. Median infective dose is that dose required to infect half of those persons exposed.

Table 10 presents typical pathogens and their relative transmissibility for pathogens commonly found in human feces. Category I comprises infections that have a low median infective dose (less than 100) and are infective immediately upon excretion. These infections are transmitted person-to-person where personal and domestic hygiene is poor. Therefore, control of these diseases requires improvement in personal cleanliness and environmental sanitation, including food preparation, water supply, and wastewater disposal. Category II comprises all bacterial diseases having a medium to high median infective dose (greater than 10,000) and are less likely to be transmitted by person-to-person contact than category I infections. In addition to the control measures given for category I, wastewater collection, treatment, and reuse are of greater importance, particularly if personal hygiene and living standards are high enough to reduce person-to-person transmission. Category III contains soil-transmitted helminthes that are both latent and persistent. Their transmission is less related to personal cleanliness because the helminth eggs are not immediately infective to humans. Most relevant is the cleanliness of vegetables grown in fields exposed to human excreta by reuses of wastewater for irrigation and sludge for fertilization. Effective wastewater treatment is necessary to remove helminth eggs, and sludge stabilization is necessary to inactivate the removed eggs.

**Table 10. Typical Pathogens Excreted in Human Feces**

| **Pathogen (group and name)** | **Associated Disease** | **Transmissibility Category [a]** |
|---|---|---|
| Virus | | |
| • Adenoviruses | Respiratory, eye infections | I |
| • Enteroviruses | Aseptic meningitis | I |
| • Hepatitis A. Viruses | Infectious hepatitis | I |
| • Reoviruses | Not well known | I |
| • Other viruses | Gastroenteritis, diarrhea | I |
| Bacterium | | |
| • *Salmonella typhi* | Typhoid fever | II |
| • *Salmonella paratyphi* | Paratyphoid fever | II |
| • *Other salmonellae* | Gastroenteritis | II |
| • *Shigella* spp. | Bacillary dysentery | II |
| • *Vibrio cholerae* | Cholera | II |
| Protozoan | | |
| • *Entamoeba histolytica* | Amoebic dysentery | I |
| • *Giardia lambia* | Diarrhea | I |

## Table 10. Typical Pathogens Excreted in Human Feces (continued)

| Pathogen (group and name) | Associated Disease | Transmissibility Category [a] |
|---|---|---|
| Helminth | | |
| • *Ancylostoma duodenale* | Hookworm | III |
| • Roundworm | Ascariasis | III |
| • Dwarf tapeworm | Hymenolepiasis | I |
| • *Necator americanus* | Hookworm | III |
| • Threadworm | Strongyloidiasis | III |
| • Whipworm | Trichuriasis | III |

[a] I = Non-latent, low infective dose; II = Non-latent, medium to high infective dose, moderately persistent; III = Latent and persistent

Source: Adapted from Feachum et al., 1983.

Fecal coliform serve as an indicator organism of other potentially present pathogenic microorganisms in water. The presence of this indicator organism indicates that the water contains feces from humans or warm-blooded animals. Although, one would expect to find these microorganisms in septic tanks receiving human sanitary wastes, the presence of high concentrations of fecal coliforms indicates that pathogens also are likely to be present.

The reliability of fecal coliform to indicate the presence of pathogens in water depends on the persistence of the pathogens relative to fecal coliform. Generally, coliforms are not reliable indicators for viruses because of the physical differences between bacteria and viruses (DeBorde et al., 1998). For pathogenic bacteria, the die-off rate is greater than coliforms outside the intestinal tract of humans. Thus, exposure in the water environment reduces the number of pathogenic bacteria relative to coliform bacteria. Viruses, protozoal cysts, and helminth eggs, however, are more persistent than coliform bacteria. For example, the threshold chlorine residual effective as a bactericide may not inactivate enteric viruses, is effective in killing protozoal cysts, and cannot harm helminth eggs. In contrast, filtration through natural sand aquifers for a sufficient distance can entrap cysts and eggs because of their relatively large size while allowing viruses to be carried through suspended in the water.

Regarding possible human immunodeficiency virus (HIV) transmission, recent studies concerning the survivability of HIV in wastewater suggest that HIV can survive in wastewater. For example, researchers recently found that HIV remained stable through 48 hours and remained infectious for 96 hours in water and wastewater, and concluded that the presence of HIV in wastewater cannot be dismissed without further investigation through field studies (Casson et al., 1997).

### 4.1.4 Summary of Constituents Detected in Septic Tank Effluent

Table 11 presents contaminants commonly observed in septic tank effluent at concentrations exceeding reference levels (e.g., primary or health-based MCLs standards, secondary MCLs, or HALs). (To be conservative, antimony, beryllium, cadmium, lead, and thallium were included in this list even though they were not detected because the respective detection limits used in the analysis were above the standards.)

**Table 11. Reference Levels for Contaminants Commonly Observed in Septic System Effluent At or Above Reference Levels**

| Contaminants | Maximum Observed Levels (mg/l) | Reference Levels (mg/l) | Data Source |
|---|---|---|---|
| Aluminum | 6.8 | 0.05 to 0.2 | Secondary MCL |
| Antimony | <0.06 | 0.003 | HAL |
| Arsenic | 0.005 | 0.002 | HAL |
| Beryllium | <0.01 | 0.0008 | HAL |
| Cadmium | <0.02 | 0.005 | HAL |
| Fecal Coliform[1] | too numerous to count | <5%+ | Primary MCL[2] |
| Formaldehyde | 9.2 | 1 | HAL |
| Iron | 2.4 | 0.3 | Secondary MCL |
| Lead | <0.05 | 0.015 | Primary MCL (Treatment Technology) |
| Manganese | 0.062 | 0.05 | Secondary MCL |
| Nitrate (as N) | 110 | 10 | Primary MCL |
| Sodium | 85 | 20 | Guidance |
| Thallium | <0.2 | 0.0005 | HAL |
| Total Nitrogen Species (as N) | 35.2 | 10 | Primary MCL |

[1] Neither health advisories nor maximum contaminant levels have been promulgated to date. Reference Level based on total coliforms.

[2] Treatment technique mandates less than 5 percent positive samples.

### 4.2 Septic Tank Characteristics

Conventional, gravity-flow septic systems typically have no moving parts or energy costs. They are widely used as an alternative to centralized wastewater treatment systems when they are neither feasible nor appropriate. When properly sited, operated, and maintained, septic systems can reduce the risk of ground water contamination and waterborne disease outbreaks, events often associated with the disposal of untreated sanitary waste.

LCSSs generally consists of a gravity fed underground septic tank or tanks, an effluent distribution system, and a soil absorption system. An alternative to the gravity fed underground septic tank or tanks would be to use a pressurized system with a distributor and calculated injection amounts (i.e., system dosing). This alternative is currently required in many states. The specific LCSS design will depend on particular site issues. For example, LCSSs can consist of:

- One or more grease trap(s);
- Several small septic tanks, serving individual residences;
- One or more large soil absorption system(s) used on a rotating basis; and
- One or more (i.e., in a series) large septic tank(s) served by a large absorption system or set of adsorption systems (USEPA, 1997b).

**Example of a LCSS**
**at a Hotel and Casino (Site #1)**

The wastewater treatment facility at Site #1 services a hotel and casino (Approx. 128,000 ft$^2$ total) and 134 space RV park. The treatment system consists of a 150,000 gallon septic tank, a four cell recirculating gravel filter, and sixteen drain fields totaling 3,680 feet of drain length. The septic tank provides primary treatment with solids removal from sedimentation and filtration. Filtration is provided as septic tank effluent is pumped through screened pump vaults to the recirculation tanks for the gravel filter. Baffling and location of the pump vault screens prevent oil and grease from leaving the septic tank and reaching the gravel filter. From the twenty-four recirculation tanks (6 per cell), septic tank effluent is pumped to the gravel filter for fixed-film biological treatment. The filter has a design flow rate of 86,000 gpd with a recirculation rate of approximately 4.2 times per day. Following treatment in the gravel filter, filter effluent returns to the recirculation tanks and depending on tank water level, either flows back into the tank or flows to one of the disinfection dosing tanks where it is pumped to the building that will house a future Ultra Violet light (UV) disinfection system. Currently, the flow bypasses the UV pilot study equipment and is diverted through a splitter box which splits flow to two drain field dosing tanks. Effluent from the future UV system will also be directed to the splitter box and subsequently to the drain field dosing tanks. Effluent is pumped from the drain field dosing tanks to a network of 16 pressure discharge drain fields constructed in fill soil above the native surface. The system is currently treating approximately 35,000 gpd.

LCSSs can also be hybrids of traditional septic tank technology (e.g., concrete vault and leach field). They may include other wastewater treatment components such as recirculating tanks and disinfection dosing tanks. Their sophistication can equal that of a conventional wastewater treatment plant. For example, an extended aeration activated sludge process configured with communicators, grease traps, aeration tanks, denitrification tanks, reaeration tanks, clarifiers, tertiary filters, and with "treated" effluent discharge to a network of drain fields is as effective as a wastewater treatment plant in removing contaminants. A typical gravity fed system is presented in Figure 1. An independent microbial disinfection process may also be included in the system before release of effluent to the soil absorption system where much of the disinfection occurs in a conventional system (See Figure 2). Alternative systems are described in Section 6 of this report.

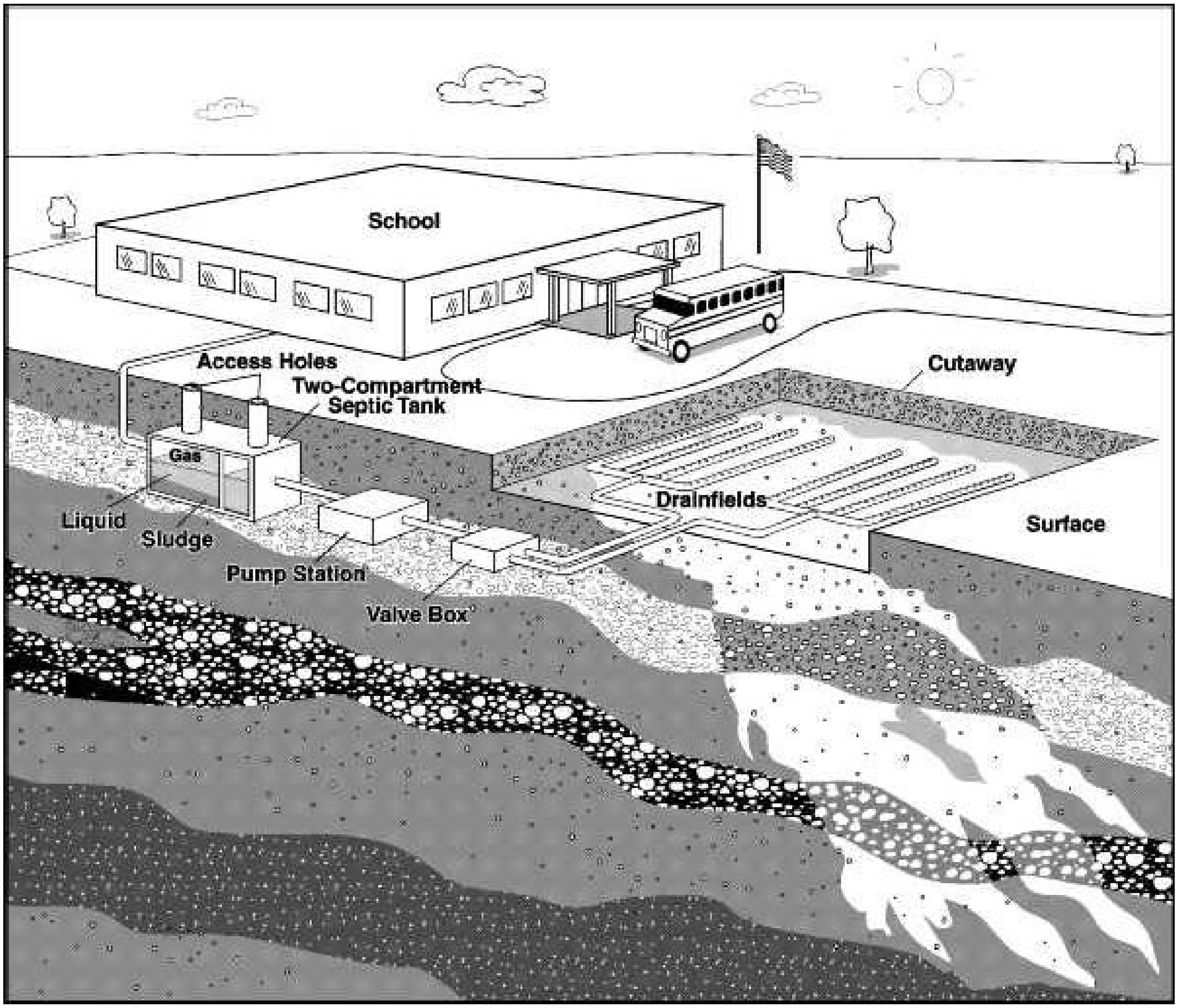
### *Pre-Septic Tank Process Units*

LCSSs can be equipped with process units designed to change the physical or chemical characteristics of the sanitary wastewater prior to entering the septic tank vault. For example, systems that receive high solids content material such as toilet paper (e.g., commercial establishments that handle a large number of people often encounter excessive solids in the form of toilet paper) can be equipped with screens and/or comminutors to remove gross solids and to chop up solid materials that are flexible enough to pass through the screen. In addition, wastewaters originating in restaurants often contain elevated levels of fats and greases, which can be removed using grease traps. Grease traps that are improperly sized or exposed to either excessively hot water (e.g., from dishwashers) or concentrated detergents or other cleaning fluids can be short-circuited and introduce elevated levels of oil and grease to the septic tank and eventually the drainfield (which can lead to premature failure of the drainfield).

### *The Septic Tank*

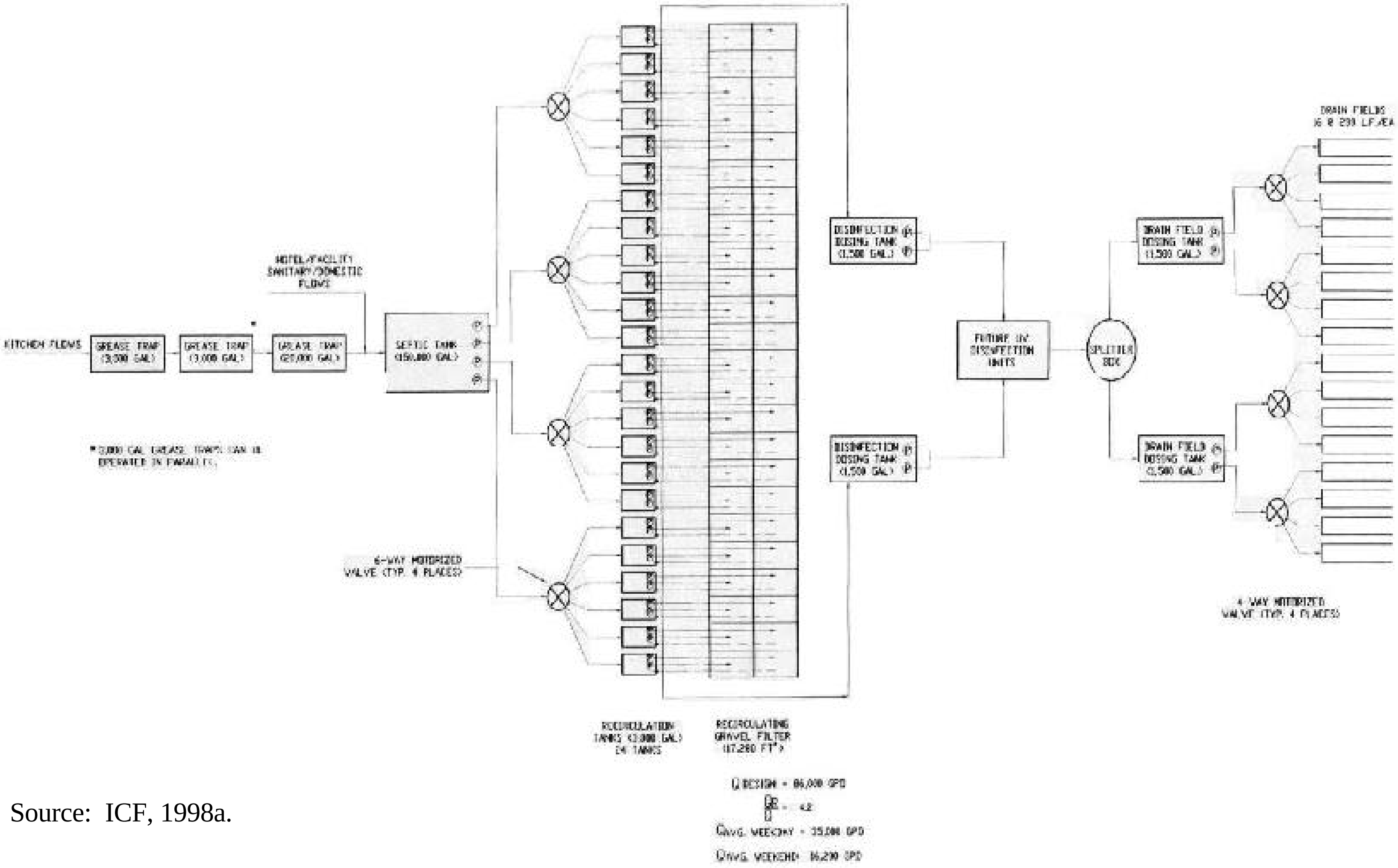
A septic tank is a buried, usually concrete, generally “watertight” sedimentation tank designed to receive and treat wastewater. (Septic tanks also can be made of fiberglass.) The raw wastewater, or influent, is retained for a period of time to allow for solids separation. The retention period for LCSSs can be less than 24 hours (residential systems typically retain influent for at least 24 - 48 hours) (Metcalf & Eddy,1979) but this time varies depending on the magnitude and frequency of loading. The chemical and physical characteristics of the influent can be affected by factors such as generator habits, climate, the use of appliances such as garbage disposals and washing machines, and the use of household chemicals (USEPA, 1997b).

**Figure 1. A Typical LCSS Installation Consisting of a Septic Tank, an Effluent Distribution System (Pump Station and Valve Box) and a Soil Absorption System (not to scale).**



Source: USEPA, 1997b.

**Figure 2. Example of LCSS Operating at an Indian Casino in Oregon, Washington (Not to Scale)**



Source: ICF, 1998a.

**Example of a LCSS at a Casino (Site #2)**

The wastewater treatment facility at Site #2 services a 40,000 ft$^2$ casino. The treatment system consists of a 1,750 gallon oil and grease interceptor tank, 17,800 gallon septic tank, 6,500 gallon drainfield pump tank, and a network of 6 pressure discharge drain fields with 920 linear feet lateral length per drain field. The recently constructed (summer 1996) replacement drain field consists of Infiltrators® placed in an existing fill area. The native soils are reported to be sands and gravels to a depth of 25 feet. The system currently treats approximately 15,000 - 17,000 gpd.

After entering the tank, influent constituents that are lighter than water (e.g., grease, oil, and fat) float to the top and form a scum layer, while those heavier than water settle to the bottom to form sludge. Discharges of grease and solids, which can clog the soil absorption system, can be avoided by periodically removing both the scum layer and sludge. Septage consists of all the materials that have settled within the septic tank, known as sludge, the materials that have risen to the surface of the tank, known as scum, and the liquid present in between the layers at the time of pumping. It is generally recommended that every 3-to-5 years the septage from residential systems be removed but it is recommended that LCSSs be inspected more frequently to determine if pumping is necessary. Septage generally contains lower concentrations of potentially toxic compounds resulting from the disposal of household chemicals or personal care products than sewage treatment plant sludges (USEPA, 1980a).

**Example of a LCSS at a Casino and Restaurant (Site 3)**

The wastewater treatment facility at Site #3 services a Casino, Buffet, Restaurant and Lounge, and Bingo Hall buildings (approximately 130,000 ft$^2$ total). The wastewater treatment facility is an extended aeration activated sludge plant built in two phases consisting of a flow equalization tank, 8 aeration tanks (4 for each of 2 phases), 2 denitrification tanks (1 for each of 2 phases), 2 reaeration tanks (1 for each of 2 phases), 2 clarifier tanks (1 for each of 2 phases), and a tertiary filter. Following tertiary filtration, plant effluent is discharged to a network of 25 drain fields. The drain field soils consist of a sandy gravelly clay. The system is currently treating between 50,000 and 120,000 gpd with an average daily flow of approximately 60,000 gpd and has a design capacity of 135,600 gpd.

Partially clarified wastewater remaining between the scum and sludge layers is displaced by incoming sewage. An outlet baffle and in newer systems "effluent filters" are typically placed at the septic tank outlet to prevent larger solids from exiting. An effluent filter can also be used to reduce the amount of suspended solids in the effluent discharge. Wastewater effluent is typically discharged from the septic tank to a soil absorption system or another unit process, such as a sand filter or recirculating gravel bed, for further treatment.

Septic tanks may contain one or two (or more) compartments, with at least two generally recommended, particularly for large systems (USEPA, 1980a). A two-compartment tank, like an effluent filter, helps to ensure that settleable solids remain in the tank and minimizes the effect of peak flows. The first compartment in a two-compartment tank typically accounts for two-thirds of the available volume and retains most of the solids, while the remaining tank volume provides final clarification of the wastewater (USEPA, 1997b). Effluent filters may be installed at the tank outlet to reduce the concentration of suspended solids. LCSSs can also be designed with several tanks in series to provide similar effluent clarification and solids digestion. Figures 3a-3c present designs of typical large-capacity septic tanks (although in Figure 3a, the gas venting would be to the surface).

**Figure 3. Septic Tanks Typically Used in Large-Capacity Systems: a) Two-compartment Tank, b) Series of One Compartment Tanks, c) One Compartment Tank with an Effluent Filter**

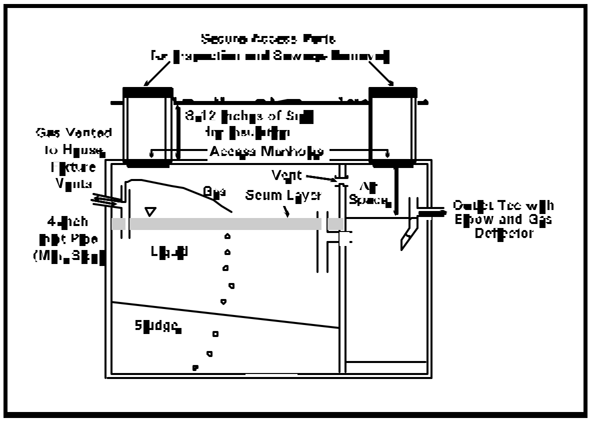


**Figure 3a**: Adapted from Laak, 1986.

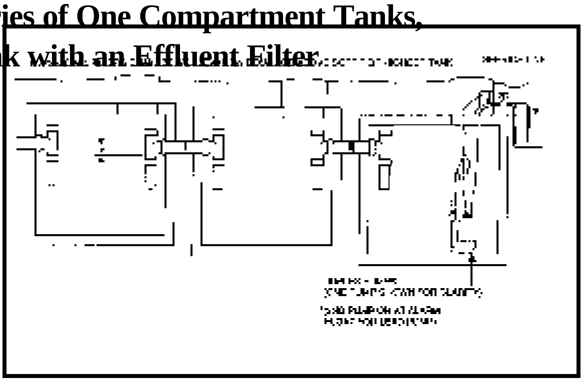


**Figure 3b**: Source: USEPA, 1991a.

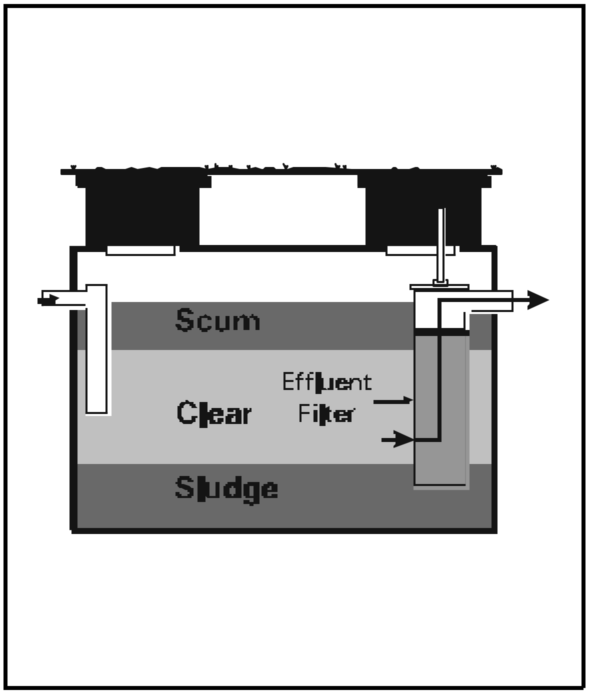


**Figure 3c**: Adapted from Bounds, 1994.

*Effluent Distribution*

There are two types of distribution networks: gravity-based systems and pressure distribution networks. The former rely on the force of gravity to distribute septic tank effluent throughout the system of perforated distribution pipes in the absorption field. Gravity systems are simple and inexpensive.

**Example of a LCSS at a Casino (Site #4)**

The wastewater treatment facility on Site #4 services two casinos and a snack bar (21,200 $ft^2$ total). The wastewater treatment system consists of two storage tanks (6,000 gallon total capacity) for peak flows in excess of plant capacity, a lift station with a 700 gallon wet well, a packaged activated sludge intermittent cycle extended aeration system, a sequencing batch reactor manufactured by Bio-Pure, and a drain field constructed of 1000 linear feet of infiltrators. The Bio-Pure packaged treatment plant consists of an aeration basin, clarifier basin, and disinfection chamber. The Bio-Pure plant discharges to an onsite drain field. Soil in the drain field area consists of organic silts and clays to a depth of 20 feet.

The interconnected storage tanks (6,000 gallon total capacity) contain a filter basket on the influent and grinder pumps to pump wastewater to the treatment plant or drain field during plant bypasses. Wastewater from one casino flows by gravity to the storage tank while wastewater from the second casino is pumped to the storage tank. The system is currently treating approximately 9,500 gpd. The design capacity of the Bio-Pure plant is 7,500 gpd while the design capacity of the drain field is approximately 9,400 gpd. With recent modifications, plant flows in excess of 7,500 gpd receive primary treatment in the storage tanks and then bypass the plant with discharge to the drain field. The system, which has been in operation since 1993, is undersized and has failed as evidenced by untreated waste pooling on the surface of the drainfield.

Pressure distribution networks rely on dosing siphons or pumps to move effluent into the drain field. Pressure distribution networks are often recommended for use with large-capacity systems or in situations where simpler, gravity-based systems could fail to provide even flow distribution. Where siphons or pumps are used, regular (e.g., annual) inspections and alarms may be required to ensure that mechanical parts are functioning properly. Some states require multiple pumps per system.

LCSSs usually incorporate some method to evenly distribute effluent wastewater into the soil absorption system. Smaller single-family systems do not always require such controls. An enclosed, underground chamber between the septic tank and soil absorption field can be equipped with a pump or siphon to control effluent distribution. Such a structure is generally referred to as a “dosing chamber” or “pumping tank.” To achieve more uniform application rates, the effluent is discharged from the dosing chamber into a network of smaller perforated pipes which are designed to release the effluent into the leach field at uniform rates. This controlled method of wastewater application is referred to as “pressure dosing” or “low-pressure dosing.” Uniform, intermittent dosing 4 to 24 times per day is controlled by a timer.

Some large septic systems may be characterized by intermittent high peak sewage flows generated over short periods. System users may employ dosing chambers or other methods to dampen peak loadings on septic tanks and absorption fields. For example, vacation resorts that experience high morning shower usage might control flows so that they are spread out over the day, while a highway rest area might have high weekend use, and would benefit from flow balancing over a weekly cycle. Systems using wastewater distribution mechanisms such as dosing chambers, which control flows, may be sized more optimally than systems sized for peak loading. Unnecessarily large septic tanks and soil absorption systems might result from sizing for peak loadings (Brown, 1991). This means that including flow control mechanisms is an important factor when determining design flow for large septic tanks and soil absorption systems.

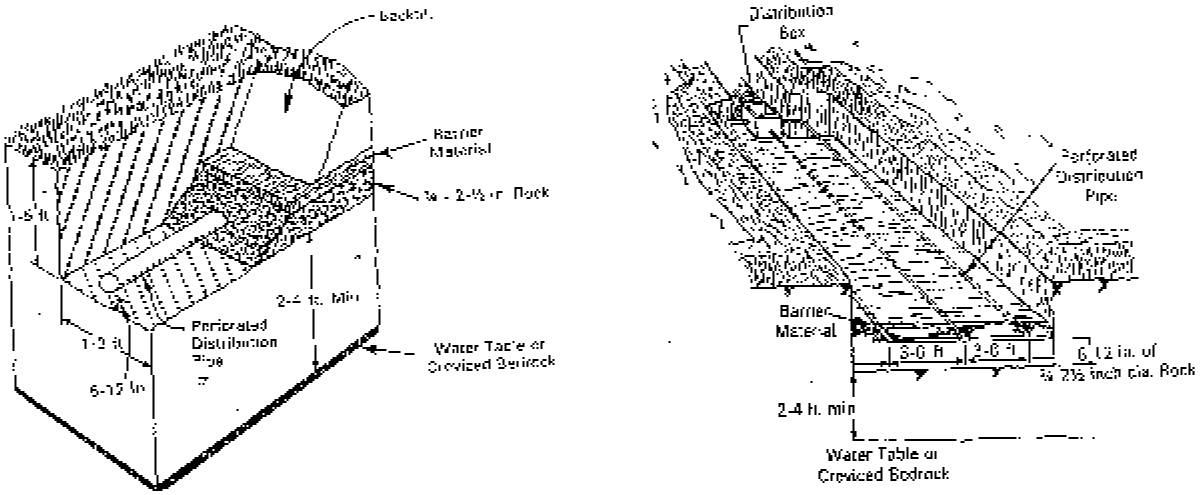
### *Soil Absorption Systems*

Soil absorption systems, also known as leach fields, absorption beds, drain fields, or subsurface wastewater infiltration systems, are below-ground land application systems. The soil absorption system receives clarified effluent from the septic tank, often via an effluent distribution system, at the soil’s infiltrative surface. Treatment of discharges to a soil absorption system occurs as the wastewater travels through the soil media below the distribution system.

Treatment occurs primarily through biological and physical processes (organic matter in the effluent is removed by filtration and biodegradation as it percolates through the unsaturated soil matrix). Biological treatment is the result of naturally occurring microbes attached to the soil particle surfaces using the nutrients found in the percolating wastewater (measured as $BOD_5$ and COD) as a source of food. Attached growth microbes are also responsible for the conversion of ammonia to nitrates (nitrification) and then, where appropriate conditions exist, to nitrogen gas (denitrification). As the percolate travels vertically and laterally through the soil void spaces, microbe populations change to match the food and oxygen supply providing reduction of $BOD_5$ (including trace organics) and ammonium concentrations. The physical process of absorption of organics to the soil particle surfaces also aides in the treatment of the wastewater. The absorption of organics and other constituents on to the soil particle surfaces allow for further biological degradation by attached microbes thus renewing the soil absorptive capacity.

Soil absorption systems have been constructed as trenches, beds, seepage pits, mounds, or leaching chambers (USEPA, 1992). While each of these systems is still in use, beds and seepage pits are no longer considered recommended practices. Trenches and beds are the most common types of soil absorption systems. Trenches are narrow and contain one distribution pipe, with infiltration occurring through the bottom and sides of the trench. A system using trenches would be using more than one with the exact number depending up onsite conditions. Beds are wider than trenches and contain more than one distribution pipe, with infiltration occurring principally through the bed bottom. Both trenches and beds are dug below the ground surface to a maximum depth of four feet above the seasonal high water table, with the purpose being to maintain an unsaturated zone greater than two to three feet above the mounded ground water surface. Perforated distribution piping is over gravel on the bottom of the trench or bed. Additional gravel is placed over the piping and a semi-permeable barrier is placed over the gravel to prevent the soil backfill from clogging the gravel. Beds are generally three to 12 feet wide, while trenches are only one to three feet wide ( USEPA, 1991b). Figure 4 shows typical configurations of drainage beds and trenches. Figure 5 presents an example of a pressurized drainfield trench with an orifice shield and Figure 6 presents an illustration of a pressurized drainfield constructed with Infiltrators®. Both orifice shields and Infiltrators® aid in the distribution and subsequent infiltration of the clarified septic tank effluent.

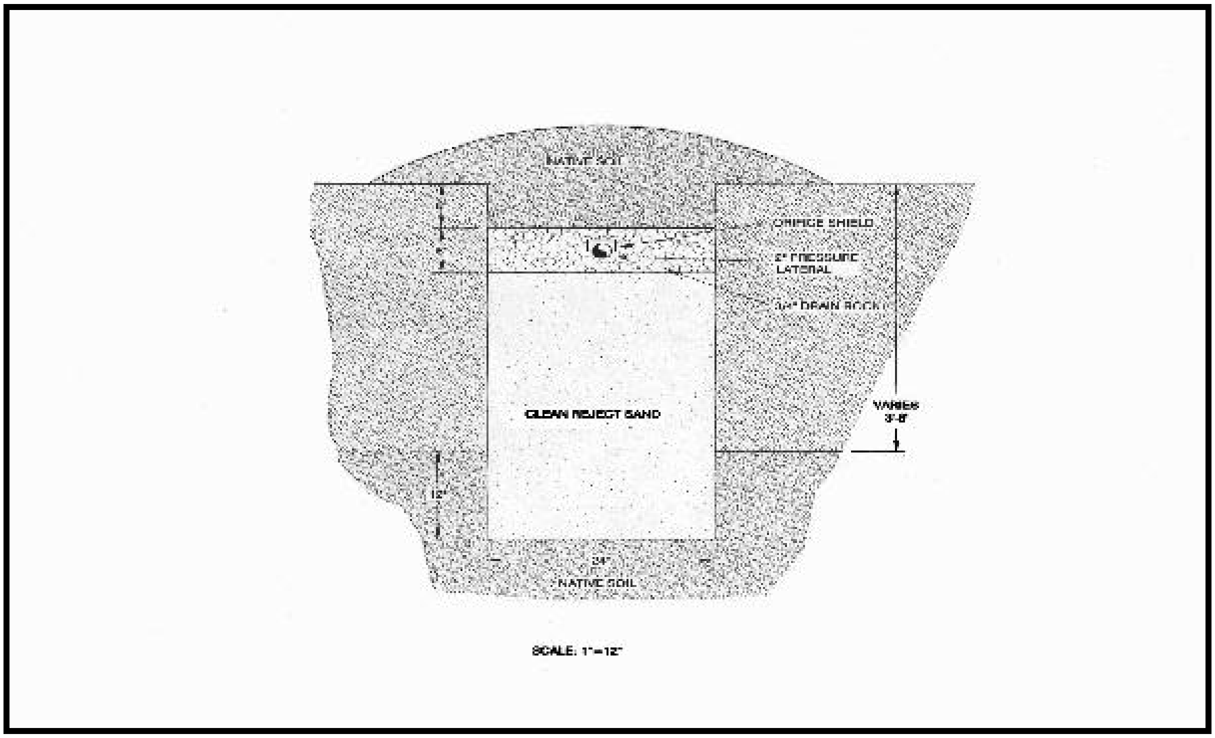
## Figure 4. Typical Drainage Configurations: (a) Drainage Trench, (b) Drainage Bed



(a) (b)

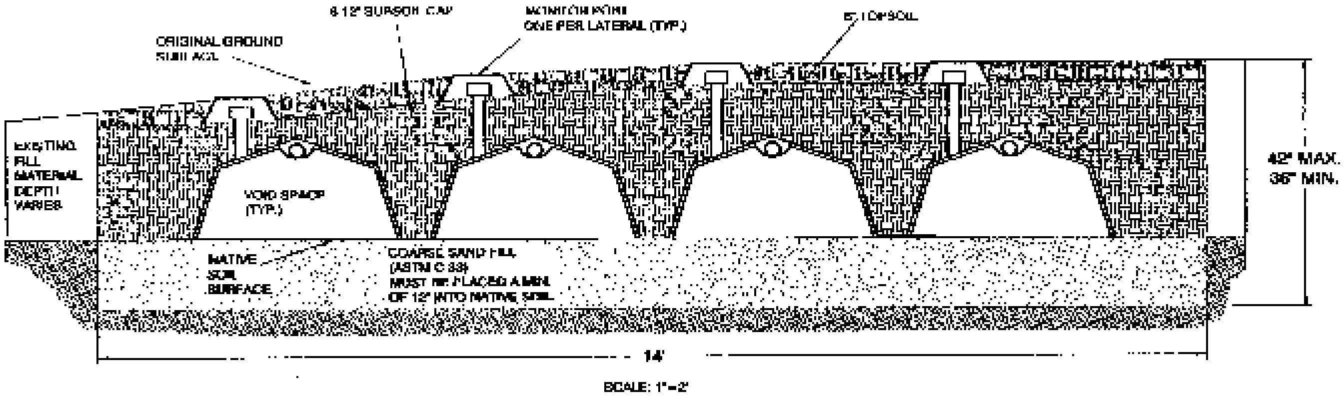
Source: USEPA, 1980a

## Figure 5. Pressure Drainfield Trench with an Orifice Shield



Source: ICF, 1998a

**Figure 6. Pressurized Drainfield Constructed with Infiltrators®**

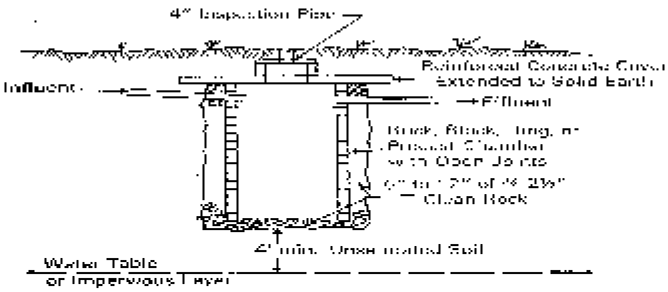


Source: ICF, 1998a

Trenches are generally recommended because they: (1) have more infiltrative area for absorption, (2) do less soil damage during construction, (3) are more easily installed on sloping sites (USEPA, 1995), and (4) allow oxygen penetration for proper treatment. While wide infiltrative surfaces, such as beds, and deep infiltrative surfaces, such as pits, require less land area, they do not perform as well as shallow trenches. This is because diffusion from the perimeter of the system is the primary pathway of oxygen to the subsurface, so shallow, narrow infiltrative surfaces enhance aeration (USEPA, 1997b).

Figure 7 presents an older soil absorption system configuration, a seepage pit, which while still in use is no longer a recommended practice. A series of seepage pits are usually dug to a maximum depth of four feet above the seasonal high water table. Brick, block, or precast chambers with open joints and bottoms are placed in each pit and backfilled with gravel. Effluent is treated by filtration and biodegradation as it passes through the sides and bottom of the pits. Seepage pits, by the nature of their construction, have a lower capacity to treat effluent, as it is introduced to a smaller infiltrative surface in deeper sediments. In addition, the limited infiltration surface may encourage anaerobic conditions during periods of significant effluent flow, significantly reducing treatment (Knape, 1984).

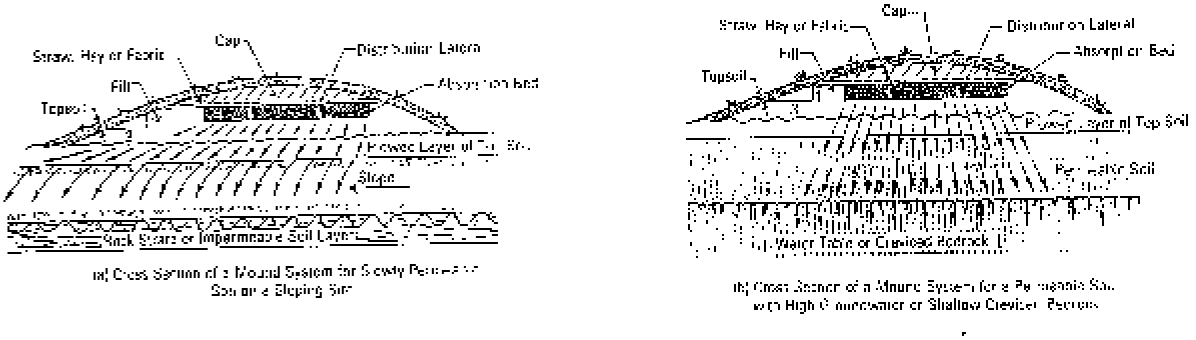
**Figure 7. Typical Seepage Pit Configuration**



Source: USEPA, 1980a.

Mound or at-grade systems can be used in areas with a high ground water table, high or crevassed bedrock, or insufficiently permeable soils (Converse and Tyler, 1990). Typically, these are areas where conventional soil absorption systems are inadequate. Figure 8 presents typical mound soil absorption system configurations. These systems are constructed by mounding permeable soils and sand on top of existing soils. Experts recommend that at least two feet of permeable unsaturated soil exist below the mound. Effluent is pumped or siphon-dosed from the septic tank to the top of the mound, and is treated by filtration and biodegradation as it percolates downward to the native soil (USEPA, 1997b). Pressurized distribution systems are used with mounds to evenly distribute the effluent over the sand (Elvebak, 1997). Mounds may be used over older, failing systems and they may be used on areas that have slopes steeper than 25 percent where a conventional system would not be feasible (Converse and Tyler, 1990).

## Figure 8. Typical Mound System Configurations



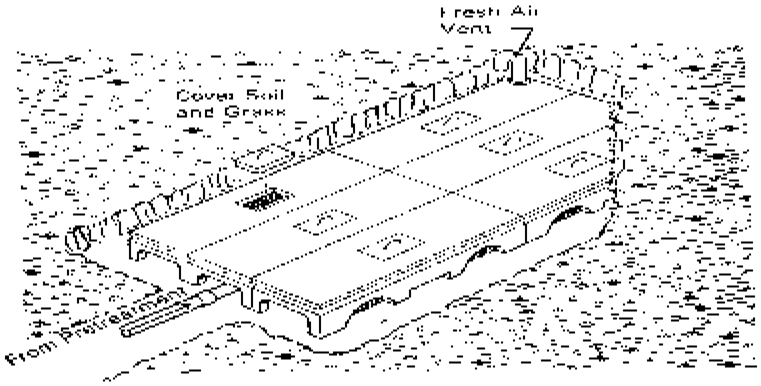
(a) Cross Section of a Mound System for Slowly Permeable Soil on a Sloping Site

(b) Cross Section of a Mound System for a Permeable Soil with High Groundwater or Shallow Creviced Bedrock

Source: USEPA, 1980a.

Leaching chambers, another less common and outdated configuration, are plastic or concrete structures that act as horizontal seepage pits. Figure 9 presents one type of leaching chamber configuration. Leaching chambers are open-bottomed plastic or concrete containers, commonly about 3-ft wide by 6-ft long, that are placed on a subsurface sand bed in a shallow trench. Wastewater is dispersed through the leaching chamber through pipes and troughs. The wastewater leaches out through the horizontal infiltrative surface and through the perforations in the sides of the chamber into the adjacent soil (USEPA, 1992).

## Figure 9. Typical Leaching Chamber Configuration



Source: USEPA, 1980a.

As effluent from the septic tank spreads out from the soil absorption system (in all configurations), a clogging mat or clogging layer forms (USEPA, 1997b). The clogging mat is a mass consisting of wastewater solids, mineral precipitates, microorganisms including facultative bacteria, protozoa, and nematodes, and the by-products of decomposition (USEPA, 1987). Organic materials are degraded and large pathogens are often attenuated. In addition, the mat slows the rate of percolation of the effluent and helps to maintain unsaturated conditions below the soil absorption system (USEPA, 1997b).

### 4.3 Operational Issues and Concerns

As noted earlier, most older LCSSs were designed and constructed with the same standards as small individual systems but on a larger scale. Commonly, the engineering design of the LCSS was slightly better but the system tended to have insufficient maintenance, as did small septic systems. The State of Idaho found this to be the case after many early community systems, which had been based on designs for individual systems, experienced hydraulic failure (defined as effluent ponding at the surface) (Burnell, 1992).

Improper design and sizing of the septic system can cause numerous problems. For example, in systems that receive excessive solids and/or oil and grease loadings, the treatment processes upstream of the drain field may not be capable of providing adequate treatment to protect the drain field from "plugging" and experiencing organic overload followed by eventual system failure. For example, cooling of oil and grease constituents that then stick to the pipe sidewalls contributes to orifice plugging. In addition, in certain situations, the clogging mat can become impermeable and also cause hydraulic failure of the system.

Septic systems may also be undersized and, therefore, unable to accommodate either the average daily flow or, more importantly, the actual peak flows. Due to the nature of most grease traps and other septic system components which are gravity flow, where inflow equals outflow over time, these systems are very susceptible to problems caused by peak flows. Peak flows in excess of the design criteria can short-circuit the system by clogging both drain field laterals and the drain field itself.

In addition, actual site conditions, such as high water tables or poor soil conditions, can adversely affect the operational efficiency of a particular septic system. For example, installation of disposal field trenches is not suggested in gravel and coarse sand soils, due to the very rapid percolation rates, unless the site is either first amended with a finer grained loamy sand for a minimum of two feet below the distribution piping, or the dosing is controlled.

System inspection may either not occur or not occur frequently enough (recommendations for large systems are annual inspections by a licensed professional). Site conditions can change over time as can system functions. If these changes pass without notice, then at a minimum, the system's lifetime may be shortened. See Section 6.4 for suggested operational and maintenance practices.

# 5. POTENTIAL AND DOCUMENTED DAMAGE TO USDWs

## 5.1 Constituent Properties

The primary constituent properties of concern when assessing the potential for Class V LCSSs to adversely affect USDWs are toxicity, persistence, and mobility. The toxicity of a constituent is the potential of that contaminant to cause adverse health effects if consumed by humans. Appendix D of the Class V Study provides information on the health effects associated with contaminants found above drinking water standards or health advisory limits in the injectate of Class V LCSSs and other Class V wells. As discussed in Section 4.1.4, the contaminants that have been observed above drinking water standards or health advisory limits in Class V LCSSs effluent are antimony, arsenic, beryllium, cadmium, formaldehyde, thallium, fecal coliform, lead, nitrate (as N), total nitrogen species (as N), aluminum, iron, and manganese.

Persistence is the ability of a chemical to remain unchanged in composition, chemical state, and physical state over time. The persistence of many of the constituents of septic tank effluent is discussed in Section 4.1. In addition, Appendix E of the Class V Study presents published half-lives of common constituents in fluids released in Class V LCSSs and other Class V wells. All of the values reported in Appendix E are for ground water. Caution is advised in interpreting these values because ambient conditions have a significant impact on the persistence of both inorganic and organic compounds.

Appendix E also provides a discussion of mobility of certain constituents found in the injectate of Class V LCSSs and other Class V wells. The mobility of these constituents in USDWs depends in part on the characteristics of the injection zone. As discussed in Section 4.1, although it is difficult to generalize about the injection zone for LCSSs because these systems have been constructed nationwide, LCSSs typically are located in well-drained soils. LCSSs, however, have been located in areas with karst or fractured bedrock. In most cases, constituent concentrations are reduced within the system (due to settling and biodegradation in the septic tank), and as the septic tank effluent travels through the soil media below the fluid distribution system (which is most commonly a leachfield). Additional attenuation of the dissolved organic matter, pathogens, and some inorganic constituents can occur in unsaturated soils below the soil absorption system. It should be noted that metals, typically present in LCSSs effluent, may temporarily adsorb onto the geologic media or change chemical state, but do not degrade as do some organic compounds. Metals may also affect the natural microbial communities enhancing or retarding the ability of the water-soil matrix to degrade organic LCSS constituents such as pesticides, bacteria, and certain viruses.

Additional discussion regarding the persistence and mobility of contaminants and biological pathogens found in LCSS effluent are provided below.

### *Evaluation of Leach Field Treatment Performance at Two LCSSs*

In a recent study, USEPA obtained data to help evaluate the potential impacts to local ground water resources as the result of onsite wastewater treatment operations. (See ICF, 1998a.) USEPA conducted sampling at two recently constructed LCSSs sites. Sampling was limited to the drain field components of the LCSS at Site #1 and #2 since it is the percolate from these systems that has the potential to impact ground water resources. Samples, therefore, were collected from the drain field dosing tanks and at various depths below the drain fields. This sampling procedure allows for evaluation of the treatment that occurs in the soil profile below the drain fields by assessing wastewater characteristics just before it enters the soil profile and after it has traveled vertically through the soil profile to the sampling location depth.

The drain field percolate samples were collected using Geoprobe water sampling equipment. The Geoprobe was equipped with a screen point ground water sampler that was driven to the desired sample depth and then pulled back to expose a 48" stainless steel screen. The screen was held inside the probe rod as the rod was pushed to depth with an expendable point on the end. When the rod was pulled back, the expendable point was left in the bottom of the hole and the screen “dropped” into the void space to allow for sample collection.

Samples were collected by inserting tubing down the hollow shaft of the probe rod to the screened sampler and then pumping the sample directly into sample containers using a vacuum pump. New tubing was used for each sample collected and all sampling equipment was thoroughly cleaned between sample depths and locations.

At Site #1, Geoprobe holes were driven at seven locations throughout the drain field area. Attempts were made to collect samples at each of the locations. However, only three locations (4GP, 6GP, and 7GP) yielded water. At Site #2, Geoprobe holes were driven at five locations throughout the drain field area. Attempts were made to collect samples at each of the locations however, only two locations (3GP and 5GP) yielded water. All of the samples were analyzed for common wastewater analytes, including: $BOD_5$, COD, fecal coliforms, nitrate, total Kjeldahl nitrogen, total oil and grease, metals (listed in Table 11) and pH. The results for samples collected at the two sites are summarized in Tables 12 and 13, respectively.

**Table 12. Site #1 - Summary of Analytical Results**

| | | **Sample Locations** | | | |
|---|---|---|---|---|---|
| **Analytes** | **Units** | **Splitter Box** | **4 GP (12' BGS)** | **6 GP[2] (13' BGS)[3]** | **7 GP (12' BGS)** |
| Biochemical Oxygen Demand (5-day) | mg/l | 5 U[1] | 5 U | 5 U | 5 U |
| Chemical Oxygen Demand | mg/l | 34 | 12 | 10 U | 10 U |
| Fecal Coliforms | MPN/100 ml | >1600 | 17 | 5 | 7 |
| Nitrate as N (EPA 300.0) | mg/l | 8.1 | 0.8 | 1.5 | 2.1 |

## Table 12. Site #1 - Summary of Analytical Results (continued)

| Analytes | Units | Sample Locations | | | |
|---|---|---|---|---|---|
| | | Splitter Box | 4 GP (12' BGS) | 6 GP[2] (13' BGS)[3] | 7 GP (12' BGS) |
| Total Oil & Grease (EPA 413.1) | mg/l | 5 U | 5 U | 5 U | 5 U |
| pH | gl elec @25C | 6.7 | 6.3 | 6.5 | 6.5 |

[1] "U" indicates that the analyte of interest was not detected to the limit of detection given.

[2] Concentrations are the average of the original and duplicate samples.

[3] BGS = Below ground surface.

Source: ICF, 1998a.

## Table 13. Site # 2 - Summary of Analytical Results

| Analytes | Units | Sample Locations | | |
|---|---|---|---|---|
| | | Pump Tank[2] | 3 GP (26' BGS)[3] | 5 GP (22' BGS) |
| Biochemical Oxygen Demand (5-day) | mg/l | 1750 | 5 U | 10 |
| Chemical Oxygen Demand | mg/l | 5100 | 10 U | 10 U |
| Fecal Coliforms | MPN/100 ml | >1600 | --[4] | <2 |
| Nitrate as N (EPA 300.0) | mg/l | 1.0 U | 84 | 110 |
| Total Oil & Grease (EPA 413.1) | mg/l | 84 | 5 U | 5 U |
| pH | gl elec @ 25 C | 6.8 | 5.8 | 5.8 |

[1] "U" indicates that the analyte of interest was not detected to the limit of detection given.

[2] Concentrations are the average of the original and duplicate samples.

[3] BGS = Below ground surface.

[4] "--" indicates sample was not analyzed for the analyte of interest due to lack of the appropriate sample container.

Source: ICF, 1998a.

Site #1 The sampling results at Site #1 show that treated effluent from the recirculating gravel filter (splitter box sample) is highly oxidized. The $BOD_5$ for the sample was less than 5 mg/l, and the COD was 34 mg/l. Although the grab sample only represents one instantaneous moment, other samples taken from the dosing tanks by facility personnel show similar results with an average $BOD_5$ of 6.6 mg/l after treatment in the recirculating gravel filter. The low $BOD_5$ shows that the majority of the organic material has been oxidized. The majority of the COD is probably indicative of the ultimate BOD since very little oxygen demand is represented by the inorganic constituents found in the sample. The relatively low nitrate concentration of 8.1 mg/l indicates that some denitrification is also occurring within the recirculating filter system. Fecal coliforms are present in significant concentrations as anticipated for an effluent that has not been disinfected. Oil and grease are below the detection limit showing efficient removal in the upstream unit processes (i.e., grease traps and septic tank).

Samples from the below the drain field (12-13 feet bgs) indicate that there is some further oxidation of the remaining organic materials as the wastewater travels through the soil profile reducing the average COD to less than 10 mg/l. Fecal coliforms are greatly reduced with the primary removal mechanisms being filtration and inactivation. Removal efficiencies for each of the contaminants of concern are listed in Table 14.

### Table 14. Site #1 - Drain Field Removal Efficiencies

| Contaminant of Concern | Removal Efficiency (%) |
|---|---|
| Biochemical Oxygen Demand (5-day) | NC |
| Chemical Oxygen Demand | 71 |
| Fecal Coliforms | 99 + |
| Nitrate as N | 82 |
| Total Oil & Grease | NC |

NC: no calculation due to concentrations being less than the detection limit for water entering the soil profile.
+: removal efficiency is most likely higher due to concentrations above the upper limit of the analysis for the water entering the soil profile.
Source: ICF, 1998a.

A similar analysis was conducted for the metals and is presented in Table 15.

### Table 15. Site #1 - Drain Field Removal Efficiencies - Inorganics (mg/l)

| Parameters | Splitter Box | 12 Feet BGS | 13 Feet BGS | Total Percent Reduction* |
|---|---|---|---|---|
| Aluminum | 0.056 | 44 | 52 | 92,757.14% |
| Antimony | < 0.006 | < 0.006 | 0.0068 | 13.33% |
| Arsenic | < 0.005 | < 0.005 | < 0.005 | -- |
| Beryllium | < 0.001 | < 0.001 | < 0.001 | -- |
| Cadmium | < 0.001 | < 0.001 | < 0.001 | -- |
| Iron | 0.16 | 28 | 53 | 33,025.00% |
| Lead | < 0.005 | 0.0087 | 0.016 | 220.00% |
| Manganese | 0.062 | 2.9 | 1.5 | 2,319.35% |
| Sodium | 52 | 55 | 56 | 7.69% |
| Thallium | < 0.02 | < 0.02 | 0.066 | 230.00% |

***** Percent reductions calculated using deepest sample; negative reductions likely represent both analytical variation in trace metals concentrations and contribution from soil (as evidenced by increase in suspended solids concentration with depth).
Source: ICF, 1998a.

Site #2 The sampling results at Site #2 show that the treated effluent from the septic tank remains a high strength wastewater and contains a high concentration of oil and grease. The $BOD_5$ for the sample was 1,750 mg/l, the COD was 5,100 mg/l, and the oil and grease concentration was 84 mg/l. The sampling method (lowering a bucket and collecting the sample from the water surface) and timing (after the pump tank was drawn down significantly due to pumping to the drain field for drain field sampling) most likely contributed to these alarmingly high concentrations. However, the sample still indicates poor performance of the septic tank and grease trap processes upstream of the pump tank since even a 75 percent reduction in the concentrations would still be cause for concern. Furthermore, previous samples taken from the pump tank indicate an average $BOD_5$ value of 450 mg/l (provided by the site). Also, a water sample taken from the pump tank and a soil sample taken from a drain field trench in June of 1997 yielded oil and grease concentrations of 38 mg/l and 198 mg/kg respectively (provided by the site). The fecal coliform concentrations are high as anticipated for a septic tank effluent.

Samples from below the drain field (22-26 feet bgs) indicate that there were significant reductions in constituent concentrations through dilution and attenuation as the effluent traveled through the soil profile. The $BOD_5$ was reduced to an average of 7.5 mg/l and both the COD and oil and grease concentrations were reduced below the detection limits of 10 mg/l and 5 mg/l respectively. These constituents are removed in the soil profile by filtration and adsorption to the soil particles. The reduction in pH along with the increase in nitrates from a non-detectable level to an average of 97 mg/l indicates that the soil provides a strong nitrifying environment. The average nitrate concentration of 97 mg/l may indicate that some denitrification is also occurring in the soil profile. Fecal coliforms were also greatly reduced from >1,600 per 100 ml to < 2 per 100 ml. Removal efficiencies for each of the contaminants of concern are listed in Table 16.

**Table 16. Site #2 - Drain Field Removal Efficiencies**

| Contaminant of Concern | Removal Efficiency (%) |
|---|---|
| Biochemical Oxygen Demand (5-day) | 99.6 |
| Chemical Oxygen Demand | 99.8 |
| Fecal Coliforms | 99.9 + |
| Nitrate as N | 0 |
| Total Oil & Grease | 94.0 |

NC: no calculation due to concentrations being less than the detection limit for water entering the soil profile.
+: removal efficiency is most likely higher due to concentrations above the upper limit of the analysis for the water entering the soil profile.
*: Nitrates and nitrites are by-products of ammonia oxidation (nitrification) and therefore increase as ammonia is oxidized.
Source: ICF, 1998a.

A similar analysis was conducted for the metals and is presented in Table 17.

**Table 17. Site #2 - Drain Field Removal Efficiencies - Inorganics (mg/l)**

| Parameters | Pump Tank | 22 Feet BGS [1] | 26 Feet BGS | Total Percent Reduction[2] |
|---|---|---|---|---|
| Aluminum | 6.8 | 140 | 62 | 811.76% |
| Antimony | < 0.06 | < 0.06 | < 0.06 | -- |

## Table 17. Site #2 - Drain Field Removal Efficiencies - Inorganics (mg/l) (continued)

| Parameters | Pump Tank | 22 Feet BGS [1] | 26 Feet BGS | Total Percent Reduction[2] |
|---|---|---|---|---|
| Arsenic | < 0.005 | < 0.005 | < 0.005 | 0.00% |
| Beryllium | < 0.01 | < 0.01 | < 0.01 | -- |
| Cadmium | < 0.02 | < 0.02 | < 0.02 | -- |
| Iron | 2.4 | 83 | 38 | 1,483.33% |
| Lead | < 0.05 | 0.051 | < 0.05 | -- |
| Manganese | 0.045 | 7.5 | 2.7 | 5,900.00% |
| Sodium | 85 | 87 | 59 | -30.59% |
| Thallium | < 0.2 | < 0.2 | < 0.2 | -- |

[1] BGS = Below ground surface.

[2] Percent reductions calculated using deepest sample; negative reductions likely represent both analytical variation in trace metals concentrations and contribution from soil (as evidenced by increase in suspended solids concentration with depth).

Source: ICF, 1998a.

Under optimal operating conditions, cations (such as sodium) are attenuated by soils in significant quantities as a result of exchange reactions within the soil matrix. Their presence in a receiving aquifer will be limited provided unsaturated flow conditions prevail in the soil adsorption system.

### *Treatability of Formaldehyde*

The biodegradation of formaldehyde was evaluated in several studies conducted by the Sanitary Engineering Laboratory at the University of California at Berkeley (hereafter referred to as the “Berkeley studies”) (Pearson et al., 1980a; Pearson et al., 1980b; Pearson et al., 1991). The Berkeley studies were conducted to document the extent of formaldehyde degradation that occurs in septic systems that receive RV wastewater that was treated with formaldehyde. The Berkeley studies were conducted using pilot-scale septic systems under a variety of flow and loading calculations. The influent and effluent formaldehyde concentrations and calculated removal rates are presented in Table 18.

## Table 18. Influent and Effluent Concentrations of Formaldehyde and Percent Reductions

| Retention Time | Influent Concentration (mg/l) | Effluent Concentration (mg/l) | Percent Removal |
|---|---|---|---|
| 3 days/continuous | 42 | 4 | 90 |
| 3 days/continuous | 194 | 15 | 92 |
| 1 day/continuous | 91 | 5.8 | 94 |
| 1 day/continuous | 361 | 54 | 85 |
| 3 days/shocked | 300 | < 3.5 | 92 (mass removal rate) |

Source: Pearson et al., 1980a; Pearson et al., 1980b; Pearson et al., 1991.

In a second study, Pearson et al. (1991) concluded as a result of their batch septic tank study: (1) formaldehyde removal declined as the dose increased; (2) at a dosing of 30 mg/l, formaldehyde removal averaged >80 percent; (3) at a dosing of 300 mg/l, formaldehyde removal averaged 79 percent. The same authors concluded as a result of their pilot-scale septic tank and leach field study that formaldehyde removal was 56 percent in the septic tank and 62 percent in the leach field at a dosing of 300 mg/l.

In a third study, formaldehyde was found to inhibit the biodegradation of wastewater (Brown et al., 1982). The authors observed that:

> "The anaerobic toxicity results show substantial reduction in biological activity at 50 to 150 mg per liter formaldehyde and no significant reduction in activity at levels of 5 to 10 mg per liter. If there was biological degradation of formaldehyde, degradation would be expected to continue until formaldehyde concentrations were reduced below 5 to 10 mg per liter. Formaldehyde is probably removed from septic tank systems by nonbiological mechanisms as well as by biodegradation. It appears that, for reasons not well understood at this time, formaldehyde removal ceases in anaerobic systems when formaldehyde concentration drops to about 5 mg per liter." (Brown et al., 1982)

*Mobility of Biological Pathogens*

The fate and transport of protozoa and parasites, bacteria, and viruses from sewage effluent are affected by the operation of the septic tank and any other treatment units preceding the drainfield, the loading pattern and rate, as well as the characteristics of the subsurface environment. Many soils are capable of filtering parasites and bacteria as the effluent moves through soil pores. One of the most important factors in removal of bacteria is the pore size of the soil matrix, with smaller pores being better able to remove bacteria. Bacteria, which have many nutritional requirements, usually die off once filtered from the effluent. Cases have been reported of active bacteria traveling distances of up to 300 feet in sandy aquifers, 2,800 feet in gravelly aquifers, and 3,300 feet in limestone bedrock (Kaplan, 1991). Note that this movement is believed atypical for properly sited, designed, and operated, and maintained septic systems. In addition to movement, bacteria may simply persist. For example, enteric bacteria have been observed to survive from 10 to 100 days in soil depending on the moisture content, temperature, organic matter, pH, sunlight, and antagonism from native soil microflora present in the soil (Canter and Knox, 1985). Generally, bacteria removal is enhanced by low effluent loading and frequent drying periods between doses.

Viruses are less easily filtered. The major means of virus removal is through adsorption onto soil particles. Dry soils may also inactivate viruses (Kaplan, 1991). One study found virus removal in soils to be three times greater in unsaturated conditions than in saturated conditions (Powelson and Gerba, 1994). The implication of this finding for large septic systems is that if ground water mounding beneath these systems were to reach the infiltrative surface, it could result in saturated flow conditions, possibly allowing greater concentrations of viruses to travel to ground water. Ground water mounding reduces the distance from the bottom of the system to the water table (MN Pollution Control Agency, 1984). This distance is a critical factor in the treatment of effluent from large septic systems because the unsaturated soil above the water table filters and absorbs contaminants (Price, 1988), including parasites, bacteria, and viruses.

The ambient environment is an important factor for effective virus removal. Research by Scandura and Sobsey (1997) determined that the risk of viral contamination is greatest in the most coarse (sand) soils, when water tables are most shallow (smallest vadose zones or unsaturated soils) and in winter when temperatures are at the lowest. However, extensive reductions of enteric viruses, bacteria, and nutrients are possible if the site has soils with clay content at or exceeding 15 percent, if the vadose zone is at or exceeds 3.28 feet, and if the drainfield distribution lines do not become submerged in the ground water.

Initial virus removal or inactivation can be reversed by changing environmental conditions. Heavy rainfall can induce saturated soil conditions or significant temperature changes (Yates, 1987). Viral organisms may persist in temperatures as cold as -20 °C, but can be inactivated by high temperatures (exceeding 31°C) (Harris, 1995; Yates, 1987). Viruses have been observed to travel more than 600 feet and survive as long as 170 days (Canter and Knox, 1985). Like bacteria removal, virus removal is enhanced by low pH and ionic strength (Canter and Knox, 1985). Virus adsorption also depends on the strain of the virus. A different strain of the same virus may adsorb to a different extent and/or at a different rate. According to Yates (1987), infectious viruses are not normally present in effluent, and are only shed in the feces of infected individuals. However, this would make larger systems more likely than smaller ones to contain such viruses.

## 5.2 Observed Impacts

### 5.2.1 Factors Contributing to System Failure

When properly designed, sited, and constructed, LCSSs can partially treat and effectively dispose of sanitary wastewater effluent. Dissolved organic matter, pathogens, and some inorganic constituents can be highly attenuated in unsaturated soils below the soil absorption system. However, the National Small Flows Clearinghouse estimates that as many as 20 to 30 percent of existing conventional single family onsite wastewater treatment systems fail during their design lifetime (Olsen, 1997; NSFC, 1996). As mentioned previously, system failure is defined as the direct or rapid movement of effluent from the soil absorption system to the saturated zone resulting in negligible attenuation of effluent constituents. System failure can result from:

C Percolation that is too rapid to attenuate contaminants;

• Effluent flow that exceeds the absorptive capacity of the soil; or

C The ground water table being too close to the infiltrate surface.

In addition, surfacing and subsequent overland flow may exacerbate improper absorption system performance by carrying contaminants resulting from system failure directly to streams, lakes, and inadequately sealed wells. However, each of these possibilities may be prevented by changing system operation and maintenance practices, such as changing dosing rates and patterns, or by careful siting, design and construction before the system is built.

Soil properties are among the most important factors when determining the optimal design for an onsite treatment system. Soil characteristics such as high porosity and permeability can result in the rapid migration of organic, inorganic, and microbial contaminants to the saturated zone, if an improper design is employed. Contaminants moving through these soils can be transported too quickly through the unsaturated zone to be effectively attenuated. The opposite can occur when soil hydraulic conductivity is too low. The result of not designing with a low enough application rate can be saturated flow through the underlying soils, and in the worst cases, ponding of effluent on the surface. A good soil system for receiving effluent is permeable enough to absorb effluent without saturating the soil, and provide a high level of treatment before the effluent reaches the ground water. Subsurface aquifers that are hydraulically over-loaded will cause ground water mounding and hydraulic failure (Canter and Knox, 1985).

Conventional septic tanks are not designed to substantially remove nitrogen or pathogens from the effluent stream but are designed to safely discharge them to the subsurface. The benign release of these contaminants to the subsurface environment is primarily dependent on dilution with ground water for nitrogen (as nitrate) and other mobile inorganics, and soil filtering for pathogens.

Inadequate planning and construction can exacerbate the potential threat as a result of poor performance and system failure. A recent survey of local and regional sanitation officials, with primary jurisdiction over onsite wastewater treatment systems, indicates that the majority of system failures and subsequent contamination are the result of improper design, siting, and construction (NSFC, 1996).

The magnitude of contamination, particularly by nitrate, is highly dependent on the characteristics of the subsurface. In general, nitrate concentrations will be highest and transported farthest in well-drained soils with high ground water flow velocity. However, even under optimal subsurface conditions for nitrate transport, only local ground water resources will be affected by contamination by a single onsite wastewater treatment system. Dilution will most often reduce nitrate concentrations below the MCL within distances of tens to hundreds of feet, depending on subsurface conditions.

### 5.2.2 Contamination Incidents

Table 19 presents case studies describing instances of LCSS failure and remediation or new construction. The contamination incidents summarized below include those reported in the published literature as well as examples from personal communications and electronic searches of the Internet. These incidents provide examples of the types of problems that can affect the continued, safe operation of LCSSs.

The case studies described in Table 19 highlight typical problems for LCSSs. The table does not compare LCSS failures with total system failures. Summary statistics and estimates provided by Marion County, Florida officials allow one such preliminary comparison (Burleson, 1999). (See Table 20 below.) Marion County began keeping electronic records on septic systems and their permits in 1992. These data were limited to only “non-private establishments” -- a proxy for LCSSs which excluded single family homes. The result of the analysis indicates that approximately 11 percent of all county septic system repairs between 1992 and 1998 were for LCSSs. Marion County officials also found that while the average drainfield typically lasts 15 to 17 years, systems in mobile home parks tend to fail more quickly because of system overloading, invasive roots, or a lack of system maintenance. They stated their goal is to have LCSSs last longer by educating owners about their systems and the importance of proper care and maintenance.

Comparing Marion County's findings with data from Florida Department of Health estimates seemingly indicate that while approximately three percent of Marion County's septic systems are LCSSs, LCSSs comprised approximately 11 percent of all septic system repair permits over a seven year period (Sherman et al., No date). However, it remains uncertain whether LCSSs are in fact failing more frequently than single family homes. Much of the difference is believed to result from the underlying data used in each analysis; the Marion County analysis utilizes a smaller data set with a shorter time-series. Furthermore, it may be that LCSS enforcement is more stringent than for other systems or that recent economic growth is causing LCSS design capacity to be exceeded, necessitating system repairs.

There are also many reported cases, and probably at least as many unreported cases, of industrial and commercial wastes being improperly disposed into septic systems (USEPA, 1986). The 1987 RTC states that dry cleaners, laundromats, paint dealers, hardware stores, funeral homes, and a variety of other industrial and commercial facilities may dispose of non-sanitary waste through septic systems (USEPA, 1987). Septic systems are not designed or constructed to handle such waste, and such misuse may result in contamination of USDWs. A study by USEPA found that large septic systems have caused ground water contamination due to improper siting, construction, operation, maintenance, and waste disposal practices. However, the incidents mentioned in the study deal solely with improper disposal of industrial waste to septic systems (USEPA, 1986). If such use occurs, the system would be considered an industrial well or a motor vehicle waste disposal well (depending on the operations at a given site) rather than a septic system, and is outside the scope of this study.

## Table 19.  Examples of LCSSs Failures

| Location (Year) | Case Study |
|---|---|
| Blackstone and Millville, Massachusetts (1998) | • In 1998, Blackstone-Millville High School septic system failed when sewage overflowed into leaching field.  System failed because of design errors and lack of maintenance.<br>• Septic system included septic tanks, pumping box, and leach field.  Its design flow was ~18,000 gpd with actual flow of ~8,000 - 9,000 gpd.<br>• Limited investigation indicated that grease clogged the field due to undersized grease traps.<br>• Given the flow onsite, school authorities were given the choice of constructing a package treatment plant or connecting to the municipal sewer.  They chose to connect to the municipal sewer  (White, 1999). |
| Eureka, Montana (1997) | • In 1997, local restaurant’s septic system failed due to improper maintenance of grease trap.<br>• Septic system was a gravity flow system constructed in late 1980s.<br>• Since owners reconstructed the leaching field, no new apparent problems have arisen  (Lind, 1999). |
| Eureka, Montana (1997) | • In 1997, local restaurant’s septic system failed due to lack of system maintenance.<br>• Septic system was originally constructed more than 30 years ago.<br>• The new system uses pressure distribution  (Lind, 1999). |
| Harrisonburg, Virginia (1997) | • Motel’s septic system led to bacterial contamination of a non-community public water supply well.<br>• Both the septic system and water supply well were subsequently abandoned.<br>• No remediation was attempted.<br>• No further information available at the time of this writing  (USEPA, 1997a). |
| Olympia, Washington (1997) | • The owner of the 105-unit Greenway Terrace Mobile Home Park (MHP) was fined $70,000 by WA Department of Ecology for continuing water quality violations.<br>• MHP relied on too small a system; mid-February 1997 drainfield failed and wastewater surfaced.<br>• Required to pump wastewater from septic tank daily.<br>• Owner complied once on February 19, when 10,000 gpd were pumped, but has not subsequently complied.<br>• On February 25, the owner was fined $50,000 and the February deadline for hookup to municipal sewer system was not met (as of April 15, 1999, the owner is connected to sanitary sewers but still has not corrected the collection system)  (Washington Department of Ecology, 1997; Emmett, 1999). |
| Dennis, Massachusetts (1996) | • Supermarket located in Patriot Square Mall failed due to excessive loading (constructed during mid-1980s).<br>• Installed series of smaller systems.<br>• No problems subsequently noted  (Dudley, 1999). |

## Table 19. Examples of LCSSs Failures (continued)

| Location (Year) | Case Study |
|---|---|
| Dennis, Massachusetts (1996) | • Eagle Pond Nursing Home constructed new system to comply with Title 5 requirements for 150 gpd per bed. (Design flow went from 14-15,000 gpd to 21,000 gpd.)<br>• State official indicated that nursing homes have an accelerated failure rate when compared with other similarly sized LCSSs.<br>• Constructed new system using Bioclere units followed by denitrification, trenches using pressure distribution, and UV disinfection. UV disinfection component was to compensate for slightly smaller field size and associated risk of pathogens and viruses (Dudley, 1999). |
| Falmouth, Massachusetts (1996) | • Coonamesett Inn was releasing untreated wastewater directly into a pit (no intercept).<br>• Owners constructed 13,000 gallon rapid infiltration system with denitrification component; effluent flows to trenches using pressure distribution. Total system cost was $250,000 (Dudley, 1999). |
| Wrentham, Massachusetts (1996) | • Wrentham school site (i.e., Delaney, Roderick, Vogal schools) septic systems needed repair and replacement to meet Title 5 regulations due to increased flow.<br>• Officials approved the use of innovative/alternative septic system for the site.<br>• Utilized a Smith & Loveless, Modular Fast innovative/alternative technology system with pressure dosing to a leaching trench soil absorption system, which likely will provide requisite enhanced treatment prior to discharge (Massachusetts, 1996a). |
| Canada (1995) | • Nitrate concentrations exceeded 10 mg/l over the entire mapped length of the plume at an elementary school septic system (See Figure 10).<br>• Site conditions of a shallow unconfined aquifer down-gradient.<br>• Effluent is highly concentrated because the wastewater is primarily toilet water.<br>• Ground water flow velocity is high (328 ft/yr) and the system is old (44 years).<br>• Chloride (42-209 mg/l), sodium (34-101 mg/l), calcium (120-249 mg/l), potassium and sulphate significantly exceeded observed background levels along the entire plume.<br>• Pathogenic microorganisms were not investigated at this site (Harman et al., 1996). |
| Florida Keys, Florida (1995) | • Fecal coliform detected in ground water several hundred meters from a septic system source, caused by characteristics of underlying limestone formation.<br>• Limestone formation has very high hydraulic conductivity. Solution flow channels that formed in the highly soluble bedrock resulted in accelerated movement of injected wastewater.<br>• Fecal contamination of shallow aquifers in the Florida Keys caused by conventional septic systems and sewage treatment plant boreholes. Authors suggested that dense population in the Florida Keys and associated wastewater disposal methods were factors leading to contamination.<br>• Area vulnerable to ground water contamination because of shallow ground water aquifer and high porosity soils.<br>• Not clear whether individual septic systems served 20 or more people (Paul et al., 1995). |

## Table 19. Examples of LCSSs Failures (continued)

| Location (Year) | Case Study |
|---|---|
| Stoughton, Massachusetts (1995) | • Blue Hills Nursing Home was approved for the use of an Innovative/Alternative remediation.<br>• Existing system experienced hydraulic failure, infiltration of ground water into the pump chamber, and ponding in one of the system leaching facilities.<br>• Septic system originally designed for 8,000 gpd but the new system increases flow to 12,000 gpd.<br>• Due to site and sizing constraints, new system is required to perform enhanced treatment prior to discharge to soil absorption system (Massachusetts, 1996b). |
| Massachusetts Highway Departments and Burger King, Massachusetts (1995) | • Replacement of Burger King and restroom facilities at rest areas along Route 24 necessitated upgrading existing septic systems.<br>• Constructed during the 1950s, these systems were non-conforming with Title 5 regulations and discharged 10,000 gpd into a water supply wellfield.<br>• Rather than constructing the recommended two large Bioclere units with the upgraded system, the owners chose to pursue a connection to the municipal sewer system (Massachusetts, 1995). |
| Missoula County, Montana (1995) | • Septic systems (not necessarily LCSSs) were suspected of causing bacterial contamination in both sewered and unsewered areas.<br>• During 1994 and 1995, testing of water samples was performed with the results being compared with data from 1978.<br>• While MCLS were not exceeded for nitrate, septic systems were effecting the area's ground water.<br>• Bacterial contamination was found; three private wells continued to test positively for bacterial contamination even after the owners were instructed to chlorinate their systems.<br>• Outbreaks of ground water borne disease have been linked to septic systems in Montana. These include: (1) An outbreak of gastroenteritis affecting approximately 400 people in Flathead County; and (2) Outbreaks of gastroenteritis in 1975 and 1995 in Big Sky.<br>• Approximately 1,800 seepage pits are estimated to exist and continue to be used in Missoula County. This was felt to be a conservative estimate because prior to 1967, no record or permit was required to install a septic system and at that time one of the most popular systems were seepage pits (Missoula City-County Health Department, 1996). |
| Westport, Massachusetts (1993) | • Moby Dick Wharf Restaurant septic system was in total failure since September 1993.<br>• Raw sewage was being discharged through their parking lot, into a storm drain and then into an outfall pipe discharging into the Westport River and nearby shellfish beds. Allegedly, this discharge forced the closure of those shellfish beds.<br>• Owners paid a $40,000 fine for their system failing and agreed to construct a new sealed septic tank, which will be equipped with alarms and pumped frequently.<br>• They also agreed to study whether they could install a fully complying Title 5 system that would recycle wastewater. If this type of system was deemed infeasible, then the owners must seek DEP approval for construction of a "tight tank" that would also require frequent pump outs (Massachusetts Environmental Strike Force, 1995). |
| Washoe Valley, Nevada (1992) | • Nitrate contamination investigated in areas where elevated nitrate concentrations first observed in the mid-1970's.<br>• Four residential neighborhoods were identified where ground water nitrate levels exceeded 60 mg/l. Ground water in two neighborhoods exceeded 90 mg/l.<br>• Three potential sources were identified, although the relative contributions of each were not identified conclusively. These included septic systems, agricultural practices, and runoff from horse corrals (McKay, 1993). |

## Table 19.  Examples of LCSSs Failures  (continued)

| Location (Year) | Case Study |
|---|---|
| Ada County, Idaho (1991) | • Brookhollow Estates, a 204-home subdivision served by a 19,000 gallon septic tank and a dosing chamber, was the subject of a ground water monitoring study.<br>• The soil absorption bed is in deep soils (depth of 12-15 feet) which are well-drained and underlain by mixed alluvium.<br>• Septic tank effluent, one observation well, three domestic wells, a nearby canal, and four monitoring wells were sampled monthly from February to October, 1991.<br>• Septic system plume had above background levels of chloride (160 mg/l), sodium (169 mg/l), bicarbonate (409 mg/l), and potassium (8.5 to 9.8 mg/l).<br>• Elevated ammonia concentrations (17 to 20.5 mg/l) and low nitrate concentrations indicated the migration of effluent nitrogen to ground water in the absence of significant nitrification.  This occurred as a result of saturated flow between the soil absorption system and the seasonal high ground water table and the great depth of the system which minimized oxygen penetration.<br>• Monitoring wells showed bacteria contamination.  Down gradient monitoring wells had total coliform counts averaging 176 to 2,220 colonies/100 ml.  Fecal coliform counts averaged 47 to 270 colonies/100 ml, and fecal streptococcus counts averaged 13 to 89 colonies/100 ml  (Burnell, 1992). |
| Washington<br>(1990-1991) | • Mobile Home Parks (MHPs) were selected because they account for approximately 20 percent of all U.S. drinking water well microbiological violations.<br>• Samples from 5 MHPs were collected from onsite drinking water wells, completed in shallow unconfined aquifers composed of glacial till with low ground water flow velocities, and onsite septic systems.<br>• Sampling revealed elevated nitrates in the ground water, the result of both septic system effluent disposal or agricultural activities in the area. While measured nitrate concentrations did not exceed MCLs, the report stressed the potential of each site for future contamination.<br>• All five MHPs were built before current onsite system regulations were drafted in Washington.  Other problems noted include development and construction near the septic systems, lack of management, lack of education and regulatory enforcement, and poor maintenance. |
| Wisconsin Heights High School<br>(1967 - 1968) | • Nitrate concentrations up to 21 mg/l were measured in a well 15 feet from the drainfield.<br>• Nitrate concentrations averaged 2.2 mg/l at a distance of 265 feet from the drainfield.  Background nitrate concentrations were between 0.8 and 1.0 mg/l during the sampling period.  Dilution appeared to be responsible for the reduction of nitrate concentrations.<br>• Nitrate was not observed at concentrations greater than 10 mg/l at any time at distances greater than 100 feet from the lower edge of the soil absorption field  (Polkowski and Boyle, 1970; Wall, 1991). |

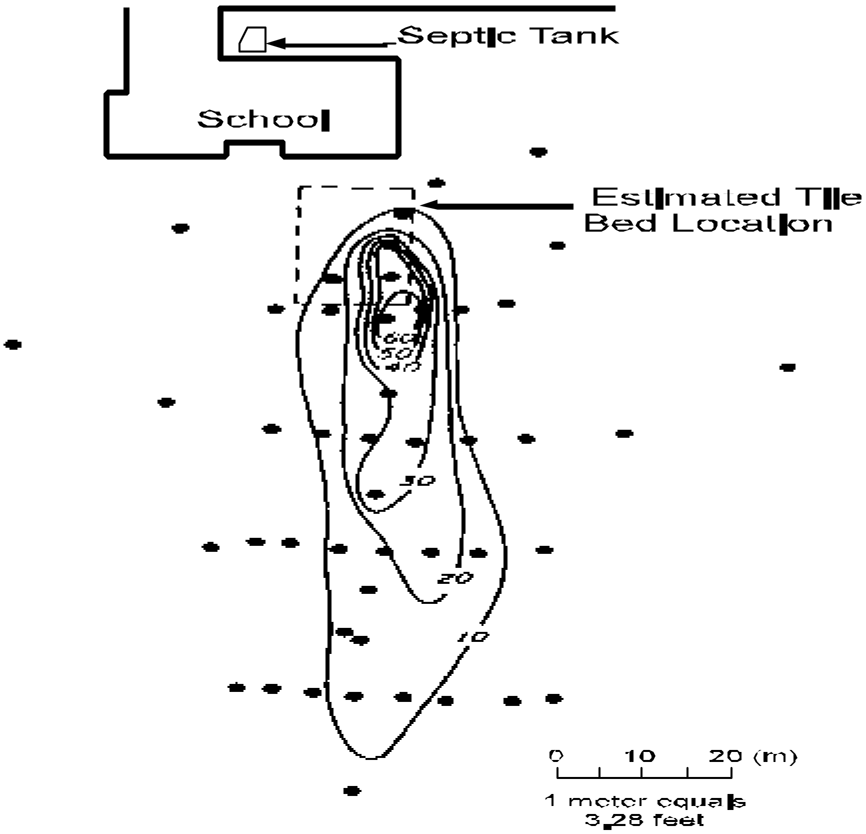
## Table 19. Examples of LCSSs Failures (continued)

| Location (Year) | Case Study |
|---|---|
| Springfield, Missouri (1988) | • Sequiota City Park contains a cave with a spring in an area underlain by highly permeable soil (residuum and limestone). The spring was part of a state park and trout hatchery and became severely degraded with sewage after the surrounding area was developed. Local authorities discovered the contamination when they found strong sewage odors upon entering the cave. Septic systems in the recharge area were believed to be the source of the contamination.<br>• Approximately 60 percent of Missouri involves soluble bedrock (limestone or dolomite), much of which is karst terrain containing solution channels. These channels move water and contaminants rapidly through the subsurface, making septic systems a potential contamination source in karst areas.<br>• Using dye tracer tests, a hydrologic connection was observed between the spring and a large septic system (serving 235 people and a cafeteria) at a nearby elementary school. The school was located 2,400 feet from the spring.<br>• The septic system had been properly constructed but poorly sited (local hydrogeology made the area unsuitable for a system of this size) (Price, 1988). |
| Easton, Massachusetts (mid-1980s) | • Easton Meadows Apartment Complex has been a problematic site since the mid-1980s when the leaching field overflowed. System failed because of design errors and lack of maintenance.<br>• Septic system included septic tanks, pumping box, and leaching field. It had a design flow rate of ~32,000 gpd and an actual flow rate of ~26,000 gpd.<br>• The septic system failed because of system overloading and poor soils.<br>• Owners are constructing a new wastewater plant with a new leaching area (White, 1999). |
| Oxford, Massachusetts (mid-1980s) | • Orchard Hills Apartment Complex experience system failure ~1985 - 1986 because of design errors and lack of maintenance.<br>• Septic system included septic tanks, pumping box, and leaching field.<br>• Owners attempted to rehabilitate the system with hydrogen peroxide during mid-1980s but failed.<br>• Now mandated to construct new treatment plant and leaching fields.<br>• New system was completed in ~1996 and has design flow of ~45,000 gpd and actual flow of ~30,000 gpd (White, 1999). |
| Minnesota (1985) | • Nitrate concentrations exceeded 10 mg/l in at least one monitoring well within the effluent plume.<br>• Occurred at four of nine LCSSs sites.<br>• At two sites, the wells with high nitrate concentrations were located more than 100 feet from the drainfield.<br>• The site with the worst nitrate contamination had monitoring wells placed 50 and 125 feet down-gradient of the drainfield with median nitrate concentrations of 24 and 16 mg/l, respectively. Background nitrate concentrations at this site were less than 0.5 mg/l (Wall, 1991). |
| Colorado (1984) | • Camp tap water contaminated by septic tank effluent from a septic system.<br>• 400 cases of gastroenteritis were caused by a Norwalk-like agent.<br>• Dye tracers revealed the system was 15.2 meters from the drinking water supply spring (Yates, 1987). |

## Table 20. Summary Statistics of LCSSs, Florida

| Type of Structure | Estimated LCSSs | Total Repairs | Non-private Establishment | Average Age |
|---|---|---|---|---|
| Barns | 19 | 0.35% | 3.26% | 14.6 |
| Church | 19 | 0.35% | 3.26% | 13.9 |
| Food Outlet | 40 | 0.75% | 6.86% | 14.3 |
| Food Service | 21 | 0.39% | 3.60% | 15.9 |
| Shopping Center | 2 | 0.04% | 0.34% | 22 |
| Multi-family Dwelling | 238 | 4.45% | 40.82% | 12.9 |
| Mobile Home Park | 28 | 0.52% | 4.80% | 11 |
| Other | 216 | 4.03% | 37.05% | 14 |
| Total LCSSs | 583 | 10.89% | – | – |
| Total County Repairs, (1992 - Oct. 1, 1998) | 5,354 | -- | -- | – |

**Figure 10. Nitrate Plume from an Elementary School.**



Source: Harman et al., 1996.

Table 21 lists several additional incidents of microbial contamination of drinking water related to LCSSs (USEPA, 1997b). The Arizona incident detailed in the table appears to be the result of several inter-related circumstances including:

- Two of the system’s five leaching fields were incapable of accepting effluent, which overloaded the other three fields and caused more accelerated infiltration of effluent.
- A malfunctioning septic tank effluent chlorinator (where effluent was treated with chlorine) caused fluctuating chlorine concentrations (in which low concentrations were not sufficient to kill microorganisms in effluent and high concentrations killed off beneficial soil organisms).
- The local alluvial plain geology allowed the rapid infiltration of wastewater through large pores and fractures in the aquifer (USEPA, 1997b).

The reasons for migration of contaminants from the septic systems in the remaining incidents presented in Table 21 are undetermined.

**Table 21. Drinking Water Contamination Incidents Caused by LCSSs**

| Location | Incident | Source of Contamination |
|---|---|---|
| Racine, Missouri | Outbreak of 28 confirmed cases of Hepatitis A at a church and a school from April through June of 1992. | Two drinking water wells contaminated with sewage from the septic system; the sewage likely contained the virus from infected persons’ stool. Dye tracers placed in the septic system were found in both church wells within five days. |
| Richmond Heights, Florida | 1,200 cases of acute gastrointestinal distress occurred between January 1 and March 15, 1974, probably caused by shigellosis (from the bacteria *Shigella*) contracted through drinking tap water. | One of the public water supply wells was continuously contaminated by sewage from a septic system at a nursery school located approximately 125 feet from the well. A dye tracer was used to track the effluent from its source to the well. Chlorination of the drinking water was interrupted two days before the epidemic began, allowing one million gallons of inadequately treated drinking water to be distributed to the community. |
| Resort area in Coconino County, Arizona | Gastroenteritis, caused by the Norwalk virus, developed in about 900 people during a visit to a new resort in a recreation area of arid central Arizona between April 17 and May 1, 1989. Of 240 guests surveyed, 110 contracted a gastrointestinal illness associated with drinking tap water from the resort's well. | At the time of the outbreak, two of the resort's five leach fields were incapable of accepting effluent. The increased flow at the operating leach fields caused water to pass through the soil quickly, reducing contact time, adsorption, and filtration. Fractures in the underlying sandstone and limestone allowed inadequately treated effluent to seep directly into the well. Dye tracers placed in the leach fields traveled to the well in three to 11 days. Failure of the automatic effluent chlorinator may have added to the problem. |

Source: USEPA, 1997b.

# 6. BEST MANAGEMENT PRACTICES

There are many best management practices (BMPs) and alternative systems that can minimize the negative effects that LCSSs may have on USDWs. These can be broadly categorized into four groups: (1) siting, (2) design, (3) construction and installation, and (4) operation and maintenance. The following discussion is neither exhaustive nor represents an USEPA preference for particular BMPs. Each state and USEPA Region may require certain BMPs to be installed and maintained based on that state's or USEPA Region's priorities and hydrogeologic conditions.

## 6.1 Siting

Proper siting is an important step towards ensuring adequate treatment of sanitary wastes by LCSSs. Siting is accomplished after performing a series of site evaluation studies. These tests are necessary in order to select the most appropriate technology and/or the most appropriate site. For instance, a site may have impermeable soils, which may require too large of a system, as well as overly permeable soils, which requires special pretreatment and dosing systems. Topographical features, elevation, depth-to-ground water, surface water hydrology contours, and ground water flow are considered by the designer. Image 1 shows a site being staked out to determine the site's elevation.

**Image 1. Site Determination**

Source: Purdue On-Site Wastewater Disposal, 1999

Several studies address geological factors that influence the siting and location of large septic systems. Septic systems with drain fields are often sited in areas containing shallow alluvial aquifers with interbedded layers of gravel, clay, and silt (USEPA, 1987). However, these systems are generally not located in areas that would be the most problematic for subsurface wastewater disposal;

Source: Purdue On-Site Wastewater Disposal, 1999 areas with a shallow impermeable layers, a shallow ground water table, or a highly permeable (coarse gravel) vadose zone. Image 2 presents one such soil evaluation.

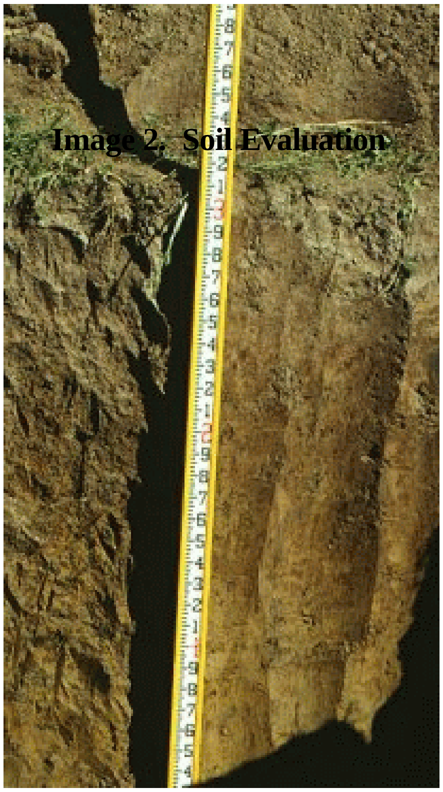


**Image 2. Soil Evaluation**

Source: Purdue On-Site Waste Disposal, 1999.

In addition to physical features, it is recommended that siting consider local environmental conditions. An article by Converse et al. (1996) discusses how these conditions, which include temperature and water supply (e.g., pH and alkalinity), may affect a septic system's efficiency. They cite how changes in temperature impact the metabolic activities of the microbial population, gas-transfer rates, and settling characteristics of the biological solids. For example, lowering ambient temperature by 18° F will reduce the system's reaction rate by almost 50 percent. Similarly, changes in water supply pH (e.g., low pH) can inhibit the performance of nitrifying organisms and provide the opportunity for filamentous organisms to grow.

Large subsurface systems generally are sited to allow space for multiple absorption fields so that fields may be rotated and given the opportunity to rest and rejuvenate. During rest, a field is aerated, allowing bacteria to decompose organics in the soil. A well-designed field left to rest for as little as six months may be considered rejuvenated (USEPA, 1997b), although resting for as long as 12 months may be more safely recommended (USEPA, 1996a).

During the rotation period, microbial life forms will die off but will reestablish themselves once the field is re-opened. This will occur naturally at a pace dictated by system environmental conditions (e.g., toxicity, microbe food sources). Use of additives is <u>not</u> considered a BMP because these products have yet to be proven to "help" systems. If improperly used, additives can clog a system's infiltrative surface. In spite of this, system owners utilize these products and states allow their use. (See Attachment A for a list of Commonwealth of Massachusetts-approved additives.) These products are mentioned in this volume <u>not</u> to encourage their use but because system owners continue to use such products.

Soils in as much as half of the United States are not suitable for conventional septic tank absorption systems (Luce and Welling, 1983). The most desirable locations are in well-drained loamy or coarse-loamy soils (USEPA, 1997b; Luce and Welling, 1983). Areas with a high water table are generally inappropriate for standard LCSSs because the insufficient unsaturated soil thickness will not allow for adequate treatment of the effluent (Burnell, 1992). Elevated systems, better pretreatment and uniform dosing and resting systems, may be the most appropriate option in such a setting.

Most states have implemented siting and construction regulations for conventional septic systems to address the factors that influence installation. However, even systems that meet state siting requirements may potentially contaminate USDWs (Williams, 1997) if improperly operated and maintained. A field study of a large-capacity septic system in Pennsylvania found ground water mounding after 2 ½ years of system operation (Walters, No date). The author notes that this condition may be the cause of the high percentage of community septic system malfunctions, since many state regulations do not cover this situation.

Improper siting of LCSSs may cause relatively high volumes of wastewater to be discharged to small areas. As discussed earlier, this could cause ground water mounding beneath the systems. Also, the infiltrative capacity of the soil in conventional soil absorption systems can decrease if the soil becomes compacted (USEPA, 1992). Compaction may occur when heavy vehicles drive over key areas of the soil absorption system during construction or afterwards. In areas risking such heavy traffic, fencing the soil absorption area and downstream zones of the plume would be a prudent method to protect the soil's treatment capabilities.

### 6.2 Design

Once site characteristics are appreciated and accounted for, design and construction of the septic system begins. System design involves a determination of the appropriate size of the tanks of a large-capacity septic system, constrained by daily flow, volume and duration of peak flow, and wastewater strength (Bounds, 1994). These factors all help determine what technology combinations are most effective at treating system influent.

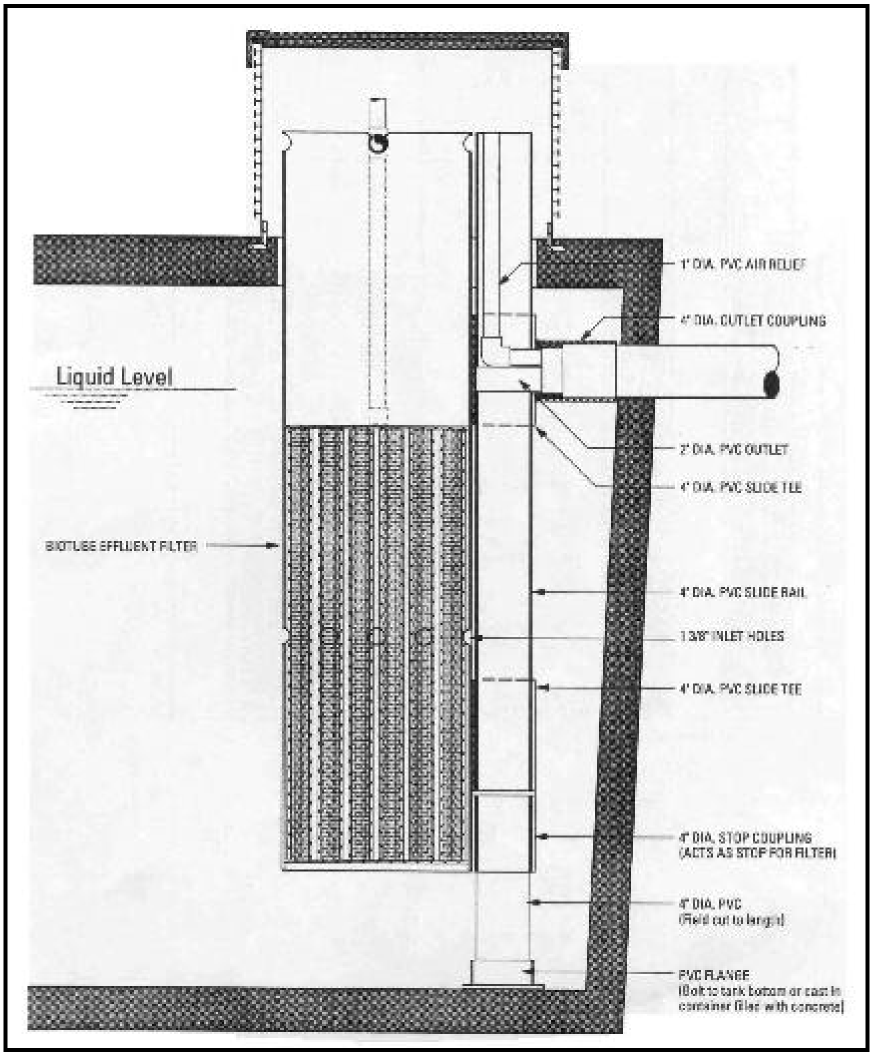
Sizing and configuration of the soil absorption component of a large septic system is based on the manner and the rate at which the effluent moves away from the system through the soil. For example, a mound may be configured long and narrow on a contour if the effluent tends to move away horizontally, rather than vertically, such as on a hillside (Converse and Tyler, 1990). Prediction of the waste load is especially critical for large systems. Accurate forecasting of population changes, and the resulting effects on the number of individuals using the system, is an important component of waste load prediction, as miscalculation may result in an overloading of the system and inadequate treatment of the effluent (USEPA, 1992). In construction of mound systems, the size distribution of the sand used to construct the mound is important. Sand that is too coarse cannot adequately treat effluent while sand that contains significant fines cannot accept high loading rates (Converse and Tyler, 1990).

In conventional systems, the septic tank may contain one or more compartments. It is recommended that the compartment(s) be tested and certified as being watertight by licensed professionals. The advantage to multiple chamber tanks compared to single chamber tanks is that they minimize the loss of solids during upset periods. In a two compartment tank, the first compartment allows initial settling of solids, and the second compartment further clarifies the effluent without interference from peak flows and digestion of solids before release to the soil absorption system.

System design may also include the use of an effluent filter insert, which can significantly improve the quality of septic tank effluent. The filter prevents large solids (particularly particles greater than 1/8") from exiting the tank. (See Figure 11.)

Effluent from the clear zone of the septic tank (the liquid between the scum and the sludge layers) enters the filter via a vertical inlet. It then enters the annular opening between the housing and biotubes, which takes advantage of the full screen surface for filtering. Upon filtration through the biotubes, the effluent flows through the outlet tee and exits the tank. These filters are easy to install, require minimal maintenance, and provide improved effluent quality. Recent testing demonstrated that effluent filter inserts produce effluent with an average TSS concentration less than 30 ppm (almost 2.5 times less than a non-screened system) (Orenco, 1997).

**Figure 11. Example of Effluent Filter Insert**



Source: Adapted from Orenco, 1997.

In addition, if a grease interceptor tank is used to handle grease, fats, and oils, the effluent can be routed to the primary tank first for further treatment rather than being routed directly to the second or pump tank (Bounds, 1994). Installation of a grease interceptor tank may be an appropriate addition to a system because an effluent stream containing grease which may all too easily overwhelm a system's infiltrative surface and cause it to fail. The typical restaurant has oil and grease concentrations varying between 1,000 and 2,000 mg/l, but the maximum effluent load is required to be less than 30 mg/l to prevent problems with the system (Crites and Tchobanoglous, 1998). Retention time in these interceptor tanks is recommended to exceed 30 minutes and must be considered in system design (Crites and Tchobanoglous, 1998).

### 6.2.1 Design Issues for Large Systems

Certain design features are generally recommended for systems treating flows greater than 1,500 gpd. These recommended general design criteria are discussed below, followed by a description of existing state-specific design criteria specific to large systems. Water Pollution Control Federation (1990) recommends that large-capacity septic system design features include:

C Trenches, 0.5 to three feet wide, excavated parallel to the surface or ground water piezometric surface contours (based on analysis or ground water mounding potential) with level bottom surfaces.

C Shallow placement of the infiltrative surfaces, less than or equal to two feet below final grade.

C Pretreatment capability to remove organics, suspended solids, grease, oils, etc. to concentrations less than or equal to typical domestic septic tank effluent.

C Uniform dosing of infiltrative surfaces four or more times daily, depending on soil type.

C Multiple drainfields (three or four minimum) to allow annual or semiannual resting and standby capacity for operational flexibility.

C Devices for monitoring daily wastewater flows, infiltrative surface ponding, ground water elevations, and plume contaminants at some downstream point.

C Multiple chambers in the septic tank, and possibly effluent filters.

Site modifications or design modifications can be made to ensure adequate performance by the septic systems. Common solutions to site limitations include modifying inappropriate soils, elevating infiltrative surfaces, reducing hydraulic and/or organic loading, reducing width and depth of infiltrative surfaces, or requiring further pretreatment to remove certain constituents.

### 6.2.2 State Design Criteria for LCSSs

A number of states have developed special design criteria for LCSSs. The definition of a large system varies between states, and states' definitions also vary from the USEPA definition under the UIC program. Specific state criteria for large systems address several areas of concern unique to larger scale systems, including the ability of available soils to treat large volumes of waste over long periods of time, the creation of a ground water mound under soil absorption fields due to large effluent volumes, system failures associated with ground water mounds, and ground water and surface water contamination incidents. A state's current regulations may differ from those of other states for a variety of site-specific reasons, and are therefore not necessarily recommended by USEPA on a national basis.

Oregon, for example, requires the following special design criteria for any treatment system that receives more than 2,500 gallons of wastewater per day:

C The use of pumps or siphons for distribution, with at least two per system.

C Relatively equal effluent distribution into the absorption units; each unit ought to receive no more than 1,300 gpd.

C A replacement (or repair) disposal area, also divided into relatively equal units, located adjacent to the initial disposal unit area.

C Alternate dosing of wastewater between soil absorption fields or units to allow saturation and aeration cycles for each unit.

C The system ought to be designed by a professional (e.g., sanitarian, hydrologist or sanitary engineer), with a written assessment of the impact of the proposed system upon the quality of drinking water and public health (Oregon Final Regulations).

For systems with a design capacity greater than 2,000 gpd, Massachusetts requires pressure distribution of effluents from septic tanks or recirculating sand filters to soil absorption systems. A dosing chamber is required for systems: designed for intermittent discharge of septic tank or recirculating sand filter effluent; using pressure dosing and that have a design flow greater than 2,000 gpd; or for which multiple soil absorption systems are proposed. Every dosing chamber, except for systems serving two dwellings or fewer, must be equipped with two pumps, the discharge lines of which must be valved to allow dosing of the entire soil absorption system by either pump. Siphons are prohibited unless they are used as part of an alternative technology. A two-compartment tank, or two tanks in series, is required when the system is designed to serve any facility other than a single-family dwelling and when system design capacity is greater than 1,000 gpd. Septic tanks in parallel require written approval of the Massachusetts Department of Environmental Protection (DEP). Grease traps are required for kitchen flows at restaurants, nursing homes, schools, hospitals, and certain other facilities (Massachusetts Final Regulations).

West Virginia requires dosing of absorption fields over 3,000 square feet in total area; absorption fields larger than 5,000 square feet must be divided into two or more units of equal size. The state also requires that land be reserved for an alternate absorption field when a structure other than a single-family dwelling, or more than one structure, is to be served (West Virginia Final Regulations). Maryland also requires dosing and resting features for multi-use, onsite sewage disposal systems designed for flows of 5,000 gpd or more (Maryland Final Regulations).

Several states require a permit review process for all large-capacity systems. Massachusetts, for example, has specific regulations regarding shared systems (serving more than one building), which must be authorized by a DEP permit. Approval is contingent upon the applicant having an operation and maintenance plan, legal documentation of ownership of the system, and documentation of a financial assurance mechanism for operation. Minnesota requires a state disposal system permit for any single or group sewage treatment systems designed to treat an average daily flow greater than 10,000 gpd (Minnesota Final Regulations). Washington requires a state waste discharge permit for septic systems with design capacities over 14,500 gpd, while Oregon requires a permit for any onsite system with flow greater than 2,500 gpd (Washington Final Regulations). In other states, local or county health departments, rather than state officials, are responsible for regulation. (See Section 7 and Attachment C of this volume for additional discussion regarding state programs.)

### 6.3 Construction and Installation

Construction and installation of the septic system ought to be conducted by individuals licensed by the state, county, or town to ensure safety and proper compliance with regulations (Ground Water Protection Council, 1994). Studies have revealed a high probability of failure when installation occurs during periods of high moisture. Smearing and compaction of soils are more likely to occur in high moisture conditions, potentially causing a reduction in the permeability of the soil and uneven wastewater distribution. It is recommended that installation be postponed if wet conditions persist (Ground Water Protection Council, 1994). Yet even in dry conditions, soil compaction can occur if sufficient care is not taken in system construction and installation. Soils with more than 25 percent of clay by weight are the greatest risk of soil compaction (Water Pollution Control Federation, 1990). Image 3 shows an instance when trench construction is recommended to be postponed.

**Image 3. Trench Construction**

Source: Purdue On-Site Waste Disposal, 1999

Maintaining soil integrity is important in order to successfully construct and operate a septic system. The construction plan generally includes explicit methods for addressing:

- Type of construction equipment;
- Construction procedures;
- Site preparation; and
- Existing soil conditions (Water Pollution Control Federation, 1990).

It is recommended that only low-load bearing equipment be used on the site, such as large rubber-tired or track-mounted vehicles (Water Pollution Control Federation, 1990). Equipment that scrapes the soil (e.g., front-end loaders, blades) must not to be used because the blade will smear the exposed soil while the tires will compact the unexposed soils. Ideally, the construction equipment would operate from outside the work area and sit on unexposed soils (Water Pollution Control Federation, 1990). This equipment would include trenchers and backhoes.

Soil damages can be minimized by utilizing effective construction procedures. These include carefully deciding where to place backfill, sand, gravel on the site as well as where to deliver and operate the equipment from. Approaching the site from either up slope or the sides will limit soil compaction. In addition, procedures to ensure that infiltrative surfaces aren't exposed more than 12 hours or during precipitation are recommended (Water Pollution Control Federation, 1990). Image 4 shows a trench being filled from the side to minimize soil damage.

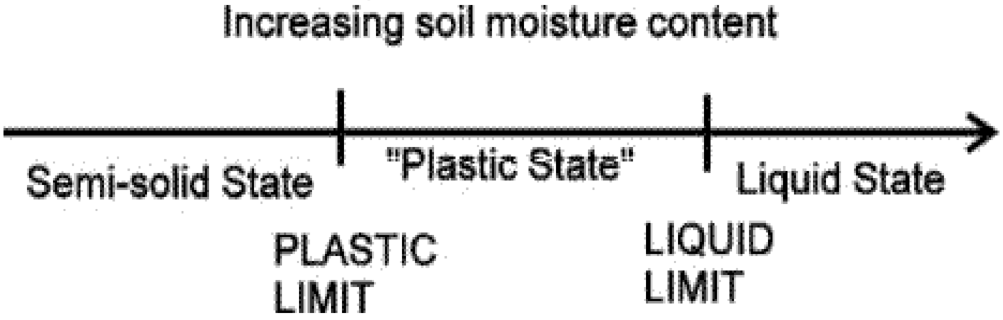
In addition, the design of new LCSSs can incorporate new products, such as infiltration chambers, to construct gravel-free leachfields (which greatly reduces site compaction). According to the manufacturer of one such product, a gravel-free leachfield increases the infiltrative efficiency of the trench by eliminating the fines commonly found in gravel systems. This manufacturer also noted that infiltration chambers can be installed more quickly than gravel systems and without the use of heavy equipment (Water Environment Federation, 1999).

**Image 4. Filling Trench with Gravel**

Source: Purdue On-Site Waste Disposal, 1999

Before the equipment is delivered to the site, the area is cleared of trees and brush and grasses (and other materials) are mown, raked and removed. It is recommended that the soil be checked again to ensure there are no conditions present to prevent construction and installation, such as the soil being frozen to within 12" of the infiltrative soil surface or the soil being near its plastic limit. The soil's plastic limit is determined by rolling a soil sample from the infiltrative surface between the hands. If the soil forms a "wire", then the soil is near its plastic limit and construction is recommended to be postponed. Image 5 highlights when soils are near their plastic limit.

**Image 5. Soil's Plastic Limit**



Source: Purdue On-Site Wastewater Disposal, 1999

If at any point during construction the soil is damaged by smearing, compaction, or puddling, the damaged soils must be removed. If this removal alters the depth to the infiltrative surface, then it may become necessary to alter the septic system's design.

### 6.4 Operation and Maintenance

By properly operating and maintaining a LCSS, two major goals are served: the system functions properly for its design life, and the potential for ground water contamination is minimized. Proper management requires that system siting decisions be integrated into land-use planning, zoning, and infrastructure development, and that operation and maintenance procedures are consistently followed. Overall management strategies are discussed below, as well as the following operation and maintenance procedures:

- Water conservation, wastewater flow reduction, pollutant mass reduction, control of household chemical use, and minimization of illegal connections or other storm water sources.
- Inspection and maintenance.
- Routine tank inspection and pump out as required.
- Rotation/resting of multiple soil absorption system.
- Troubleshooting.

#### 6.4.1 Overall Management Strategies

To reduce the possibility of system failures, regularly scheduled inspections and maintenance are crucial, especially with larger systems which have more maintenance-intensive mechanical components, such as pumps. Wastewater management utilities and districts can successfully manage decentralized, onsite systems; by collecting user fees for maintenance, repair, and replacement costs, utilities can provide comprehensive services such as comprehensive site evaluation, system design, site lay-out, and inspections (USEPA, 1995). Homeowners associations can be developed to educate users about a communal system. It is recommended that each user know who to call if a high water or pump failure light or alarm activates.

System failures may also be avoided by siting systems in appropriate areas, and by encouraging commercial and residential development in urbanizing areas where sewers are planned or exist. Sewage management agreements between health districts and municipalities can be used to protect certain vulnerable aquifers and to concentrate growth in certain areas, which makes sewering the areas more cost effective. The sewage management agreements contain specific obligations which the communities must meet in order to provide long-term protection of ground water. The communities also create municipal ordinances or resolutions that require all new subdivisions to connect to the municipal sewers as they are developed (Panhandle Health District). These types of agreements are just one example of how management of septic systems (including larger and smaller systems) can be integrated into land-use planning and zoning decision-making.

### 6.4.2 Water Conservation and Pollutant Mass Reduction

Some LCSSs may fail simply from overuse. Hydraulic overloading results if actual wastewater flows are greater than system design flows. Two solutions to this problem are to prevent non-sanitary waste water (e.g., precipitation) from infiltrating the LCSS and to undertake water conservation measures. A public information and awareness program can be used to inform users on the importance of water conservation. A housing development with centralized management of a large-capacity cluster system could provide either education about or installation of water-saving devices. Altering wasteful habits, improving maintenance of existing plumbing, and installing high-efficiency plumbing fixtures can reduce water consumption considerably. In a commercial setting, reliability and performance requirements for fixtures, appliances, and equipment could be used to meet conservation goals.

To be effective, water conservation devices ought to reduce effluent flow rates below the design capacity of the soil absorption system. Using water-saving toilets, shower heads, faucets, and front-loading washing machines can significantly reduce residential water use. Installation of low-flow fixtures on faucets and toilets can reduce domestic wastewater flows by more than 50 percent. User acceptance of such devices is generally very good, even when water use is not metered (so user cost savings are not realized), and minimal maintenance problems are encountered. Additional housekeeping aspects of water conservation include eliminating leaks and drips, maintaining proper water pressure at the tap, and, if allowed by local regulations, installing a grey water recycle system. Water conservation can be a low-cost method of addressing inadequate flow in a soil absorption system.

In addition to reducing water use, discouraging the use of garbage disposals or grinders can reduce the organic loading on the system. Pollutant mass reductions will likely occur along with water conservation measures, so that wastewater will not become more concentrated. Pretreatment systems may be used in conjunction with a conventional system to reduce mass loadings as well. Use of chemical drain cleaners or chemical products claiming to improve septic system performance is not recommended for system users. Some of these chemicals may corrode system components, and some can damage the soil's ability to adequately treat effluent. Educating system users about local household hazardous waste collection programs can help eliminate the discharge of these chemicals to septic systems. This includes products containing enzymes or bacteria, which have not been proven to enhance septic system performance.

### 6.4.3 Inspection and Maintenance

The developer of a housing complex or a commercial strip mall, the owner of a local business or mobile home park, or a community could be the owner of a large-capacity system, and thus responsible for its management. Maintenance can be required through local ordinance, and state or local permitting authorities can specify performance requirements, including the frequency of inspection and pumping. Problems, however, may arise from lack of oversight of LCSSs. For example, large systems that serve multiple housing units are often maintained by absentee management companies or homeowners' associations. With the turnover of association officers, septic system maintenance is often overlooked (Price, 1988; USEPA, 1986). Regular monitoring and inspections will help to ensure proper maintenance and operation of the system.

Most septic tank inspections are performed as part of the pumping service to identify broken baffles or cracked pipes. Rather than scheduling system pumping at set intervals, experts prefer to see regular inspections being performed to determine whether pumping is required. Older tanks are more difficult to inspect because access ports may be buried. Newer systems, equipped with surface risers, are easier to locate and inspect; however, many states do not require risers.

Various devices are used to measure the depth of the scum and sludge layers, including sticks or hollow tubes equipped with light sources for viewing depths. Accumulation rates can be estimated based on depth changes since the last inspection. Similarly, changing water levels can indicate a leaky tank.

**Image 6. Nearly Complete Trench with Observation Well**

Source: Purdue On-Site Wastewater Disposal, 1999.

Some states limit the use of siphons as a dosing device in favor of pressure distribution systems, while others allow siphons, but require frequent inspection and maintenance. Inspecting the soil absorption field for evidence of effluent surfacing above ground, the presence of septic solids, or surface erosion due to runoff of wastewater breaching the soil surface is an important maintenance activity. (Image 6 shows a trench with observation wells.) Pumps must also be regularly inspected and maintained.

The soil absorption system area has to be properly maintained and protected. Management practices include fencing off the area to deter vehicles from driving and parking on the surface and generally restricting activities which could impair the treatment capabilities of the soil.

Finally, experts recommend regularly sampling a site's ground water quality. Sampling can include testing for specific conductance, TDS, total organic carbon, nitrogen species, phosphorus, chloride and alkalinity. Sample results are compared to initial ground water quality measurements to determine the system's impact. Ground water mounding can be monitored by checking water levels and comparing the current levels to the results of the initial site investigation.

### 6.4.4 Pumping

Septage must be removed as necessary to ensure proper operation of the septic system. (Septage removal depends upon tank inspections and not a rigid pumping schedule.) As described earlier, septage consists of the materials that settle within the septic tank, known as sludge, the materials that rise to the surface of the tank, known as scum, and the liquid present in between the layers at the time of pumping. Telephone directories may be consulted for a list of properly licensed companies that pump and dispose of septage (USEPA, 1997b; Sponenberg et al., 1985). It is recommended that the septic tank access port(s) be located for easy accessibility by septic tank pumpers (Ground Water Protection Council, 1994), however some state codes require burial of the ports.

### 6.4.5 Rotation/Resting of Soil Absorption Fields

A LCSS design with several soil absorption fields is important in order to allow alternating use of the fields. With this design, effluent is spread over a larger area so that the soil's capacity to assimilate waste organics and nutrients is less likely to be exceeded.

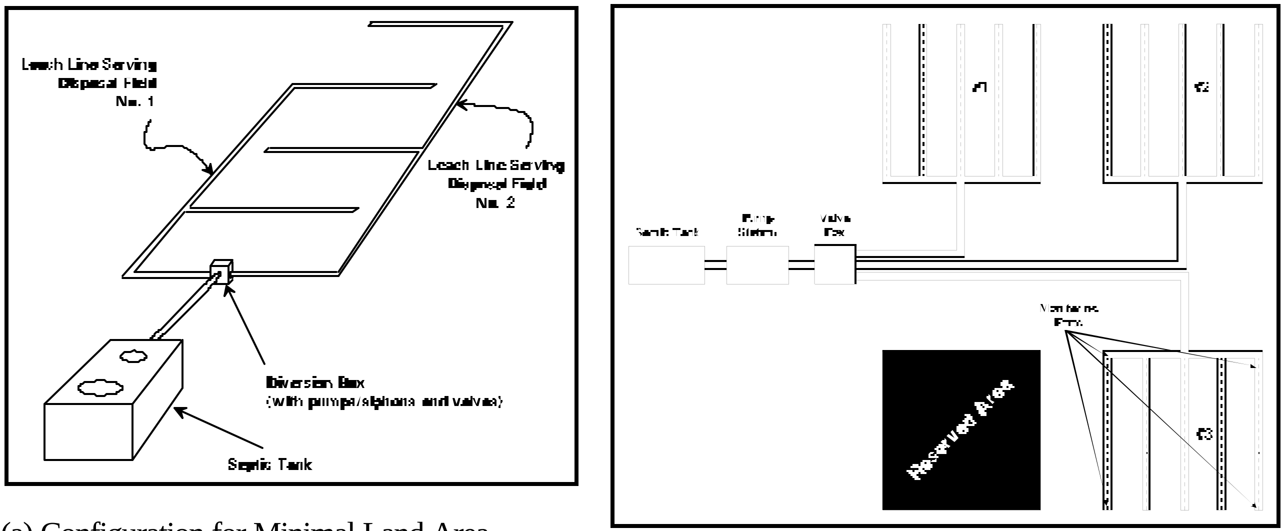
Alternating drain fields include several soil absorption systems that can be cycled into and out of service by means of a control valve or diversion box. The resting drain field can also serve as a back-up system if the operational drain field is being repaired. However, this is only a last resort, lest the resting stage be ineffective due to unintended use. Figures 12a and 12b shows two variations for alternating drain field design. Figure 12b shows a dedicated reserve area with three alternating fields; this may not always be necessary with adequate site conditions and resting periods.

When a drain field is allowed to rest, incoming air provides oxygen for aerobic bacteria to decompose organics that have accumulated in the soil biomat. This process may take one to several months, depending on the soil type, thickness of the clogging layer, and the climate. Systems left to rest more than six months during warm, dry weather are generally considered to be rejuvenated. Two full-sized drain fields, if properly designed, constructed, operated, and maintained, may last indefinitely if used only in alternate years (Perkins, 1989).

For new LCSS, it is advisable to construct the soil absorption system in a minimum of four sections (less if initial flows are well below the design flow), with each section capable of receiving 50 percent of the design septic tank effluent flow rate. In doing so, only two of the leach field areas remain on line at any given time. Each of the units may be taken out of service and rested during the year. System operation and maintenance requirements are limited to switching the direction of flow three or four times per year and conducting visual system inspections. In this way, at least six months of rest is guaranteed for each system. If long cold or wet periods are inherent in the local climate and soils are finer than sandy, a longer resting period may be advisable.

An example of the multiple drain field design is the “checkerboard” design used in Oregon. The initial absorption facility as well as the replacement area are divided into relatively equal units, adjacent to each other in a checkerboard design. Each unit is designed not to receive more than 1,300 gpd. Effluent distribution will alternate between the initial and replacement soil absorption units (Bijan, 1996).

**Figure 12. Drain Fields Configured for Alternation**



(a) Configuration for Minimal Land Area

(b) Configuration for Larger Available Land Area

Source: Adapted from Washington Department of Health, 1994.

### 6.4.6 Troubleshooting and Corrective Action

Although good design can help minimize the potential for system malfunctions, there will be cases of system failures. Image 7 shows how a LCSS can visibly fail, with raw sewage flowing to the surface (i.e., in the middle of the snow). The failure of a septic system is usually noticed when one of the following occurs:

- Slow drainage from plumbing fixtures, or backup from individual septic tanks into houses connected to a LCSS. Usually this is a problem associated with plumbing, or in a pretreatment device, but sometimes the problem can be associated with the soil absorption system itself.

- Unpleasant odors, soggy soil, dead grass or the appearance of wastewater surfacing over the leach field.

**Image 7. LCSS Drain Field Failure at Mistequa Park**

Source: ICF, 1998a.

## Causes of Septic System Failures

System failures are often caused by a crusted, or clogged, layer accumulating at soil infiltrative surfaces.

The clogging mat performs several useful functions, such as biodegradation of organic materials, attenuation of pathogen concentrations, and retarding effluent migration through the soil. Excess clogging, however, can reduce the infiltration rate of soil below the design rate for normal strength domestic septic tank effluent. Soil permeability, system design, and maintenance can all affect the degree of clogging and whether it becomes a problem.

The most important factors in controlling excess clogging include site selection, using trenches that optimize uniform distribution with effluent dosing, periodic long-term resting or rotation of the absorption fields, and controlling the concentration of organics and solids in the soil system inlet through the use of outlet filters in the septic tank and/or pretreatment devices such as sand filters.

Less obvious effects that may indicate a septic system failure (but which could also have other causes), include:

- Local outbreaks of various illnesses, including gastrointestinal illness, associated with consumption of local drinking water.

- Documented contamination of ground water or surface water, associated with various contaminant sources, including high nitrate and ammonia nitrogen concentrations, bacteria, or other pathogen indicators.

- Excessive weed or algae growth near shore if the system is located near surface water.

Septic systems can fail for reasons other than improper siting. For example, septic systems can receive hydraulic or waste loadings exceeding design flow or be improperly or insufficiently maintained. The consequences can include the discharge of incompletely treated wastewater and possible contamination of a USDW.

Listed below are some typical causes of septic system failure:

- Under-design, including the faulty design of the septic tank, a soil absorption system with inadequate hydrogeological conditions or inadequate size, or inadequate tank foundation materials that result in differential settlement and shearing of inlet or outlet pipes.

- Faulty installation, including plugged inlets or outlets from the tank, plugged lines, not enough stone in trenches, smeared soil interface (due to a number of causes, including conducting construction during wet weather), or uneven grades.

- Hydraulic overload or improper maintenance (e.g., broken or disconnected outlet devices or the addition of inappropriate chemicals to the system).

- Pump or siphon failure.

- Excessive clogging of infiltrative surfaces.

If any of the conditions noted above appear, it is recommended that efforts be taken to identify the nature and scope of any system malfunction. If the problem can be readily repaired and further testing shows that ground water or surface water has not been contaminated, then continued use of the renovated or upgraded system is appropriate. If the problems are more severe and contamination is evident, pretreatment or alternative means of wastewater treatment must be used. During the transition period, water conservation can be practiced to minimize the strain on the system. It is recommended that the owner/operator notify the local county health agency and the state environmental agency immediately upon the appearance of any warning signs of contamination.

Septic system additives are not capable of relieving problems associated with ground water or surface water contamination. These problems are usually linked to structural damage, clogging, or saturation of the soil absorption system, none of which are effectively treated by simple chemical additives. In fact, the use of chemicals may worsen the situation by destroying the capability of the system to accept or treat wastes or by directly contaminating ground water or surface water.

If septic systems have been used improperly to dispose of industrial or commercial waste streams, investigation is warranted, and closure and/or remediation may be required. USEPA's *Guidelines for Closure of Shallow Underground Waste Disposal Wells* will outline steps required to determine whether closure is required. This guidance will outline the steps recommended for determining if closure is necessary and will describe the closure process. It will also provide information regarding typical wastes produced by various industries and the sampling methods appropriate for various potential contaminants.

## 6.5 Alternative Systems

There are a number of alternative configurations that can reduce contaminant levels in septic system effluents. Several of these are aimed specifically at reduction of nitrate levels. A selection of these alternative systems are briefly explained below.

### 6.5.1 Sand Filters

Free access (intermittent) sand filters (ISF) and recirculating sand filters (RSF) are unit processes that may be used between the septic tank and the soil absorption system to further treat effluent before discharge to the soil. (Sand filters are also installed below ground but this is not a recommended BMP due to the difficulty in performing routine inspection and maintenance.) Single-pass ISFs typically involve collection drains overlaid with gravel and sand. Effluent is applied and allowed to percolate through the sand. A biological mat forms on top of the sand resulting from decomposition of organic matter. Viruses may also adsorb to biological secretions on or near the mat (Kaplan, 1991). At high loading rates, the mat must be periodically rested or tilled and possibly replaced with fresh sand to control system clogging. RSF systems retain most of the effluent for multiple passes through the sand. The retained portion can be recirculated back to either the septic tank or the recirculation tank where it is mixed with influent.

Sand filters can produce high quality effluent. Concentrations of BOD and SS are typically reduced by more than 95 percent in optimally performing systems (Tchobanoglous and Burton, 1991). Characteristics of the sand media, such as effective size and uniformity coefficient, are important for proper treatment. Sand that is too coarse will allow effluent to pass too quickly, while sand that is too fine can cause hydraulic failure (Otis, No date). However, even with the sand media being properly sized, the system risks hydraulic failure because a dosing load that is too high may overwhelm most other performance variables.

RSF systems typically include a denitrification step that has been demonstrated to remove 40 to 50 percent nitrogen from effluent (Crites and Tchobanoglous, 1998). Wastewater is supplied to a recirculation tank from both the septic tank and the sand filter. Denitrification typically occurs in the recirculation tank. As discussed earlier, temperature and efficiency are directly related (i.e., decreasing temperature results in decreasing efficiency). Specifically, RSF systems do not remove nitrogen as efficiently in cold weather as they do in warmer weather (USEPA, 1992). Use of filter systems can reduce the size requirement of the soil adsorption system as a result of the additional treatment of the effluent.

### 6.5.2 Aerobic Treatment Units

In LCSSs, aerobic treatment (AT) units are typically a second step in the treatment stream, using effluent from either the septic tank or its own pre-settling tank. While many configurations are available, the common goal of AT units is to remove organic matter and dissolved and colloidal solids that are not removed by simple sedimentation, typical in a standard septic tank (USEPA, 1980a). A secondary results of aerobic treatment includes seasonal nitrification (oxidation) of ammonia. (As well, aerobic treatment may aid in the inactivation of pathogenic organisms.)

AT systems can provide several advantages over conventional septic systems, including:

- Lower BOD and SS;
- Reduced fecal coliform bacteria; and
- Reduced odor.

The potential disadvantages for AT systems include:

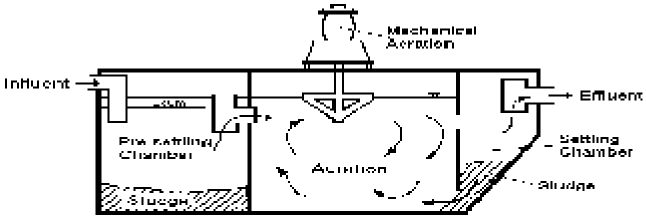
- Regular operation and maintenance required, including more frequent inspection;
- More frequent residuals pumping; and
- Continuous energy expense for mechanical systems.

In addition, AT systems are less able to withstand surge flows or rapid changes in climate (Converse et al., 1996).

AT systems can be suspended growth or fixed growth. Both provide oxygen to the wastewater, contact between the microorganisms and the wastewater, and solids separation. In suspended growth systems, the microorganisms are suspended in the wastewater by mixing, either with a mechanical mixer or blower and diffusor. The mixing process also supplies oxygen. Fixed growth systems provide a surface on which microorganisms grow. Wastewater flows across the microbes which extract the soluble organic matter. Oxygen is supplied by natural ventilation or by aeration of the wastewater and the solids are removed by settling.

The most common process scheme available for onsite wastewater treatment is suspended growth by extended aeration. Figure 13 shows a typical extended aeration system.

**Figure 13. Typical Configuration of a Flow-through Extended Aeration System.**
**(An air diffuser unit is often used in place of a mechanical aerator.)**



Onsite AT systems are typically multi-chambered (Montgomery, 1988). Wastewater is introduced into a pre-settling chamber where heavy solids separate from the liquid. Partially clarified liquid passes to the aeration chamber where a continuous flow of oxygen is introduced by mechanical mixing or submerged air diffusors. The aerated wastewater passes to the final settling chamber where the biological solids settle out and is returned to the aeration chamber as an innoculent. The clarified effluent then exits the final settling chamber for distribution, typically to a soil absorption system.

### 6.5.3 Septic Tank Effluent Pump Systems

Septic tank effluent pump (STEP) systems are septic tanks utilized to remove grease and solids. The screened septic tank effluent is pumped via a high-head turbine pump into a pressurized collection system. The typical STEP system is composed of a building sewer line, septic tank, effluent screen vault, pump basins (usually for commercial facilities), effluent screens, pumps, service lateral, and valves.

STEP systems have been used across the U.S. in a variety of soils and terrains, such as in areas with shallow soils, high ground water tables, rocky soils, or rocky terrain. Although uphill collection is most ideally suited for STEP systems, rolling terrain, in general, takes advantage of the systems capabilities.

These systems are cost effective alternatives to conventional gravity sewers and can utilize existing septic tanks as part of its system. However, in such instances, a separate pump basin (including an effluent vault or screen) is used to minimize carry-over of solids and grease. When sludge depth nears 21 inches or the scum layer thickness nears 10 inches (in a 1,000-gallon tank), scheduling the removal of the septage is recommended. It is not necessary to regularly clean the main lines of the STEP system. The average time between service calls (for older STEP systems) is 3.5 years (Crites and Tchobanoglous, 1998). Odors from the air relief value boxes can be adequately absorbed onto activated carbon, and odors from the pump stations are vented to a drainfield for soil scrubbing.

As with any LCSS, experts suggest that the plan and design of a STEP system consider local topography, density of service area buildings, and use of existing septic tanks. Furthermore, because STEP systems have been utilized for existing unsewered communities (areas in which an established housing density exists), it is recommended that current and future land use and population density also be considered during the planning and design phase.

### 6.5.4 Nitrogen Reduction Systems

The principal mechanism of nitrogen removal in treatment systems is biological nitrification-denitrification. Nitrification and denitrification involve the conversion of nitrogen through oxidation and reduction reactions. Both nitrification and denitrification depend on temperature, sludge retention period (or sludge age), pH levels, and biomass concentration (Crites and Tchobanoglous, 1998). The following paragraphs discuss the nitrification-denitrification process and nitrate removal systems.

Nitrification, which requires the input of oxygen, consists of two oxidizing steps that are performed by two types of chemoautotrophic bacteria collectively called nitrifiers, (e.g., *Nitrosomonas* for the first step; *Nitrobacter* for the second) (Benefield, 1982). Ammonia is oxidized to produce nitrites, hydrogen ions, and water. In the second step, nitrites can be oxidized further to nitrates.

$$2NH_3 + 3O_2 \rightarrow 2NO_2^- + 2H^+ + 2H_2O$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^-$$

This can be expressed as:

| | | |
|---|---|---|
| **$NH_3$ $\rightarrow$** | **$NO_2^-$ $\rightarrow$** | **$NO_3^-$** |
| **ammonia to** | **nitrite to** | **nitrate** |

The nitrifiers are extremely sensitive to changes in pH and will require additional alkalinity (via an external source) when insufficient natural alkalinity is present. Compared to an effluent with a large ammonia concentration, a nitrified effluent is more preferable for surface discharge to reduce the oxygen demand on receiving waters.

Denitrification is the process of removing combined nitrogen from soil and water by reducing nitrate to release nitrogen gas to the atmosphere. The removal of nitrate from an effluent stream by denitrification requires an anaerobic environment, the presence of facultative, heterotrophic microorganisms, and a source of organic carbon. During the decomposition of organic matter, after the supply of oxygen is exhausted from aerobic microbial respiration, microorganisms continue to respire organic matter as long as nitrate is present. The nitrate is reduced to the level of nitrite by bacteria (e.g., *Pseudomonas, Achromobacter, Bacillus, Micrococcus*). These nitrites may then be further reduced to nitrogen gas (Eckenfelder, 1980).

$$NO_3^- + BOD \rightarrow N_2 + CO_2 + 2H_2O + OH^- + cells$$

This can be expressed as:

| | | | |
|---|---|---|---|
| **$NO_3^-$ $\rightarrow$** | **$NO_2^-$ $\rightarrow$** | **$N_2O$ $\rightarrow$** | **$N_2$** |
| **nitrate to** | **nitrite to** | **nitrous oxide to** | **nitrogen gas** |

The rate of denitrification relative to the presence of dissolved oxygen is significantly influenced by the pH of the mixture. Under alkaline conditions, denitrification is promoted by strict anaerobic conditions. However, under acidic conditions active denitrification occurs in the presence of dissolved oxygen (Eckenfelder, 1980). A carbon supply (e.g., methanol) that is supplied by untreated sewage, or an industrial wastewater can increase the rate of denitrification, but is not normally used for those systems.

ISFs and RSFs, septic tanks with attached growth reactors, the RUCK system, ion exchange, an experimental Canadian construction method, and vegetation are all examples of onsite nitrogen removal processes and will be described in the following paragraphs.

Recirculating (multipass) granular medium filters (ISFs and RSFs) are low-rate, packed bed filters that are utilized in the treatment of wastewater from individual homes and other small decentralized facilities. (See Section 6.5.1.) In a recirculating system, a portion of the filtered liquid is diverted for reuse, with the remaining liquid being sent for disposal. The diverted liquid is returned to a recirculation tank where it is mixed with effluent from the septic tank and then reapplied to the filter medium. Based on forward flow from the septic tank, 3:1 to 5:1 are typical recirculation ratios for multipass systems (Crites and Tchobanoglous, 1998).

A septic tank with an attached growth reactor consists of a small trickling filter unit that is placed above the septic tank. Once the septic tank effluent is pumped over the filter, it passes through and over the plastic medium and becomes nitrified. The ammonia is then denitrified in the anaerobic media filter. System performance is highest when using a hydraulic loading rate of 2.5 gallons per minute over a three foot deep unit containing hexagonally corrugated plastic with a surface area of 67 $ft^2/ft^3$. Total nitrogen removal rates of 78 percent have been reported, which result in effluent nitrogen concentrations of less than 15 mg/l (Crites and Tchobanoglous, 1998).

The RUCK system, a proprietary variation of the ISF system, separates grey water from blackwater, providing 80 percent nitrogen removal (Crites and Tchobanoglous, 1998). Blackwater originating from toilets, sinks, and showers is treated in the blackwater septic tank and is then passed through an ISF. Grey water originating from the kitchen and laundry is treated in the grey water septic tank and then mixes with the ISF effluent.

In the Rock Storage Filter-2 (RSF-2) system, nitrification occurs in the recirculating sand filter while denitrification occurs in the anaerobic filter. Nitrogen removal rates as high as 80 to 90 have been obtained from experiments with the RSF-2 system, with the effluent's total nitrogen concentrations ranging from 7.2 to 9.6 mg/l (Crites and Tchobanoglous, 1998).

Ion exchange is another alternative method that has been used in the laboratory and limited field sites to reduce nitrogen levels after either anaerobic treatment (as ammonium) or aerobic treatment (as nitrate). In the former method, septic tank effluent is treated by pumping effluent across an ion exchange unit. These units have either cationic surfaces that remove ammonium or anionic surfaces that remove nitrate.

Canadian researchers have recently developed an experimental construction method known as special septic system lateral fields construction (Nebraska DEQ, 1996). Field tests have demonstrated a 60 to 100 percent reduction in nitrate and phosphate concentrations. Denitrification occurs as effluent seeps through a sequence of porous media. As ammonium in sewage effluent seeps through the first layer of sand, it oxidizes to nitrate. As nitrate seeps into the next layer of silt and sawdust, it is converted to nitrogen gas through the process of heterotrophic denitrification. The nitrogen gas then rises through the soil and is released to the atmosphere. This denitrification layer may be installed horizontally in the subsurface, or it may be installed as a vertical wall that intercepts the nitrate plume down-gradient from the septic system. Phosphates convert to an immobile solid phase through chemical precipitation. The system has comparable installation expenses to conventional systems, but may take more time to install.

No energy use or maintenance is required for long periods of time because of the passive nature of the treatment (Robertson and Cherry, 1995).

Vegetation can also play a role in reducing septic system nitrogen contamination (Ehrenfeld, 1987). The ability of vegetation to uptake nitrogen varies based on plant species and the spatial relationship between the plant location and the drainage field (Ehrenfeld, 1987). (See Attachment B of this volume for a list of "high moisture plants" catalogued by Merced County, California.) Specifically, nitrogen uptake is not limited to larger vegetation (e.g., trees) but may include crops or grasses because nitrification-denitrification occurs mainly in the root zone. For example, Bermuda grass has been found to remove between nine and 46 percent of nitrogen in a soil absorption system if it is harvested regularly (USEPA, 1992). For systems using water hyacinths (i.e., constructed wetlands), the wastewater with its various forms of nitrogen must flow past these roots because the bacteria responsible for nitrogen conversion are located in the water hyacinth roots. In any system, if roots are unable to intercept the effluent plume, then the presence of vegetation will not result in additional nitrogen uptake (Ehrenfeld, 1987). While vegetation can be used to reduce nitrogen, it is not a year-round method; the local growing season dictates the annual length of time that plants will be active and removing nitrogen (USEPA, 1992). Recent research on nitrogen removal by constructed wetlands indicates nitrogen removal rates can range from 20 to 60 percent, with higher percentages anticipated on average during warmer seasonal periods (Thom et al., 1998; McCarthy et al., 1998).

# 7. CURRENT REGULATORY REQUIREMENTS

As discussed below, several federal, state, and local programs exist that either directly manage or regulate LCSSs, or impact them indirectly through broad based water pollution prevention alternatives.

## 7.1 Federal Programs

On the federal level, management and regulation of LCSSs falls primarily under the UIC program authorized by the SDWA. Some states and localities have used these authorities, as well as their own authorities, to extend the controls in their areas to address endemic concerns associated with LCSSs.

### 7.1.1 SDWA

Class V wells are regulated under the authority of Part C of SDWA. Congress enacted the SDWA to ensure protection of the quality of drinking water in the United States, and Part C specifically mandates the regulation of underground injection of fluids through wells. USEPA has promulgated a series of UIC regulations under this authority. USEPA directly implements these regulations for Class V wells in 19 states or territories (Alaska, American Samoa, Arizona, California, Colorado, Hawaii, Indiana, Iowa, Kentucky, Michigan, Minnesota, Montana, New York, Pennsylvania, South Dakota, Tennessee, Virginia, Virgin Islands, and Washington, DC). USEPA also directly implements all Class V UIC programs on Tribal lands. In all other states, which are called Primacy States, state agencies implement the Class V UIC program, with primary enforcement responsibility.

LCSSs currently are not subject to any specific regulations tailored just for them, but rather are subject to the UIC regulations that exist for all Class V wells. Under 40 CFR 144.12(a), owners or operators of all injection wells, including LCSSs, are prohibited from engaging in any injection activity that allows the movement of fluids containing any contaminant into USDWs, "if the presence of that contaminant may cause a violation of any primary drinking water regulation ... or may otherwise adversely affect the health of persons."

Owners or operators of Class V wells are required to submit basic inventory information under 40 CFR 144.26. When the owner or operator submits inventory information and is operating the well such that a USDW is not endangered, the operation of the Class V well is authorized by rule. Moreover, under section 144.27, USEPA may require owners or operators of any Class V well, in USEPA-administered programs, to submit additional information deemed necessary to protect USDWs. Owners or operators who fail to submit the information required under sections 144.26 and 144.27 are prohibited from using their wells.

Sections 144.12(c) and (d) prescribe mandatory and discretionary actions to be taken by the UIC Program Director if a Class V well is not in compliance with section 144.12(a). Specifically, the Director must choose between requiring the injector to apply for an individual permit, ordering such action as closure of the well to prevent endangerment, or taking an enforcement action. Because LCSSs (like other kinds of Class V wells) are authorized by rule, they do not have to obtain a permit unless required to do so by the UIC Program Director under 40 CFR 144.25. Authorization by rule terminates upon the effective date of a permit issued or upon proper closure of the well.

Separate from the UIC program, the SDWA Amendments of 1996 establish a requirement for source water assessments. USEPA published guidance describing how the states should carry out a source water assessment program within the state's boundaries. The final guidance, entitled *Source Water Assessment and Programs Guidance* (USEPA 816-R-97-009), was released in August 1997.

State staff must conduct source water assessments that are comprised of three steps. First, state staff must delineate the boundaries of the assessment areas in the state from which one or more public drinking water systems receive supplies of drinking water. In delineating these areas, state staff must use "all reasonably available hydrogeologic information on the sources of the supply of drinking water in the state and the water flow, recharge, and discharge and any other reliable information as the state deems necessary to adequately determine such areas." Second, the state staff must identify contaminants of concern, and for those contaminants, they must inventory significant potential sources of contamination in delineated source water protection areas. Class V wells, including LCSSs, should be considered as part of this source inventory, if present in a given area. Third, the state staff must "determine the susceptibility of the public water systems in the delineated area to such contaminants." State staff should complete all of these steps by May 2003 according to the final guidance.[5]

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[5] May 2003 is the deadline including an 18-month extension.

**Table 22. A Representative Sample of State Definitions of LCSSs (continued)**

## 7.2 State and Local Programs

As discussed in Section 3 above, LCSSs are located throughout the U.S. and frequently are regulated by state and local programs. Attachment C of this volume describes many of these programs in greater detail.

The USEPA's Class V UIC program regulates septic systems capable of serving 20 or more people per day ("large-capacity septic systems") (40 CFR 146.5(e)(9)) but does not define the gpd equivalent of 20 or more persons.[6] As described in Section 7.1, USEPA directly implements the UIC Class V program in 19 states or territories. Many states, including both Primacy States for UIC Class V wells and states in which USEPA directly implements the Class V program, have also adopted regulations for LCSSs. Their definitions of "large," however, do not always correspond directly to USEPA's definition.

As Table 22 indicates, many states use a discharge limit (e.g., 5,000 gpd) to define "large-capacity." A few use a combination of a discharge limit and the number of people served (not shown).

**Table 22. A Representative Sample of State Definitions of LCSSs**

| States | Flow Definition of LCSSs |
|---|---|
| Arizona | greater than 20,000 gpd |
| Arkansas* | greater than 5,000 gpd |
| Colorado | greater than 2,000 gpd |
| Connecticut* | greater than 5,000 gpd |
| Delaware* | greater than 2,500 gpd |
| Florida* | greater than 5,000 gpd for commercial flows (10,000 gpd for residential flows) |
| Idaho* | greater than 2,500 gpd |
| Illinois* | greater than 1,500 gpd |
| Indiana | greater than 750 gpd (proposed) |
| Maryland* | greater than 5,000 gpd |
| Massachusetts* | greater than 10,000 gpd |
| Minnesota | greater than 10,000 gpd |
| Missouri* | greater than 3,000 gpd |
| Nebraska* | greater than 1,000 gpd (proposed) |
| Nevada* | greater than 5,000 gpd |
| New Hampshire* | greater than 2,500 gpd |

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[6] Sanitary engineers' estimates of 20 persons equivalent range between 2,000 - 5,000 gpd.

| **States** | **Flow Definition of LCSSs** |
|---|---|
| New Jersey* | greater than 2,000 gpd |
| New Mexico* | greater than 2,000 gpd |
| North Carolina* | greater than 3,000 gpd |
| Oklahoma* | greater than 5,000 gpd |
| Oregon* | greater than 2,500 gpd |
| Pennsylvania | greater than 10,000 gpd |
| South Dakota | greater than 7,500 gpd |
| Washington* | greater than 3,500 gpd |

* UIC Class V Primacy State

At least four different combinations of "large system" definitions and regulatory stringency are possible. Four combinations are outlined below and include regulatory examples from states to highlight each of the combinations.

- *Define LCSSs by large discharge and impose stringent requirements for LCSSs*. Some states define large systems as those receiving relatively large discharges (e.g., at least 10,000 gpd), and have adopted strict operating requirements for large systems. Massachusetts and Minnesota, for example, both use 10,00 gpd as the cutoff for LCSSs and have strict requirements for siting, construction, and operation. Florida defines LCSSs as 5,000 gpd or more and issues operating permits that are renewed annually depending on sampling results.

- *Define LCSSs as large discharge and impose additional, but less stringent, requirements for LCSSs*. Some states with a high cut-off point for defining a large septic system have adopted relatively less stringent standards. Arizona, for example, uses a cut-off point of 20,000 gpd, regulates septic systems below that cut-off through a general license, and regulates systems above the threshold by individual permits.

- *Define LCSSs as moderate discharge and impose stringent requirements for LCSSs*. Some states may adopt a relatively low cut-off point for defining a large septic system and also adopt stringent standards for such systems. Washington, for example, uses 3,500 gpd as the cutoff for defining LCSSs and requires UIC permits as well as construction and operating permits under its septic program, as well as annual reporting, annual renewal of operating permits, and other requirements. Delaware defines a large system as one with a flow of 2,500 gpd or more and issues site-specific operating requirements and inspects all large systems annually.

- *Define LCSSs as moderate discharge and impose relatively less stringent requirements for LCSSs*. Some states use much lower cut-off points to define a large system and have adopted relatively less stringent requirements. New Jersey, for example, defines large systems as those larger than 2,000 gpd and exempts large systems from obtaining discharge permits if they meet the construction standards in the regulations. Indiana regulates systems with more than 2,000 gpd and requires a construction permit based on technical guidance. In Tennessee, a large system is defined as one with a disposal field with an area greater than 2,250 square feet. The setback between drainfields and public water supplies is only 50 feet. Tennessee does not impose specific operating requirements, only a performance standard stating that it is the owner's responsibility to maintain the system in a safe and sanitary manner.

Finally, some states regulate all systems the same way, regardless of capacity. South Dakota, for example, defines a small septic system as serving 30 or fewer persons or producing 7,500 gpd or less, but does not address systems larger than small systems in its regulations.

State Class V UIC regulations and state requirements for large-capacity septic systems also can interact in a number of ways. Many states, for example, have separate regulatory frameworks for Class V UIC wells and for septic systems. The regulations may be complementary, with compliance required with both the Class V UIC requirements and the septic requirements for large septic systems, or one regulatory framework may predominate. Florida, for example, requires septic systems to satisfy both the state's UIC requirements and the requirements for onsite sewage treatment systems. Some states require individual permits for LCSSs under their Class V UIC regulations, but do not require operating permits or stricter conditions for LCSSs under their LCSS-specific regulations until a higher cutoff is reached. Thus, Rhode Island requires permits for all Class V wells, including septic systems, but imposes no additional requirements on septic systems until they reach 10,000 gpd. Direct Implementation states, which generally will not have enacted state-specific UIC requirements, are likely to have septic system regulations that require approval (if not a permit) before construction of a LCS begins.

Regulatory authority among the states varies widely. Four typical regulatory schemes are as follows:

- *General authority to protect USDWs*. The state UIC program director has discretionary authority to take actions necessary to protect USDWs. State septic regulations also are intended to protect the public health and prevent significant harm to ground water or surface water but may provide less discretionary authority to do so.

- *Permit-by-rule*. Under some state Class V UIC programs, an entire class of wells is deemed authorized as long as they comply with standards and requirements found in the regulations. State programs to regulate septic systems generally do not use permits by rule.

- *General permit*. Under some state Class V UIC programs, an identical permit, based on state technical regulations, is issued for each well in a specified class of wells. State programs to regulate septic systems generally do not make as extensive use of general permits.

- *Authority to issue site-specific permits, inspect, and take enforcement action*. This authority may be linked to technical standards in the regulations and/or may give the state UIC program director discretion to include standards necessary to protect USDWs. Similar authorities are delegated to the administrators of state septic system regulatory programs. Sometimes the technical standards for septic systems are provided in a guidance document rather than through regulations.

Although state septic system regulations vary widely, they also generally share a number of common features:

- Large systems are often permitted by states. County health departments also may supervise LCSSs, instead of or in addition to state environmental departments. When county health departments permit LCSSs, they generally apply state permitting standards.

- Construction requirements for LCSSs are generally very prescriptive. Minimum requirements do not vary substantially among the states. Most regulations, for instance, require a separation of 3-4 feet between the bottom of an absorption system and the water table. Other requirements address the materials of tanks, and the design, construction and installation of the absorption trenches, pipes, and distribution systems, as well as connections from buildings to tanks. Most states require a construction permit to be issued before construction begins.

- Most states have general authority to protect public health. Many also have requirements that contaminants in ground water must not exceed drinking water standards (i.e., MCLs). Therefore, even if a state does not have specific authority to issue and enforce permits for large-capacity septic systems, they can use these general authorities to take enforcement action against a facility that has polluted or threatens to pollute ground water. In some states, the general authority also is available to address Class V UIC wells that threaten ground water.

- Many states specify that septic systems are to be used for disposal of sewage and domestic wastewater only.

# ATTACHMENT A
# LIST OF SEPTIC TANK/DRAINFIELD ADDITIVES APPROVED BY MASSACHUSETTS

(Source: Massachusetts Department of Environmental Protection, 1998)

In accordance with Title 5 (section 15.027), the following is a list of septic system additives that have been allowed for use, with certain conditions, as it has been determined that the product will not harm the septic system components, or adversely affect system function or the environment when used on a schedule recommended by the manufacturer. (It is important to stress that the Department's determination to allow the use of an individual constituent is not an endorsement or approval with respect to the benefit, effectiveness, or performance of the system additive.)

C **Bio Rem St** (septic system additive) Caldwell Environmental. Contact person - Robert Caldwell, 978/266-1221 or 1-800-370-0077.

C **Bio Rem Gt** (soil absorption system conditioner/restorative) Contact person - Robert Caldwell, 978/266-1221 or 1-800-370-0077.

C **Septic Zest** (septic system additive) Analab Inc., 59 Davis Ave, Norwood, MA. Contact person - Mr. Kieth Marshall.

C **Trap Zap Plus** (septic system additive, soil absorption system conditioner/ restorative) Trap Zap Environmental Inc., P.O. Box 8619, 59 Lee Ave, Haledon, N.J. 07538-8619. Contact person - E.Charles Hunt, President.

C **LS-1472** (septic system additive) AquaTerra Biochemical Corporation of America, 1917 Lancaster Hutchins Road, P.O. Box 496, Lancaster, Texas 75146. Contact person - Carolyn Seroka, Regulatory Specialist, 214/438-0857.

C **Advanced Formula Rid-X** (septic system additive) Reckitt & Colman, Inc. 225 Summit Ave, Montvale, N.J. 07645-1575.

C **Ultra Rid-X** (septic system additive) Reckitt & Colman, Inc. 225 Summit Ave, Montvale, N.J. 07645-1575.

C **Aid Ox** (septic system additive) Cloroben Corporation, 1035 Belleville Tpk, Kearny, N.J. 00732. Contact person - John Wrobleski.

C **BIO-REM E-D** (septic system additive) Cape Cod Biochemical Co., P.O. Box 990, Pocasset, MA 02559. Contact person - Rick Howe.

C **CCLS** (septic system additive) Cape Cod Biochemical Co., P.O. Box 990, Pocasset, MA 02559. Contact person - Rick Howe.

C **Septic Helper 2000** (septic system additive) Miller Plante, Inc., P.O. Box 2117, Cliffside Park, N.J. 07010. Contact person - Herb Miller, President.

C **Microbe/Lift** (septic system additive) Ecological Laboratories, Inc., 70 N. Main Street, Freeport, N.Y. 11520. Contact person - Barry Richter.

C **Lenzyme and Trap Clear** (septic system additive) Lenzyme, Inc., P.O. Box 10356, Green Bay, Wisconsin. Contact person - Jeffrey Gaieski.

C **Bio Choice ES** (septic system additive) Osprey Biotechnics, 2530 Trailmate Drive, Sarasota, FL, 34243. Contact person - Peter Vandenbergh, VP.

C **K-Zyme Bioac P Plus** (septic system additive) The Conservation Consortium, 4380 Main St., Cummaquid, MA 02637. Contact person - Louis Vuilleumier.

C **Bio-Clean** (aka Plumb Clean, Wastes Go, Tank Guard) (septic system additive) Kinzie & Payne Biochemical Corp., 953 Gardenview Office Parkway, St. Louis, MO 63141. Contact person - Richard Kinzie, VP.

C **Septic Scrub** (septic system additive) ARCAN Enterprises, Inc., 10 Kevin Road, Scotch Plains, N.J. Contact person - David Keeton, President.

C **Liquid Plumr Septic System Treatment**, (septic system additive) The Clorox Company, P.O. Box 493, Pleasanton, CA 94566. Contact person - Janet Martinez.

C **Septic Booster/Septic Wash**, (septic system additive) Labadini Excavation, P.O. Box 812226, Wellesley, MA 02181. Contact person - Richard Labadini.

C **MicroSorb** (septic system additive) MicroSorb Environmental Products, Inc.; 106 Longwater Drive, Norwell, MA 02061. Contact person - William E. Baird, President.

C **Bio-Charge** (septic system additive) In-Sink Erator, 4700 21st Street, Racine, WI 53406. Contact person - Nicholas J. Hirsch, Manager.

C **Munox** (septic system additive) OSPREY Biotechnics; 2530 Trailmate Drive, Sarasota, FL 34243. Contact person - Peter A. Vandenbergh, V.P.

C **Nature's Power ST**(septic system additive) BioSolutions, Inc., 6 Stratton Drive, Westborough, MA 01581. Contact person - Patricia Labovitz.

C **Eco Solve 2000** (septic system additive) Microclean Environmental, Inc., P.O. Box 427, Spicewood, Texas 78669. Contact person - Jerome Guinn.

- **The Natural Recycler (FDB-6, KB-VF, KB-4F)** (septic system additive) Biostem LLC, 8829 Tradeway, San Antonio, Texas 78217. Contact person - David L. Johnson, Chairman.
- **Microbe/Lift Septic Tank Powder and Pro-Pump Powdered Digestant for Septic Tanks and Leach Fields** (septic system additive) Ecological Laboratories, Inc., 70 Main Street, Freeport, N.Y. 11520. Contact Person - Gayle Richter.

- **ProPump Septic Digestant and Microbe-Lift/ST** (septic system additive) Ecological Laboratories, Inc., 70 Main Street, Freeport, N.Y. 11520. Contact Person - Gayle Richter.

- **Pro-Pump Cold Weather Powder** (septic system additive) Ecological Laboratories, Inc., 70 Main Street, Freeport, N.Y. 11520. Contact Person - Gayle Richter.

- **Nature's Power System Restorer** (septic system additive) BioSolutions, Inc., 6 Stratton Drive,Westborough, MA 01581. Contact person - Patricia Labovitz.

# ATTACHMENT B
# LIST OF VEGETATION CONSIDERED TO "HELP" ONSITE SEPTIC SYSTEMS

The Merced County Division of Environmental Health in the State of California considers the following plants to be "high moisture plants which may temporarily assist in increasing the transpiration of moisture from a leaching area." They note, however, that plantings alone cannot solve a "severe sewage problem."

| Common Name | Scientific Name |
|---|---|
| **Conifers** | |
| Mt. Atlas Cedar | *Cedrus atlantica* |
| Deodar Cedar | *Cedrus deodara* |
| Maidenhair Tree | *Ginkgo biloba* |
| Hollywood Juniper | *Juniperus chinensis* torulosa |
| Yew Plum Pine | *Podocarpus macrophyllus* |
| Coast Redwood | *Sequoia sempervirens* |
| Bald Cypress | *Taxodium distichum* |
| American Cypress | *Taxodium mucronatum* |
| American Arbor Vitae | *Thuja occidentalis* |
| Giant Arbor Vitae | *Thuja plicata* |
| **Palms and Palm-Like Plants** | |
| Big Blue Hespar Palm | *Erythea armata* |
| Guadalupe Palm | *Erythea edulis* |
| Canary Island Date Palm | *Phoenix canariensis* |
| True Date Palm | *Phoenix dactylifera* |
| Sengal Date Palm | *Phoenix reclinata* |
| California Fan Palm | *Washingtonia filifera* |
| Mexican Fan Palm | *Washingtonia robusta* |
| **Broad-leaved Evergreen Trees** | |
| Bottle Tree | *Brachychiton populneum* |
| Bottle Brush | *Callistemon viminalis* |
| Hackberry | *Celtis occidentalis* |

| Common Name | Scientific Name |
|---|---|
| Cocculus (Larne Shrub) | *Cocculus laurifollus* |
| Silk Oak | *Grevillea robusta* |
| Glossy Privet | *Ligustrum lucidum* |
| Magnolia | *Magnolia grandiflora* |
| Giant Bamboo | *Phyllostachys bambusoides* |
| Southern Live Oak | *Quercus virginiana* |
| California Bay | *Umbellularia californica* |
| **Deciduous Trees** | |
| Oregon Maple | *Acer macrophyllum* |
| Box Elder | *Acer negundo* californicum |
| Japanese Maple | *Acer palmatum* |
| Purple Japanese Maple | *Acer palmatum* atropurbureum |
| Norway Maple | *Acer platanoides* |
| Swamp (Red) Maple | *Acer rubrum* |
| Silver Maple | *Acer saccharinum* |
| Italian Alder | *Alnus cordata* |
| White Alder | *Alnus rhombifolia* |
| Cerimoya | *Annona cherimola* |
| Red (River) Birch | *Betula nigra* |
| Water Birch | *Betula occidentalis* |
| White Birch | *Betula populifolia (alba)* |
| Smoke Tree | *Cotinus coggyria* |
| European beech | *Fagus sylvatica* var. *purpurea* |
| Modesto Ash | *Fraximus velutinu* modesto |
| Crepe Myrtle | *Lagerstroemia indica* |
| Sweet Gum | *Liquidambar styraciflua* |
| Tulip tree, Yellow Poplar | *Liriodendron tulipifera* |
| Osage Orange | *Maclura pomifera* |
| Chinaberry Tree | *Melia azederach* |
| Fruitless Mulberry | *Morus alba* stiblingi |

| **Common Name** | **Scientific Name** |
|---|---|
| Western Sycamore | *Platanus racemosa* |
| White Poplar, Silver Poplar | *Populus alba* |
| Balsam Poplar | *Populus balsamifera* |
| Carolina Poplar | *Populus candensis* |
| California Cottonwood | *Populus fremontii* |
| Black Cottonwood | *Populus trichocarpa* |
| Weeping Willow | *Salix babylonica* |
| Black Willow | *Salix niora* |
| Small-leaved linden | *Tilia cordata* |
| Dutch Elm | *Ulmus holiandica* |
| Jujube | *Ziziphus jujuba* |

Source: Adapted from Merced County Division of Environmental Health, 1999.

# ATTACHMENT C
# STATE AND LOCAL PROGRAM DESCRIPTIONS

This attachment extends the discussion begun in Section 7.2 of state and local programs. By focusing on states from different parts of the country, the four combinations of system flow definitions and regulatory stringency described in Section 7.2 can be better understood. Both UIC and septic-system specific requirements, and their interactions, are described when both are part of the state's regulatory framework. The descriptions highlight the state's definition of LCSSs and outline the licensing and other administrative requirements LCSSs must satisfy, and indicate whether licensing or other regulatory actions take place at the state or local level.

## C.1 Large Discharge and Stringent Requirements

### Florida

Florida is a Primacy State for UIC Class V wells. Septic systems in Florida are permitted by either the Department of Health (DOH) or the Department of Environmental Protection (DEP), depending on the flow rate of the system and whether the system utilizes a drainfield. The DOH permits systems with drainfields and flow rates under 5,000 gpd under the state's Standards for Onsite Sewage Treatment and Disposal Systems, Chapter 64E-6, Florida Administrative Code (FAC). The DEP permits systems with flow rates of 5,000 gpd or greater.

Under Florida's UIC requirements, wells that are part of domestic wastewater treatment systems, including septic systems wells receiving domestic wastewater other than those wells specifically excluded in Rule 62-528.120(4)(b) FAC, are classified as Class V Group 3 wells (62-528.600(2)(c) FAC). Rule 62-528.120(4)(b) exempts most individual or single family domestic waste residential septic systems or non-residential septic systems receiving only domestic wastewater which have the capacity to serve fewer than 20 persons per day from Florida's UIC regulations.

#### *Permitting*

A septic system may not be built without an onsite sewage treatment and disposal system permit issued under Chapter 64E-6. The DOH requires submission of detailed plans for establishments with proposed domestic sewage flow rates more than 2,500 gpd or commercial sewage flow rates more than 1,000 gpd (64E-6.004(4) FAC).

Underground injection through a Class V Group 3 well is prohibited except as authorized by permit by the DEP. Owners and operators are required to obtain a Construction/Clearance Permit before receiving permission to construct. The applicant is required to submit detailed information, including well location and depth, description of the injection system and of the proposed injectate, and any proposed pretreatment. When site-specific conditions indicate a threat to a USDW additional information must be submitted. Finally, all Class V wells are required to obtain a plugging and abandonment permit. Although §62-528.630 FAC provides for a general permit for certain categories of injection wells, Class V Group 3 domestic wastewater wells are not included, and must obtain an individual permit (62-528.630 (2) and (7) FAC).

Special rules apply to the Monroe County area (the Florida Keys). The UIC rules provide that all Class V Group 3 wells designed to inject domestic wastewater in Monroe County must be required as part of the operation permit application to provide reasonable assurance that operation of the well will not cause or contribute to a violation of surface water standards (62-528.630 (7) FAC). The septic system requirements specify that the DOH Monroe County Health Department will be the permitting agent for an aerobic treatment unit, filter unit, and injection well, where the estimated sewage flow will not exceed 2,000 gpd. For units between 2,000 gpd and 10,000 gpd the DOH will permit the aerobic treatment unit and filter unit and the DEP will permit the well (64E-6.018(b)(2) FAC).

### *Siting and Construction*

The onsite sewage treatment rule contains detailed specifications for system location and site evaluation criteria. A system must be at least 100 feet from a public drinking water well if the facility has an estimated sewage flow of more than 2,000 gpd. Special siting requirements are applied for estimated domestic sewage flows exceeding 5,000 gpd but not exceeding 10,000 gpd. The rules specify that no more than 5,000 gpd of wastewater may be discharged into any single onsite sewage treatment and disposal system (64E-6.005(9) FAC).

Under the UIC requirements, specific construction standards for Class V wells have not been enacted by Florida, because of the variety of Class V wells and their uses. Instead, the state requires the well to be designed and constructed for its intended use, in accordance with good engineering practices, and the state must approve the design and construction through a permit. Class V wells are required to be constructed so that their intended use does not violate the water quality standards in Chapter 62-520 FAC at the point of discharge, provided that the drinking water standards of 40 CFR Part 142 (1994) are met at the point of discharge (62-528.635 FAC).

### *Operating Requirements*

Domestic wastewater treatment wells (Class V Group 3) are required to obtain an operating permit. In addition, all Class V wells are required to be used or operated in such a manner that they do not present a hazard to a USDW. Domestic wastewater effluent must meet criteria established in specified rules of the FAC. Pretreatment of injectate must be performed, if necessary to ensure the fluid does not violate the applicable water quality standards in 62-520 FAC.

## Massachusetts

Massachusetts is a Primacy State for Class V UIC wells. The definitions of Class V wells do not include LCSSs, although the rules specify that Class V includes injection wells not included in Classes I through IV (310 CMR 27.03(5)). Injection of fluids through wells is prohibited except as authorized, and provided there is compliance with the state's Environmental Code and the Underground Water Source Protection Rules. The Environmental Code contains rules for onsite sewage treatment and disposal systems (310 CMR 15.000 et seq.) (Title 5) which are implemented by local Boards of Health. Systems with capacities exceeding 10,000 gpd are considered large systems under Title 5; all Title 5 systems with capacities greater than 2,000 gpd must be designed by a Massachusetts Registered Professional Engineer (310 CMR 15.220). The Ground Water Discharge Permit (GWDP) program implemented by the Massachusetts Department of Environmental Protection (DEP) also pertains to liquid effluent discharge of sanitary sewage.

*Permitting*

Discharge of pollutants to the ground water is prohibited without a GWDP issued by DEP. Discharge of liquid effluent into a Class V injection well, and discharge of a liquid effluent via subsurface leaching facilities, including but not limited to leaching pits, galleries, chambers, trenches, fields, and pipes, are specifically stated to require GWDPs (314 CMR 5.03).

Certain facilities are exempted from the requirement to obtain a GWDP:

- Systems receiving less than 10,000 gpd, provided that they are designed, constructed, and maintained, in accordance with the state's standards for onsite sewage treatment and disposal systems in 310 CMR 15.000.

- Systems receiving 10,000 to 15,000 gpd, provided that they are approved, constructed, and maintained after March 31, 1995, in accordance with 310 CMR 15.000.

- Systems receiving less than 15,000 gpd, provided that they are designed, constructed, and maintained in accordance with 310 CMR 15.000 or in accordance with its predecessor minimum standards for sanitary sewage (314 CMR 5.05(1)).

Systems required to obtain a GWDP will obtain a Minor GWDP if they discharge from 15,000 gpd to 150,000 gpd. Dischargers in excess of 150,000 gpd, or providing treatment of sewage more advanced than secondary treatment, which includes nitrification/denitrification and/or phosphorus removal, will obtain a Major GWDP. Both must supply a complete engineering report (including hydrogeological data) from a Professional Engineer, final engineering drawings, a ground water monitoring well plan, and supporting information.

A GWDP may require that no discharge may result in a violation of the Massachusetts Ground Water Quality Standards, and MCLs must be met at the point of discharge. A GWDP also may specify other general conditions (314 CMR 5.19), as well as special conditions established on a case-by-case basis. It also creates effluent limitations, compliance schedules, and monitoring, recordkeeping, reporting, and other specific requirements (314 CMR 5.10).

The requirements for onsite sewage treatment and disposal systems in 310 CMR 15.000 (Title 5) that are implemented by local approving authorities, defined as the board of health or its authorized agents or agents of health districts (310 CMR 15.003(2)), include:

- Recirculating sand filters if the system has a design flow greater than 2,000 gpd and is located in a nitrogen-sensitive area;

- Field verification of the site for suitability, percolation testing, and site assessment;

- Specified setback distances from property lines and areas of public water supplies;

- Specified effluent loading rates based on soil type; and

- Specified percolation rates.

These requirements are applicable to approvals of the construction, upgrade, or expansion of an onsite subsurface sewage disposal system unless it is one of the following:

- A system receiving only sanitary sewage where the total design flow is less than 10,000 gpd.

- A system or systems serving a facility with a total design flow of 10,000 gpd or greater but less than 15,000 gpd constructed in accordance with certain specified requirements formerly in effect.

- A facility for which subdivision approval has been obtained to construct dwellings with a cumulative design flow of 10,000 or greater if a permit has been approval to construct a system on each subdivision lot and separate lots will be conveyed to independent owners.

*Siting and Construction*

The requirements in 314 Part 5 for GWDPs specify detailed requirements for siting of systems; design; construction, repair and replacement of systems; and inspection and maintenance (314 Part 5, Subparts B - D).

**Minnesota**

USEPA Region 5 directly implements the program for UIC Class V injection wells in Minnesota. In addition, the state has adopted a nondegradation policy for its ground waters, and generally prohibits discharge of sewage or other wastes into the saturated or unsaturated zones (7060.0500 and 7060.0600 Minnesota Rules (MR)). The siting, design, construction, and maintenance of septic systems (individual sewage treatment systems or ISTS) are regulated by Chapter 7080 of the Minnesota Rules. Counties were required to adopt similar standards by January 1999.

*Permitting*

ISTSs with average design flows of 10,000 gpd or greater are required to obtain a State Disposal System (SDS) permit from the Minnesota Pollution Control Agency. The threshold applies both to a single system and to groups of systems located on adjacent properties and under single ownership

(7080.0030 MR). Permit applicants for an SDS permit must perform a site evaluation and a hydrogeologic study of the potential effects of the system on ground water quality.

*Siting and Construction*

The hydrogeologic study also will be used to determine ground water monitoring requirements (7080.0110 MR). Detailed minimum technical standards for system sizing, tanks, piping, effluent distribution, dosing of effluent, final treatment and disposal, and maintenance are specified (7080.0060 to 7080.0300 MR).

*Operating Requirements*

Systems with SDS permits must meet drinking water standards at monitoring wells located at the downgradient property boundary. Site-specific monitoring requirements also may be included in the permit.

### C.2 Large Discharge and Less Stringent Requirements

**Arizona**

USEPA Region 9 directly implements the program for UIC Class V injection wells in Arizona. The state’s ground water protection statute addresses LCSSs. Under the Arizona Revised Statutes (Title 49, Chapter 2, Article 3 - Aquifer Protection Permits) any facility that “discharges” is required to obtain an Aquifer Protection Permit (APP) from the Arizona Department of Environmental Quality (ADEQ) (§49-241.A). A discharger will not be required to obtain an APP if ADEQ determines that it will be “designed, constructed, and operated so that there will be no migration of pollutants directly to the aquifer or to the vadose zone” (§49-241.B) or some other exemption or permitting requirement applies.

*Permitting*

The Arizona APP Rules (Chapter 19, sub-chapter 9, October 1997) define an injection well as “a well which receives a discharge through pressure injection or gravity flow.” Any facility that discharges is required to obtain an individual APP from ADEQ, unless the facility is subject to a general permit. The state’s rules pertaining to general permits specify that a general permit is issued for sewage disposal systems that have flows less than 20,000 gpd and meet the following conditions:

C The subsurface disposal system must be located in soil that has a percolation rate faster than 60 minutes per inch but not faster than 1 minute per inch.

C The discharge density of effluent from the system (based on average daily flow) is not greater than a specified number of gallons or an equivalent of total nitrogen per day per acre, given specified nitrate concentrations in the ambient ground water.

- The bottom of the subsurface disposal system is at least a specified number of feet above static ground water level, at a specified soil percolation rate (R18-9-126.C).

The materials received by the system must be typical sewage and not contain specified materials such as motor oil, gasoline, paints, varnishes, solvents, pesticides, fertilizers, or similar materials.

An LCSS that must obtain a permit is required to include specific information in its application. The required information includes topographic maps; facility site plans and designs; characteristics of past as well as proposed discharge; and best available demonstrated control technology, processes, operating methods, or other alternatives to be employed in the facility. In order to obtain an individual permit, a hydrogeologic study must be performed. This study must include a description of the geology and hydrology of the area; documentation of existing quality of water in the aquifers underlying the site; any expected changes in the water quality and ground water as a result of the discharge; and the proposed location of each point of compliance (R18-9-108).

## C.3 Moderate Discharge and Stringent Requirements

### Washington

Washington is a Primacy State for UIC Class V wells. Washington UIC regulations (WAC 173-218-090) prohibit new Class V wells (i.e., wells constructed after 1984) that inject industrial, municipal, or commercial waste fluids into or above an USDW.

#### *Permitting*

Existing Class V wells injecting industrial, municipal, or commercial waste fluids must apply to the Department of Ecology for approval to operate. The department issues permits under the state waste discharge program (WAC 173-216). Wells injecting other fluids are only required to meet inventory requirements. Most large septic systems probably fall under the last category, because the quality of the water they inject is supposed to be equivalent to that of residential sewage. Onsite sewage systems are also regulated by the Department of Health (DOH) under WAC 246-272, with large systems with design flows greater than 3,500 gpd subject to additional requirements, including operating permit requirements, specified in WAC 246-272-08001.

The Department of Ecology has authority for systems larger than 14,500 gpd and for mechanical treatment systems larger than 3,500 gpd. The DOH has authority over most other large systems. The DOH may transfer authority for large onsite sewage systems to the local department of health on a case-by-case basis. Large system operators must obtain a permit (valid for two years) before beginning construction, repair, or expansion. With their plans they must submit a report signed by an engineer, including a site and soil analysis, discussion of compliance with other regulations, and a management plan (including O&M tasks and schedules, creation of a management entity, monitoring and reporting schedules).

#### *Siting and Construction*

Setbacks between drainfields and public and private wells and surface water (whether used as a water supply or not) are 100 feet minimum. Separation between drainfields and springs used as public water supplies must be at least 200 feet.

Within areas of special concern, the permit issuing authority may require onsite sewage systems to meet additional standards, such as setbacks, design standards, or monitoring requirements. Areas of special concern may include shellfish beds, sole source aquifers, wellhead protection areas, flood-prone areas, and other areas designated by local health departments or the Department of Ecology.

Some design standards for large systems are not included in the regulations. They are in a separate document called "Design Standards for Large On-Site Sewage Systems." All large systems must be built according to the criteria listed in this manual. The regulations do include minimum setbacks, vertical separations, lot sizes, and other standards which apply to large systems. They are very detailed and depend on soil type and land use. For example, depending on soil type, the minimum lot size is 1 to 2.5 acres per 450 gpd of sewage if there is a private well on the lot or 12,500 square feet to 22,000 square feet per 450 gpd if there is no well on the lot.

The DOH requires large systems to have a management entity approved by the department.

Large systems must construct three drainfields, each able to hold 50 percent of the design flow. The third drainfield is to be used during repair and rest of the first two fields. In addition, an area the size of one of the drainfields must be reserved in case an existing drainfield fails. Each drainfield must have a monitoring port at each corner. Each trench must be 4.5 feet apart. The gravel fill used in drainfields must be 0.75-1.5 inches in diameter.

No formula is provided for determining appropriate drainfield size, but the quantity obtained by dividing design flow by the proposed area must not exceed the loading rate for each soil type provided in the design standards manual.

Standards for septic tanks, pumps, and dosing chambers are provided in a separate manual, the DOH's "Design and Construction Standards for On-Site Wastewater System Tanks." Some requirements are included in the regulations: the minimum design flow must be 1.5 times the maximum daily flow; the tank must be designed to contain liquid to a depth of no more than six feet (preferably five feet); the tank must also be designed such that a volume equal to 20 percent of the liquid capacity must be reserved for storage of scum.

Minimum capacities for wastewater flow include 65 gpd per person for motels and hotels, 300 gpd per bed for hospitals, 360 gpd per unit for mobile homes, 16 gpd per person for schools with cafeterias, gyms, and showers, and 50 gpd per seat for restaurants.

### *Operating Requirements*

New and existing large systems built after July 1984 that are required to obtain operating permits must renew those permits annually. Owners must submit an O&M manual and submit an annual report describing how the system has been operated, maintained, and monitored. O&M tasks are also described in the management plan submitted before construction.

The DOH conducts a "pre-site" inspection as well as a final inspection before operation begins. The DOH also may ask local health departments for assistance in inspection or site review. Within special areas of concern, onsite sewage systems will be inspected by the local health officer every three years. Systems serving food service establishments must be inspected annually.

Onsite systems of all sizes are required to check the level of solids in the tank every three years, pump the tank when necessary, preventing soil compaction, and divert runoff.

## C.4 Moderate Discharge and Less Stringent Requirements

### Indiana

USEPA Region 5 directly implements the program for UIC Class V injection wells in Indiana. In addition, the state Department of Health (DOH) has authority over commercial septic tank absorption fields. DOH does not regulate systems with capacities of less than 2,000 gpd. It provides smaller systems with its Bulletin S.E. 13, "On-site Water Supply and Wastewater Disposal for Public and Commercial Establishments" (1988). Furthermore, such systems are regulated by local sewage disposal ordinances, if any. DOH approves systems over 2,000 gpd.

*Permitting*

DOH requires systems over 2,000 gpd to obtain permits. A commercial onsite wastewater disposal facility is required to obtain a construction permit (410 IAC 6-10-5). An application must supply construction plans and maps, a report by a certified professional soil scientist or similar expert, a calculation of wastewater characteristics and estimated flow, and other information as necessary. Detailed technical requirements for such systems are provided in Bulletin S.E. 13.

*Operating Requirements*

The construction permit may incorporate any limitations, terms or conditions necessary to provide a functional, easily operated, enduring commercial onsite wastewater disposal facility, or to prevent a health hazard, nuisance, surface water pollution, or ground water pollution (410 IAC 6-10-9). In addition, the rules incorporate the operating requirements in Bulletin S.E. 13 by reference.

### Tennessee

USEPA Region 4 directly implements the program for UIC Class V injection wells in Tennessee. In addition, the state has enacted a regulation addressing underground injection in Section 1200-4-6-.01 of the Tennessee Administrative Code (TAC) pursuant to the state's Water Quality Control Act. The statute protects all waters of the state, including ground water. Under the Tennessee UIC rules, construction and operation of an injection well is prohibited unless authorized by an injection well permit or by a rule of the Department of Environment and Conservation (DE&C) (1200-4-6.03 TAC). The UIC rules explicitly prohibit the use of any well to dispose of water carrying human waste, household or business waste, raw sewage or the effluent from any septic tank or other sewer system of any kind (1200-4-6-.14 TAC, citing the Water Code §39-6-103(a)).

The DE&C regulates subsurface sewage disposal systems (1200-1-6 TAC). The rules define a large conventional system as a system exceeding 2,250 square feet of disposal field. The rules also specify that when the design daily flow from a single source exceeds 3,000 gpd, separate disposal fields, each of which cannot exceed 3,000 gpd, are required (1200-1-6.06 TAC).

*Permitting*

No subsurface sewage disposal system may be constructed without a permit (1200-1-6-.05 TAC). The septic system rules do not provide details concerning the contents of the application or the criteria for issuing a permit. In practice, design plans must be submitted.

*Siting and Construction*

The septic system rules specify criteria for the design of the system, construction procedures, required capacity, tank design, effluent treatment devices that may be used, location with respect to other features such as dwellings, streams, and sinkholes, design of dosing systems, installation procedures, maintenance, and other features (1200-1-6-.06 to 1200-1-6-.14 TAC). The rules state that the variety of wells and uses preclude specific construction standards. A well must be designed and constructed for its intended use, in accordance with good engineering practices, and the design and construction must be approved by the DE&C. Wells must be constructed so that their intended use does not violate the water quality standards (1200-4-6-.14(7) TAC).

*Operating Requirements*

Operating requirements for septic systems are established in the construction permit on a case-by-case basis.

**Utah**

Utah is a Primacy State for UIC Class V wells. Large septic systems are also regulated by the Department of Environmental Quality (DEQ) under Rule R317-5, “Large Underground Wastewater Disposal Systems.”

*Permitting*

Existing and new Class V injection wells are authorized by rule until further requirements under future rules become applicable (R-317-7-6). Large systems are defined as those systems receiving discharge of domestic wastewater exceeding 5,000 gpd. While not prohibited outright by the state, systems larger than 15,000 gpd are discouraged (R317-5-1.1).

### *Siting and Construction*

The DEQ must review all plans for new systems or extensions of existing systems. An engineering report must be submitted with the plans for a large system. All designs must be prepared under the supervision of a registered professional engineer (R-317-5-1.2 and 1.3). After plan review, the Utah Water Pollution Control Committee issues a construction permit.

General performance standards for siting and construction provide that location and installation shall be such that with reasonable maintenance, a system will function properly and not create a nuisance or health hazard or endanger water quality. In addition, due consideration must be given to the size and shape of the area in which the system is installed, slope of natural and finished grade, soil characteristics, maximum ground water elevation, proximity of water supplies or water bodies, possible flooding, and expansion potential. Setbacks between disposal systems and shallow wells or springs ought to be at least 1,500 feet. Setbacks less than 1,500 feet will be reviewed on a case by case basis. Disposal systems must be set back at least 100 feet from deep wells. The setback from reservoirs and other surface water bodies also should be at least 100 feet, although exceptions may be made.

Septic tanks receiving wastewater flows of more than 1,500 gpd must have a minimum capacity of 1,125 gallons plus 75 percent of the daily wastewater flow. Liquid depth in the tank must be between 30 and 72 inches. Tanks may be divided into up to three compartments. Other requirements apply for the inlets and outlets to the tank. A minimum of five percolation tests at different sites must be performed to determine appropriate placement of absorption systems.

If a common wastewater disposal system is used for multiple units under separate ownership, the system must be built as two independent systems, each able to accept the maximum daily flow. Undeveloped land appropriate for an absorption system must also be reserved in the event a third absorption system is necessary. In addition, an organization must be created which will have responsibility for the system (R-317-5-1.6). Detailed requirements are included in the rules for absorption fields. The regulations also include standards for design of absorption beds and seepage pits.

### *Operating Requirements*

There are no specific operating requirements, only performance standards. The owner is required to operate and maintain the system so that it functions properly. An O&M manual must be written and be available at inspection (R-317-5-1.4).

### *Inspection*

Systems must be inspected by the Department of Health after installation but before backfilling.

## C.5 Standard Requirements Regardless of Discharge

### South Carolina

South Carolina is a Primacy State for UIC Class V wells. The state's UIC program is implemented by the Department of Health and Environmental Control (DHEC). The UIC regulations are found in Chapter 61 Part 87 of the state regulations. Unauthorized injection of any fluids to the subsurface or ground waters of the state by means of an injection well is prohibited except as authorized by permit or rule (R61-87.4). The movement of fluids containing wastes or contaminants into USDWs as a result of injection is prohibited if the waste or contaminant may cause a violation of any drinking water standard or otherwise adversely affect the health of persons (R61-87.5).

The UIC rules divide Class V wells into two groups. LCSSs are not assigned to either group (R61-87.10E.and F). Instead, the state classifies industrial disposal wells and municipal or privately owned disposal wells for disposing of domestic sewage or other waste not hazardous or radioactive as UIC Class I wells (R61-87.11 A(1)(b)). The rules provide that no person may construct, operate, or use a UIC Class I well for injection (R61-87.11 A(2)).

Individual sewage treatment and disposal systems are permitted and regulated by the DHEC under separate regulations (Chapter 61 Part 56). The septic regulations also do not define large septic systems, except to specify that when the actual or estimated sewage flow exceeds 1,500 gpd, the system must meet large system standards developed (apparently on a case-by-case basis) by the Health Authority (R61-56§V.D). The state may require that the design of the individual sewage disposal system be prepared by a Registered Professional Engineer (R61-56 §VI.A.6).

#### *Permitting*

A permit to construct must be obtained from DHEC prior to construction. An application form is provided, and the Health Authority of DHEC performs a site evaluation to determine the feasibility of the system (R61-56 §IV.A).

#### *Siting and Construction*

The Health Authority will determine if the site meets minimum standards for soil texture, depth of soil to rock, and maximum seasonal high water elevation. The maximum seasonal high water table elevation may not be less than 6 inches below the bottom of the proposed soil absorption trenches or alternate system. Depth to rock or other restrictive horizons must be more than 1 foot below the bottom of the proposed absorption trenches or alternative system.

The Health Authority is authorized to develop large system standards for systems with estimated wastewater flow exceeding 1,500 gpd, and systems exceeding that flow will be required to meet such standards (R61-56 § V). Plans for systems with estimated flows exceeding 1,500 gpd also may be required to be prepared by a Registered Professional Engineer (R61-56 §VI.A.6). The rules specify minimum technical requirements for systems and construction criteria (R61-56 §§VI - XI).

## South Dakota

South Dakota's UIC regulations (South Dakota Administrative Rule (SDAR) 74:55:02:03) do not require Class V well operators to obtain permits. Class V wells may inject but are subject to the provisions of the state's statutory ground water protection strategy (SD Codified Law 34A2). The state also regulates large septic systems under its regulations for water supply and treatment systems (SDAR 74:53), specifically under 74:53:01, "Individual and small on-site wastewater systems." South Dakota defines an individual onsite wastewater system as a system or facility for treating, neutralizing, stabilizing, or dispersing wastes from one source. A "small" onsite wastewater system is defined as a system or device for the collection, storage, treatment, neutralization, stabilization, and dispersal of wastewater from dwellings or other facilities which serve 30 or fewer individuals or produce 7,500 or less gpd of wastewater. Some of these systems could qualify as LCSSs under the federal definition. Systems larger than small systems are not addressed in these regulations.

### *Permitting*

All except conventional individual systems must submit plans and specifications to the Department of Environment and Natural Resources (DENR) for review and approval before construction begins (SDAR 74:53:01:03). The rule does not specify that a construction permit is required, only "approval." Installers of individual and small onsite wastewater systems must be certified (SDAR 74:53:02:02). Requirements for obtaining installers' certification are specified in SDAR 74:53:02.

### *Siting and Construction*

Designers of each system must take into consideration the distance from any producing water well to the proposed septic tank and absorption system, the slope of the site and the gradient from any water well to the system, the seasonal high water table, regular water table, percolation rate, lot size, and the type of and maximum daily wastewater flow to be treated (SDAR 74:53:01:14).

A separation of at least four feet is required between an absorption bed, the lowest construction joint on a septic tank, or any other component of a subsurface absorption system, and the seasonal high water table, regular water table, bedrock, or impervious soil layers (SDAR 74:53:01:15). Setbacks of 150 feet are required between absorption fields and wells less than 100 feet deep. A minimum of 100 feet is required between absorption fields and cisterns, reservoirs, lakes, and streams.

The minimum lot size for installation of a septic system is 20,000 square feet, or one acre (43,560 square feet) if a private well is also on the lot (SDAR 74:53:01:16).

Septic tanks must be capable of supporting a static vertical load of 1,000 pounds per square foot when backfilled. Concrete tanks poured onsite must be at least 3.5 inches thick; fiberglass or plastic tanks must be at least 0.25 inches thick. Tanks larger than 3,000 gallons fabricated as a single unit must have two or more compartments, of which the minimum dimension is two feet. Each compartment must have an access hole. Liquid depth in the tank must be between 30 and 72 inches. There are also detailed requirements for inlet and outlet elevations and baffle positions (SDAR 74:53:01:23).

Tank capacity must be increased by 20 percent if the tank will be receiving waste from a garbage disposal. Tanks receiving large amounts of oil or grease must have grease interceptors with a minimum capacity of 750 gallons. Water from garbage disposals may not be discharged into grease interceptors. Septic tanks receiving wastewater flows of more than 1,500 gpd must have a minimum capacity of 1,125 gallons plus 75 percent of the daily wastewater flow (SDAR 74:53:01:25).

A dosing chamber must be installed when the total length of absorption lines exceeds 750 feet, the area of the absorption system exceeds 1,200 square feet, or any single absorption line exceeds 100 feet in length. The chamber must have an automatic siphon or pump with level control switches and an alarm system (SDAR 74:53:01:27).

A percolation test (with a minimum of three test holes) is required before installation of absorption fields. Requirements for distribution of septic tank effluent to absorption fields vary based on elevation changes within the absorption field. Absorption systems may not be located in floodplains without prior written approval (SDAR 74:53:01:28). An absorption system must have at least two trenches of about equal length. Each may not be wider than three feet, and the bottom of the trench must be between 18 and 48 inches below the ground surface. Each trench must be at least six feet apart. The fill in the trenches must be between 0.5 and 2.5 inches in size (SDAR 74:53:01:35). There are additional requirements for mound or evapotranspiration individual or small systems. Plans for these must be prepared by a professional engineer or licensed plumber (SDAR 74:53:01:37).

#### *Operating Requirements*

Operation of approved systems must be in accordance with plans and specifications (SDAR 74:53:01:03). No system may cause a violation of any existing water quality standard, cause a health hazard, fail to meet the requirements for primary treatment before being discharged to an absorption system, or discharge wastewater into surface or state waters, except for some gray water systems, or into unused wells, gravel pits, or fissured rock formations. Runoff must not be allowed to enter wastewater systems (SDAR 74:53:01:08-17).

The DENR is authorized to inspect installation, equipment, and operation of an onsite wastewater system at any time, but there is no minimum inspection requirement (SDAR 74:53:01:42).

### Texas

Texas is a Primacy State for UIC Class V wells. The Injection Well Act (Chapter 27 of the Texas Water Code) and Title 3 of the Natural Resources Code provide statutory authority for the UIC program. Regulations establishing the UIC program are found in Title 30, Chapter 331 of the Texas Administrative Code (TAC). Underground injection is prohibited, unless authorized by permit or rule (331.7 TAC). By rule, injection into a UIC Class V well is authorized, although the Texas Natural Resources Control Commission (TNRCC) may require the owner or operator of a well authorized by rule to apply for and obtain an injection well permit (331.9 TAC). The permit by rule, however, does not apply to new (post 1986) Class V wells used for the disposal of over 1,000 gpd of sewage or sewage effluent, which must apply for and receive a permit from the TNRCC before operation (331.9 (b) TAC).

Texas also has a separate regulatory process, administered by the TNRCC, for permitting onsite sewage facilities. The TNRCC may delegate the authority to a local government entity authorized by the TNRCC (285.3 and 285.2(5) TAC).

### *Permitting*

The TNRCC rules on onsite sewage facilities address planning, installation, construction, operation, and maintenance of onsite sewage facilities. Such systems are defined as systems that produce not more than 5,000 gpd and are used only for disposal of sewage produced on the site (30 TAC 285.2).

No UIC permit or authorization by rule is allowed where an injection well causes or allows the movement of fluid that would result in the pollution of a USDW. A permit or authorization by rule must include terms and conditions reasonably necessary to protect fresh water from pollution (331.5 TAC). Although most Class V wells in Texas are authorized by rule, injection into new Class V wells used for the disposal of over 1,000 gpd of sewage or sewage effluent must obtain an individual permit before operation may begin (331.9(b) TAC). Detailed permitting procedures and requirements are not supplied in the regulations.

### *Siting and Construction*

The Texas requirements for onsite septic systems specify planning, construction, and installation standards and maintenance and management practices (285.32 - 285.39 TAC). In addition, special requirements are specified for onsite septic systems in the recharge zone of the Edwards Aquifer (285.40 TAC).

The UIC program specifies that all Class V wells must be completed in accordance with explicit specifications in the rules, unless otherwise authorized by the TNRCC.

### *Operating Requirements*

The design and proposed operation of an onsite septic system will be reviewed in the permitting process. Maintenance and management practices are also specified by rule, and are required to be supplied to the owner of the system by the installer (285.39 TAC).

The UIC program does not specify operating requirements in its regulations.

# ATTACHMENT D
# METHODS OF TRACKING EFFLUENT FLOW IN GROUND WATER

Several different methods have been developed to model the movement of potential contaminants through septic systems and into the ground water. Some of these methods are discussed below.

McKay (1993) explored potentially using tracer tests to site septic systems and nitrogen isotopes to delineate the source of nitrogen. The study concluded that as a management tool in regulating and siting septic systems, tracer tests appear to have limited potential. The utility of the tracer test is limited by the expense of the necessary number of observation wells. However, nitrogen isotopes were reported as showing some promise as a means of delineating sources of nitrate and ammonia.

Canter and Knox (1984) found that no specific technical methodology existed for evaluating ground water effects of septic tank systems. However, they identified two empirical assessment methodologies, one analytical method, and a solute transport model that were helpful in evaluating the effect of large-scale systems on ground water. Magner developed a two-dimensional model to predict the ground water flow field below large soil absorption systems (Magner et al., 1987). The model was applied to two systems in Minnesota and, using piezometers to monitor actual conditions, was found to be a reasonable predictor of the flow fields. The authors conclude that the model can be used to estimate the impact of potential pollutants to neighboring wells.

Bauman and Schafer (1984) found that there were several numerical models available to predict pollutant flow in ground water systems, but they tended to be complex and require a high level of mathematics skills, computer access, and a detailed knowledge of site-specific aquifer characteristics. The authors developed a simplified numerical model, requiring limited site-specific data, that can be used by local authorities to evaluate the impacts of septic systems on ground water. Officials can also use the model to compare the susceptibility of local aquifers to ground water contamination from septic systems. USEPA Region 10 has been using the Bauman-Schaffer model for Sole Source Aquifer project reviews that involve proposed LCSSs or single-family septic systems (Williams, 1997).

Luce and Welling (1983) conducted a study of the movement of nitrates, phosphates and fecal coliform from septic disposal systems installed in selected Connecticut soils. Results of the study were compared with prediction models currently being used by the Connecticut Department of Environmental Protection in their permitting procedure and the Nelson-Ward prediction model. The authors provide no indication of whether the models accurately predicted the fate and transport of the contaminants in the subsurface.

Yates (1987) presented a rating system which can be used to site septic systems to minimize the potential for these systems to cause microbial contamination of ground water. The rating system identified several factors important in the fate and transport of microorganisms from septic systems. A later study by Yates and Yates (1989) presented a method of determining appropriate setback distances for septic systems to minimize viral contamination of drinking water. In a study by Bechdol et al. (1994), the authors used VIRALT, an USEPA-approved model that predicts the fate of viruses, to evaluate the effect of septic system discharges on drinking water wells. Finnemore (1995) took the accurate and widely applicable hand calculations of Hantush and generated a numerical computer model which predicts mounding of the ground water table beneath recharge sources, including septic systems. Uebler et al. (1991) have developed a simplified ground water mounding model for use with a hand held calculator. Given that several field studies have shown how septic system effluent moves in plumes rather than as an advancing front, it is probable that each of these models will require modification to account for immediate local impact prediction.

Examples of such local models used to estimate contamination risk include the following programs. In a paper by Missoula City-County Health Department (1996), the DRASTIC model was used to analyze and rank unsewered areas of Montana. The DRASTIC model is an “aquifer sensitivity method” that evaluates local hydrogeologic features and determines the relative sensitivity of ground water to septic systems. Massachusetts developed a stand-alone model to assess the impact of land use decisions on water quality in MA DEP approved Zone II (i.e., well recharge area) (Massachusetts, 1999).

In Massachusetts, another model, SepTrack, is used by local officials to track septic system permits and other system information, such as maintenance and inspection schedules (Deal, 1998). In Michigan, a program was developed using Microsoft Visual Basic to monitor ponding in absorption trenches and to control trench dosing at a LCSS operated by the Rose Hill Center (average flow of 5,300 gpd) (Loudon et al., 1998).

Part of successful system management is determining the system’s lifespan, given local conditions. Keys et al. (1998) developed a mass-balance model for gravel wastewater infiltration systems in sandy soils to estimate system lifespan and loading rates. In addition, Adams et al. (1998) developed the Failure Analysis Chart for Troubleshooting Septic Systems (FACTSS) flowchart, which allows owners to identify why their system failed and what they can do to repair it, if allowed to do so.

# REFERENCES

Adams, A., M.T. Hoover, B. Arrington, and G. Young. 1998. "FACTSS: Failure Analysis Chart for Troubleshooting Septic Systems," In On-Site Wastewater Treatment, Proceedings of the Eighth International Symposium on Individual and Small Community Sewage Systems. Orlando, Florida, March 8-10, 1998. St. Joseph, MI: American Society of Agricultural Engineers.

Alyeska Pipeline Service, Co. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 26, 1995.

American Gas Association. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 27, 1995.

Bauman, B.J. and W.M. Schafer. 1984. "Estimating Ground-Water Quality Impacts From On-Site Sewage Treatment Systems," In On-Site Wastewater Treatment. Proceedings of the Fourth National Symposium on Individual and Small Community Sewage Systems. New Orleans, LA, December 10-11, 1984. New Orleans, LA: American Society of Agricultural Engineers.

Bechdol, M.L. A.J. Gold, and J.H. Gorres. 1994. "Modeling Viral Contamination from On-Site Wastewater Disposal in Coastal Watersheds," In On-Site Wastewater Treatment, Proceedings of the Seventh International Symposium on Individual and Small Community Sewage Systems. Atlanta, Georgia, December 11-13, 1994. Atlanta, GA: American Society of Agricultural Engineers.

Benefield, L.D. and C.W. Randall. 1995. Biological Process Design for Wastewater Treatment. Charlottesville: Teleprint Publishing, Inc.

Bijan, P. 1996. Oregon Department of Environmental Quality, Water Quality. Telephone Conversation with Kevin Blake, ICF Inc. October 1996.

Bounds, T.R. 1994. "Septic Tank Sizes for Large Flows," In Proceedings of the Seventh International Symposium on Individual and Small Community Sewage Systems. Atlanta Georgia, December 11-13, 1994. St Joseph, Michigan: American Society of Agricultural Engineers.

Brown, B.A. and C.M. Spence. 1991. "Design of Control Devices to increase Reliability of Large Onsite Sewage Systems," In Proceedings of the 6th National Symposium on Individual and Small Community Sewage Systems. Chicago, IL.

Brown, C.A., K.B. Kiernan, J.F. Ferguson, and M.M. Benjamin. 1982. "Treatability of Recreational Vehicle Wastewater at Highway Rest Areas." Transportation Research Record 995, Transport. Res. Board. Washington, DC.

Burnell, B.N. 1992. Development of Management Tools for Community Septic Systems. Idaho Department of Health and Welfare.

Burleson, B. 1999. Marion County Health Department, Florida. Telephone Conversation with Kevin Blake, ICF Inc. April 1999.

Canter, L.W. 1987. "Chapter 4: Ground Water Pollution Sources." Ground Water Quality Protection. Lewis Publishers, Inc.

Canter, L.W. and R.C. Knox, eds. 1985. "Ground Water Pollution from Septic Tank Systems." In Septic Tank Effects on Ground Water Quality. Chelsea, Michigan: Lewis Publishers, Inc. 45-83.

Canter, L. and R.C. Knox. 1984. Evaluation Of Septic Tank System Effects on Groundwater Quality. National Center for Groundwater Research, University of Oklahoma, U.S. EPA.

Casson, L.W., M.O.D. Ritter, L.M. Cossentino, and P. Gupta. 1997. "Survival and Recovery of Seeded HIV in Water and Wastewater," Water Environment Research. 69(2): 178-179.

Converse, J.C., J.O. Peterson, and E.J. Tyler. 1996. "Aerobic Systems for Onsite Treatment of Domestic Wastes." University of Wisconsin College of Agricultural and Life Sciences, Madison, Wisconsin. January 1996.

Converse, J.C. and E.J. Tyler. 1990. "Wisconsin Mound Soil Absorption System Siting, Design and Construction Manual." University of Wisconsin Small Scale Waste Management Project School of Natural Resources College of Agricultural and Life Sciences, Madison, Wisconsin. January 1990.

Crites, R. and G. Tchobanoglous. 1998. Small and Decentralized Wastewater Management Systems. Boston: WCB/McGraw-Hill.

Deal, K. 1998. "Analysis of Septic System Failure in Gallatin County, Montana." Montana State University Extension Service, May 1998.

DeBorde, D. C., W.W. Woessner, B. Lauerman, and P.N. Ball. 1998. "Virus Occurrence and Transport in a School Septic System and Unconfined Aquifer," Ground Water 36 (September-October) 5: 825-834.

Dudley, B. 1999. Massachusetts Department of Environmental Protection. Telephone Conversation with Kevin Blake, ICF Inc. March 5, 1999.

Eastburn, R.P. and W.F. Ritter. 1984. "Denitrification in On-Site Wastewater Treatment Systems - A Review," In On-Site Wastewater Treatment. Proceedings of the Fourth National Symposium on Individual and Small Community Sewage Systems. New Orleans, LA, December 10-11, 1984. New Orleans, LA: American Society of Agricultural Engineers.

Eckenfelder, Jr., W.W. 1980. Principles of Water Quality Management. Boston: CBI Publishing Company, Inc.

Ehrenfeld, J.G. 1987. “The Role of Woody Vegetation in Preventing Ground Water Pollution by Nitrogen from Septic Tank Leachate.” Water Resources. 1987, 21(5): 605-614.

Elvebak, M. 1997. Minnesota Pollution Control Agency, Water Quality Division, Memorandum to Anhar Karimjee, Office of Water, U.S. Environmental Protection Agency, St. Paul, Minnesota. November 5, 1997.

Emmett, K.1999. Washington Department of Ecology. Telephone Conversation with Kevin Blake, ICF Inc. April 15, 1999.

R.G. Feachum, D.J. Bradley, H. Garelick, and D.D. Mara. 1983. “Sanitation and Disease, Health Aspects of Excreta and Wastewater Management,” In World Bank Studies in Water Supply and Sanitation. Chichester and Wiley.

Finnemore, E.J. 1995. “A Program to Calculate Ground-Water Mound Heights.” Ground Water. 1995, 33(1): 139-143.

Florida Department of Environmental Protection. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 25, 1995.

Ground Water Protection Council. 1994. An Overview of the Design and Installation of On-Site Wastewater Treatment Systems. Oklahoma City, OK: Ground Water Protection Council.

Harman, J., W.D. Robertson, J.A. Cherry, and L. Zanini. 1996. “Impacts on a Sand Aquifer from an Old Septic System: Nitrate and Phosphate.” Groundwater. 1996, 34(6): 1105-1114.

Harris, P.J. 1995. “Water Quality Impacts from On-Site Waste Disposal Systems to Coastal Areas through Groundwater Discharge.” Environmental Geology. 1995, (March):262-268.

Hawaii Department of Health. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 24, 1995.

ICF Incorporated. 1998a. “Onsite Wastewater Treatment System Evaluations for Facilities on Indian Tribal Lands in EPA Region 10,” Prepared for U.S. EPA Region 10 (OW-136), EPA Contract No. 68-C6-0029. September 30, 1998.

ICF Incorporated. 1998b. “Initial Look at Recreational Vehicle Waste Disposal at Roadside Rest Areas Serviced by Septic Tank Systems,” Draft Memorandum to Robyn Delehanty, dated November 23, 1998.

Kaplan, B. 1991. “Degradation of Groundwater by Septic Systems.” Septic Systems Handbook, Lewis Publishers, 133-144.

Keys, J.R., E.J. Tyler, and J.C. Converse. 1998. “Predicting Life for Wastewater Absorption Systems,” In On-Site Wastewater Treatment, Proceedings of the Eighth International Symposium on Individual and Small Community Sewage Systems. Orlando, Florida, March 8-10, 1998. St. Joseph, MI: American Society of Agricultural Engineers.

Knape, B.K. 1984. “Sewage Disposal Wells,” In Underground Injection Operations in Texas, A Classification and Assessment of Underground Injection Activities. 11.1-11.13, 13.16. Austin, Texas: Texas Department of Water Resources.

Laak, Rein. 1986. *Wastewater Engineering Design for Unsewered Areas* - 2nd Edition. Technomic Publishing Co. Inc.

Lawson, H.W., M.M. Braun, R.I. Glass, S.E. Stine, S.S. Monroe, H.K. Atrash, L.E. Lee, and S.J. Englender. 1991. “Waterborne Outbreak of Norwalk Virus gastroenteritis at a Southwest U.S. Resort: Role of Geological Formations in Contamination of Well Water.” The Lancet (May 18, 1991): 1200-1204.

Lind, K. 1999. Lincoln County, Montana, Department of Environmental Health. Telephone Conversation with Kevin Blake, ICF Inc. April 14, 1999.

Luce, H.D. and T.G. Welling. 1983. Movement of Nitrates, Phosphates, and Fecal Coliform Bacteria from Disposal Systems Installed in Selected Connecticut Soils. Office of Water Research and Technology, NTIS no. PB83-219808.

Magner, J.A., D.B. Wall, W.J. Zaadnoordijk, and R.A. Piper. 1987. “Predicting the Ground Water Flow Field Under Large Soil Absorption Systems Using a Simple Two-Dimensional, Analytical Model,” In On-Site Wastewater Treatment Proceedings of Fifth National Symposium on Individual and Small-Community Sewage Systems. Chicago, Illinois, December 14-15, 1987. Chicago, IL: American Society of Agricultural Engineers.

Massachusetts Final Regulations. No date. *Chapter 15, Sections 15.223 - 15.254, 15.290 - 15.293.*

Massachusetts Department of Environmental Protection. 1999. “The Nitrogen Loading Computer Model.” <http://www.state.ma.us/dep/brp/dws/noticewb.html.> (February 19, 1999).

Massachusetts Department of Environmental Protection. 1998. “List of Septic Tank/Drainfield Additives Approved by Massachusetts.” Commonwealth of Massachusetts; Executive Office of Environmental Affairs; Department of Environmental Protection; Bureau of Resource Protection. July 1998.

Massachusetts Department of Environmental Protection. 1996a. “Innovative Septic System Repair at Wrentham Schools.” <http://www.state.ma.us/dep/sero/files/wrentham.html.> (April 6,1999).

Massachusetts Department of Environmental Protection. 1996b. “Blue Hills Nursing Home Septic Repair.” <http://www.state.ma.us/dep/sero/files/bluehill.html.> (February 19,1999).

Massachusetts Department of Environmental Protection. 1995. "DEP Works with Burger King for Better Resource Protection." <http://www.state.ma.us/dep/sero/files/burgers.html.> (April 6,1999).

Massachusetts Environmental Strike Force. 1995. "Westport Restaurant, Owners, to Pay $40,000 for Allegedly Polluting Shellfish Beds." < http://www.state.ma.us/dep/esf/files/westport.htm.> (December 29, 1998).

McCarthy, B., R. Axler, S.M. Geerts, J. Henneck, D. Nordman, J. Crosby, and P. Weidman. 1998. "Performance of Alternative Treatment Systems in Northern Minnesota," In On-Site Wastewater Treatment, Proceedings of the Eighth International Symposium on Individual and Small Community Sewage Systems. Orlando, Florida, March 8-10, 1998. St. Joseph, MI: American Society of Agricultural Engineers.

McKay, W.A. 1993. Application of Groundwater Tracers and Nitrogen Isotopes in the Evaluation of Septic System Contamination at Washoe Valley, Nevada. Submitted to U.S. EPA, Shallow Injection Well Initiative, December 1993.

Merced County Division of Environmental Health. 1999. "Vegetation and Septic Systems."< www.co.merced.ca.us/envhlth/ehprog/vegetat.htm.> (March 5, 1999).

Metcalf & Eddy, Inc. 1992. Washington Shallow Well Initiative: Septic System Study. Prepared for U.S. EPA, Region 10, May 1, 1992.

Metcalf & Eddy, Inc. 1979. Wastewater Engineering: Treatment/Disposal/Reuse. Revised. George Tchobanoglous. New York: McGraw-Hill Book Company.

Miller, J.C. 1972. "Nitrate Contamination of the Water-table Aquifer in Delaware," Delaware Geological Survey Report of Investigations, No. 20. 1972.

Minnesota Final Regulations. No date. *Chapter 7080, Section 7080.0030, Subpart 1A.*

Minnesota Pollution Control Agency. 1984. High Rate Soil Absorption (HRSA) Task Force Final Report. Roseville, Minnesota: Minnesota Pollution Control Agency. November 1984.

Mississippi Department of Environmental Quality. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 25, 1995.

Missoula City-County Health Department. 1996. "Evaluation of Unsewered Areas in Missoula, Montana." Missoula Valley Water Quality District, Environmental Health Division. March 1996.

Monsanto. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 19, 1995.

Montgomery, T. 1988. Home-Scale Wastewater Treatment Systems. New Alchemy Institute, Tech. Bulletin No. 6.

National Funeral Home Directors Association. 1995. “Funeral Home Wastestream Audit Report.” June 9, 1995.

National Small Flows Clearinghouse 1997. A Guide to State Level Onsite Regulations. Morgantown, WV: National Small Flows Clearinghouse, WWBKRG01. September 1997.

National Small Flows Clearinghouse. 1996. Summary of Onsite Systems in the United States, 1993. Morgantown, WV: National Small Flows Clearinghouse. December 1996.

National Small Flows Clearinghouse. 1995a. Septic Tanks From the State Regulations. Morgantown, WV: National Small Flows Clearinghouse, WWPCRG25. March 1995.

National Small Flows Clearinghouse. 1995b. Site Evaluation from the State Regulations. Morgantown, WV: National Small Flows Clearinghouse, WWPCRG27.

National Small Flows Clearinghouse. No date. Fact Sheet Package: On-Site Systems. Morgantown, WV: National Small Flows Clearinghouse.

Nebraska Department of Environmental Quality. 1996. “New Septic System Lateral Field Design Approved.” News Release. October 30, 1996.

Ohio Environmental Protection Agency. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 25, 1995.

Olsen, T. 1997. National Small Flows Clearinghouse. Telephone Conversation with Kevin Blake, ICF Inc.

Oregon Final Regulations. No date. *Chapter 340, Division 71-520-On-Site Sewage Disposal - Large Systems.*

Orenco Systems Inc. 1997. Orenco Systems Inc. Handbook. Sutherlin, Oregon. February 26, 1997.

Otis, R.J. No date. “Onsite Wastewater Treatment: Intermittent Sand Filters.”

Panhandle Health District I. No date. Rathdrum Prairie Aquifer Protection Program, Idaho, *Sewage Management Agreements.*

Paul, J.H., J.B. Rose, S. Jiang, C. Kellogg, and E.A. Shinn. 1995. “Occurrence of Fecal Indicator Bacteria in Surface Waters and the Subsurface Aquifer in Key Largo, Florida.” Applied and Environmental Microbiology. 61(6): 2235-2241.

Pearson, F.H., H.R. McLean, and S.A. Klein. 1991. “Pilot-scale Septic Tank Treatment of Preservative-laden Waste,” Journal Water Pollution Control Federation. 63: 999-1011.

Pearson, F., D. Jenkins, H. McLean, and S. Klein. 1980a. “Recreation Vehicle Waste Disposal in Roadside Rest Septic Tank Systems.” Federal Highway Administration, Sacramento, CA. June 1980.

Pearson, F., C. Shiun-Chung, and M. Gautier. 1980b. “Toxic Inhibition of Anaerobic Biodegradation.” Journal Water Pollution Control Federation. 52(3): 472-482.

Perkins, R.J. 1989. *Onsite Wastewater Disposal.* Lewis Publishers, Inc.

Polkowski, L.B. and W.C. Boyle. 1970. “Ground Water Quality Adjacent to Septic Tank-soil Absorption System,” University of Wisconsin Engineering Experiment Station.

Powelson, D.K. and C.P. Gerba. 1994. “Virus Removal from Sewage Effluents During Saturated and Unsaturated Flow Through Soil Columns.” Water Research. 1994, 28(10): 2175-2181.

Purdue On-Site Wastewater Disposal. 1999. “On-Site Images.” <danpatch.ecn.purdue.edu/~epados/septics/image.htm> (August 9, 1999).

Price, D.J. 1988. “Contamination Problems and Siting Considerations Associated with Septic Tanks in Karst Areas of Missouri” In Proceedings of the International Symposium on Class V Injection Well Technology Las Vegas, NV, Sept. 13-15, 1988. Las Vegas, NV: Underground Injection Practices Council Research Foundation, (1988): 99-117.

Reneau, Jr., R.B., C. Hagedorn, and M.J. Degan. 1989. “Fate and Transport of Biological and Inorganic Contaminants from On-Site Disposal of Domestic Wastewater.” Journal of Environmental Quality. 18(2): 135-144.

Ritter, W.F. and A.E.M. Churnside. 1984. “Impact of Land Use on Ground Water Quality in Southern Delaware.” Ground Water. 1984, 22 (January-February):1: 38-47.

Robertson, W.D. and J.A. Cherry. 1995. “In Situ Denitrification of Septic-system Nitrate Using Reactive Porous Media Barriers: Field Trials.” Ground Water. 1995, 33 (1): 99-111.

Santa Clara Valley Water District. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 16, 1995.

Scandura, J.E. and M.D. Sobsey. 1997. “Viral and Bacterial Contamination of Groundwater from On-Site Sewage Treatment Systems.” Wat. Sci. Tech. 1997, 35(11/12):141-146.

Sherman, K.M. et al. 1988. “Class V Sewage Disposal System Research in the State of Florida.” In Proceedings of the International Symposium on Class V Injection Well Technology, Las Vegas, NV, Sept. 13-15, 1988, Las Vegas: Underground Injection Practices Council Research Foundation, (1988): 99-117.

Sherman, K.M. et al. No date. “Class V Sewage Disposal System Research in the State of Florida.” Florida Department of Health and Rehabilitative Services, Tallahassee, FL.

Snyder, D.T., D.S. Morgan and T.S. McGrath. 1994. “Estimation of Ground-Water Recharge from Precipitation, Runoff into Drywells, and On-Site Waste-Disposal Systems in the Portland Basin, Oregon, and Washington.” Water-Resources Investigations Report 92-4010, U.S. Geological Survey, Portland, Oregon, 26-31.

South Dakota Department of Natural Resources. 1995 Comments on Proposed Class V Rule (60 FR 44652). October 26, 1995.

Sponenberg, D., J.K. Kahn, and K.P. Seveback. 1985. “A Homeowners Guide to Septic Systems.” Virginia Water Resources Research Center, Virginia Tech.

Tchobanoglous, G. and F. Burton. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse, 3rd Edition, Metcalf and Eddy, New York, NY: McGraw-Hill.

Texas Chemical Council. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 26, 1995.

Thom, O.M., Y.T. Wang, and J.S. Dinger. 1998. “Long-term Results in Residential Constructed Wetlands,” In On-Site Wastewater Treatment, Proceedings of the Eighth International Symposium on Individual and Small Community Sewage Systems. Orlando, Florida, March 8-10, 1998. St. Joseph, MI: American Society of Agricultural Engineers.

Tyler, E.J., R. Laak, E. McCoy, and S.S. Sandhu. 1977. “The Soil as a Treatment System, ” In Proceedings of the Second National Home Sewage Treatment Symposium, Chicago, IL, Dec. 12-13, 1977. Chicago: American Society of Agricultural Engineers, (1977): 22-37.

Uebler, R.R., R. Marinshaw, S. Berkowitz, and S. Steinbeck. 1991. “A Simplified Technique for Groundwater Mounding Analysis,” In Proceedings of the 6th National Symposium on Individual and Small Community Sewage Systems, Chicago, IL, December 16, 1991. Chicago: American Society of Agricultural Engineers, (1991): 201-205.

U.S. Department of Energy. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 30, 1995.

U.S. Department of Health and Human Services, Indian Health Service. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 27, 1995.

U.S. Environmental Protection Agency (USEPA). 1999a. “Integrated Risk Information System (IRIS).” Office of Research and Development, National Center for Environmental Assessment. Cincinnati, OH. <http://www.epa.gov/ngispgm3/iris/index.html.> (March 1999).

U.S. EPA. 1999b. “National Primary Drinking Water Regulations Technical Fact Sheets.” Office of Water. Office of Ground Water and Drinking Water. Washington, D.C. <http://www.epa.gov/OGWDW/hfacts.html.> (March 1999).

U.S. EPA. 1998a National Primary Drinking Water Regulations. (40 CFR §141.32).

U.S. EPA. 1998b National secondary drinking water regulations. (40 CFR §143).

U.S. EPA. 1997a. USEPA Region 3, UIC staff interview by USEPA, Philadelphia, PA. 1997.

U.S. EPA. 1997b. Large-Capacity Septic System Guidance. DRAFT. Office of Water. Washington, D.C. EPA 816-R-97-002. March 1997.

U.S. EPA. 1996a. Region 9, Drinking Water Program. Wastewater Treatment Alternatives to Septic Systems. Guidance Document. San Francisco, CA: Region 9 Drinking Water Program, EPA/909-K-96-001. June 1996.

U.S. EPA. 1996b. Drinking Water Regulations and Health Advisories. Office of Water. Washington, D.C. EPA 822-B-96-002.

U.S. EPA. 1995. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. Office of Water. Washington, D.C. PB93-234672. 1995.

U.S. EPA. 1993. Health Advisories for Drinking Water Contaminants. Office of Water Health Advisories. Lewis Publishers, Ann Arbor.

U.S. EPA. 1992. An Overview and Research Bibliography for Reducing Nitrogen Loading from Septic Systems. Office of Water. Washington, D.C. July 1992.

U.S. EPA. 1991a. Alternative Wastewater Collection Systems. Office of Research and Development, Office of Water. Washington, D.C. EPA/625/1-91/024. October 1991.

U.S. EPA. 1991b. Guidance on Reducing Nitrogen Loading from Septic Systems. Office of Water. Washington, D.C. December 1991.

U.S. EPA. 1987. Report to Congress: Class V Injection Wells. Office of Water. Washington, D.C. EPA 570/9-87-006. September 1987

U.S. EPA. 1986. Septic Systems and Ground-Water Protection: A Program Manager's Guide and Reference Book. Office of Ground-Water Protection. Washington, D.C. EPA 440/6-86-006. July 1986.

U.S. EPA. 1984. National secondary drinking water regulations. EPA 570/9-76-000.

U.S. EPA. 1980a. Design Manual - Onsite Wastewater Treatment and Disposal Systems. EPA 625/1-80-012. October 1980.

U.S. EPA. 1980b. Sources of Toxic Compounds in Household Wastewater. Office of Research and Development. Cincinnati, OH. EPA-600/2-80-128. August 1980.

Viessman, Jr., W. and M.J. Hammer. 1993. <u>Water Supply and Pollution Control</u>. New York: Harper Collins College Publishers.

Wall, D.B. 1991. "Septic Systems: Contributions to Ground Water Nitrogen and Best Management Practices to Reduce Nitrogen Contamination," In <u>Nitrogen in Minnesota Ground Water</u>. St. Paul, Minnesota: Minnesota Pollution Control Agency, Chapter 1.

Walters, D.H. No date. <u>Case Study Number 8: Iselin, Pennsylvania, Community Absorption Bed</u>. Morgantown, WV: National Small Flows Clearinghouse, West Virginia University. WWBLCS08.

Washington Department of Ecology. 1997. "Mobile Park Owner Fined $70,000 for Water Quality Violations." <http://www.wa.gov/ecology/pie/1997news/97-036.html.> (April 13, 1999).

Washington Department of Ecology. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 25, 1995.

Washington Department of Health. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 4, 1995.

Washington Department of Health. 1994. Design Standards for Large On-Site Sewage Systems. December 1993, Amended July 1994.

Washington Final Regulations. No date. *Title 173, Chapter 216, Section 050(1)(f).*

Water Environment Federation. 1999. <u>Wastewater Technology</u>. "Problem Solvers: Infiltrator Chambers Minimize Environmental Concerns at Resort Leachfield." Alexandria, VA. 2(3):16-18.

Water Pollution Control Federation. 1990. <u>Natural Systems for Wastewater Treatment: Manual of Practice FD-16</u>. Alexandria, VA.

Westinghouse Hanford Company. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 24, 1995.

White, R. 1999. Massachusetts Department of Environmental Protection. Telephone Conversation with Kevin Blake, ICF Inc.

Williams, J. 1997. USEPA Region 10. Memorandum to Anhar Karimjee, Office of Water, U.S. Environmental Protection Agency. October 4, 1997.

Wyoming Department of Environmental Quality, Water Quality Division. 1995. Comments on Proposed Class V Rule (60 FR 44652). October 25, 1995.

Yates, M.V. 1987. Septic Tank Siting to Minimize the Contamination of Ground Water by Microorganisms. Washington, D.C.: U.S. EPA, Office of Ground-Water Protection, June 1987.

Yates, M.V. and S.R. Yates. 1989. "Septic Tank Setback Distances: A Way to Minimize Virus Contamination Of Drinking Water." Ground Water. 27 (2):202-208.

Ziebell, W.A., D.H. Nero, J.F. Deininger, and E. McCoy. 1975. "Use of Bacteria in Assessing Waste Treatment and Soil Disposal System," In Proceedings of the National Home Sewage Disposal Symposium, Chicago, IL, Dec. 9-10, 1974, Chicago: American Society of Agricultural Engineers, (1975): 58-63.