U.S. Department of Housing and Urban Development
Office of Policy Development and Research

ON-SITE RECIRCULATING SAND FILTERS FOR TREATMENT AND DISPOSAL OF RESIDENTIAL WASTEWATER

NAHB RESEARCH CENTER

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Prepared for:

U.S. Department of Housing and Urban Development
Office of Policy Development and Research

Prepared by:

NAHB Research Center
Upper Marlboro, MD

Instrument No. DU100K000005911
September 1994

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Acknowledgements

This report was prepared by the NAHB Research Center under funding from the U.S. Department of Housing and Urban Development. The principal authors are Michael Bruen, PE, and Mark Nowak, with assistance from Timothy Waite, PE, and Mark Gibson.

Special appreciation is extended to William Freeborne of HUD for review and guidance, and to Richard Piluk and Ed Peters of the Anne Arundel County, Maryland, Health Department for extensive technical assistance throughout the project.

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EXECUTIVE SUMMARY

BACKGROUND

The 1990 Census reveals that 25 percent of existing housing is located in areas without public sewers. Census figures also show a nationwide 15 percent increase in unsewered units between 1980 and 1990. Even in states where the majority of homes are sewered, a substantial unsewered population may exist. For example, over 80 percent of homes in New York and California are sewered, although these states have 1.51 and 1.16 million unsewered homes, respectively.

Builders and homeowners in unsewered areas rely predominantly on conventional septic tank-soil absorption systems for sewage disposal. Nevertheless, only about 32 percent of the land area in the United States is suitable for the use of conventional septic tank-soil absorption systems. [1] The combination of these large areas of adverse soil conditions with the extent and growth of unsewered housing warrants the investigation and development of improved on-site wastewater treatment and disposal technologies. The on-site recirculating sand filter (RSF) system is one such advanced technology.

With a RSF, effluent from a septic tank flows by gravity to a recirculation tank where it is then pumped to a filter. The sand filter consists of coarse sand or similar media underlain by collection piping. A portion of the filtrate collected in the piping is diverted to the final soil disposal area while the remainder is returned to the recirculation tank where it mixes with liquid waste received from the septic tank. RSF systems have been shown to produce effluent with pollutant concentrations much lower than conventional septic tank effluent. The improved effluent quality is reported to increase soil absorption and reduce soil clogging in poor soils, reducing both the soil infiltration area required and the potential for system failure.

Demonstration Sites

Tasks undertaken during this project included demonstration and monitoring of RSF systems under typical operating conditions. Three sites were selected for the demonstration and monitoring tasks. All three sites, located in Anne Arundel County, Maryland, are retrofits of existing failed conventional on-site systems. New conventional septic tank/drainfields were not considered a practical alternative at any of the sites due to poor soil conditions that contributed to a history of disposal area failures. Septic tanks and other parts of the existing systems were re-used in the RSF systems if they were in good operating condition.

Sampling and observation ports were installed to monitor each system's performance. Regular visits (twice a month, typically) were conducted to collect and transport samples to an

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[1]EPA 1980, *Design Manual: On-Site Wastewater Treatment and Disposal Systems*, Office of Research and Development, Cincinnati, OH, 1982.

independent laboratory for analysis. Observations of ponding in the trenches were measured and recorded along with pump hour meter readings.

The system at Site A serves a three-bedroom home with five occupants. An existing concrete septic tank was retained for use in the system. The county's typical full-scale RSF system was installed at this site with a 1,500 gallon septic tank, sand filter, and gravelless drainfield.

The system at Site B serves a three-bedroom home with six occupants. An existing concrete septic tank was pumped out and caved in during construction. A new 1,500 gallon septic tank, sand filter, and gravelless drainfield were installed.

The Site B system was a modified version of the typical county RSF. The modification eliminated the separate pump pit tank by recirculating sand filter effluent directly back to the septic tank. Sand filter effluent is directed back to the house lateral feeding the first compartment of the septic tank and the pump is located in the second compartment.

The system at Site C serves a three-bedroom home with five occupants. During construction, an existing, damaged septic tank was pumped out and demolished. A 1,500 gallon septic tank, 500 gallon pump pit, sand filter, and gravelless (Infiltrator) drainfield were installed.

To investigate increased loading rates on the filter, only a portion of the filter at Site C was dosed during the monitoring period. This was possible by dividing the tank into two equal areas. Half of the filter has the typical 24 inch sand layer while the sand depth in the other half is reduced to 18 inches. During the monitoring period, only the side with the 18 inch sand layer was dosed.

Conclusions

The three sites constructed and monitored under this project illustrate the increased treatment efficiency of RSF systems compared to conventional septic systems. At Sites A and C, average reductions for Fecal Coliform and BOD exceeded 90 percent, and over 80 percent for Total Suspended Solids. Although still impressive compared to septic tank effluent, Site A average reductions for nutrients were considerably lower than at Site C. Reductions for Phosphorus and Nitrogen were 38 percent and 36 percent, respectively, at Site A. Average reductions increased to 60 percent for Phosphorus and 73 percent for Total Nitrogen at Site C. It is not clear at the time of this report why poorer performance was achieved at Site A, although investigations into water softener chemicals and other potential additives are continuing.

At Site B, RSF effluent was recirculated directly to the septic tank, which prevented establishment of baseline septic tank concentrations and percent reductions for pollutants. However, with the exception of Phosphorus, average effluent concentrations at Site B were lower than those at Sites A or C.

The soils at each site were incompatible with existing county regulations for conventional septic systems. However, visual observations during the first ten months of operation indicate that the RSF effluent was accepted by the soil at a much higher rate that would be expected with septic tank effluent, despite the fact that these were considered heavy-use homes with five or more occupants. Site A was operating on less than 16 feet of 3-foot-wide trench, Site B on less than 12 feet of trench, and Site C on just over 19 feet. Further monitoring should be conducted to assess long-term performance.

Results of the cost-saving features in this study suggest RSF systems could be constructed at a much lower cost than with current practice. For example, the elimination of the pump pit at Site B did not appear to degrade the RSF system's treatment performance. It also appears that the reduce-sized filter used at Site C was successful in achieving high treatment efficiencies and that loading rates much higher than those previously reported may be acceptable. These changes, together with some material substitutions and reductions, could reduce costs by $1,200 or more.

Overall, current costs of RSF systems are higher than conventional septic systems and will likely remain higher even if the cost saving features discussed in this report are adopted. However, the real benefit of RSF technology is that the improved treatment efficiencies will permit advanced on-site treatment and disposal on soils that are typically considered marginal or unacceptable for conventional septic systems.

INTRODUCTION

OBJECTIVE

This report is part of a program sponsored by the U.S. Department of Housing and Urban Development (HUD) to research and evaluate cost-saving methods and materials for residential construction. The purpose of the program is to investigate innovative methods and materials which preserve or improve existing construction practices while potentially lowering costs. Specifically, this report focuses on the use of on-site recirculating sand filter systems as a method for treatment and disposal of residential wastewater from individual homes.

The main objectives of this project are:

1. To demonstrate and investigate the feasibility and costs of on-site recirculating sand filters.

2. To document the hydraulic performance and effluent quality of these systems.

3. To provide builders, engineers, and regulatory officials with technical guidance in the use and construction of on-site sand filter systems.

BACKGROUND

Collection of wastewater by gravity sewers and treatment at a centralized plant is the most common sewage disposal practice for large densely populated areas. In many areas of the United States, however, construction of conventional sewers and wastewater treatment plants is economically or physically impractical. The 1990 Census reveals these unsewered areas are significant, amounting to 25 percent of existing housing. Table 1 illustrates the extent of unsewered housing by geographical region as reported in Census figures. The data shows a nationwide 15 percent increase in unsewered units between 1980 and 1990. According to the Census, even in states where the majority of homes are sewered, a substantial unsewered population may exist. For example, over 80 percent of homes in New York and California are sewered, although these states have 1.51 and 1.16 million unsewered homes, respectively.

Table 1
EXTENT AND GROWTH OF UNSEWERED HOUSING
Source: U.S. Census

Region	1990 Total Housing Units	1990 Units Unsewered	Percent Unsewered	Increase in Unsewered Units 1980-1990	Percent Increase 1980-1990
Midwest IL,IN,IA, KS,MI,MN,MO,NE, ND,SD,OH,WI	24,492,718	5,888,337	24%	390,670	7%
Northeast CT,MA,ME,NH,NJ, NY,PA,RI,VT	20,810,637	5,058,511	24%	594,061	13%
South AL,AR,DE,FL,GA, KY,LA,MD,MS,NC, OK,SC,TN,TX,VA, DC,WV	34,627,331	10,851,032	31%	1,747,526	19%
West AK,AZ,CA,CO,HI, ID,MT,NV,OR,UT, WA,WY	22,332,992	4,161,405	19%	708,843	21%
TOTALS	102,263,678	25,959,285	25%	3,441,100	15%

Although holding tanks, package treatment plants, and some innovative systems are utilized in a small number of homes, builders and homeowners in unsewered areas rely predominantly on conventional septic tank-soil absorption systems for sewage disposal. Nevertheless, only about 32 percent of the land area in the United States is suitable for the use of conventional septic tank-soil absorption systems. [2] Adverse soil conditions often preclude the development of housing in unsewered areas and result in failures of existing conventional systems due to soil clogging or insufficient treatment of effluent.

Figure 1 illustrates that in general many areas with the highest percentage of septic tank-soil absorption systems also have the most restrictive soil conditions. The combination of these large areas of adverse soil conditions with the extent and growth of unsewered housing warrants the investigation and development of improved on-site wastewater treatment and disposal technologies. The on-site recirculating sand filter (RSF) system is one such advanced technology.

[2]EPA 1980, *Design Manual: On-Site Wastewater Treatment and Disposal Systems*, Office of Research and Development, Cincinnati, OH, 1982.

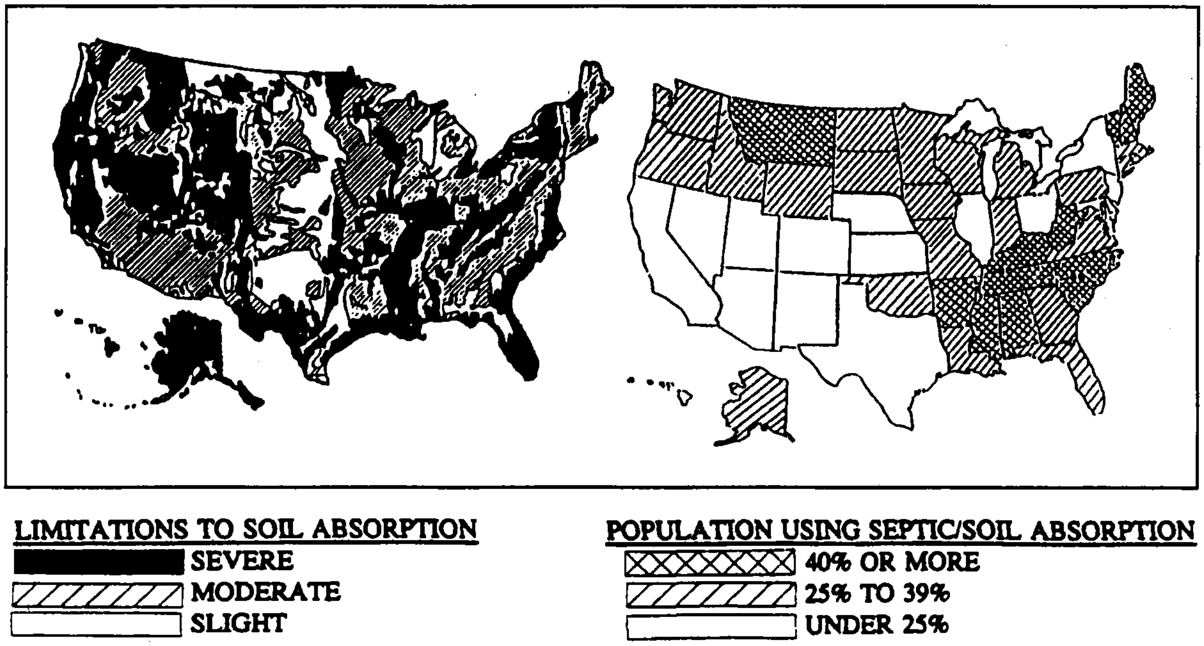

Figure 1. Distribution of Adverse Soils and Septic Tank Soil Absorption Systems in the United States
Source: EPA, National Small Flows Clearinghouse, "Needs Assessment", 1987

A schematic of a typical RSF system is shown in Figure 2. Effluent from a septic tank flows by gravity to a recirculation tank where it is then pumped to a filter. The sand filter consists of coarse sand or similar media underlain by collection piping. A portion of the filtrate collected in the piping is diverted to the final soil disposal area while the remainder is returned to the recirculation tank where it mixes with liquid waste received from the septic tank. RSF systems have been shown to produce effluent which is clear and odorless, and has pollutant concentrations much lower than conventional septic tank effluent. The improved effluent quality is reported to increase soil absorption and reduce soil clogging in poor soils, reducing both the soil infiltration area required and the potential for system failure.

Very little, if any, nitrogen reduction occurs in the soil below a conventional disposal trench. Thus, dilution is the primary treatment mechanism. In areas with conventional septic systems, large minimum lot areas are often required to provide sufficient groundwater volumes to dilute the nitrogen to safe concentrations. RSFs have demonstrated the ability to reduce a significant percentage of nitrogen compared with septic tank effluent. This may result in smaller lot sizes, particularly in environmentally sensitive areas where the land area for on-site disposal is sometimes determined by the amount of nitrogen in the groundwater recharge from septic systems and other sources. Nitrogen reductions, in combination with improved soil acceptance rates, could provide the flexibility to allow clustered zoning, higher densities, and other techniques that contribute to the affordable housing stock, even in areas with poor soils.

On-site recirculating sand filters also offer a remedy for areas experiencing failed soil absorption systems. Existing, failed soil absorption systems can be retrofit with recirculating sand filters to improve the quality of effluent to a level acceptable for the existing soil. This can correct problems of sewage surfacing in yards or backing-up into homes.

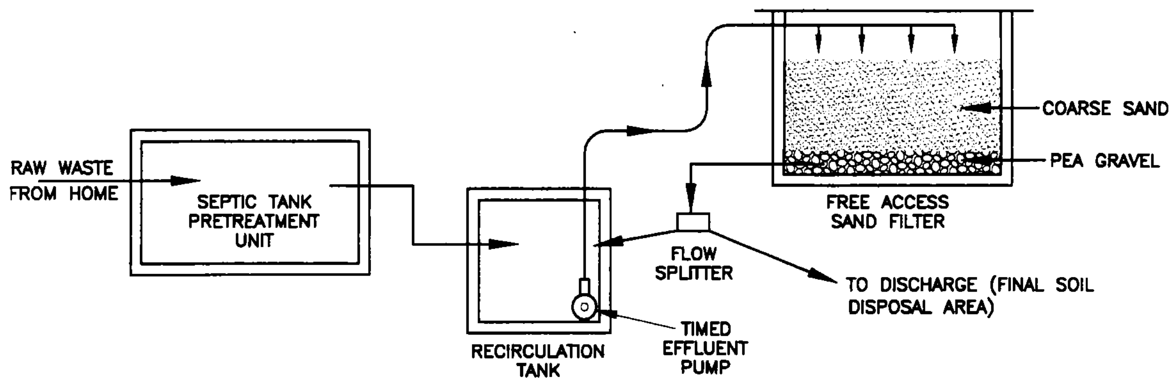

Figure 2. Schematic of Recirculating Sand Filter

PROJECT TASKS

Three tasks were undertaken to achieve the objectives of this project: an assessment of the RSF technology; demonstration and monitoring of RSF systems under typical operating conditions; and preparation of design and construction recommendations for RSF systems.

The technology assessment included review of the literature to determine the background and the status of on-site RSFs and to identify research needs.

During the demonstration task, three RSF systems were installed. Results of the literature review were used to modify existing design recommendations to allow us to examine the impact on RSF performance of increased design rates to the filter, reduced trench sizes, and combining the septic tank and mixing chamber (recirculating tank) into a single unit. The results of these tasks are presented in the following sections.

TECHNOLOGY ASSESSMENT

GENERAL

Recirculating sand filter technology has been studied since the late 1960s with several investigators reporting advanced levels of treatment achieved by the system. A literature review reveals the bulk of the research has involved improving the treatment performance and effluent quality of RSFs with a focus on the nitrogen reducing capabilities of the system. The U.S. Environmental Protection Agency (EPA) and some state and local regulatory agencies have established design criteria for these systems based on results of this earlier research. [3] Some research reports have documented the treatment performance of RSFs constructed with bottom ash and other alternate filter media. [4] [5] Few efforts have been directed at lowering the cost of the system for individual homes while maintaining an advanced level of treatment.

The development of RSF technology has resulted in some limited regional application and installation of RSF systems. Large RSF systems serving commercial properties or residential communities have become more widely accepted. Since 1976 in the states of Oregon, Washington, and California, more than 150 recirculating sand filters treating between 500 and 100,000 gallons of wastewater per day have been installed. [6] Due to prohibitive costs, unfamiliarity with the technology, or regulatory barriers, wide acceptance and application of individual on-site RSFs has not occurred. Some areas including parts of Maryland and North Carolina, however, have recognized the value of on-site RSFs to retrofit failed soil absorption systems and allow the technology for new housing on an experimental basis.

RSF POLLUTANT REMOVAL PERFORMANCE

The pollutant removal processes in on-site systems are complex and in some cases not fully understood. The pollutant parameters commonly analyzed in wastewater treatment systems are nitrogen, biochemical oxygen demand (BOD), total suspended solids (TSS), fecal coliform (FC), and phosphorus. Table 2 summarizes some of the concentrations of these pollutants for septic tank effluent and RSF effluent. The following discussion summarizes and provides a general understanding of pollutant concentrations and presents results from other investigations of RSFs. This information is important in evaluating the sampling results presented later in this report.

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[3]Ibid., p. 2.

[4]Sandy, A.T., et al., "Enhanced Nitrogen Removal Using a Modified Recirculating Sand Filter", *Fifth National Symposium on Individual and Small Community Sewage Systems*, ASAE, Chicago, IL, 1987.

[5]Lumb, B.E., et al., "Nitrogen Removal for On-Site Sewage Disposal: A Recirculating Sand Filter/Rock Task Designs", *Transactions of ASAE*, St. Joseph, MI, 1990.

[6]Ball, H.L., "Sand Filters: State of the Art and Beyond", *Proceedings of the Sixth National Symposium on Individual and Small Community Sewage Systems*, ASAE, Chicago, IL, 1991.

TABLE 2
POLLUTANT LEVELS RELATED TO RSF TREATMENT

POLLUTANT	SEPTIC TANK EFFLUENT	RSF EFFLUENT QUALITY	REDUCTION DUE TO RSF ADDITION	NPDES[1] REQUIREMENT
BOD(5)	138 mg/l[2]	5-10 mg/l[3]	85-95%[3]	30 mg/l
FC	5,000,000 MPN/100ml[2]	10,000 MPN/100ml[4]	2-4 logs[5]	14-200 MPN/100ml
NITROGEN	45 mg/l[2]	13-27 mg/l[6]	40-70%[6,7]	3-10 mg/l
PHOSPHORUS	13 mg/l[5]	1.7 mg/l[8]	80%[8]	0.18-2.00 mg/l
TSS	49 mg/l[2]	5-10 mg/l[3]	70-90%[3]	30 mg/l

Notes:
[1] National Pollutant Discharge Elimination System (NPDES) requirements for surface discharge. These values do not apply to soil absorption disposal and are shown only to provide a perspective on pollutant concentrations.
[2] University of Wisconsin, *Management of Small Waste Flows*, EPA-600/2-78-173, Municipal Environmental Research Laboratory, EPA, Cincinnati, OH, 1978.
[3] Anderson, D.L., Siegrist, R.L., and Otis, R.J., *Technology Assessment of Intermittent Sand Filters*, Municipal Environmental Research Laboratory, EPA, Cincinnati, OH, 1985.
[4] Hines, M.W. and Favreau, R.E., "Recirculating Sand Filters: An alternative to Traditional Sewage Absorption Systems", *Proceedings of the National Sewage Disposal Symposium*, ASAE, 1975, pp. 130-136.
[5] EPA, 1980, *Design Manual: On-Site Wastewater Treatment and Disposal Systems*, Office of Research and Development, Municipal Environmental Research Laboratory, Cincinnati, OH, 1982.
[6] Whitmeyer, et al., "Overview of Individual On-Site Nitrogen Removal Systems", *On-Site Wastewater Treatment, Proceedings of the Sixth National Symposium on Individual and Small Community Sewage Treatment*, ASAE, 1991, Publication 10-91, pp. 143-154.
[7] Cadmus Group, *Guidance on Reducing Nitrogen Loading From Septic Systems*, The Cadmus Group, Inc. for EPA, Office of Drinking Water, 1991, Contract No. 68-Co-0020.
[8] Piluk, R.J. and Hao, O.J., "Evaluation of On-Site Waste Disposal System for Nitrogen Reduction", *Journal of Environmental Engineering*, ASCE, 1989, Vol. 115, No. 9, pp. 725-740.

Nitrogen

Nitrogen removal is a concern in on-site wastewater systems due to its reported hazard in drinking water supplies. Forms of total nitrogen include nitrate, nitrite, and total Kjeldahl nitrogen (TKN) which is the sum of ammonium and organic nitrogen. The EPA has set maximum concentration levels of 10 mg/l nitrate-nitrogen and 1 mg/l nitrite-nitrogen in drinking water. Nitrite-nitrogen exists in an unstable oxidation state and is unlikely to reach groundwater through the soil without transforming to another nitrogen form. [7] Nitrate-nitrogen, on the other hand, is highly mobile in soil pore water and is a much greater threat. [8]

The process by which nitrogen is removed in an RSF is well-documented in the literature. Nitrogen can be removed from wastewater biologically through plant uptake, microbial

[7]Cadmus Group, *Guidance on Reducing Nitrogen Loading From Septic Systems*, The Cadmus Group, Inc. EPA, Office of Drinking Water, 1991, Contract No. 68-Co-0020.

[8]Ibid.

assimilation, or denitrification. Denitrification is the primary nitrogen removal process which takes place in an RSF system.

Denitrification involves the reduction of nitrate-nitrogen to nitrogen gas that is released to the atmosphere. For denitrification to occur, nitrogen in septic tank effluent must first be nitrified (NH_4^+ reduced to NO_2^- , NO_2^- transformed to NO_2^-). This is an aerobic process which requires a source of energy (carbohydrates in wastewater), near neutral pH (4.5-7.5), and temperatures above 5 degrees C (41°F). [9] These conditions are present in most instances in domestic wastewater.

Denitrification follows nitrification and is an anaerobic process which requires an energy source and slightly acid to neutral pH level. A useable form of carbon must be added to nitrified wastewater since the nitrification process has removed much of the energy source originally present. [10] This is accomplished in an RSF system by combining residential wastewater from the septic tank with recirculated nitrified sand filter effluent. Denitrification linearly decreases with increasing dissolved oxygen and virtually ceases at dissolved oxygen concentrations greater than or equal to 1.0 mg/l. [11] Denitrification is also temperature dependent; its rate decreases with decreasing temperature. [12]

Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD), measures the change in dissolved oxygen content of wastewater over time. BOD provides an indication of the organic waste content that depletes the oxygen resources of receiving water. BOD is used as a parameter in the design process and as a measure of evaluating the performance of wastewater treatment plants.

Total Suspended Solids (TSS)

The level of total suspended solids (TSS), is frequently used as an indicator of the strength of wastewater. TSS represents those solids present in the sample which are not settleable or volatile. TSS is determined by drying and weighing the residue removed after filtering the sample through a glass fiber filter. (Solids that pass through the filter are called "dissolved solids"; TSS and displaced solids combined are referred to as total solids).

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[9] Whitmeyer, R.W., et al., "Overview of Individual On-Site Nitrogen Removal Systems", *On-Site Wastewater Treatment, Proceedings of the Sixth National Symposium on Individual and Small Community Sewage Treatment*, ASAE, 1991, Publication 10-91, pp. 143-154.

[10] Ibid.

[11] Ibid.

[12] Cadmus, p. 6.

Fecal Coliform

Fecal coliform, or E. coli, grows in the intestines of warm blooded animals and is an indicator organism used to detect the presence of human pathogens. Indicator organisms are identified to avoid the prohibitively-expensive task of testing and detecting all types of viruses. The anaerobic septic tank environment does little to remove fecal coliforms, although the biological clogging mat formed in soil absorption areas has been found to be an effective barrier to bacterial transport. [13] RSFs have been shown to significantly reduce effluent fecal concentrations, but are well above the acceptable effluent level of 14 to 200 MPN/100 ml depending on the receiving water for NPDES permitted at municipal wastewater treatment plants.

Phosphorus

Phosphorus in septic tank effluent originates primarily from either detergent containing phosphates or human excreta. Many areas, including the state of Maryland, currently ban the sale of detergents with phosphates, greatly reducing the phosphorus level of septic tank effluent. Phosphorus is retained or immobilized in most soils in and around the soil absorption field.

SAND FILTER SIZE AND LOADING RATES

Sizing of the sand filter component of an RSF system is dependent on the design filter loading rate. Guidelines for the filter loading rate have been presented by the EPA, state regulatory agencies, and researchers. The EPA has suggested loading the filter at 12.5 to 20.8 centimeters per day (three to five gallons per day per square foot). [14] These loading rates refer to forward flow (only the unrecycled portion of the flow) onto the filter. Some guidelines also suggest requiring minimum filter areas for single-family RSF systems of 100 square feet. If the homes are equipped with automatic washers and dishwashers, 144 square feet has been suggested.[15] [16]

There is evidence which suggests higher loading rates and thereby smaller filters may be possible when a coarse sand is used in the filter and the pump is programmed to frequently dose the filter for short durations. In Anne Arundel County, Maryland, single-family homes with 45 square foot filters have been dosed at up to 29.2 cm/d (7 gpd/sf). Very little maintenance has been required on these systems, nor has clogging been experienced.

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[13] Bicki, T.J., et al., *Impact of On-Site Sewage Disposal Systems on Surface and Groundwater Quality*, Soil Science Department, University of Florida, Gainesville, FL, 1984.

[14] Hines, M.W. and Favreau, R.E., "Recirculating Sand Filters: An Alternative to Traditional Sewage Absorption Systems", *Proceedings of the National Sewage Disposal Symposium*, ASAE, 1975, pp. 130-136.

[15] Ibid.

[16] Ralph, D.J. and Vanderholm, D.H., "Design Construction and Costs of Recirculating and Filters", *Proceedings of the Illinois Private Sewage Disposal Symposium*, 1978, pp. 37-51.

SOIL ABSORPTION RATE OF RSF EFFLUENT

The improved quality of wastewater possible with an RSF may allow increased soil application rates and thus decrease the size of trenches that form the drainfield, since investigators generally agree that BOD, suspended solids, and fecal coliform organisms are primarily responsible for creating soil clogging. [17] Based on soil type alone, drainfield disposal areas based on EPA design rates range from 0.8 to 5.0 cm/d (0.2 to 1.2 gpd/sf). These EPA design recommendations do not recognize reductions in disposal area for RSF systems.

Research has resulted in the development of conceptual hydraulic loading rates based on the soil classification system used in Norway and nine years of research and practical experience. Recommended loading rates for clayey, loamy, and fine sandy soils are 7.5 cm/d (1.8 gpd/sf) for RSF effluent compared with 1.0 cm/d (0.24 gpd/sf) for septic tank effluent alone. Recommended loading in sorted soils is 15 cm/d (3.6 gpd/sf) and in coarse sand and gravel 30 cm/d (7.2 gpd/sf).[18] [19]

Increased soil loading rates of RSF effluent have also been demonstrated under actual conditions. In one instance, a nine-year-old trench system receiving RSF effluent was found to adequately handle 8.3 cm/d (2 gpd/sf). This is eight times the EPA's recommended loading rate of 1.0 cm/d (0.25 gpd/sf) for the soil at the site. [20] In another study, distribution beds from three RSF systems were dosed at rates of 7.9 to 11.7 cm/d (1.89 to 2.8 gpd/sf), with satisfactory performance. [21]

[17]Wilson, S.A., Ronayne, M.P. and Paeth, R.C., *Recirculating Sand Filter Systems*, Oregon On-Site Experimental Systems Program - Final Report, Oregon Department of Environmental Quality, 1982.

[18]Siegrist, R.L., "Hydraulic Loading Rates for Soil Absorption Systems Based on Wastewater Quality", *On-Site Wastewater Treatment, Proceedings of the Fifth National Symposium on Individual and Small Community Sewage Treatment,* ASAE, 1987, Publication 10-87, pp. 232-241.

[19]Jensen, P.D. and Siegrist, R.L., "Integrated Loading Rate Determination for Wastewater Infiltration System Sizing", *On-Site Wastewater Treatment, Proceedings of the Sixth National Symposium on Individual and Small Community Sewage Treatment*, ASAE, 1991, Publication 10-91, pp. 182-191.

[20]Loudon, T.L. and Birnie, G.L., "Performance of Trenches Receiving Sand Filter Effluent in Slowly Permeable Soils", *On-Site Wastewater Treatment, Proceedings of the Sixth National Symposium on Individual and Small Community Sewage Treatment*, ASAE, 1991, Publication 10-91, pp. 313-323.

[21]Wilson.

RSF COSTS

The cost of RSF systems for individual homes has been documented on a limited basis in the literature. However, design variations involving additional tanks and filters have created a wide range of potential costs. Reported material and installation costs from three studies include:

- $8,300 to $12,000 [22]
- $8,300 [23]
- $8,000, [24] for RSF with a sand polishing filter

Conventional septic tank with disposal trench costs from four studies include:

- $3,000 [25]
- $3,000 to $4,000 [26]
- $3,500 [27]
- $2,815 [28]

BARRIERS TO ACCEPTANCE AND USE OF RSFS

Although RSF systems have been shown to improve the effluent quality of on-site septic systems, there are both institutional and functional elements which must be addressed before widespread acceptance of the technology can occur.

First, the goals and expectations of on-site wastewater treatment are generally idealistic. Innovative on-site wastewater treatment systems, like the RSF, develop in the conservative public health and regulatory fields. This has resulted in expectations for on-site facilities to work 100 percent of the time, require no routine maintenance, and be simple enough for semi-skilled persons to design and install.[29] The establishment of reasonable performance criteria for on-site systems and technical support on how to meet these criteria is essential if regulatory officials,

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[22]Cadmus, p. 6.

[23]Whitmeyer, p. 7.

[24]Piluk, R.J. and Hao, O.J., "Evaluation of On-Site Waste Disposal System for Nitrogen Reduction", *Journal of Environmental Engineering,* ASCE, 1989, Vol. 115, No. 9, pp. 725-740.

[25]Ibid.

[26]*New Alchemy,* "We Design Our House", New Alchemy Institute, East Falmouth, MA, 1986, No. 26.

[27]Cadmus, p. 6.

[28]Hanson, M.E. and Jacobs, H.M., "Land Use and Cost Impacts of Private Sewage System Policy in Wisconsin", *On-Site Wastewater Treatment, Proceedings of the Fifth National Symposium on Individual and Small Community Sewage Treatment,* ASAE, 1987, Publication 10-87, pp. 26-39.

[29]Otis, "Demythologizing the Septic Tank", *The Sixth National Symposium on Individual and Small Community Sewage Systems,* ASAE, Chicago, IL, 1991.

installers, and builders or developers are going to employ the technology. The technical support will need to include optimum dosing and sizing guidelines for RSF systems.

Another barrier to the acceptance of RSFs is the perception and opinion by much of the general public that on-site systems are only a temporary measure remaining in place until sewers can be extended to serve a community. Although the septic system has undergone few changes over the years, there have been improvements in materials and installation practices which reduce the likelihood of problems. Concrete septic tanks today have design lives equal to sewer pipes, are equipped with improved baffles, and can be made watertight. Some tanks have double compartments to protect them from excessive solids reaching the drainfield and creating soil clogging problems. The knowledge regarding optimum septic tank pumping intervals, proper siting of systems, soil permeability analysis, and trench construction has increased over the years and improved the reliability and reduced the required maintenance of septic systems. The image problem of on-site systems, however, still suffers as many older systems are still in place. When problems with a system do occur, the inconvenience to homeowners and neighbors is impressionable.

A political barrier to the approval and construction of on-site systems, including innovative systems like the RSF, has been insistence by no-growth advocates that sewer collection and conveyance to centralized plants is the only effective method of dealing with residential wastewater. Valid concerns related to preserving the character of communities and protecting critical areas are sometimes masked behind attacks at on-site system performance. These attacks can inhibit the development of environmentally beneficial technologies which provide advanced levels of wastewater treatment. Potentially, on-site systems offer environmental benefits by avoiding the disturbance created by the construction of trunk sewers, averting the concentration of wastewater at centralized plants, and replenishing the groundwater supply. Separating the issue of on-site wastewater treatment performance from zoning and land use debates is a difficult but important obstacle for innovative technologies to overcome.

There are also physical aspects of RSF systems which present obstacles to its acceptance and use. The cost of the system can be seen as prohibitively expensive. Regulatory agencies are also reluctant to approve RSFs due to concerns that homeowners will neglect to maintain the systems and failed systems will become their responsibility when original homeowners, builders, or installers are out of the picture. One solution to this problem has been the establishment of both public and private maintenance entities assigned the responsibility of inspecting and ensuring the proper function of on-site systems. The Appendix contains an example of a public management entity agreement. There is also concern about the performance of the system in cold climates as the outdoor temperature is expected to affect the biological treatment process and pollutant removal ability. Finally, the sand filter is often placed above-ground in order to limit the disposal trench depth and maximize the unsaturated zone between the trench infiltrative surface and the groundwater table. Homeowners may view the sand filter structure as unattractive lawn furniture, (see Photo 1).

Photo 1: Typical Sand Filter Extending Above Grade

DEMONSTRATION AND MONITORING

Three sites were selected for the demonstration and monitoring tasks. All three sites, located in Anne Arundel County, Maryland, are retrofits of existing failed conventional on-site systems. New conventional septic tank/drainfields were not considered a practical alternative at any of the sites due to poor soil conditions that contributed to a history of disposal area failures. Septic tanks and other parts of the existing systems were re-used in the RSF systems if they were in useable condition.

Background

The Anne Arundel County Health Department has approved the use of RSF systems on an experimental basis and has more than 75 RSF systems currently operating in its jurisdiction. Because of the improved quality of sand filter effluent, RSF systems are approved in the county for the repair of failing septic systems because of slowly permeable soil or an inadequate unsaturated soil buffer zone; limited additions to houses on sites with soils that are not suitable for conventional systems; and new home construction on existing plotted lots. The typical RSF installation approved by the Anne Arundel County includes a two compartment septic tank, a pump pit, a sand filter, and a drainfield. The second 500 gallon compartment of the septic tank is used as a mixing chamber for recirculated sand filter effluent and settled flow from the first compartment.

The 500 gallon concrete pump pit tank is typically equipped with a 3/4 horsepower pump. The pump is wired to a control panel, shown in Photos 2 and 3.

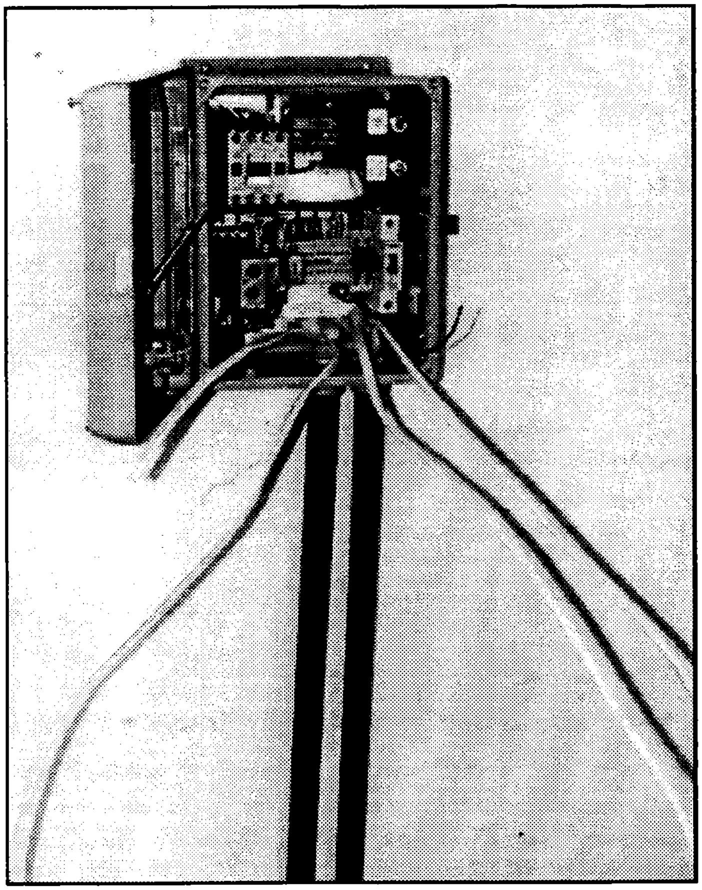
Photo 2: **Pump Controls**

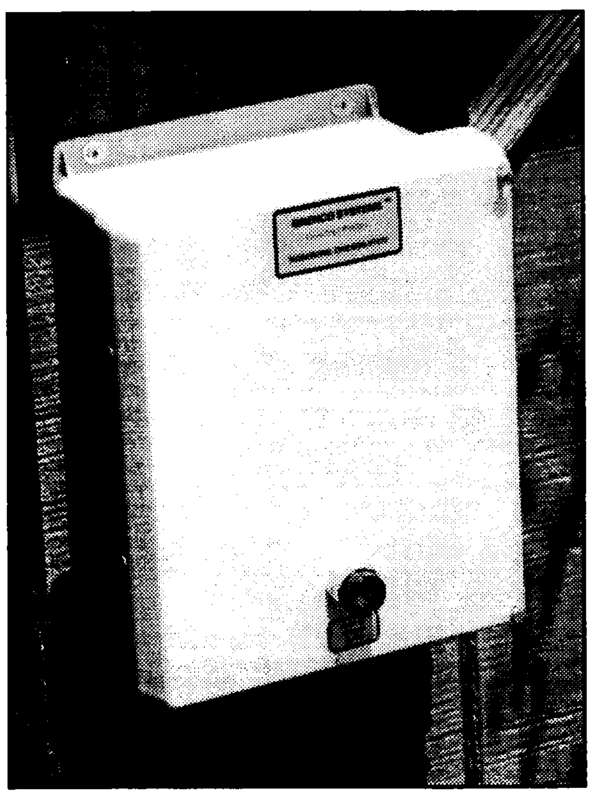
Photo 3: **Pump Control Box**

The pumps were set to operate for one minute intervals every 30 minutes. The control panels were equipped with high water alarms which sound and activate the pumps when the liquid level in the pump pits trip the high water float.

The sand filter is contained in a 4-foot-high, 45 square foot concrete box dosed by a one and one-half inch PVC distribution pipe. The distribution pipe has one-half inch holes spaced at thirty inches on center which spray up onto a six-inch PVC pipe cut in half lengthwise (as shown in Photo 4 and Photo 5). Indrain units, which consist of thin plastic molds covered in a filter cloth, are set directly below the distribution lateral. The indrain units are thought to help distribute the effluent uniformly over the filter. The sand layer consists of 24 inches of well-screened sand with an effective size of 1.0 mm and a uniformity coefficient less than 2.5. A four-inch perforated PVC collection pipe is placed at the bottom of the filter box tank in a six-inch layer of pea gravel. A recirculation ratio of three-to-one is achieved by constructing a four-inch-high brick and mortar wall at the bottom of the sand filter to separate flow returning to the mixing tank from flow leaving for final disposal in the trench (as shown in Photo 6). Filter fabric is placed over the indrains and distribution lateral, and sand is then packed to the top of the box to control odors. A pressure-treated wood top with one-half inch foam insulation is used as a cover for the filter (as shown in Photo 7). The drainfields are typically gravelless units ("Infiltrator") placed directly on the native soil as shown in Photo 8.

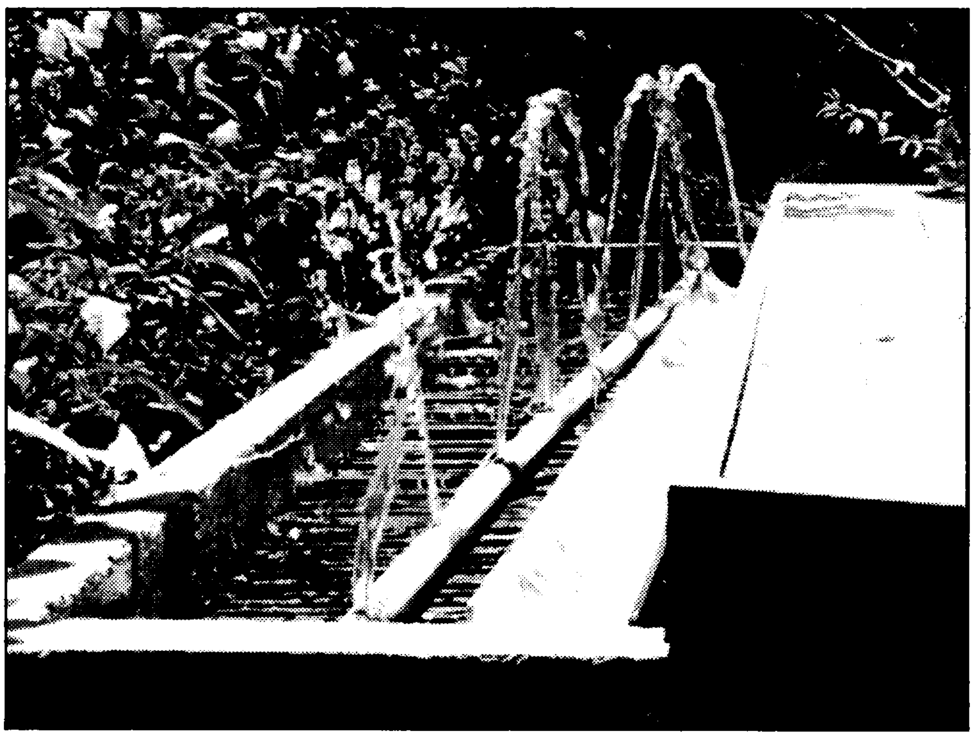

Photo 4: **Lateral in Top of Filter**

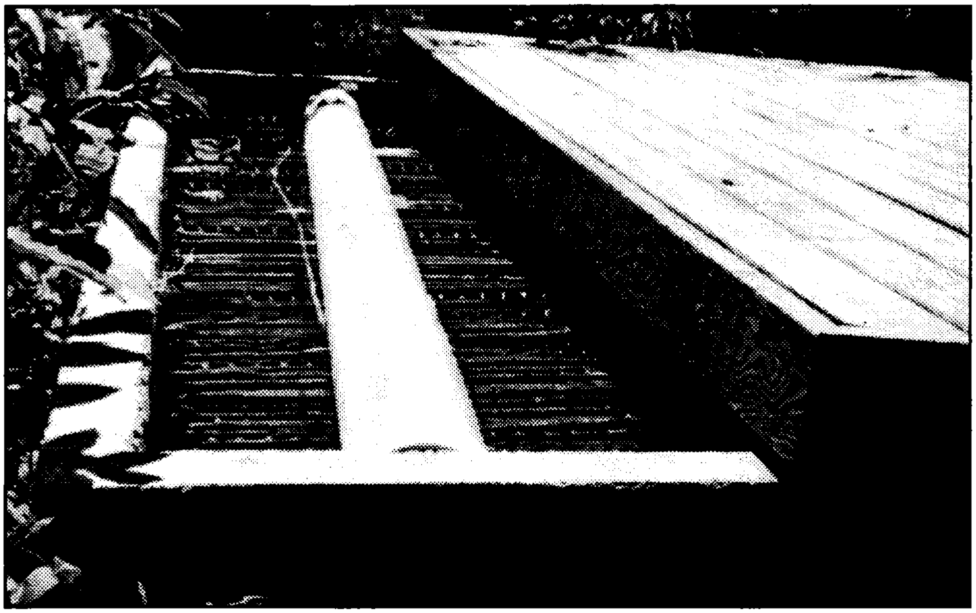

Photo 5: PVC Pipe Over Openings in Lateral

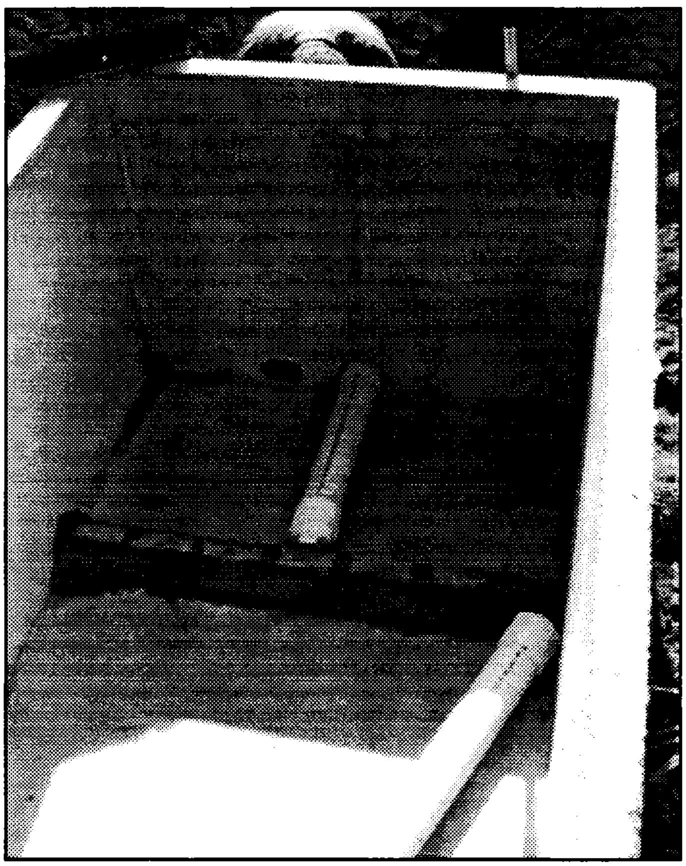

Photo 6: Brick Wall at Bottom of Filter Box Used to Direct Flow of Effluent

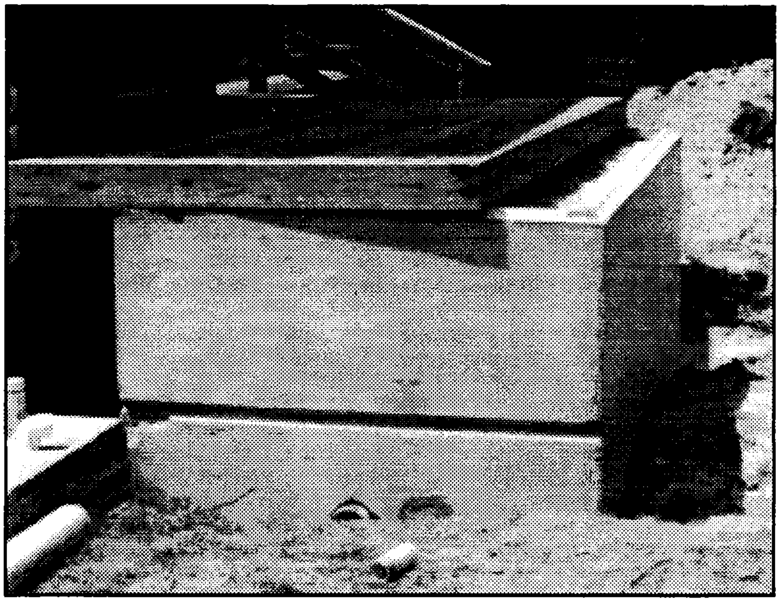

Photo 7: Wood Top Used to Cover Sand Filter

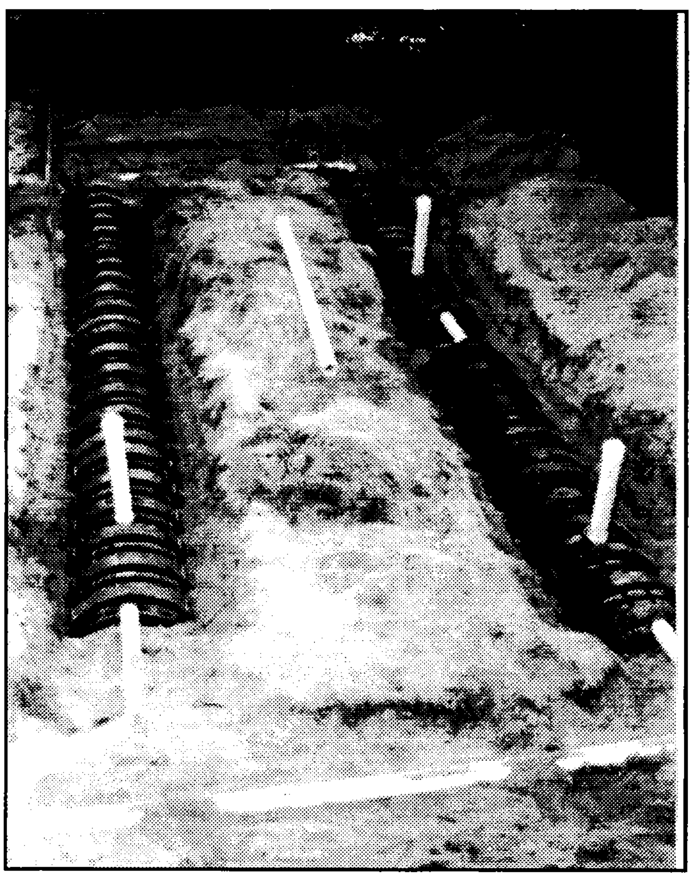

Photo 8: "Infiltrator" Units Used as an Alternative to Gravel Trenches

Demonstration Sites

The three RSF systems studied in this project were generally designed in accordance with the Anne Arundel County Health Department guidelines. However, some modifications were included to allow investigation of cost reductions of the system. Specifically, the modifications included:

(1) reduced size of the disposal trench;
(2) reduced depth and area of the sand filter; and,
(3) elimination of the separate pump pit tank.

Sampling and observation ports were installed to monitor each system's performance. The sites were monitored during construction to document installation. In addition, regular visits (twice a month, typically) were conducted to collect and transport samples to an independent laboratory for pollutant analysis. Observations of ponding in the trenches were measured and recorded along with pump hour meter readings. A description of the monitoring plan and laboratory analysis procedures is included in the Appendix.

SITE A - GAMBRILLS, MARYLAND

This system serves a three-bedroom home with five occupants. An existing concrete septic tank was retained for use in the system. The county's typical full-scale RSF system was installed at this site with a 1,500 gallon septic tank, sand filter, and gravelless drainfield constructed as shown in Figure 3.

The soil at the infiltrative surface of the disposal trench is a brown sandy lean clay. A percolation test performed by the county resulted in an infiltrative rate of greater than 30 minutes per inch. Permits for construction of new homes or additions to existing homes are typically disapproved when percolation rates exceed this value.

Only one of the 45 foot infiltration trenches was operated during the monitoring period. Visual inspections were conducted through observation ports. No ponding was observed in the first monitoring port and there was no evidence of moisture reaching the second port or subsequent ports in the trench.

Initially, the homeowners complained of odors from the sand filter, since it was located next to the front porch of their home. Additional sand was packed above the distribution lateral, on top of filter tank, which eliminated this problem. No other maintenance of the system was required during the monitoring period.

SITE B - PASADENA, MARYLAND

This system serves a three-bedroom home with six occupants. An existing concrete septic tank was pumped out and caved in during construction. A new 1,500 gallon septic tank, sand filter, and gravelless drainfield were installed as shown in Figure 4.

The system was a modified version of the typical county RSF. The modification eliminated the separate pump pit tank by recirculating sand filter effluent directly back to the septic tank. Sand filter effluent is directed back to the house lateral feeding the first compartment of the septic tank and the pump is placed in the second compartment (as shown in Figure 5). A manufactured filter (as shown in Photo 9) was placed at the outlet of the first compartment to prevent solids from reaching the pump chamber and damaging the pump.

The soil at the infiltrative surface of the disposal trench is a brown, poorly-graded sand with silt. A percolation test showed a result of three minutes per inch. County standards would normally require approximately 100 feet of three-foot-wide trench at this percolation rate.

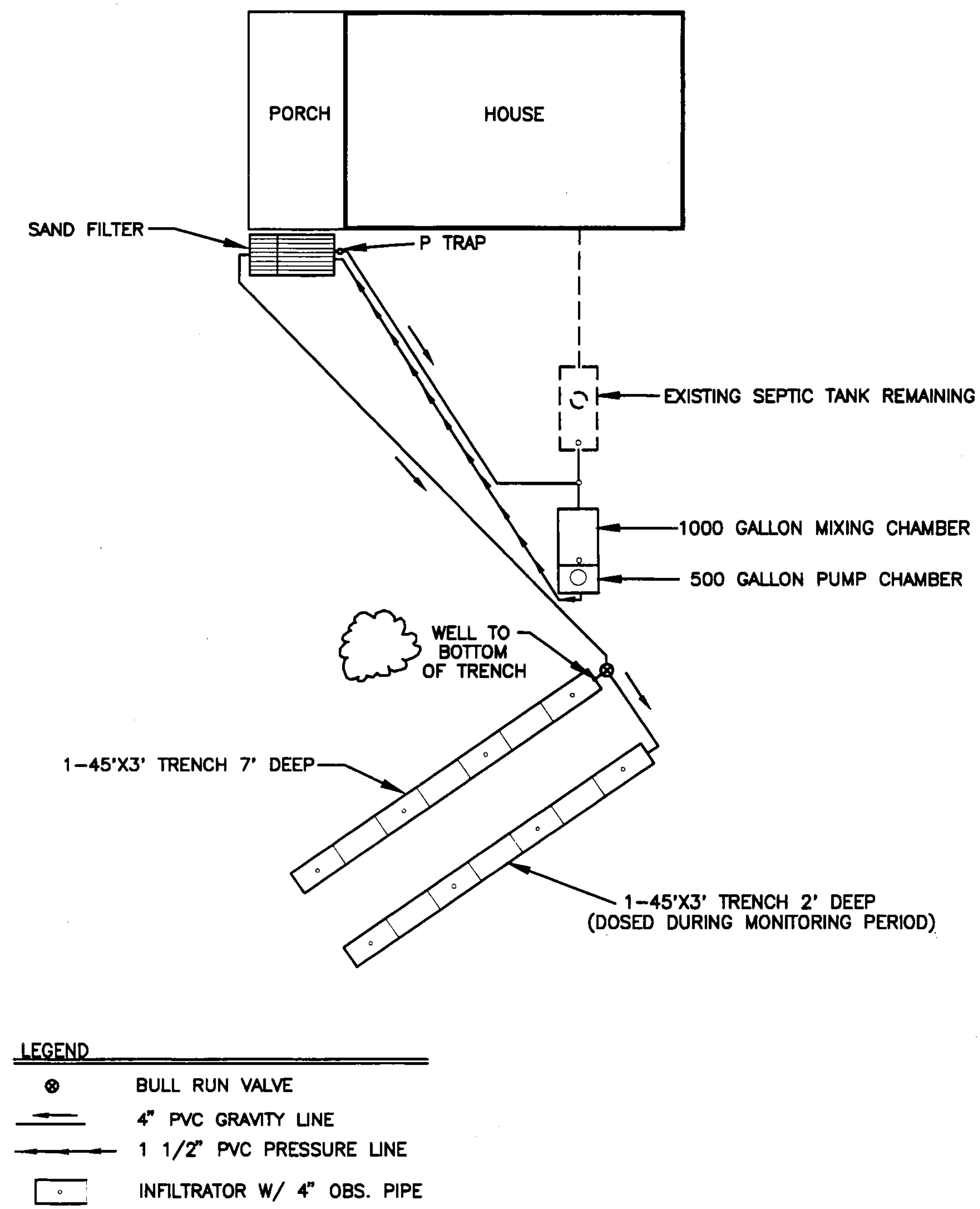

Figure 3. RSF Plan for Site A
Gambrills, Maryland
SCALE: 1" = 20'

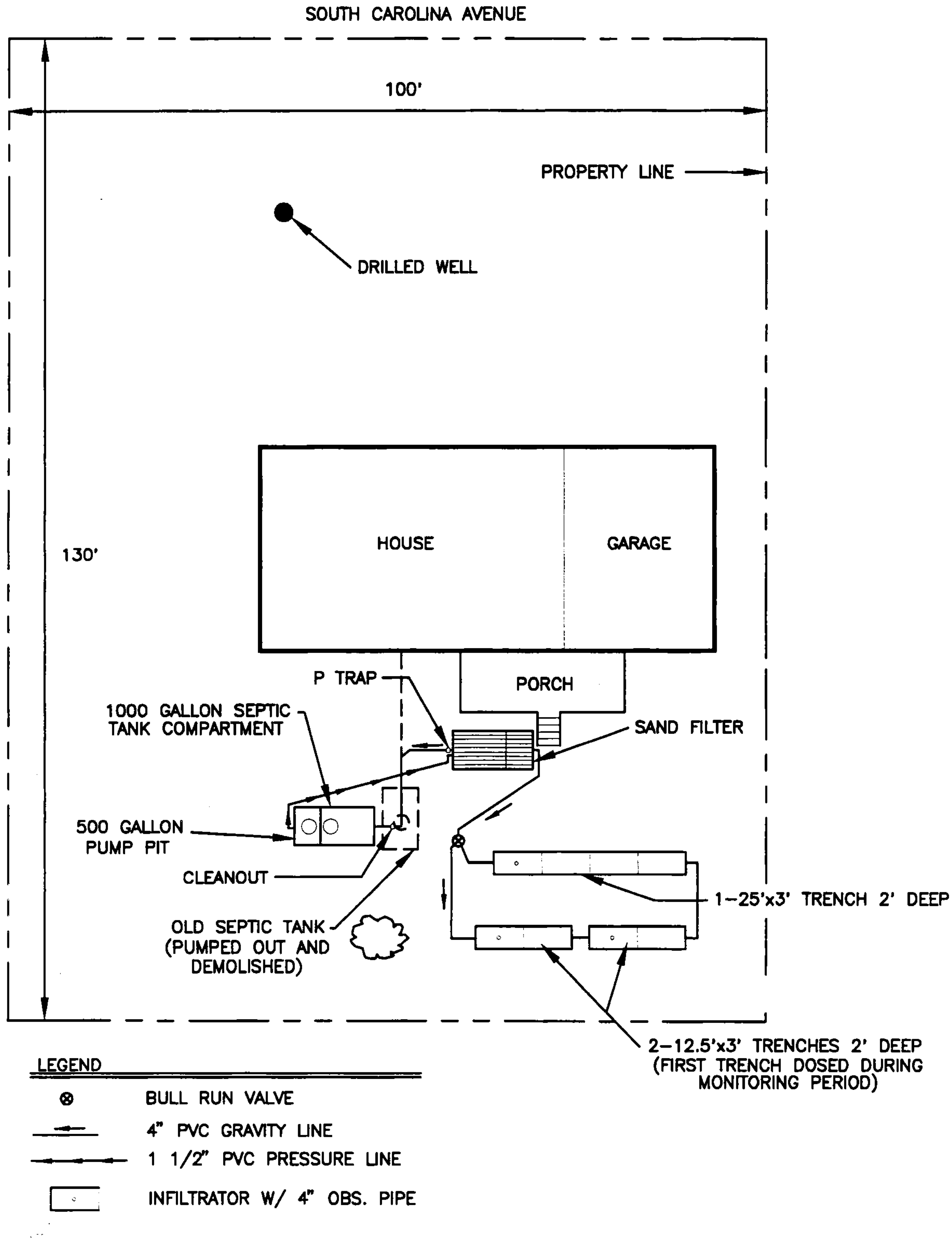

Figure 4. RSF Plan for Site B
Pasadena, Maryland
SCALE: 1" = 20'

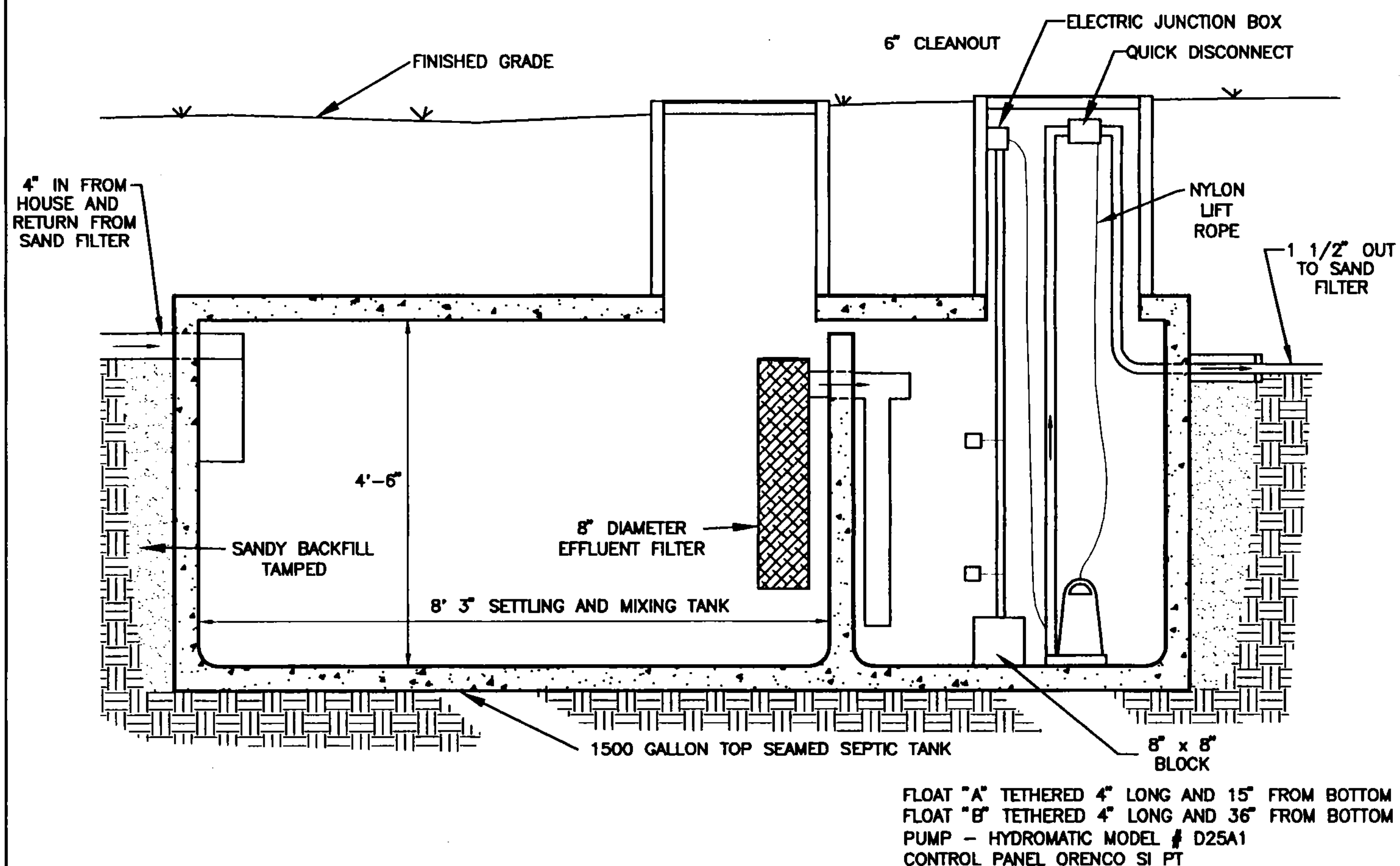

Figure 5. Septic Tank and Pump Pit for Site B
Pasadena, Maryland
SCALE: 1" = 2'

Photo 9: Filter Used at Outlet of First Chamber of Septic Tank

During the monitoring period, effluent from the sand filter was directed to one 12.5-by-3-foot shallow gravelless trench. No ponding was measured in the trench. In addition, no maintenance of the RSF system was required.

SITE C - ANNAPOLIS, MARYLAND

This system serves a three-bedroom home with five occupants. The home is the ranger station for a county park that overlooks the South River and Chesapeake Bay. During construction, an existing, damaged septic tank was pumped out and demolished. A 1,500 gallon septic tank, 500 gallon pump pit, sand filter, and gravelless (Infiltrator) drainfield were installed as shown in Figure 6.

The soil present at the infiltrative surface of the disposal trench is a brown sand. Auger borings at the site indicated the presence of clay lenses below the surface and the possibility of areas of perched groundwater. A percolation test performed by the county resulted in an infiltrative rate of greater than 30 minutes per inch was measured. Anne Arundel County disapproves permits for construction of new homes or additions to existing homes on septic systems when rates exceed this value.

To investigate increased loading rates on the filter, only a portion of the filter was dosed during the monitoring period. This was possible by placement of valves and a partition within the filter box. The partition is a one-half inch plywood sheet wrapped in polyethylene which extends through the sand layer and divides the tank into two 22.5 square foot areas (as shown in Photo 10). Half of the filter has the typical 24 inch sand layer while the sand depth in the other half is reduced to 18 inches (as shown in Figure 7). During the monitoring period, the side with the 18 inch sand layer was dosed while the other half of the filter had the distribution pipe shut off.

Only one 19-by-3-foot trench was initially operating during monitoring. The trench had varying depths of ponding which averaged five inches over the monitoring period. On two occasions, ponding depths or visual observations at the second monitoring port indicated overflow had occurred into a second 19-by-3-foot trench. During the monitoring period, no maintenance of the system was required.

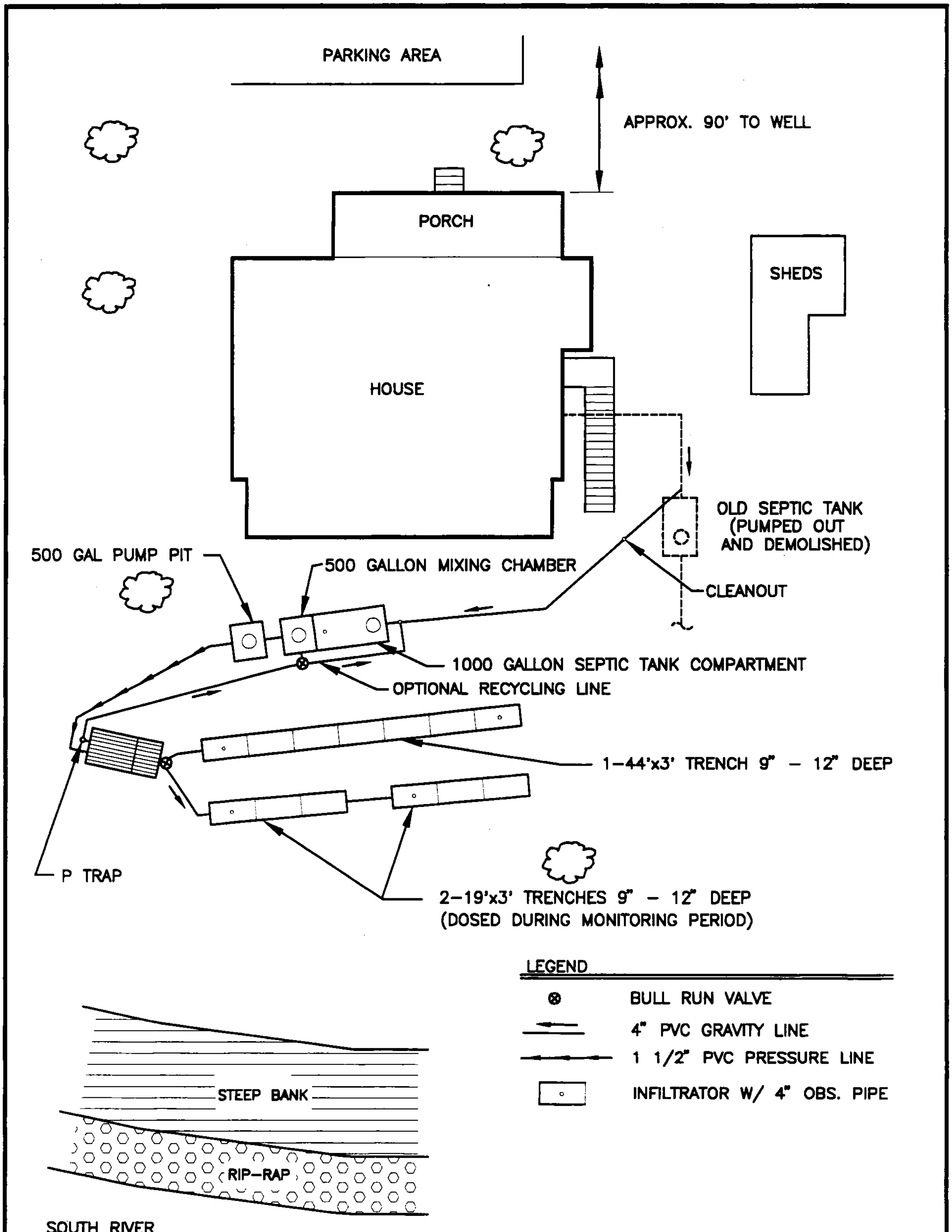

Figure 6. RSF Plan for Site C
Annapolis, Maryland
SCALE: 1" = 20'

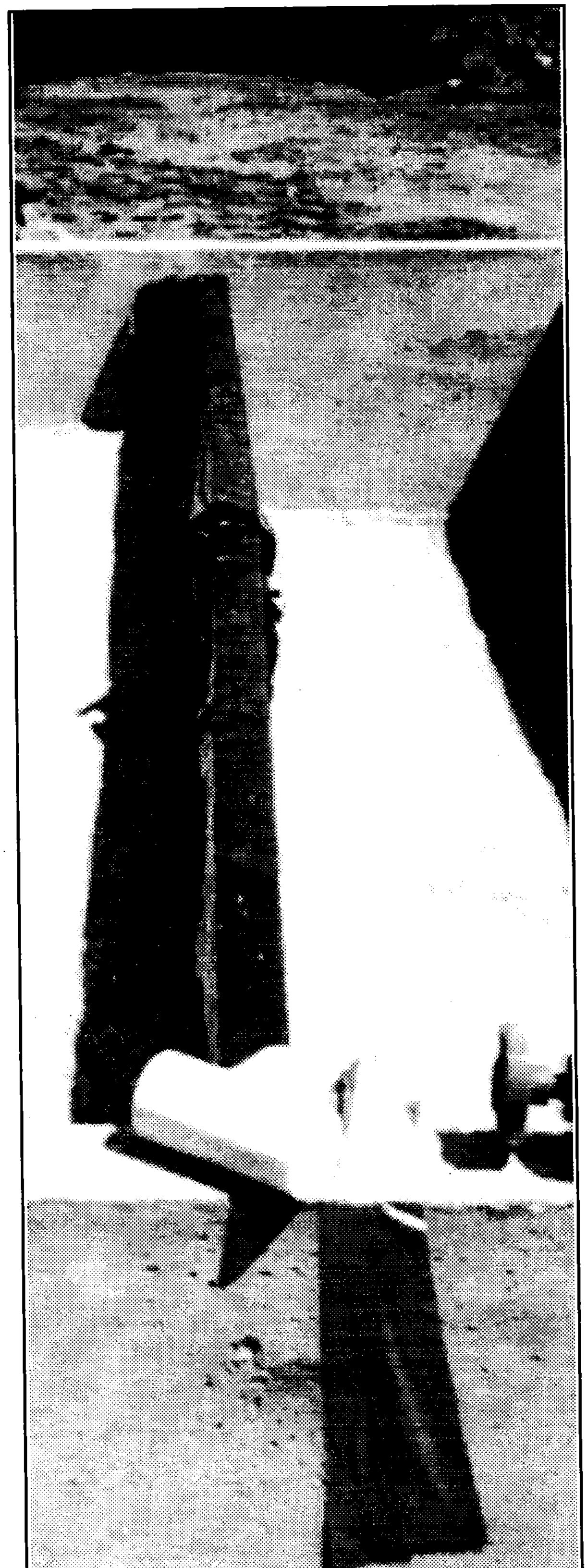

Photo 10: **Dividing Wall in Filter at Site C**

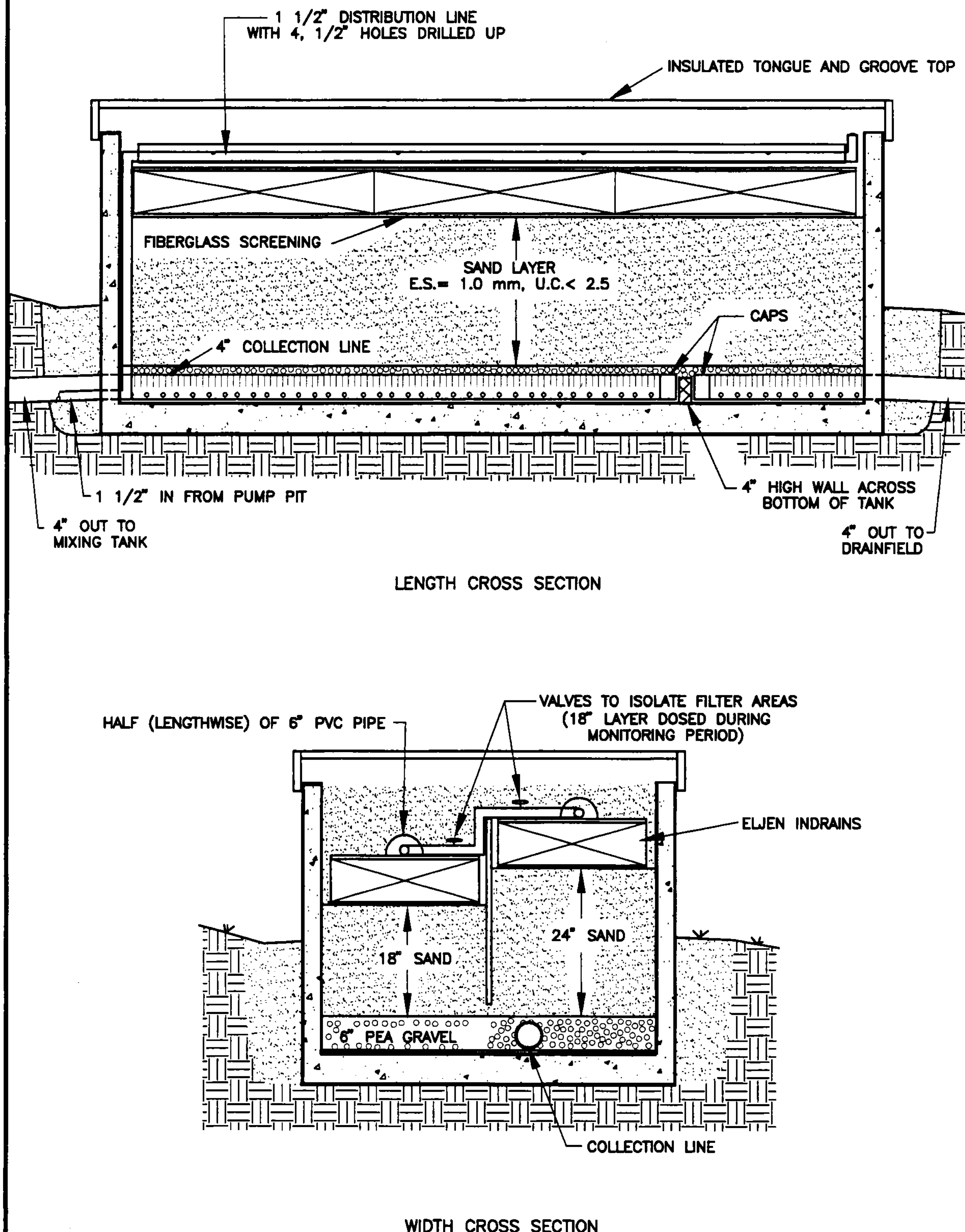

Figure 7. Sand Filter Detail for Site C
Annapolis, Maryland
SCALE: 1" = 2'

ANNE ARUNDEL COUNTY MONITORING PROGRAM

In addition to the three systems discussed in this report, the Anne Arundel County Health Department has monitored three other RSF systems operating in the county. The extent and frequency of sampling has been dependent on available funding for sample collection and analysis. Results of laboratory analysis indicate these RSF systems, using a three to one recirculation ratio, produce effluent with average BODs of 2.4 mg/l (99 percent reduction), suspended solids of 9.9 mg/l (88 percent reduction), and total nitrogen of 21 mg/l (64 percent reduction). These results are summarized in Table 3.

Table 3
SAND FILTER PERFORMANCE SUMMARY
ANNE ARUNDEL COUNTY, MARYLAND

SYSTEM TYPE	SEPTIC TANK			SAND FILTER			% REDUCTION		
	BOD	SS	N	BOD	SS	N	BOD	SS	N
Bigalow[1]	217	76	55	3	9.7	22.1	98.6	87.3	59.8
Melton[2]	124	57	45	1.8	5.1	14.1	98.5	91.0	68.6
Smith[3]	234	105	74.8	2.3	14.8	27.1	99.0	86.0	63.7
AVERAGE	192	79	58.3	2.4	9.9	21.1	99%	88%	64%

Notes
[1]Average of 19 sampling dates from August 1992 to August 1993.
[2]Average of 20 sampling dates from July 1990 to April 1993.
[3]Average of 13 sampling dates from May 1991 to June 1993.

Little or no maintenance of these systems has been required. Two of these systems have been operating for more than seven years. At one of these seven-year-old sites, less than seven and one-half feet of a three-foot wide trench has been required in a home with eight occupants.

Cost of RSF Systems

As noted earlier, the costs of an RSF system as reported in the literature, vary considerably, with a range between $8,000 to $12,000. This wide range is most likely due to design variations and local labor and materials costs.

Because of variations in the way the systems in this project were constructed (e.g., system modifications such as the elimination of the separated pump pit at one site, a modified filter at another, and the use of an existing septic tank at the third site), the three demonstration sites experienced slightly different costs.

A summary of the costs for a typical system, installed per county specifications, is shown in the Table 4. These costs are based on the actual costs from Site B and an estimated cost for a pump pit. The end result is that the typical "county approved" system costs about $6,270.

Table 4
ESTIMATED CONSTRUCTION COST OF A TYPICAL RSF SYSTEM

	ITEM	UNIT	QUANTITY	UNIT COST	TOTAL COST
MATERIALS	Infiltrators	EA	8	$ 29.00	$ 232.00
	Endcaps	EA	6	9.00	54.00
	Risers & Lids	EA	2	100.00	200.00
	Septic Tank	EA	1	700.00	700.00
	Sand Filter Tank	EA	1	290.00	290.00
	Wooden Top	EA	1	275.00	275.00
	Sand	-	1	600.00	600.00
	Elgin Indrain	EA	4	125.00	500.00
	Control Panel	EA	1	500.00	500.00
	Effluent Filter	EA	1	65.00	65.00
	Pipe & Fittings	JOB	1	350.00	350.00
	Bull-valve	EA	1	69.00	69.00
	Pump Pit	EA	1	420.00	420.00
SUBTOTAL					$ 4,255.00
MISCELLANEOUS					
	Permit	EA	1	265.00	265.00
	Electric hook-up	JOB	1	350.00	350.00
	Equipment, Labor & Profit	--	1	1,400.00	1,400.00
SUBTOTAL					$ 2,015.00
TOTAL CONSTRUCTION COST					$ 6,270.00

It is likely that further research could reduce the cost of the RSF system significantly. Results of this work suggest relocation of the pump pit does not impact effluent quality. This could reduce costs by about $700. There is also considerable questions over the need for the indrain system in the sand filter which adds about $500 to the cost of the RSF. Smaller filters, plastic filter boxes, and less costly filter media could further reduce costs by several hundred additional dollars.

Monitoring Results

The key variables that determine the surface area required for an RSF are the hydraulic loading rate (or volume of flow) and the pollutant loading rate. These are also the variables that determine the acceptance rate of the soils in the absorption field. For the RSF systems in this project, the hydraulic load is defined as one quarter the total flow. This represents only the forward flow and not the recirculated portion.

Hydraulic Rates (Filter)

The EPA has recommended loading rates of 3.0 to 5.0 gpd for RSFs. The experience of Anne Arundel County over the last seven years has shown that higher rates can be applied without degrading the quality of the effluent or clogging the filter. Thus the typical county filter is 24 inches deep and 45 square foot in surface area.

In order to evaluate an even smaller filter, a reduced depth and surface area was used at Site C in this project. The programmable timer in the control panel was set to activate the pump for one minute intervals every half hour. Based on readings from the hour meter in the control panel and a head test at the distribution lateral, loading rates were determined using a method described by the EPA. [30]

The 18-inch-deep, 22.5 square foot filter section at Site C was dosed at an average rate of 16.6 gpd/sf during the first ten months of operation. This is between 3.3 and 5.5 times the EPA recommendations. To date, effluent quality has not been degraded (see section below).

Hydraulic Rates (Soil)

The loading rate on the soil is of particular interest because it impacts the length of trench required and, indirectly, the size of lot required. Monitoring of trenches under this program was limited to visual observation of ponding depths at various points along the trenches.

As stated earlier, all of the trenches in the three sites are operating on relatively short sections of trench, compared to conventional septic system requirements. Site A was operating on less than about 16 feet of 3-foot-wide trench and Site B on less than 12.5 feet of trench. Site C generally operated on 19 feet of trench, except for two occasions where some minor overflow into a second 19-foot trench occurred.

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[30] EPA, 1980, *Design Manual: On-Site Wastewater Treatment and Disposal Systems*, Office of Research and Development, Cincinnati, OH, 1982.

Although the improved effluent quality is the primary reason for successful operation on these relatively short trench lengths, it has been shown that gravelless trenches such as the Infiltrator brand used in these sites also increases the acceptance rate of a trench. Further research should examine RSF performance with gravel trenches. Since soil clogging occurs over time, visual observations of the three sites should also continue to access long-term performance.

Effluent Quality

Effluent was monitored over a ten-month period from September 1993 through July 1994. Samples were generally taken twice each month except for a short period in the spring during which monitoring was suspended to conserve funds and allow for later warm-weather monitoring. A summary of all data is provided in the Appendix.

Table 5 presents a summary of the average effluent quality from the three sites over the monitoring period. These represent the effluent from the sand filter (P-Trap) and from the septic tank at Sites A and C. At Site B, the pump was installed in the second chamber of the septic tank. Percent reductions for Site B are therefore not shown since this arrangement does not allow for determination of baseline pollutant levels in the septic tank.

In order to look at RSF performance under extreme conditions, we also examined pollutant reductions during the two hottest and two coldest months. This is illustrated in Table 6.

Because the P-Trap represents the effluent being discharged to the drainfield, it is of particular interest to compare this to known qualities of septic tank effluent. Table 7 shows some typical septic tank effluent quality as reported by Canter and Knox[31]. Figures 8, 9, and 10 express the P-Trap results from the demonstrations in this project as a percent of the typical levels in Table 7. As shown in the Figures, considerable reductions are achieved with the RSF compared to a conventional septic system, although all systems show significant variability.

[31]Canter, L. and Knox, R., *Septic Tank System Effects on Ground Water Quality*, Lewis Publishers, Inc., Chelsea, MI, 1986.

Table 5
Average Concentrations Over Entire Monitoring Period

	Effluent Concentration							
	Site A			Site B		Site C		
Pollutants	Septic Tank	RSF (P-Trap)	Reduction in %	Pump* Pit	RSF (P-Trap)	Septic Tank	RSF (P-Trap)	Reduction in %
BOD	295	23	92%	72	9	324	22	93%
TSS	90	17	81%	56	8	143	16	89%
Total Nitrogen	45.3	29.1	36%	20.1	19.8	53.1	14.3	73%
Phosphorus	7.6	4.7	38%	13.1	12.0	8.5	3.4	60%
MPN Fecal	444,375	9,276	98%	489,444	26,061	1,864,200	47,036	97%

*The pump at Site B was placed in the second chamber of a dual-zone septic tank.

Table 6
Average Percent Reduction During
Two Coldest and Two Warmest Months

	SITE A		SITE C	
Pollutant	**Coldest**	**Warmest**	**Coldest**	**Warmest**
BOD	95%	91%	87%	97%
Solids	85%	79%	94%	91%
Total Nitrogen	40%	43%	74%	87%
Phosphorus	41%	32%	52%	80%
MPN Fecal	98%	99%	97%	96%

Table 7
Typical Effluent Concentrations From Septic Tanks
(after Canter and Knox)

Pollutant	**Concentration**
Suspended Solids	75 mg/l
BODs	140 mg/l
Total Nitrogen	40 mg/l
Total Phosphorus	15 mg/l

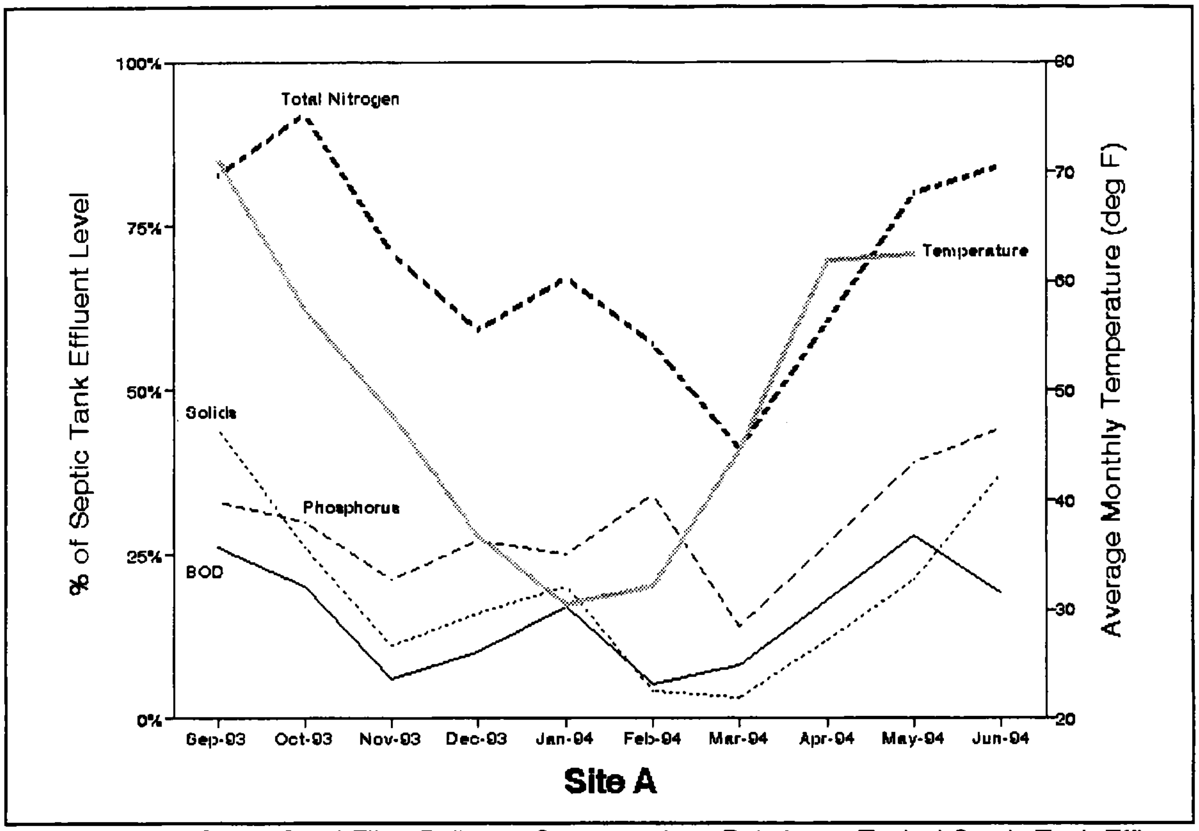

Figure 8: Site A Sand Filter Pollutant Concentrations Relative to Typical Septic Tank Effluent Concentrations

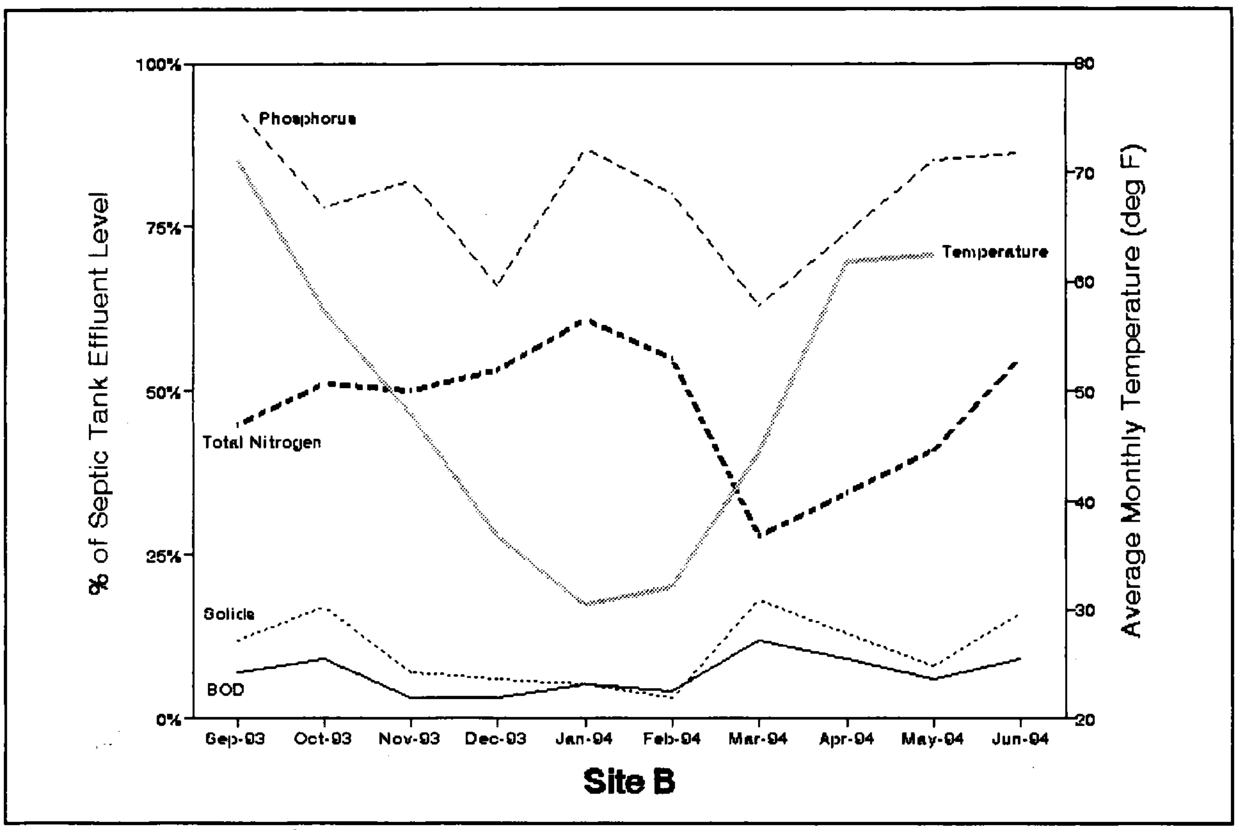

Figure 9: Site B Sand Filter Pollutant Concentrations Relative to Typical Septic Tank Effluent Concentrations

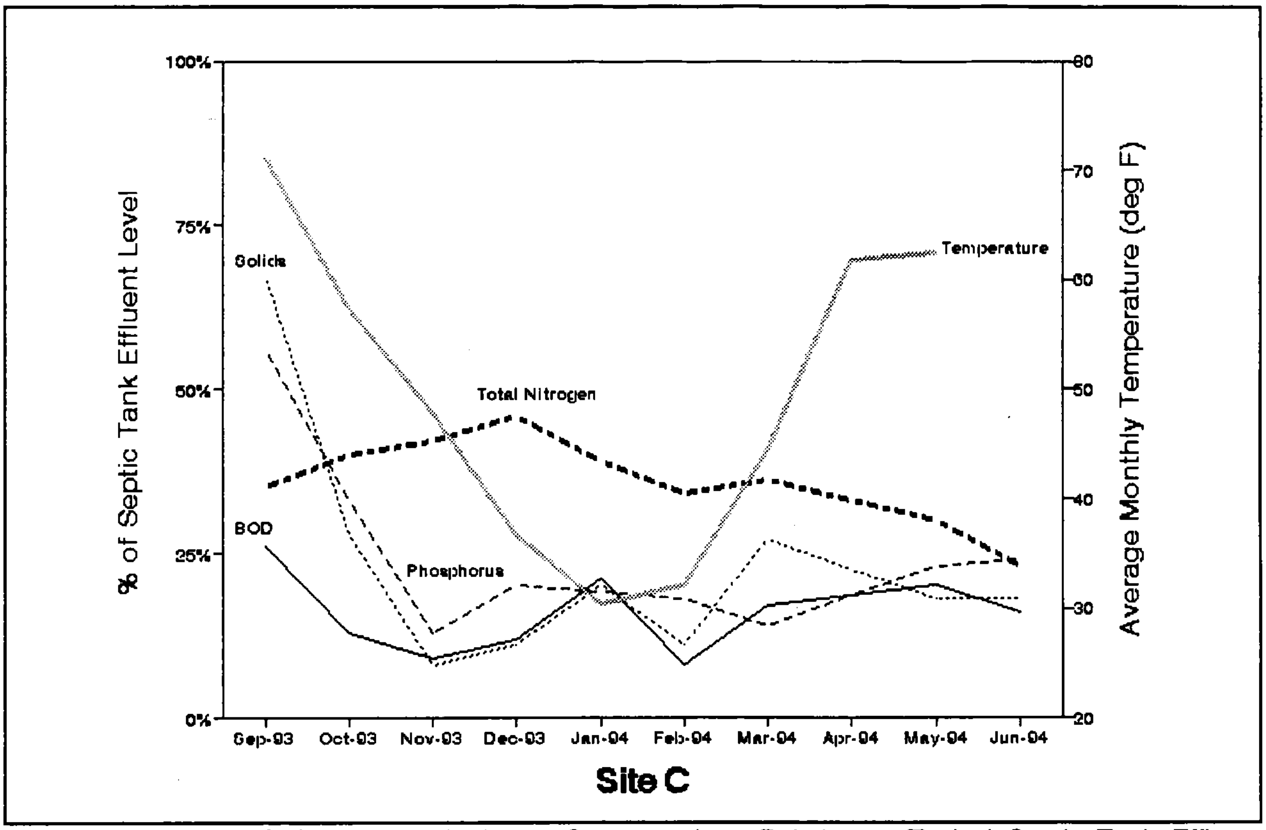

Figure 10: Site C Sand Filter Pollutant Concentrations Relative to Typical Septic Tank Effluent Concentrations

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The three sites constructed and monitored under this project illustrate the increased treatment efficiency of RSF systems compared to conventional septic systems. At Sites A and C, average reductions for Fecal Coliform and BOD exceeded 90 percent, and over 80 percent for Total Suspended Solids. Although still impressive compared to septic tank effluent, Site A average reductions for nutrients were considerably lower than at Site C. Reductions for Phosphorus and Nitrogen were 38 percent and 36 percent, respectively, at Site A. Average reductions increased to 60 percent for Phosphorus and 73 percent for Total Nitrogen at Site C. It is not clear at the time of this report why poorer performance was achieved at Site A, although investigations into water softener chemicals and other potential additives are continuing.

At Site B, RSF effluent was recirculated directly to the septic tank, which prevented establishment of baseline septic tank concentrations and percent reductions for pollutants. However, with the exception of Phosphorus, average effluent concentrations at Site B were lower than those at Sites A or C.

The soils at each site were incompatible with existing county regulations for conventional septic systems. However, visual observations during the first ten months of operation indicate that the RSF effluent was accepted by the soil at a much higher rate that would be expected with septic tank effluent, despite the fact that these were considered heavy-use homes with five or more occupants. Site A was operating on less than 16 feet of 3-foot-wide trench, Site B on less than 12 feet of trench, and Site C on just over 19 feet. Further monitoring should be conducted to assess long-term performance.

Results of the cost-saving features in this study suggest RSF systems could be constructed at a much lower cost than with current practice. For example, the elimination of the pump pit at Site B did not appear to degrade the RSF system's treatment performance. It also appears that the reduce-sized filter used at Site C was successful in achieving high treatment efficiencies and that loading rates much higher than those previously reported may be acceptable. These changes, together with some material substitutions and reductions as described in the cost section of this report, could reduce costs by $1,200 or more.

Overall, current costs of RSF systems are higher than conventional septic systems and will likely remain higher even if the cost saving features discussed in this report are adopted. However, the real benefit of RSF technology is that the improved treatment efficiencies will permit advanced on-site treatment and disposal on soils that are typically considered marginal or unacceptable for conventional septic systems.

Recommendations

Based on the results of this study and a review of previous research, the following observations are offered:

- RSFs offer an alternative to conventional septic tank/soil absorption systems and should be given serious consideration for new home construction on soils with low hydraulic conductivities and/or where higher quality effluent is required.

- RSFs offer opportunities in repair of existing conventional septic systems that are experiencing disposal trench failures. In repair applications, costs of the RSF system can be lowered significantly by using existing tasks if they are in good operating condition.

- Long-term studies should be conducted to develop improved design criteria that recognize the benefits of improved soil acceptance rates with RSF effluent. At a minimum, visual observations of the three sites in this study should continue for several years.

- Additional research should be conducted to evaluate some of the promising cost-saving features investigated under this study. This would include longer-term monitoring of the reduced-sized filter at Site C and the combined pump pit/septic tank configuration at Site B. Additional sites with these features should also be constructed and monitored.

- Updated guidelines should be developed for loading rates on filters to reflect the experiences of Anne Arundel County and the results of this study. This would require improved methods for determining actual hydraulic loading rates on systems in operation.

APPENDIX

Contents

RECIRCULATING SAND FILTER MONITORING PLAN

Construction at all three RSF sites was complete by the first week of August, 1993. A four to six week wait prior to sample collection was allowed to permit maturation of the filter and system. Collection of samples began on September 15, 1993 and proceeded through February, 1994. The samples were collected by Research Center staff and the laboratory analysis was performed according to applicable EPA standards by Martell Laboratories of Baltimore, Maryland. Laboratory analysis consisted of testing concentrations of phosphorus, biochemical oxygen demand, total suspended solids, fecal coliform, and nitrogen in the forms of nitrate, nitrite, and total Kjeldahl nitrogen. Samples were collected from each site at approximately two week intervals.

The sample collection procedure by the Research Center relied on grab samples obtained during site visits. The samples were retrieved from the sampling points with a parastolic pump (Masterflex 7570) and placed in appropriately marked sample containers furnished by Martell Laboratories. Storage of the samples was in accordance with EPA standards in coolers furnished by Martell. Sampling began downstream at the cleanest point in the system and moved up to avoid contaminating sampling equipment. To insure proper sampling procedures were followed, experienced representatives from Anne Arundel County, Maryland, and Martell Laboratories supervised the sample collection initially and at periodic intervals.

Samples at the three sites were generally collected at three locations: from the P-Trap after the sand filter, from the pump pit, and from inside the outlet baffle of the septic tank. In addition to obtaining a sample from each sampling point, one duplicate sample from a selected point was taken as a quality control measure.

A log was used to record measurements and general observations during each site visit. The presence and amount of trench ponding, required maintenance, odors, or homeowner comments were recorded.

The National Oceanic and Atmospheric Administration (NOAA) provided data on temperature and precipitation during the monitoring period from a nearby weather station.

LABORATORY ANALYSIS METHODS

Laboratory analysis of samples was performed by Martell Laboratory Services Inc. of Baltimore, Maryland in accordance with their quality assurance and quality control plan. Martell participates in many quality assurance programs, including (1) State of Maryland, (2) Commonwealth of Virginia, (3) State of Delaware and EPA wastewater, drinking water, and microbiology programs; the U.S. Geological Survey multimatrix program; and the U.S. Department of Agriculture certification program. Martell is a member of the American Society for Testing and Materials. All sample analyses were performed in accordance with published methodologies as follows.

BOD
Biochemical Oxygen Demand
EPA Method 405.1 (5 Days, 20 degrees C)
STORET NO. 00310
Carbonaceous 80082
Approved for NPDES CBOD: pending approval for Section 304(h), CWA
Issued 1971
Editorial revision 1974

FECAL COLIFORM
Standard Total Coliform Multiple-Tube (MPN) Tests
Standard Method 908 A.

NITROGEN
Nitrogen, Kjeldahl, Total
EPA Method 351.3 (Colorimetric; Titrimetric; Potentiometric)
STORET NO. 00625
Approved for NPDES
Issued 1971
Editorial revision 1974 and 1978

Nitrogen, Nitrate-Nitrite
EPA Method 353.1 (Colorimetric, Automated, Hydrazine Reduction)
STORET NO. Total 00630
Approved for NPDES and SDWA
Issued 1971
Reissued with revision 1978

Nitrogen, Nitrate-Nitrite
EPA Method 353.2 (Colorimetric, Automated, Cadmium Reduction)
STORET NO. Total 00630
Approved for NPDES and SDWA
Issued 1971
Editorial revision 1974 and 1978

Nitrogen, Nitrite
EPA Method 354.1 (Spectrophotometric)
STORET NO. Total 00615
Approved for NPDES

PHOSPHORUS
Phosphorus, Total
EPA Method 365.4 (Colorimetric, Automated, Block Digestor AA II)
STORET NO. 00665
Pending approval for NPDES and Section 304(h), CWA
Issued 1974

TOTAL SUSPENDED SOLIDS
Residue, Non-Filterable
EPA Method 160.2 (Gravimetric, Dried at 103 - 105 degrees C)
STORET NO. 00530
Approved for NPDES
Issued 1971

LABORATORY ANALYSIS RESULTS

Site A	BOD EPA 405.1	Solids EPA 160.2	Nitrite EPA 354.1	Nitrate EPA 353.1	Nitrate+Nitrite EPA 353.2	Kjeldahl EPA 351.3	Phosphorus EPA 365.4	MPN Fecal SM 908
Septic Tank								
09/15/93	380	145	0.13	0.05	0.18	55.0	7.0	20,000
10/11/93	270	60	0.05	0.05	0.03	36.0	6.0	900,000
10/25/93	280	57	0.07	0.04	0.09	52.0	7.2	110,000
11/22/93	260	72	0.05	0.02	0.02	29.5	7.8	80,000
12/07/93	380	180	0.08	0.07	0.15	39.0	7.2	1,100,000
12/20/93	300	36	0.05	0.02	0.05	41.0	6.2	1,700,000
01/06/94	385	83	0.06	0.02	0.02	49.0	8.2	170,000
01/18/94	220	70	0.04	0.02	0.06	32.0	5.1	70,000
01/31/94	310	28	0.05	0.02	0.04	37.0	5.5	420,000
02/15/94	300	60	0.05	0.03	0.08	42.0	8.6	90,000
03/17/94	200	29	0.05	0.03	0.03	43.0	5.8	220,000
05/05/94	140	52	0.06	0.06	0.02	33.0	6.8	300,000
05/19/94	290	125	0.03	0.06	0.09	52.0	10.2	500,000
06/07/94	330	95	0.04	0.02	0.04	71.0	12.4	500,000
06/21/94	390	290	0.03	0.00	0.03	55.0	9.6	30,000
06/30/94	280	65	0.11	0.08	0.08	57.0	8.0	900,000
Average	**295**	**90**	**0.06**	**0.04**	**0.06**	**45.2**	**7.6**	**444,375**
Pump Pit								
09/15/93	98	190	0.09	0.10	0.19	38.0	6.0	24,000
10/11/93	178	49	0.05	0.04	0.04	37.5	5.8	160,000
10/25/93	120	420	0.05	0.02	0.05	44.5	7.1	130,000
11/22/93	180	32	0.05	0.02	0.02	29.0	5.2	17,000
12/07/93	97	33	0.05	0.38	0.42	32.0	5.0	80,000
12/20/93	100	42	0.04	0.02	0.06	30.0	4.6	140,000
01/06/94	120	34	0.09	0.02	0.02	34.0	4.5	90,000
01/18/94	82	30	0.06	0.04	0.10	26.0	4.1	30,000
01/31/94	90	17	0.20	1.30	1.50	28.0	5.0	160,000
02/15/94	92	50	0.03	0.02	0.04	23.0	5.2	90,000
03/17/94	42	15	2.17	0.64	2.81	12.0	2.2	90,000
05/05/94	90	710	0.03	0.02	0.04	29.0	6.2	50,000
05/19/94	98	90	0.03	1.67	1.70	39.0	10.4	1,600
06/07/94	170	186	0.02	0.05	0.07	39.0	7.8	160,000
06/21/94	66	34	0.03	0.07	0.10	30.0	8.2	50,000
06/30/94	104	60	0.09	0.83	0.92	36.0	8.0	500,000
Average	**108**	**124**	**0.19**	**0.33**	**0.50**	**31.7**	**6.0**	**110,788**
P-Trap								
09/15/93	37	33	2.62	18.45	21.05	12.0	4.9	3,000
10/11/93	21	21	0.86	16.06	16.92	18.0	4.5	28,000
10/25/93	36	18	0.07	28.88	28.95	9.5	4.4	500
11/22/93	8	8	0.12	19.78	19.90	8.3	3.2	40
12/07/93	21	16	0.17	8.63	8.80	14.0	4.4	2,200
12/20/93	8	9	0.21	15.52	15.73	8.4	3.6	3,200
01/06/94	31	19	0.33	9.45	9.78	19.0	3.7	11,000
01/18/94	28	20	0.23	14.08	14.31	10.0	3.6	7,000
01/31/94	11	6	0.64	17.75	18.39	8.5	4.0	700
02/15/94	7	3	0.36	17.16	17.52	5.1	5.1	55
03/17/94	11	2	0.19	14.42	14.61	1.8	2.2	570
05/05/94	32	18	0.11	22.68	22.79	11.1	4.9	400
05/19/94	48	14	0.30	15.57	15.87	14.0	6.7	80,800
06/07/94	39	60	0.30	22.38	22.67	8.4	7.9	1,350
06/21/94	28	17	0.37	33.43	33.79	5.6	6.3	95
06/30/94	12	7	0.41	19.14	19.55	11.3	5.6	9,500
Average	**23**	**17**	**0.45**	**18.34**	**18.79**	**10.3**	**4.7**	**9,276**

Site B

	BOD EPA 405.1	Solids EPA 160.2	Nitrite EPA 354.1	Nitrate EPA 353.1	Nitrate+Nitrite EPA 353.2	Kjeldahl EPA 351.3	Phosphorus EPA 365.4	MPN Fecal SM 908
Pump Pit								
09/15/93	51	29	0.04	0.02	0.04	20.0	14.5	160,000
10/11/93	49	49	0.02	0.08	0.10	18.0	13.5	160,000
10/25/93	76	46	0.02	0.04	0.06	18.0	13.0	900,000
11/11/93	88	20	0.03	0.03	0.06	22.0	12.0	1,600,000
11/22/93	68	35	0.02	0.03	0.05	17.0	14.0	160,000
12/07/93	49	39	0.15	0.18	0.33	22.0	14.5	530,000
12/20/93	54	28	0.35	6.54	6.89	17.0	8.8	220,000
01/06/94	58	40	1.79	1.54	3.33	18.0	13.0	900,000
01/18/94	80	42	1.05	1.41	1.46	23.0	16.0	500,000
01/31/94	52	24	3.64	6.85	10.49	16.0	12.0	500,000
02/15/94	72	30	2.25	6.36	8.61	14.0	12.0	300,000
03/03/94	40	24	1.74	1.08	2.82	12.0	10.5	500,000
03/17/94	102	20	0.11	0.05	0.05	11.0	12.0	1,600,000
05/05/94	66	19	0.06	0.06	0.05	18.0	14.0	300,000
05/19/94	54	24	0.00	1.20	1.20	16.0	13.0	50,000
06/07/94	145	18	0.07	0.07	0.14	30.0	15.2	160,000
06/21/94	102	375	0.04	0.09	0.13	15.0	14.0	110,000
06/30/94	84	140	0.05	0.63	0.68	19.0	13.6	160,000
Average	**72**	**56**	**0.63**	**1.46**	**2.03**	**18.1**	**13.1**	**489,444**
P-Trap								
09/15/93	10	9	0.37	13.50	13.90	4.0	14.0	5,000
10/11/93	10	6	0.08	18.36	18.46	2.6	11.0	5,000
10/25/93	15	20	0.08	14.88	14.96	4.5	12.5	70,000
11/11/93	5	5	0.02	17.29	17.30	2.9	12.0	19,500
11/22/93	4	6	0.03	14.87	14.90	5.3	12.5	60,000
12/07/93	4	6	0.02	16.33	16.35	1.1	12.0	50,000
12/20/93	5	4	0.12	16.74	16.85	8.0	7.8	16,500
01/06/94	7	4	0.24	18.05	18.29	5.9	13.0	2,300
01/18/94	6	5	0.19	17.37	17.56	4.5	15.0	2,000
01/31/94	7	4	0.10	23.87	23.96	3.2	11.0	920
02/15/94	5	2	0.19	18.28	18.47	3.4	12.0	6,000
03/03/94	30	24	0.43	8.59	9.03	5.2	9.8	160,000
03/17/94	5	3	0.02	5.78	5.78	1.9	9.3	50,000
05/05/94	11	6	0.16	12.46	12.61	5.0	12.5	12,500
05/19/94	7	6	0.11	12.12	12.23	3.2	13.0	3,000
06/07/94	24	15	0.11	18.60	18.71	4.7	13.4	1,585
06/21/94	5	4	0.13	10.85	10.98	3.9	12.8	1,300
06/30/94	10	17	0.07	24.28	24.35	3.9	12.6	3,500
Average	**9**	**8**	**0.14**	**15.68**	**15.81**	**4.0**	**12.0**	**26,061**

Site C

	BOD EPA 405.1	Solids EPA 160.2	Nitrite EPA 354.1	Nitrate EPA 353.1	Nitrate+Nitrite EPA 353.2	Kjeldahl EPA 351.3	Phosphorus EPA 365.4	MPN Fecal SM 908
Septic Tank								
09/22/93	1650	630	0.06	0.04	0.10	130.0	56.0	20,000
10/11/93	230	60	0.06	0.06	0.04	52.0	6.4	1,600,000
10/25/93	260	85	0.05	0.02	0.06	57.0	6.6	500,000
11/11/93	120	82	0.02	0.03	0.05	26.0	2.6	9,000,000
11/22/93	320	146	0.03	0.07	0.10	48.0	4.8	1,600,000
12/07/93	160	76	0.55	0.47	0.47	39.0	4.5	3,000,000
12/20/93	230	123	0.37	0.02	0.33	48.0	5.6	2,400,000
01/06/94	220	144	0.04	0.01	0.01	43.0	4.0	2,200,000
01/18/94	120	58	0.06	0.05	0.05	35.0	4.5	1,400,000
01/31/94	230	166	0.04	0.02	0.06	54.0	5.0	5,000,000
02/15/94	128	290	0.04	0.02	0.05	67.0	7.0	33,000
05/19/94	220	85	0.03	0.03	0.06	37.0	4.1	170,000
06/07/94	528	70	0.05	0.02	0.05	60.5	4.8	330,000
06/21/94	205	69	0.04	0.02	0.02	39.0	4.4	600,000
06/30/94	240	55	0.04	0.03	0.07	59.0	6.6	110,000
Average	**324**	**143**	**0.10**	**0.06**	**0.10**	**53.0**	**8.5**	**1,864,200**
Pump Pit								
09/22/93	43	73	0.03	0.19	0.21	20.0	9.2	160,000
10/11/93	39	48	0.08	0.10	0.22	13.5	6.8	160,000
10/25/93	48	32	0.19	0.60	0.79	14.0	4.2	500,000
11/11/93	17	12	0.45	3.76	4.21	7.6	1.3	500,000
11/22/93	72	35	0.03	0.09	0.12	19.0	3.0	280,000
12/07/93	35	34	3.23	0.64	3.87	13.0	3.0	400,000
12/20/93	90	190	4.12	1.83	5.95	14.0	3.8	500,000
01/06/94	44	18	0.76	5.00	5.76	1.3	3.2	300,000
01/18/94	86	244	0.64	0.56	1.20	32.0	9.6	160,000
01/31/94	48	24	2.69	4.11	6.80	12.0	2.6	280,000
02/15/94	27	18	0.08	0.55	0.63	7.6	3.0	1,600,000
03/03/94	58	50	0.20	0.02	0.18	19.0	2.8	1,600,000
03/17/94	40	18	1.79	0.71	2.50	12.0	2.8	300,000
05/19/94	66	32	0.02	0.03	0.05	21.0	4.0	300,000
06/21/94	36	19	0.04	0.02	0.05	12.0	3.8	90,000
06/30/94	24	9	0.03	0.02	0.04	17.0	4.4	16,000
Average	**48**	**53**	**0.90**	**1.14**	**2.04**	**14.7**	**4.2**	**446,625**
P-Trap								
09/22/93	37	50	0.76	7.27	8.03	6.0	8.4	11,000
10/11/93	18	18	0.53	8.22	8.75	4.6	6.2	160,000
10/25/93	18	24	0.83	9.72	10.55	8.4	3.8	19,000
11/11/93	8	3	0.21	11.07	11.28	2.6	1.3	2,200
11/22/93	17	10	0.34	14.24	14.58	5.6	2.6	9,200
12/07/93	19	8	0.80	13.63	14.43	1.8	2.7	1,600
12/20/93	15	9	0.89	16.95	17.83	2.4	3.2	16,500
01/06/94	17	12	0.21	14.24	14.45	2.4	2.8	3,300
01/18/94	33	20	0.69	7.80	8.49	6.5	3.4	160,000
01/31/94	38	13	1.25	10.39	11.64	3.4	2.4	88,000
02/15/94	11	9	0.05	12.43	12.47	1.3	2.7	10,500
03/03/94	30	34	1.25	3.40	4.70	13.0	2.3	160,000
03/17/94	18	7	0.61	8.54	9.15	2.1	2.0	13,500
05/05/94	30	10	0.21	4.34	4.55	5.3	3.4	27,500
05/19/94	27	17	0.11	0.97	1.08	13.0	3.6	160,000
06/07/94	18	10	0.20	1.37	1.57	7.3	2.8	700
06/21/94	25	17	0.24	0.74	0.98	5.6	3.6	300
06/30/94	23	13	0.13	0.12	0.25	12.0	4.4	3,350
Average	**22**	**16**	**0.52**	**8.08**	**8.60**	**5.7**	**3.4**	**47,036**

Mean Monthly Temperature

MONTH -YEAR	Mean Temp
Sep-93	71.1
Oct-93	57.4
Nov-93	47.9
Dec-93	36.8
Jan-94	30.3
Feb-94	32.1
Apr-94	44.4
Apr-94	61.7
May-94	62.4
Jun-94	NA*

*NA = not available at the time this report was prepared.

SAMPLE MANAGEMENT AGREEMENT
State of North Carolina

THIS AGREEMENT is made and entered into this ___ day of____, 19__ by and between ____________ (hereinafter the "owner") and ____ (hereinafter the "Management Entity").

WITNESSETH

WHEREAS, the owner owns or controls the property upon which a ground absorption sewage treatment system (hereinafter "system") is installed, such system being designated and alternative sewage treatment and disposal system; and

WHEREAS, a contract shall be executed between the system owner and a management entity prior to the issuance of an Operation Permit for said system; and

WHEREAS, the conditions of the Operation Permit for said system be that a properly executed contract between the system owner and a management entity shall be in effect for as long as the system is in use; and

WHEREAS, the owner shall manage the alternative sewage treatment and disposal system.

NOW THEREFORE, in consideration of the premises and of the mutual covenants and promises contained in this Agreement, it is hereby agreed by and between the owner and Management Entity as stipulated below.

1. The Management Entity Obligations. The Management Entity shall perform the following services on the owner's system located at

____

____

a. The Management Entity shall inspect the system at least annually.

b. The Management Entity shall file or cause to be filed a memorandum of this agreement with the register of deeds of the county in which the subject property is located in all situations.

The memorandum shall indicate the property is subject to the terms of this agreement and that the terms of this agreement shall run with the land as a restrictive covenant.

c. The Management Entity shall report the results of its inspections to the local health department annually.

d. The Management Entity shall notify the owner within 48 hours of any inspection that indicates a need for system repair.

e. The Management Entity shall notify the owner of needed repairs which are outside of the scope of routine inspection. The owner shall obtain the necessary repair permit for the system.

f. The Management Entity shall establish and revise from time to time schedules of fees, charges and penalties for required inspections of sewage treatment systems.

2. The Owner's Obligations.

a. The owner shall pay to the Management Entity a fee per year for periodic inspections and periodic reports. The owner shall pay to the approved contractor his fees for any work performed on the system as a result of nonscheduled service or maintenance calls.

The owner shall employ or shall contract with an approved contractor to make the repairs as directed by the repair permit and within the time limitations set by the Management Entity.

b. Within 30 days of receipt of notice of needed repairs pursuant to paragraph 1. above, the owner shall request the Contractor to complete needed repairs.

c. If the owner does not have the system repaired within the time limits given by the Management Entity, the Management Entity shall employ or shall contract with an approved contractor to make the repairs as directed by the repair permit.

The actual cost incurred in making the necessary system's repair and an administrative fee shall be paid by the owner.

In that event, the annual fee and/or any repair cost shall be paid within thirty (30) days after the receipt of a statement. If the charges are not paid, such charges shall be collected as unpaid taxes.

d. The owner shall provide the Management Entity and approved contractor with such access to the system as is reasonably necessary for the Management Entity and the approved contractor to comply with the terms of this Agreement.

3. Term. This Agreement shall remain in effect until such time as county, community or city sewer is provided and connected.

4. Assignment. Assignment by the Owner. The Owner shall notify the Management Entity of the name and address of any purchaser of the property on which the system is located. The Owner shall also notify any purchaser of the property on which the system is located of the existence of this Agreement and shall assign all rights and duties under the Agreement to said purchaser.

5. Representations. The Parties represent to each other that each has the power, authority and legal right to enter into and perform its obligations as set forth in this Agreement.

6. No Implied Waiver. The waiver by either Party of a default or a breach by the other Party of any provision of this Agreement shall not operate or be construed to operate as a waiver of any subsequent default or breach. The failure at any time of either Party to enforce any provision of this Agreement (a) shall not be construed to be a waiver of such provisions, or of any other provisions; and (b) shall not in any way affect the validity of this Agreement, or any part of this Agreement, or the right of either Party thereafter to enforce each and every provision of this Agreement.

7. Notice. Every notice required under this Agreement shall be in writing and shall be deemed sufficiently given if delivered in person or sent by certified or registered mail, return receipt requested, postage prepaid to the Party to be notified and addressed as follows:

To the owner:

____

____

To the Management Entity:

____

____

The date of any Notice shall be the date of personal delivery or the date shown on the return receipt as the date of delivery or attempted delivery, as the case may be. Changes in the respective addresses to which notice may be directed may be made from time to time by either Party by notice to the other party.

8. Place of Agreement. This agreement and any questions concerning its validity, construction or performance shall be governed by the laws of the State of North Carolina, notwithstanding the place of execution, or the order in which the signatures of the Parties are affixed.

9. Entire Agreement and Amendment. This Agreement supersedes all prior negotiations, agreements and understandings between the Parties with respect to the subject matter hereof and constitutes the entire Agreement between the Parties with respect to the subject matter hereof. To be effective, any amendment or modifications to this Agreement must be in writing and must be signed by the Parties.

10. Severability. In the event any provision of this Agreement shall, for any reason, be determined to be invalid, illegal or unenforceable in any respect, the Parties shall negotiate in good faith and agree to such amendments, modifications or supplements of or to this Agreement or such other appropriate actions as shall, to the maximum extent practicable in light of such determination, implement and given effect to the intentions of the Parties as reflected in this Agreement shall, as so amended, modified, supplemented or otherwise affected by such action, remain in full force and effect.

IN TESTIMONY WHEREOF, the Parties hereto have executed this Agreement in duplicate originals, one of which is retained by each of the Parties, the day and year first above written.

____
(Owner)

Witness:

____

____
(Management Entity)

NAHB RESEARCH CENTER
400 Prince George's Boulevard • Upper Marlboro, MD 20772-8731 • (301) 249-4000