

SURFACE DISCHARGE TREATMENT SYSTEM  
USING INTERMITTENT SAND FILTERS  
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Introduction

The main objective of the Small Scale Waste Management Project has been to investigate on-site treatment and disposal of household wastewater. From these investigations, evaluations of existing systems and recommendations as to alternative systems have been made. To date, a majority of the evaluations and recommendations for alternate systems have involved sub-surface disposal systems. This is because past practices of on-site disposal of household wastewater has relied upon the septic tank and soil absorption field. This disposal system if designed, installed, operated and maintained properly is a reliable and economical system.

Realistically, however, there are many site conditions where limitations prohibit adequate disposal of household wastewater to sub-surface absorption fields. Mound or fill systems are an alternative; however, they remain to rely to some extent on adequate soil conditions. Another alternative disposal system involves the discharge of treated wastewater to surface waters. This alternative has not been used in practice due to lack of design information, uncertainty as to required effluent qualities and the existence of high installation and maintenance costs.

In response to this the Project has been evaluating a promising surface discharge disposal system since 1973. The system includes primary wastewater treatment via septic tank or aerobic treatment unit and secondary treatment via intermittent sand filters and disinfection. It is the intent of this paper to briefly summarize the Engineering

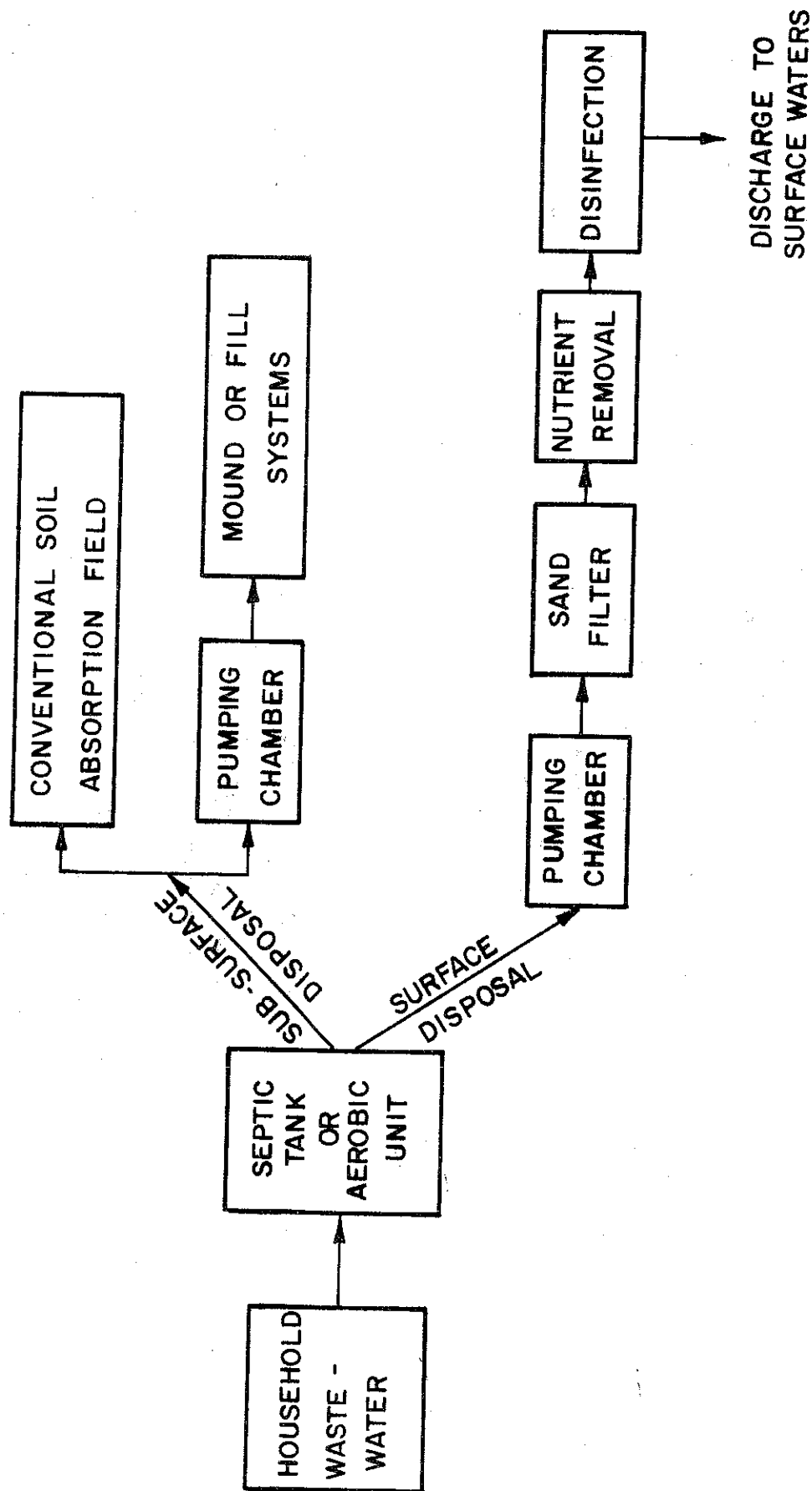
technology of this surface discharge disposal system and also to recommend the direction of future research in the development of this alternative.

### Design

Figure 1 shows the generalized flow pattern for on-site disposal of household wastewater. Final disposal of treated wastewater is either sub-surface or surface. Sub-surface disposal methods include conventional soil absorption fields and the alternate mound systems. Surface disposal of household wastewater requires additional treatment beyond that provided by the septic tank or aerobic treatment unit. A pumping chamber, intermittent sand filtration, disinfection and variable degrees of nutrient removal are necessary to prevent pollution of surface waters.

Previous use of intermittent sand filters has been discouraged due to large surface area requirements and to the negative attitude of state and local regulatory officials toward these systems. Most sand filters in use today require three feet of soil cover and are designed at a loading rate of  $\leq 0.5 \text{ gpd/ft}^2$  (NR 110.30 Intermittent sand filters). It was the objective of the Project to increase loading rates to the sand filters so surface areas could be reduced to 50 to 100  $\text{ft}^2$ . It was expected that the increased loading rates would cause temporary clogging and that maintenance to the sand surface would be required. Removable and insulated covers were installed to ease maintenance and to prevent freezing. A plan and profile of the sand filter is shown in Figure 2. Disregard surface area dimensions. As shown, the entire sand filter is below ground level except for the top 4 inches.

FIGURE 1 - FLOW DIAGRAM, ON-SITE WASTE WATER DISPOSAL



# FIGURE 2 - INTERMITTENT SAND FILTERS

(1 IN. = 2.54 cm)

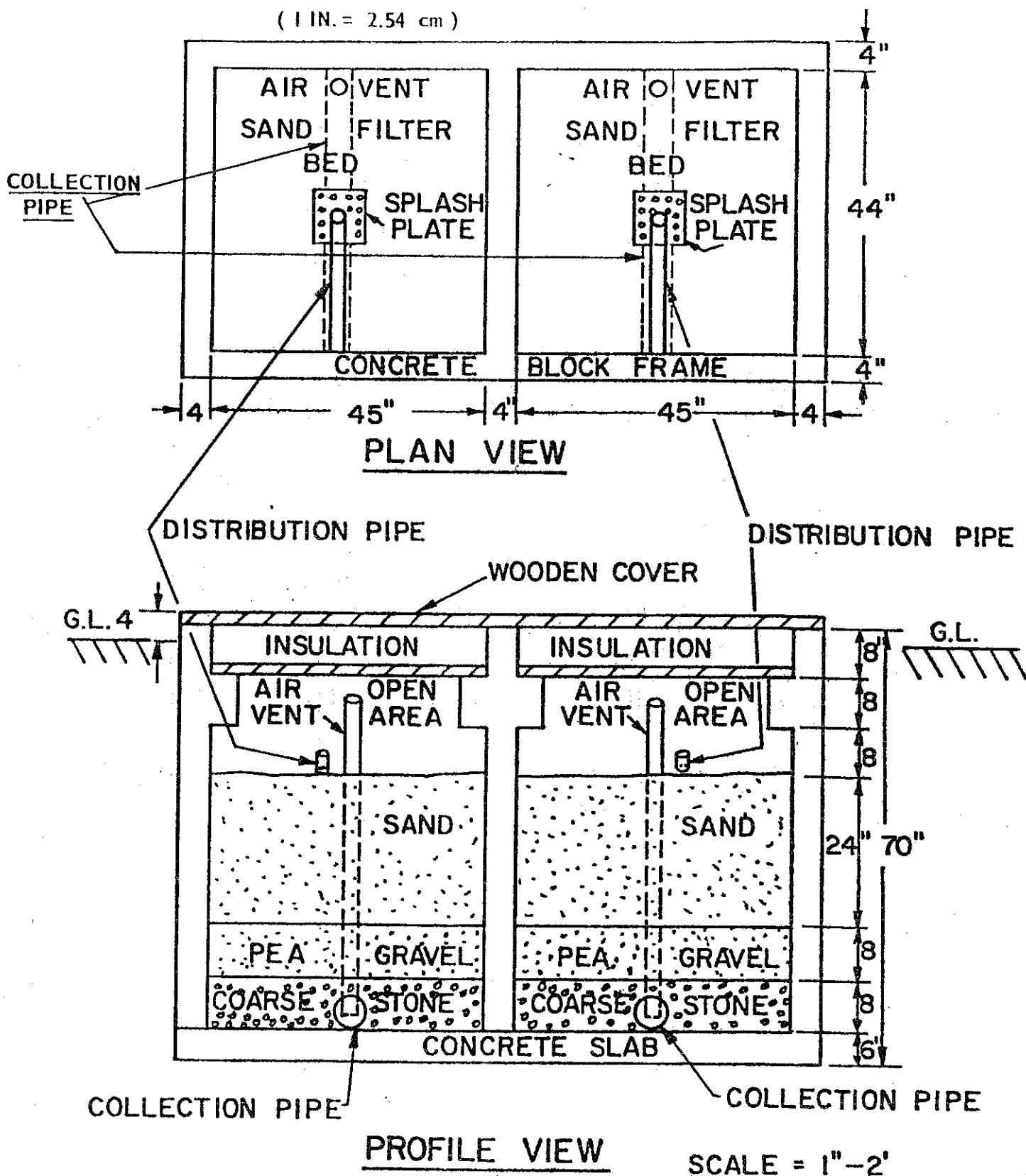


FIGURE 3

# COMPONENTS AND FLOW DIAGRAM OF INTERMITTENT SAND FILTRATION SYSTEM

(1 in. = 2.54 cm; 1 ft. = 0.3 m)

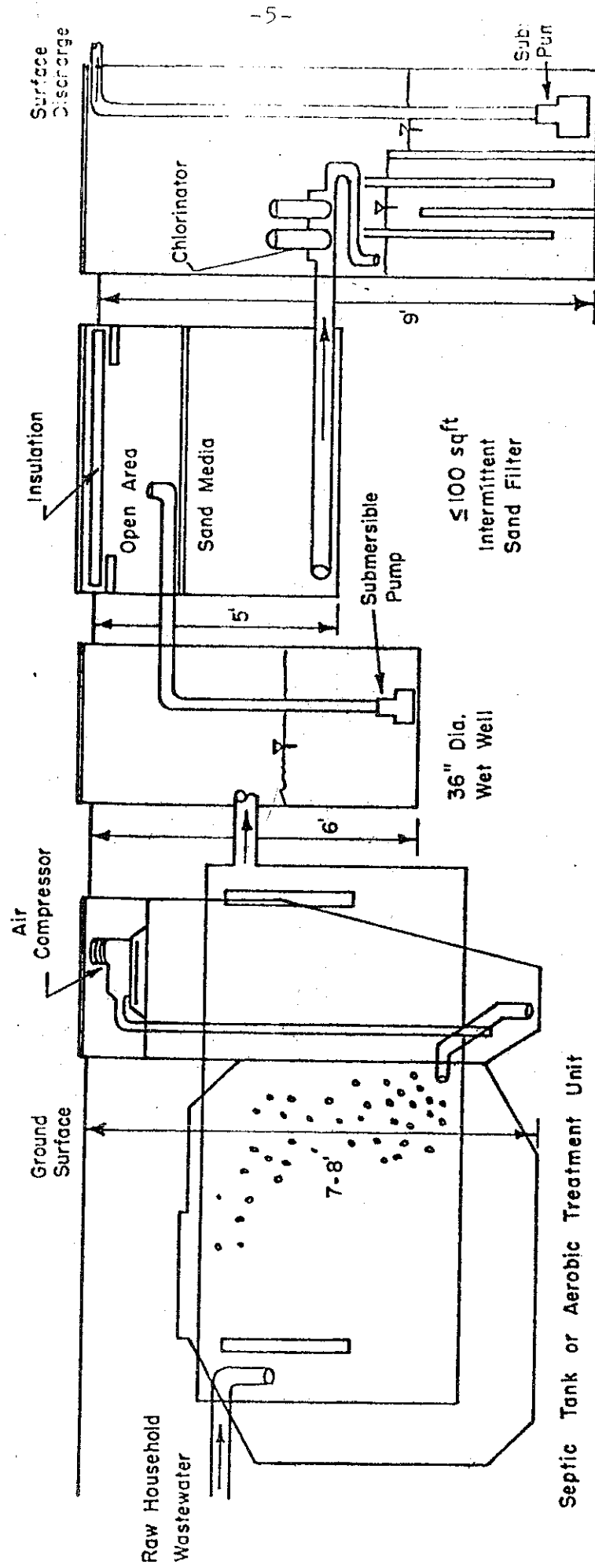


Figure 3 shows a detail flow diagram of the intermittent sand filtration system. Household wastewater is received by a septic tank or aerobic treatment unit from which it drains into a pumping chamber. A submersible pump doses the sand filters 3 to 10 times/day, dependent on flow rates. After filtering through the sand the treated wastewater is collected for disinfection and nutrient removal. Unless adequate elevation is available, a submersible pump will be required to lift the final effluent to the surface.

Standard sizing of the septic tank or aerobic treatment unit is recommended (approximately 1000 gallon capacity). All pumping chambers are recommended to be at least 36 inches in diameter and 1/3 hp submersible pumps are adequate for the system.

Required surface areas and the amount of maintenance of the sand filter is dependent upon the type of primary treatment applied to the wastewater. For treating septic tank effluent 2 filter beds, each 50 ft<sup>2</sup> are recommended. Operation of the sand filters would involve applying the entire waste load to one 50 ft<sup>2</sup> filter for 3 months after which the entire waste load would be directed to the other 50 ft<sup>2</sup> filter. Upon switching filter beds, maintenance is performed to the used filter bed. After 3 months of use, the surface of the filter bed is raked to a depth of 2 to 4 inches. After another 3 months of use the top 4 inches of the sand filter bed should be replaced with clean sand. The operation schedule of alternating beds and performing maintenance to the sand surface should insure proper operation.

If an aerobic treatment unit pre-treats the household wastewater instead of a septic tank, only 1-50 ft<sup>2</sup> filter bed is recommended.

Maintenance would involve removing a crust formed on top of the sand along with the top 1 inch of sand. Replacement of the top 1 inch of sand is also recommended. Frequency of performing this maintenance is once every 6 months.

Methods of disinfection investigated by the Project have included dry-feed chlorination and ultra-violet irradiation. A Project report "Dry Feed Chlorination of Wastewater On-Site" summarizes the chlorination of sand filter effluents. Information on the use of ultra-violet irradiation of sand filter effluent is being gathered.

Nutrient concentrations of concern to regulating agencies are nitrogen and phosphorus. Nitrogen from the sand filtration system is in nitrate-N form. Concentrations of ammonium-N are  $\leq 2\text{mg/l}$  so no significant oxygen demands on the receiving surface waters is expected. Phosphorus from the sand filtration system is in the orthophosphate-P form. Depending upon the receiving waters that are discharged to denitrification and/or orthophosphate-P removal may be required. Design and evaluation of these systems is presently being performed.

#### Effluent Quality

The effluent quality data presented is based on an analysis of samples taken over a period of 2 1/2 years at field demonstration sites. Thirteen parameters were monitored; however, only biochemical oxygen demand ( $\text{BOD}_5$ ), total suspended solids (TSS), and total coliforms are listed in Table 1. Numbers listed are mean values.

Table 1: Effluent Quality Data

	Septic Tank Effluent	Aerobic Unit Effluent	Sand Filter Effluent	Chlorinated Effluent
BOD <sub>5</sub> (mg/l)	123	26	4-10	2-5
TSS (mg/l)	48	48	6-11	5-7
Total Coliforms (#/100 ml)	$9.0 \times 10^5$	$1.5 \times 10^5$	$1.3-18 \times 10^3$	3-35

Suggested effluent standards for discharge to intermittent streams are BOD<sub>5</sub> - 4 mg/l, TSS - 5 mg/l and total coliforms  $\leq 1.0 \times 10^3$ /100 ml. As can be seen, it is entirely possible that sand filter systems with proper disinfection will meet these effluent standards.

#### Cost Analysis

A major concern of any on-site treatment and disposal system is the installation, operation and maintenance costs. For the surface discharge disposal system proposed here, the costs are largely dependent upon the filter size, the availability of quality filter sand and the amount of maintenance required for the sand filter. These factors are dependent upon the type of effluent applied to the sand filters. Tables 2 and 3 give a detailed cost analysis, when septic tank effluent and when aerobic unit effluent is applied to a sand filter. Total annual costs were determined by considering installation and operation costs of the filters amortized at 10% over a 25 year lifetime using 1976 dollars. It was assumed that a 3 bedroom home would be served and that a sand with effective size  $\approx 0.4$  mm and uniformity coefficient  $\approx 3.5$  was available. For Wisconsin the availability of this sand type is quite variable, dependent upon local conditions.



Table 2: Intermittent Sand Filter Cost Analysis  
(using septic tank effluent)

Assume: 3 bedroom home  
septic tank effluent  
sand eff. size  $\approx 0.4$  mm, unif. coef.  $\approx 3.5$   
alternating beds each 50 ft<sup>2</sup> area; total area = 100 ft<sup>2</sup>  
interest rate - 10%  
estimated lifetime - 25 years

Equipment Cost

filter basin, media, cover - \$ 775

Installation Cost - \$ 450

Initial Capital Cost - \$775 + \$450 = \$1225

Maintenance Cost

alternating raking and replacing  
sand surface once every 3 months

raking sand, 2 hr. labor  
x \$5/hr. x 2 occurrences - \$20/yr.

replacing 4" of surface  
sand 2500# - \$ 4

std. delivery cost - \$16

3 hrs. labor x \$5/hr. - \$15

cost per occurrence \$35

\$35/occurrence x 2 occurrences/yr. \$ 70/yr.

Total Annual Maintenance Cost \$20 + \$70 = \$ 90

Total Annual Cost (T.A.C.) = 1225  $\left(\frac{a}{p}\right) \frac{10\%}{25} + 90$

T.A.C. = 135 + 90

T.A.C. = \$225

Table 3: Intermittent Sand Filter Cost Analysis  
(using aerobic unit effluent)

Assume: 3 bedroom home  
aerobic unit effluent  
sand eff. size  $\approx 0.4$  mm, unif. coef.  $\approx 3.5$   
1 sand bed - 50 ft<sup>2</sup> area  
interest rate - 10%  
estimated lifetime - 25 years

Equipment Cost

filter basin, media, cover - \$385

Installation Cost - \$300

Initial Capital Cost - \$385 + \$300 = \$685

Maintenance Cost

remove top crust of sand once  
every 6 months

replace 1" of surface  
sand 625# - \$ 5

delivery cost - \$10

3 hrs. labor x \$5/hr. \$15

cost per occurrence \$30

\$30/occurrence x 2 occurrences/yr. \$ 60

Total Annual Maintenance Cost \$ 60

Total Annual Cost (T.A.C.) = 685  $(\frac{a}{p}) \frac{10\%}{25} + 60$

T.A.C. = 75 + 60

T.A.C. = \$135

Table 4: Cost of Intermittent  
Sand Filter System

	<u>Annual Cost</u>	<u>Initial Capital Cost</u>
Septic Tank - 1000 gal. -	\$ 59	\$ 445
Wet Well Pumping Chamber -	44	320
Intermittent Sand Filter - 100 ft <sup>2</sup> Alternating Beds -	225	1225
Chlorination and Settling Chamber -	<u>120</u>	<u>670</u>
TOTAL (Sampling cost not included)	\$448	\$2660

	<u>Annual Cost</u>	<u>Initial Capital Cost</u>
Aerobic Treatment Unit -	\$243	\$1375
Wet Well Pumping Chamber -	44	320
Intermittent Sand Filter - 50 ft <sup>2</sup> bed loaded continuously -	135	685
Chlorination and Settling Chamber	<u>120</u>	<u>670</u>
TOTAL (Sampling cost not included)	\$542	\$3050

Table 5: Cost of Holding Tank System

Assume: 3 bedroom home  
5 day holding capacity  
interest rate - 10%  
estimated life - 25 years

Equipment Cost

1000 gallon tank - \$225

Installation Cost

excavation, plumbing, backfill - \$200

Initial Capital Cost - \$445

Maintenance Cost

dependent on 1) water use, 2) hauling cost

Water Use (gpd)	Hauling Cost (\$/gal.)		
	2	3	4
200	\$1460	\$2190	\$2920
300	\$2190	\$3285	\$4380

annual maintenance costs range \$1460 - \$4380

Total Annual Cost (T.A.C.) =  $445 \left( \frac{a}{p} \right) \frac{10\%}{25} + \text{maintenance cost}$   
(assume maintenance cost = \$2190)

T.A.C. = 49 + 2190

T.A.C. = \$2239

It is important to note that the aerobic unit - intermittent sand filter system requires only 1/2 the surface area and 1/2 the amount of maintenance as the septic tank - intermittent sand filter system. Due to this the initial capital cost and the annual maintenance cost are reduced for the sand filter loaded with aerobic unit effluent. This cost benefit is neutralized, however, when the annual cost of an aerobic treatment unit is compared to the annual cost of a septic tank. This is shown in Table 4 along with total annual costs and total initial capital costs for the aerobic unit and septic tank sand filter systems. It is noted that sampling costs are not included in the total annual cost. Since discharge is to surface waters, DNR will require some type of sampling program. The cost of a sampling program is dependent upon the number of parameters monitored, the frequency at which they are required and the cost of analysis. Assuming only BOD<sub>5</sub>, TSS and fecal coliforms are monitored at a frequency of once per month and that the analyses are performed by an independent laboratory, the sampling cost could be  $\approx$  \$20-35/month or \$240-420/year. This cost is highly variable and could be reduced by 1/2 if the required sampling frequency were once every 2 months. A cost comparison between an intermittent sand filter system and the presently allowed holding tank system can also be made. Table 5 estimates the highly variable cost of a holding tank system. Hauling costs make this alternate considerably more expensive than an intermittent sand filter system including the sampling cost calculated above.

#### Future Research

The future research recommended here is an attempt to use intermittent sand filters as a workable on-site surface discharge treatment

system. Engineering technology relating to the design, operation and maintenance of the septic tank, aerobic unit, pumping systems and sand filters is firmly established at this time. Information on the use of on-site nutrient removal and disinfection mechanisms is currently being gathered in the laboratory and at the Arlington field site.

It is strongly recommended that the sand filter technology available at this time be evaluated at private residences under experimental approvals. Information on the proper design and maintenance of the sand filters will be effectively evaluated by following this recommendation. Also a better idea of initial installation and maintenance costs will be established.

The Project has already been in contact with a private resident who is interested in installing a surface discharge treatment system. They are located in the Ashland area on Lake Superior and presently depend on a holding tank disposal system. Maintenance to the system would be performed under contract by a local plumber.

Since the successful use of the intermittent sand filter system is dependent upon required maintenance, any large development area using sand filter disposal systems will require some type of institutional control. Formation of special districts and/or sanitary districts are recommended if numerous sand filter systems are to be used. This type of development leaves many unanswered questions. For this reason it is also strongly recommended that a demonstration project be initiated involving a housing development area or community. Such a project would help answer many of the questions encountered in a large scale development using a surface discharge disposal sys-

tem. Numerous engineering decisions will have to be made for the proper use of these systems. By working with a small community, it should be established if an on-site surface discharge disposal system is a practical alternative.