/DEVELOPMENT OF A PROTOTYPICAL DESIGN PROCESS FOR THE USE OF A MICROBIAL/REED FILTER SYSTEM FOR ON-SITE DOMESTIC WASTEWATER TREATMENT/

by

CARL WOODLAND BENGTSON

B. S., University of Nebraska, 1979

A MASTERS THESIS

snbmitted in partial fulfillment of the

reqnirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1986

Approved by:

Major Professor

TABLE OF CONTENTS

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

ACKNOWLEDGEMENTS

The Author of this document has many to whom he owes much appreciation.

To Professor Dennis Law, the author's chairman, whose guidance, counseling and advice helped to make this document possible.

The author would like to thank his committee members, Professors Tom Musiak and James Koelliker for their help and guidance in this endeavor.

To Dr. Bill C. Wolverton for taking the time from a busy schedule to show the author around NASA's experimental projects and providing supportive literature.

Tribute also goes to the faculty and students of the Department of Landscape Architecture whose efforts have made the time at Kansas State University a rich and rewording experience.

To the writer's parents, whose love and understanding nurtured a respect for nature and man's place within it.

To the author's wife Deborah Jo, whose moral support and helping hand has made this document and the dream of a Masters Degree in Landscape Architecture a reality that he will never forget.

CHAPTER I

INTRODUCTION

INTRODUCTION

Although water is one of the most common elements found on this planet it remains one of the most essential requirements for our existence. Because of its abundance it is taken for granted and abused.

Surface water contamination from improperly treated domestic and industrial waste discharged into river and stream systems has been a problem in the United States for many years.

In addition, failing or poorly designed septic systems, deep-well injection of hazardous chemical wastes, and improper landfill operations have been contaminating groundwater supplies from which a large part of the U.S. population receive their drinking water.

Because of these and other factors, domestic wastewater treatment is one of the major problems confronting every community and city in the United States.

Safe disposal of human and domestic wastes is necessary to protect the health of the individual, and the community, while protecting the integrity of the environment.

In the 1800's as population densities increased, so did the concern for protection of public health. This concern gave rise to the sanitation reform movement of the 1800's and the advent of municipal sewage collection systems. Because a collection system depends on a means for transporting the wastes to a centralized point for treatment and disposal, water became the convenient vehicle for conveyance. Therefore, wastewater typically consists of a combination of water and discarded materials from homes, businesses, and industry. Human wastes, laundry detergents and additives, various homeowner and small business oriented chemicals also contribute to the content of the wastewater of even remote communities. These organic, chemical, and physical materials must be removed before water can be safely returned to the environment for reuse.

There are basically three types of wastewater treatment processes: physical, chemical, and biological. During the late 1800's and early 1900's many municipal sewage collection and treatment systems were built in this country, primarily to protect public health. They relied on physical and chemical processes to remove or expedite the removal of large objects, floating materials, and settlable solids from the wastewater. The resulting graywater (wastewater that does not contain sewage) was usually disinfected and neutralized before disposal in a nearby body of water.

Later, as public awareness over environmental issues grew, cities in heavily polluted areas turned to more effective treatment involving biological processes as well as the chemical and physical processes of the early systems. Biological processes use microbial action to degrade and stabilize colloidal and dissolved organic materials in wastewater. If this material is not stabilized before entering receiving waters, the dissolved oxygen in receiving waters can be depleted due to free oxygen requiring microorganisms metabolizing organic and oxidizing nutrients too rapidly. This biochemical oxygen demand (BOD), if too great, can remove large quantities of oxygen from the water causing the deterioration of aquatic life.

In recent years an awareness of the value of good clean water has prompted many communities to pursue an advanced form of wastewater treatment. In these "tertiary" systems, treatment goes beyond removing solids, suspended materials, and dissolved organic material to include the removal of dissolved inorganic chemicals. These compounds (nitrogen and phosphorus for example), if discharged in large quantities, can cause population explosions of algae.

As water use becomes more critical, the need for efficient reuse policies and treatment systems will become more necessary in areas of the United States. Already community-wide facilities for graywater reuse have been successfully implemented in Cocoa Beach and St. Petersburg, Florida. Golf course and recreation field irrigation with graywater has proven an economical alternative to "metered" water while providing a means for groundwater recharge in the region from which it was drawn.

As cities sprawled, the ability to accommodate the additional loads of wastes became taxing on most municipal centralized collection systems. Construction halts and slow downs through aewer moratoriums have become commonplace in many areas of the

United States. These moratoria, once imposed, remain in effect until the central collection system can be upgraded or sewer mains extended to service the new areas. When cities plan for expansion in particular directions they usually install oversized or deep sewer mains to accommodate increased flows in the future, and, thereby, avoid sewer moratoriums. The high cost of oversized and excessively deep sewer mains is passed on to the homebuyer adding to the cost of housing.

With the advancements of transportation and communication technology, people were afforded the freedom of choice in locating their dwellings and businesses. No longer must they rely on the close proximity of services and resources to support their lifestyles and businesses. A need for more sub-regional or on-lot systems to provide adequate wastewater treatment without the expense and problems associated with hook-ups to conventional centralized collection systems exists in the country today.

These systems need to be mechanically simple to keep maintenance and energy requirements low, thereby avoiding replacement of an expensive system with an equally or more expensive alternative. To accomplish this, the system must also be economical in both design and construction costs.

Microbial/reed filter systems developed and tested by the National Aeronautics and Space Administration (NASA) prove to meet these needs while providing the additional benefits of removing not only the floating and suspended components, but also dissolved compounds in wastewater. Such systems are made up of three major components: a sludge collecting and digesting chamber, a hybrid microbial filter/vascular plant unit, and a means of discharge to the environment.

The microbial filter/vascular plant unit uses rooted cold tolerant plants such as the common reed (Phragmites communis) growing on the surface of a microbial rock-filter bed. The microbial filter-reed system has an advantage over the floating aquatic plant system in that wastewater is only exposed to the atmosphere after treatment, reducing the risk of odor problems, and allowing the system to be installed in highly populated areas. The system can be used in colder climates when installed below the frost line, and estuarine environments with higher salt concentrations because of the salt/cold-tolerant characteristics of reeds. Higher chemical concentrations in wastewater can be tolerated because a high microbial cell density is sustained and partially retained on the surface of the filter. The high microbial cell density in the filter unit also increases the potential for adding industrial waste to domestic sewage without upsetting the microbial process.

PURPOSE OF STUDY

The purpose of this thesis is to develop a prototypical design process or methodology for implementing a microbial/reed filter system for domestic wastewater treatment in the most cost effective and least site intrusive means possible.

DEVELOPMENT OF STRATEGY

The strategy for developing this prototypical design process will be first, to review the history of wastewater treatment and identify the current trends of onsite wastewater treatment systems. Second, analyze and describe the parameters of the wastewater and system components as well as the site conditions and how they will affect the system's design. Third, develop a prototypical design process for the integration of a microbial/reed filter system for the treatment of domestic wastewater with a development site.

The process will be tested by applying it to a housing project currently under development. This testing on a case study should identify any problems or omissions in the process while providing an example of the process' implementation under real conditions.

Landscape Architects, by the nature of their profession, are charged with the stewardship of the land. This responsibility coupled with their work with land reclamation and development, resource evaluation and planning issues requires landscape architects to be aware of alternative wastewater treatment systems to conventional centralized collection systems and their ramifications.

It is hoped, this thesis will serve as a guide to the professional wishing to explore the incorporation of a microbial/reed filter system in a development. The author hopes that this thesis will add to the practical body of knowledge in landscape architecture.

Definition of terms will be found in the glossary at the end of this thesis.

CHAPTER II

HISTORY & TRENDS

People, despite their dreams and endeavors, are a part of the natural environment of this planet. Being so, they are tied into the planet's natural cycles of necessities. These cycles, although all interrelated, can be isolated and diagrammed to provide a means to better understanding their components and pathways.

One of these natural cycles is the nutrient cycle as shown in Figure 2.1. This schematic describes, in a very simplified form, the complex biological processes that have evolved to recycle the finite resources of air, water, and nutrients available to us. This whole cycle is efficient and dependent only on the balance between the components and an energy source to overcome energy used during transformation. This source is conveniently supplied by solar radiation from outside the cycle. Any change on the part of one of these factors will cause a chain reactive disruption in the others.

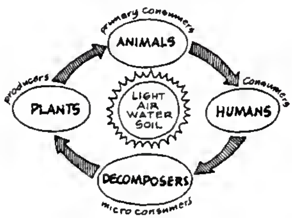


Figure 2.1 The Nutrient Cycle

Source: Van der Ryn, Sim, The Toilet Papers, (Capra Press 1978) p. 113.

For thousands of years, and in most agricultural countries to this day, this natural cycle was recognized to be very efficient at recycling our wastes. It was carried out in the soils, rivers, lakes, wetlands, and forests around us wherever the various components were brought together.

Up until the mid 1800's the most common means of domestic waste disposal in the United States and Europe were private privies and cesspools. Though the use of crude variants of the modern day sewage lagoon can be traced back to the 15th century in Europe, and was the basis for sewage systems developed in the late 1800's for Berlin and Paris, their use was nonexistent in the United States because of a seemingly limitless hinterland in which to expand.

These simple on-site or subregional systems were more than adequate for controlling wastes and disease as long as the population density was low. People made use of the facilities rather than discharging their wastes into adjacent lots or streets, and sited facilities with common sense (ie. not next to one's well). Indeed, the systems were a far cry from medieval Europe when bathing was scorned and wastes in the cities were haphazardly dumped into the streets. Even the habits of the nobility at that time were not much better than the general populous. Their castles usually were equipped with simple stalls called "garderobes", which were built into the castle walls and emptied into the moat, perhaps adding to it's defensive purposes.

With the coming of the industrial age, cities became centers for processing and marketing the resources of the hinterlands as well as providing the support services needed for exploiting the wilderness's vast resources. The densities in urban areas increased as the populations expanded to supply the labor needed to fuel the new non-agrarian economy. As the population density rose for an area the natural ability of the environment to absorb and cleanse domestic and industrial wastes was greatly overwhelmed.

In 1828 a German chemist, Wohler, discovered the chemical synthesis of urea. This quickly led to the production of fertilizers from fossil fuels and the elimination of the reliance on recycled wastes to provide the required nutrients for plant growth in the western world. Therefore, increased urbanization and an economy based on industry and technology, rather than agriculture caused the nutrient cycle to become unbalanced and fragmented as diagrammed in Figure 2.2.

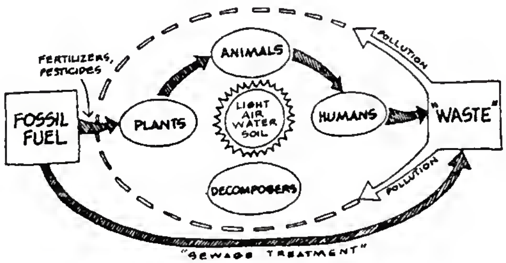


Figure 2.2 The Nutrient Cycle Disrupted

Source: Van der Ryn, Sim, The Toilet Papers, (Capra Press 1978) p. 113.

This unbalanced state manifested itself as well water pollution, widespread filth, and disease. According to Jon A. Peterson in the Journal of Social History,

> "the failure of private lot waster removal first became apparent in England where similar arrangements existed. Because the English response would influence American reactions to comparable predicaments,it deserves special attention. In England during the first half of the nineteenth century, the once sharp distinction between sewers as surface-water drains and cesspools and privies as waste receptacles broke down with disastrous results. As early as 1815 Parliament revoked its ban against draining excremental wastes into common sewers, and in 1847 made this practice mandatory. Behind these changes lay the pressures of urbanization. The fast grown densely packed towns of England could no longer cope with wastes by confining them to the immediate habitat of the city resident. By officially opening sewers to fecal matter, English authorities acknowledged the necessity of removing human ordure beyond the confines of the household lot. But this measure only made matters worse; the established channels, built to man-size dimensions and sluggish in their flow, often clogged with fecal debris, to say nothing of animal carcasses, garbage and other refuse that had never been easily excluded from sewers. English sanitarians of the 1840's denounced the results, condemning sewers as 'elongated cesspools'. In crowded impoverished districts, the breakdown of private lot waste removal easily transcended that epithet. Wastes of all sorts disfigured the cramped housing courts of the workers, accumulated in cellars, collected in the streets, and choked up ditch-drains."

To reduce these problems the sanitary reformers of the age pressured for many changes, among which those of Edwin Chadwick and Fredrick Law Olmsted will be mentioned in this writing.

From his concern with the need for self-flushing sewers Edwin Chadwick proposed the use of a gravity flow system supplemented by the popular invention by Tom Crapper, the water closet. His hopes were that a combination of storm water runoff and wastes diluted in household water could be removed by way of an integrated sewer system, that conformed to the terrain. Wastes would be disposed onto agricultural areas where their deposition would be a great asset instead of a liability.

Although considered a great leap forward in public sanitation, this technological approach was plagued with problems, some of which still effect today's environment. Infectious diseases are spread primarily through water. Therefore, water transportation and disposal mobilized organisms which were otherwise confined. With the widespread use of waterclosets and the subsequent spread of infectious diseases, death rates rose. From 1859 to 1900, cholera epidemics in London and other cities were directly traceable to contamination and leaking of sewage into water supplies. This was in contrast with rural areas, where the use of privies was common and the epidemics were much less severe relative to the population's size.

With the realization of the relationship between disease and water supply contamination from fecal material came the widespread use of chlorine, a powerful disinfectant agent, as a technological answer to the problem of disinfecting both sewage discharge and water supplies.

The use of chlorine itself poses several problems. Some bacteria are suspected to be mutating to forms that have a higher tolerance for a chlorine-laced environment. Recent research has also shown that pathogenic viruses such as hepatitis and polio are not killed by chlorine and are able to survive for months in the discharged waters which are subsequently used for water supplies and recreation downstream. Other problems associated with chlorine use are; the tendency for recombination with other chemicals accruing in wastewater to form carcinogens in water that is subsequently used for drinking water, chloroform formation which is harmful to the atmosphere's ozone layer, and the formation of toxic acids from reactions with sea salt when discharged into marine environments.

During the turn of the century, when many people were praising sewers as great solutions to public sanitation problems, some medical authorities with a keener insight to the problem were critical of water based disposal systems. Dr. Vivian Poore,MD., wrote in Conservancy or Dry Sanitation Versus Water Carriage, J. Donkin (1906),

> "Sanitation is a purely agricultural and biological question; it is not an engineering question and it is not a chemical question, and the more of engineering and chemistry we apply to sanitation, the more difficult the purifying agriculture. Our houses are flushed away but we pay for it by fouling every natural source of pure water. If there comes an outbreak of typhoid as often as not we find drains to blame; but as a matter of fact we prescribe more drains as a remedy. We doubtless manufactured typhoid retail in the old days, but with the invention of the water closet we unconsciously embarked in the wholesale business."

Chadwick's enlightened vision of recycling wastes on agricultural land, thus attempting to correct the imbalance of the nutrient cycle, was unfortunately never realized. Instead, it was found to be much more convenient and economical to discharge the contents of the sewer lines into nearby water bodies with no concern over who might use that water downstream and for what purpose.

The combination of storm runoff, industrial and domestic wastes into one system caused the introduction of heavy metals into wastewater. Cadmium from tire wear on pavement and various metal compounds used in industrial processes and household activities interfere with the natural decomposers and the environment in general. Most conventional centralized treatment systems, added to the sewer systems in this century in response to health and environmental concerns, have little tolerance for heavy metals and, therefore, not only fail to remove or neutralize them but also lose their capacity to treat organic wastes.

This problem is reflected by the recent concern of environmental and fishing groups around the Puget Sound. Toxic levels of chemicals, heavy metals, and dangerous levels of fecal bacteria have been showing up in shellfish and bottom fish in bay after bay of the coves that open off the Puget Sound. Federal and state officials have warned against eating fish from the polluted areas and municipalities have been ordered to provide secondary sewage treatment by 1991 in an attempt to reduce pollution levels in the Sound.

The practice of discharging either raw or primary treated wastewater into water bodies rather than land application has led to many environmental, aesthetic and design problems resulting from the fecal material alone. On a trip to the Miami Beach area during the 60's this author was abhorred with the quantity of raw sewage collecting with the flosam on the beaches. Upon inquiring as to the reason, the answer revolved around the reduction of costs associated with municipal sewer hookup. To minimally comply to the present codes, the hotels had run individual sewer lines out several hundred feet into the Atlantic for disposal purposes. It seemed rather pathetic that companies who spent so much capital to accommodate guests would be so negligent for the care and protection of the primary attraction of their sites.

This "out of sight, out of mind" attitude inherent with ocean dumping techniques has been raising havoc with marine environments wherever raw or poorly treated sewage outfalls occur. In Los Angeles, for example, the municipal treatment plant discharges both primary and secondary treated sewage at the edge of a marine canyon 300 feet deep. The sea urchins thrived on the wastes and proliferated to the point that they threatened the beds of the giant sea kelp which provided the habitat and food source for the marine life in the area. In response to this threat, the Los Angeles County Department of Parks and Recreation, in 1971, recruited volunteer divers in an attempt to kill the sea urchins. This seems to be an extravagant attempt to balance the nutrient cycle and was doomed to failure for it failed to address the problem at it's source, the poorly-treated or misplacement of the discharge.

Urban design has also been influenced by gravity flow wastewater systems. In the case of Seattle, the overwhelming popularity of Mr. Crapper's watercloset was accommodated by the direct discharge off the city shoreline into the gently sloping tidal marshes. The steep hills feeding one end of the system and a rapid tidal fluctuation, because of the topography of the bay, created a back surge from the other end of the system. Users were rudely aware of the tidal schedules. Many an unwary user of the facilities that were unfortunate to live between the wharfs and halfway up the coastal hill were greeted by a fountain of wastewater to remind them of their oversight. This backwash drained from the houses into the unpaved streets making them nearly impassable. In response to this, the city raised the street level to nearly a full story which required one wishing to enter a building to tie up his horse on street level and descend to the building entrance below by means of a ladder. After existing in this state of affairs for several years the city abandoned the first floor in the entire area subjected to these periodic flooding and capped over the sidewalks. Thus, the second floors became the entry level in an entire area of the city and the prior street level was abandoned to storage.

As a leader of the U.S. Sanitary Commission during the Civil War, Fredrick Law Olmsted became keenly aware of health problems and their solutions as they pertained to site conditions. In his latter career as a landscape architect, he drew upon these insights to incorporate the aesthetic and cultural resources of a natural landscape with its sanitation potentials.

J. A. Peterson points out in the Journal of Social History,

> "Olmsted's suburban planning also embraced the topographical concerns of sanitarians. Realizing that slapdash development of outlying districts by conventional subdividers often created health hazards-for example, malaria, as a consequence of inadequate drainage-Olmsted emphasized thorough site preparation and design. He fitted roadways to the natural terrain not only with an eye to the

picturesque effects but with a view to natural drainage contours as well."

Olmsted's recognition of the need for large green spaces open to the light and air, though his concern was for the dissipation of respiratory gasses that he felt were responsible for disease communication, addressed the need for incorporation of ecological niches or greenbelts throughout the city to reduce the population density and increase the plant density of an area. This allowed the environment to better absorb the populations wastes by reducing the load per unit area imposed on it.

Traditional methods of waste management are facing major problems throughout this country, fueling serious interests in alternatives methods.

In addition to the problems already mentioned, Betty N. MacDonald, in Individual Onsite Wastewater Systems, has drawn up a compendium of the problems associated with municipal waste water treatment methods and are included in Table 2.1.

TABLE 2.1 POSSIBLE PROBLEMS ASSOCIATED WITH CONVENTIONAL TREATMENT SYSTEMS

1. Water supply problems will become more accute as conflicting needs compete for limited quantities of water. According to the United States Geological Survey in its annual research report for 1974, American water usage has doubled in the last 25 years and a further doubling of water requirements for the manufacturing and mineral industries alone is foreseen by the year 2000. The report predicts that although one gallon of water may be reused four or five times today, much more extensive multiple usage and much more stringent limits on pollution will become necessary.
2. Water costs are high and will be higher as various consumers bid for a finite supply. It is estimated that the average North American family annually uses 35,000 gallons of water for toilet flushing, or 40 percent of the municipal water supply that goes to private homes, an extravagant and hardly justifiable use of large quantities of purified drinking water to carry away relatively small quantities of wastes.
3. In addition to water costs, the costs of construction, maintenance, and operation of centralized waste treatment facilities, including sewer lines, treatment plants, and sludge disposal, are rising as we attempt to meet urban growth needs, costs exacerbated by continuing inflationary pressures. In western countries currently the infrastructure investment for wastewater facilities is said to be about $500 to $600 per person.
4. Energy costs at large centralized sewage treatment plants are enormous. At full capacity a 300 million gallons per day waste treatment plant is estimated to consume as much as 900,000 kilowatt hours of electricity, 500 tons of chemicals, and 45,000 gallons of fuel oil daily. Rising energy costs and limited energy supplies may well prove to be decisive factors in locating and sizing treatment facilities and in determining methods of treatment and disposal even where water supply is not limiting.
5. Excessive centralization has led to excessive system size with a potential for discharge of large volumes of untreated sewage in the event of such episodes as equipment breakdown, power failure, employee strike, or high water bypass.
6. Despite intensive, expensive methods of treatment, the inevitable risk remains of transmitting diseases to water-users downstream from the point of effluent discharge.
7. Incomplete removal of nutrients from effluent may lead to accelerated eutrophication of lakes and estuaries.
8. Inability to keep up with growing volumes of wastes which have overloaded sewage facilities has led to frustrating attempts to limit development through such techniques as moratoria on commercial and residential sewer applications and plans for phased, or timed, development.

Source: MacDonald, Betty N., "The Impact of On-lot Systems on Land Development: A Citizen's View", Individual Onsite Wastewater Systems, (Michigan: Ann Arbor Science, 1977) p. 25.

These problems can be substantially resolved with the use of on-site treatment systems that are more energy efficient, environmentally compatible, and more closely aligned with the nutrient cycle.

ON-SITE WASTEWATER TREATMENT SYSTEMS

Since our society is firmly attached to using flush toilets, only alternatives that will accommodate their incorporation into a system will be considered in this thesis. Of the many systems available to developers and homeowners, only those that are economically reasonable and practical for incorporation into home sites, subdivisions, or industrial sites will be considered. The systems that fit these parameters are; septic tanks and their absorption fields, modified septic systems, wastewater lagoons, modified lagoons, overland flow, and microbial/reed filter systems.

Septic tanks -- Septic tanks and their absorption fields have been the most commonly used on-site system in the U.S. A typical septic system, from Individual Onsite Wastewater Systems, is shown in Figure: 2.3 and 2.4. The septic tank acts like a settling tank and anerobic digester for incoming sewage. Since these tanks require a long holding period to accomplish this they are usually sized at least four times larger (usually 1,000 gallons) than the expected household daily volume of sewage. A typical tank's effluent will still have an organic matter content 3-4 times the concentration allowed by the Environmental Protection Agency's (EPA) standards for discharge to waters of the U.S. and a suspended solids content twice the EPA's standards for discharge. This requires the addition of an absorption field to the system to reduce these levels further through biological activity in the soil. These soil communities recycle nutrients, transform disease-causing organisims into harmless protoplasms (without the use of chlorine), degrade residual organic matter and reduce water content through evaporation and infiltration. The size of this field depends on the amount of water used in the home and the capacity of the soil to absorb the effluent.

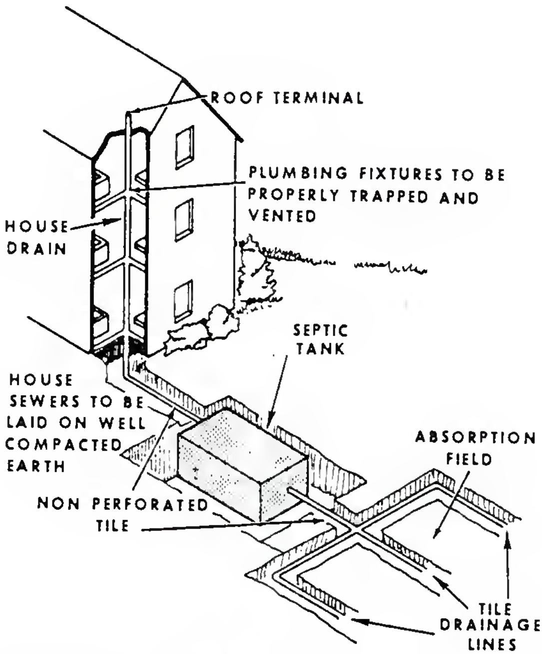


Figure 2.3 Typical Septic System

Source: McClelland, Nina I., Individual Onsite Wastewater Systems, (Michigan: Ann Arbor Science, 1977) p. 182.

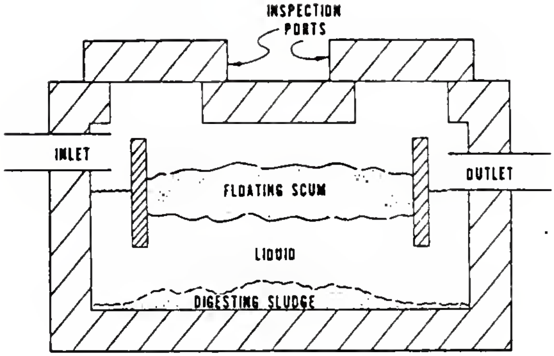


Figure 2.4 Typical Septic Tank

Source: McClelland, Nina I., <u>Individual Onsite Wastewater Systems</u>, (Michigan: Ann Arbor Science, 1977) p. 183.

Septic tank and adsorption fields, therefore, offer the potential for recycling purified water to the ground water from where it came. Areas in the Southwest discovered that their water tables were falling when they were connected to centralized sewers which discharged water out of the area after being previously served by septic systems.

The use of these systems is limited largely by the soil's capacity to accept the water discharged to it and the maintenance (periodic sludge removal) it receives.

Safe subsoil disposal is difficult in sandy or heavy clay soils, areas of high water tables, high use density, steeply sloped sites or fractured rock (as shown in Figure 2.5 from <u>Sewer Moratoria: Causes, Effects, Alternatives</u>). This may require extensive site work in some incidences (ie. installation of a raised sand bed to lay the drain tiles in if the water table or rock is too close to the surface) or an arrangement of lots as in Figure 2.6 if the required space is available.

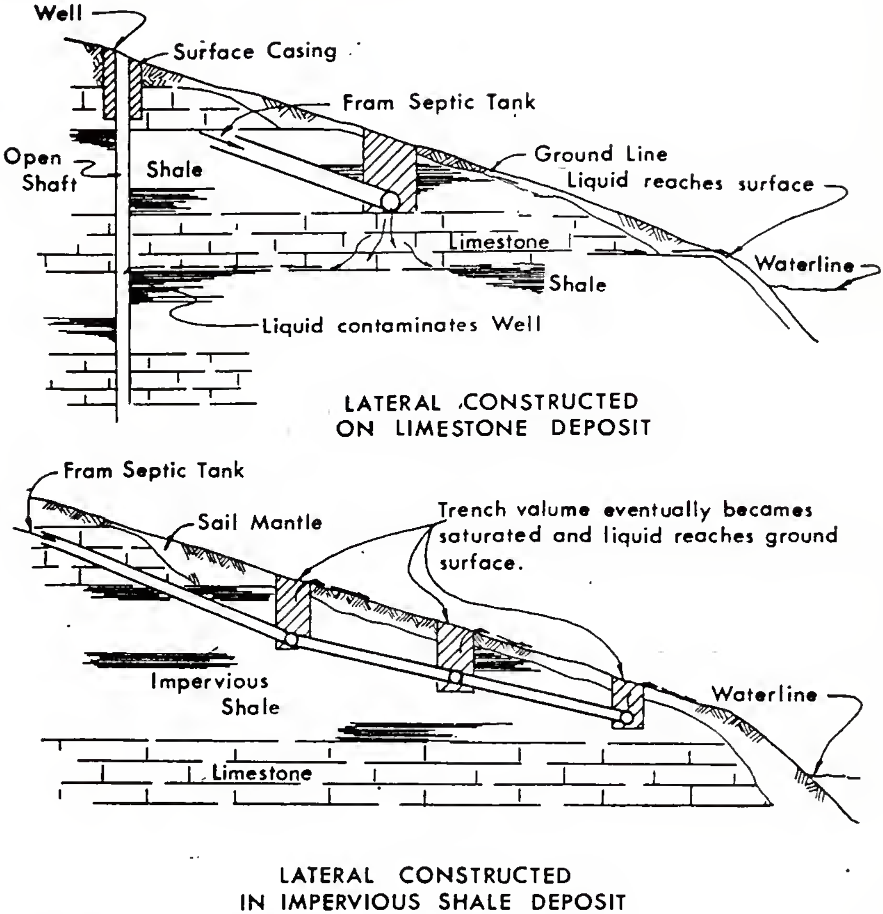


Figure 2.5 **Problems Associated With Lateral Placement and Rock Substrate**

Source: Oblinger-Smith Corp., Pottawatomie, Riley Counties Water and Sewer Plan, (1971) p. 113.

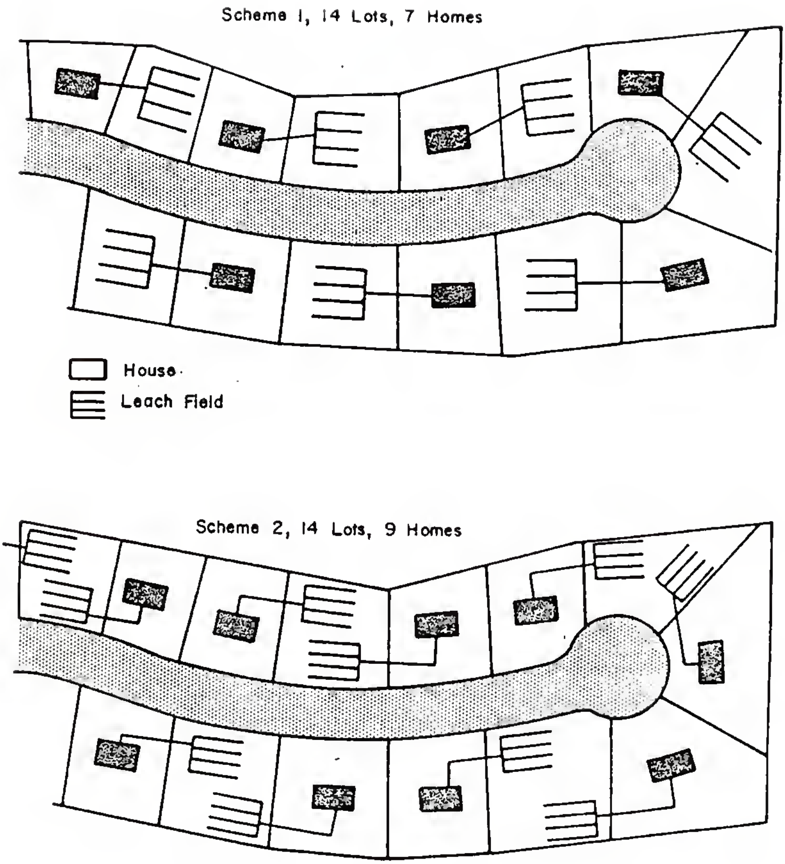


Figure 2.6 Alternative Development Schemes for Interim Septic Tank/Leach Fields

Source: United States Department of Housing and Urban Development, Sewer Moratoria: Causes, Effects, Alternatives, (U.S. Government Printing Office, 1977) p. 31.

Modified septic systems -- Research by Dr. Wolverton, et.al., has shown that the performance of septic tanks and drain fields can be greatly enhanced by the addition of microbial/reed beds (as shown in Figure 2.7) or through incorporation of the drain field with the landscaping of a site, thus providing a dual function of water treatment and conservation as shown in Figure 2.8.

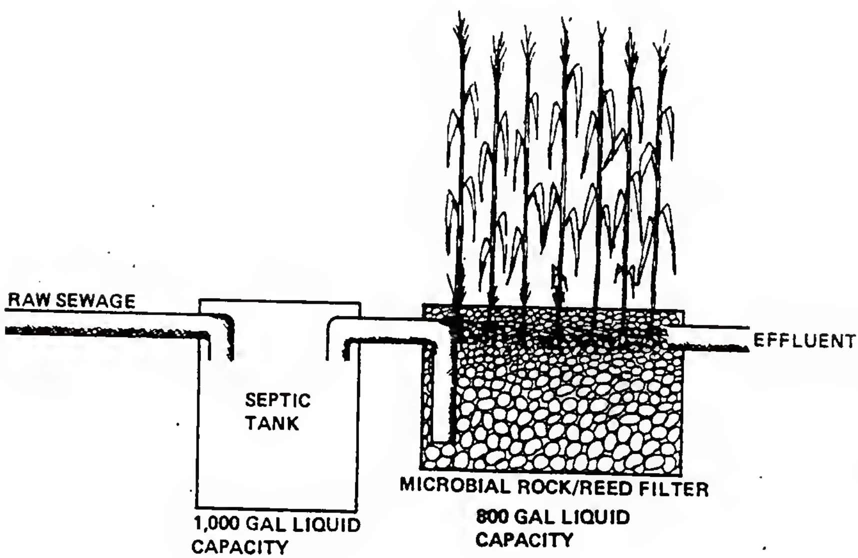


Figure 2.7 National Space Testing Laboratories South Gate Wastewater Treatment System

Source: Wolverton, B.C., and McDonald, R.C., Basic Engineering Criteria and Cost Estimation for Hybrid Microbial Filter-Reed Wastewater Treatment Concept, (NASA, TM-84669, 1982) p. 11.

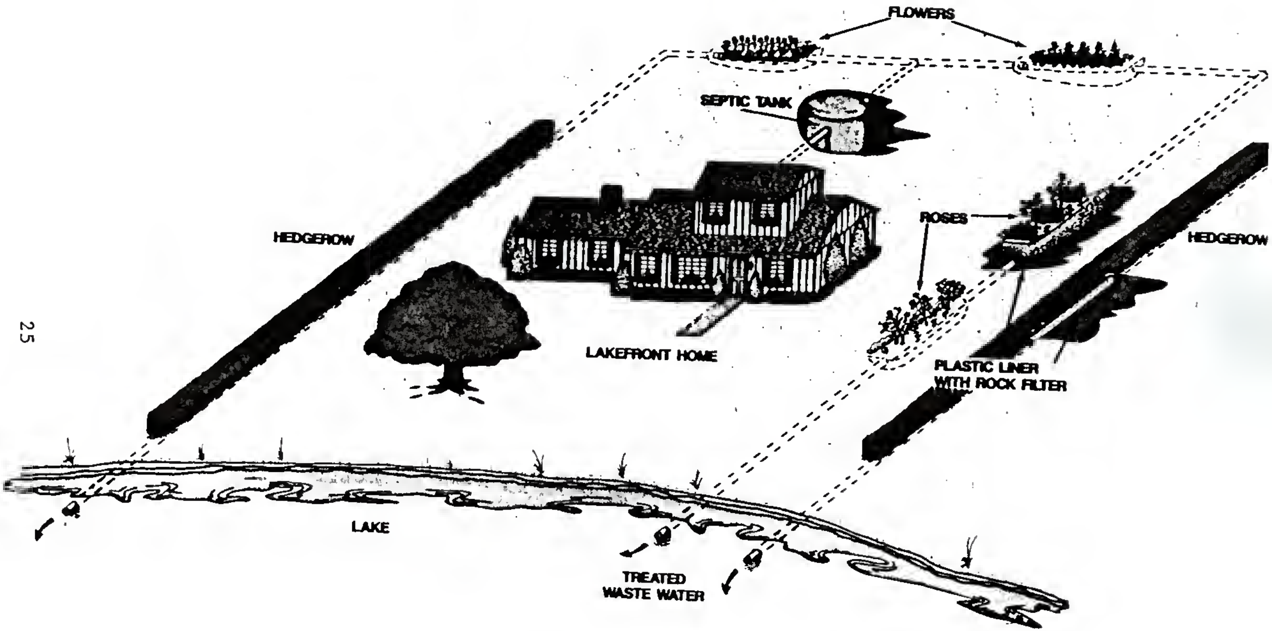


Figure 2.8 Incorporation of Drain Field With Home Landscaping

Source: Wolverton, B.C., Original Art Work.

Wastewater lagoon -- The second most common type of onsite or sub-regional system found in this country is the wastewater lagoon which is used primarily for small communities and industrial wastewater. In the basic form of this system (shown in Figure 2.9) sewage is purified through the action of sun, wind bacteria, algae, snails and other scavengers feeding on the decomposing wastes. Solids separate by gravity to form a sludge on the bottom where it decomposes under anaerobic conditions. In the upper levels of the lagoon, bacteria and algae form a symbiotic relationship to aerobicaly decompose and stabilize the wastewater.

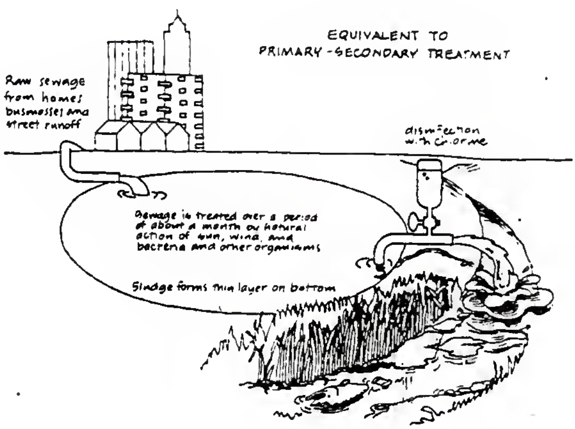


Figure 2.9 Typical Wastewater Lagoon

Source: Van der Ryn, Sim, The Toilet Papers, (Capra Press 1978) p. 102-3.

Some problems of these systems can be attributed to the algae. Since the algae are not active to any degree during the winter months or at night, odor problems may occur due to a reduction in aerobic conditions. Therefore, the addition of mechanical aeration might be required to raise oxygen levels. Furthermore, as algae rapidly multiply and die they add to the organic matter thus raising waste and suspended solid levels in the wastewater.

Another drawback of lagoon systems is the need for fairly large tracks of land and the suitability of the soil for proper containment. If the soil is not suitable, it can be amended by the use of clay blankets or synthetic membranes depending on the site constraints. The advantages and disadvantages of various membranes and edge sealing materials are shown in Figure 2.10, (from the Urban Land Institute).

Material	Thickness	Advantages	Disadvantages	Joints
Vinyl (PVC)	500 gauge (0.127 mm)—too thin for most uses; 1000 gauge (0.254 mm); 1500 gauge (0.381 mm).	Resistant to impact damage. Very easily joined and patched with solvent adhesive. Black vinyl (unlike clear vinyl) resistant to sunlight.	More expensive than polyethylene. Life expectancy unknown.	Solvent welded; allow 6 inches overlap; lay smooth but slack.
Black poly-ethylene	500 gauge min.	Inexpensive. Black polyethylene is resistant to sunlight; clear, polyethylene deteriorates and becomes brittle.	Not resistant to impact damage. Difficult to patch.	Heat sealed; lay with at least 10 percent slack.
Butyl	Usually 760 mm.	Highly resistant to impact damage. Need not be covered except in high puncture risk areas.	Expensive.	Special adhesive.

Sealing materials.

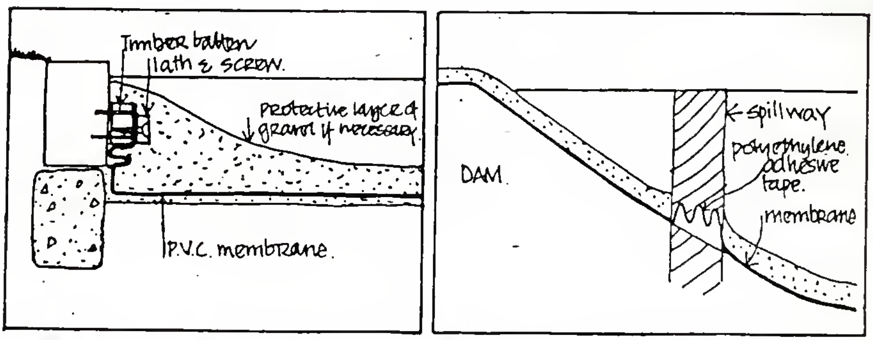


Figure 2.10 Various Synthetic Membranes and Sealing Materials

Source: Urban Land Institute, Lakes and Ponds, (UBI Press, 1976) Technical Bulletin #72, p.53.

Modified lagoons -- Research by Dr. Wolverton, et. al., has shown that performance levels of waste water lagoons can be upgraded by the incorporation of vascular plants. The use of water hyacinth (*Eichhornia crassipes*), in warmer regions, and duckweed (*Lemna minor* & *Spirodela polyrhiza*), in temperate regions, replace the need for algae to provide the oxygen needed for aerobic decomposition.

Since both of these plants float on the surface, they cut out the sunlight to lower layers of the pond discouraging algae growth and do not add to the organic matter or suspended solid loads. Because these floating plants add oxygen to the wastewater the lagoons do not require aeration to prevent odors unless the system is receiving a heavy load from the influent. Since the roots also extend down from the surface they provide an additional substrate for bacterial activity.

Another asset of this modified system is the potential for the conversion of harvested plant material into animal feed, organic fertilizer and soil conditioners, human food, and methane gas for fuel. Harvest of hyacinths from natural water bodies has not proved economically feasible but this problem is overcome in the densely packed geometric environment of the lagoon. If the influent contains heavy metals, chemical residues, or radioactive contaminants, it will not be suitable for food or fertilizer use, though these conditions do not preclude their use for methane production. After digestion contaminated residual sludge could be placed in clay-lined pits to provide a future "mine" for chemical extraction.

Though this system has been extensively tested in many southern regions it has some inherent climatic restraints because of the low tolerance of these plants to salt or cold environments.

This system and some of its applications are shown in Figure 2.11.

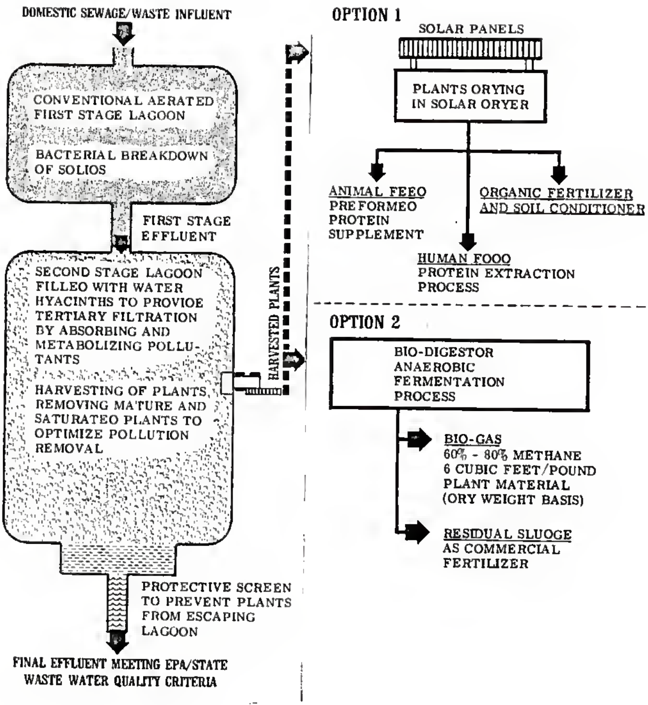
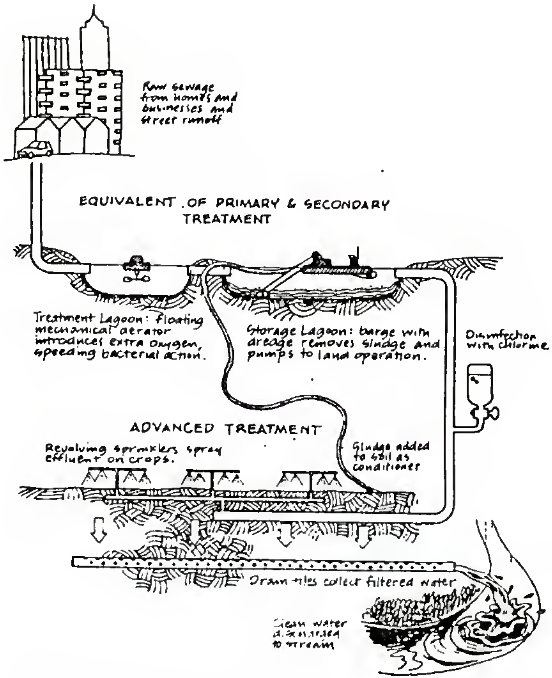


Figure 2.11 Modified Sewage Lagoon

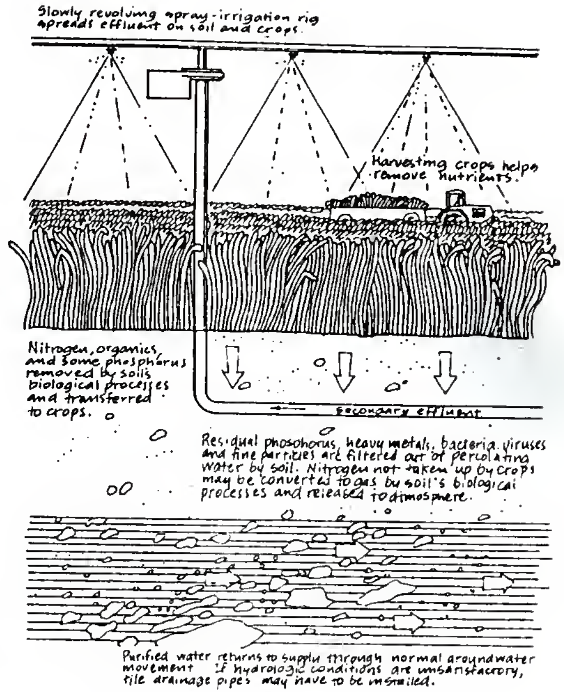
Source: NASA, <u>NASA & flowers</u>, NASA Promotional Brochere.

Overland Flow

Another modification of the lagoon system (shown in Figure 2.12) incorporates the use of overland flow to improve effluent quality while recycling water and nutrients. Contact with the air, crops, and microbes in the soil purifies the water as it is sprayed from slowly revolving sprinklers. The purified water recharges the ground water or may be impounded for recreation, drinking, irrigation, fire protection, cooling towers, or aesthetic purposes. Sludge that settles in the lagoons would be periodically dredged and applied to the soil as a conditioner and additional fertilizer. Though the land costs would be increased by this modification they could be offset by the preservation of open space around a community or the sale of crops and fertilizer.



Aerated lagoons and spray irrigation: a natural water treatment system.



Detail of spray irrigation system. Water is purified by passing through the soil filter.

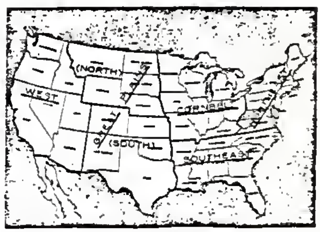
Figure 2.12 Modified Sewage Lagoon

Source: Van der Ryn, Sim, The Toilet Papers, (Capra Press 1978) p. 105.

Overland flow systems that do not require lagoons have been used successfully in Davis, California, and in campgrounds in Europe. Wastewater is applied at the top of a grassy slope underlain with a impervious layer. As the water flows in a thin film it is cleaned by the soil, vegetation, and microbes at the soil surface. The clean water is then collected in open ditches at the bottom of the slopes for discharge or reuse. Slopes may be planted with selected species to handle a specific wastewater or may be planted with plants from Table 2.2 to meet general domestic wastewater requirements.

TABLE 2.2 GRASSES AND LEGUMES FOR OVERLAND FLOW SYSTEMS

Grass or Legume	Northeast	Cornbelt	Southeast	Great Plains North	Great Plains South	West
Kentucky bluegrass	•	•				
Redtop	•	•				
Tall fescue	•	•	•		•	•
Smooth bromegrass	•	•		•	•	•
Red fescue	•					
Timothy	•	•				
Reed canarygrass	•	•		•		•
Birdsfoot trefoil	•	•				•
Orchardgrass		•				
Pensacola bahiagrass			•			
Bermudagrass			•		•	
Zoysia			•			
Sericea lespedeza			•			
Crimson clover			•			
Kudza			•			
Intermediate wheatgrass				•		•
Western wheatgrass				•	•	
Switchgrass				•	•	
Big bluestem				•	•	
Tall wheatgrass				•		•
Indiangrass				•	•	
Crested wheatgrass				•		•
Sideoats grama				•	•	
Siberian wheatgrass						•
Buffalograss					•	
Beardless wheatgrass						•
Streambank wheatgrass						•
King Ranch bluestem					•	
Pubescent wheatgrass						•
Creeping meadow foxtail						•
Lehmann lovegrass						•
Hardinggrass						•
Prairie cordgrass				•		



Source: U.S.D.A., Grass Waterways in Soil Conservation, (U.S.D.A. Leaflet 477, 1971).

The site must be steep enough to prevent ponding but also gentle enough to prevent erosion and allow a sufficient contact period. A 2-4% slope has been suggested by Lonvil G. Rich. [1] Therefore, this system could be easily adapted to rolling terrain. Maintenance will need to be considered in this type of system since the slopes must be carefully graded to prevent channeling (which short circuits the system) and promote uniform distribution.

Land requirements run high for community scale systems. To process a one million gallon per day flow, some 15 to 100 acres might be needed. [2] This need will depend on the type of crop, soil, waste, climate, application rates and the desired level of effluent treatment. Though an initial expense this land would benefit communities or subdivisions by preserving open space and greenbelts, recharging ground water, and possibly the marketing of crops and forage grasses.

Microbial/reed filter

The current research suggests that the most economical and efficient alternative for small communities and subdivisions in temperate to cold climates is the microbial/reed filter system. The system shown in Figure 2.13 would have a construction cost of $137 per household, if a PVC-lined system is required, or $112 per household, if a natural clay blanket barrier is used, (based upon

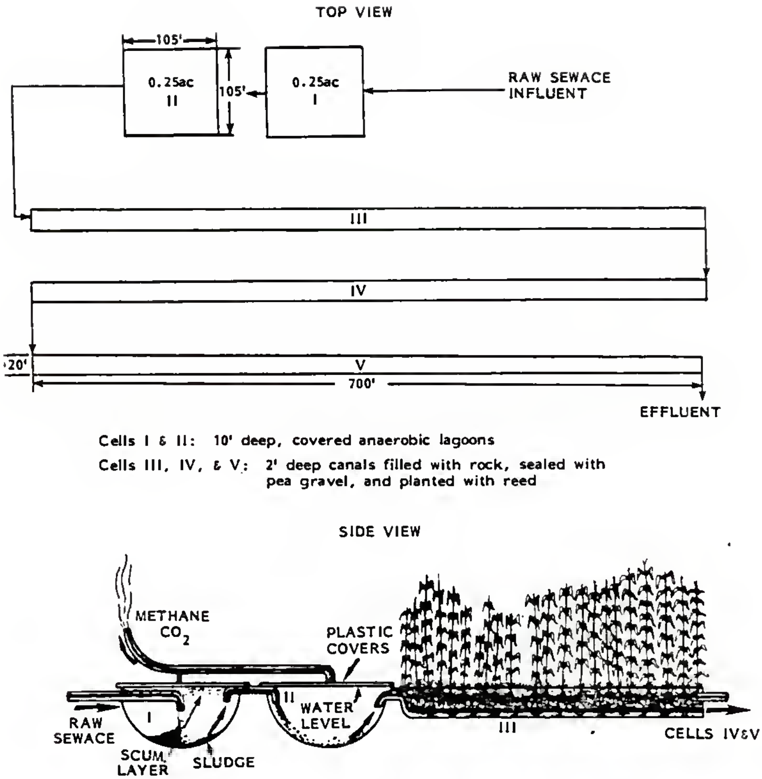
---

[1] Rich, Linvil G., Low-Maintenance, Mechanically Simple Wastewater Treatment Systems, (New York: McGraw-Hill Book Company, 1980) p. 186.

[2] Bastian, Robert K. & Benforado, Jay, "Waste Treatment: Doing What Comes Naturally", Technology Review, Feb/March 1983, p.61.

750 homes and 1982 cost estimates by Dr. Wolverton and Rebecca McDonald [3]). This would provide a substantial savings to the $500-$1000 charged in many areas for sewer hookup thus helping to make housing more affordable.

[3] Wolverton, B. C., and McDonald, R. C., Basic Engineering Criteria and Cost Estimations for Hybrid Microbial/Filter-Reed Wastewater Treatment Concept, (NASA, TM-84669,1982).



Fignre 2.13 Wastewater Treatment Facility Overview For a Community of 3,000 Based on Anaerobic Filter and Vascular Aqnatic Plant Technology

Source: Wolverton, B.C., and McDonald, R.C., Basic Engineering Criteria and Cost Estimations For Hybrid Microbial Filter-Reed Wastewater Treatment Concept, (NASA, TM-84669, 1982) p. 12.

The system is comprised of two components due to the presence of suspended solids in the wastewater. The first part of the system consists of ten-foot deep, covered anaerobic lagoons. In these cells solids collect by gravity settling and undergo anaerobic digestion to reduce the volume while stabilizing the sludge. During this process gasses are produced, some of which (methane) may be burned as an energy source.

The second part consists of a high surface area microbial filter made up of rocks or plastic support medium for growing large quantities of microorganisms. A cold and salt tolerant aquatic plant (Common Reed, _Phragmites communis_) is planted on the surface of the filter so the roots may feed down into the filter area. The plant roots and microbes work in a synergistic manner to treat and purify the wastewater.

Roots of this plant have an extremely high tolerance to chemical-laced environments and actually remove them from their surroundings and concentrate them in their roots. In doing so, the reeds prevent the chemicals from interfering with the microbial activity while providing a convenient means of chemical removal.

The resulting effluent is extremely clean and ready for reuse as a source of graywater or discharge into the environment within a matter of days, depending on the size, flow, and loading of the system.

Contrast & Comparison

Advantages and disadvantages of the various systems discussed can be better compared and contrasted from Table 2.3. In this

Table a maximum denotation refers to a high correlation and a minimum denotation refers to a low correlation. In addition, the use of these alternative systems can prevent the overloading of current central systems as new sewer lines are added with urban growth. These systems might prove to be the deciding factor in whether or not a development is feasible. A project might have to be abandoned if a package plant or sewer main extension is too costly or the site constraints (ie. soil, topography, or rock presence) are too great and these alternative systems are overly regulated or restricted.

TABLE 2.3 ALTERNATIVE ONSITE TREATMENT SYSTEMS COMPARED TO CONVENTIONAL CENTRALIZED TREATMENT SYSTEMS

CONSIDERATIONS	SEPTIC FIELDS	SEPTIC & M/R	LAGOON	LAGOON VASCULAR	LAGOON OVERLAND	OVERLAND FLOW	M/R FILTER	CONVENTIONAL SYSTEM
A. Reliability Requirements								
1. Resistance to Shock loads of Organics & Toxic Materials	Min.	Max.	Mod.	Max.	Max.	Max.	Max.	Min.
2. Resistance to Intermittent Operations	Max.	Max.	Min.	Min.	Mod.	Max.	Max.	Max.
3. Operator Skill Required	Min.	Min.	Min.	Min.	Min.	Min.	Min.	Max.
4. Succeptable to Site Restraints	Max.	Min.	Mod.	Mod.	Max.	Max.	Min.	Mod.
5. Climatic Restraints	Mod.	Min.	Mod.	Mod.	Mod.	Mod.	Min.	Mod.
B. Costs								
1. Land Requirement	Mod.	Min.	Max.	Max.	Max.	Max.	Mod.	Mod.
2. Capitol Costs	Min.	Min.	Min.	Min.	Min.	Min.	Min.	Max.
3. Operation & Maintenance	Min.	Min.	Min.	Min.	Mod.	Mod.	Min.	Max.
C. Aesthetics								
1. Visual	Max.	Max.	Min.	Mod.	Max./Mod.	Max.	Max.	Min.
2. Odor	Min.	Min.	Mod.	Mod.	Mod.	Mod.	Min.	Min.
3. Effluent Quality	Mod.	Max.	Min.	Max.	Max.	Max.	Max.	Min.
D. Regional Recycle Potential								
1. Quality Water	Mod.	Max.	Mod.	Max.	Max.	Max.	Max.	Min.
2. Nutrients	Max.	Max.	Mod.	Max.	Max.	Max.	Max.	Mod.
3. Chemicals	Min.	Max.	Min.	Max.	Max.	Max.	Max.	Min.
4. Ground Water	Max.	Max.	Max.	Max.	Max.	Max.	Max.	Min.

In the past decade and until 1985 the Environmental Protection Agency has recognized the need for and advantages offered by onsite and subregional wastewater treatment systems. This recognition is reflected in their offer to fund up to 85% of a community's treatment system if they are using an alternative to conventional, centralized systems. This is in contrast to their offer to originally fund up to 75% (later dropped to 55%) of a conventional system if the community chose against an alternative system. [4] While these systems may be cost prohibitive for individual homes (except those using septic and modified septic systems) their potential application to small communities and subdivisions appears to be great.

Centralized sewage collection and treatment systems have taken the responsibility for sanitation out of the private sector and placed it under the domain of public authorities while also providing a means to control growth and urban development. Ideally, land use planning and controls would be a more rational means of controlling suburban development than sewer constraints.

---

[4] Bastian, Robert K. and Benforado, Jay, "Waste Treatment: Doing What Comes Naturally", Technology Review, Feb/March 1983, p.62.

CHAPTER III

ANALYSIS AND DESCRIPTION

INTRODUCTION

A wide variety of onsite wastewater treatment system designs exist in the literature. Some of these were pointed out and discussed in the section on background and trends.

The primary criteria for selection of one design over another is the system's capacity for protecting the public health while protecting the integrity of the environment. The second criterion is that the system must be economical in design, construction, operation and maintenance.

Current research suggests that the most economical and efficient alternative wastewater treatment system for small communities and subdivisions in temperate to cold climates is the microbial/reed filter.[1]

This system uses simplified biological processes in combination with the oldest wastewater treatment technology (septic tanks and trickling filters) and the latest developments in anaerobic filter and vascular plant wastewater treatment. By the nature of the system's design, the microbial/reed filter system has the most flexibility towards adaptation to various site constraints.

---

[1] Wolverton,B.C., "THE ROLE OF PLANTS AND MICROORGANISMS IN ASSURING A FUTURE SUPPLY OF CLEAN AIR AND WATER", Seminar Presented at: CBI Industries, Plainfield, Illinois, March 26,1984.

DESCRIPTION OF THE MICROBIAL/REED FILTER WASTEWATER TREATMENT SYSTEM

The microbial/reed filter system is made up of two major components; a sludge collecting and digestion chamber and a hybrid microbial filter / vascular plant unit as shown in Figure 3.1.

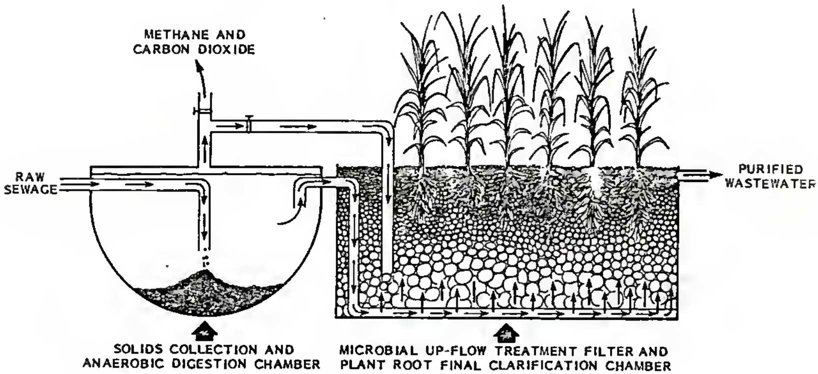


Figure 3.1 Microbial Filter/Vascular Plant Unit

Source: Wolverton, B.C. and McDonald, R.C., "Harnessing The Power of Green Plants and Microorganisms for Earth and Space Applications," Paper Presented at: NASA Goddard Space Flight Center, Engineering Colloquia, April 5, 1982, p. 3.

Settling Chamber

The raw sewage enters the first chamber where the solids are allowed to settle and undergo anaerobic digestion. Under anaerobic conditions, biogas is generated while the solids are reduced in bulk and stabilized. Therefore, the settling chamber accomplishes three functions: 1) biological conversion of organics to biogas, 2) gravity thickening of sludge solids, and 3) temporary storage of stabilized sludge. The major components of the biogas are methane and carbon dioxide with trace gasses such as hydrogen sulfide. This process of anaerobic stabilization of organic materials is diagrammed in Figure 3.2.

INSOLUBLE ORGANICS Extracellular Enzymes → SOLUBLE ORGANICS
Acid Producing Bacteria → ORGANIC ACIDS Methane Producing
Bacteria → $CH_4 + CO_2$ + TRACE GASSES ↑

Figure 3.2 Anaerobic Stabilization of Organic Materials

Methane is produced at an approximate rate of one cubic foot per person per day.[2] The chamber must be able to vent the large amounts of biogas that will be generated when the system is receiving wastewater from several homes. The methane fraction of this biogas may be collected and burned as an energy source or disposed of for odor control. Odor control can best be accomplished by either flaring off the biogas or venting it under the microbial/reed filter (as shown in Figure 3.1) where it will enhance plant growth and provide a carbon source for anoxic denitrification, a process in which gaseous nitrogen is liberated without oxygen.

---

[2] Wolverton, B.C. and McDonald, R.C.; "Basic Engineering Criteria and Cost Estimations for Hybrid Microbial Filter-Reed (Phragmites communis) Wastewater Treatment Concept", NASA Technical Memorandum TM-84669,NSTL Station, MS, September 1982, p. 4.

This settling chamber may range in size from a conventional septic tank to a lagoon covered by a floating, synthetic membrane or a primary grit chamber of conventional municipal treatment plants depending on the population the system is to serve.

To determine the capacity required by the chamber, the characteristics and amount of the wastewater will need to be identified. A minimum detention time for domestic wastewater in this first unit of 2.5 days is recommended for a 50% or greater reduction of BOD5 and Total Suspended Solids (TSS) while lowering the risk of sludge reaching and clogging the rock filter which is to follow in the system.[3]

Two units, each sized individually to accommodate the flow rate, should be planned to operate in series but with the capability of operating in parallel. This would serve the dual purpose of providing a safety margin and a means for isolating one chamber for maintenance without impeding the system's capacity to effectively handle wastewater treatment.

Microbial/Reed Filter

The second major component is the microbial filter/vascular plant unit. The microbial filter is not a filter in the true sense but is an attached growth process in which a stable surface area for microbial attachment and growth is provided by an inert medium. This provides for the partial retention of microorganisms in the system as wastewater passes through. The high surface area

---

[3] Oswald, W.J., et al , Integrated Pond Systems for Subdivisions, Journal Water Pollution Control Federation, 1967, 39(8): 1289.

gives a mean cell residence time of approximately 100 days with a relatively short retention time.[4] This inert medium comprises the lower portion of the filter and is contained in an impervious trench. To retain the wastewater, the trench may be lined with a plastic membrane, sealed with poured in place concrete, or sealed with a clay blanket depending on the amount of clay on-site. The inert medium may consist of crushed rock 2.5-7.5 cm in diameter or a vinyl core medium.

Inert Medium Comparison. The vinyl core media is a lightweight honeycomb-type plastic medium that has been in use for trickling filter treatment systems for several decades and can be obtained commercially. This synthetic medium has many advantages over crushed rock. It is lightweight and, therefore, easier to transport and install than the rocks, thus providing approximately four times the surface area of the rocks. It also can create up to 97% voids as compared with the 40-50% void of a rock medium.[5] These advantages must be compared with costs, however, since vinyl may cost more per system than rocks in most parts of the country.

The effluent from the settling chamber enters the bottom of the microbial filter and flows upward through it as microbial action metabolizes the dissolved organic material. This lower portion is

---

[4] Metcalf and Eddy, Inc., Wastewater Engineering: Treatment/ Disposal/Reuse, 2nd ed., Mcgraw-Hill Book Co., New York, 1979, p. 455-460.

[5] Wolverton, B.C., "Hybrid Wastewater Treatment System Using Anaerobic Microorganisms and Reed (Phragmites communis), Economic Botany, 36(4), 1982, p.378.

anaerobic in nature and breaks down complex organic compounds into those that can be assimilated by the reeds.

The top 5-8 cm of the microbial/reed filter is composed of sand or gravel 0.25-1.3 cm in diameter and the live roots of the reeds. This top layer serves as a support medium for the reeds while providing a surface sealer. The plant roots and attached microorganisms affect odor control, enhance BOD5 and ammonia removal, and clarify the liquid prior to discharge to the environment.[6]

Aquatic plants such as common reed (Phragmites communis) release small amounts of oxygen from their roots into the water in which they are growing. Studies with plant/rock filters suggest that sufficient oxygen is being contributed by these roots to enhance nitrification of septic tank-type effluent but not enough to sustain the root zone in a complete aerobic state. Therefore, anoxic conditions conducive to denitrification also prevail.[7]

WASTEWATER CHARACTERISTICS

Range of Flows

The amount of wastewater may be calculated on the basis of population numbers, fixtures served, land use densities or a review of historical usage depending on the scale of the development to be

---

[6] Wolverton, B.C. and McDonald, R.C., "Harnessing The Power Of Green Plants And Microorganisms For Earth And Space Applications", Paper Presented at: NASA Goddard Space Flight Center, Engineering Colloquia, April 5, 1982, p.4.

[7] Wolverton, B.C.,McDonald, R.C., and Duffer, W.R., "Microorganisms and Higher Plants for Waste Water Treatment", Journal of Environmental Quality, Vol. 12, no. 2, 1983, p.236-242.

serviced. If the system is to serve a fluctuating population (e.g. seasonal) the greatest use rate should be used in calculations to insure that the system does not become overloaded during peak use and that adequate preliminary treatment occurs before wastewater enters the microbial/reed filter. This range of wastewater flows would also need to be determined to size the microbial/reed filter unit. The capacity would be determined by the amount of void space provided by the filter media and available for hydraulic retention and the length of detention required to provide adequate treatment for the site's region. This last point will be discussed in the section on wastewater content.

Range of Wastewater Temperature

The range of temperature of the wastewater is important to determine for two primary reasons. First, since anaerobic microorganisms are very sensitive to widely varying temperatures, it is desirable to moderate this range as much as possible to insure stable bacterial growth rates and colonies. Domestic wastewater from similar households will have the same narrow range of wastewater temperature and will not pose a severe threat to the anaerobic population of the settling chamber. If commercial or light industry is being serviced along with domestic users, the capability for moderating the effluent temperature in a holding tank or oversized main might be desirable before allowing the effluent to enter the settling chamber. Second, once the wastewater temperature is known, the winter activity of the microbial/reed filter can be forecasted for a given region.

Studies have shown that the roots of common reed are active during the winter months when the shoots are dormant.[8] Therefore, as long as the trench bottoms are located below frost line and microclimates are moderated with windbreaks and good solar orientation, adequate treatment of the primary chamber's effluent will occur during the winter months.

In extreme northern latitudes or in regions of exceedingly harsh conditions in the winter months the possibility of supplemental heating of the wastewater with solar collectors or biogas produced in the primary chamber might be advantageous to insure adequate treatment of the wastewater without increasing the retention time.

BOD5, TSS, & Nutrient Concentrations

The characteristics of the wastewater as to the concentration of BOD5, TSS, nitrogen, and phosphorus need to be determined to establish the degree of treatment required for an area.

The degree of treatment varies widely across the country depending upon the concerns of a particular region or site. This degree of treatment can be determined from the effluent quality parameters written into the wastewater discharge permit requirements for the area in question. The legal limits for discharge to surface waters anywhere in the United States have been established by the Clean Water Act of July, 1977, but several areas

---

[8] McDonald, R.C., Vascular Plants For Decontaminating Radioactive Water And Soils, NASA Technical Memorandum TM-X-72740, Aug. 1981, p. 9.

have much more stringent minimums levels for these parameters as shown in Table 3.1.

TABLE 3.1 TYPICAL EFFLUENT QUALITY LIMITATIONS

AREA	BOD5 mg/l	TSS mg/l	NH3-N mg/l	TOTAL N mg/l	TOTAL P mg/l
Lake Tahoe, Calif.	2	2	0	1	0.5
Recreational Waters	5	5	0	1	1
Great Lakes	10	10	5	-	1
EPA Minimum	30	30	-	-	-

* All concentration limits are expressed as the maximum daily average allowable.
* A dash indicates no limitations.

Source: Adapted from United States Department of Housing and Urban Development, Sewer Moratoria: Causes, Effects, Alternatives, (U.S. Government Printing Office, 1977) p. 88.

Effluent limitations are usually numerically specified for an area and may include not only the above parameters but also dissolved oxygen, coliform bacteria, pH, heavy metals, toxic materials, temperature, and some synthetic organics depending on the concerns of a given region.

Studies indicate that microbial/reed filters can meet the high effluent quality for most all of these parameters if the retention time is adjusted to meet the required treatment levels for an area.[9] Figures 1, 2, and 3 in Appendix I are results of

9 Wolverton, B.C. and McDonald, R.C., Basic Engineering Criteria and Cost Estimations for Hybrid Microbial Filter-Reed Wastewater Treatment Concept, (NASA, TM-84669,1982).

experiments by NASA and can be used to determine exact detention times depending upon the initial loading rate, treatment efficiency of the settling chamber, and the maximum discharge concentrations permitted by local, state and federal regulations. The EPA maximum discharge limit for discharge to surface waters anywhere in the United States (secondary treatment levels) is denoted on Figures I.1 and I.2 and the tertiary level on Figure I.3 for easy reference.

Effluent from anaerobic treatment processes contain reduced forms of nitrogen such as ammonia and organic nitrogen. Nitrogen and phosphorus are nutrients that encourage algae growth and promote eutrophication of water bodies. Therefore, if the microbial/reed filter is the final treatment step before discharge to the environment in areas where these nutrients are a concern, a modification must be made in the system's design.

This modification is discussed in Dr. B. C. Wolverton's <u>Upgrading Septic Tanks Using Microbial/Plant Filters</u>:

> "The design of plant/microbial rock filter for BOD5 and TSS reduction is less critical as to depth and hydraulic detention times if nitrification/ denitrification is not important...The design for nitrogen removal from septic tank effluent is critical as to depth of filter and hydraulic detention times. Since autotrophic nitrifying bacteria have a growth rate that is much slower than the heterotrophic bacteria which predominate in the anaerobic septic tank, a mean cell residence time is required in the plant/rock filter system...The aquatic plant roots are contributing sufficient oxygen to septic tank-type effluent liquid to enhance nitrification, but not enough to sustain this zone in a complete aerobic state. Therefore, anoxic conditions conducive to denitrification also prevail. Since nitrite is an intermediate in both the nitrification and denitrification processes, the most probable N pathway is:

$$\text{Organic Nitrogen} \xrightarrow{\text{Ammonification}} NH_4^+$$

$$\xrightarrow{\text{Partial Nitrification}} NO_2^- \xrightarrow{\text{Denitrification}} N_2 \uparrow$$

So one must consider the effluent quality desired in designing the plant/rock filter for treating effluent from anaerobic processes. Shallow filter depths with increased hydraulic detention times are required to achieve nitrification/denitrification."

The nitrogen removal potential of reed is 330-800 and 350-850 kg/ha for above and below ground mass, respectively; the phosphorus removal is 10-80 and 38-74 kg/ha, respectively.[10]

Studies have shown that the microbial/reed system meets the tertiary nutrient standards of 3 mg/l for nitrogen and that the total phosphorus content of the wastewater can be reduced from 4.4 to 2.0 mg/l when treated for 24 hours in the filter unit.[11] Though this does not meet the tertiary nutrient standards of 1 mg/l for phosphorus, it does represent a significant reduction. Further reduction may be necessary using lime coagulation of the final effluent. In areas where the effluent quality limitations are very low or where increased retention times are exceedingly long, an alternative to discharging to a surface water might be desirable. These alternatives will be discussed later in this chapter.

---

10 Wolverton, B.C., "Hybrid Wastewater Treatment System Using Anaerobic Microorganisms and Reed (<u>Phragmites communis</u>), <u>Economic Botany</u>, 36(4), 1982, p. 374.

11 ibid.

Pathogen Concentrations

Historically, the standards and techniques for wastewater treatment grew out of a concern for preventing the transmission of disease thereby protecting the public health.

In sewage from a single family residence, there may or may not be pathogens, depending upon the family history of disease, but the potential for the presence of disease is there at all times. This potential is greatly increased when sewage is combined from several households as in a wastewater treatment system servicing a cluster home development.

Elizabeth McCoy and Wayne A. Ziebeil discuss the reason for this potential for disease in their paper "The Effects of Effluents on Groundwater : Bacteriological Aspects".

> "In fresh raw sewage the kinds and numbers of bacteria are predominantly those of intestinal origin. The gut offers an excellent environment for the growth of bacteria such as the coliform group, fecal streptococci, lactobacilli and numerous minor groups including some pathogens...It is a generalization of medical bacteriology that man is subject to various enteric diseases during which pathogens are shed in the feces in tremendous numbers. Most patients cease to shed after recovery but some continue as carriers, even though apparently well."

> "As the fresh sewage passes through treatment conditions change and new types grow and compete with the intestinal bacteria. The microflora of sewage is thus a complex mixture of bacteria growing and dying as they find the opportunity. In the aggregate, they are capable of biodegradation of numerous chemical compounds in the waste. Thus the bacteria are useful, in fact, essential to the treatment process. And in this respect, they differ from the viruses, which are merely carried along without multiplication after leaving the body."

To determine the potential danger to the public health from an effluent, various discharge limitations for fecal coliform counts are usually numerically specified for an area. An example of some of these limits are shown in Table 3.2 for the same four areas compared in Table 3.1.

TABLE 3.2 TYPICAL COLIFORM COUNT LIMITATIONS

AREA	FECAL COLIFORM COUNTS MPN/100 ml
Lake Tahoe, Calif.	3
Recreational Waters	25
Great Lakes	200
EPA Minimum	200

Source: Adapted from United States Department of Housing and Urban Development, Sewer Moratoria: Causes, Effects, Alternatives, (U.S. Government Printing Office, 1977) p. 88.

These fecal coliform counts are used as convenient representative indicators for the potential presence of pathogens and are not the sole microorganisms of concern to health officials.

The limitations referred to in Table 3.1 are for the discharge to surface waters, and the effluent may still require disinfection before discharge in more stringently regulated areas or where the discharge may directly enter groundwater that serves as a potable water source without pretreatment.

To further reduce these bacterium levels in the effluent and thereby reduce the potential for disease transmittal, it is best to follow the microbial/reed filter unit with a means for disinfection before final discharge to surface waters.

Due to the problems associated with chlorination as pointed out in the background and history chapter, it is desirable to rely on an alternative form of disinfection. This can be accomplished through ultraviolet radiation or reliance on soil contact. Ultraviolet radiation has several disadvantages when compared to soil contact. It is energy intensive by the nature of its physical operation and requires a greater level of operation and maintenance skill, as well as higher costs.

Pathogen Survival in Soil

The soil biota are composed of various bacteria, fungi, protozoa, rotifers, microscopic and macroscopic nematodes, earthworms, insects and larger animals. Bacteria added to this biota from wastewater effluent are fed upon by these soil organisms converting them to harmless matter. Soil type, temperature, pH, bacterial and virus adsorption to soil particles, soil moisture and nutrient content, and bacterial antagonisms are all factors affecting bacterial survival and movement in the soil. Therefore, it is difficult to specify a depth of soil through which wastewater must percolate to remove potentially hazardous levels of sewage borne pathogens.

The survival times of various pathogenic organisms in soil vary greatly depending on the above mentioned factors and the ability of the organism to lie dormant. The range of this variance can be seen in Table 3.3.

TABLE 3.3 SURVIVAL TIMES OF VARIOUS PATHOGENS IN SOIL

Organism	Group	Survival Times
Ascaris Ova	Parasitic Worms	2.5-7 years
Entamoeba cysts	Protozoa	40-170 days
Salmonella	Bacteria	1-85 days
Coliform group	Bacteria	100-150 days
Mycobacterium	Bacteria	5-15 months
Enteroviruses	Viruses	???

Source: McClelland, N.I., *Individual Onsite Wastewater Systems*, Ann Arbor Science Publishers Inc, Ann Arbor, Mich.,1977, p. 101.

Research indicates that high organic matter levels, high soil moisture, lower temperatures, and reduced competition increase pathogen survival times in soil.[12]

The movement of a pathogen through a porous medium such as soil is largely dependent upon the size of the organism. The larger pathogens, such as worm eggs, generally exceed the average soil pore diameter and, therefore, are removed near the soil-effluent interface by the physical process of filtering. Pathogenic bacteria and viruses, on the other hand, are small enough to move through most soil pores and their movement is related to the hydraulic conductivity and adsorption processes of the soil. Adsorption processes in soil are determined by the amount and type of clay, quantity of iron and aluminum hydrous oxides, and the

---

12 Miller, F.P. and Wolf, D.C., "Renovation of Sewage Effluents by the Soil" in *Individual Onsite Wastewater Systems*, ed. McClelland, N.I., (Ann Arbor: Ann Arbor Science, 1977), p. 100-101.

amount of soil organic matter.[13] According to Fred P. Miller in his paper "Renovation of Sewage Effluents by the Soil":

> "Soil pH has been found to be inversely related to the adsorption potential of a soil. Generally, low pH values result in greater adsorption. The importance of the type of cation on the exchange complex is explained by the possible formation of a clay-cation-virus system in which the cation serves as a bridge between the negatively charged clay or organic matter unit and the virus. Trivalent cations such as Al+++ and Fe+++ are more noted for their bridge forming properties than divalent cations such as Ca++ and Mg++ which are more important than monovalent cations such a K+ and Na+."

The reliance on this capacity for soil to purify wastewater has been the basis for the reliability of septic tank/absorption field systems to effectively purify wastewater when such systems are properly installed and maintained.

Though no reports of research pertaining to pathogen survival times in a microbial/reed filter unit can be found in the literature, a system incorporating this concept in conjunction with a soil surface or subsurface discharge method would offer an added means of purification over a standard septic tank and absorption field system. This is due to several facts: First, since the microbial/reed filter would offer several environments in which microorganisms would compete for survival with an established population in residence on the filter media before exposure to the soil biota, there should be a reduction in pathogen numbers in the effluent. Second, the further reduction of organic matter as the effluent passes through the filter unit would also reduce the

---

[13] Hamaker, J.W., "Adsorption" in <u>Organic Chemicals In the Soil Environment</u>, eds. Goring, C.A.I. and Hamaker, J.W., (New York: Marcel Dekker, Inc. 1972), pp 49-143.

pathogen survival times. Third, the reduction in TSS provided by the filter unit would reduce the potential for virus and pathogenic bacteria adsorbed onto particles in suspension to be passed on to the environment. Fourth, the mat formed by the plant roots and the pea gravel would act as a physical separator of the larger pathogens such as worm eggs. Consideration of these facts and the ability of soils to purify wastewater would suggest that a microbial/reed filter system in conjunction with a soil contact discharge should provide adequate protection against the conveyance of pathogenic organisms.

Concentration of Toxic, Organic, and Inorganic Compounds

The source of sewage will dictate the amount and kinds of environmental pollutants present in the wastewater. Domestic sources can contribute significant amounts of toxic, organic and inorganic substances to the wastewater. Synthetic detergents, alkylbenzene sulfonates, gasoline, phenols, pesticides, and other miscellaneous chemicals contribute to wastewater. In addition to these chemicals, many heavy metals and other dangerous elements have been found in sewage from industrial communities. The following is a list of some of the more common elements found in sewage:

* Cadmium
* Chromium
* Cobalt
* Copper
* Iron
* Lead
* Manganese
* Mercury
* Molybdenum
* Nickel
* Tin
* Zinc
* Boron
* Arsenic
* Selenium

Some of these heavy metals, such as lead and mercury, are highly mobile in an aquatic environment but do not pose a threat when applied to the soil since they are rapidly bound up with the soil particles. Some studies have indicated that substances such as gasoline and phenols can travel great distances in soils.[14] Therefore, soils alone do not provide an effective means for treating all wastewater, especially industrial effluents containing gasoline, phenols and other miscellaneous chemicals.

The microbial/reed filter system has demonstrated the ability to remove hazardous chemicals such as phenols, benzene, dibrome, lindane and chlordane from wastewaters and contaminated river water. Reeds have also demonstrated the ability to concentrate, in their roots, radioactive elements such as cesium, cobalt, and

---

[14] McGauhey, P.H. and Krone, R.B., "Soil Mantle as a Wastewater Treatment System", Sanitary Engineering Research Laboratory, College of Engineering and School of Public Health, Univ. of Calif., Berkely, Report No. 67-11 (1967).

strontium in addition to cadmium and other toxic heavy metals.[15,16]

Therefore, a wastewater system incorporating microbial/reed filter technology can provide adequate treatment for several toxic substances found in wastewater before the effluent is discharged to the environment. This not only supports the system's application for industrial use but also for insuring a good quality effluent in areas where the discharge has the potential of entering the same groundwater that may be supplying domestic users.

POLITICAL ENVIRONMENT AND RESTRAINTS

The local, state, and federal political environments of the site's location will dictate the level of treatment required and the allowable means of discharge to the environment.

Federal Limitations

The Clean Water Act of July, 1977, established maximum levels for BOD5 and TSS concentrations that wastewater may contain anywhere in the United States when discharged to surface waters. The act also established Congress' intent to encourage innovative and alternative wastewater treatment technologies. This encouragement took the form of construction grants awarded through EPA programs. In recognition of the apprehension of some city

---

[15] Wolverton, B.C. and McDonald, R.C., "Harnessing the Power of Green Plants and Microorganisms for Earth and Space Applications", Paper Presented at NASA Goddard Space Flight Center, Engineering Colloquia, April 5, 1982.

[16] Wolverton, B.C.and McDonald R.C., "Microbial Filters and Higher Plants for Treating Hazardous and Toxic Chemicals", Progress Report on NASA/EPA Joint Program (Agreement No. AD80F2A104), July, 1983.

officials, Congress has also allowed the government to pay all eligible expenses to modify or replace these alternative systems should they fail.

State Limitations

States have the responsibility for protecting the general health and welfare of their citizens except for any limitations stated in the individual state's constitution and bylaws. This responsibility is usually delegated to the state health agency or water quality board. At the least the state may limit its responsibility to establishing minimum standards to be adopted by local jurisdictions which in turn may establish stricter standards if the need exists.

State limits and standards are often considered more effective than local ones since they are less likely to be influenced by local interest and power groups which may weaken onsite regulations for their own benefits.

Besides setting treatment levels for an area, most states perform some degree of management over the onsite system's design and/or operation. At most, the state may retain all regulating functions over onsite systems. This would range from validating the site evaluation to final monitoring and enforcement of state statutes concerning protection of the public health and the environment.

State agency's typically have more resources to hire and retain experienced, qualified individuals for overseeing the regulation of onsite systems than most local governments.

Local Limitations

Governmental. In some states, the responsibility for regulating onsite wastewater treatment systems is delegated by the state legislature to units of local government. These local governmental bodies may range from municipalities and counties to quasi-governmental units.

The EPA describes these units and their powers in their report, Design Manual: Onsite Wastewater Treatment and Disposal, as follows:

> Municipalities - Incorporated units of government have full responsibility for the general welfare of their citizens; have broad financing authority, including the authority to levy property taxes, to incur general obligation debts, to use revenue bonding and to impose special assessments upon benefited property; and are legal entities authorized to contract, commence law suits, and own property.
>
> Unincorporated Government (County) - Unincorporated governmental units often have authority equal to municipalities; however, these units may not have the authority for some onsite program management responsibilities, e.g., ownership of onsite systems which do not serve county institutions. Typically, these units have financial authority and legal entity status similar to municipalities.
>
> Quasi-Governmental Units - These units include regional (multi-county) water quality boards, regional planning commissions, local or regional health departments/boards, councils of government, and other agencies with exception of special purpose entities. Their authority varies with the intended purpose of each unit; however, the financial authority is typically less than that of municipalities and unincorporated governmental units.

Private. Private organizations do not rely on enabling legislation, but are founded on the legal right of individuals to enter into contracts. However, in some states they are often subject to review or regulation by the state public service or utility commissions.

These private organizations may be set up to operate for profit or as a nonprofit organization. These entities include homeowners' associations, private cooperatives, sole proprietorships, and partnerships. The homeowner typically enters into a contract with these private entities for the provision of services. These services could include maintenance and operation of the owner's system, or the private entity could own the system and charge the homeowner for the use of the system.

SITE INVENTORY AND ANALYSIS

Topography

The physical relief and features that characterize the site will determine construction costs, design considerations and siting possibilities. If the problem of sewage disposal is addressed and included in the development concept from the beginning, forethought can be given to the platting to provide the best division of suitable building and treatment sites within the lot lines. Since the most inexpensive means of transporting sewage is by gravity flow, the consideration of the site's topography is important.

Slope. The degree and type of slope of the site will determine the best alternative for the system's location. Concave slopes will concentrate runoff, creating both erosion problems and the potential for system failure. These areas should be avoided when possible in minimize this potential and construction costs. Convex slopes, in contrast, will disperse overland flows and allow a system and diversion ditch to be blended into the landscape more effectively.

If the site has little to no natural gradient, the wastewater may need to be pumped between system units or the site will require extensive grading to provide both positive surface drainage and flow through the treatment system. In either case, the alternatives will lead to high construction costs for system implementation.

Excessive gradients onsite will also lead to higher construction costs than a site with moderate slopes. This can be attributed to site preparation costs and increased mechanical complexity in the system's design.

To prepare the site, areas will require leveling to accommodate building sites for both structures and the treatment system. Specialized equipment and excessive hand labor will be needed when steep slopes are present. This condition will raise construction costs drastically by demanding a more diversified equipment fleet, slowing of construction schedules and/or raising labor costs.

The ideal hydraulic flow for wastewater treatment purposes is a plug flow. This type of flow is in contrast to turbulent flow and can be conceptually compared in Figure 3.3.

Figure 3.3 Plug verses Turbulent Flows

Turbulent flow can cause inadequate treatment in the system by causing hydraulic wash out of sludge contained in the settling chamber which will result in the clogging of the filter media, connecting pipes and the soil if the final discharge is to a soil contact scheme. This mixing of the effluent caused by turbulent flow can also lead to inadequate retention times. This in turn will decrease the treatment efficiency of the systems resulting in a poor quality effluent being discharged to the environment.

To prevent turbulent flows, the system's design will need to be modified for exceedingly steep sites. This modification will call for the incorporation of multiple tiers within the system, connected by drop inlets, to moderate the flow rate as the wastewater moves down slope. This will increase construction and maintenance costs as the drop inlets will need to be inspected periodically for clogs.

Excessive grades will cause an increased potential for runoff, especially in areas of high precipitation as the water runs off before it can percolate into the soil. This can be further compounded by tight soils and slope configuration as previously pointed out. This runoff can affect the microbial reed filter unit's ability to effectively provide treatment by overloading the system with water and sediment resulting in decreased hydraulic retention times and the possibility of washing out effluent and/or gravel which disrupts the reeds' roots. A diversion ditch placed upslope from the microbial/reed filter unit would intercept this overland flow and provide a means of diverting the flow to noncritical areas. Though this diversion ditch would increase construction costs, the price would be marginal in comparison to the protection afforded to the microbial/reed filter unit.

Another problem associated with excessive slopes is the limits imposed on the location of the settling chamber. Since the chamber will require periodic inspection and maintenance, access will need to be addressed in its siting.

Wetlands and Areas Subjected to Flooding. Depressions, floodplains, gullies, and bases of long concave slopes should be avoided for system's location whenever possible. These areas will have the danger of flooding with the same results associated with runoff system overloading discussed previously. An added problem of wetlands and areas with high water tables is the problem of flotation and the resulting disruption of wastewater flows and system mechanics. If these areas cannot be avoided, the facility will need to be flood proofed by raising the microbial/reed filter unit and discharge appurtenances out of danger on suitable fill and/or surrounding the unit and/or discharge fields with a dike system. This addition to the construction costs will need to be included in the system's estimated costs.

Fault Zones. As with areas of potential flooding, fault lines and zones should be avoided when siting the system to avoid the danger of water contamination and pathogen exposure in the event of a natural disaster.

Soils

After topography, but closely related to it, the next most important site consideration is the soil characteristics. The soil will affect both the choice of discharge alternatives and the design/construction considerations that must be addressed to provide a reliable and efficient wastewater treatment system. Though other site factors may limit these alternatives and influence the design/construction considerations, they are not inherent to the soil itself but imposed on it by the site (e.g. high water table or shallow bedrock).

The general type of soil and its characteristics will need to be identified to determine these discharge alternatives and the design/construction considerations.

The benefits of a soil contact concept for final treatment and discharge has already been discussed and proves to be the most desirable means of safely returning the treated wastewater to the environment when permitted.

Permeability. Onsite disposal of the treated wastewater by a soil contact concept is primarily dependent on the physical property of the soil's hydraulic conductivity. This is important to insure that the potential for water movement through the soil is sufficient to prevent the treated wastewater from ponding or flowing on the surface when a recollection scheme is not part of the discharge alternative concept.

The hydraulic conductivity is usually tested and expressed as a measure of the soil's permeability. In most states, the determination of this permeability for a soil is the basis for evaluating a site's compliance with health codes for a soil contact discharge concept. The soil's permeability is documented by the application of an onsite testing procedure. These procedures are included in Appendix II for reference.

Once a site's location is specifically known, a preliminary evaluation of the soil's permeability can be made based on information from the detailed soils map available from the Cooperative Soil Survey of the U.S. Department of Agriculture or data obtained elsewhere for identical soil types. The relationship and sequence of these three methods for determining a soils permeability are diagrammed in Figure 3.4.

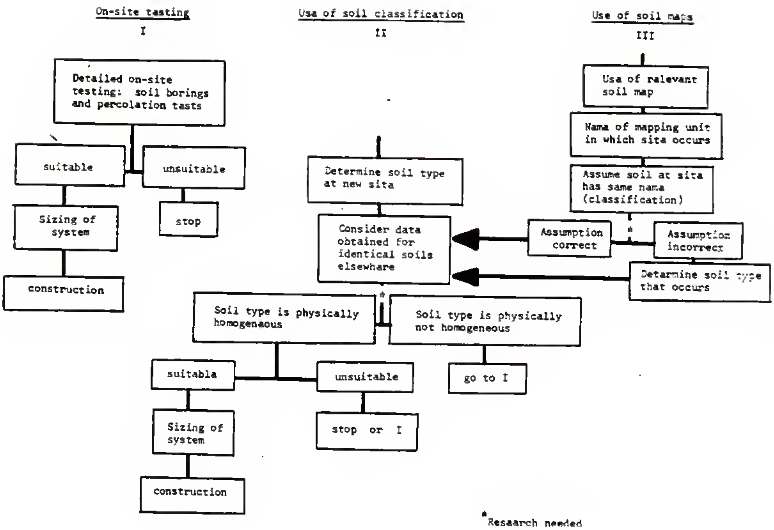


Figure 3.4 Relationship of 3 Methods for Determining Soil Permeability

Source: Baker, F. G., Bouma, Johannes, "Measurement of Soil Hydraulic Conductivity and Site Selection for Liquid Waste Disposal." McClelland, Nina I., ed. Individual Onsite Wastewater Systems. (Ann Arbor: Ann Arbor Science, 1977) p. 127.

Once the permeability of the soil has been determined the soil can be evaluated as to its feasibility for use as a means of disposing of wastewater that has passed through the settling chamber and microbial/reed filter units. The limits imposed by the soils permeability can be determined in Table 3.4. Since various boards and agencies use either percolation rates or permeability rates to determine soil suitability and absorption field area requirements the two are included for easy reference.

TABLE 3.4 SOIL LIMITATIONS BY PERMEABILITY RATE

	LIMITS		
	Slight	Moderate	Severe
Permeability in/hr	2.0-6.0	0.6-2.0	<0.6
Percolation min./in	30-10	100-30	<100

Source: Adopted from the Soil Conservation Service. Soil Survey Manual, USDA Handbook 18, U.S. Government Printing Office, Washington D.C., 1951, p. 503.

A typical absorption field or other means of land disposal will be adequate for soils that have slight to no limitations as to percolation rates.

Soils with moderate percolation rates may require an oversized absorption field or the incorporation of a means for dosing (alternate charging and resting) the field periodically depending on the severity of the slow percolation rate.

If low percolation rates are encountered on the site, a modification to the absorption field (such as placing the field on suitable fill or oversizing the field) or an alternative discharge disposal method may be needed. The alternatives may range from discharge to a surface water body to the incorporation of a lagoon or evaporation/transpiration bed in the systems design. These alternatives will be discussed further later in the thesis.

Corrosiveness to Materials. Some soils are corrosive to steel and/or concrete. This kind of information can normally be found in the Cooperative Soil Survey of the U.S. Department of Agriculture under the engineering properties for the given soil type.

Under corrosive conditions, system components must be protected to avoid structural failure leading to partially treated wastewater being discharged to the environment. This protection may be provided by replacing the corrosive soil with suitable material when backfilling the components. In situations where a suitable fill is not readily available or where its use would prove cost-preventive, steel or concrete can be protected with a coating. Most manufacturers of settling tanks will supply their units with protective paint or suggest suitable coatings if requested. These coatings may include epoxy, bitumastic and chlorinated rubber products, and will usually provide adequate protection. In areas with soil conditions that are known to be exceedingly corrosive, a cathodic protection may be desirable. A specialist's advice may be required if this excessive corrosive condition is suspected onsite.

Differential Settlement. All structures sited on soil as opposed to rock are susceptible to the problem of differential settlement. When soils settle under structures, tilting may occur causing stress to be placed on a facility threatening its structural integrity. Settling can lead to both the disruption of mechanics (e.g. the fracturing of connecting pipework) and uneven flows through the system. Even slight tilting of a system can cause not only the separation and leaking of connections but also the uneven distribution of wastewater within the system, resulting in inadequate retention times and the potential for partially treated wastewater to be discharged to the environment.

To alleviate this problem, the soil may need to be amended with aggregate, replaced or compacted with special procedures (e.g. vibratory probes, minimal lifts, etc.).

Shrinking and Swelling. Soils high in certain clays have the tendency to shrink and swell under varying moisture contents. This condition can lead to the same problems of disrupted mechanics and uneven flows that are encountered when the soil settles. As with settling problems, a soil with a high potential for shrinking and swelling should be amended with aggregate or replaced to avoid future problems.

Due to the problems that differential settling or shrinking and swelling pose, a knowledge of possible problems and their solutions associated with a soil is extremely useful and at certain sites essential to the design, siting, and construction of an onsite wastewater treatment system. Before final design begins, the section on engineering properties of a soil found in the U.S.D.A. Cooperative Soil Survey should be reviewed for the soil in question, to determine any potential for problems. If a question concerning the soil encountered onsite still remains, consulting a soil scientist or soil engineer might be beneficial.

High Water Table. The problem of a high water table onsite is one more imposed on the soil by the site's location than one of the soil itself. A high water table will cause the potential for a variety of problems in design, construction, operation and maintenance of most onsite wastewater treatment systems.

In the case of a microbial/reed filter system, a high water table will cause construction problems with the placement of the settling chambers and the discharge field if a subsoil discharge concept is used. Settling chambers range in composition from fiberglass to steel and/or concrete. Lightweight materials such as fiberglass may have problems with flotation in soils with high water tables and will need to be partially filled with water during placement to insure proper alignment and flows during operation. The problem of flotation will also arise during maintenance operations when the chamber will need to be pumped out to remove the accumulated sludge. If care is not exercised by the maintenance personnel, the mechanics of the system can be disrupted causing uneven flows or a potential for the discharge of partially treated wastewater to the environment.

Most regulations for onsite wastewater treatment systems that use a subsoil discharge for the final effluent define a minimum separation between the bottom of the system and the ground water. This is to prevent groundwater pollution from occurring when septic tank and absorption fields are used in areas of a high water table. Systems using a microbial/reed filter unit between a settling tank and absorption field do not pose this threat due to the high level of treatment attained from the microbial/reed filter. The high water table limits should still be given careful consideration since the potential for wastewater to back up during heavy use and overflow into the microbial/reed filter does exist.

In some instances, it may be desirable to raise the absorption field with fill or drop the water table with curtain and/or underdrains. Though these modifications will increase construction costs, they will provide a means of complying with the regulating agency's restrictions for minimum separation distances between trench bottoms and water tables for absorption field application.

Shallow Bedrock. Shallow bedrock can be a construction and design problem regardless of the type of site improvement planned. This condition usually raises "flags" of caution to contractors to warn of increased expense. This increase in construction costs can be attributed to the time and expense for rock removal to accommodate the site improvements or the modifications to the collection system (e.g. pumping). Microbial/reed filter systems have the flexibility of adapting to this restriction through system modifications.

The settling chamber and microbial/reed filter units may be placed above ground and the wastewater either pumped or piped, depending upon available elevation differences onsite, through the system. The units, in this case, should be screened and blended into the site to avoid any negative visual impacts. In northern latitudes the problem of heat loss in winter would need correction. This could be corrected through the use of 1) insulating sidewalls and pipes of the units, 2) supplemental heating of wastewater with solar collectors and/or methane generated by the system, and 3) erection of semi-permanent cold frames.

Due to the potential for ground water pollution, the use of a subsurface absorption field without modifications in areas of shallow bedrock is unfeasible for partially treated wastewater. Most onsite treatment regulating agencies have set a minimum distance between absorption field trench bottoms and bedrock that is allowable. This is to prevent the potential of wastewater passing through fractures to the groundwater or surfacing after saturating the soil overlying an impervious rock formation. The absorption field could be raised with fill as in the case of a high water table if an alternative discharge scheme is not acceptable.

These alternatives for discharging the treated wastewater may range from discharge to a water body to discharge to evapo/transpiration beds or contained lagoon systems depending on local restrictions and evaporation potentials.

pH. The interaction of soil and wastewater pH can influence the sorption mechanism and ability of a soil to remove some inorganic constituents of the wastewater when a soil contact scheme is used for final effluent discharge.

Organic acids not removed by the system prior to discharge to the soil may show an increase in pH as they are degraded by biological processes occurring as the effluent moves through the soil. Furthermore, biodegradable constituents at or near neutral pH may become more acidic as microbial action within the soil produce carbon dioxide and organic acids.[17]

Some heavy metals may have opposite binding reactions in the soil. Manganese, for example, is released at a pH below 6.5 while molybdenum, is released at pH above 7.0 (neutral).[18] Therefore, fluctuations in pH can affect the solubility and sorption of various effluent constituents, such as phosphate, molybdenum, and manganese.

Compaction. Soils high in clay content are susceptible to compaction especially during construction operations. Therefore, the location of soil discharge fields should be delineated on earthwork diagrams and staked off in the field to avoid unnecessary equipment access to these areas. This will negate the expense of loosening and amending the soil to correct for compacted conditions.

Vegetation

Vegetation can offer many benefits to the system and site designs. It can be planted to screen objectionable views (e.g. settling chambers placed above ground in areas of shallow bedrock), moderate microclimates (e.g. provide windbreaks), reduce water content of beds by transpiration, and help integrate the system into the site design.

---

[17] Bouwer, H. and Chaney, R. L., "Land Treatment of Wastewater", in Advances in Agronomy, N.C. Brady, Ed. (New York: Academic Press, 1974).

[18] Leeper, G. W., MANAGING THE HEAVY METALS ON THE LAND, (New York: Marcel Dekker, 1978).

The presence of vegetation onsite can be a good indicator of various local conditions. The natural occurrence of some species can indicate areas of ground water seeps or high water tables while other species might give an indication of a soil's pH, composition, or the degree of compaction.

Trees with shallow roots, such as silver maples should be removed or avoided near wastewater treatment system locations. This will help prevent the disruption, from the action of roots, of tanks, pipes, and trenches. Likewise, plants with invasive roots should be removed in close proximity to the treatment system to avoid the potential clogging of the microbial/reed filter or discharge units.

Deciduous trees can present the problem of trash fouling the microbial/reed filter unit, thus, to reduce maintenance costs, should not be placed in close proximity to the units. On the other hand, deciduous trees offer the advantage of allowing light penetration during the winter months thereby increasing solar warming. Therefore, care should be taken with the placement of deciduous vegetation to optimize benefits while minimizing disadvantages such as avoiding downwind positions during periods of leaf drop.

Climate

A development's geographical location and the site's features will determine the macro- and microclimates present.

In northern locations, the problems of wastewater heat loss during the winter month's will be compounded in exposed sites.

These areas should be avoided when possible and/or moderated with windbreaks.

Many areas located near marine environments or salt deposits will have the problem of salt spray or seeps. If the system cannot be located away from these problems the use of salt tolerant species would be in order. The use of common reed (Phragmites communis) in the microbial/vascular plant unit provides the flexibility for the systems use in salt environments. Common reed prefers salinities below 10 ppm, but can tolerate up to 40 ppm for short periods.[19]

The precipitation amounts and intensity of an area will need to be determined to calculate the amount of potential runoff to be accommodated by a diversion ditch system, thereby providing adequate size for its interception. Expected precipitation amounts and intensities will also influence the physical size of the microbial/reed filter unit to provide adequate capacity for the wastewater and precipitation entering the unit. This will avoid the potential for overflow during periods of heavy rains and saturated soil conditions if the final effluent is not discharged to a water body.

Urban Pollution

The type and concentration of urban pollution may be a concern in regions of poor air quality. As precipitation washes materials out of the atmosphere, they may enter the system via the

---

19 Wolverton, B.C., " Hybrid Wastewater Treatment Systems using Anaerobic Microorganisms and Reed (Phragmites communis), Economic Botany, 36(4), 1982, p.374.

microbial/reed filter unit. If this is a concern the incorporation of charcoal segments or plant material specifically chosen for the pollutants' removal may be desirable in sections of the microbial/reed filter.

Wildlife

Wildlife and a microbial/reed filter system for wastewater treatment may interact to affect either one or both of the concerns involved. The presence and location of migratory routes and animal trails should be noted during preliminary site visits to determine their influence on possible system's unit locations. If a conflict is unavoidable, measures must be taken for discouraging or diverting large animals away from the microbial/reed filter and discharge units to avoid disruption or soil compaction of the units involved.

Covering pipe openings with screens or placing them in gravel beds will discourage nuisance or destructive species from entering and plugging openings, thereby, causing the potential for backup and overflow.

The system's impact on wildlife refuges or environmentally sensitive areas will need to be addressed when the final discharge will be in close proximity to these areas.

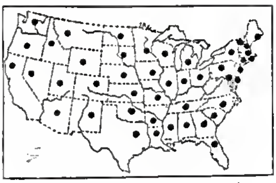
PLANTING DESIGN COMPATIBILITY

Plant Description

Common reed (Phragmites communis), as shown in Figure 3.5, occurs throughout the world and is the most widespread of the emergent aquatic plants.[20] It is a course perennial with hard, erect stems 1 to 5 meters high, emerging from long, coarse, scaly creeping rootstocks. The leaves are long with flat linear blades, 1 to 5 cm wide. Spikelets are plumelike, large terminal panicles 15 to 40 cm long. Its name comes from the greek (phragma) in reference to its growth like a fence along streams.

---

[20] Sculthorpe, C.D., The Biology of Aquatic Vascular Plants (London: Arnold Press, 1967), p.110.



MAP *Phragmites communis.*

Phragmites communis. Plant, × ½; spikelet and floret, × 3. (Hitchcock 5078, N.Dak.)

Figure 3.5 Common Reed (<u>Phragmites communis</u>)

Source: Hitchcock, A. S., <u>MANUAL OF THE GRASSES OF THE UNITED STATES</u>, United States Department of Agriculture Publication No. 200, (Washington D.C.: GPO, 1935).

In the southwest it is called by the Mexican name "carrizo" and is used for lattices in the construction of adobe huts. The stems were used by the Indians for arrow shafts and in Mexico and Arizona for mats and screens, thatching, cordage and carrying nets.[21]

Design Description

Due to common reed's dense growth and height, it is a strong vertical element that can be used as a screen of undesirable views or to contain views onsite. These properties also make it a good candidate for use as a background for other plantings. It has a course textured appearance when viewed up close but at a distance it would take on a medium to medium fine texture making it a good transition between turf and the natural landscape or a distant tree line, as shown in Figure 3.6. It has an appearance similar to bamboo and, therefore, can add a tropical or oriental look to a site.

---

21 Hitchcock, A.S., MANUAL OF THE GRASSES OF THE UNITED STATES, United States Department of Agriculture Publication No.200, (Washington, D.C.: GPO, 1935).

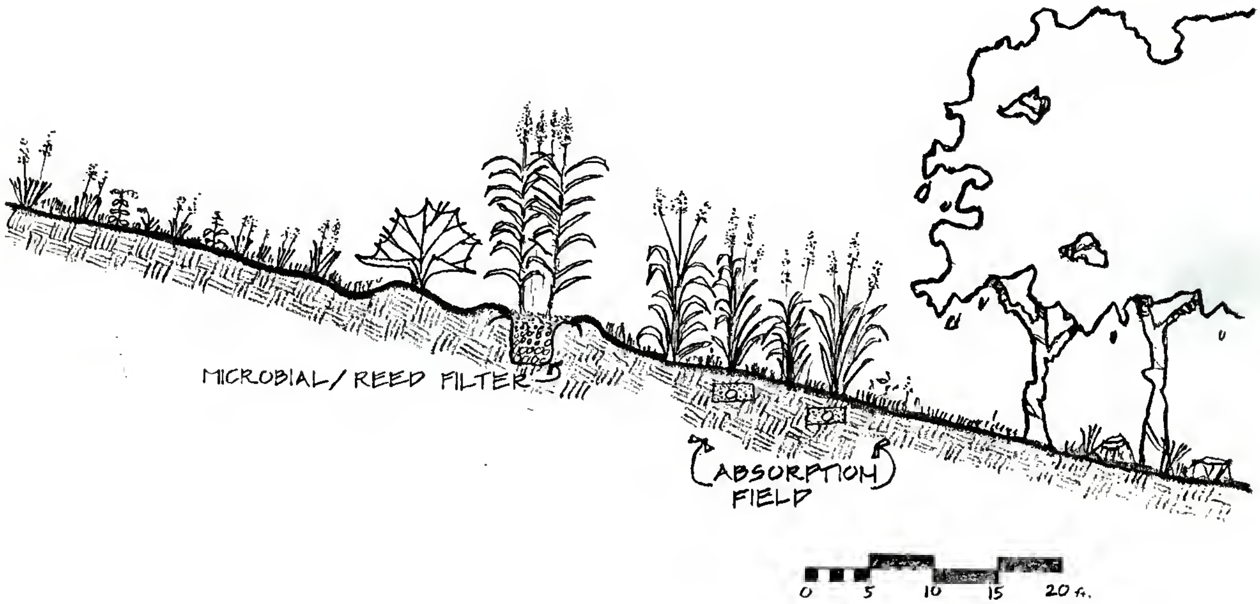


Figure 3.6 Microbial/Reed Filter Unit as a Transition Between Grassland and Treeline

The alignment of the microbial/reed filter unit must follow the contours of a sloping site to facilitate plug flow through the system. This alignment and the dense upright growth habit of reeds creates a strong linear form that can be visually dominant on-site. Plant material can be used to control the eye of the viewer, thereby reducing the visual dominance of the microbial/reed filter unit. This visual appearance can be changed by selecting plant material that contrasts or blends with the reeds through an infinite combination of form, texture and color.

The selection of plant material can also discourage access to the reed bed. Thick, thorny or bee-attracting species will provide a natural barrier to discourage unauthorized people from disrupting the microbial/reed filter unit. Care should be used in selecting plant material to avoid species with familiar edible fruits (e.g. raspberries, blackberries, etc.). This will help avoid potential health problems caused when people forage for wild fruits. Plant species with fleshy fruits should also be avoided as their litter drop may attract flies, posing potential health problems. Other considerations in plant selection are: avoid plants with disruptive or invasive roots, avoid plants with high litter that may clog the filter media or pose a fire threat, use species that require a minimum of maintenance, and avoid plants that create offensive odors that may be misinterpreted as a malfunction in the wastewater treatment system (e.g. female Ginko biloba).

Control of Plant

Though the common reed can be a colonial species forming a dense mat that chokes other plants out, it rarely produces viable seeds. Its primary means of reproduction is vegetative by means of creeping rhizomes and stolons. During periods of stem growth it may be propagated by cuttings placed in soil or filter media. The rootstocks will replace the removed stem while the stem will form a new rootstock.

There are no reports in the literature that suggest common reed to be a nuisance or noxious weed. If control of escaped colonies is required, the plant may be dug up or sprayed with an appropriate herbicide.

DISCHARGE ALTERNATIVES

Soil Contact

The capacity for soil to remove pathogens, inorganic, organic, and toxic constituents found in wastewater was covered in previous sections. This capacity, coupled with the potential for groundwater recharge, makes a soil contact concept the desirable choice for discharging the treated wastewater to the environment. Of the variety of methods using some form of soil contact, only absorption fields, irrigation, overland flow and contact basins will be addressed.

Absorption Field. Absorption fields are the most commonly used and most tested means of discharging treated or partially treated wastewater to the soil for onsite treatment systems. This is due to the low cost and long association of absorption fields with septic tank for onsite systems.

Most states have developed standards for absorption fields' design and construction when used in conjunction with septic tanks. Some of these standards are listed in Table 3.5.

TABLE 3.5 STATE STANDARDS FOR ABSORPTION FIELD DESIGN

Absorption Field Design

State	Setbacks: Well	Setbacks: Surface Water	Minimum Spacing (Feet)	Minimum Cover (Inches)	Minimum Percolation Restrictions	Trench Widths (Inches)	Sizing
Alabama	50—75		6	6	None	16—36	Perc
Alaska	50—100	50—100	6	12	None	12—36	Perc & Soils
Arizona	50—100	100	8	12	None	12—16	Perc
Arkansas	- - -	- - -	- - -	- - -	- - -	- - -	- - -
California	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Colorado	100	50	6	12	None	18—36	Perc
Connecticut	75	50	6—9	6	None	18—36	Perc
Delaware	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Florida	75—100	50	6—8	12	None	16—24	Perc & Soils
Georgia	100	50	10	12	None	16—36	Perc & Soils
Hawaii	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Idaho	100	100—300	6	12	None	12—36	Perc & Soils
Illinois	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Indiana	50—100	50	6—7.5	12	None	16—36	Perc
Iowa	100—200	25	7.5	12	None	16	Perc
Kansas	**50**	**50**	**6 - 7.5**	**8**	**yes**	**12 - 36**	**perc**
Kentucky				None			Perc
Louisiana	100			6—12	None	12—16	Perc
Maine	100—300	50—100	10	2—6	None	24	Soils
Maryland	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Massachusetts	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Michigan	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Minnesota	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Mississippi	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Missouri	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Montana	100	100	6	12	Yes	12—36	Perc & Soils
Nebraska B.	100	50	6	6	No	16—36	Perc
Nevada	100	100	6	4—6	Yes	12—24	Perc
New Hampshire	75	75	6—7.5	6	None	12—36	Perc
New Jersey	- - -	- - -	- - -	- - -	- - -	- - -	- - -
New Mexico	- - -	- - -	- - -	- - -	- - -	- - -	- - -
New York	- - -	- - -	- - -	- - -	- - -	- - -	- - -
North Carolina	- - -	- - -	- - -	- - -	- - -	- - -	- - -
North Dakota	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Ohio	50		6	6	None	6—30	Soils
Oklahoma	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Oregon	50—100	50—100	10	6	None	24	Soils
Pennsylvania	100	50	6	12	Yes	12—36	Perc
Rhode Island	100	50	6	12	None	18	Perc
South Carolina	- - -	- - -	- - -	- - -	- - -	- - -	- - -
South Dakota	100	100	6		Yes		Perc
Tennessee	50	50	6	12	None	16—36	Perc & Soils
Texas	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Utah	100	100	6—7.5	12	None	12—36	Perc
Vermont	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Virginia	35—100	50—100	6—9	None	None	16—36	Perc & Soils
Washington	75—100	100	8	8	Yes	18—36	Perc & Soils
West Virginia	100	100	6	12	None	12—36	Perc
Wisconsin	50—100	50	10	12	None	16—36	Perc & Soils
Wyoming	100	50	6—7.5	6—12	None	12—36	Perc

* A dash indicates no response to survey
* Kansas standards are highlighted for case study reference

Source: Adapted from Plews,G.D., "The Adequacy And Uniformity of Regulations for Onsite Wastewater Disposal - A State Viewpoint" in <u>Individual Onsite Wastewater Systems, ed. McClelland, N.I.,</u> (Ann Arbor: Ann Arbor Science, 1977) p.175.

These standards were adopted to insure adequate treatment to protect the quality of groundwater and prevent the conveyance of pathogens among humans when partially treated wastewater was applied to the soil.

The degree of wastewater treatment achieved from the incorporation of a microbial/reed filter unit before discharge to an absorption field would negate most of the concerns that these standards would protect. However, for the sake of expediting the system's approval by the regulating agency unfamiliar with the benefits that the microbial/reed filter unit provides, the incorporation of these standards into the system design is recommended.

Absorption fields are composed of a trench with perforated drain tile embedded in gravel, crushed rock, or other suitable material. A typical section of an absorption field trench is shown in Figure 3.7.

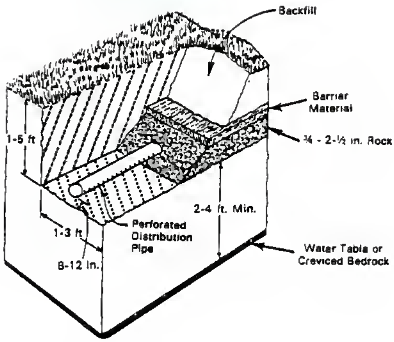


Figure 3.7 Typical Absorption Field Trench

Source: United States Environmental Protection Agency, <u>Design Manual: Onsite Wastewater Treatment and Disposal Systems</u>, Report No: EPA-625/1-80-012, Oct. 1980, p.209.

The trenches are laid out so that they follow the contour of the slopes and should be graded uniformly at 2-4 in./100 ft. to provide uniform distribution over the trench aggregate. The lengths suggested by the literature are to be limited to 100 ft. to avoid the possibility of flow disruption along the pipe, thereby rendering the remaining downstream length of the trench useless. However, since the aggregate transmits the wastewater, a disruption along the pipe length will not necessarily make this fear warranted.

The size of the area needed for the field is dependent on the amount of treated wastewater to be disposed of and the percolation rate of the soil onsite. The generally accepted means for determining this surface area is a curve graph based on domestic wastewater and the total number of bedrooms of the dwellings being served. This curve is represented in Figure 3.8.

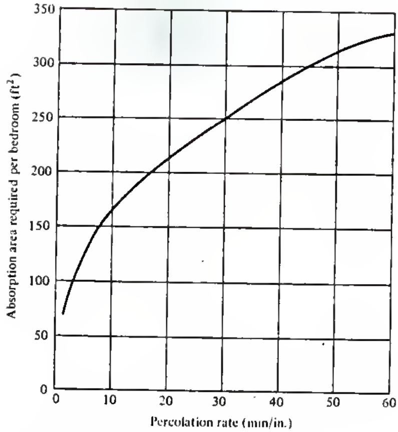


Figure 3.8 Absorption Field Area Curve

Source: Clark, J.W., Viessman Jr., and Hammer, M.J., Water Supply and Pollution Control, (New York: Harper & Row, 1977), p. 614.

The required absorption area attained from this curve and multiplied by the total number of bedrooms served by the system will give the surface area needed for the trench bottom. Trenches can then be sized to width and length to provide the required area while retaining the regulations for minimum spacing between laterals, setbacks, and trench widths that are required for the site's location or region. A distribution box is usually included in an absorption field layout to ensure equal distribution of wastewater among all the laterals of the system. The importance of its inclusion and relationship to the layout of the laterals is dependent on the site's topography.

On level ground the inclusion of a distribution box is not critical and the absorption field may be laid out as in Figure 3.9.

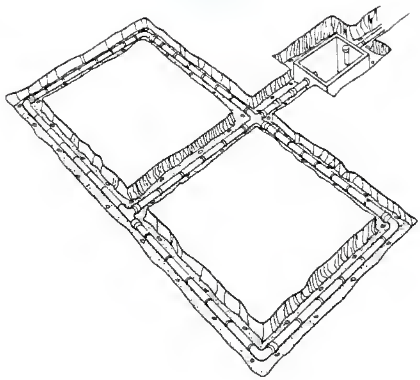


Figure 3.9 Absorption Field System for Level Ground

Source: Clark, J.W., Viessman Jr., and Hammer, M.J., Water Supply and Pollution Control, (New York: Harper & Row, 1977), p. 615.

On sloping ground the inclusion of a distribution box is more critical to insure proper effluent distribution among the trenches. This relationship of the distribution box to the laterals or distribution pipes is shown in Figure 3.10.

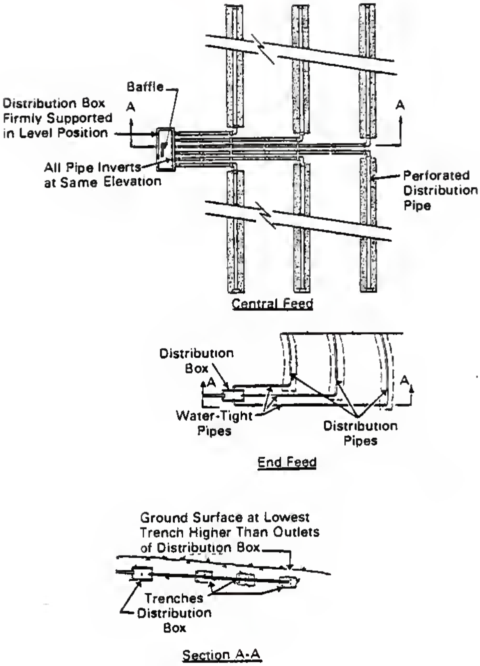


Figure 3.10 Absorption Field System for Sloping Ground

Source: United States Environmental Protection Agency, Design Manual: Onsite Wastewater Treatment and Disposal Systems, Report No.: EPA-625/1-80-012, Oct., 1980, p. 277.

The choice of central feed or end feed to the trenches is dependent on the area required for the absorption field. Larger area requirements would be accommodated better by a central feed configuration.

On excessive slopes with moderate to high percolation rates, the use of a distribution box may be excluded when relief lines are used in conjunction with the multiple trenches. Relief lines may be located anywhere along the trench but successive trenches should be separated by 5 to 10 feet to avoid short-circuiting the system. The incorporation of a relief line distribution with an absorption field is shown in Figure 3.11.

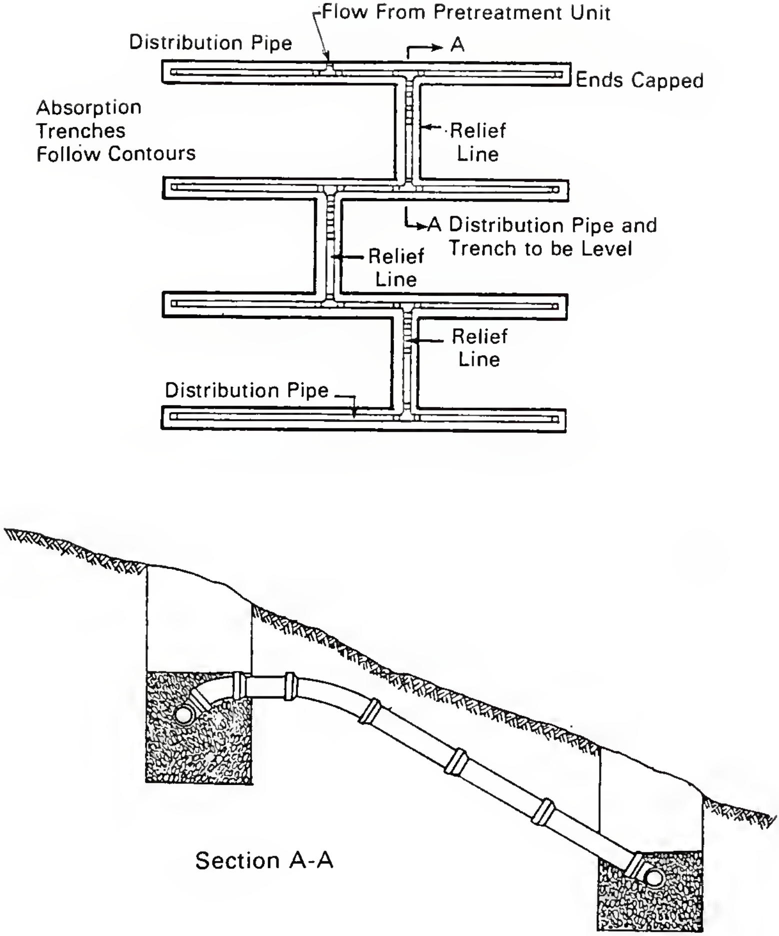


Figure 3.11 Relief Line Distribution Network

Source: United States Environmental Protection Agency, Onsite Wastewater Treatment and Disposal Systems, Report No.: EPA-625/1-80-012, Oct., 1980, p. 279.

Further modifications of the absorption field due to site conditions have already been discussed in previous subsections under the site inventory and analysis section. Additional absorption field design and construction requirements can be obtained from the regulating agency that has jurisdiction over the site's location.

Soil Surface Discharge. Wastewater that has been treated to the degree that a settling chamber and microbial/reed filter system provides may be discharged to the soil surface for further treatment and returned to the environment. Three methods of applying this treated wastewater are shown in Figure 3.12.

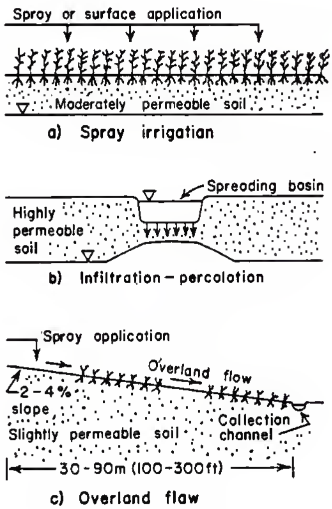


Figure 3.12 Land Application Methods for Treated Wastewater

Source: Rich, L. G., Low Maintenance Mechanically Simple Wastewater Treatment Systems, (New York: McGraw Hill, 1980) p. 186.

The selection of the appropriate method will be determined by the type of soil, accessibility to children, amount of slope onsite, availability of land to accommodate the method, and the local restrictions for groundwater and effluent quality. These considerations and specific design details can be found in Evaluation of Land Application Systems, Tech. Bull. EPA-430/9-75-001. The discussion here will be limited to generalities of the three methods for applying treated wastewater to the soil since the exact design, construction and operation details are dependent on the latitude and degree of treatment required for the site's location.

Irrigation methods are best used when the site is relatively flat with moderately permeable soils. The amount of land required and the liquid loading rate of this method are dependent upon the annual water balance for the site's location. This water balance can be equated as follows:

$$q = E + I - P$$

where: q = amount of liquid that can be applied.

E = evapotranspiration rate of the crop.

I = percolation rate of the soil.

P = precipitation rate of the area.

This rate must be computed for each month of the year and for the particular crop or ground cover used. The smallest value attained for any one month is then selected as the maximum rate at which the effluent can be applied. The area required can then be determined by dividing the monthly quantity of wastewater by the maximum application rate.

Though the irrigation method of effluent discharge has the additional expense of construction, operation and maintenance of the irrigation system, it would provide some return in revenue from the sale of the crop if there was a market for it.

Spreading basins operate principly through evaporation and infiltration-percolation properties to return the treated wastewater to the environment. This method is best used when the site is flat to moderately sloping with highly permeable soils. The land area required is determined from the liquid loading rate as determined from the annual water balance as for the irrigation method previously discussed. The transpiration rate of crops or groundcover would not be of central importance in this method since the majority of the treated wastewater would be removed through evaporation to the atmosphere and percolation through the soil. Once this required area is known, the basin may be sized to provide the required surface area for the soil/effluent contact.

Overland flow was discussed in its use as a treatment system in Chapter II. Presently, the main design parameters are determined from the liquid loading rate (as determined in the irrigation method), terrace width, and slopes available onsite. This method is best used when the site is sloped at 2-4% with slightly permeable soils. Generally, effluent is applied over a period of several hours once a week and collected in ditches at the foot of the slope. Concave slopes do not lend themselves to this method since flows will tend to converge creating erosion problems and poor soil/effluent contact. Grasses are more suited to use with this soil surface discharge concept than are row crops due to the potential for erosion between rows.

These three methods and their characteristics are compared and contrasted in Table 3.6 for land disposal of secondary effluents for a community of approximately 11,000 people.

TABLE 3.6 COMPARISON OF LAND DISPOSAL METHODS FOR TREATED WASTEWATER

Characteristic	Disposal methods: Irrigation	Infiltration-percolation	Overland flow
Liquid loading rate	1.3–10 cm/week	10–300 cm/week	5–14 cm/week
Land required for 4000 m^3/day (1.06 MGD)	60–243 ha (150–600 acres)	1.2–25 ha (2–66 acres)	20–60 ha (50–150 acres)
Minimum depth to groundwater	1.5 m (5 ft)	4.6 m (15 ft)	
Application techniques	Spray or surface	Usually surface	Usually spray
Soils	Moderately permeable	Highly permeable	Slighty permeable
Probability of influencing groundwater quality	Moderate	Certain	Slight
Removals (%)			
BOD and SS	98+	85–99	92+
Nitrogen	85+	0–50	70–90
Phosphorus	80–90	60–95	40–80
Metals	95+	50–95	50
Microorganisms	98+	98+	98+

Source: Rich,L.G., Low Maintenance Mechanically Simple Wastewater Treatment Systems, (New York: McGraw-Hill, 1980) p. 187.

The percentages of removals in Table 3.6 are the amount of additional cleansing that the particular method provides.

Evaporation

Evaporation systems can be used to dispose the treated wastewater to the atmosphere so that no discharge to surface or groundwater occurs. This method provides a means for returning treated wastewater to the environment on sites with limitations such as a high water table, shallow bedrock, or impermeable soils that would eliminate the use of a soil contact method of discharge. These systems can be modified to incorporate some discharge through the soil to supplement that lost to the atmosphere.

Evaporation systems use natural processes to evaporate the wastewater discharged to it. These natural processes of sun, wind, moisture and temperature gradients determine the amount of water that can be evaporated from a bed or lagoon system. When plants are used in conjunction with the system, the process of transpiration by the vegetation will add to the amount of water that can be removed. The amount of water removed can be further increased if the conditions allow for some percolation and infiltration of the wastewater into the soil as previously mentioned. Since an evaporation system relies on these natural processes, they are influenced by the site's climate. In areas where the rate of precipitation exceeds the evaporation rate, the use of contained beds or sealed lagoons are not feasible. Therefore, the year-around use of contained evaporation/ evapotransporation systems for treated wastewater are limited to use in arid and semiarid regions where the evaporation rate exceeds the precipitation rate all year long avoiding the expense of storage during periods of negative net evaporation.

The use of a contained treated wastewater disposal system may be further limited by the regulations imposed by the local health and environment agencies. In some water-short areas where consumptive water use is forbidden (e.g. Colorado) the use of contained evaporation or evapotransporation methods may not be allowed. These systems are also construction intensive. Therefore, the costs associated with their implementation may prove to be preventative.

Evapotransportation Beds

Evapotransporation beds usually consist of a sand bed overlying a wastewater distribution network of piping and are contained by an impermeable liner of clay or synthetic membrane as in Figure 3.13, or they are left unlined to allow for percolation into the soil if conditions permit.

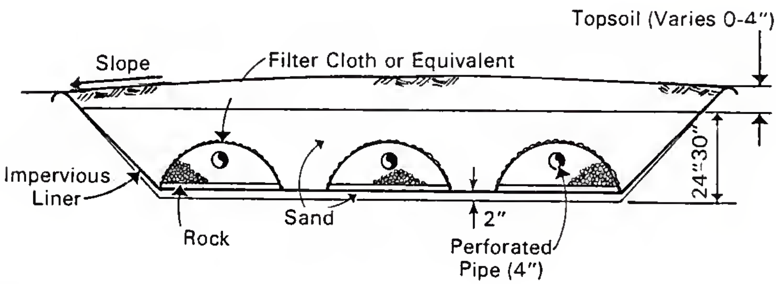


Figure 3.13 Typical Evaporation Bed

Source: United States Environmental Protection Agency, Design Manual: Onsite Wastewater Treatment and Disposal Systems, Report No.: EPA-625/1-80-012, Oct. 1980, p. 302.

The surface of the bed is usually planted with vegetation to increase water lost through transpiration as pointed out earlier. Septic tanks provide an acceptable degree of pretreatment to remove settlable and floating solids to prevent the physical clogging of the distribution pipes and soil pores. Therefore, the use of a microbial/reed filter unit between the settling chamber and a evapotransporation bed would provide an excellent degree of pretreatment and eliminate the concern of clogged systems, thereby significantly increasing the life of the bed.

As the wastewater enters the base of the bed, it is distributed uniformly by the perforated pipes. The wastewater then rises to the upper layers of the bed through the capillary action in the sand, where it is evaporated to the atmosphere directly or taken up by the plant roots and transpired to the atmosphere through the plant's leaves.

Lagoons

The use of lagoons and modified lagoon systems for wastewater treatment was discussed in Chapter II. Lagoons can also be used as a means for treated wastewater disposal by the processes of evaporation and transpiration. Their use would be limited by their acceptance by the local regulating authorities and the limitations discussed previously for the general evaporation methods.

The degree of pretreatment provided by the settling chamber and microbial/reed units would reduce the maintenance costs of sludge removal but the costs of fencing the lagoon, frequent trimming of vegetation on the lagoons embankments, insect control, and aquatic plant removal (when the potential for root penetration of lagoon liners exist) may make this method undesirable. The relatively clean water would have a potential of providing fire protection to areas without pressurized mains and hydrants through the inclusion of a dry hydrant installation as shown in Figure 3.14.

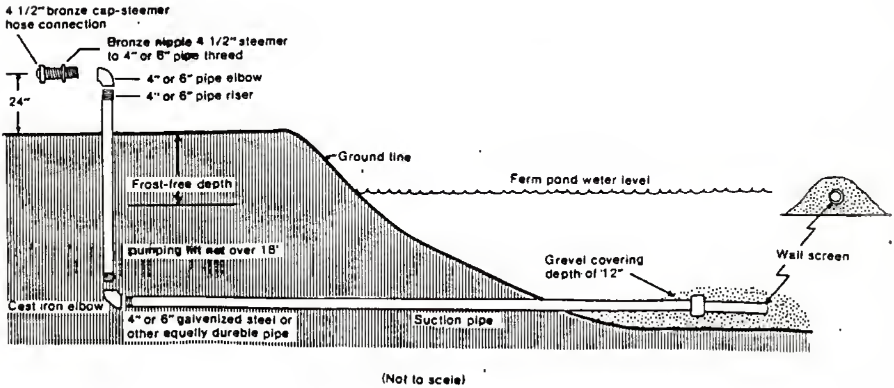


Figure 3.14 Detail of Dry Hydrant Installation

Source: Tourbier, J., and Westmacott, R., Lakes and Ponds, (Urban Land Institute : Tech. Bul. No. 72, 1977) p. 37.

Besides fire protection, lagoons can offer the potential for an irrigation reservoir for use on community common space, recreational areas, or for a community-wide graywater system, thereby preserving clean water for potable uses.

Industrial sites may also find the lagoon system a desirable part of a wastewater treatment system providing a reservoir for cooling water and industrial uses if the treated wastewater does not pose a threat to machinery by its contents (e.g. salts).

Surface Discharge

In areas where the effluent discharge limitations to open water are not overly stringent, the treated wastewater may be discharged directly to surface waters if they are available. This may require that the effluent be disinfected prior to discharge and/or retained for an increased time in the microbial/reed unit before being released to the environment to comply with discharge limits of the area. This method provides the benefits of maintaining stream flows or lake elevations in the receiving waters. Care must be used in positioning the outfall pipe to insure that flows are dissipated before discharge thereby avoiding erosion and turbulence problems in or near the receiving waters.

SAFETY MARGINS

Microbial/reed filter systems for onsite wastewater treatment can include several means of providing safety margins for securing safe operation of the system. Though these measures will increase the costs involved with the system, their value to the acceptance of the system by the regulating agency merits this expense.

Oversize System

To provide a margin of safety, the components of the system may be oversized from the design standards required by the regulating agencies. This practice would accommodate any large flow that was imposed on the system as well as decreasing maintenance costs during operation.

Settling Chamber. The benefits of including two settling chambers, each sized to accommodate the flows individually, was pointed out earlier in this chapter. With this arrangement, the system's operation is not impaired during maintenance periods since the chamber may be isolated by diverting the wastewater to the other chamber through a system of valves and pipes. During normal operations the chambers are arranged in series thereby providing an increased reduction of BOD5 and TSS. This would provide for an extra degree of treatment before the wastewater enters the microbial/reed filter unit to insure adequate treatment in this unit and further reduce the chance for settlable or floating solids entering and clogging the filter media.

Microbial/reed Filter Unit. The inclusion of precipitation rates for the region of the site, coupled with the use of the minimum void space predictions for filter media when sizing the microbial/reed filter unit for the wastewater capacity, would eliminate the chance of the unit's overload. This precaution would prevent any partially treated wastewater from being discharged to the environment and eliminate the chance of hydraulic washout of the filter media or the disruption of the reeds.

Discharge Method. If the same practice of using liberal capacities in sizing the appropriate discharge method are used, the safe return of the treated wastewater to the environment is insured. If an absorption field is used as the method of discharge, the use of the curve in Figure 3.8 in determining the field's area would provide for the inclusion of in-sink garbage grinders and mechanical washers. Since the inclusion of a microbial/reed filter unit between the settling chamber and the absorption field would provide an excellent degree of pretreatment before the wastewater enters the soil, the use of the curve would result in a larger than necessary field. This would insure adequate surface area for the percolation of treated wastewater into the soil thereby preventing any possibility of overloading the absorption field.

Monitor Wells

The inclusion of inspection pipes at unit outlets in the system would provide limited access for inspection of the system and a means of obtaining samples for monitoring the system's performance.

In the case of pipework following the settling chamber, this monitor well may consist of a tee and standpipe capped at the surface. This would allow a "grab" sample to be attained by lowering a vial into the wastewater flow.

Near the end of the microbial/reed filter unit and when subsurface or evaporation beds are used as the means of final discharge to the environment, these wells may consist of standpipes extending down to the bottom of the trench with the top extending to or above the grade and fitted with a removable cap. The portion of the standpipe within the aggregate should be perforated to allow a free flow of the wastewater into the pipe. This arrangement would allow both a means of inspection and sample collection at various points throughout the system. The inclusion of an inspection pipe with an absorption field trench or microbial filter is shown in Figure 3.15.

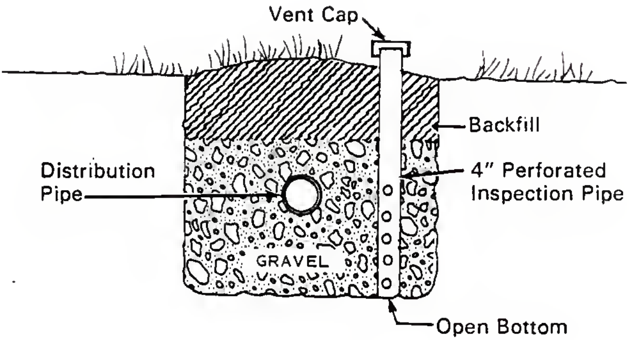


Figure 3.15 Typical Inspection Pipe

Source: United States Environmental Protection Agency, Design Manual: Onsite Wastewater Treatment and Disposal Systems, Report No. EPA-625/1-80-012, Oct., 1980, p. 228.

Regulating Agency

Homeowners Association. Placement of the responsibility for maintenance and inspection of the onsite wastewater treatment system in the hands of a homeowners association, with mandatory membership of all development residences, will insure that the system receives proper maintenance and operates efficiently. This will avoid any problems associated with system failure due to neglect by the homeowners. This policy should become part of the development's protective covenants and be signed by all people buying a lot or home within the development to insure compliance.

Revenue for supporting this policy would be generated by additional fees added to the homeowners association dues. These fees should be of adequate size to support the maintenance and periodic testing of the system while providing an input to a fund for future renovations or repairs to the system if the need arises.

Engineering Firm

The services of an engineering firm should be obtained to review and approve the system's design before construction. Their service should be retained after construction for consultant purposes and the periodic collecting and sampling of wastewater in the system to insure proper operation.

Automatic Controls

In areas of high population densities or fragile environments, the inclusion of automated monitors or controls may be desirable. These may range from sensors to electrically controlled valves incorporated in or near the system. The incorporation of dissolved oxygen sensors in the wastewater stream could detect a change in wastewater characteristics indicating a possible problem in the system. Moisture blocks could be placed under the trench liners to "warn" of a breach in the barriers should the situation occur.

With the advancements in microcircuitry and data handling, these sensors could be hooked up to a microprocessor that would monitor the system and warn of potential problems. In the event of a failure, the microprocessor could sound an alarm, activate an autocaller and message to maintenance personnel, or stop and/or divert wastewater flows from the failed unit within the system.

Though these systems will increase the costs of a wastewater treatment system, their inclusion might be warranted for some developments in populated areas or where a wastewater system failure might threaten an environmentally sensitive area.

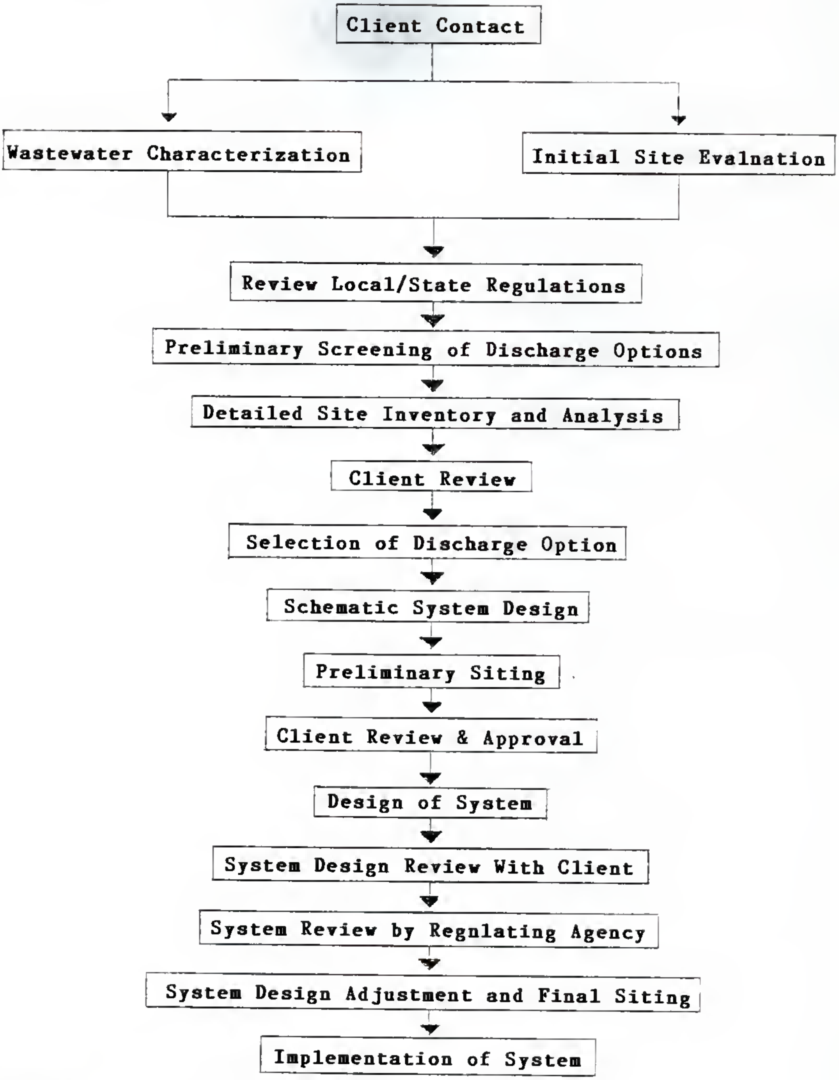
CHAPTER IV

PROTOTYPICAL DESIGN PROCESS AND CASE STUDY

PROTOTYPICAL DESIGN PROCESS

Designing a microbial/reed filter system for on-site wastewater treatment for a development can be a complex task if not approached in a logical sequential manner. This approach can best be accommodated by the implementation of a design process for identifying the site constraints and system parameters to integrate the wastewater treatment system with the site in the best way possible.

A prototypical design process for the use of a microbial/reed filter system is shown in Figure 4.1.



Fignre 4.1 Prototypical Design Process for an Onsite Microbial/Reed Filter System.

Client Contact

The initial step in the process is the client contact. At this point the designer should review the development concepts of the client to acquire an understanding of concerns and the character to be perceived by the development. This will help prevent future misunderstandings and facilitate integrating the system with the site later on. The designer should also know the development's location, program parameters, protective covenants, if available at this time. Base maps should be acquired for future reference.

Wastewater Characterization

As with any system for treating wastewater, the characteristics of the wastewater must be determined for flow rates, temperature, and constituents. These wastewater parameters were discussed in Chapter III under the appropriate headings and will not be discussed in the same depth here.

In the case of proposed developments, the wastewater characteristics cannot be empirically measured. Therefore, they must be predicted using established data from other sources. A strategy for predicting wastewater characteristics is suggested by the EPA and is shown in Figure 4.2.

Determine Primary Uses of System
(eg. single-family home, cluster home, restaurant, etc.)

↓

Identify Wastewater Characteristics Needed
(eg. quantity, BODs, etc.)

↓

Determine Physical Characteristics of Development
* source of wastewater
  (eg. fixtures, appliances, etc.)
* design parameter units
  (eg. bedrooms, occupants, seating spaces, etc.)
* occupancy patterns
  (eg. seasonal, etc.)

↓

Obtain Characterization Data From Literature
* tables in Appendix III
* standard wastewater references
* other sources

↓

Gather Existing Measured Characterization Data Applicable to Facility or Development
* water meter records
* holding tank pumpage records
* other sources

↓

Evaluate Available Data
* select data judged most accurate
* determine if other data is needed

↓

Calculate Wastewater Characteristics

↓

Determine Need for Safety Margins

↓

Estimate Wastewater Characteristics

Figure 4.2 Strategy for Predicting Wastewater Characteristics

Source: Adapted from: EPA, Design Manual: Onsite Wastewater Treatment and Disposal Systems, Report No. EPA-625/1-80-012, Oct. 1980, p. 67.

Initial Site Evaluation

The designer should obtain as much information about the site and its location from published reference sources before proceeding to the field. These sources may include, but should not be limited to, soil surveys, United States geological survey maps, national atlases, and planning reports.

After compiling a site inventory regarding soils, geology, topography, climate, surrounding land use, existing utilities, existing water bodies, and historical sites, the designer should visit the site to verify the data collected and add to this inventory any site features (eg. rock outcroppings, vegetation, animal trails, etc.) influencing the system's design or location.

Review State/Local Regulations

The limitations imposed on onsite wastewater treatment systems by the regulating agency will need to be reviewed to analyze the impact that the site conditions will have on the system's design and the degree of treatment that will be required by the system.

Preliminary Screening of Discharge Options

At this point the designer should be able to narrow the choice of the alternatives for final discharge to the environment of the treated wastewater. Some of the choices will be eliminated by the site constraints, others by the client or regulating agency. A detailed analysis of the site for all discharge options is not cost effective since the site characteristics that must be analyzed will vary with the discharge options. Therefore, the purpose of this preliminary screening step is to eleminate the discharge options with the least potential for use to enable the detailed site inventory and analysis that follows to concentrate on the constraints involved with the discharge options, that retain the most potential for use.

Detailed Site Inventory and Analysis

Once the range of discharge options have been narrowed, a detailed site inventory and analysis should be performed to identify the discharge option(s) that can best be integrated with the site and development in the least intrusive manner.

This inventory and analysis should include tests to verify the soil engineering properties as found in the USDA Soil Survey for the development location. The most important soil tests, due to the benefits of discharging treated wastewater into the soil, are the percolation tests of the areas the designer initially feels most appropriate for soil contact discharge methods. This information will determine area requirements for the discharge alternatives and provide supporting data for approval of the system by the regulating agency later in the design process.

In addition to the soil, the constraints imposed on a discharge method need to be assessed further than in the initial site evaluation step. These site considerations and the modifications to the wastewater treatment system and/or discharge method were discussed in Chapter III under the Site Inventory and Analysis section.

Client Review

Once the range of viable discharge options has been narrowed to the most optimum choice(s), the designer and client should meet to review the alternatives. A meeting at this point in the process will save time and resources by insuring that the concerns and desires of the client have been addressed before proceeding to the final selection of a discharge method.

Selection of the Discharge Method

If at this stage more than one appropriate option for discharging the treated wastewater to the environment still exists a final selection should be made. This final selection should be based on cost estimates, operation and maintenance requirements, and development compatibility of the discharge options determining the most practical and desirable alternative available.

Schematic System Design

Once the discharge alternative has been identified, the entire wastewater treatment system may be conceptually designed to explore various system configurations and their relationship to the development.

Modifications to the system should be included in the schematic to show how the design proposes to overcome the constraints imposed by the site.

Preliminary Siting

The schematic system design can then be fitted to the site to further explore system configurations and assess the proposed system modifications. This preliminary siting will aid in identifying any design details that require special attention later in the process as well as serving as a "check" to insure that relevant site considerations have not been overlooked.

By exploring various system configurations and system unit locations, the best match of system and site can be attained. By taking the time to thoroughly explore the alternatives, the designer will add validity to his final design and system location, thereby improving his case for system approval by the regulating agency.

Client Review & Approval

The designer should meet with the client again at this time to present and review the schematic design and the system's integration with the site and development. Any changes in the development or project program can best be accommodated at this stage of the process before the final design is developed. This will save time and effort in getting the system's design "off the table" and into the ground.

System Design

Once the schematic design and preliminary unit locations have been approved or revised by the client, system component sizing can be started. The capacities for the various system components will be determined from the development program, wastewater characteristics, required degree of treatment, and site constraints.

Once the parameters of system capacities have been determined the wastewater treatment system can be fitted to the site. If the preliminary siting of the system met with the client's approval, the system would only need to be integrated into the development. The relationship to the dwellings and the site would be finalized to provide maintenance access to the settling chambers, optimum orientation of the microbial/reed filter providing a favorable microclimate, adherence to limitations imposed by the regulating agency, and preservation of unique features of the site. The goal of the designer at this point is to adapt the wastewater treatment system to the site and development in the best manner, thereby blending the system with the site. If this is done well, the system will appear to be part of the natural features of the site providing the functional purpose of treating the development's wastewater. The ultimate goal of the designer when integrating the system and site should be the creation of an ecologically sound environment that serves the needs of the development.

System Design Review

The final system design and its site adaption design should be presented to the client for review. This will insure that all parameters have been met as well as any concerns aired by the parties involved. If changes are required, they should be minor at this time. If the design process has been followed, the major problems should have been identified and resolved early in the process.

System Design Review by Regulating Agency

Once the final design meets with the client's approval, it should be presented to the regulating agency for its approval.

After receiving the system's design and supportive data, the regulating authorities will either approve the system or suggest changes that must take place.

System Design Adjustment and Final Siting

If the system is approved, the final siting of the system on the site can be done and the system design can be coordinated with the construction documents for the rest of the development.

If the design receives approval, subject to any revisions, these changes would need to be made in the design and the subsequent approval obtained before the final siting is done.

If the treated wastewater disposal method chosen for the system utilizes the percolation of treated wastewater into the soil (eg. absorption field, spreading basin, etc.), the area designated for this location should be roped off and delineated on construction drawings to avoid unnecessary compaction by heavy equipment.

Implementation of System

In this stage the cost estimate for the system is made, construction documents and bidding documents are prepared if the construction is to be bid competively.

The professional services of the designer may be completed at this time or they may continue to include supervision, observation, or consultation during the bidding, contract award, and construction process.

CASE STUDY

The prototypical design process for the use of a microbial/reed filter system described previously was tested by applying it to a housing project currently under development. This testing of a case study was to identify any problems or omissions in the process while providing an example of the process' implementation under real conditions.

Selection of the Case Study

The choice of a site to serve as a case study was based on several objectives. These objectives were:

1) A development for domestic use, either for single-family detached units, cluster homes or a mixture of both.

2) The study site should be in close proximity to Manhattan, Kansas, to facilitate access to the site for data collection.

3) The study site should be a planned development that was presently undeveloped.

4) The study site should represent a variety of site conditions.

5) The study site should be available for use as a case study.

The second phase of development of Cedar Springs Ranch proved to meet these objectives and, therefore, was chosen as the subject for the case study.

Description of Case Study Subject

Cedar Springs Ranch is a phased housing development located in Pottawatomie County, 5 miles northeast of Manhattan, Kansas.

The first phase is already under construction and the second phase is scheduled for development within the next decade. Phase one consists of single family attached homes on large lots that provide adequate conditions for the use of septic tanks and absorption field facilities. Phase two is planned to have a mixture of both single family lots and cluster home lots. It is these cluster home lots that were targeted for the case study.

Cluster Development Program

The proposed clusters will contain 6 homes with 2-3 bedrooms per home and four occupants each. The developers have a market target of young professionals, young families and retired couples wishing to locate in a suburban development which incorporates the natural beauty of the Flint Hills in the northeast Kansas landscape. The projected selling price of the each home is $60,000.

The developer's concept for Cedar Springs Ranch development is the creation of an ecologically sound environment for the cohabitation of the residence and the wildlife of the area. Therefore, the incorporation of a microbial/reed filter concept for wastewater treatment is compatible with the developer's concept for the site.

Regulatory Environment

Local and State Health Departments. The regulation of onsite wastewater treatment and disposal systems in Kansas are conferred and imposed upon the State Board of Health. It is the responsibility of this board to assure a sound and economical development maintaining healthy and sanitary conditions. This will enable the state to realize maximum benefits of development, and protect the health, safety and well-being of the people of the state of Kansas.

Private Controls. Cedar Springs Ranch Development has a requirement for mandatory membership of all homeowners in a homeowner's association. This association controls any decisions involving environment or aesthetic considerations that influence Cedar Springs Ranch. These controls are affected through a declaration of protective covenants that bind the homeowner to the association's articles by contract law.

Wastewater Characteristics

The strategy suggested in the design process for determining wastewater characteristics were followed.

Determine Primary Functions of Development The primary function of the study site for the prototypical design process are cluster homes for domestic use.

Identify Wastewater Characteristics That Will Be Needed. The primary wastewater characteristics needed for the system design will be the flow rate of the wastewater, the BODs, TSS, and organic and inorganic constituents of the wastewater.

Determine the Physical Characteristics of the Development. The source of the wastewater from these cluster homes is from plumbing fixtures and appliances hooked to the sewerage system serving the homes.

The design parameter units will be both occupants and bedrooms of the cluster homes. Therefore, the cluster will have 18 bedrooms and a maximum occupancy of 24 people. The occupancy patterns will be assumed to be constant year-round.

Obtain Characterization Data From Literature. From Appendix III, one can deduce the following levels for the daily wastewater characteristics:

Quantity of wastewater per cluster: 47 gal./person/day
BODs: 360 mg/l
TSS: 400 mg/l
Nitrogen concentrations: 63 mg/l
Phosphorus concentrations: 23 mg/l

Gather Existing Measured Characterization Data Applicable to Development. Since this Phase is in the planning stage, no records exist. However, the daily average consumption of four persons occupying a dwelling in Manhattan during non-irrigation season is 62 gal per person.[1] In contrast to these figures, the average daily water use in the city of Manhattan during the non-irrigation season is 114 gal. per person.[2] This high figure could be attributed to the extra water consumption from the fire fighters, commercial businesses (eg. car washes, restaurants, etc.) and public use (eg. pools, ice rinks, etc.). Therefore, the average daily domestic use of people in this area could be assumed to be 100 gal./person/day.

Evaluate Available Data. Though the estimated quantity of wastewater produced per day may range from 47 gal./person/day (EPA estimate) to 100 gal./person/day (Manhattan Water Dept. estimate), the actual flow is probably somewhere between the two. The average

---

1. Based on 1985 Water Records for 715 Thurston, Manhattan, KS.

2. Based on the Conversation of 3/5/86 with Allen Schinman, Superintendent of Utilities for Manhattan, KS.

daily use for a residence in Manhattan, KS (62 gal./person/day) is probably a more realistic value for wastewater quantities.

Since the Kansas State Board of Health uses the number of bedrooms to size septic tanks and absorption fields, these parameters should be used for calculating the settling chamber capacities and absorption field area.

Calculate Wastewater Characteristics. The typical wastewater characteristics can be calculated from the values obtained in the "Obtain Characterization Data From Literature" section by the number of occupants in the cluster home development. These calculations are as follows:

Quantity of wastewater per cluster:
47 gal/person/day x 24 people = 1,128 gal/day
Quantity of wastewater per cluster:
100 gal/person/day x 24 people = 2,400 gal/day
Quantity of wastewater per cluster home:
47 gal/person/day x 4 people = 188 gal/day
Quantity of wastewater per cluster home:
100 gal/person/day x 4 people = 400 gal/day
Maximum BOD5 Concentration:
63.2 gm/person/day / 178 l/person/day = 355 mg/l
Minimum BOD5 Concentration:
63.2 gm/person/day / 378 l/person/day = 167 mg/l
Maximum TSS Concentration:
70.7 gm/person/day / 178 l/person/day = 397 mg/l
Minimum TSS Concentration:
70.7 gm/person/day / 378 l/person/day = 187 mg/l
Maximum Nitrogen Concentration:
11.2 mg/person/day / 178 l/person/day = 63 mg/l
Minimum Nitrogen Concentration:
11.2 mg/person/day / 378 l/person/day = 30 mg/l
Maximum Phosphorus Concentration:
4.0 mg/person/day / 178 l/person/day = 22 mg/l
Phosphorus per cluster home:
4.0 mg/person/day / 378 l/person/day = 11 mg/l

Estimated Wastewater Characteristics. From these calculated values, we can estimate the wastewater characteristics to be as follows in Table 4.1.

TABLE 4.1 WASTEWATER CONCENTRATIONS

Parameter	High Concentration	Low Concentration
BOD5	355 mg/l	167 mg/l
TSS	397 mg/l	187 mg/l
Nitrogen	63 mg/l	22 mg/l
Phosphorus	22 mg/l	11 mg/l

* if assume a 50% reduction of BOD5 and TSS within the settling chamber then the settling chamber effluent range would be:

Parameter	High Concentration	Low Concentration
BOD5	177 mg/l	84 mg/l
TSS	199 mg/l	94 mg/l

If the upper value for each parameter is used in calculations, it would inherently add a margin of safety.

Initial Site Evaluation

The primary soil onsite is the Clime-Sogn silty clay loam. These soils are moderately deep, well drained and located generally on the more sloping side slopes of ridges of uplands that are dissected by many drainageways. Narrow bands of exposed limestone are common and calcareous shale may occur at about 34 inches in the Clime soils and limestone may occur at about 14 inches in the Sogn soils. The presence of bedrock may suggest a limitation for the use of basements with the dwellings. The two soils occur as closely intermingled, alternating bands that are too narrow to be mapped separately.

The USDA suggests that the permeability of the Clime soils is slow and the Sogn soils moderate. Surface runoff is high for both soil types. The shrink-swell potential is moderate in both soils due to the presence of expansive clay. The soil survey suggests that proper design, reinforcement and installation of footings, foundations and base drains, backsloping the excavations and back filling with non-expansive material is necessary to provide potential longevity of structures. The corrosiveness to concrete is low for both soils and low for steel in the Sogn series, but high in the Clime series. Neither soil is suggested to provide suitable fill or building material. The potential for septic tank absorption fields is suggested to be low for both soils due to the slow permeability, depth of soil, shrink-swell potential and slope of the soil services. The potential for sewage lagoons is evaluated as medium. Depth of soil and slope are the suggested as limiting factors for this discharge method..

Vegetation. The major vegetation onsite is native little bluestem, big bluestem, and sideoats gramma. Woodlands border the site to the east and small clumps of trees and brush are dispersed throughout the site and along the drainage swale comprising the southern lot line.

Hydrology. No streams occur within the site, but the eastern lot line is defined by a small stream that is fed by springs from the development's southern property.

Well-boring records suggest that this lot will receive its potable water from shale and limestone formations lying between

1020 and 1060 feet. This will be at least 100 feet below the lowest point of the cluster site.

The depth to any potable water source used on the entire development and the potential discharge area within the cluster home is over 60 vertical feet and lies downslope from the location of these potential users.

Topography. The study site lies on north to northeast facing slopes at an elevation between 1160 and 1226 feet above sea level. These slopes range from 5% to 20% and are convex in shape. The lesser slopes occur along the western and eastern regions of the site and suggest that they be preserved for building and treated wastewater discharge respectively.

Climate. Annual average rainfall for the area is 32.1 inches, which is greater than the state average of 26.8 inches. Of this rainfall, approximately 74% occurs within the growing season which extends from about mid-april to mid-october..

The mean temperature of the study site is 29.2 degrees Farenheint in January and 80.2 degrees Farenheint in July.

Wildlife. No endangered species occur on the site or the development. The type of wildlife is indigenous to the region. The largest carnivores are coyote and wild dogs and the largest herbivores are the white-tail deer which are numerous on the development. An initial site visit indicated the presence of a well-used deer trail along the eastern treeline of the study site as noted in Figure 4.3.

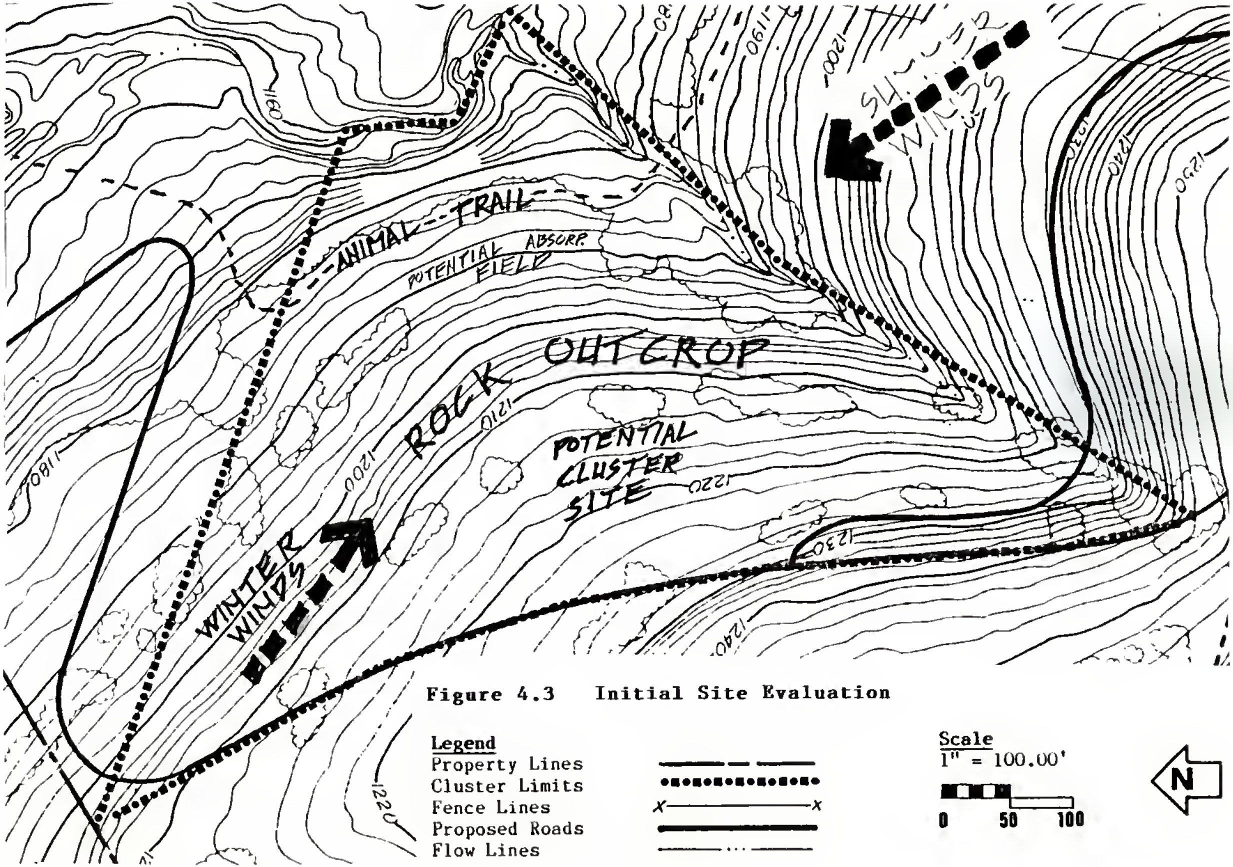


Figure 4.3 Initial Site Evaluation

Utilities. Currently, no utilities exist within phase two of the Cedar Springs Ranch development. Furthermore, no community-wide water distributions or sewerage systems are planned at this time.

Historical Sites. A portion of the old Oregon Trail Cutoff traverses the southern most part of the second phase of development. This trail, however, does not pass through or near the cluster lot that is to serve as a study site.

No other historically significant features exist within the boundaries of the development.

Review of State/Local Regulations

State Regulations. As pointed out in the previous section, the regulation of onsite wastewater treatment and disposal systems is the responsibility of the State Board of Health. The State limitations that apply to the study site will be discussed. Other limitations may apply to developments in other regions of the state that do not apply to Cedar Springs Ranch.. For example, Cedar Springs Ranch's watershed is downstream from the Tuttle Creek Dam. Therefore, it is not in the sanitation district that regulates areas that might have an impact on the reservoir.

Presently the state limits for minimal treatment of sewage is secondary treatment (e.g. 30 mg/l or less for BODs and TSS). Any discharge to surface water must additionally be disinfected (eg. chlorination). Disposal discharge facilities should be remote from water sources (50 feet horizontal distance) separated from structures and foundations (25 ft.) and should not discharge directly into the groundwater (at least 4 ft. separation from water table) or into creviced rock (at least 4 ft. separation from bedrock). Discharging sewage into abandoned wells, pits extending to the water table or sinkholes is forbidden.

Subsoil contact or sewage lagoons are the favored forms of onsite discharge but other forms may be acceptable if they: 1) provide an adequate and reliable means of treating the sewage, 2) have a satisfactory point for discharge or disposal of the treated sewage, and 3) have a reliable plan of operation. Sewage lagoons, if used, must be totally retentive due to stringent water pollution control standards.

Subsoil discharge of treated sewage must be in soil that possesses an acceptable percolation rate without interference from groundwater or impervious strata below the absorption system. The maximum time allowed for standing water to drop 1 inch in a test hole (as described in Appendix II) is 60 minutes. Soils with inadequate percolation are deemed unsuitable for subsoil disposal methods without modifications to the system as pointed out in chapter III.

Local Regulations. The protective covenants for Cedar Springs Ranch establishes several restrictions that will affect discharge options available for disposal of the treated wastewater.

Article XI, p. 10 of the General Covenants requires the approval of all construction plans by an Architectural and Environmental Control Committee, and p. 11 forbids the placement of sewage disposal systems within 200 ft. of stream beds. This concern for preserving the water quality of the streams is also reflected in

Article XII, p. 13 which prohibits the pollution of any springs, creeks, lakes, or ponds within the boundary of the Cedar Springs Ranch Development.

Preliminary Screening of Discharge Options

Since unretained lagoons are not permitted, the size requirements for containing the treated wastewater for evaporation coupled with expense of site modifications would make this option cost preventative.

Overland flow concepts would also be unfeasible on this site due to area requirements, soil properties (eg. rapid runoff potential), excessive slopes (eg. 5-20%), and the proximity to homes which might pose a potential for aesthetic conflicts.

Surface discharge is also unfeasible without amending the protective covenants and establishing a means for disinfecting the treated wastewater before discharge.

With these options eliminated, coupled with the state's preference for subsoil disposal, the use of a subsurface disposal or evapotranspiration beds would seem to be the most practical options for further investigation.

Detailed Site Inventory and Analysis

Due to the elimination of all options other than subsurface and evapotranspiration beds for ultimate discharge of the treated wastewater, the properties of the soil and evaporation rate at the study site would require further investigation.

Since the general description for the acceptability of an absorption field in the Clime-Sogn soils series was low, the need for percolation tests was in order. An area of the site was identified in plan and in the field as having the potential of meeting the state and local regulations while providing gravity flow (to avoid the expense of pumping).

Tests were carried out, as described in Appendix II, and results recorded. The locations of the percolation test holes are shown on Figure 4.4. The results of the percolation tests are reported in Table 4.2. The test holes that drained within 30 minutes were measured every 10 minutes. Results appear below the results for holes that did not completely drain within 30 minutes as specified in the testing procedures.

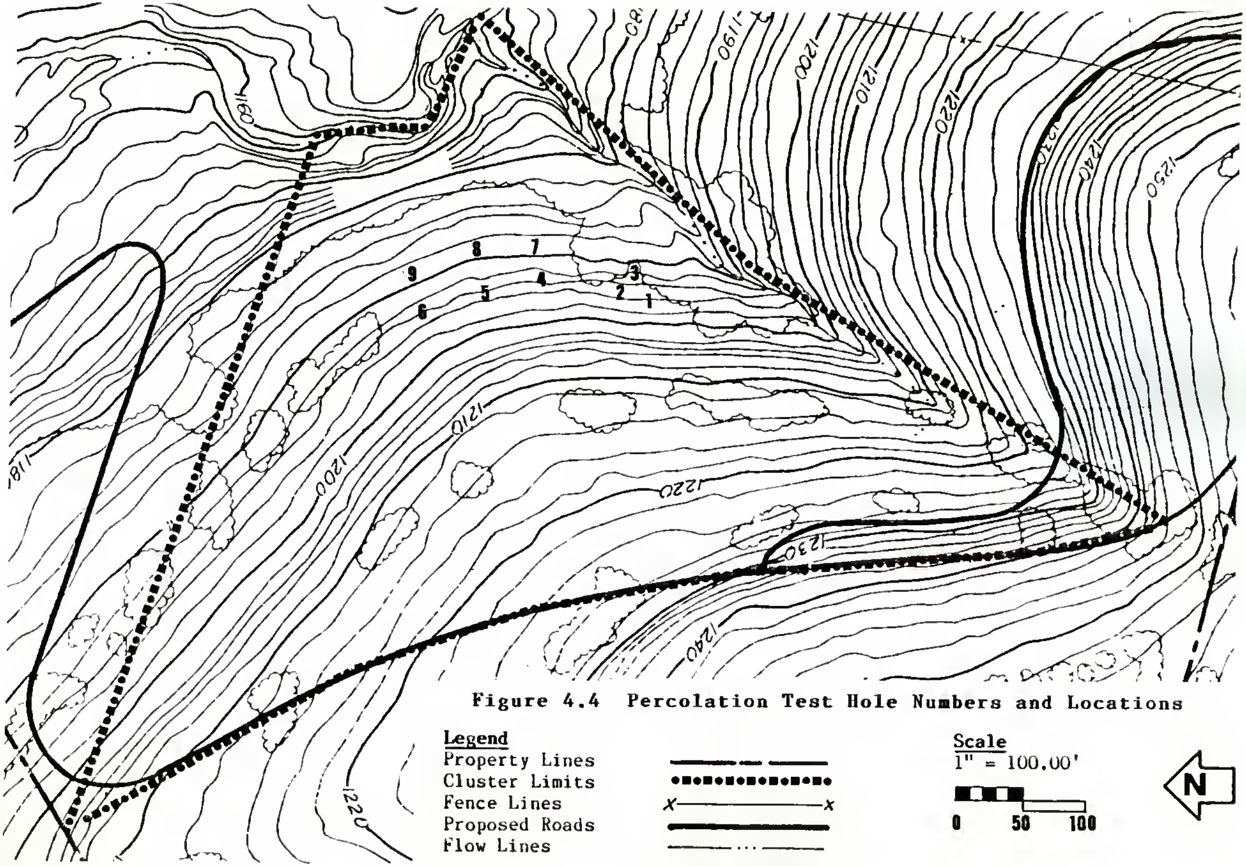


Figure 4.4 Percolation Test Hole Numbers and Locations

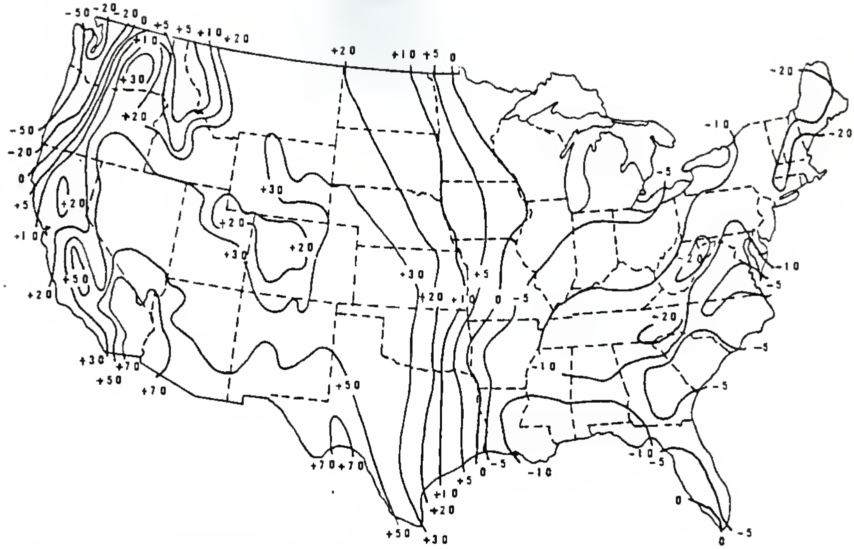
TABLE 4.2 PERCOLATION TEST DATA AND RESULTS

TEST RESULTS
(drop in inches/time step)

Time Step	HOLE #									
(30 min./step)	1	2	3	4	5	6	7	8	9	
1	1.13	1.75		1.13	1.00	3.75				
2	1.25	1.86		0.88	0.75	4.00				
3	1.13	1.50		1.00	0.75	3.25				
4	1.50	1.88		1.00	0.88	3.00				
5	1.50	2.00		1.00	0.75	3.00				
6	1.50	2.00		1.00	0.75	2.75				
7	1.50	2.00		1.00	0.75	2.75				
8	1.50	2.00		1.00	0.75	2.75				
(10 min./step)										
1			2.75				4.50	2.50	3.25	
2			2.75				4.25	2.25	3.00	
3			2.75				3.75	2.00	2.00	
4			2.75				3.75	2.00	2.50	
5			2.75				3.75	2.00	2.50	
6			2.75				3.75	2.00	2.50	
Percolation Rate (Min./In.)	20	15	3.60	30	40	10.9	2.7	5.0	4.0	Average Rate 14.58
Required Absorption Field (sq. ft.)	210	190	109	250	283	170	95	125	115	188

The results indicate that there is sufficient percolation in the area tested to provide adequate disposal of the treated wastewater. Due to the nature of the soil to shrink and swell, the settling chambers will need to be backfilled with amended soil to avoid disrupted flows.

The evaporation potential for the site is good according to Figure 4.5, but due to the system's construction and the benefits of soil disposal of the treated wastewater, the choice of an evapotransporation method was not pursued.



\+ Potential Evapotranspiration more than mean annual precipitation

— Potential Evapotranspiration less than mean annual precipitation

Figure 4.5 Potential Evaporation Vs. Mean Annual Precipitation

Source: EPA, Design Manual: Onsite Wastewater Treatment and Disposal Systems, Report No. EPA-625/1-1-80-012, p. 16.

Systematic System Design and Preliminary Siting

Once the use of a subsurface soil discharge method is decided upon, the entire wastewater treatment system is conceptually designed and schematically fitted to the site to attain the optimum relationship of the system to the site and development. This schematic is shown in Figure 4.6.

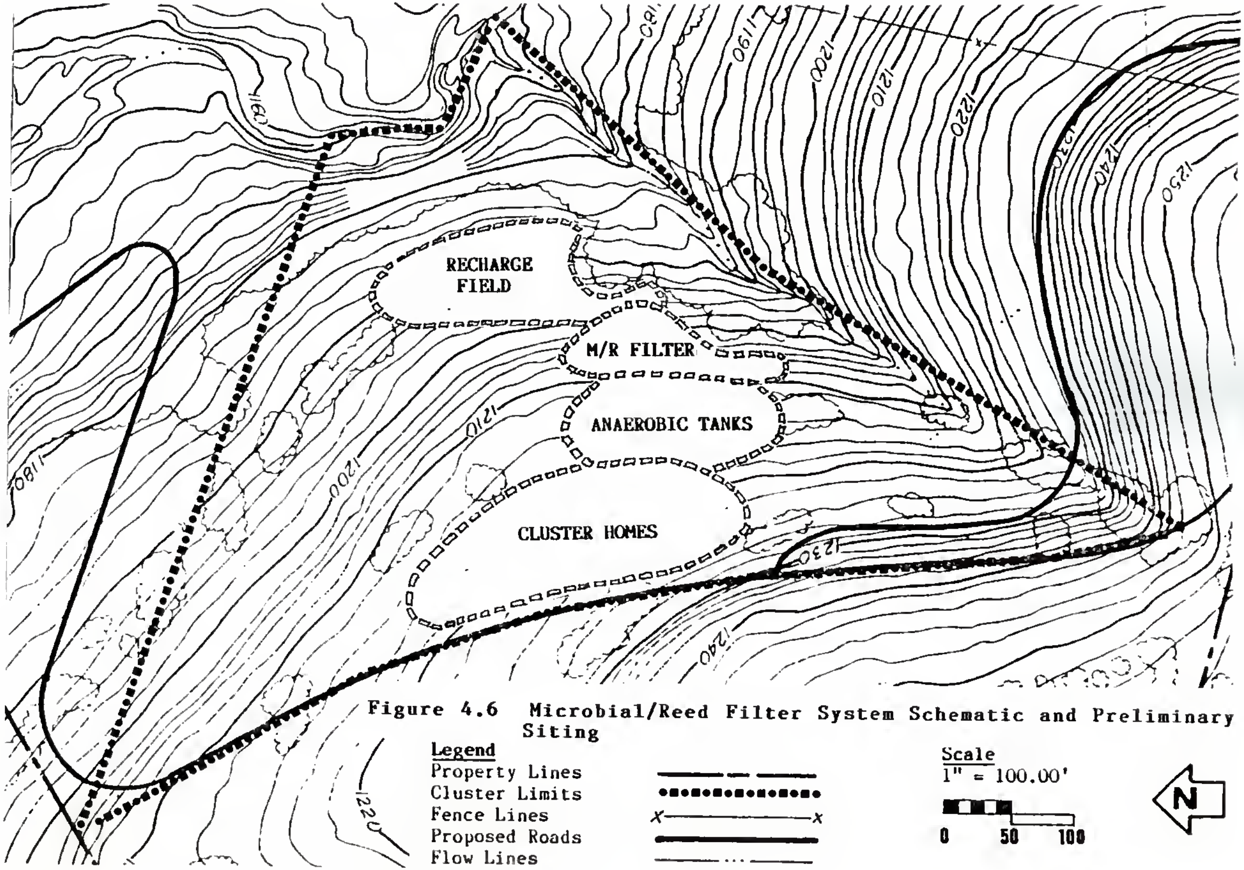


Figure 4.6 Microbial/Reed Filter System Schematic and Preliminary Siting

After the preliminary siting of the microbial/reed filter design is completed, it becomes apparent that a means for diverting potential surface runoff away from the microbial/reed filter unit is needed. Therefore, a diversion ditch was incorporated into the design. A conceptual schematic showing the system's relationship to the cluster home and the inclusion of a windbreak and a diversion ditch, for intercepting overland flow, is shown in Figure 4.7.

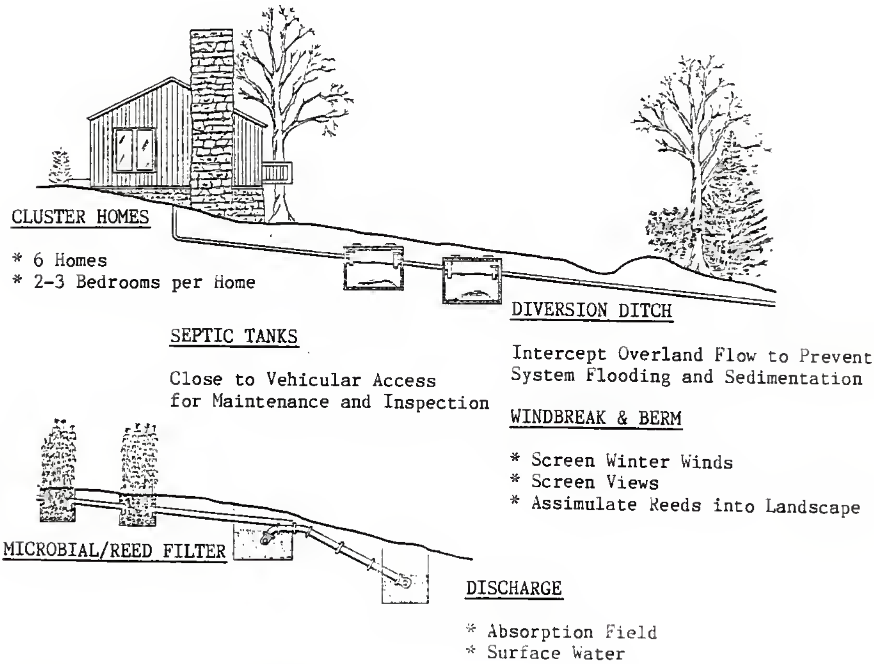


Figure 4.7 Microbial/Reed Filter Conceptulization

Client Review

After conceptually designing the system and receiving approval of the preliminary siting, it was decided that several smaller settling chambers serving 2 or 3 of the homes comprising the cluster development might be more cost effective than a pair of large settling chambers. In this way, standard prefabricated septic tanks could be used in place of the poured-in-place chambers that would have been required.

System Design

The system components were then sized to determine their capacities along with the required area needed. This was done in an attempt to blend the wastewater treatment system, development and site into one entity that represented an ecologically sound environment.

Settling Chambers. The decision to use standard septic tanks to serve the purpose of the large settling chambers dictated that two cluster units should enter each tank. Since the homes comprising the cluster are projected to have three bedrooms apiece, the size of the tanks would have to accommodate 6 bedrooms. Therefore, the necessary capacities of each tank were determined to be 1,500 gallons complying with state standards. Table 4.3 shows the minimum tank requirements correlated to the number of bedrooms per house as suggested by the Kansas Department of Health and Environment.

TABLE 4.3 LIQUID CAPACITY OF TANK (gallons)

Number of Bedrooms	Recommended Minimum Tank Capacity
2 or less	750
3	900
4	1,000
5	1,250
6	1,500

Source: Kansas Department of Health and Environment, A Manual of Recommended Standards for Locating, Constructing and Operating Septic Tank Systems for Rural Homes, Bulletin No. 4-2, March 1984, p. 19.

These tanks are to be located near vehicular access to facilitate pumpage and inspection during maintenance operations.

Microbial/Reed Filter. The method of sizing the microbial/reed filter units was determined to be the quantity of wastewater produced by the cluster home.

If the maximum amount of wastewater produced per day was estimated to be 2,400 gal./day, the microbial/reed filter unit using rocks with 40% void space, the capacity would need to be 6,000 gal. or 802 cubic feet.

If the trenches for accommodating the microbial/reed filter are excavated with a standard 36-inch bucket on a backhoe to a depth of three feet the unit's length would be 89 feet. This depth would provide natural insulation of the unit in winter since the bottom is below frostline with the heat produced by the wastewater. This would insure continued operation during the winter.

Absorption Field. The absorption field's capacity is determined by the state approved method of correlating the percolation rate of the soil with the number of bedrooms to be served. Since the average percolation rate was determined to be 14.58 minutes per inch, the square feet required per bedroom would be 188 square feet as determined from Figure 4.8.

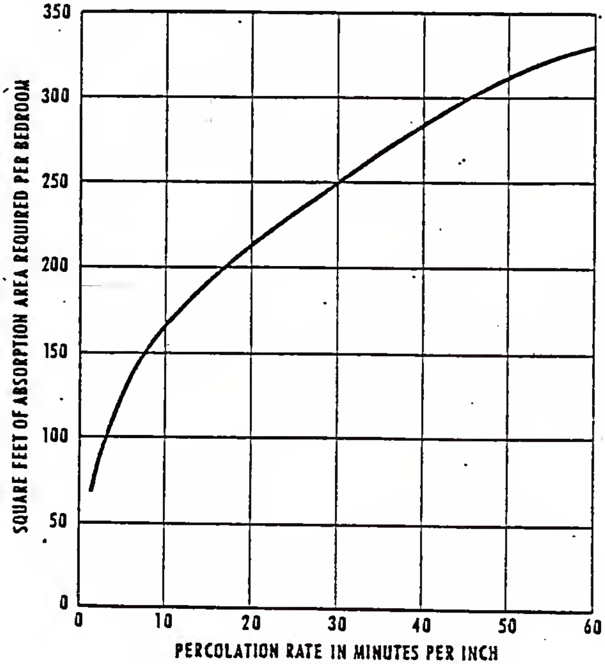


Figure 4.8 Absorption Area Requirements

Source: Kansas Department of Health and Environment, <u>A Manual of Recommended Standards for Locating, Constructing and Operating Septic Tank Systems for Rural Homes</u>, Bulletin No. 4-12, March 1984, p. 7.

Therefore, the required area for the bottom of the absorption field trenches would be 3,384 square feet based on the projected 18 bedrooms per cluster development. If the trenches are 3 feet wide, using the same backhoe bucket used to excavate the microbial/reed filter trench, the total length of the absorption field would be 1,128 feet long.

The limit of approximately 100 feet for maximum trench length should be used in determining the number of laterals needed. Therefore, the absorption system would consist of a distribution box feeding eleven laterals spaced no closer than 7.5 feet between the trench center lines.

After determining these physical capacities and area requirements, the wastewater treatment system was integrated with the site as shown in Figure 4.9 and conceptually shown in section in Figure 4.10.

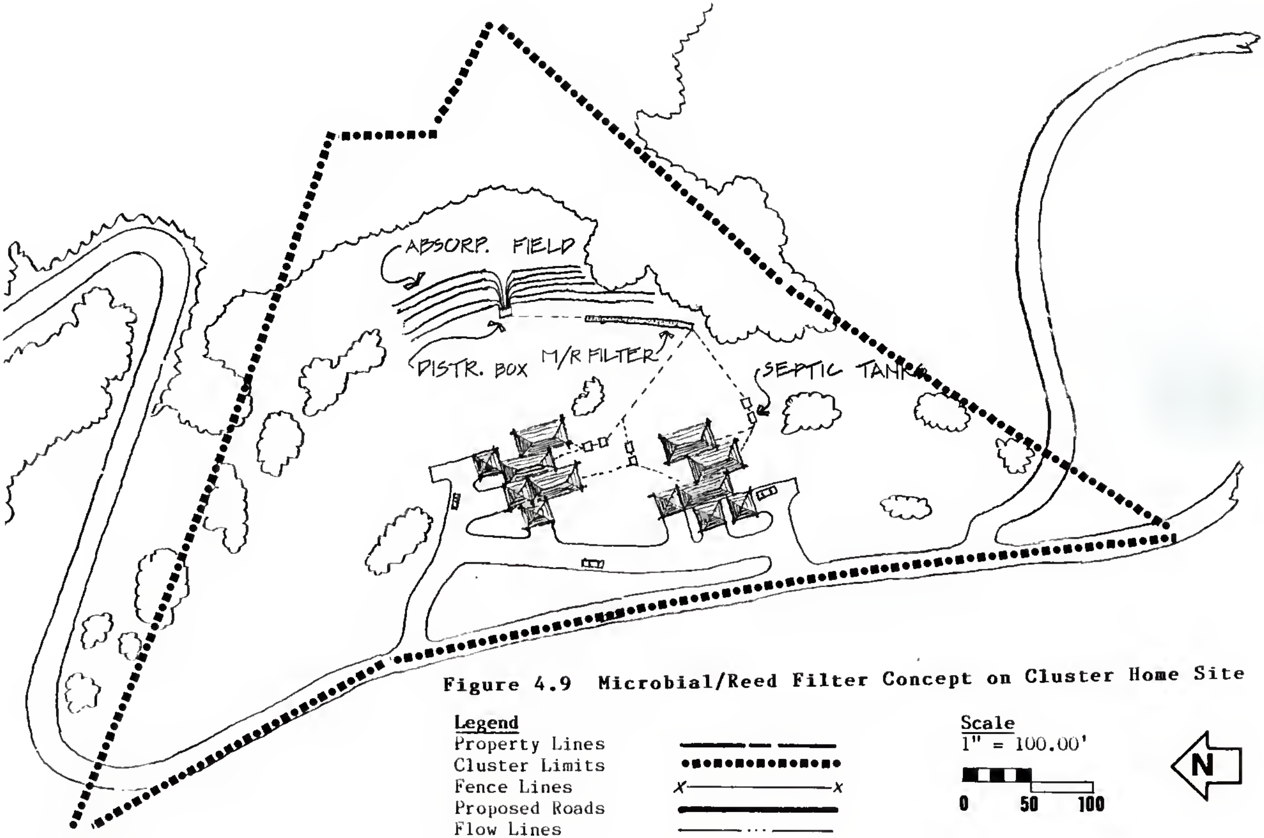


Figure 4.9 Microbial/Reed Filter Concept on Cluster Home Site

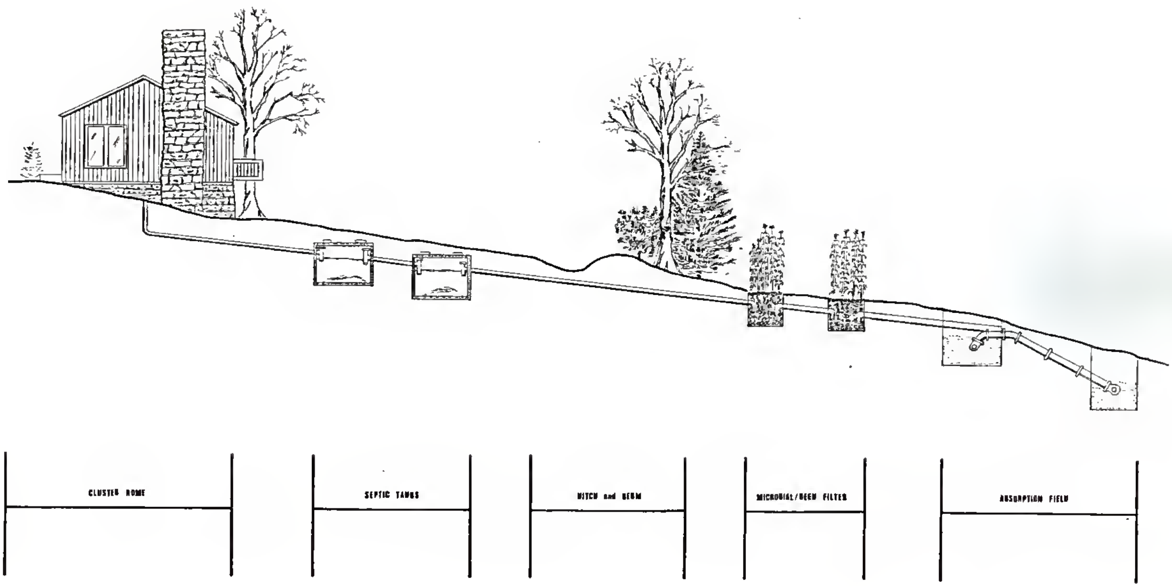


Figure 4.10 Conceptual Section of Microbial/Reed Filter System

Visual Integration of Microbial/Reed Filter System & Site. To reduce the visual dominance of the reeds, plant material should be planted around the microbial/reed filter unit. Using the criteria set forth in the section on design description in chapter III, a planting plan was developed and is shown in Figure 4.11. This planting plan will integrate the reeds onto the site, discourage unauthorized access, and reduce the visual prominence of the microbial/reed filter unit while requiring little to no additional maintenance.

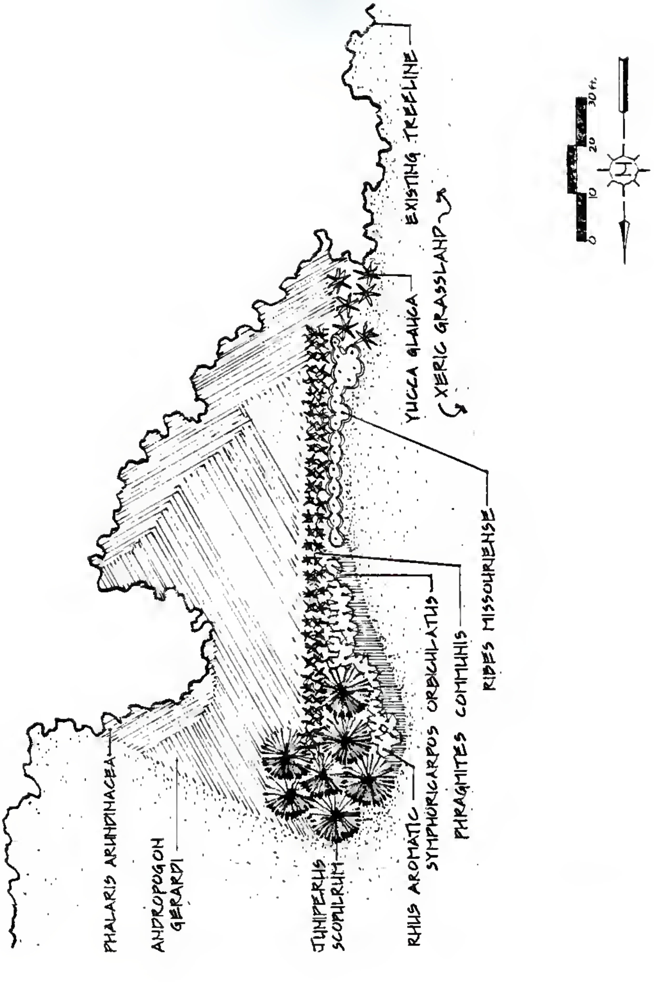


Figure 4.11 Planting Plan for Integration of Microbial/Reed Filter and Site

Operation and Maintenance

Of the three components that comprise the wastewater treatment system, only the settling chamber will require periodic maintenance.

Settling Chamber. Standard maintenance procedures for septic tanks should be followed for maintaining the settling chamber.

To prevent insufficient retention times, increased sludge scouring, and the potential of solids reaching the microbial/reed filter, the settling chamber should be pumped-out periodically. The EPA suggests that tanks should be inspected at least every 2 years to determine scum and sludge accumulation rates. Once this rate is determined, an inspection and pump-out frequency can be established. If an inspection program is not implemented, a pump-out frequency of once every 3 to 5 years should be expected. Upon completion of the pump-out operation, the inlet and outlet structures and key joints should be inspected for damage before resuming service.

The EPA suggests the following list of considerations pertaining to settling tank operation and maintenance:

1. Climbing into tanks can be very dangerous, as the tanks are full of toxic gases. When using the access port, take every precaution possible. Do not lower an individual into the tank without a proper air supply, and safety rope tied around chest or waist.
2. The access port, rather than the inspection pipe (when

present), should be used for pumping so as to minimize the risk of harm to the inlet and outlet baffles.

3. Leaving solids in the tank to aid in starting the system is not necessary.

4. When pumped, the tank must not be disinfected, washed or scrubbed.

5. Special chemicals are not needed to start activity in a settling chamber.

6. Special additives are not needed to improve or assist chamber operation once it is underway. No chemicals additives are needed to "clean" settling chambers. Such compounds may cause sludge bulking and decreased sludge digestion. However, ordinary amounts of bleaches, lyes, caustics, soaps, detergents and drain cleaners do not harm the system. Other preparations, some of which may claim to eliminate the need for settling chamber pumping, are not necessary for proper operation and are of questionable value.

7. Materials not readily decomposed (e.g., sanitary napkins, coffee grounds, cooking fats, bones, wet-strength towels, disposable diapers, facial tissues, cigarette butts) should never be flushed into settling chambers when avoidable. They will not degrade in the chamber, and can clog inlets, outlets, microbial filter unit, and the disposal system.

Microbial/Reed Filter Unit. Once installed the microbial/reed filter unit should require little to no maintenance. Since the reeds may require a full season to become firmly established the construction of the microbial/reed filter unit prior to building the homes should be encouraged. This would provide a lead time before start-up of the system.

The collecting and testing of "grab" samples on a yearly or semi-yearly basis would provide a means of monitoring the system and help insure proper operation.

The diversion ditch will require annual and post-storm inspection to insure free flow. This will prevent the possibility of runoff and sediment entering the microbial/reed filter unit during periods of peak runoff.

Absorption Field. Once installed, the subsurface soil absorption field will require little to no attention due to the high level of wastewater treatment that the microbial/reed filter unit provides. Unlike absorption fields associated with conventional septic tanks, the incorporation of the microbial/reed filter will prevent the biological "mat" from forming on the bottom of the trenches. This "mat" formation is the primary reason for absorption field failure.

The presence of invasive colonial woody plant species in the absorption field will need to be checked periodically to protect against the possibility of trench clogging from root invasion.

Cost Estimate

A cost estimate for the wastewater treatment system, based on prices quoted by Bayer Construction Company of Manhattan, Kansas, and Dr. B. C. Wolverton [3], was prepared and is shown in Figure 4.12.

ITEM	QUANTITY	UNIT COST	TOTAL COST
Settling Chamber			
Septic Tank	6	$500	$3,000
Tank Excavation	148 cy	1	148
Backfill	37 cy	6	222
Microbial/Reed			
Excavation	30 cy	1	30
20 mil PVC Liner	990 sf	.25 *	247
Rock Medium	27.5 cy	8 *	220
Pea Gravel	2.5 cy	6 *	15
Reeds	1,350	.10 *	135
PVC Connecting Pipe	500 ft	12.50 *	6,250
Absorption Field			
Trench & Appurtenances	1,128 ft	6 *	6,768
GRAND TOTAL			**$17,035**

* installed price

Figure 4.12 Cost Estimation

[3] Wolverton, B. C. and McDonald, R. C., Basic Engineering Criteria and Cost Estimations for Hybrid Microbial Filter-Reed Wastewater treatment Concept. (NASA, TM-84669, 1982).

CHAPTER V

RESULTS AND CONCLUSIONS

The use of microbial/reed filter systems for the onsite treatment of domestic sewage has been proven to be an effective and economical means of handling the problem of safe disposal of human and domestic wastes. The use of onsite systems also maintain water tables in the region where they are used by providing a cyclical use pattern.

If the design process shown in Figure 5.1 is followed for the implementation of a microbial/reed filter system, the resulting product should provide excellent wastewater treatment while being aesthetically and ecologically compatible with a site. Since the process has several stages where the assumptions or parameters are checked and reviewed, it possesses an inherent system of checks and balances.

The incorporation of these stages in the process should make the design process applicable to most sites, if the process is followed in a logical and sequential order. This is due to the attempt by the author to base the design process on identifying the limits imposed on wastewater treatment by the site and political environment insuring their resolution in the design. The process allows the limitations to determine acceptable discharge and configuration alternatives rather than forcing an alternative to overcome a limitation.

The earlier in the project that the wastewater treatment is addressed, the greater the benefit to the whole development.

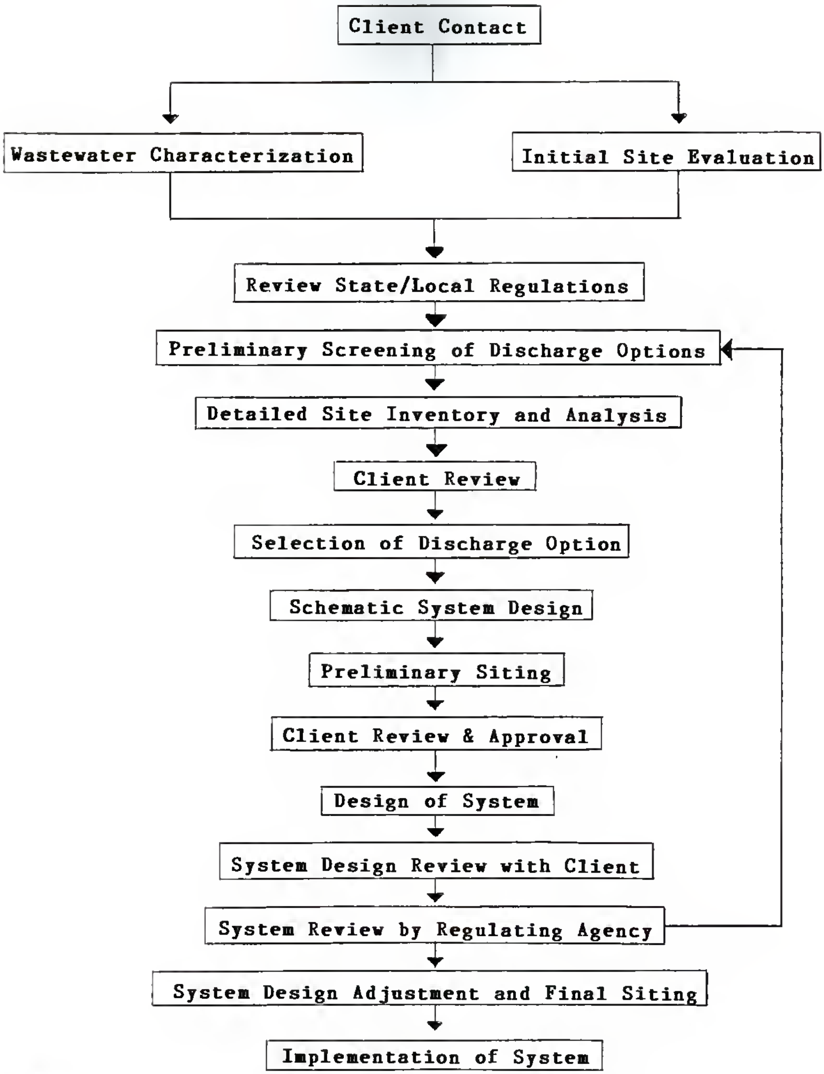


Figure 5.1 Prototypical Design Process for an Onsite Microbial/Reed Filter System.

Unfortunately, the process cannot be tested to the final implementation stage at this time. This is due to the fact that the use of a microbial/reed filter system has not been presented to the regulating agencies, as of this time, and the development of Cedar Springs Ranch is not scheduled for several years.

The study site served as a good case study since it provided many of the site considerations that are encountered in housing developments. This allowed the design process to be tested in a real life setting rather than restricting it to a theoretical set of circumstances.

REFERENCES

1. Bastian, Robert K. and Benforado, Jay, "Waste Treatment: Doing What comes Naturally", Technology Review, February/March 1983, pp. 59-66.

2. Barnes, D. and Wilson, F., The Design and Operation of Small Sewage Works, (New York: Halsted Press Books, 1976).

3. Bouwer, H. and Chaney, R. L., "Land Treatment of Wastewater", in Advances in Agronomy, N. C. Brady, Ed. (New York: Academic Press, 1974).

4. DeJong, J., The Purification of Wastewater With the Aid of Ponds With Rushes or Reeds, (Philadelphia: University of Pennsylvania Press, 1976).

5. EPA, Design Manual: Onsite Wastewater Treatment and Disposal Systems, Report No. EPA-625/1-1-80-012.

6. Hamaker, J. W., "Adsorption" in Organic Chemicals in the Soil Environment, eds. Goring, C. A. I. and Hamaker, J. W., (New York: Marcel Dekker, Inc. 1972), pp. 49-143.

7. Hitchcock, A. S., Manual of the Grasses of the United States, United States Department of Agriculture Publication No. 200, (Washington, D.C.: GPO, 1935).

8. Kansas Department of Health and Environment, A Manual of Recommended Standards for Locating, Constructing and Operating Septic Tank Systems for Rural Homes, Bulletin No. 4-12, March 1984.

9. Leeper, G. W., Managing the Heavy Metals on the Land, (New York: Marcel Dekker, 1978).

10. MacDonald, Betty N., "The Impact of On-lot Systems on Land Development: A Citizen's View", Individual Onsite Wastewater Systems, (Michigan: Ann Arbor Science, 1977).

11. McClelland, Nina I., Individual Onsite Wastewater Systems, (Michigan: Ann Arbor Science, 1977).

12. McGauhey, P. H. and Krone, R. B., "Soil Mantle as a Wastewater Treatment System", Sanitary Engineering Research Laboratory, College of Engineering and School of Public Health, University of California, Berkley, Report No. 67-11 (1967).

13. McDonald, R. C., Vascular Plants For Decontaminating Radioactive Water and Soils. NASA Technical Memorandom TM-X-72740, Aug. 1981, p. 9.

14. Metcalf and Eddy, Inc., Wastewater Engineering: Treatment/Disposal/Reuse, 2nd ed., McGraw-Hill Book Co., New York, 1979, p. 455-460.

15. Miller, F. P. and Wolf, D. C., "Renovation of Sewage Effluents by the Soil" in Individual Onsite Wastewater Systems, ed. McClelland, N. I., (Ann Arbor: Ann Arbor Science, 1977), p. 100-101.

16. NASA, NASA & flowers, Promotional Brochere.

17. Oblinger-Smith Corp., Pottawatomie, Riley County's Water and Sewer Plan, (1977).

18. Oswald, W. J., et al, Integrated Pond Systems for Subdivisions, Journal Water Pollution Control Federation, 1967, 39(8): 1289.

19. Peterson, Jon A., "The Impact of Sanitary Reform Upon American Urban Planning 1840-1890", Journal of Social History, Vol. 13, No. 1, pp.83-103, 1979, reprinted in Kruekeberg, D. A., ed., Center For Urban Policy Research (Rutgers), pp. 13-39.

20. Rich, Linvil G., Low-Maintenance, Mechanically Simple Wastewater Treatment Systems, (New York: McGraw-Hill Book Company, 1980).

21. Sculthorpe, C. D., The Biology of Aquatic Vascular Plants, (London: Arnold Press, 1967), p. 110.

22. Seidel, K., "Macrophytes and Water Purification", Biological Control of Water Pollution, J. Tourbier and R. W. Pierson, Jr., eds. (Philadelphia: University of Pennsylvania Press, 1976).

23. U.S.D.A., Grass Waterways in Soil Conservation, (U.S.D.A. Leaflet 477, 1971).

24. Urban Land Institute, Erosion and Sediment Control, (ULI, 1978).

25. United States Department of Housing and Urban Development, Sewer Moratoria: Causes Effects Alternatives, (U.S. Government Printing Office, 1977).

26. Van der Ryn, Sim, The Toilet Papers, (Capra Press, 1978).

27. Wolverton, B. C., and McDonald, R. C., Basic Engineering Criteria and Cost Estimations For Hybrid Microbial Filter-Reed Wastewater Treatment Concept. (NASA, TM-84669, 1982).

28. Wolverton, B. C., and McDonald, R. C., "Harnessing the Power of Green Plants and Microorganisms for Earth and Space Applications", Paper Presented at: NASA Goddard Space Flight Center, Engineering Colloquia, April 5, 1982, p. 4.

29. Wolverton, B. C., et.al., "Microorganisms and Higher Plants for Waste Water Treatment", Journal of Environmental Quality, Vol. 12, No. 2, April/June, 1983).

30. Wolverton, B. C., The Role of Plants and Microorganisms in Assuring a Future Supply of Clean Air and Water (NASA, 1984).

31. Wolverton, B. C., "The Role of Plants and Microorganisms in Assuring a Future Supply of Clean Air and Water", Seminar Presented at: CBI Industries, Plainfield, Illinois, March 26, 1984.

32. Wolverton, B. C., and McDonald, R. C., "Upgrading Flacultative Wastewater Lagoons With Vascular Aquatic Plants", Journal Water Pollution Control Federation, Washington D. C., (February 1979).

33. Wolverton, B. C., et. al., Water Hyacinths and Alligator Weeds For Final Filtration of Sewage, (NASA: TM-X-72724, May 1975).

34. Wolverton, B. C., "Hybrid Wastewater Treatment System Using Anaerobic Microorganisms and Reed (Phragmites communis), Economic Botany, 36(4), 1982, p. 374.

35. Wolverton B. C. and McDonald R. C., "Microbial Filters and Higher Plants for Treating Hazardous and Toxic Chemicals", Progress Report on NASA/EPA Joint Program (Agreement No. AD80F2A104), July 1983.

GLOSSARY

Aerobic - a condition whereby free dissolved oxygen exists in the wastewater.

Anaerobic - a condition where there is an absence of dissolved oxygen in the wastewater.

Anoxic - a condition where there is an oxygen deficiency in the wastewater. A condition whereby the dissolved oxygen content is between an aerobic and anaerobic state.

Antagonism - the sum of the mutual interference between dissimilar organisms occupying or attempting to occupy the same ecological niche.

BOD - (Biochemical Oxygen Demand) a measurement of the effect wastewater will have on the oxygen content of a stream or other receiving water due to the action of bacteria on the organic content of the wastewater. This action is usually measured after a period of time (standard is 5 days) and is the most widely used indicator of pollution. Since oxygen is essential to aquatic life a higher BOD rate indicates a greater threat to the environment.

Cesspool - a clay or masonry-lined underground vault for the collection and storage of wastewater. Cesspools are required to be impervious and not overflowing, have the capacity to be completely emptied, and be adequately covered and ventilated. Simular to a septic tank but not connected to a discharge component (e.g. absorption field).

Coliform bacteria - a group of bacteria found predominantly in the intestines of humans and animals. Among the members of this group is fecal coliform, a commonly used indicator of potential water contamination by pathogenic organisms.

Curtain drain - a trench excavation in which perforated drainage pipe is placed in a bed of course aggregate. They are placed around the upslope perimeter of soil absorption sites to lower perched water tables.

Effluent - wastewater discharged from a treatment process or system.

EPA - the U.S. Environmental Protection Agency; the federal agency that is primarily responsible for protection of natural resources, including water and air.

Eutrophication - the process by which natural waters, especially lakes and ponds, become enriched with dissolved nutrients and usually deficient in oxygen; the process of aging of a body of water.

Green space - an area void of residential or commercial land use; usually reserved for recreation or population density control.

Gray water - wastewater that does not contain sewage.

Heavy metal - those metals that come from an industrial of domestic source. Although essential for health in minute quantities they prove to be toxic to man and the environment if concentrations are great.

Lagoon - a manmade pond or lake used to impound wastewater for treatment or temporary storage.

Microbial - a reference to the action of microscopic organisms such as bacteria.

Nutrients - elements essential to support life. Nutrients act to stimulate the growth of algae and promote eutrophication in water bodies receiving wastewater. Normally used in wastewater terminology to refer to phosphorus, nitrogen, and carbon.

Organic matter - a general term used to describe biological material in wastewater.

Pathogens - organisms or viruses in wastewater capable of causing disease in humans.

pH - a deaignation for the negative logarithm of the hydrogen ion concentration. It is used as a measurement of acidity (low values) or alkalinity (high values) of wastewater. Values for pH range from 0 to 14; a solution with a pH of 7 is considered neutral.

Primary treatment - the most elementary level of wastewater treatment. This treatment separates the suspended, settleable, and floating solids from the liquid fraction by gravity separation. Primary treatment plants were once common but are being supplemented by treatment facilities with a higher degree of treatment to comply with pollution control requirements.

Privy - a dry toilet system in which wastes are composted to humus. A privy consists of a pit covered by a small outbuilding. They are common in rural areas and Third World countries.

Protective covenants - private controls imposed on a development to preserve the integrity of the community.

Secondary treatment - national minimum treatment for all public wastewater treatment plants. Secondary treatment processes remove most of the dissolved organic matter and bacteria from the wastewater while removing more solids than primary treatment.

Sewage - any substance that contains any of the waste products, excrement, or other discharges from the bodies of human beings or animals, or chemical or other wastes from domestic, manufacturing of other forms of industry, including garbage that has been reduced by the action of garbage grinder.

Sewerage system - the pipes and other appurtenances used in the conveyance and treatment of sewage.

Sewer moratoria - a regulatory action temporarily limiting housing construction in an area due to existing or potential deficiencies in the wastewater treatment or collection facilities.

Sludge - the accumulated solids separated from wastewater during primary and/or secondary treatment.

Shock Resistant - the ability of a system to maintain adequate treatment levels when an excessive organic load or toxic substance has been imposed.

Sorption - is the binding of one substance by another through the mechanism of absorption (taking in or reception by molecular or chemical action), adsorption (a binding of substances on a surface), and persorption (the adsorption of materials in pores only slightly wider than the diameter of the adsorbed molecule).

Sub-division - the division of a lot, tract or parcel of land into three or more lots, plats, sites, or other divisions of land for the purpose, immediate or future, of sale or building development including the streets, alleys or other portions thereof intending to be dedicated for public use.

Tertiary Treatment - follows secondary treatment and provides very high levels of pollutant removal of nutrients such as phosphorous, nitrogen and additional amounts of solids and organic matter.

Total Suspended Solids - the undissolved substances suspended in wastewater.

Wastewater - water that has been used for domestic or commercial purposes. Water that is not suitable for human consumption without proper treatment.

APPENDIX I

MICROBIAL/REED FILTER TREATMENT CURVES

Source: Wolverton, B.C., and McDonald, R.C., Basic Engineering Criteria and Cost Estimations For Hybrid Microbial Filter-Reed Wastewater Treatment Concept, (NASA, TM-84669, 1982)

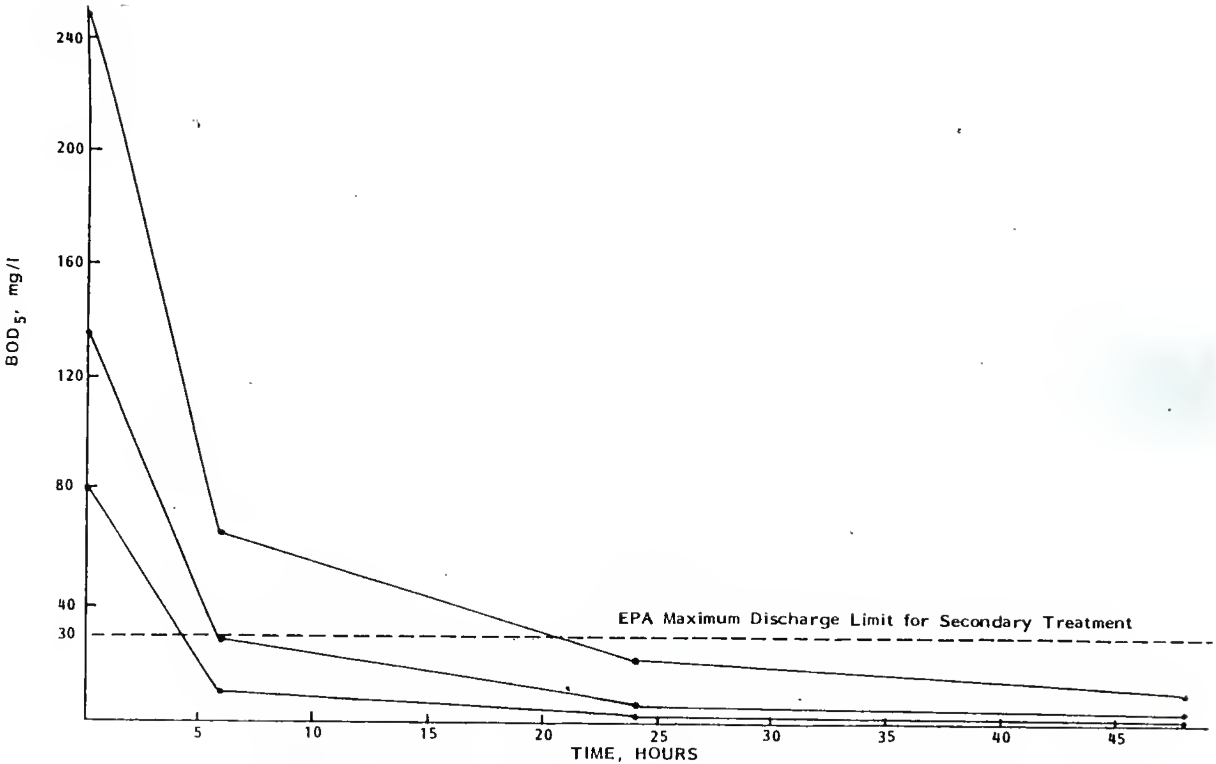


FIGURE I.1 Each curve represents the average of four experiments with similar initial BOD$_5$'s. The sewage was treated for 24 hours in anaerobic settling tanks. The initial BOD$_5$'s were obtained on the effluent from the settling tank during transfer to the microbial/reed rock filters (av. temp. 23°C).

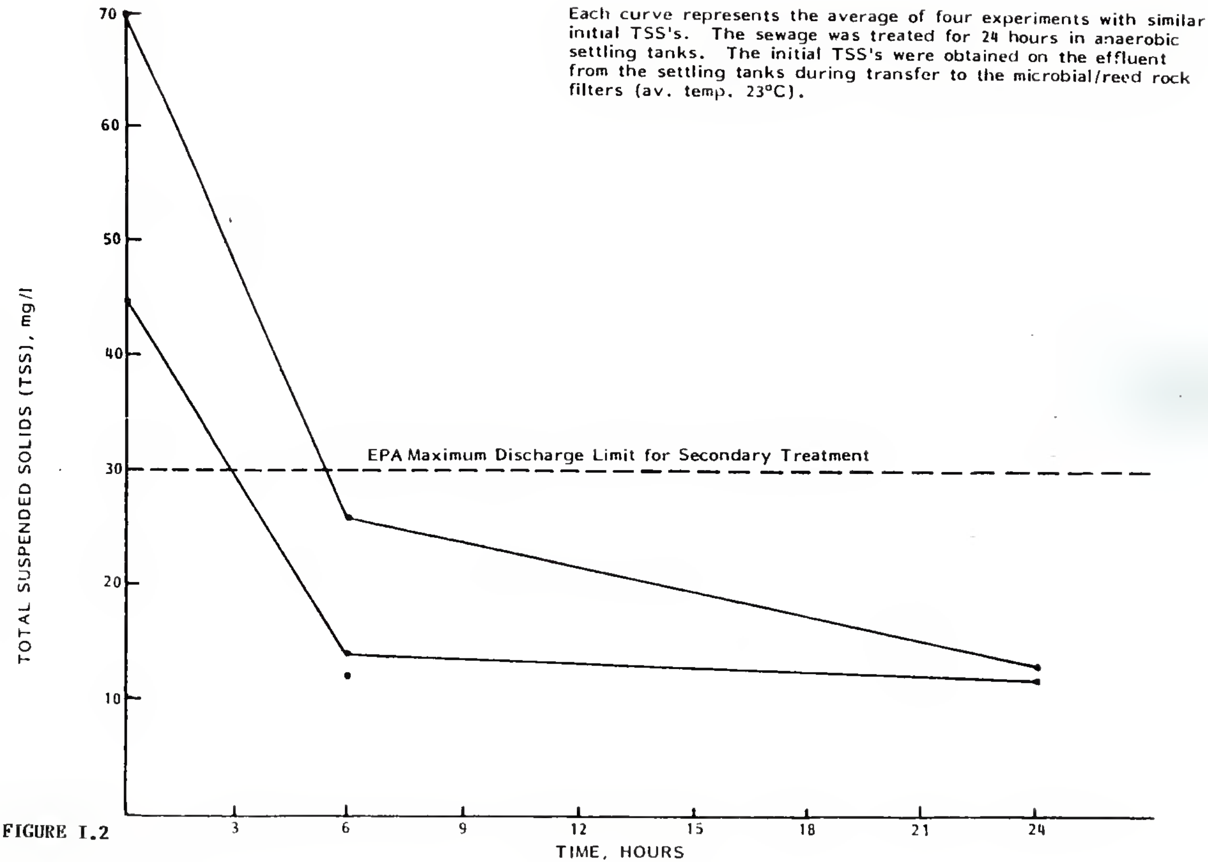
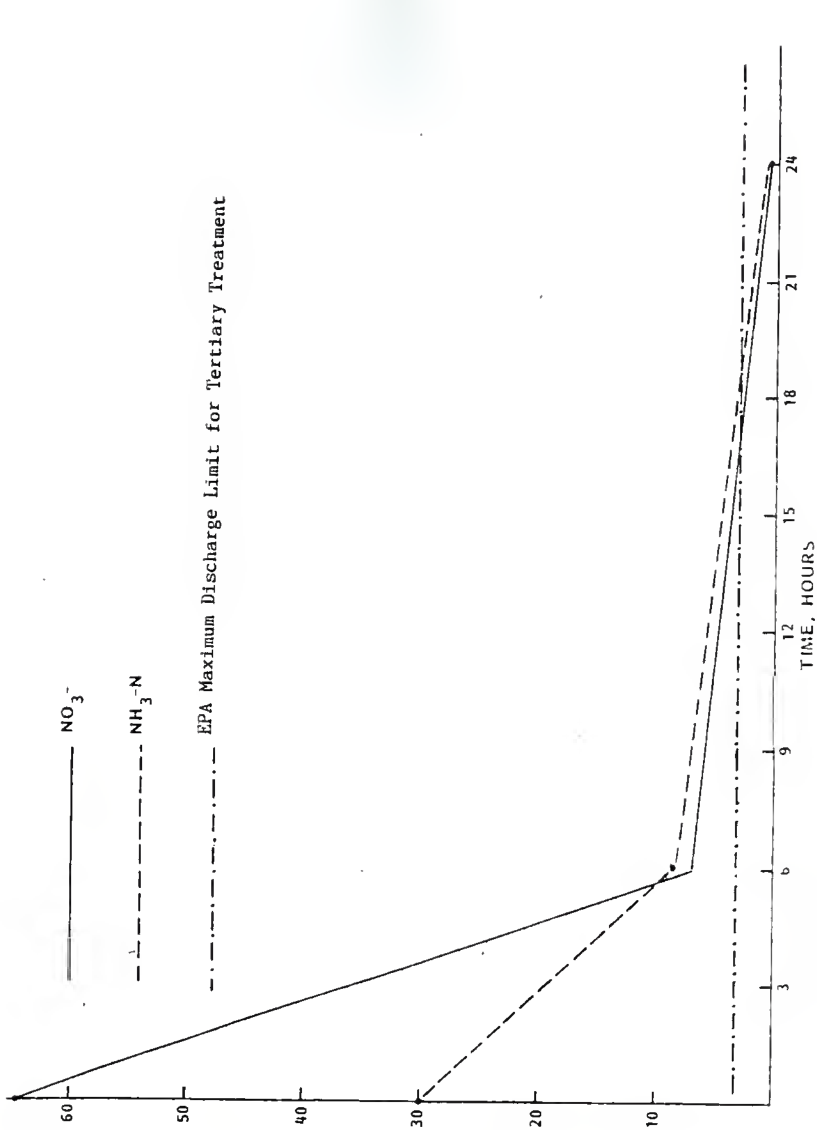

Each curve represents the average of four experiments with similar initial TSS's. The sewage was treated for 24 hours in anaerobic settling tanks. The initial TSS's were obtained on the effluent from the settling tanks during transfer to the microbial/reed rock filters (av. temp. 23°C).
EPA Maximum Discharge Limit for Secondary Treatment
TOTAL SUSPENDED SOLIDS (TSS), mg/l
70
60
50
40
30
20
10
3
6
9
12
15
18
21
24
TIME, HOURS

FIGURE I.2



NO_3^-
NH_3-N
EPA Maximum Discharge Limit for Tertiary Treatment
CONCENTRATION, mg/l
60
50
40
30
20
10
TIME, HOURS
3
6
9
12
15
18
21
24

FIGURE I.3

APPENDIX II

PERCOLATION TEST PROCEDURE

Source: EPA, Design Manual : ONSITE WASTEWATER TREATMENT AND DISPOSAL SYSTEMS, Report No. EPA 625/1-80-012, p.56.

TABLE II.1

FALLING HEAD PERCOLATION TEST PROCEDURE

1. Number and Location of Tests

   Commonly a minimum of three percolation tests are performed within the area proposed for an absorption system. They are spaced uniformly throughout the area. If soil conditions are highly variable, more tests may be required.

2. Preparation of Test Hole

   The diameter of each test hole is 6 in., dug or bored to the proposed depths at the absorption systems or to the most limiting soil horizon. To expose a natural soil surface, the sides of the hole are scratched with a sharp pointed instrument and the loose material is removed from the bottom of the test hole. Two inches of 1/2 to 3/4 in. gravel are placed in the hole to protect the bottom from scouring action when the water is added.

3. Soaking Period

   The hole is carefully filled with at least 12 in. of clear water. This depth of water should be maintained for at least 4 hr and preferably overnight if clay soils are present. A funnel with an attached hose or similar device may be used to prevent water from washing down the sides of the hole. Automatic siphons or float valves may be employed to automatically maintain the water level during the soaking period. It is extremely important that the soil be allowed to soak for a sufficiently long period of time to allow the soil to swell if accurate results are to be obtained.

   In sandy soils with little or no clay, soaking is not necessary. If, after filling the hole twice with 12 in. of water, the water seeps completely away in less than ten minutes, the test can proceed immediately.

4. Measurement of the Percolation Rate

   Except for sandy soils, percolation rate measurements are made 15 hr but no more than 30 hr after the soaking period began. Any soil that sloughed into the hole during the soaking period is removed and the water level is adjusted to 6 in. above the gravel (or 8 in. above the bottom of the hole). At no time during the test is the water level allowed to rise more than 6 in. above the gravel.

   Immediately after adjustment, the water level is measured from a fixed reference point to the nearest 1/16 in. at 30 min intervals. The test is continued until two successive water level drops do not vary by more than 1/16 in. At least three measurements are made.

   After each measurement, the water level is readjusted to the 6 in. level. The last water level drop is used to calculate the percolation rate.

   In sandy soils or soils in which the first 6 in. of water added after the soaking period seeps away in less than 30 min, water level measurements are made at 10 min intervals for a 1 hr period. The last water level drop is used to calculate the percolation rate.

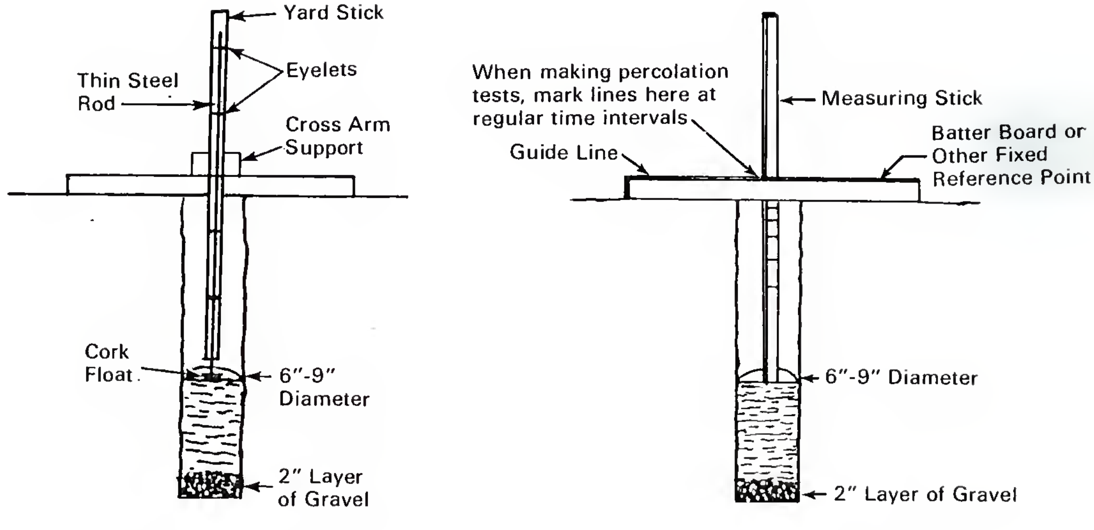
5. Calculation of the Percolation Rate

   The percolation rate is calculated for each test hole by dividing the time interval used between measurements by the magnitude of the last water level drop. This calculation results in a percolation rate in terms of min/in. To determine the percolation rate for the area, the rates obtained from each hole are averaged. (If tests in the area vary by more than 20 min/in., variations in soil type are indicated. Under these circumstances, percolation rates should not be averaged.)

   Example: If the last measured drop in water level after 30 min is 5/8 in., the percolation rate = (30 min)/(5/8 in.) = 48 min/in.

FIGURE II.1

CONSTRUCTION OF A PERCOMETER



(a) Floating Indicator (b) Fixed Indicator

APPENDIX III

TYPICAL WASTEWATER CHARACTERISTICS

Source: EPA, Design Manual : ONSITE WASTEWATER TREATMENT AND DISPOSAL SYSTEMS, Report No. EPA 625/1-80-012, p.58.

TABLE III.1

CHARACTERISTICS OF TYPICAL RESIDENTIAL WASTEWATER[a]

Parameter	Mass Loading gm/cap/day	Concentration mg/l
Total Solids	115 - 170	680 - 1000
Volatile Solids	65 - 85	380 - 500
Suspended Solids	35 - 50	200 - 290
Volatile Suspended Solids	25 - 40	150 - 240
BOD_5	35 - 50	200 - 290
Chemical Oxygen Demand	115 - 125	680 - 730
Total Nitrogen	6 - 17	35 - 100
Ammonia	1 - 3	6 - 18
Nitrites and Nitrates	<1	<1
Total Phosphorus	3 - 5	18 - 29
Phosphate	1 - 4	6 - 24
Total Coliforms[b]	-	10^{10} - 10^{12}
Fecal Coliforms[b]	-	10^{8} - 10^{10}

[a] For typical residential dwellings equipped with standard water-using fixtures and appliances (excluding garbage disposals) generating approximately 45 gpcd (170 lpcd). Based on the results presented in (5)(6)(7)(10)(13).

[b] Concentrations presented in organisms per liter.

TABLE III.2

POLLUTANT CONTRIBUTIONS OF MAJOR RESIDENTIAL WASTEWATER FRACTIONS (gm/cap/day)

Parameter	Garbage Disposal	Toilet	Basins, Sinks, Appliances	Approximate Total
BOD_5	18.0 10.9 - 30.9	16.7 6.9 - 23.6	28.5 24.5 - 38.8	63.2
Suspended Solids	26.5 15.8 - 43.6	27.0 12.5 - 36.5	17.2 10.8 - 22.6	70.7
Nitrogen	0.6 0.2 - 0.9	8.7 4.1 - 16.8	1.9 1.1 - 2.0	11.2
Phosphorus	0.1 0.1 - 0.1	1.2 0.6 - 1.6	2.8 2.2 - 3.4	4.0

TABLE III.3

POLLUTANT CONCENTRATIONS OF MAJOR RESIDENTIAL WASTEWATER FRACTIONS[a] (mg/l)

Parameter	Garbage Disposal	Toilet	Basins, Sinks, Appliances	Combined Wastewater
BOD_5	2380	280	260	360
Suspended Solids	3500	450	160	400
Nitrogen	79	140	17	63
Phosphorus	13	20	26	23

[a] Based on the average results presented in Table [illegible] and the following wastewater flows: Garbage disposal - 2 gpcd (8 lpcd); toilet - 16 gpcd (61 lpcd); basins, sinks and appliances - 29 gpcd (110 lpcd); total - 47 gpcd (178 lpcd).

TABLE III.4

TYPICAL WASTEWATER FLOWS FROM COMMERCIAL SOURCES

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

TABLE III.5

TYPICAL WASTEWATER FLOWS FROM RECREATIONAL SOURCES

Source	Unit	Wastewater Flow Range (gpd/unit)	Wastewater Flow Typical (gpd/unit)
Apartment, Resort	Person	52.8 - 74	58.1
Cabin, Resort	Person	34.3 - 50.2	42.3
Cafeteria	Customer	1.1 - 2.6	1.6
	Employee	7.9 - 13.2	10.6
Campground (developed)	Person	21.1 - 39.6	31.7
Cocktail Lounge	Seat	13.2 - 26.4	19.8
Coffee Shop	Customer	4.0 - 7.9	5.3
	Employee	7.9 - 13.2	10.6
Country Club	Member Present	66.0 - 132	106
	Employee	10.6 - 15.9	13.2
Day Camp (no meals)	Person	10.6 - 15.9	13.2
Dining Hall	Meal Served	4.0 - 13.2	7.9
Dormitory, Bunkhouse	Person	19.8 - 46.2	39.6
Hotel, resort	Person	39.6 - 63.4	52.8
Laundromat	Machine	476 - 687	581
Store Resort	Customer	1.3 - 5.3	2.6
	Employee	7.9 - 13.2	10.6
Swimming Pool	Customer	5.3 - 13.2	10.6
	Employee	7.9 - 13.2	10.6
Theater	Seat	2.6 - 4.0	2.6
Visitor Center	Visitor	4.0 - 7.9	5.3

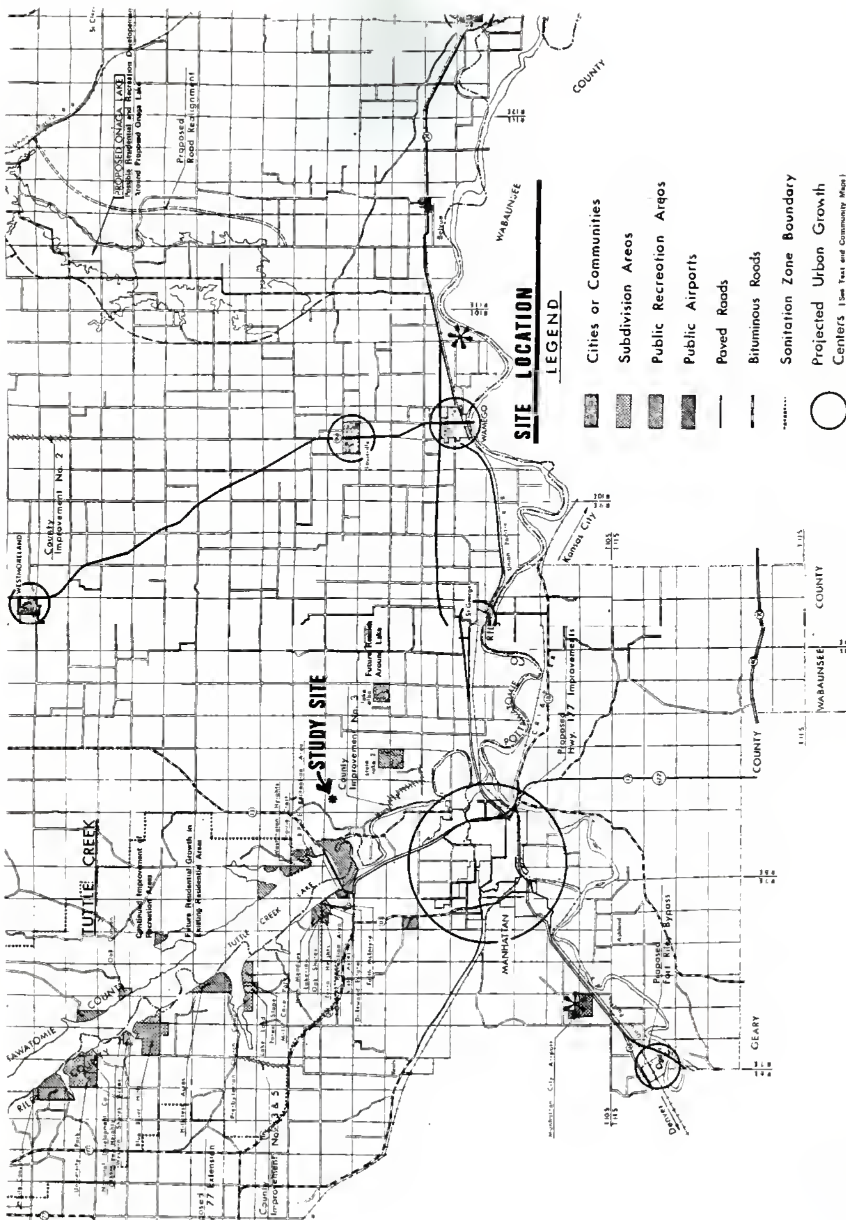
TABLE III.6

TYPICAL WASTEWATER FLOWS FROM INSTITUTIONAL SOURCES

Source	Unit	Wastewater Flow Range (gpd/unit)	Wastewater Flow Typical (gpd/unit)
Hospital, Medical	Bed	132 - 251	172
	Employee	5.3 - 15.9	10.6
Hospital, Mental	Bed	79.3 - 172	106
	Employee	5.3 - 15.9	10.6
Prison	Inmate	79.3 - 159	119
	Employee	5.3 - 15.9	10.6
Rest Home	Resident	52.8 - 119	92.5
	Employee	5.3 - 15.9	10.6
School, Day:			
With Cafeteria, Gym, Showers	Student	15.9 - 30.4	21.1
With Cafeteria Only	Student	10.6 - 21.1	15.9
Without Cafeteria, Gym, Showers	Student	5.3 - 17.2	10.6
School, Boarding	Student	52.8 - 106	74.0

APPENDIX IV

STUDY SITE LOCATION


SITE LOCATION
LEGEND
Cities or Communities
Subdivision Areas
Public Recreation Argos
Public Airports
Paved Roads
Bituminous Roads
Sonitation Zone Boundary
Projected Urban Growth Centers (See Text and Community Maps)
STUDY SITE
County Improvement No. 3
TUTTLE CREEK
TUTTLE CREEK LAKE
Continued Improvement of Recreation Areas
Future Residential Growth in Existing Residential Areas
PROPOSED ONAGA LAKE
Possible Residential and Recreation Development Around Proposed Onaga Lake
Proposed Road Realignment
County Improvement No. 2
WESTMORELAND
WAMEGO
MANHATTAN
Future Residential Around Lake
Proposed Hwy. 177 Improvements
Proposed Fort Riley Bypass
County Improvement No. 3 & 5
Proposed Hwy. 77 Extension
WABAUNSEE
COUNTY
WABAUNSEE COUNTY
GEARY
POTTAWATOMIE COUNTY
Kansas City
Denver

DEVELOPMENT OF A PROTOTYPICAL DESIGN PROCESS
FOR THE USE OF A MICROBIAL/REED FILTER SYSTEM
FOR ON-SITE DOMESTIC WASTEWATER TREATMENT

by

CARL WOODLAND BENGTSON

B. S., University of Nebraska, 1978

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1986

ABSTRACT

Safe disposal of human and domestic wastes is necessary to protect the health of the individual and the community, while protecting the integrity of the environment. The problem of safe disposal of wastea is one of the major problems facing most cities, communities and developments today.

Preserving a source of potable water has become increasingly difficult as surface and groundwater supplies have become contaminated from improperly treated wastewater entering stream and river systems. Poorly designed septic systems are another source of contamination to groundwater.

The purpose of this study was to develop a prototypical design process providing a logical sequential procedure for integrating an onsite microbial/reed filter waatewater system in the least intrusive manner possible. The prototypical design process was developed by identifying and analyzing the parameters of domestic wastewater, microbial/reed components and site conditions to determine their impact on the system design. This prototype was then tested, by applying it to a study site, identifying any problems or omissions in the deaign process.

Results of the study indicates that the prototype suggested is a valid process that could be employed by professional landscape architects in similar land planning scenarios.