AzOWRA

Arizona Onsite Wastewater
Recycling Association

Onsite Wastewater Educational Conference & Exhibition

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Treatment Technologies Workbook

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1. INTRODUCTION

Adequately managed on-site wastewater systems are a cost-effective and long-term option for meeting public health and water quality goals in rural areas. Decentralized systems currently serve approximately 25 Percent of the U.S. population, and approximately 37 percent of new development.

For most of the 20th century, wastewater management entailed either large municipal centralized treatment facilities for highly populated areas, or conventional onsite systems (septic tanks with soil absorption or cesspools) for rural areas.

Less than one-third of the land area in the U.S. has soil conditions suitable for conventional soil absorption systems. Numerous innovative alternatives to the conventional septic tank and soil absorption system have evolved in response to the demand for an environmentally acceptable and economical means of disposing domestic wastewater onsite and into the restrictive soil conditions common in many areas.

The treatment and disposal of wastewater takes place in three principle areas or categories: (1) The treatment device (or black box), (2) The disposal device, (3) the in-situ soil. There is significant ambiguity regarding what is a treatment device and disposal device. For the purpose of this document the definitions are:

- Treatment Device – A constructed discrete device or system that increases water quality through physical, biological or chemical means independent of receiving soils.
- Disposal Device – A constructed device or mechanism that maximizes the natural soil simulative capacity. *(All treatment takes place in or at the soil interface. If no significant treatment is expected to occur outside the soil boundary, the device is purely disposal).*

As mentioned above, in addition to the treatment taking place in the actual treatment device, suitable soil is an effective treatment medium for effluent treatment. The soil consists of billions of microorganisms, including bacteria, protozoa, fungi, molds and other organisms. These organisms interact with the minerals, organic matter, water and gases that comprise the soil. This complex community along with the physical structure of the soil itself provide the mechanisms by which the wastewater becomes purified as it percolates through the soil and returns to the underlying groundwater, or is transpired by plants or evaporated.

Because of the enormous variations in temperature, soils, water use, availability of filtration media and climate throughout the world, no single design has been used everywhere. Instead, different treatment and disposal alternatives can be combined to produce optimum solutions for particular sites. New treatment technologies are being developed, but the basic principles of wastewater treatment remain constant. The complexity of the system required for a particular site varies with the infiltrative capacity of the soil, geology, and climate, topography of the site and regional rules and regulations.

The following manual describes a variety of on-site systems, both treatment and disposal devices, but by no means covers all systems currently in use or presently being developed. The treatment devices and disposal devices have not been specifically separated in the document therefore it is up to the reader to understand the differences in treatment and disposal devices. This document reports on system uses, process descriptions and design criteria as well as necessary operation and maintenance and system advantages vs. disadvantages.

Arizona Administrative Code (A.A.C.) Title 18, Chapter 9 (AKA the "Unified Water Quality Permit Rules" or "the Aquifer Protection Permit Program" or simply "the rule") are the state of Arizona rules that define the acceptable installation and operation of residential onsite wastewater systems. Although this report does not go into detail on specific regulatory requirements, the specific code is listed in the title of each system type. This report enhances the Unified Water Quality Permit Rule by reporting on a variety of on-site systems that must be designed per the rules (in the state of Arizona).

The systems described within are in numerical order of the rule. Environmental Hydrosystems Ltd recognizes this may cause some confusion to the reader. The intent is to prioritize and familiarize the reader to the rule first then the particulars of the systems described.

This report is not rule and is not intended to modify or alter any rule. Care was taken in the development of this document to assure it conforms with the rule, however if the authors inadvertently provided rule conflicts, the rule takes precedence over this report. All designers are responsible to know the rules and to prepare a submittal that complies with the rules.

Although design strategies, details, and specifications often refer to proprietary systems, EHS Ltd nor AZOWRA endorses any particular treatment or disposal devise/component. Designers and contractors are responsible to make informed decisions on the best treatment and disposal system available for the particular client and environment they are designing for. To maintain a strong knowledge base EHS Ltd recommends designers and contractors continue to educate themselves by discussing issues with piers and vendors and to take advantage of educational opportunities such as the AZNOWR Onsite Wastewater Education Conference and Exhibition. courses offered by the University of Arizona and others.

2. CONVENTIONAL SYSTEMS

Conventional systems typically use no electricity or mechanical devices. Besides periodic pumping of accumulated solids, conventional systems operate by natural processes. Gravity provides all the power through differential head needed for the water and wastes to flow through the system. Treatment of the wastewater is accomplished by natural physical, chemical and biological processes in the treatment unit and soil absorption system.

If adequate site and soil conditions are available, conventional systems can provide adequate treatment and disposal of sewage for many years when properly constructed and maintained.

2.1 CESSPOOLS

Before septic tanks were common, sewage from homes was often disposed of in covered vertical pits called cesspools. The cesspool was an early predecessor of the current-day septic system, providing a subsurface system for disposal of waterborne sewage. The use of cesspools was primarily driven by convenience and their location was governed mainly by the nearest available land. Sometimes cesspools were constricted in the basements of urban buildings.

Cesspools are now viewed as undesirable by public health officials, due, in part to historical experiences with overused and failed systems as well as increased concerns for groundwater protection. Section A309 of the rule prohibits the use of cesspools.

2.2 SEPTIC TANK (A.A.C. R18-9-E302)

All onsite systems designs are judged in comparison with the basic septic tank/soil absorption system. So prevalent is this view that the septic tank/soil absorption system is commonly referred to as a "conventional" system, and most other designs are referred to as "alternative" systems.

2.2.1 PROCESS DESCRIPTION

A septic tank is a buried, watertight container used to clarify and partially treat wastewater. The septic tank has been in use in one form or another for over 100 years. The variables of a septic tank are: material, size, shape, number of chambers, number and style of baffles, gas venting provisions and accessories such as effluent filters.

The septic tank was originally designed to serve as a settling basin to separate scum and grit from the liquid. The effluent from the tank then was sent to a sewer or the soil for disposal. The clarification function of the tank was known, but the biological processes that partially digested the sewage were discovered by accident. Scientists found that the organic solids in the wastewater decomposed if they stayed in the tank long enough. Therefore, the septic tank is designed to accomplish two tasks: (1) clarification and (2) treatment.

2.2.1.1 Clarification

Clarification is a function of the detention time and the water extraction method. Solids settle out of the water based on size and specific gravity. Smaller lighter particles take longer to settle than heavier particles. Clarification also includes the removal of fats, oils and greases, which float to the surface along with soapsuds and "scum". The variables of a septic tank are: material, size, shape, number of chambers, number and style of baffles and gas venting provisions.

2.2.1.2 Treatment

Treatment consists of biological treatment by anaerobic digestion. Anaerobic treatment partially decomposes the organic matter into simpler compounds that can be treated further in the septic tank or discharged into the soil for aerobic treatment.

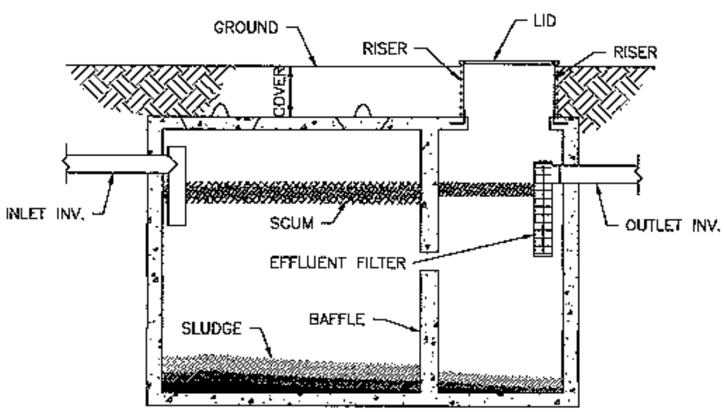
2.2.2 DESIGN CRITERIA

Design and operational considerations for septic tanks include: (1) configuration, (2) materials, (3) structural integrity, (4) watertightness (5) size, (6) appurtenances and (7) operation and maintenance. A well-designed tank can remove 60 to 90 percent of the total suspended solids (TSS) and 30 to 80 percent of the biochemical oxygen demand (BOD) resulting in:

- TSS concentration of 75 mg/l (30 day average)
- BOD of 150 mg/l. (30 day average)
- Total Nitrogen (as N) of 53 mg/l (5 month average)
- 95 percent of the time the LOG_{10} of the Fecal Coliform Colony forming units per 100 ml is less than or equal to 8.

2.2.2.1 Configuration

Efficient clarification takes time to complete because fats, oils, greases, and suspended solids travel slowly in water and may require hours to either float to the top or settle to the bottom. The shape of the tank must be designed to maximize the detention time of the wastewater. Surface area is more critical for settleability than depth, so a shallow, wide tank is preferable to a deep, narrow tank if both have the same volume capacity. Shallow tanks are also easier to transport and install and poses less of a safety risk because the content level of the tank is not much deeper than the height of an average person.



Septic Tank

An improperly configured tank will allow wastewater to "short-circuit" through the tank to the outlet.

Short-circuiting can allow solids to migrate to the absorption field if the wastewater is not given sufficient time for the solids to settle out. Equally important is a level tank. Tanks that are improperly installed (not level) or become un-level due to post consolidation may cause improper treatment or physical damage to the tank.

2.2.2.2 Materials

Typically, septic tanks are made of concrete, polyethylene or fiberglass. Steel and redwood have been used in the past but is no longer accepted by most regulatory agencies. Long term "creep", resulting in deformation has been a problem with polyethylene tanks. Both polyethylene and fiberglass tanks can easily be moved by a labor crew, whereas concrete tanks are typically moved about by a truck equipped with a crane and boom. Fiberglass tanks are often used in areas inaccessible to concrete tank delivery trucks. Both polyethylene and fiberglass tanks are more prone to "floating" than concrete tanks. Regardless of the material of construction the tank must be watertight and structurally sound.

2.2.2.3 Structural integrity

The long-term performance of the septic tank will depend on its structural integrity. Structural integrity is dependent on the method of construction, he composition of the tank materials, the location of seams and the installation procedures including bedding and backfill.

2.2.2.4 Watertightness

Watertight tanks are a necessity for the protection of the environment and for the operation of the system. Each tank should be tested for watertightness and structural integrity by filling the tank with water before and after installation. Hydrostatic testing is conducted at the factory by filling the tank with water and letting it stand for 24 hours. If no water loss is observed after 24 hours, the tank is acceptable. Because some water absorption may occur with concrete tanks, the tank should be refilled and allowed to stand for an additional 24 hours. If the water loss after the second 24-hour period is greater than 1 gallon the tank should be rejected (ASTM C1227 (Precast Concrete Septic Tanks)). It is important that the above procedure be repeated once the tank is installed.

2.2.2.5 Size

Tank size and household water usage determine the detention time of the tank. As mentioned above, efficient clarification takes time to complete because fats, oils, greases, and suspended solids travel slowly in water and may require hours to either float to the top or settle to the bottom.

No. of Bedrooms	Fixture Count	Minimum Design Liquid Capacity (gallons)	Design Flow (gal/day)
1	7 or less	1000	150
	more than 7	1000	300
2	14 or less	1000	300
	more than 14	1000	450
3	21 or less	1000	450
	more than 21	1250	600
4	28 or less	1250	600
	more than 28	1500	750
5	35 or less	1500	750
	more than 35	2000	900
6	42 or less	2000	900
	more than 42	2500	1050
7	49 or less	2500	1050
	more than 49	3000	1200
8	56 or less	3000	1200
	more than 56	3000	1350

Criteria for Septic Tank Size and Design Flow (A.A.C. R18-9-A314.4)

Residential Fixture Type	Fixture Units	Residential Fixture Type	Fixture Units
Bathtub	2	Sink, bar	1
Bidet	2	Sink, kitchen (including	2
Clothes Washer	2	Sink, service	3
Dishwasher (separate from kitchen)	2	Utility tub or sink	2
Lavatory, single	1	Water closet, 1.6 gpf	3
Lavatory, double in master bedroom	1	Water closet, >1.5 to 3.2 gpf	4
Shower, single stall	2	Water closet, > 3.2 gpf	6

gpf stands for gallons per flush

Fixture Units (A.A.C. R18-9-A314.4)

A septic tank also accomplishes treatment through the biological activity of anaerobic or facultative bacteria. This type of biodegradation may take many hours to fully work, so treatment efficiency is linked to detention time. Over the years a number of empirical relationships have been developed to estimate the required detention time. The recommended detention time ranges from 36 to 48 hours, but the absolute minimum is 24 hours.

The septic tank will serve as a receptacle for all the Settleable and floatable materials until the tank is pumped. For this reason, the tank design must include provisions for adequate storage. The storage capacity is based on the intended use of the tank and the anticipated pumping interval. A tank that is too full of solids will have a shortened detention time and will not function properly and will allow unwanted substances to pass through to the soil absorption system.

2.2.2.6 Appurtenances

Influent baffles restrict and redirect the flow of the influent to help prevent short-circuiting. Baffles control the flow of the settleable and floatable materials. Effluent baffles prevent floatables, scum, or suspended solids from flowing into the leach field. Baffles come in many sizes and styles; the simplest is just a bend and extension in the inlet or outlet pipe. Baffles can also be concrete or fiberglass partitions attached to the ceiling and/or floor of the tank.

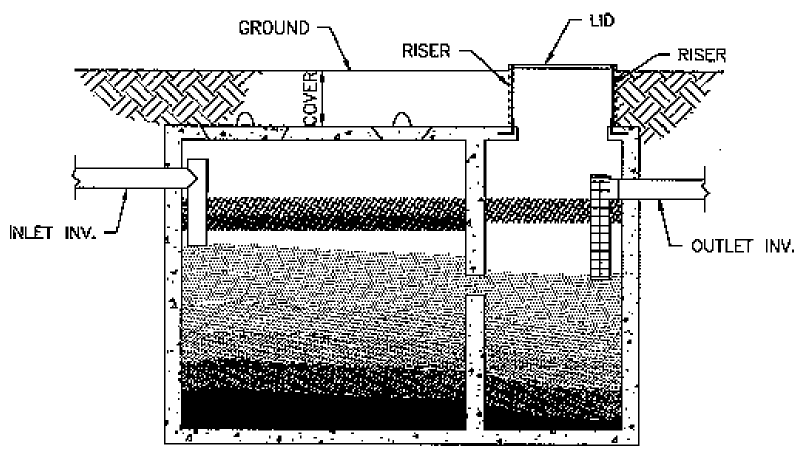
Compartmentalization can enhance the operation of the septic tank. A two-compartment tank helps to eliminate the possibility of short-circuiting wastewater through the system.

The effluent filter has been one of the most significant improvements in septic tank design in decades. The most serious problem with septic systems is the migration of solids, grease or oil into the leach field. The effluent filter is an effective way to prevent this. A filter restricts and limits passage of suspended solids out of the tank. Solids in a filtered system's effluent discharge are significantly less than those produced in a non-screened system. The effluent filter is relatively inexpensive and can be quickly installed or retrofitted. If the filter becomes clogged it can easily be removed, hosed off back into the entrance of the septic tank and reinstalled. The top of the tank has covered, removal manholes to allow for routine inspection and pumping. For easier location and access to the manholes, a riser should be constructed over each manhole, extending from the top of the tank to the ground surface. It is important the homeowner understands that the septic tank manholes should always remain accessible for maintenance.

2.2.3 OPERATION & MAINTENANCE

The system is designed to provide treatment and disposal for normal domestic sewage. No non-biodegradable material should be introduced into the wastewater treatment and disposal system. Plastic and paper (except toilet paper) are examples of non-biodegradable materials that should not be placed down the drain. Normal amounts of dirt and small non-biodegradable debris (buttons, dental floss, etc.) from washing will inevitably get into the system. These solids will be retained in the septic tank until it is pumped during its normal maintenance. Oils and grease should not be placed down the drain in excess quantities. Normal washing of greasy dishes is not considered excessive. Routinely draining fat from a frying pan, deep fryer, or roasting pan down the drain would be considered excessive. A garbage disposal may be used on the system but its use should be restricted. A garbage disposal should not be used for the bulk disposal of food preparation waste, therefore the homeowner should be discouraged from installing one.

Because septic tanks are buried and are out of sight, many homeowners forget that septic systems require periodic maintenance. Failure to pump-out the septic tank is possibly the greatest single cause of septic system failure. After several years of use, a build-up of bottom sludge and floating scum will reduce the effective capacity of the system. As mentioned earlier this means the wastewater passes through the tank too fast, and solids may eventually plug the pipes in the leach field.



Poorly Maintained Septic Tank

To avoid leach field failures inspect the tank at regular intervals and pump when necessary. Due to many variables it is recommended that the tank be inspected every year and base pump-outs on these annual inspections. As the years pass, you should be able to see a pattern of sludge and scum accumulation. Always keep records of inspections and dates when the tank has been pumped.

The tank should be pumped by a licensed pumper with a vacuum tank truck. The pumper will use a hose and vacuum everything out of the tank (both solids and liquid). Waste pumped from the tank is called septage. It is approximately 5% solids and 95% water. The septage waste must be taken to a licensed disposal site because of the potential health problems with contamination.

The effluent filter on the tank outlet that may require cleaning more than once a year. This is accomplished by simply removing the filter and hosing it off back into the septic tank and re-installing the filter.

2.3 CONVENTIONAL DISPERSAL METHODS (A.A.C. R18-9-E302)

After treatment from the septic tank or any other devise, the water must be discharged back into the environment. This is often done through a "conventional soil absorption system such as a disposal trench, Bed, Chamber or Seepage Pit. Regardless of the disposal method, it is designed to discharge the treated effluent below ground into the natural soil for final treatment and disposal.

2.3.1 TRENCH

The conventional trench system consists of shallow level excavations, usually 1 to 5 feet deep and 1 to 3 feet wide. The excavated area is filled with 6 inches of porous medium, such as gravel. A distribution network of 3 or 4 inch perforated leach pipe is placed over the media. A single leach line is laid in each trench. A semi-permeable barrier such as building paper or a geo-textile fabric is placed on top of the pipe and trench to mitigate fine soil migration into the bottom of the trench. Typically the disposal system will consist of multiple trenches less than 100' in length. The effluent from the septic tank trickles through the network through the media and into the soil. Treatment of the wastewater occurs in the soil of the trench system, the media is used simply for distribution of the effluent evenly throughout the trench.

2.3.2 DESIGN CRITERIA

The size, design and location of the trench drainfield depends on a variety of factors, such as local soil characteristics, the design flow, ground slope and depth to a subsurface limiting condition. The objective of the system is to distribute the effluent into an area with an adequate depth of suitably permeable, unsaturated soil.

The conventional trench is constructed below grade in a natural or undisturbed soil horizon. Conventional trenches are passive, effective and inexpensive treatment systems because the assimilative capacity of many soils can reduce most pollutants found in residential wastewaters.

The rule allows conventional trenches to be designed based on bottom area and side wall area of the effective depth. Effective depth is defined as the height from the bottom of the trench excavation to the bottom of the leach pipe.

Conventional Trench

DESIGN CALCULATIONS FOR DISPOSAL TRENCH SYSTEMS

DESIGN CALCULATIONS

System design flow = ______________________ gallons per day (B)

Percolation rate = ______________________ (mpi) SAR value = __________________ gallons per day / ft² (C)

(B / C) = __________________________ total square feet.

Sidewall depth (1’-3’) = ____________ feet x 2 = ____________ feet (D) Trench width (1’-3’) = ___________ trench ft² (E)

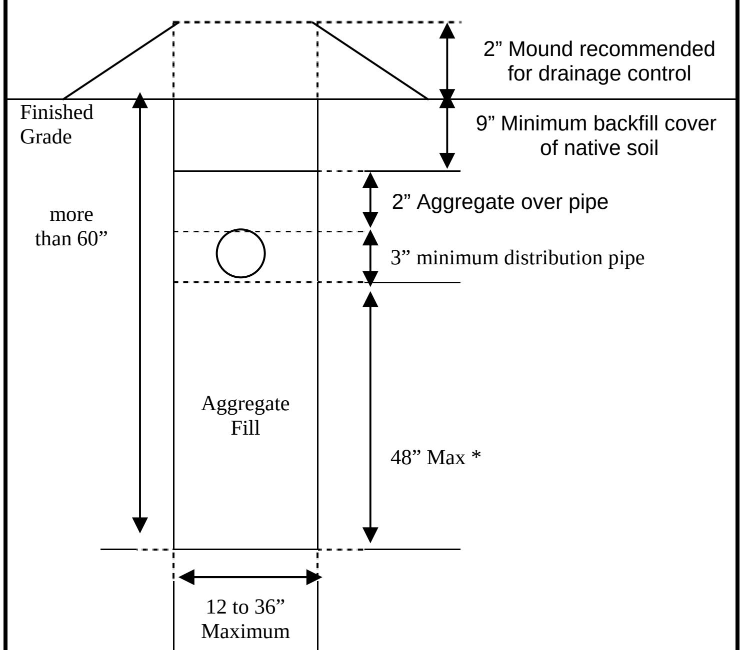
D + E = _____________ feet (F) (Maximum trench credit = 9’, or 11' with 312G form)

Constructed trench length = (B) / ((C) x (F)) = ____________ / (_________ x __________) = ____________ / ____________ = ____________ linear feet (G)

DRAWINGS NOT TO SCALE

SHALLOW TRENCH DESIGN

Please note that on a level lot the depth to grade will exceed the 9” minimum backfill.



* NOTE: Although there is no maximum trench depth a maximum of 11 square feet of absorption area is allowable.

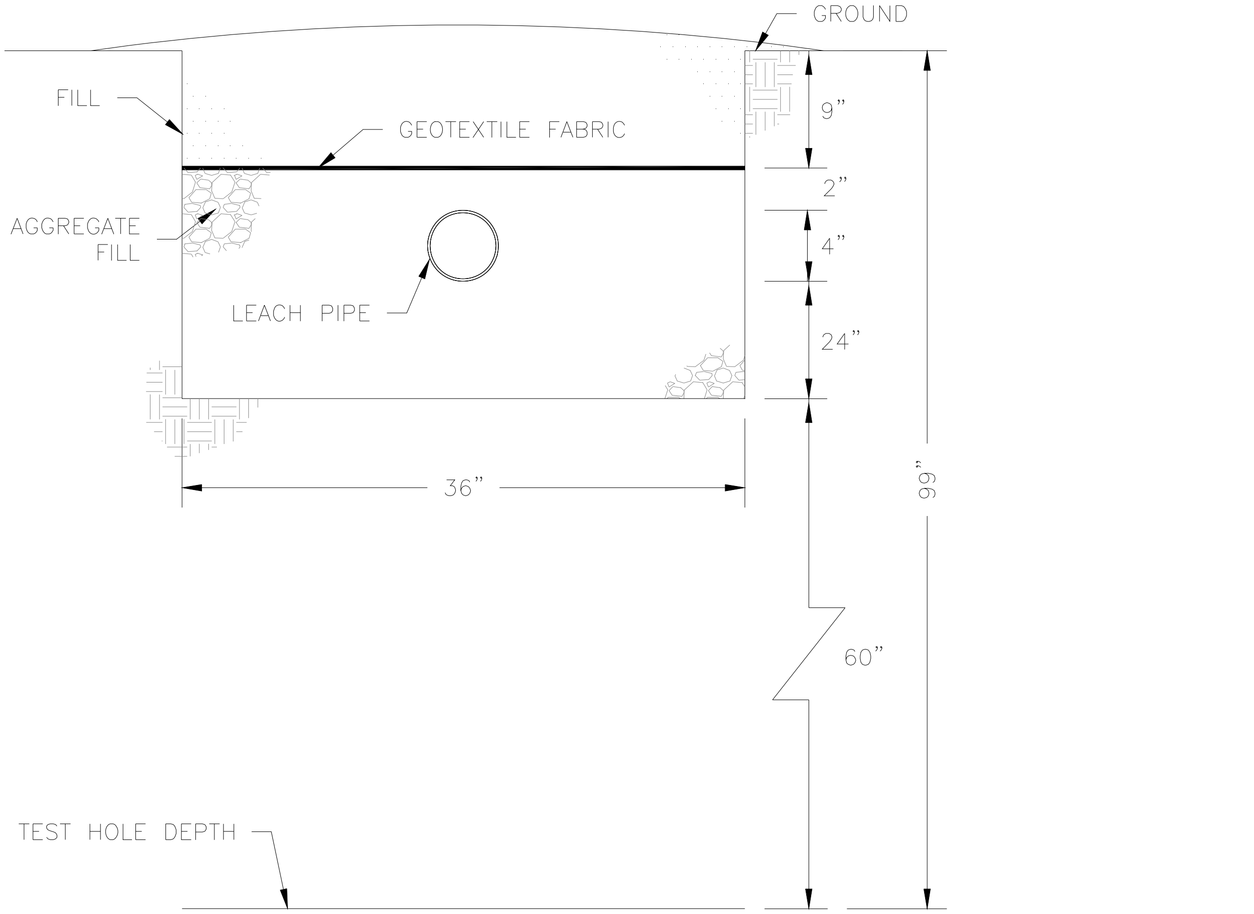
Trenches	Minimum	Maximum
1.Number of Trenches	1 (2 are recommended)	No max
2.Length of trench[1]	---	100 ft
3.Bottom width of trench	12 in	36 in
4.Trench absorption area (sf of absorption area per linear ft of trench)	No min	11 sf
5.Depth of cover over aggregates around pipe	9 in	24 in[2]
6.Thickness of aggregate material over pipe	2 in	2 in
7.Thickness of aggregate material under pipe	12 in	No max
8.Slope of disposal pipe	Level	Level
9.Dispoal pipe diameter	3 in	4 in
10.Spacing of trenches (sidewall to sidewall)	2 times effective depth[3] or five ft, whichever is greater	No max

1. If unequal trench lengths are used, proportional distribution of wastewater is required.
2. For more than 24 inches, Standard Dimensional Ration 35 or equivalent strength pipe is required.
3. The effective depth is the distance between the bottom of the disposal pipe and the bottom of the trench bed.

2.3.2.1 Problem Statement

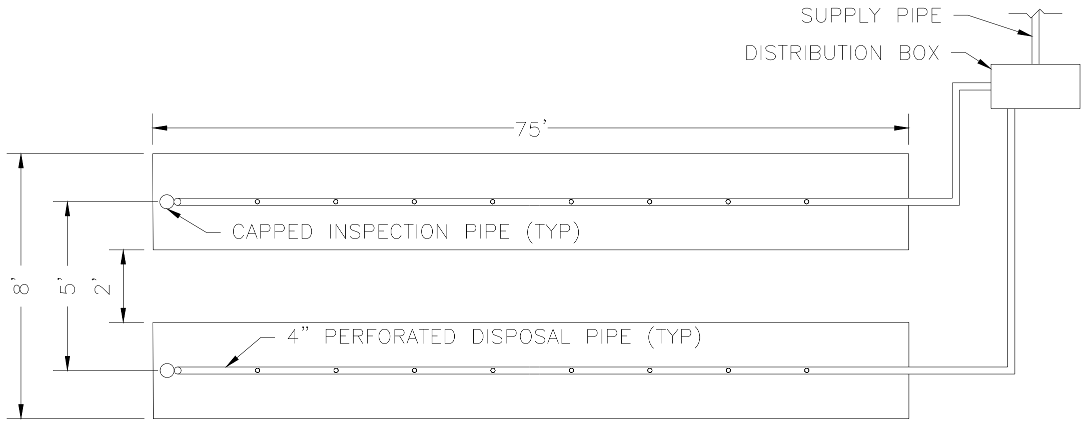
Design a conventional 36 inch wide trench for a single three bedroom family residence. A soil evaluation was done by others and it was determined the soil consisted of a silt loam with moderate structure. Per A.A.C. R18-9-A312.D.2.b this soil type as an application rate of 0.60 gpd/sf. The test hole had a total depth of 87" to bedrock.

<u>A.A.C. R18-9-E302.C.2.c</u>



<u>Conventional Trench Problem Detail</u>

Required Absorption Area	=	Design Flow (gpd)/Soil Application Rate (gpd/sf)		
=	450 gpd (from chart on page 4) / 0.60 gpd/sf		=	750 sf
Trench Absorption Area	=	Width (ft) + (2 * Effective Depth (ft))		
	=	3 ft + (2 * 1 ft)	=	5 ft/lf
Length of Trench	=	Required Absorption Area / Trench Absorption Area		
	=	750 sf / 5 ft/lf	=	150 lf



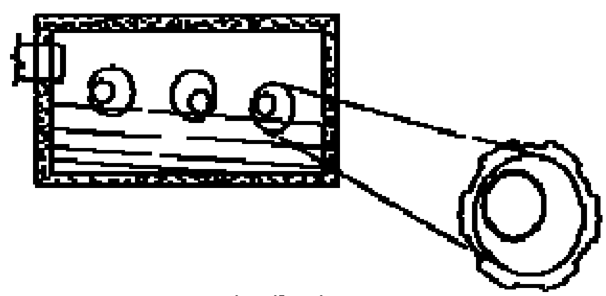
Conventional Trench Plan View

A.A.C. R18-9-E302.C.2.c will not allow trenches to be longer than 100' and trenches should be of equal length, the design will need two trenches 75 feet long, with 5 foot separation between the leach pipe or 2 foot separation between the disposal trenches. The total footprint area is 75 ft * 8 feet which is 600 square feet.

2.3.3 OPERATION & MAINTENANCE

The leach field requires little to no operational maintenance as it is a passive disposal system. It does, however, require periodic inspections. Inspection pipes are typically provided in the design to allow the measurement of the effluent level in the aggregate within a leach trench. The presence of some ponded effluent in the trenches during dosing or for periods particularly in the winter may be considered normal operation. Surfacing of water is not considered normal and corrective measures must be taken immediately if surfacing is observed.

If a distribution box (D-box) is used, it is imperative the D-box is level to assure equal flow to each trench. Several distribution boxes available on the market have the ability to be field leveled. There are also products such as the Dial-A-Flow® which can be used to equalize flow out of distribution boxes.



Distribution Box Cross - Section

Dial-A-Flow®

2.3.4 ADVANTAGES

- According to the U.S. EPA, where site conditions are suitable, subsurface soil absorption is usually the best way to disperse wastewater back into the environment because of its simplicity and low cost.

2.3.5 DISADVANTAGES

- As stated above, gravel is used in conventional disposal fields because it is relatively inexpensive and readily available in most areas, not because it out-performs other materials as treatment or dispersal media.
- If unwashed distribution rock is used, dust or "fines" (very fine particles) can remain in the gravel or can be created with it is installed in the trenches. These fines may clog the drain field infiltrative surface.
- The soil layer at the bottom of the trench may become compacted due to the weight of the gravel and the machinery used to transport and install it. Wastewater may have difficulty percolating through the compacted soil. In addition, as the gravel settles against the soil, it may "mask" or "shadow" a significant percentage of the soil infiltrative surface.

2.3.6 BED

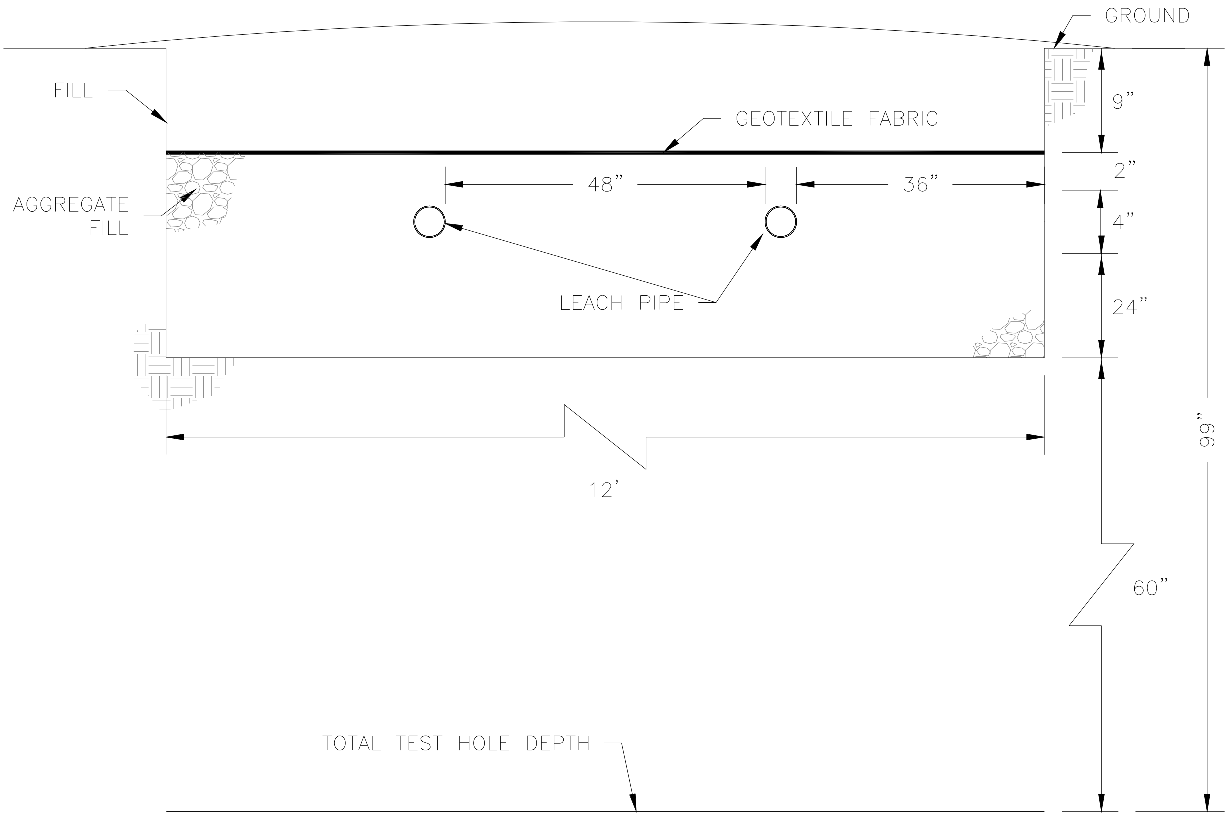
A disposal bed is similar to a disposal trench but multiple pipes are placed in a single excavated area 10 to 12 feet wide and 3 to 5 feet deep. The excavated bed is filed with gravel, the distribution pipe is laid and covered with a semi-permeable barrier like the trench system before buried with topsoil.

2.3.6.1 Problem Statement

Design a Disposal Bed 12 feet wide (to account for pipe diameter) for a single three bedroom family residence. A soil evaluation was done by others and it was determined the soil consisted of a silt loam with moderate structure. Per A.A.C. R18-9-A312.D.2.b this soil type as an application rate of 0.40 gpd.sf. The test hole had a total depth of 87" to bedrock.

Gravity Beds	Minimum	Maximum
Number of distribution pipes	2	—
Length of bed	—	100 feet
Distance between pipes	4 feet	6 feet
Width of bed	10 feet	12 feet
Distance from pipe to sidewall	3 feet	3 feet
Depth of cover over pipe	9 inches	14 inches
Aggregate material under pipe	12 inches	—
Aggregate material over pipe	2 inches	2 inches
Slope of distribution pipe	Level	Level
Distribution pipe diameter	3 inches	4 inches

A.A.C. R18-9-E302.C.3.c



Bed Problem Detail

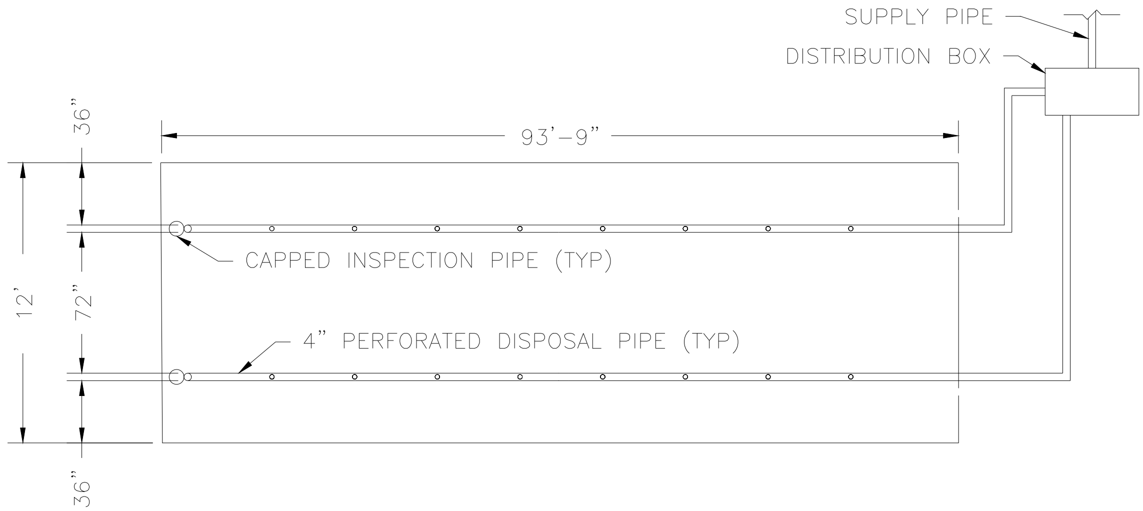
A.A.C. R18-9-A312.D requires a bed to use a more conservative SAR therefore if the SAR was 0.60 gpd/sf for a trench it is only 0.40 gpd/sf for a bed.

Required Absorption Area = Design Flow (gpd)/Soil Application Rate (gpd/sf)
= 450 gpd (from chart on page 4) / 0. 40 gpd/sf = 1125 sf

Bed Length = Minimum Bed Area / Bed Width
= 1125 sf / 12 ft = 93.75 ft

Absorption Area = Bottom Area (Length * Width) + Sidewall [(Width * 2 * Effective Depth) + (Length * 2 * Effective Depth)]
= 93.75 ft * 12 ft + (12 ft * 2 * 1) + (93.75 ft * 2 * 1) = 1336.5 sf

The actual absorption area is 211.5 square feet larger than the minimum absorption area, therefore the bed design is adequate.



Bed Plan View

2.3.7 OPERATION & MAINTENANCE

The bed requires no operation as it is a passive disposal system. It does, however, require periodic inspections. Inspection pipes are typically provided in the design to allow the measurement of the effluent level in the aggregate within a bed. The presence of some ponded effluent during discharge or for periods particularly in the winter may be considered normal operation.

2.3.8 DESIGN CRITERIA

The bed is constructed below grade in a natural or undisturbed soil horizon. Beds are passive, effective and inexpensive treatment systems because the assimilative capacity of many soils can reduce most pollutants found in residential wastewaters.

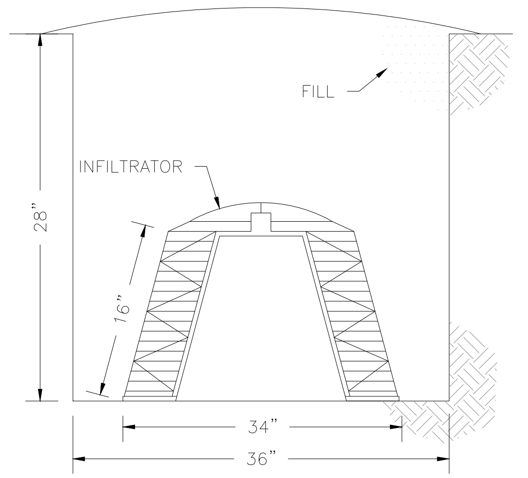
Soil characteristics, lot size, and proximity of sensitive water resources affect the use of conventional trenches.

Arizona statutes only allow the bottom of the bed to provide an infiltrative surface.

2.3.9 CHAMBER SYSTEM

Chamber systems use some material other than gravel or rock in the excavation to provide an infiltrate surface onto which septic tank effluent is distributed along the length of the trench. These systems provide some capacity to store effluent until it can be absorbed into the soil and also to inhibit sand and silt infiltration.

Chamber systems have some advantages over the conventional trench or bed system. Chambers are installed much faster and have increased volume of void space per unit length compared to conventional stone trenches. Soil compaction is reduced since the need to use heavy equipment to haul and place gravel is eliminated. The area required for soil absorption is reduced for when compared to Conventional trenches.



Chamber Trench

Like conventional drain fields, chamber systems can be designed to work on a variety of home sites and under many conditions. Although gravel is a common resource and is usually fairly inexpensive, high quality gravel is not always readily available. In some areas the cost of transportation can raise the cost of the onsite system considerably. In these areas, using the light-weight chambers may be preferable.

Because of the light weight, heavy equipment may not be needed. This can minimize the disruption to the property that machinery can cause. Also, the lighter weight makes it easier to handle which may reduce labor costs and allow systems to be constructed in areas inaccessible to heavy machinery.

Chamber systems may be a good choice in areas that have soils susceptible to "smearing" or other structural damage. Soil structure can be negatively impacted by the weight of the gravel or by construction and heavy machinery on site. Constructing a conventional trench requires several tons of gravel and numerous trips up and down the sides of the trenches with a loader or gravel truck. This can cause the soil around the drain field to compact, reducing its permeability.

Using improperly washed gravel increases the possibility that dust or other fine materials will find its way into the system as gravel is dumped and shoveled. The dust and debris can clog the soil. Fines can be minimized by using chamber systems.

Depending upon the geometry of the conventional trenches (depth and width) credits may be taken during the design of chamber systems that may reduce the size of the disposal field.

2.3.10 DESIGN CRITERIA

The chamber trench is constructed below grade in a natural or undisturbed soil horizon. Chamber trenches are passive, effective and inexpensive treatment systems because the assimilative capacity of many soils can reduce most pollutants found in residential wastewaters.

Soil characteristics, lot size, and proximity of sensitive water resources affect the use of chamber trenches. A.A.C. R18-9-E302.C.4.a allows a reduction in trench size based on the geometries of the actual chambers used.

DESIGN CALCULATIONS FOR CHAMBER TECHNOLOGY

CHAMBER TECHNOLOGY

Chamber manufacturer: ______________________ Chamber type/model: ______________________

Width of the open bottom absorption surface of the chamber = ________________ feet (B)

Vertical height (louver height) of the chamber sidewall = ________________ feet (V)

Length of the chamber = ________________ feet (L)

A = (1.8 x B x L) + (2 x V x L) Absorption area of each chamber =

(1.8 x ____________ x ____________) + (2 x ____________ x ____________) =

(______________) + (*10.38* ______________) = ______________ feet (A)

System design flow = ________________ gallons per day (F)

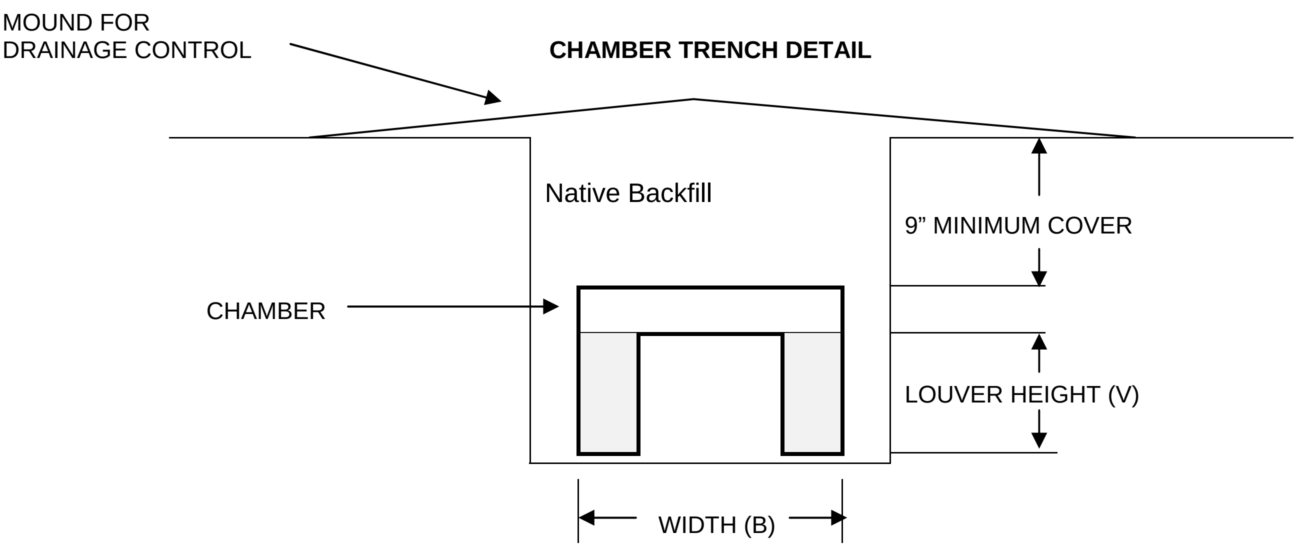
Percolation rate = ____________ SAR value = ____________ gallons per day / ft (G)

(F / G) = ____________ / ____________ = ____________ square feet of leaching area required (S)

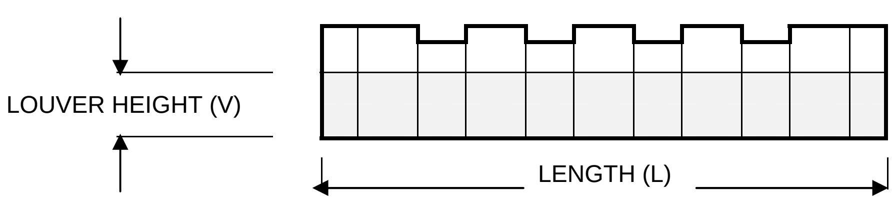
(S / A) = ____________ / ____________ = ____________ total #chambers. (N)

(L x N) = ____________ x ____________ = ____________ linear ft.

CHAMBER TRENCH DETAIL



CHAMBER SIDE VIEW

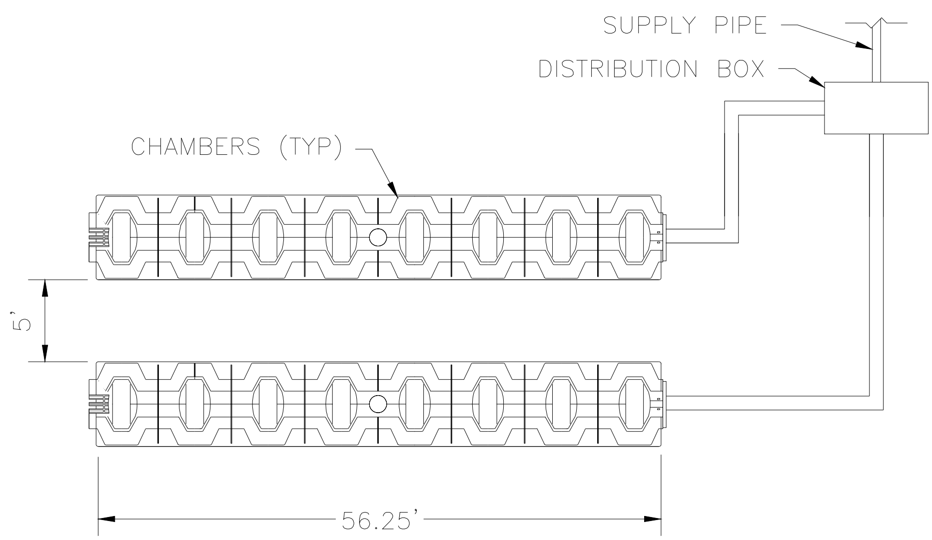


2.3.10.1 Problem Statement

Design a chamber trench for a single three bedroom family residence using Infiltrator® Sidewinder High Capacity Chambers. A soil evaluation was done by others and it was determined the soil consisted of a silt loam with moderate structure. Per A.A.C. R18-9-A312.D.2.b this soil type as an application rate of 0.60 gpd.sf. The test hole had a total depth of 87" to bedrock.

The Infiltrator® Sidewinder High Capacity Chamber is 75inches long, 34 inches wide and 16 inches high. The sidewall louvers are 10 inches high.

Required Absorption Area	=	Design Flow (gpd)/Soil Application Rate (gpd/sf)		
	=	450 gpd (from chart on page 4) / 0.60 gpd/sf	=	750 sf
Chamber Absorption Area	=	(1.8 * Chamber Width * Chamber Length) + (2 * Sidewall Height * Chamber Length)		
	=	(1.8 * 2.8 * 6.25) + (2 * .83 * 6.25)	=	41.9 sf
Number of chambers	=	Required Absorption Area / Chamber Absorption Area		
	=	750 sf / 41.9 ft/Chamber	=	18
Total Length of Trench	=	18 Chambers * 6.25 ft	=	112.5ft



Chamber Trench Plan View

Although the Unified Water Quality Permit Rules do not specify a maximum chamber trench length, for consistency we will have two 56.25 foot trenches, each with 9 chambers.

2.3.11 OPERATION & MAINTENANCE

The chamber trench requires no operation as it is a passive disposal system. It does, however, require periodic inspections. Inspection pipes are typically provided in the design to allow the measurement of the effluent level within each trench. The presence of some ponded effluent in the trenches during dosing or for periods particularly in the winter may be considered normal operation.

3. ALTERNATIVE SYSTEMS

Due to the possibility of high groundwater, poor soil, shallow soil over bedrock or if the disposal field is located at a distance or uphill from the house not all sites are suitable for conventional systems. Approximately two-thirds of the U.S. is estimated to be unsuitable for the installation of conventional septic systems. In such cases, successful wastewater treatment and disposal is possible with a variety of alternative systems.

As with the conventional systems, the objective of the alternative systems is to provide on-site treatment and disposal of wastewater with no adverse impacts on the environment or public health. Because alternative systems are used on sites with marginal soil conditions or other problems the margin of safety is limited, and any failure is likely to be difficult to correct. Due to this, alternative systems should be based on established design criteria and demonstrated success under similar site and soil conditions. To ensure a properly functioning system it is essential that the system be properly constructed, operated and maintained.

3.1 COMPOSTING TOILET SYSTEM (A.A.C. R18-9-E303)

Composting toilets (also known as dry, biological, or waterless toilets) contains and processes excrement, toilet paper, carbon additive and sometimes food wastes. Unlike a septic system, a composting toilet relies on unsaturated conditions where aerobic bacteria break down wastes, just as they do in a yard waste composter. If sized and maintained properly, a composing toilet reduces its original volume by 70 to 90 percent. The end product is a soil-like material called humus. Although the humus is a very stable inert product it must be disposed of properly. Typically this is done by a licensed septage hauler in accordance with state and local regulations. Some areas allow for the disposal of the humus to be tilled into the ground in gardens growing non-edible plants.

3.1.1 WHY USE A COMPOSTING TOILET

The composting toilet is a non-water-carriage system that is well suited, but not limited to, remote areas where water is scarce, or areas with low percolation, high water tables, shallow soil, or rough terrain. The use of composting toilets in place of conventional flush toilets can reduce water use and allow a property owner to install an absorption field 35 to 40 percent smaller than a full-sized one. Some homeowners may simply be water conscious and wish to not waste potable water through toilet flushing.

Composting toilet systems are not flush-and-forget technology. They require a consciousness of what’s put into the toilet, some maintenance and well thought out siting and installation. They will also typically require electricity for operating ventilation fans and heaters.

Some people love composting toilets and others hate them. Usually peoples feelings towards them is based on prior experiences with a particular system. Some systems are just poorly installed. The most common installation mistakes are siting them in cold places, not draining away extra moisture (called leachate), and under-sizing the system. And most importantly, although composting toilet manufactures have come along way with the designs of the toilet itself, many people feel very uncomfortable on anything besides the standard porcelain stool.

Composting toilet systems range from little 7-gallon composters for boats to large aerated two-bin systems that serve more than 100 people daily. There are many different composting toilet designs, but they all have the same typical components:

- A waterless toilet stool or micro-flush toilet.
- A composter to which one or more dry or micro-flush toilets flow.
- A screened air inlet to provide air for the process.
- An exhaust system, often fan-forced, to remove odors, carbon dioxide, and water vapor.
- An access door to remove the end product.

Some systems may also have process controls, such as mixers and a means of draining and managing excess leachate. Some systems use gravity that requires a multistructural footprint.

3.1.2 DESIGN CRITERIA

A composting toilet is a well-ventilated container that provides the optimum environment for unsaturated, but moist, human excrement for biological and physical decomposition under sanitary, controlled aerobic conditions.

The main process variations are continuous or batch composting. Continuous composters are single chambers where excrement is added to the top, and the end product is removed from the bottom. Batch composters are actually two or more composters that are filled and then allowed to cure without the continuous addition of new potentially pathogen-contaminated excrement. Alternating concrete double-bins are the most common batch system.

The composting unit must be constructed to separate the solid fraction from the liquid fraction and produce a stable, humus material with less than 200 MPN per gram of fecal coliform. Once the leachate has been drained or evaporated out of the unit, the moist, unsaturated solids are decomposed by aerobic organisms using molecular oxygen.

Many compost systems have heated compost chambers to provide and maintain optimum temperature requirements for year-round usage.

3.1.3 OPERATION & MAINTENANCE

Operation and maintenance for composting toilet systems requires continuous attention. Composting is carried out by bacteria and fungi. These microorganisms thrive best in a warm, moist well-aerated environment. Composting is most efficient at temperatures of a least 65 F, and up to 135 F. In cold climates, the temperature inside the composter must be monitored to assure it is operating at peak temperature. Microorganisms need 40 to 70 percent moisture content to optimally decompose organics. Composting microorganisms need air. Aeration can be improved by mixing the material, adding wood shavings or popcorn (to create air spaces) and by batching it.

For the composting microbes to fully transform the high nitrogen content of excrement to compost, they need an adequate amount of carbon, about 30 parts of carbon for each part of nitrogen. Good carbon sources are untreated bark mulch, wood shavings, rice hulls, oak leaves, etc. The carbon sources must be added based on the amount of system use.

As with all wastewater treatment systems, management is critical to the efficiency of the system. The level and consistency of the material in the pile must be monitored periodically.

The compost should be removed periodically, anywhere from every three months for a cottage system to every two years for a large central system. Finished humus has the consistency of composted leaves and should smell earthy but not offensive. The humus should be sent to a treatment facility or bury it under at least 12 inches of soil, preferably within the root zones of non-edible plants that can use the nutrients. Many users place the composted material outside to finish composting and add more mulch and yard waste.

If any leachate is drained from the composters it should either be disposed of in a septic tank, removed by a septage hauler, or taken to a treatment plant for further treatment.

3.1.4 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.

Advantages:

- Composting toilet systems do not require water for flushing and thus reduce water consumption.
- These systems reduce the quantity and strength of the wastewater to be disposed of onsite.
- They are well suited for remote sites.
- Composting toilet systems have low power consumption.
- Composting human waste and burying it around tree roots and not edible plants keeps organic wastes productively cycling in the environment.
- Composting toilets systems can often accept kitchen wastes.
- Composting toilet systems divert nutrient and pathogen containing effluent from soil, surface and ground water.

Disadvantages:

- Maintenance of composting toilet systems requires more responsibility and commitment by users and owners than conventional wastewater systems.
- Removing the finished end product is an unpleasant job if the system is not properly installed or maintained.
- Composting toilet systems must be used in conjunction with a graywater system.
- Smaller units may have limited capacity for accepting peak loads.
- Improper maintenance makes cleaning difficult and may lead to health hazards and odor problems.
- Using an inadequately treated end product as a soil amendment may have possible health consequences.
- There may be aesthetic issues because excrement in some systems may be in sight.
- Too much liquid in the composter can disrupt the process if it is not drained and properly managed.
- Most composing systems require a power source.
- Improperly installed or maintained systems can produce odors and unprocessed material.

3.2 LOW-PRESSURE DOSING SYSTEMS (PRESSURE DISTRIBUTION A.A.C. R18-9-E304)

The Low Pressure Dosing System (LPDS) originated in North Carolina and Wisconsin. They were developed as an alternative to conventional soil absorption systems to eliminate problems such as clogging, mechanical sealing of the soil trench during construction, anaerobic conditions due to continuous saturation and high weather table. The LPDS is a shallow pressure-dosed soil absorption system with a network of small diameter perforated pipes placed 10 to 18 inches deep in narrow trenches 12 inches wide

3.2.1 WHY USE A LOW PRESSURE DOSING SYSTEM

In a conventional system effluent discharges from the septic tank in direct response to wastewater entering the tank and flows by gravity through the perforated pipes with in the leach field. Effluent is unevenly distributed within the leach field. It trickles out of the holes nearest the leach field inlet or at points of lowest elevation. Eventually a biological mat forms beneath these areas, and the reduced infiltrative capacity of the biomat forces incoming effluent to seep further down through the trench gravel to an area of fresh soil. Over time, the biomat progresses until the entire leach field is covered and a stabilized slow infiltration rate is attained. Even as this mature state little or no effluent reaches the far end of the perforated pipe. It has been distributed down the trench through the trench's rock or gravel.

Uneven distribution of effluent with the leach field may result in localized overloading of the soil. This may cause insufficient treatment as effluent infiltrates rapidly into soil around the localized distribution points, or an accelerated biomat may cause clogging of the leach field pipes.

Low Pressure Dosing Systems were developed as an alternative to conventional soil absorption systems to eliminate problems mentioned above. The LPDS has the following features that overcome these problems: (1) shallow placement, (2) narrow trenches, (3) continuous trenching, (4) uniform distribution, (5) resting and re-aeration between doses.

3.2.2 PROCESS DESCRIPTION

There are three main components to the LPDS system: (1) a treatment unit such as a septic tank or secondary treatment device, (2) a pump chamber or dosing system, and (3) disposal system consisting of small diameter distribution laterals with small perforations.

3.2.2.1 The Septic Tank

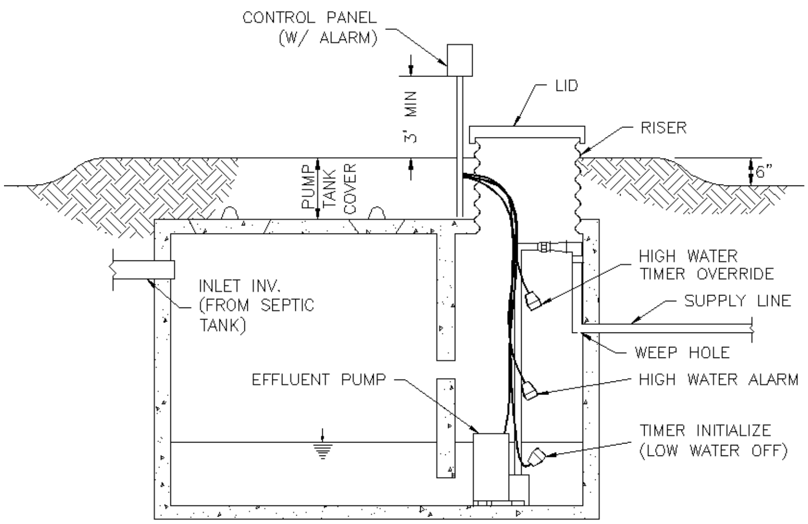
As mentioned in the conventional systems section the septic tank is a large, buried container, typically constructed of concrete, fiberglass or polyethylene. Wastewater from the building being served flows into the tank. Heavy solids, or sludge, settle to the bottom where anaerobic bacterial partially decomposes them. Lighter solids, scum, such as fats, oils and greases rise to the top. The septic tank is design in the same manner as described in previous sections. The clarified effluent from the septic tank flows, by gravity, through an effluent filter and into the pump chamber.

3.2.2.2 The Pump Chamber

The pump chamber is typically a modified septic tank with a pump, pump controls and alarm system. The pump is submerged in the effluent in the pump chamber. When enough water is present to dose the disposal system, a float turns on a programmable timer that turns the pump on until the initial timed dose is complete. The timer not only provides a specific design dose to the distribution laterals it also provides a specific design "resting" period for the disposal field. For example the timer may allow the pump to operate for ten minutes in every four hours, provided there is sufficient effluent in the pump chamber. The "resting" period assures the disposal field has the proper amount of time to allow the previous dose of water to work its way through the subsoil before another dose of water is applied. The pump provides adequate pressure to pass the water through the supply line and to the distribution laterals and orifices in the disposal field.

As mentioned above the pump chamber is also equipped with an alarm. The alarm is activated by a float to warn of pump or system problems. The alarm float is set so that an alarm is activated if the effluent rises above a predetermined level.

In the event of extreme water usage, a timer override float is installed in the tank to force the pump to dose the disposal field in the event the pump tank is about to overflow. This should happen very rarely, and in the event this occurs the homeowner should immediately curtail water usage.



Pump Chamber

3.2.2.3 Disposal System

The pump moves the effluent through the supply line and manifold to the distribution laterals in the trenches under a low pressure (typically five feet of head). These laterals are a network of PVC pipes that have small, drilled perforated holes usually from 1/8 to 1/4 inches in diameter and spaced at three to five feet intervals (exact dimensions are determined for each system).

The laterals are placed in narrow gravel-filled trenches ten to 18 inches deep and spaced five or more feet apart. The narrow (12 inch) trenches allow enough storage volume so that the depth of the effluent does not exceed two or three inches of the total trench depth during each dosing cycle.

3.2.3 DESIGN CRITERIA

Two critical factors that affect the performance of an LPDS are dosing and distribution of the effluent. The dosing and resting periods help maintain aerobic conditions in the soil and around the distribution trench. Uniform distribution cannot be overemphasized in the performance of the system. The effluent must be distributed evenly over the soil absorption field without hydraulically overloading it.

3.2.3.1 Soil Requirements

A LPDS should be located in soils that have suitable or provisionally suitable texture, structure, consistence, depth and permeability. A minimum of 48 inches of usable soil is required between the bottom of the absorption trenches and any underlying restrictive horizons such as bedrock and a minimum of 60 inches is required between the bottom of the absorption trench and the seasonal water table.

3.2.3.2 Space Requirements

The size of the distribution network will depend on the size of the residence it serves and the soil conditions. An area of equal size must also be available for possible future replacement of the system.

3.2.3.3 Topography

There are special design considerations for LPDS located on slopes. If the pumping system is lower than the distribution field the dose must exceed the pipe volume. If the field is lower than the pumping system the system must be designed to ensure that effluent will not leave the pump chamber with the pump turned off. Care must be taken to assure there is no more than a ten percent difference in head between any of the lateral orifices. In colder climates, the system should be designed so effluent does not remain in the supply line or freezing may occur causing clogging or possible pipe rupture.

3.2.4 OPERATION & MAINTENANCE

With a few simple maintenance procedures, a properly designed and installed LPDS will last for several years. This system does have some mechanical equipment that will need care and replacement.

The system is designed to provide treatment and disposal for normal domestic sewage. No non-biodegradable material should be introduced into the wastewater treatment and disposal system. Plastic and paper (except toilet paper) are examples of non-biodegradable materials that should not be placed down the drain. Normal amounts of dirt and small non-biodegradable debris (buttons, dental floss, etc.) from washing will inevitably get into the system. These solids will be retained in the septic tank until it is pumped during its normal maintenance. Oils and grease should not be placed down the drain in excess quantities. Normal washing of greasy dishes is not considered excessive. Routinely draining fat from a frying pan, deep fryer, or roasting pan down the drain would be considered excessive. A garbage disposal may be used on the system but its use should be restricted. A garbage disposal should not be used for the bulk disposal of food preparation waste.

The septic tank as described above retains heavy and light materials and provides anaerobic digestion. Eventually the materials retained in the septic tank will have to be removed. There is a filter on the tank outlet that may require cleaning more often. This is accomplished by simply removing the filter and hosing it off back into the septic tank and re-installing the filter.

The pump chamber should be checked for sludge and scum buildup and pumped as well as the septic tank. The pump and floats should be checked annually and replaced or repaired as necessary. All electrical parts and conduits should be checked for proper operation and corrosion. Follow all of the manufacturer's operation and maintenance instructions. All equipment must be tested and calibrated according to the manufacturers specifications. It is critical that both the septic tank and pump chamber be watertight.

The maintenance required for the disposal field is minimal. To reduce the possibility of failure to the disposal field all surface water and roof drainage should be diverted around the area. As a minimum the laterals should be flushed annually. Also, check the field for the following conditions:

- Spongy (saturated) areas developing or ponding in the absorption area
- Clogging of the distribution system.

If the effluent level in the pump chamber reaches the alarm float, the alarm light and buzzer will activate. The following items should be checked if the alarm activates:

- Check to see if a circuit breaker has been tripped or a fuse is blown. The pump should have a separate circuit with its own breaker or fuse. If the pump is on a circuit with other equipment, that equipment can trip the breaker.
- If the electrical connections are the plug-in type check to see if a pump or float switch has come unplugged and make sure the switch and pump plugs are making good contact in their outlets.
- The floats or other parts in the pump chamber such as the electrical power cord or lifting rope can become tangled. Make sure the floats can operate freely in the pump chamber.
- Be sure the floats or support cables are clean of debris that could limit the mobility of the float switches.

Make sure to turn off the power supply at the circuit breaker and unplug all power cords before handling the pump or floats. Do not enter the pump chamber. Accumulated gases inside the chamber are poisonous and displace air causing a lack of oxygen. Both of these conditions can be fatal. Most alarms are equipped with a silence button located on the control panel. By using water conservatively the reserve storage in the pump chamber should allow enough time to correct the problem.

3.2.5 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.
Advantages:

- Shallow placement of trenches in LPDS installations promotes evapotranspiration and enhances growth of aerobic bacteria.
- Absorption fields can be located on sloping ground or on uneven terrain.
- Improved distribution through pressurized laterals disperses the effluent uniformly throughout the entire leach field area.
- Periodic dosing and resting cycles enhance and encourage aerobic conditions in the soil.

- Shallow, narrow trenches reduce site disturbances and thereby minimize soil compaction and loss of permeability.
- LPDS systems allow placement of the leach field area upslope of the building being served.
- LPDS systems overcome the problem of peak flows associated with gravity-fed systems.

Disadvantages:

- Small orifices have an increased potential for clogging by solids.
- Need for electricity and mechanical equipment (in some circumstances siphons can be used in place of pumps).
- Increased monitoring and maintenance is required.
- Orifice sizing and spacing is critical especially in areas with steep topography.
- 10% increase in soils application rate

3.3 GRAVELLESS TRENCH (A.A.C. R18-9-E305)

A gravelless system uses alternative materials, such as rubber, sand, fiber membrane, plastic, glass or expanded clay, shale or polystyrene foam chips in place of gravel. The alternative materials function similarly to gravel. They can support the sidewalls of the trenches and prop up the perforated leach pipe so they do not lie directly on the soil and clog. When the soil is saturated from weather or excessive wastewater loads, the effluent can be stored in the media until the soil absorbs it. Like gravel, the media helps to distribute the wastewater along the length of the trenches.

Gravelless systems may take several forms, including open-bottomed chambers, fabric-wrapped pipe, and synthetic materials such as expanded polystryrene foam chips. Many of these types of drain fields are located throughout different sections of Arizona's Unified Water Quality Permit Rules (i.e. A.A.C. R18-9-E302 and E309). The gravelless system defined by A.A.C. R18-9-E305 is a large-diameter corrugated plastic pipe covered with a permeable nylon filter fabric instead of gravel or rock. The area of fabric in contact with the soil provides the surface for the effluent to infiltrate the soil. The pipe is 8 or 10 inches in diameter and is placed in a 12 to 24 inch wide trench. These systems can be installed in hand-dug trenches where conventional gravel systems would not be possible.

3.3.1 WHY USE GRAVELLESS TRENCH'S.

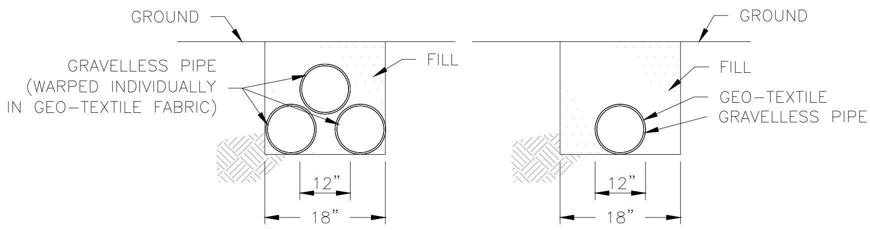
Like conventional drain fields, gravelless systems can be designed to work on a variety of home sites and under many conditions. Although gravel is a common resource and is usually fairly inexpensive, high quality gravel is not always readily available. In some areas the cost of transportation can raise the cost of the onsite system considerably. In these areas, using the light-weight alternative may be preferable.

Because of the light weight, heavy equipment may not be needed. This can minimize the disruption to the property that machinery can cause. Also, the lighter weight makes it easier to handle which may reduce labor costs and allow systems to be constructed in areas inaccessible to heavy machinery.

Gravelless systems may be a good choice in areas that have soils susceptible to "smearing" or other structural damage. Soil structure can be negatively impacted by the weight of the gravel or by construction and heavy machinery on site. Constructing a conventional trench requires several tons of gravel and numerous trips up and down the sides of the trenches with a loader or gravel truck. This can cause the soil around the drain field to compact, reducing its permeability.

As stated previously, using improperly washed gravel increases the possibility that dust or other fine materials will find its way into the system as gravel is dumped and shoveled. The dust and debris can clog the soil. Fines can be minimized by using gravelless media.

Depending upon the geometry of the conventional trenches (depth and width) credits may be taken during the design of gravelless systems that may reduce the size of the disposal field.



<u>Gravelless Trench</u>

3.3.2 DESIGN CRITERIA

The gravelless trench consists of an 8 or 10 inch perforated pipe surrounded by a geo-textile fabric. The fabric provides a substrate for bio-mat development and biological treatment. The pad is porous and allows good circulation of effluent and air to support aerobic biological growth.

3.3.2.1 Hydraulic Loading

The hydraulic loading is based on the area of the geo-textile fabric. Multiple pipes (up to 3) may be used to further reduce the trench length.

3.3.2.2 Problem Statement

Design a gravelless trench using a single pipe, bundle of two pipes and bundle of three pipes for a single three bedroom family residence using ADS SB2® Gravelless Pipe. A soil evaluation was done by others and it was determined the soil consisted of a silt loam with moderate structure. Per A.A.C. R18-9-A312.D.2.b this soil type as an application rate of 0.60 gpd.sf. The test hole had a total depth of 87" to bedrock.

The ADS SB2® Gravelless Pipe is 10 inches in diameter.

Required Absorption Area	=	Design Flow (gpd)/Soil Application Rate (gpd/sf)		
	=	450 gpd (from chart on page 4) / 0.60 gpd/sf	=	750 sf
Absorption Area	=	for 10 inch diameter pipe, 3 sf of absorption area is allowed per linear foot (A.A.C. R18-9-E305.D.2.b). For bundles of three pipes, the absorption are is 2 times the absorption area of a single pipe (A.A.C. R18-9-E305.D.2.d).		
Total Length of Trench				
Single Pipe	=	750 sf / 3 sf/lf	=	250 ft
2 pipes	=	750 sf / (2 sf/lf * 1.67)	=	225 ft
3 Pipes		750 sf / (3 sf/lf * 2)	=	125 ft.

As can be seen above a single gravelless pipe will require 250 ft of trench, which would amount to 3 trenches 84 feet long with an area of approximately 588 square feet (the trenches can be as narrow as 12 inches). Two or three pipes will require 24 inch trenches. Two pipes will require three trenches at 75 feet long for a total area of 750 square feet. Three pipes will required two trenches at 63 feet long for a total area of 378 square feet.

3.3.3 OPERATION & MAINTENANCE

The gravelless trench requires no operation as it is a passive disposal system. It does, however, require periodic inspections. Inspection pipes are typically provided in the design to allow the measurement of the effluent level within each trench. The presence of some ponded effluent in the trenches during dosing or for periods particularly in the winter may be considered normal operation.

3.3.4 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.

Advantages:

- May be less expensive than gravel or rock if gravel or rock is not readily available in the immediate vicinity of the system.
- Due to the light weight structural damage to soils is reduced; the need for heavy equipment is not necessary; cost of construction may be minimized.
- Minimizes the possibility of fines from rock clogging the infiltrative surface of the trenches.
- May decrease the size of the required trenches.

Disadvantages

- If rock and gravel is readily available the use of gravelless systems may be cost prohibitive.

3.4 EVAPOTRANSPIRATION SYSTEMS (A.A.C. R18-9-E306 & E307)

Evapotranspiration (ET) is a method of onsite wastewater treatment and disposal that offers an alternative to conventional soil absorption systems for sites where protection of the surface water and groundwater is essential. An ET system is unique in its ability to dispose of wastewater into the atmosphere through evaporation from the soil surface and/or transpiration by plants, without necessarily discharging it to the surface water or groundwater reservoir. However, in certain cases, the ET concept also offers flexibility by combining seepage with evaporation as and alternative option.

3.4.1 WHY USE AN EVAPOTRANSPIRATION SYSTEM.

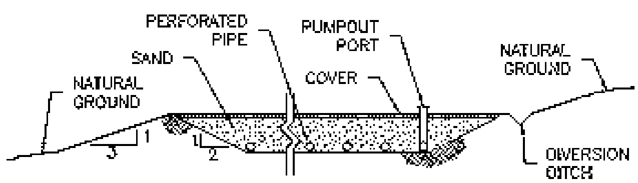
An ET system is a feasible option in semi-arid climates and locations where the annual evaporation rate exceeds the annual rate of precipitation and wastewater applied. The ET System can eliminate all or most of the effluent from being discharged into an environment with limitations on nitrogen discharges or impervious soils.

3.4.2 PROCESS DESCRIPTION

Evapotranspiration is the net water loss caused by the evaporation of moisture from the soil surface and transpiration by vegetation. For continuous evaporation, three conditions must be met. (1) There is a latent heat requirement of approximately 590 cal/g of water evaporated at 15 C, (2) A vapor pressure gradient is needed between the evaporative surface and the atmosphere to remove vapor by diffusion, convection, or a combination of the two, (3) There must be a continuous supply of water to the evaporative surface.

Evapotranspiration is also influenced by vegetation of the disposal field. Theoretically, evapotranspiration can remove high volumes of effluent in the late spring, summer and early fall, especially if good transpiring vegetation is used.

There are three main types of evapotranspiration systems; (1) evapotranspiration (ET), (2) evapotranspiration/absorption (ETA) and mechanical.



Evapotranspiration Bed

3.4.2.1 Evapotranspiration (ET)

The ET system is the most commonly used evapotranspiration system used. The main components are (1) a treatment unit, usually a septic tank and (2) an ET bed with wastewater distribution piping, a bed liner (unless the soils are determined to be impermeable), fill material, monitoring wells, overflow protection and a surface cover. Vegetation has to be planted on the surface of the bed to enhance the transpiration process.

The clarified effluent from the septic tank flows into the lower portion of a sealed ET bed that has a continuous impermeable liner (or dense impermeable subsoils) and carefully selected sands. Capillary action in the fine sand causes the wastewater to rise to the surface and escape through evaporation as water vapor. In addition, vegetation transports the wastewater from the root zone to the leaves, where it is transpired as a relatively clean condensate. This design allows for complete wastewater evaporation and transpiration with no discharge to nearby soil.

3.4.2.2 Evapotranspiration/Absorption (ETA)

The second type of evapotranspiration system is known as an evapotranspiration/absorption (ETA), which is an unsealed bed where evaporation and transpiration are the primary means of disposal, but percolation is also used. This design provides discharge to both the atmosphere and subsurface.

3.4.2.3 Mechanical

The third type of evapotranspiration system is the use of mechanical devises. There are two types of mechanical evaporation systems. The first is a rotating disk mechanical evaporation unit. The disks rotate slowly so that the moisture on their wetted surfaces can evaporate into the air moving over the unit.

The second type is a concentric cylinder unit where forced air enters at the center of the cylinder and moves outward through wetted cloth wraps and is discharged as vapor.

Mechanical systems use a very small amount of electricity and require a minimal amount of maintenance.

3.4.3 DESIGN CRITERIA

3.4.3.1 Hydraulic Loading

Accurate estimates (daily, weekly and monthly) of flow rates must be calculated as part of the design process to prevent overloading problems associated with under-sizing or over-sizing a system. A water budget should be completed which shows that the ET bed will not saturate to grade nor have a saturated level higher than the capillary rise of the soil. The design flow rate should include a factor of safety to account for peak flows or future increased site use.

3.4.3.2 Area

The use of the ET system can be constrained by limited land availability and site topography. For year-round, single-family homes, ET systems generally require about 4,000 to 6,000 square feet of available land.

3.4.3.3 Topography

Slopes greater than 15% can be used if terracing, serial distribution, and other necessary design features are incorporated.

3.4.3.4 Climate

The most important performance consideration of any ET system is the rate of evaporation. This is largely affected by climatic conditions such as precipitation, wind speed, humidity, solar radiation and temperature. Since these factors continually change from time to time, evaporation rates will also vary significantly, which must be considered in the design.

Although most of the precipitation will be absorbed into the ET bed, hydraulic overloading could occur if more water enters the system than is evaporated. Provisions for long-term storage of excess water can be expensive. Therefore the evaporation rate must exceed the precipitation rate, which makes and ET system suitable for areas of relatively low rainfall. For ETA systems, the climate requirements are not as well defined, although the soils must be able to accept all of the influent wastewater if net evaporation is zero for any long period of time.

3.4.3.5 Capillary Rise

The sand in the ET bed must be fine enough to draw up water from the saturated zone to the surface by capillary action. The potential for capillary rising must be slightly more than the depth of the bed. However, the sand should not be too fine or the bed can be clogged by solids from the wastewater. The capillary rise of the chosen material must be known to justify the design. Typical acceptable materials have a capillary rise between 18 and 36 inches.

3.4.3.6 Cover & Vegetation

The vegetation that is used in an ET system must be able to handle the varying depths of free water surface's in the bed. Grasses, alfalfa, broad-leaf trees, and evergreens are some of the vegetation used in ET beds that have been known to increase the average annual evaporation rate from the ET bed to a rate higher than that for bare soil. Grasses and alfalfa also result in nearly identical or reduced evaporation rates as compared to bare soil in the winter and the spring when evaporation rates are normally at a minimum. Similarly, topsoil has been shown to reduce evaporation rates. Some evergreen shrubs have resulted in slightly higher evaporation rates than bare soil throughout the year. Water seekers with hair roots, such as berries, are not recommended because the distribution pipes could become clogged. Dark gravel or rock (typically volcanic cinder) has been used instead of vegetation in some applications. The dark colored rock absorbs heat and accelerates evaporation.

3.4.3.7 Soil Permeability (for ETA only)

Soil permeability affects the performance of ETA beds that involve seepage into the soil in addition to evaporation. A portion of pretreated wastewater is absorbed and treated by the soil. Generally, the wastewater must travel through 2 to 4 feet of unsaturated soil for adequate treatment before reaching the groundwater. Since the effluent in an ETA bed is considered equivalent to the discharge form the pretreatment unit the minimum vertical separation required is dependent upon the degree of pretreatment included in the complete system.

ADEQ rules require the designer to provide water mass balance calculations with the Notice of Intent to Discharge. The water mass balance calculation must show that the system functions during the winter months. The average minimum temperature must be above 20° F. No more than 1/3 of the annual precipitation may fall in a 30-day period. This technical memo provides guidance to the designer on a method to meet those requirements. There are other methods, formats and presentations that will meet the requirements of rule and will be acceptable to CCHD.

The water mass balance must show the monthly evaporation, precipitation, effluent loading for one year in suitable units. (Units must be carefully and consistently calculated and applied.) The source for that data must be provided along with a justification for any adjustment. Those values must then be used to calculate the depth of effluent in the ET Bed each month of the year. The ET Bed must dispose of all effluent every month of the year.

The value for the average daily minimum temperature must be provided for each month in the year. The source for that data must be provided along with a justification for any adjustment. The value for the average daily maximum temperature should be provided for each month in the year.

The ET bed is designed on a monthly basis therefore a monthly average flow is appropriate for design purposes. (All other systems, including the septic tank serving the ET Bed, are designed on a daily basis therefore the daily maximum flow is the appropriate design flow value.) ADHS Engineering Bulletin 11, "Minimum Requirements for Design, Submission of Plans and Specifications of Sewage Works" indicates a ratio of 2:1 between the maximum and average flow is appropriate. The designer must submit an A312G form for any adjustment of the design flow including the one proposed in this paragraph.

The reduction for grey water, as a percentage, established in rule and technical memo may be applied to the monthly average flow calculated above. Refer to those documents for the values and conditions on their use.

Attached is a sample calculation of the water mass balance. (The spreadsheet was prepared by Engineering and Environmental Consultants, Inc. for their internal use only. It is not available from CCHD. It is used solely to provide a sample output format.)

EVAPOTRANSPIRATION BED DESIGN CALCULATIONS

ET Bed Data:

Length, at surface:	120.00	ft		
Width, at surface:	50.00	ft		
Depth of Sand:	3.00	ft		
Area, at surface =			6,000.	sf
Void Ratio in Sand:	0.30	: 1		
Seepage Loss:	0.0000	gpd/sf	0	gpd/acr

Weather Data:

Evaporation Level (Average, Minimum, or Maximum):	Averag

Effluent Loading:

Actual Number of Bedrooms:	3		
Design Number of Bedrooms:	4		
Daily Design Flow @ 150 gpd/bedroom =		600	gpd
Daily Max. / Monthly Ave.:	2.00		
Monthly Average Flow =		300	gpd
Adjustment for Graywater:	1.00		
ET Bed Design Flow =		300	gpd
Effective Application Rate =		0.050	gpdpsf

Month	Evapor-ation (in)	Precipi-tation (in)	Seepage (in)	Effluent (in)	Liquid Change (in)	Liquid Depth (in)
Initial Estimate of Depth at End of December:						11.41
January	1.76	2.05	0.00	2.49	2.78	20.66

February	2.48	1.76	0.00	2.25	1.53	25.75
March	4.00	1.91	0.00	2.49	0.40	27.07
April	5.28	1.07	0.00	2.41	(1.8	21.06
May	7.20	0.57	0.00	2.49	(4.1	7.25
June	7.92	0.51	0.00	2.41	(5.0	0.00
July	7.92	1.90	0.00	2.49	(3.5	0.00
August	7.20	2.08	0.00	2.49	(2.6	0.00
September	5.52	1.48	0.00	2.41	(1.6	0.00
October	4.24	1.49	0.00	2.49	(0.2	0.00
November	2.64	1.41	0.00	2.41	1.18	3.92
December	1.76	1.52	0.00	2.49	2.25	11.41
Annual	57.92	17.75	---	---		
					Mini	0.00
					Max	27.07

Initial Estimate of Depth at End of December within 1%? YES
Maximum Depth does not exceed Basin Depth? YES

NOTES:

1. Designer shall confirm compliance with the applicable requirements. This spread sheet is
2. The ET Bed is assumed to have vertical sides for the purpose of this model.
3. Refer to the Weather Spreadsheet for details on evaporation, precipitation, and temperature
4. "Liquid Depth" is the depth of liquid in the sand medium with the specified void ratio.

BASIC WEATHER DATA: Location: Sedona

Month	Evaporation				Precipitation (in.)		Temperature	
	Average (in.)	Minimum (in.)	Maximum (in.)				Minimum (°F)	Maximum (°F)
January	2.20	1.53	3.35		2.05		29.1	54.8
February	3.10	1.95	4.16		1.76		31.6	59.6
March	5.00	3.20	6.60		1.91		34.5	64.0
April	6.60	4.37	8.37		1.07		40.7	72.7
May	9.00	6.29	10.84		0.57		47.5	81.2
June	9.90	7.54	11.41		0.51		56.3	92.2
July	9.90	7.98	14.43		1.90		63.9	96.1
August	9.00	6.20	10.68		2.08		62.4	93.3
September	6.90	4.16	8.60		1.48		57.1	88.8
October	5.30	3.10	7.00		1.49		47.4	78.1
November	3.30	1.84	4.70		1.41		36.3	65.3
December	2.20	1.60	3.20		1.52		29.7	56.3
Annual	72.4	49.76	93.34		17.75			
						Minimu	29.1	54.8
						Maximu	63.9	96.1

WEATHER INPUT DATA:

Evaporation Adjustment:	0.800
Precipitation Adjustment:	1.000
Temperature Adjustment:	1.000

PROJECT WEATHER DATA:

Month	Evaporation				Precipitation (in.)		Temperature	
	Average (in.)	Minimum (in.)	Maximum (in.)				Minimum (°F)	Maximum (°F)
January	1.76	1.22	2.68		2.05		29.1	54.8
February	2.48	1.56	3.33		1.76		31.6	59.6
March	4.00	2.56	5.28		1.91		34.5	64.0
April	5.28	3.50	6.69		1.07		40.7	72.7
May	7.20	5.03	8.67		0.57		47.5	81.2
June	7.92	6.03	9.13		0.51		56.3	92.2
July	7.92	6.38	11.55		1.90		63.9	96.1
August	7.20	4.96	8.55		2.08		62.4	93.3
September	5.52	3.33	6.88		1.48		57.1	88.8
October	4.24	2.48	5.60		1.49		47.4	78.1
November	2.64	1.48	3.76		1.41		36.3	65.3
December	1.76	1.28	2.56		1.52		29.7	56.3
Annual	57.92	39.81	74.67		17.75			
						Minimu	29.1	54.8
						Maximu	29.7	56.3

WEATHER DATA NOTES:

1. Precipitation: Arizona Climate, 1985, U of A.
2. Temperature: Arizona Climate, 1985, U of A.
3. Evaporation: Cooperative Extension Service, U of A & USDA "Evaporation from

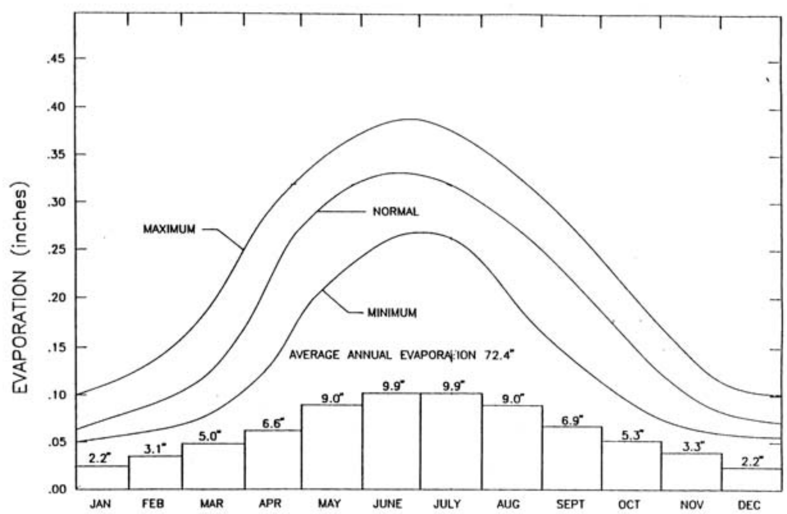
Open Water Surfaces in Arizona", 1970.

4. Precipitation and Temperature Adjustment is used to match data location to project location.
5. Evaporation Adjustment is based on the state map for the data.

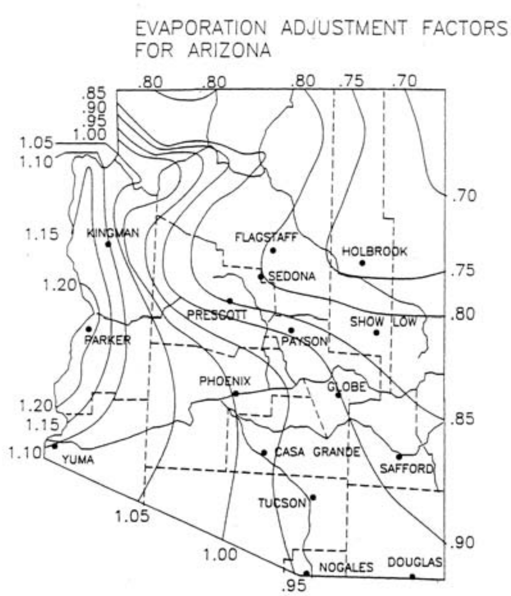
Evaporation from Open Water Surfaces in Arizona

NOTES:

1. These figures were copied from ADEQ Engineering Bulletin 12, Minimum Requirements for the Design and Installation of Septic Tank Systems and Alternative On-site Disposal Systems", dated June 1989. This document is no longer a current regulatory document.
2. These figures were originally from "Evaporation from Open Water Surfaces in Arizona", Folder 159, by The Agricultural Experiment Station and the cooperative Extension Service, The University of Arizona, 1970.
3. They have been used as a conservative determination of Evapotranspiration from onsite wastewater systems. Other methods may be equally appropriate for design purposes.



MAXIMUM, NORMAL AND MINIMUM DAILY EVAPORATION AND AVERAGE MONTHLY EVAPORATION FROM OPEN WATER SURFACES (Adjustment Factor = 1.00)

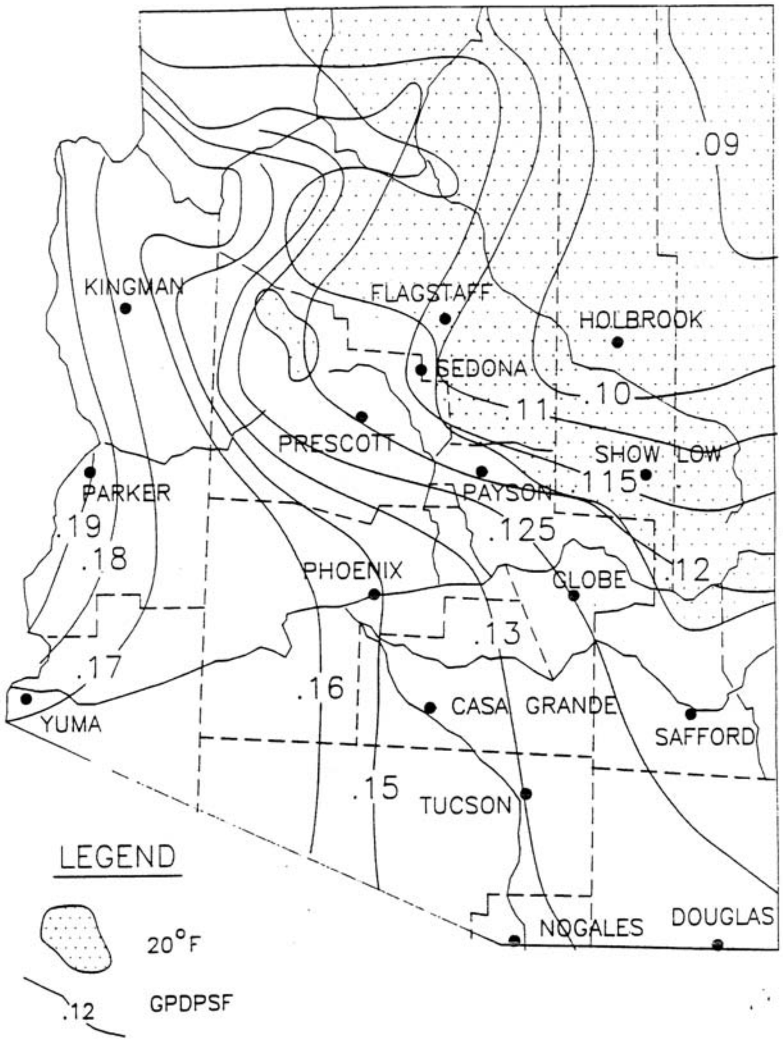


Evaporation Bed Application Criteria

NOTES:

1. This figure was copied from ADEQ Engineering Bulletin 12, Minimum Requirements for the Design and Installation of Septic Tank Systems and Alternative On-site Disposal Systems", dated June 1989. This document is no longer a current regulatory document.
2. It was used for sizing ET Beds from 1989 to 2001 and is provided for information purposes only. A water balance as required by current ADEQ rule will indicate that an ET Bed designed using this figure will fail at design loadings.

EVAPOTRANSPIRATION BED
APPLICATION CRITERIA



3.4.4 OPERATION & MAINTENANCE

Regular operation and maintenance for ET and ETA systems is usually minimal, mostly involving typical yard up-keep such as trimming the vegetation. Storm water diversion features such as swales/berms may need upkeep and repair from accumulated sediment or damage caused by prairie dogs or gophers. The septic tank is used for pretreatment it should be maintained as indicated in previous sections. The following is a list of recommended operational practices:

- Ensure all storm-water is diverted around the system.
- Use only high transpiration plants that are suitable for wetness at ground level.

If an ET or ETA system is properly installed on a suitable site, scheduled maintenance should rarely be needed except in cases of poor operating practices such as irregular septic tank pumping or large storm events.

3.4.5 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.

Advantages:

- ET systems may overcome site, soil, and geological limitations or physical constraints of land that prevent the use of subsurface wastewater disposal methods.
- The risk of groundwater contamination is reduced with ET systems that have impermeable liners.
- ET systems can be used to supplement soil absorption for sites with slowly permeable, shallow soils with high water tables.
- ET systems could be used for seasonal application, especially for summer homes, parks or recreational parks in areas with high evaporation and transpiration rates.
- Reductions in horizontal and vertical setbacks are permitted.
- There is no need for a reserve area.

Disadvantages

- ET systems are governed by climatic conditions such as precipitation, wind speed, humidity, solar radiation, and temperature.
- ET systems are not suitable in areas where the land is limited or where the topography is irregular.
- They have a limited storage capacity, and are thereby unable to store much winter wastewater for evaporation in the summer.
- There is a potential for overloading from infiltration and precipitation.
- Care must be taken to assure the liner is not torn during construction.
- ET systems are generally limited to sites where evaporation exceeds annual rainfall by at least 24 inches.
- Transpiration and evaporation can be reduced during the winter when the vegetation is dormant.

3.5 WISCONSIN MOUND (A.A.C. R18-9-E308)

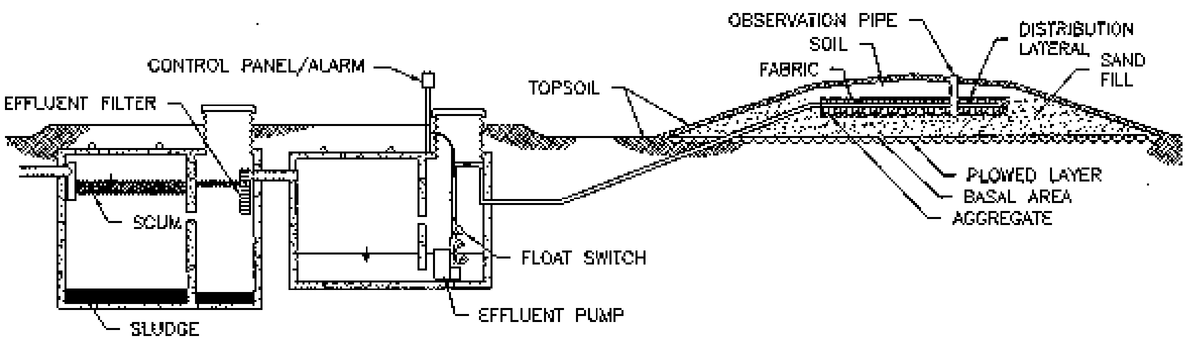
The mound system was originally developed by the North Dakota Agricultural College in the 1940's and was known as the Nodak Disposal System. In 1976, the small scale Waste Management Project at the University of Wisconsin began a study of mound systems. In 1979, the project issued a design manual describing site conditions and design criteria for mounds. Ongoing research and monitoring of mounds has lead to further refinement of the siting and design criteria. In 1990 an updated mound manual was released. There is also a 2000 Mound Manual but current Arizona rules do not recognized the 2000 manual).

3.5.1 WHY USE A WISCONSIN MOUND

Mounds were developed to overcome three conditions: (1) slow or fast permeable soils, (2) shallow soil cover over creviced or porous bedrock, and (3) a high water table. A site that has any one, or a combination of, these conditions is not suited for a conventional system. Because acceptable soil conditions are not always found below the surface, the mound allows the conditions to be created above the surface.

3.5.2 PROCESS DESCRIPTION

There are three main components to the mound system: (1) a treatment unit such as a septic tank or secondary treatment device, (2) a pump chamber or dosing system, and (3) the mound disposal system.



Typical Mound System

3.5.2.1 The Septic Tank or Secondary Treatment Device.

The objective of the conventional septic tank or secondary treatment unit is to remove pollutants such as BOD and Suspended solids prior to discharge to the mound. BOD can cause in increase in the biomat that could ultimately lead to the sand media in mound to clog. The solids could fill void spaces in the media and also cause the mound to clog.

3.5.2.2 The Pump Chamber

The pump chamber operates exactly as mentioned above in the Low Pressure Dosing System.

3.5.2.3 The Mound

The mound is a leach field that is raised above the natural soil surface. The mound is composed of a sand fill that has a gravel-filled bed and a network of small diameter pipes called the distribution system.

From the pump chamber, effluent is pumped through the pipes in controlled pressure doses so that uniform distribution is achieved throughout the bed. The effluent comes out of the pipes through small orifices and flows downward through the gravel bed and into the sand. Treatment occurs as the effluent moves through the sand and returns to the natural soil.

3.5.3 DESIGN CRITERIA

Two factors that determine the size and configuration of a mound are how the effluent moves away and the rate at which it moves away from the system. The prediction of the movement and rate of movement is done from the soil and site information obtained from test hole observations and percolation tests.

A suitable depth of soil is required to treat the effluent before it reaches the limiting condition, such as bedrock, a high water table, or a slowly permeable soil layer. The vertical separation distances between limiting layers varies, but typically ranges between one to four feet depending upon the amount of pretreatment.

Mound absorptions systems should be long and narrow and should follow the contour. The more restrictive the site, the narrower and longer the system should be.

A high water table is determined by direct observation and interpretation of soil mottling or other criteria. The bedrock should be classified as crevice, non-crevice semi-permeable, or non-crevice impermeable. This will help determine the depth of the sand media required.

Loading rates should be based on soil texture, structure and consistence, with the percolation test used to confirm the soil analyses. However, at this time percolation tests are used in Arizona to estimate the soil permeability by relating an empirical loading rate to the percolation rate.

Mounds can be constructed on sites with slopes up to 25%. The slope limitation is primarily for construction safety, because it is difficult to operate equipment on steep slopes. Furthermore, more fill material is needed for steeper slopes, which significantly affects the cost of the system.

Mounds have increased setbacks of 30' slowlsope from the toe of the mound to property lines, drives, etc…

Mounds should not be constructed in flood plains, drainage ways, or depressions unless flood protection is provided. Another siting consideration is maintaining horizontal separation distances from wells, surface waters, springs, dry washes, road cuts, buildings and property lines.

The selection of the sand fill material is critical to the performance of the mound. Suitable sand is one that can be loaded at a reasonable rate and adequately treat the effluent. The sand should contain 20 percent or less material greater than 2.0 mm and 5 percent or less material finer than 0.053 mm. It should also have a size distribution that meets ASTMC-33 specifications.

For residential mounds, the daily wastewater volume is usually determined by the number of bedrooms in the house. Flows in Arizona for individual homes are up to 150 gallons per day (gpd) per bedroom. Mounds that are treating effluent with higher strength wastes have different criteria, possibly including pretreatment.

3.5.3.1 Landscaping

There are several things that can be done to help protect the mound and make it ascetically appealing at the same time. The right vegetation cover helps limit erosion from the mound and make it more attractive. However, the wrong cover can do irreparable damage to the mound. Do not plant trees, shrubs, or any plant with an extensive root system on the mound. The roots will interfere and possibly destroy the distribution system. The mound can be outlined with trees or shrubs, but they should be at least 20 feet away. Also, avoid planting vegetables or herbs on the mound.

The best things to plant on the mound are low-maintenance grasses, such as a mixture of creeping red, hard and sheep's fescues, and perennial flowers such as daylilies and peonies. Because the mound will tend to dry on top, plant grasses and other ground cover that are resistant to water stress there. Cool season grasses and other plants may be planted on the sides of the mound

Use minimal tilling when planting and establish a cover as quickly as possible to limit erosion. The topsoil on the mound should be at least six inches, but no more than 30 inches deep. Keep traffic on the mound to a minimum, if you plant a lawn, plan to mow it only two or three times a year. If you have pets or children, you may need to erect a fence around the area. Do not irrigate or water the mound once you have vegetation on it.

The actual shape of the mound may be changed somewhat to suit individual landscaping and site needs. Constructing a contoured mound works well for hillsides. One built at a right angle can be used in the corner of a flat property. A rectangular mound is often used when there is plenty of room and a uniform slope. Landscaped areas around the mound can serve as a privacy barrier, a wind block or as a screen to block unsightly views.

3.5.4 OPERATION & MAINTENANCE

With a few simple maintenance procedures, a properly designed and installed mound system will last for many years. This system does have some mechanical equipment that will need care and replacement.

The treatment unit and pump chamber must be operated and maintained as mentioned in other sections of this document. For example the septic tank should be checked for sludge and scum buildup and pumped as needed. The effluent filter should be removed and cleaned as needed.

The maintenance required for mounds is minimal. To reduce the possibility of failure to the mound all surface water and roof drainage should be diverted around the mound. As a minimum the laterals should be flushed annually. Also, check the mound for the following conditions:

- Ponding in the absorption area
- Seepage out of the side or toe

- Spongy areas developing on the side, top, or toe
- Clogging of the distribution system.
- Upgradient storm drainage for accumulated storm water.

3.5.5 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.

Advantages:

- The mound system enables use of land that may otherwise be unsuitable for ground or at-grade systems.
- The natural soil utilized in a mound system is usually the top layer, which is typically the most permeable.
- Construction damage can be minimized since there is little excavation required in the mound area.
- Mounds can be utilized in most climates.

Disadvantages:

- Construction costs can be high do to expensive fill materials and the need for hand labor.
- Care must be taken to not damage the top permeable topsoil under the mound.
- The location of the mound may affect drainage patterns and limit land use options.
- Need for electricity and mechanical equipment (in some circumstances siphons can be used in place of pumps).
- Mounds may not be aesthetically pleasing in some cases.

3.6 ENGINEERED PAD (A.A.C. R18-9-E309)

Engineered pads are composed of prefabricated modular unites comprised of geo-textile fabric and cuspated spacer cores. The engineered pad provides an alternative to conventional rock or gravel trenches and provides additional passive treatment to septic tank effluent.

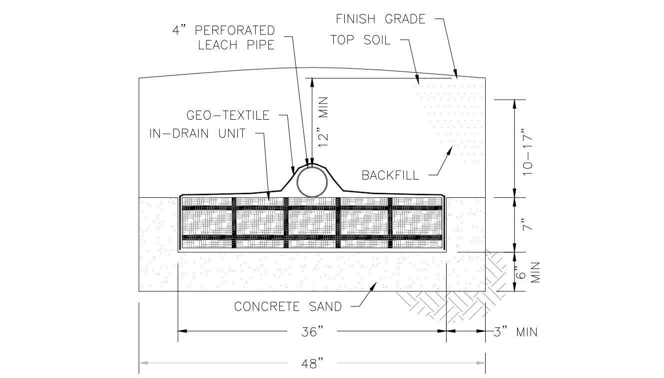
3.6.1 WHY USE ENGINEERED PADS.

Like conventional drain fields, engineered pads can be designed to work on a variety of home sites and under many conditions.

Engineered pads provide increased treatment and allow for smaller disposal fields and reduce the minimum vertical separation from subsurface limiting layers..

3.6.2 PROCESS DESCRIPTION

The engineered pads utilize a geo-textile primary treatment zone and concrete sand as a secondary treatment zone for passive filtration of septic tank effluent. The pads utilize shallow installation and uniform soil loading to enhance evapo-transpiration, oxygen transfer in the secondary treatment zone, which reduces BOD_5 and protects the long-term acceptance rate of the soil. Effluent treatment occurs within the biomat, which develops on the geo-textile fabric. The internal passive treatment provides an extra level of protection for the soil infiltration.



Engineered Pad

3.6.3 DESIGN CRITERIA

The engineered pad consists of a manufactured pad surrounded with 6 inches of concrete sand under and on each side of the pads. Multiple pads may be placed end to end with no sand separating each pad.

The pads receive wastewater from a septic tank through 4" perforated leach pipe installed lengthwise on top of the pads. The entire system is then covered by the geo-textile fabric. The fabric provides a substrate for bio-mat development and biological treatment. The pad is porous and allows good circulation of effluent and air to support aerobic biological growth.

3.6.3.1 Hydraulic Loading

Tests have shown that engineered pads may be loaded at 0.4 to 1.0 gpd/sf of biofabric surface without plugging or fouling by biomass or interior damage of the geo-textile fabric.

3.6.3.2 Soil Permeability

Due to the reduction in BOD_5 and TSS a reduction in soil application rates is allowable, however the overall size of the trenches is dependant upon the most conservative design based on either soil application rates or pad application rates.

3.6.4 OPERATION & MAINTENANCE

Engineered pads require no operation as it is a passive disposal system. It does, however, require periodic inspections. Inspection pipes are typically provided in the design to allow the measurement of the effluent level within each trench. The presence of ponded effluent in the trenches indicates the trenches are being hydraulically overloaded and a reduction in water use must commence immediately.

3.6.5 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.

Advantages:

- Pretreatment of effluent via a two-stage biomat.
- Protection of soil long term acceptance and greater long-termleaching capacity..
- ET systems can be used to supplement soil absorption for sites with slowly permeable, shallow soils with high water tables.
- Infiltration areas required are smaller than conventional disposal trenches.
- Lower site impacts.

Disadvantages

- Higher cost than conventional systems due to the cost of the engineered pads and concrete sand.
- They have a limited storage capacity, and are thereby unable to store wastewater during high flows or seasonal saturation.
- There is a potential for overloading from infiltration and precipitation.

3.7 SAND FILTERS (A.A.C. R18-9-E310)

3.7.1 INTERMITTENT SAND FILTER

Sand filter systems have been used for wastewater treatment in the U.S. since the late 1800s. In 1876, the community of Lenox, Massachusetts, built a sand filter system and by 1893 six other communities were using sand filters for wastewater treatment. During the same period, sir Edward Frankland of England was documenting work with natural sand beds.

3.7.1.1 Why use an intermittent Sand filter

ISFs have proven to be a reliable technology when they are properly designed, constructed, and maintained. Their performance is consistent and they have low operation and maintenance requirements.

ISFs may enable development or use of difficult sites. They can remedy existing malfunctioning systems and they can be a good option for homes in environmentally sensitive areas.

3.7.1.2 Process Description

ISFs are used as the second step in wastewater treatment after solids in raw wastewater have been separated in a septic tank, aerobic unit or other sedimentation tank. Wastewater treated by sand filtration is usually colorless and odorless.

ISFs have 24-inch deep filter beds of carefully graded media. Sand is a commonly used media, but anthracite, mineral tailings and bottom ash have also been used. The surface of the bed is intermittently dosed with effluent that percolates in a single pass through the sand to the bottom of the filter. The dosing frequency is controlled by a programmable timer, much the same as the LPDS and mound. After a set volume is collected in the under-drain a float switch activates a pump and the treated effluent is pumped to a leach field. The two basic components of ISF systems are a primary treatment unit, such as a septic tank or other sedimentation system, and a sand filter.

ISFs remove contaminants in wastewater through physical, chemical, and biological treatment processes. Most treatment occurs in the first six to twelve inches of the filter surface. The organic matter breaks down in the filter. Particles stick to grain surfaces or get caught in crevices or voids on grains or in spaces between grains. In addition, negatively charged grain surfaces can attract positively charged waste particles and bond with them through a process called adsorption. Chemical bonding also takes place as certain particles in the wastewater come in contact with and react with the media.

Although the physical and chemical processes play and important role in the removal of many particles, the biological processes play the most important role in sand filters. Like the soil in every backyard, sand filters are home to a variety of organisms, many of which contribute to treatment by consuming organic matter in the wastewater.

Bacteria are the most abundant organisms in the filters, and they do most of the work. There are other beneficial life forms found in the filters such as protozoa and worms, which contribute to treatment.

After the filter has had a chance to mature, a complete enclosed ecological system develops as the organisms multiply and rely on each other to survive.

The most significant part of the filter ecosystem is a thick layer called the biomat that eventually forms near the surface of the filter. This layer contains bacteria that consume particles in the wastewater. In turn, protozoa feed on the bacteria and help prevent the biomat from becoming so dense that it clogs the filter. This balance between the various life forms and the physical and chemical processes that take place in the sand filter results in extremely efficient wastewater treatment.

3.7.1.3 Design Criteria

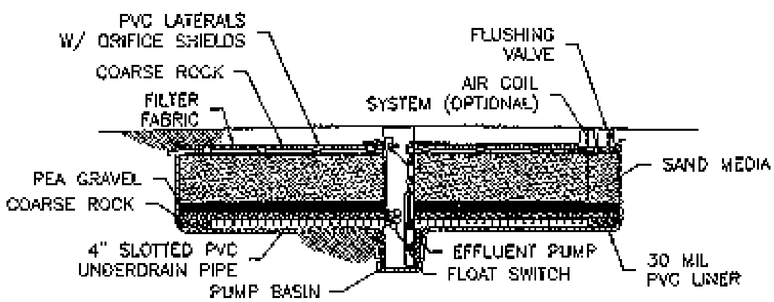
ISFs are typically built below grade in excavations three to four feet deep and lined with an impermeable membrane. The under-drain is surrounded by a layer of graded gravel and crushed rock. Pea gravel is then placed on top of the graded gravel and then sand is laid over the top of the pea gravel. Another layer of graded gravel is laid down, with the distribution pipes running through it. A flushing valve is located at the end of each distribution lateral. Lightweight filter fabric is placed over the final course of rocks to keep silt from moving into the sand while allowing air and water to pass through. The top of the filter is then backfilled with topsoil that may be planted with grass.

3.7.1.4 Gravity Discharge

One variety of buried ISFs is the gravity discharge ISF. It is usually located on a hillside with the long axis perpendicular to the slope to minimize the excavation required. Because the effluent leaving the sand filter flows out by gravity, the bottom of the sand filter must be several feet higher that the leach field. To achieve that difference in elevation a sand filter may be constructed partially above ground.

3.7.1.5 Pumped Discharge

Another type of buried sand filter is the pumped discharge sand filter. This system is usually constructed on level ground, but its location in relation to the leach field is not critical since a pump located within the sand filter bed allows effluent to be pumped to a leach field at any location or elevation. Discharge piping goes over the sand filter liner, or through a sealed boot in the liner so that the integrity of the liner is protected.



Intermittent Sand Filter

3.7.1.6 Open Bottom

A third type of buried sand filter has no impermeable liner and does not discharge to a leach field, but rather directly to the soil below the sand.

3.7.1.7 Operation & Maintenance

The operation and maintenance of a sand filter is minimal when properly sized. Buried sand filters used for residential applications can generally perform for extended periods of time.

Primary O&M tasks require minimal time and include inspecting the dosing equipment, maintaining the filter surface, checking the discharge head on orifices and flushing the distribution manifold annually. The pump and floats should be checked annually and replaced or repaired as necessary. All electrical parts and conduits should be checked for proper operation and corrosion. Follow all of the manufacturer's operation and maintenance instructions. All equipment must be tested and calibrated according to the manufacturers specifications. The septic tank should be checked for sludge and scum buildup and pumped as needed.

In extremely cold temperatures, adequate precautions must be taken to prevent freezing of the filter system by using removable covers.

3.7.1.8 Advantages & Disadvantages
Some Advantages and Disadvantages are listed below.

Advantages:

- ISFs produce a high quality effluent.
- Leach fields can be small and shallow.
- ISFs have low energy requirements.
- The treatment capacity can be expanded through modular design.
- ISFs can be installed to blend into the surrounding landscape.
- The soil cover prevents odors.
- ISFs are stable and work well for intermittent usage.

Disadvantages:

- The land area required may be a limiting factor.
- If appropriate filter media is not available locally, cost can be high.
- Clogging of the filter media is possible.
- ISFs can be sensitive to extremely cold temperatures.

3.7.2 RECIRCULATING SAND FILTERS (A.A.C. R18-9-E310)

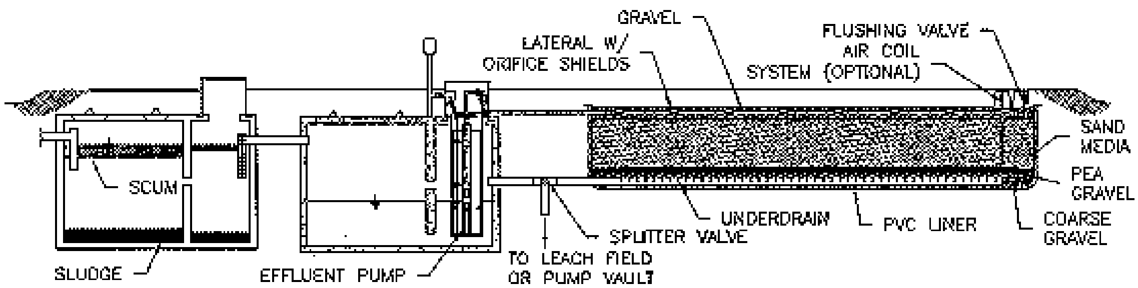
The recirculating sand filter (RSF) concept was introduced in the late 1960s and early 70s by public health engineers from Illinois who were experimenting with sand filter designs. An RSF system is a modified version of the single-pass open sand filter. It was designed to alleviate the odor problems associated with open sand filters. The odors were eliminated through recirculation, which increases the oxygen contend in the effluent that is distributed on the filter bed.

3.7.2.1 Why use a recirculating Sand filter

Wastewater treated in a RSF contains more oxygen that eliminates odors. “The final sand filter effluent also is of a higher quality. Recirculating sand filter media is somewhat coarser than other sand filter media and therefore is less prone to clogging. Hydraulic loading rates typically are two to three times higher than ISF's meaning that less land area is generally needed to treat the same amount of wastewater.

3.7.2.2 Process Description

The RSF treats wastewater with the same processes as the intermittent sand filter. The three basic components of an RSF are a pretreatment unit, a recirculating tank and open sand filter.



<u>Recirculating Sand Filter System</u>

3.7.2.3 Design Criteria

Wastewater first flows into a septic tank for primary treatment. The partially clarified effluent then flows into a recirculation tank, which is equipped with a pump, alarm, a timing mechanism, and float switches.

The volume of the recirculation tank should be equivalent to at least one day’s design flows. In the recirculation tank, effluent from the septic tank and the sand filter filtrate are mixed and pumped back to the sand filter bed. The dosing frequency is controlled by a programmable timer in the control panel.

After receiving treatment in the sand filter, the wastewater collects in the under-drains and a portion of it is directed back to the recirculation tank, where it mixes with the septic tank effluent and is recirculated to the sand filter. The remaining sand filter effluent bypasses the recirculation tank and goes to the leach field.

The ratio of sand filter effluent recirculation ranges from 3:1 to 5:1. How the amount is controlled varies with individual system designs.

3.7.2.4 Operation & Maintenance

RSFs require simple routine maintenance. Primary O&M tasks include inspecting the dosing equipment, maintaining the filter surface, checking the discharge head on orifices, and flushing the distribution manifold annually. The surface of the sand bed should be kept vegetation free.

The septic tank should be checked for sludge and scum buildup and pumped as needed. The recirculation tank should also be inspected and maintained as necessary.

The pump and floats should be checked annually and replaced or repaired as necessary. All electrical parts and conduits should be checked for proper operation and corrosion. Follow all of the manufacturer's operation and maintenance instructions. All equipment must be tested and calibrated according to the manufacturers specifications.

3.7.2.5 Advantages & Disadvantages

Some Advantages and Disadvantages are listed below.

Advantages:

- RSFs provide a very good effluent quality with over 95% removal of biochemical oxygen demand (BOD) and total suspended solids (TSS).
- The treatment capacity can be expanded through modular design.
- RSFs are effective in applications with high strength wastewater.
- A significant reduction in nitrogen is achieved.
- Less land area is required than for single-pass filters.

Disadvantages:

- If appropriate filter media is not available locally, cost can be high.
- Weekly maintenance is required for the media, pumps and controls.
- RSFs can be sensitive to extremely cold temperatures.

3.8 PEAT BIO-FILTERS (A.A.C. R18-9-E311)

Peat has been used for wastewater treatment since 1891. In Italy a professor of hygiene and the director of public health in Rome described using an early septic tank in combination with a "peat filter" to treat wastewater.

Peat is partially decayed organic matter mainly of plant origin. It consists of partly decomposed remains of roots, stems, leaves, flowers, fruits and seeds. In peat bogs the soil and the peat that forms on it, are saturated with water for much or all of the year. The partially decayed organic matter cannot complete its decomposition process because of the saturated conditions that exist in the peat bogs. Most of the living roots in the bog are situated in the semi-aquatic layer where the plant heads are just above water. Below this layer, there is an anaerobic zone where the pace of decomposition in the waterlogged soil is very slow. In the depths of the anaerobic layer decomposition has almost stopped. In these conditions peat or partly decomposed plant remains, accumulates in layers. In its natural state, peat may consist of as much as 98 percent water. One of its features is the capacity to bind or retain water. This natural water binding ability of peat accounts for its widespread use in horticultural applications and it also allows for a very long residence time when used to filter wastewater.

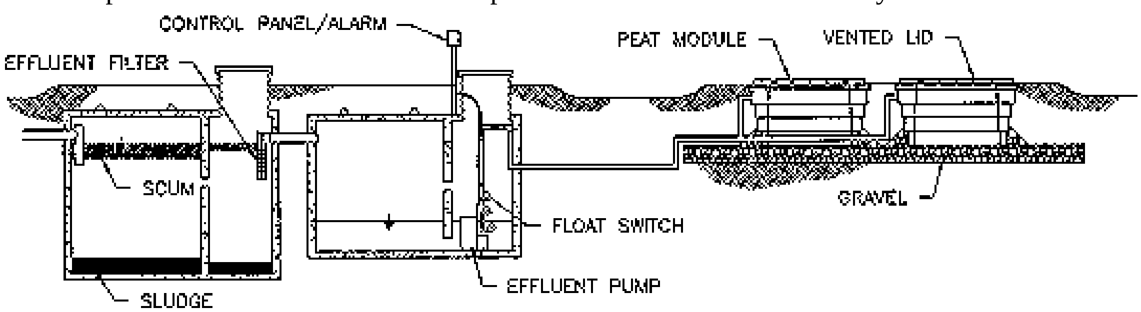
3.8.1 WHY USE A PEAT BIO-FILTER

Peat bio-filters performance is consistent for intermittent or year round use and they have low operation and maintenance requirements. The bio-filter module(s) can be placed at grade to meet vertical separation requirements or can be place in the ground up to the lid for aesthetics. The design footprint for a peat bio-filter can be considerably smaller than a mound or sand filter.

3.8.2 PROCESS DESCRIPTION

Just like the sand filter, peat bio-filters are used as the second step in wastewater treatment after solids in raw wastewater have been separated in a septic tank, aerobic unit or other sedimentation tank.

The treatment technology is based on simple, passive bio-filtration principles. The treatment of the wastewater within the system is achieved by a combination of unique physical, chemical and biological interactions between the wastewater and the fibrous media. A complex chemical structure permits a number of separate treatment and attenuation processes to occur simultaneously.



Peat Bio-filter System

In a mature peat bio-filter the biological transformation processes are crucial in maintaining the treatment efficiency. The bulk of the treatment and assimilation processes are achieved by diverse micro-flora that adhere to the surface of the peat media. This micro-flora is largely composed of aerobic and facultative aerobic heterotrophic bacterial from a large number of genera.

A wide variety of "higher life" forms such as protozoan, rotifers, worms, insects and larvae also live in the media matrix. These organisms play an important role in keeping the bacterial population in check thereby maintaining a balanced and stable ecosystem. The larger numbers of heterotrophic bacteria are found in the upper portions of the filter media and nitrifiers become more prevalent deeper into the filter. Therefore, the assimilation of waste is affected within the upper portions of the filter and nitrification occurs deeper in the filter.

3.8.3 DESIGN CRITERIA

The effluent from the septic tank can go directly to the peat module(s) by gravity or can be collected in a pump chamber and pumped to the peat module(s). If a pump is used the system is usually activated by a programmable timer.

The partially clarified effluent is evenly distributed over a specialized fibrous peat media that is contained in a number of molded polyethylene modules. The effluent percolates through the unit and emerges as a clear innocuous liquid from the base of the system. The long residence time allows the wastewater a much greater contact time with the treatment media that results in a very efficient single pass or recirculating treatment system.

The module(s) are placed on a gravel bed at grade and then covered with topsoil or a hole can be dug and the module(s) can be placed on the gravel base and buried to their lids. The lids allow air into the module and therefore should not be covered.

Once distributed evenly over the peat media the effluent moves laterally and vertically within the module(s). There are two methods for the effluent to exit the module(s). The treated effluent either weeps through holes drilled in the base of the module and disperses directly into the gravel pad or the effluent can be collected into a separate pump basin and pressure dosed to a typical leach field.

3.8.4 OPERATION & MAINTENANCE

The septic tank should be checked for sludge and scum buildup and pumped as needed. A effluent filter is recommended and should be maintained as needed.

If a pump chamber or pump basin is used the pump(s) and floats should be checked annually and replaced or repaired as necessary. All electrical parts and conduits should be checked for proper operation and corrosion. Follow all of the manufacturer's operation and maintenance instructions. All equipment must be tested and calibrated according to the manufacturers specifications.

The treatment technology is based on simple bio-filtration principles. There is no requirement for moving parts or forced aeration mechanisms. The peat module(s) are low-maintenance and require no annual pumping or backwashing. They should be racked annually to break up any biomat that may be forming and to level the media.

3.8.5 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.

Advantages:

- High effluent quality.
- Due to the modular design installation is simple.
- The treatment capacity can be expanded through modular design.
- Easy to install pre-assembled units.
- Nitrogen reduction is often times possible.
- Peat bio-filters are stable and work well for intermittent usage.
- Depending on design peat bio-filters have little to no energy requirements
- Little land area is required.
- Easily accessible for monitoring and does not require a lot of skill to maintain.

Disadvantages:

- Annual inspections must be completed by a trained operator.
- Treatment media has a limited useful life and has to be replaced with new media depending on the use.

3.9 TEXTILE BED FILTERS (A.A.C. R18-9-E312)

Recent research has resulted in an advanced packed bed treatment technology that uses a textile medium. The textile medium, typically in the form of small chips or "coupons", has a complex fiber structure that offers an extremely large surface area for biomass attachment. The textile porosity is very high providing high hydraulic conductivity and excellent air movement through the medium.

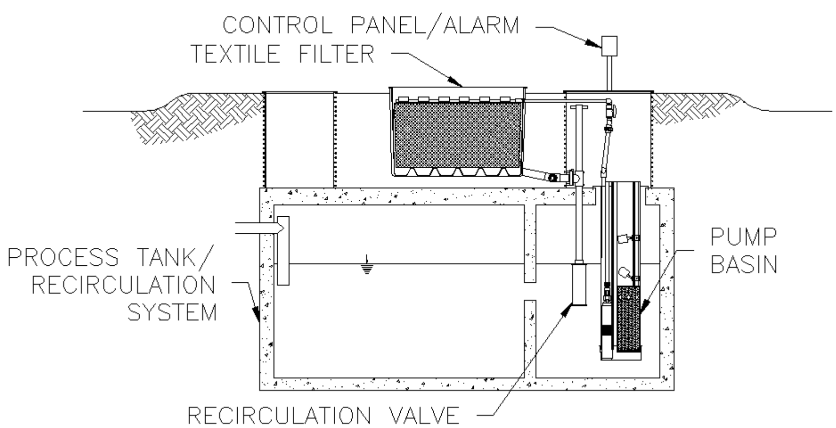
3.9.1 WHY USE A TEXTILE BED FILTER

Textile bed filters provides all the benefits inherent of sand filters but overcomes some limitations such as (1) land area, (2) media quality or accessibility and (3) installation quality.

1. Land area – Some sites lack the land area required for a sand filter. Sand filters for single-family residences typically require between 100 and 400 square feet. The land area needed for a textile bed filter is much smaller, typically 20 to 40 square feet, because the loading rates are 5 to 20 times higher.
2. Media quality or accessibility – Good quality sand media is occasionally not locally available. In addition, getting sand to some sites such as mountainous regions or isolated areas can be difficult. The manufactured textile medium ensures consistent quality and availability.
3. Installation – The lightweight textile medium and small filter size make pre-manufactured treatment units practical, eliminating onsite construction and reducing installation time, labor and construction errors.

3.9.2 PROCESS DESCRIPTION

The textile bed filter treats wastewater with the same processes as the intermittent sand filter. The two basic components of the textile bed filter are a process tank/recirculating tank and textile filter unit.



Textile Bed Filter

The wastewater percolates both through and between the textile media. A visible biological film attaches onto the filter medium. Due to the high porosity within the filter aerobic conditions exist that are ideal for microbes that break down the organics in the liquid and convert ammonia to nitrate. Other conditions exist that result in further nitrogen reduction within the media. Eighty percent of the filtrate recirculates back to the high-carbon, low-oxygen (anoxic) environment of the process tank that is ideal for microbes that reduce nitrates to nitrogen gas (denitrification). Harmless nitrogen gas is then released freely back into the atmosphere.

3.9.3 DESIGN CRITERIA

The process tank is sized based on daily flows. It also contains a pump and timer. Typically, the pump will dose the textile filter(s) for one minute every 20 minutes. A splitter ball valve will divert a minimum of 80% of the flow back into the process tank. The remaining effluent will be diverted to a disposal system, such as pump chamber and leach trenches or a variety of other disposal methods.

The textile filters come in prepackaged modules that can be placed on top of the process tank. The top of the filter modules must be at-grade to allow air into the system.

3.9.4 OPERATION & MAINTENANCE

Inspect the processing tank for liquid depth, color of scum and effluent, and sludge and scum thickness. (After the first year's measurement of septic tank sludge and scum thickness, measurements only need to be taken about every three years.). Measurements of solids accumulation help to determine when the tank needs pumping. A recommendation for pumping should be made when there is an accumulation of scum extending to a depth of about three inches above the top of the outlet ports of the pumping system or an accumulation of sludge to a depth within six inches below the bottom of the outlet ports.

The pumping system should be inspected annually to ensure that all pumps are operating properly. The inspection should include:

1. Verify that there are no obvious holes or leaks in the pump tank riser.
2. Verify that the float cords are neatly wrapped inside the riser so they cannot interfere with the operation of the floats.
3. Verify the high water alarm works by lifting the top float up.
4. Verify the programmable timer settings are correct.
5. Read and record the elapsed timer meter and or cycle counter if the control panel is equipped with these devices.
6. Inspect recirculating splitter device.

If a strong or offensive odor is emitted from the filter, measure the DO levels in the filtrate and recirculation chamber and adjust the recirculation time if necessary. The following textile filter items should be checked annually:

1. Check the organic build-up on the media under the orifices.
2. Clean and flush the manifold.
3. Check residual pressure against start-up value. If the pressure is more than 20% higher than the start-up value, perform additional cleaning and verify that all orifices are clear.
4. Inspect for ponding. The filter should not be saturated. Effluent should move freely through the media. If there is a build-up of oil and grease that is causing the ponding, scrape a sample from the

biomat and have it analyzed by a lab.

3.9.5 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.

Advantages:

- Textile filter beds produce a high quality effluent.
- Leach fields can be small and shallow.
- Low energy requirements.
- The treatment capacity can be expanded through modular design.
- Stable and work well for intermittent usage.
- Need smaller land area than most systems.
- Ease in construction

Disadvantages:

- Systems are relatively new and long-term capabilities are unknown.
- Media may need replacing after several years of use.
- Clogging of the filter media is possible.
- May be sensitive to extremely cold temperatures.

3.10 SEWAGE VAULT (A.A.C. R18-9-E314)

A sewage vault is simply a holding tank used to collect wastewater to be pumped and disposed of off site. Vaults are typically permitted and installed temporarily, not exceeding two years.

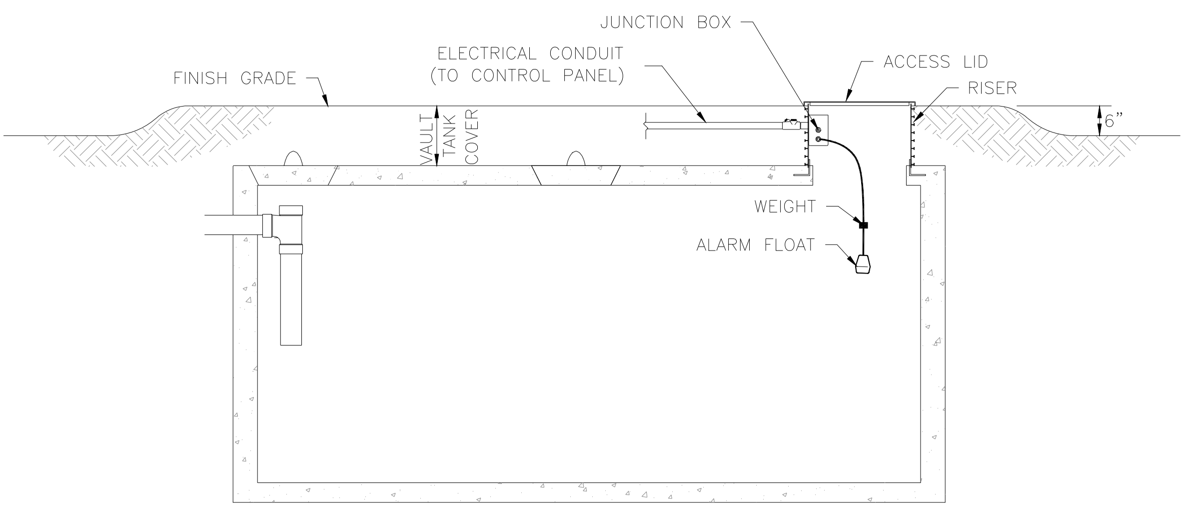
3.10.1 WHY USE A SEWAGE VAULT.

Sewage vaults should only be used if there is a severe site constraint that prevents a conventional or alternative disposals system from being installed or as a temporary means to handle wastewater until a treatment and discharging system can be installed.

3.10.2 DESIGN CRITERIA

Vaults are designed to store a minimum of 1,500 gallons per bedroom or 10 times the calculated design flow. Under no circumstances may the vault discharge wastewater, all wastewater must be pumped. The pumping and disposal must comply with all state and local laws, rules and ordinances.

Additionally the vault must be equipped with an audio/visual alarm indicating when 85% of the vaults capacity has been reached.



Vault

3.11 AEROBIC TREATMENT UNITS (A.A.C. R18-9-E315)

Aerobic systems are similar to conventional septic systems in that they both use natural processes to treat wastewater. But unlike septic anaerobic treatment, the aerobic treatment process requires oxygen. Aerobic treatment units, therefore, use a mechanism to inject and circulate air inside the treatment tank. This mechanism requires electricity to operate.

For this reason, aerobic systems cost more to operate and need more routine maintenance than most septic systems. However, when properly operated and maintained, aerobic systems can provide a high quality wastewater treatment alternative to septic systems.

3.11.1 WHY USE AEROBIC TREATMENT?

Aerobic Treatment Units (ATUs) have proven to be a reliable technology when they are properly designed, constructed, and maintained. When properly monitored and maintained their performance is consistent.

ATUs may enable development or use of difficult sites. They can remedy existing malfunctioning systems and they can be a good option for homes in environmentally sensitive areas.

3.11.2 PROCESS DESCRIPTION

Aerobic systems treat wastewater using natural processes that require oxygen. Bacteria that thrive in oxygen-rich environments work to break down and digest the wastewater inside the aerobic treatment unit.

Like most onsite systems, aerobic systems treat the wastewater in stages. Sometimes the wastewater receives pretreatment before it enters the aerobic unit, and the treated wastewater leaving the unit requires additional treatment or disinfection before being returned to the environment.

Such a variety of designs exists for home aerobic units and systems that it is impossible to describe a typical system. Instead, it is more practical to discuss how some common design features of aerobic systems work and the different stages of aerobic treatment.

3.11.2.1 Pretreatment

Some aerobic systems include a pretreatment step to reduce the amount of solids in the wastewater going into the aerobic unit. Solids include greases, oils, toilet paper, and other materials that are put down the drain or flushed into the system. Too much solid material can clog the unit and prevent effective treatment.

Some pretreatment methods include a septic tank, a primary settling compartment in the pretreatment unit, or a trash trap. Pretreatment is optional but can greatly improve a unit's performance.

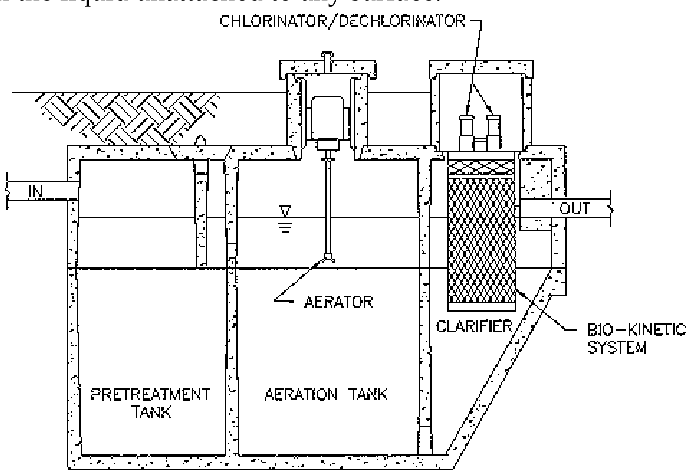
3.11.2.2 Aerobic Treatment Units

The main function of the aerobic treatment unit is to collect and treat household wastewater, which includes all water from toilets, bathtubs, showers, sinks, and laundry. Aerobic units themselves come in many sizes and shapes-rectangular, conical, and some shapes that defy classification. There are two typical aerobic treatment designs: (1) suspended growth units and (2) attached growth units.

The process most aerobic units use to treat wastewater is referred to as suspended growth. These units include a main compartment called an aeration chamber in which air is mixed with the wastewater. Since most home aerobic units are buried underground like septic tanks, the air must be forced into the aeration chamber by an air blower or through liquid agitation.

The forced air mixes with wastewater in the aeration chamber, and the oxygen supports the growth of aerobic bacterial that digests the solids in the wastewater. This mixture of wastewater and oxygen is called the mixed liquor.

The treatment occurring in the mixed liquor is referred to as suspended growth because the bacterial grow as they are suspended in the liquid unattached to any surface.



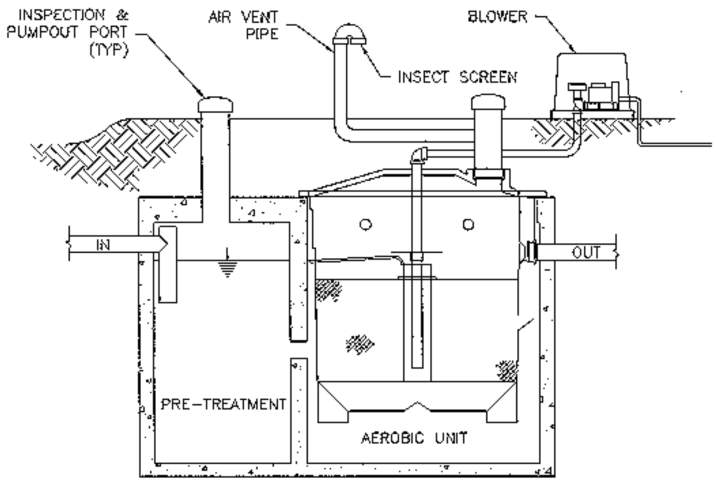
Suspended Growth ATU

Unfortunately, the bacterial cannot digest all of the solids in the mixed liquor, and these solids eventually settle out as sludge. Many aerobic units include a secondary chamber called a settling chamber or clarifier where excess solids can settle. Other designs allow the sludge to accumulate at the bottom of the tank.

In aerobic units designed with a separate settling compartment, the sludge returns to the aeration chamber (either by gravity or by a pumping device). The sludge contains bacterial that also aid in the treatment process. Although, in theory, the aerobic treatment process should eventually be able to consume the sludge completely, in practice, the sludge does build up in most units and will need to be pumped out periodically so that solids don't clog the unit.

An alternative design for aerobic treatment is the attached growth system. These units treat wastewater by taking a surface made of material that the bacteria can attach to, and then exposing that surface alternately to wastewater and air. This is done either by rotating the surface in and out of the wastewater or by dosing the wastewater onto the surface. Pretreatment is required. The air needed for the process either is naturally present or is supplied mechanically.

Attached growth systems, such as trickling filters and rotating disks, are less common than suspended growth systems, but have certain advantages. For example, there is no need for mixing, and solids are less likely to be washed out of the system during periods of heavy household water use.



Attached Growth ATU

3.11.2.3 Flow Design

The way and the rate in which wastewater is received by and flows through the aerobic unit differs from design to design. Continuous flow designs simply allow the wastewater to flow through the unit at the same rate that it leaves the home. Other designs employ devices (such as pretreatment tanks, surge chambers, and baffles) to control the amount of the incoming flow. Batch process designs use pumps or siphons to control the amount of wastewater in the aeration tank and/or to discharge the treated wastewater in controlled amounts after a certain period.

Controlling the flow of wastewater helps to protect the treatment process. When too much wastewater is flushed into the system all at once, it can become overburdened, and the quality of treatment can suffer. The disadvantages to mechanical flow control devices are that, like all mechanical components, they need maintenance and run the risk of malfunctioning.

3.11.3 DESIGN CRITERIA

Aerobic units should be large enough to allow enough time for the solids to settle and for the wastewater to be treated. The daily wastewater volume is usually determined by the number of bedrooms in the house. Flows in Arizona for individual homes are up to 150 gallons per day (gpd) per bedroom.

The needed size of an aerobic unit is often estimated the same way the size of a septic tank is estimated, by the number of bedrooms (not bathrooms) in the house. It is assumed that each person will use approximately 50 to 100 gallons of water per day, and that each bedroom can accommodate two people. When calculated this way, a three-bedroom house will require a unit with a capacity of 300 to 600 gallons per day.

Some health departments require that aerobic units be sized at least as large as a septic tank in case the aerobic unit malfunctions and oxygen doesn't mix with the wastewater. In such cases, the aerobic unit will work as a septic tank, which will, at least, provide partial treatment for the wastewater.

Lower temperatures tend to slow down most biological processes, and higher temperatures tend to speed them up. The aerobic process itself creates heat, which, along with the heat from the electrical components, may help to keep the treatment process active. However, cold weather can have adverse effects on the performance of aerobic units.

In one 1977 study of aerobic units, bulking of the sludge seemed to occur when the temperature of the mixed liquor fell below 15 degrees Celsius (59 degrees Fahrenheit). Problems can sometimes be avoided by insulating around the units.

3.11.4 OPERATION AND MAINTENANCE

Aerobic treatment systems are not accepted in all areas. Regulations for onsite systems can vary from state to state and county to county. A major reason that aerobic systems are not more widely used is concern about improper operation and maintenance by homeowners. Aerobic systems require regular maintenance, and abuse or neglect can easily lead to system failure.

A typical inspection should include removing the unit's cover and checking its general appearance. Check pipes and the inside of the aeration chamber and note the appearance of the wastewater inside the unit and its color and odor. If the unit includes a chlorinator, this too will need to be checked and may need cleaning. Samples may be taken of the mixed liquor from the aeration chamber, as well as the final treated wastewater. Check to see that all mechanical parts, alarms, and controls are in working order, and that solids are pumped from the system if needed.

It is important that mechanical components in aerobic systems receive regular inspection and maintenance. For example, air compressors sometimes need to be oiled, and vanes, filters, and seals may need to be replaced. Malfunctions are common during the first few months after installation. In most cases, homeowners do not have the expertise to inspect, repair, and maintain their own systems.

Most aerobic units have controls that can be switched on and off by the homeowner in case of emergency. Aerobic units also are required to have alarms to alert the homeowner of malfunctions. Depending on the design of the system, controls and alarms can be located either inside or outside the home, and alarms can be visible, audible, or both.

Homeowners should make sure that controls and alarms are always protected from corrosion, and that the aerobic unit is turned back on if here is a power outage or if it is turned off temporarily.

To assure homeowners are receiving a reputable ATU most states require the system to by approved by the NSF International (formerly the National Sanitation Foundation). NSF has tested aerobic units according to the requirements of ANSI/NSF Standard 40. NSF is a nonprofit organization devoted to the protection of the environment through the development of product standards, product evaluations, research, education and training. The American National Standards Institute (ANSI) is the recognized accredited in the U.S. for organizations that develop consumer standards and for those that provide independent product evaluations. NSF is accredited by ANSI for both of these areas of service. Aerobic units that satisfy the requirements of ANSI/NSF Standard 40 may carry the NSF mark.

If your unit carries the NSF approval, it will include the first two years of service visits with the purchase price and an option to renew the service contract after two years. It is a good idea for homeowners to renew their service agreements after two years or to find another service organization to take over the job.

In addition to routine maintenance, NSF requires service contractors to stock replacement parts for mechanical components and to be available for emergency servicing. Under the original two-year agreement, failed equipment is replaced at no additional cost to the homeowner.

The service contract may or may not cover such problems as damage from power failures, breaking or crushing of pipes leading to and from the system, flooding, fires, homeowner misuse, and other catastrophes beyond the control of the manufacturer.

Service visits will most likely be carried out by the dealer or another independent service organization that has an agreement with the manufacturer. In other cases, health departments will have maintenance management programs, such as sanitary districts, for aerobic systems in their area.

The first service visit should be scheduled immediately after the system is installed to make sure that everything is working correctly. The service contractor may also arrange a meeting with the homeowner to go over issue, such as proper operation, what to do in case of emergency, etc. With the first visit, the maintenance service contract should be issued to the homeowner.

The maintenance contract should include at least two service visits per year for the next two years. The number of visits and service performed will differ from; unit to unit and location to location depending on manufacturers' recommendations and local regulations.

It is a good idea for the homeowner or service provider to keep detailed records about the system and service visits. NSF-approved units are required to include a user's manual that describes such things as the manufacturer's recommendations for the unit, the system design, how to operate and maintain it, as well as how to tell if it is working properly. The state license, the date the system was installed, the type of disinfection, and any modifications to the system should also be recorded.

Other important information to keep on hand includes where to contact the owner if nobody is home, where to find a key to the system, and the schedule for service visits.

Homeowners should keep their own copies of all records and permits.

3.11.5 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.
Advantages:

- Can provide a high level of treatment.
- May extend the life of a leach field.
- May allow for a reduction in leach field size.

Disadvantages:

- Increased annual cost from continuously running air supply.
- Need for electricity and mechanical equipment.
- Requires frequent routine maintenance.
- Subject to upsets under sudden heavy loads (attached growth ATU's less susceptible) or when neglected.

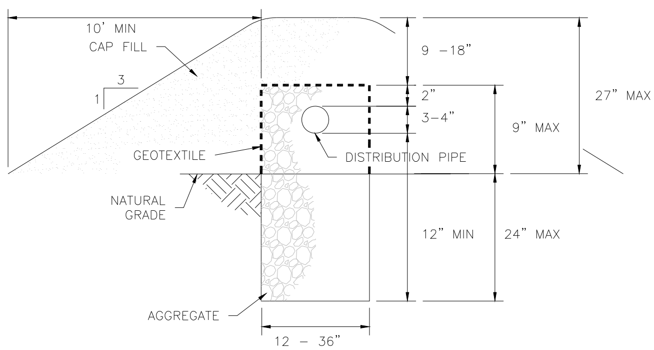
3.12 CAP SYSTEM (A.A.C. R18-9-E317)

A caped system is simply a conventional disposal trench with the distribution pipe placed near or slightly above grade and covered with a soil cap, consisting of engineered fill.

3.12.1 WHY USE A CAP SYSTEM.

A cap system is used if there is little native soil overlying fractured or excessively permeable rock or a high water table does not allow the minimum vertical separation to be met by a conventional trench.

3.12.2 PROCESS DESCRIPTION



Cap System

3.12.3 DESIGN CRITERIA

The cap system material must be free of debris, stones, frozen clods, or ice and is similar than the soil of the disposal site. The trench bottom must be at least 12 inches below the bottom of the disposal pipe and not more than 24 inches below the natural grade.

The aggregate cover over the disposal pipe must be 2" thick and the top of the aggregate is no more than 9 inches above natural grade. The cap fill above the top of the aggregate must be at least 9 inches thick but not more than 18 inches thick. The side slopes of the cap fill must be no steeper than 3 to 1 (horizontal to vertical) and must extend for a minimum of 10' beyond the actual trench excavation.

3.12.4 OPERATION & MAINTENANCE

The cap system requires no operation as it is a passive disposal system. It does, however, require periodic inspections. Inspection pipes are provided in the design to allow the measurement of the effluent level in the aggregate within a leach trench. The presence of some ponded effluent in the trenches during dosing or for periods particularly in the winter may be considered normal operation.

Care must be taken to assure the cap fill is not susceptible to erosion. Any erosion that takes place must be repaired immediately. Human or animal traffic or activities should be restricted.

3.12.5 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.

Advantages:

- Cap systems may overcome shallow soils over limiting subsurface conditions.

Disadvantages

- Increased cost.
- Increased maintenance due to the possibility of erosion.
- Prairie dogs, gophers or other tunneling rodents must be kept out of the disposal area.

3.13 CONSTRUCTED WETLANDS (A.A.C. R18-9-E318)

Natural wetlands, marshes, swamps, and bogs play an important role in protecting water quality. Constructed or artificial wetland systems mimic the treatment that occurs in natural wetlands by relying on plants and a combination of naturally occurring biological, chemical and physical processes to remove pollutants from the water. Because constructed wetland systems are designed specifically for wastewater treatment, they typically work more efficiently than natural wetlands. Some constructed wetland system designs can closely resemble natural wetlands enough to provide additional habitat areas for many birds, animals and insects that thrive in wetland environments.

3.13.1 WHY USE A CONSTRUCTED WETLAND

Constructed wetlands can treat wastewater from a variety of sources. One of the more common uses is to provide additional or advanced treatment of wastewater from homes, businesses and even communities. Wetlands treat wastewater that has already had most of the solid materials removed from it through some type of primary or secondary treatment.

Homes, businesses, farms, schools and other individual wastewater sources in rural areas sometimes can add a constructed wetland to a septic system or other onsite system to replace or assist a soil absorption field. Some onsite systems can be specifically designed from the start to use a constructed wetland in addition to a soil absorption field on properties with site constraints, such as tight or saturated soils.

Wetlands are good at handling intermittent periods of both light and heavy wastewater flows. Therefore, they often work well with wastewater treatment systems that serve hotels, campsites, resorts and recreational areas.

In environmentally sensitive areas, constructed wetlands can be used with onsite systems to improve the quality of the effluent before it is returned to the environment. They are also used on farms as an inexpensive way to provide extra treatment to animal wastes and by certain industries such as pulp and paper mills. Constructed wetlands are common in mining regions and are used to treat mine drainage.

Wetlands are not practical for treating industrial wastewater that includes pesticides, herbicides or large amounts of ammonia. Additionally wetland plants may accumulate high concentrations metals from some wastewater sources. This may affect the habitat value of the wetland.

3.13.2 PROCESS DESCRIPTION

There are two main types of constructed wetlands used for wastewater treatment: (1) surface flow wetlands (also called free-water surface wetlands) and (2) subsurface flow wetlands.

3.13.2.1 Surface Flow Wetland

Surface flow systems most resemble natural wetlands both in the way they look and the way they provide treatment. Both designs can be used to treat wastewater from individual and community sources, but surface flow wetlands are usually more economical for treating large volumes of wastewater.

Wetlands are areas on land where the ground maintains saturated conditions for much of the year.

Surface flow wetlands stay saturated enough to maintain a shallow level of water and wastewater (4 to 18 inches deep) above the soil.

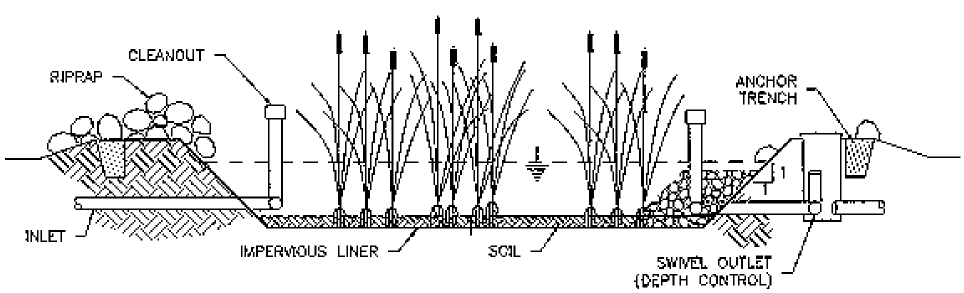
Wetland plants also are present in surface flow system, and natural forces such as wind, sun, rain and temperature affect the plants, water and the treatment processes in these systems.

As soon as wastewater enters a surface flow wetland cell, natural processes immediately begin to break down and remove the waste materials in the water. Before the wastewater has moved very far in the wetland small suspended waste materials are physically strained out be submerged plants, plant stems, and plant litter in the wetland. The roots, stems, leaves, and litter of wetland plants also provide a multitude of small surfaces where wastes can become trapped and waste-consuming bacterial can attach themselves.

Bacteria provide the majority of wastewater treatment. Aerobic bacteria thrive in wetlands wherever oxygen is present, especially near the surface. Wind, rain, wastewater and anything else that agitates the water surface can add oxygen to the system. Anaerobic bacteria thrive where there is little or not oxygen. In surface flow cells, oxygen is scarce in the lower substrate and soil.

When the bacterial consume waste particles in the water they convert them into other substances, such a methane, carbon dioxide and new cellular material. Some of these substances are used as food by plants and other bacteria.

For any of the processes in wetlands to work, the wastewater must remain in the system long enough for treatment to occur and for viruses in the wastewater to die-off naturally. The hydraulic residence time for wastewater in surface flow systems is based on wastewater strength, the level of desired treatment and climatic factors.



Surface Flow Wetlands

One of the most important factors affecting treatment is temperature. Biological treatment processes tend to speed up in warm weather and slow down in cold weather. In cold climates, systems must be large enough to accommodate the longer hydraulic residence times needed for treatment.

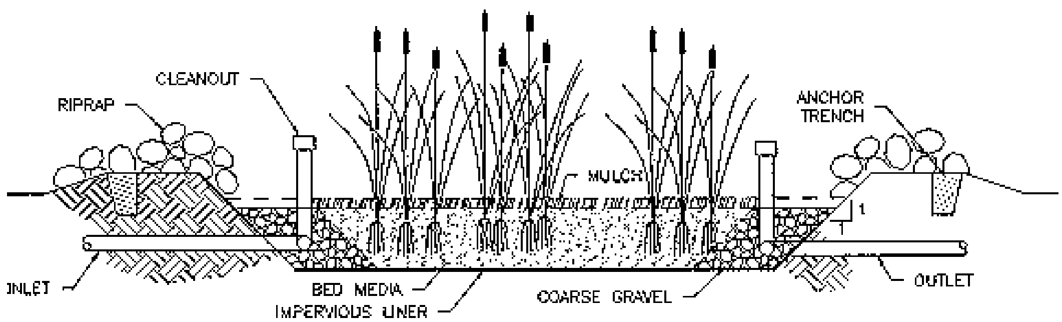
Plants help treatment processes in several ways. The wetland plants filter wastes, regulate flow and provide surface area for bacterial and treatment. Floating plants, such as water lilies and emergent plants, such as cattails, shade the water surface and control algae growth. Even in winter when plants are dormant, they often are contributing to treatment

Plants also contribute to treatment by taking up nutrients, metals, and other substances and retaining them. Many of these substances can accumulate again in the wetland when the plants die and decompose. Therefore harvesting vegetation is a good idea.

3.13.2.2 Subsurface Flow Wetland

Each subsurface flow wetland cell is filled with a treatment media, such as rock or gravel, which is placed on top of the soil or lining on the cell bottom. The depth of the media layer is usually about one to two feet. The wastewater flows just below the media surface and remains unexposed to the atmosphere while it saturates the layers below. The saturated media and soil, together with the wetland plants roots, create conditions below the surface of the system that are conducive to treatment.

Treatment in the subsurface flow system is more efficient than in the surface flow wetland because the media provides a greater number of small surfaces, pores and crevices where treatment can occur. Waste-consuming bacterial attach themselves to the various surfaces, and waste materials in the water become trapped in the pores and crevices on the media and in the spaces between media. Chemical treatment also takes place as certain waste particles contact and react with the media.



Sub-surface Flow Wetlands

Biological treatment in subsurface flow wetlands is mostly anaerobic because the layers of media and soil remain saturated and unexposed to the atmosphere. Commonly used plants are cattails, bulrushes and reeds. These plants are able to grow extensive roots even in these anaerobic conditions. The area where the roots grow is called the root zone and usually includes the upper six to twelve inches of media. If cells are alternated or allowed to rest periodically, or if the water level is regularly cycled, the roots can reach throughout the media layer.

Some wetland plant roots contribute oxygen to the cells, which allow some aerobic treatment to take place in the root zone. The plants further contribute to wastewater treatment by providing additional surfaces where bacterial can reside and where waste materials can become trapped. Plants also take up and store some of the metals and nutrients in the wastewater.

3.13.3 DESIGN CRITERIA

3.13.3.1 Surface Flow Wetland

The size and configuration of surface flow systems are based on estimates and strengths of the influent.

Designers must also consider climatic factors, such as temperatures, evapotranspiration rates, and precipitation amounts to predict and maintain the level of water in the system. Designs typically include multiple cells each providing the same level of treatment that may be operated simultaneously or independently.

Most surface flow wetland cells are self-contained rectangular-shaped basins surrounded by banks on all sides. The inlet and outlet are located on opposite sides. Exceptions include certain systems in arid climates designed for no discharge, which do not have an outlet, and systems used for advanced treatment that open directly to natural wetland areas.

The bottoms of surface flow wetlands cells should be somewhat free of bumps and ridges and have a slight downgrade (approximately 0.5 percent) to assist the flow of wastewater through the cell by gravity. Cells usually must be excavated by backhoe or by hand.

The cell bottom must also be self-contained to prevent wastewater from seeping into the groundwater below and the surrounding environment. It is usually necessary to line the bottom of the cells with clay, bentonite, or a synthetic liner. Soil or other material must be placed on top of the lining to form a substrate that will support the growth of wetland plants.

Surface flow systems can treat wastewater much more efficiently than natural wetlands. The reason for this is that the rate and pattern in which wastewater flows through the system is controlled by the design.

In natural wetlands, wastewater tends to flow through relatively narrow, well-established channels and may never even be exposed to a large portion of wetland area. To prevent this short-circuiting of the wastewater flow, and to make the best use of every inch of cell space, the wastewater in constructed wetlands should be evenly distributed across the width of each cell. Wastewater enters surface flow cells by means of perforated distribution pipes, gated pipes, or a series of weirs at the inlet. At the outlet, most systems have control valves and other devices to help operators adjust the water level.

Even the rectangular shape of the cells and the amount and placement of wetland plants is designed to optimize wastewater flow and treatment. The ratio of the cells' length to its width (the aspect ratio) usually ranges from 2:1 to 4:1, but may be higher depending on the site and other factors.

Systems designs must estimate the amount of head loss wetland vegetation is likely to cause in flow rates. The placement of the plants can be planned and arranged as well. For example, some surface flow cells are designed to have areas of open water as well as areas of dense vegetation to allow wind and sunlight to reach parts of the cell to influence flow and treatment.

Most systems are designed for the wastewater to flow once through the system. However, systems can be designed to re-circulate all or a portion of the effluent to treat the wastewater more than once.

3.13.3.2 Subsurface Flow Wetland

Like surface flow systems, subsurface flow systems consist of one or more rectangular cells, which may be operated in parallel or in series. It is common for subsurface systems to be designed with multiple cells operated in parallel to allow the cells to be alternated and rested during maintenance. The bottoms of the cells may be slightly sloped (up to 0.5 percent) to assist the flow of wastewater through the system.

A natural clay or synthetic lining may be necessary for certain sites with high groundwater or permeable soils. Wetlands should be sited away from downspouts and natural drainage areas to avoid excess water from entering the system.

Choosing the treatment media is one the most important design considerations for subsurface flow wetlands. Designers must carefully consider the type, size, uniformity, porosity and hydraulic conductivity of the media material. These characteristics affect the flow of wastewater in the system and the system performance.

Gravel and rock are the most common media used in subsurface flow wetlands. Whatever type or size of media is chosen, the most important concern is that it be as uniform in size as possible. When different size media are placed together the finer materials settle into the open spaces leaving little room for the wastewater flow.

To prevent system clogging the treatment media should be sorted and measured to ensure its uniformity. It should also be washed to remove any fines. A method used to analyze the size and uniformity of treatment media includes sorting them through a series of mechanical sieves of diminishing size. These characteristics are expressed as the media's "effective size" and "uniformity coefficient". The effective size of medium-size gravel is about 32 millimeters and the effective size of coarse gravel is about 128 millimeters.

Certain characteristics of the media determine the rate and pattern of the flow and the efficiency of the treatment. Gravel in the small to medium size range tends to work better than coarse gravel because of the following:

- Medium sized gravel offers a greater number of surfaces where biological treatment can take place than course gravel.
- The smaller spaces between medium sized gravel tend to provide better support for plant growth than the large spaces between coarse gravel.
- Medium sized gravel is more likely than coarse media to promote the slow, even non-turbulent flow of wastewater through the system.
- Medium sized gravel is not as likely to become clogged by the accumulation of solids as fine gravel or sand.

Once the type and size of the media is chosen, its porosity and hydraulic conductivity should be verified in a field or laboratory test. These characteristics are used together with information about the wastewater and the site to design the system.

Most subsurface flow wetlands are designed so that wastewater travels through the length of the cell one time to receive treatment. Typical retention times range from two to six days.

The inlet and outlet areas of subsurface flow systems are sloped more dramatically than the rest of the treatment bed and are filled with coarse gravel or rock to prevent clogging in these areas. Wastewater enters the system either above the gravel at the inlet or below it through perforated pipe or weirs. It is important that the wastewater is distributed as evenly as possible as it flows into the cell to prevent short-circuiting.

Subsurface flow cells are usually designed with aspect ratios of 3:1 or less. Wider cells tend to be more cost-effective because long narrow cells must be deeper and require more treatment media. In addition, the wastewater is less likely to back up in wider cells if too much water enters the system or it the rate of flow changes.

Formulas such as Darcy's law or Ergun's equation can be used to estimate the flow rate through the cells. A combination of approaches and built-in safety factors must be used to ensure system performance. The design can also incorporate a controlled outlet by using and adjustable pipe which can be swiveled up or down to allow the cell to drain to a desired level.

3.13.4 OPERATION & MAINTENANCE

3.13.4.1 Surface Flow Wetland

Surface flow wetlands have few operation and maintenance requirements, but maintenance must be performed properly to ensure system performance. Operation may entail alternating cells or adjusting water levels and harvesting vegetation. Some systems may have banks and berms that need to be maintained, and inlet and outlet structures that should b cleaned periodically. Mosquitoes and burrowing animals present problems in some systems. Different control methods are available, including natural solutions, such as trapping and relocating animals, introducing fish that eat insect larvae, and building bat houses. Over excavating around and below the wetland cell and filling with 2 to 3" leach rock covered with a sand can protect the cell from tunneling rodents.

3.13.4.2 Subsurface Flow Wetland

Surface flow wetlands have few operation and maintenance requirements, but maintenance must be performed properly to ensure system performance. Operation may entail alternating cells or adjusting water levels and harvesting vegetation. Some systems may have banks and berms that need to be maintained, and inlet and outlet structures that should be cleaned periodically and vegetation that may need harvesting.

3.13.5 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.

Advantages:

- Constructed wetlands are typically inexpensive to build and maintain.
- They require little or no energy to operate.
- They can provide effective tertiary treatment.
- They can provide additional wildlife habitat.
- They can be aesthetically pleasing additions to homes and neighborhoods.
- They are viewed as an environmentally friendly technology and are generally well received by the public.
- Accept a wide range of flow scenerio's

Disadvantages:

- Constructed wetlands require more land area than many other treatment options.
- Surface flow wetlands can attract mosquitoes and other pests.
- Wetlands are not appropriate for treating some wastewater with high concentrations of certain pollutants.
- The performance of wetlands may vary based on usage and climatic conditions.
- There may be a prolonged initial start-up period before vegetation is adequately established.
- Vegetation may need to be periodically harvested and dead vegetation may need to be removed.

3.14 SAND LINED TRENCH (A.A.C. R18-9-E319)

Sand lined trenches are composed of engineered placement of sand excavated in native soil. Wastewater is dispersed throughout the media by a timer controlled pump in periodic uniform doses that maintain unsaturated flow conditions.

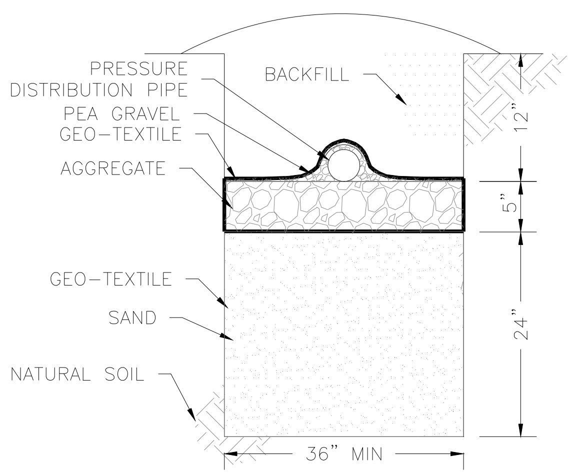
3.14.1 WHY USE A SAND LINED TRENCH.

Like conventional drain fields, sand lined trenches can be designed to work on a variety of home sites and under many conditions.

Sand lined trenches provide increased treatment and allow for smaller disposal fields and reduce the minimum vertical separation from subsurface limiting layers..

3.14.2 PROCESS DESCRIPTION

The sand lined trench utilizes the intermittent dosing of effluent over a course sand to achieve both physical treatment through filtration and biological treatment in the same manner intermittent sand filters work. Review 3.7 Sand Filters (A.A.C. R18-9-E310) for a more indepth discussion on the process description.



Sand Lined Trench

3.14.3 DESIGN CRITERIA

Sand lined trenches are built below grade in 36” wide trenches. There is a minimum of 5 inches of gravel used for dispersal of the effluent. The depth of sand below the gravel is a minimum of 24 inches. A permeable geo-textile fabric is placed all around the gravel layer.

3.14.4 OPERATION & MAINTENANCE

Sand lined trenches require no operation as it is a passive disposal system. It does, however, require periodic inspections. Inspection pipes are typically provided in the design to allow the measurement of the effluent level within each trench. The presence of ponded effluent in the trenches indicates the trenches are being hydraulically overloaded and a reduction in water use must commence immediately.

3.14.5 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.

Advantages:

- Protection of soil long term acceptance and greater long-term leaching capacity..
- ET systems can be used to supplement soil absorption for sites with slowly permeable, shallow soils with high water tables.
- Infiltration areas required are smaller than conventional disposal trenches.
- Minimum vertical separations to subsurface limiting conditions can be reduced.

Disadvantages

- They have a limited storage capacity, and are thereby unable to store wastewater during high flows or seasonal saturation.
- A pump is required which will increase cost.
- If appropriate sand media is not available locally, cost can be high.

3.15 DISINFECTION (A.A.C. R18-9-E320)

Disinfection destroys pathogenic and other microorganisms in wastewater, such as bacteria, protozoan cysts, and viruses. All pretreatment processes used in onsite wastewater management remove some pathogens, but data is limited on the magnitude of this destruction.

A number of methods can be used to disinfect wastewater. These include chemical agents, physical agents, and irradiation. For onsite applications, only a few of these methods have proven to be practical (i.e., simple, safe, reliable, and cost effective). Although ozone and iodine can be and have been used for disinfection, they are less likely to be employed because of economic and engineering difficulties. The two most common methods of disinfection for on-site systems is chlorination and ultraviolet irradiation.

3.15.1 WHY USE DISINFECTION.

Disinfection is generally required in three onsite-system circumstances. The first is after any treatment process that the effluent is to be surface discharged. The second is before a susbsurface disposal field where there is inadequate soil (depth to ground water or structure too porous) to meet ground water quality standards. The third is prior to some other immediate reuse (onsite recycling) of effluent that stipulates some specific pathogen requirement (e.g., toilet flushing or vegetation watering).

3.15.2 CHLORINATION

Chlorine is a powerful oxidizing agent and has been used as an effective disinfectant in water and wastewater treatment for a century. Chlorine may be added to water as a gas, liquid or solid. Because the gas can present a significant safety hazard and is highly corrosive, it is not recommended for onsite applications. Currently, the solid form (calcium hypochlorite) is most favored for onsite applications.

Calcium hypochlorite is typically dosed to wastewater in an onsite treatment system using a simple tablet feeder device. Wastewater passes through the feeder and then flows to a contact tank for the appropriate reaction. The contact basin should be baffled to ensure that short-circuiting does not occur. Chlorine and combined chlorine residuals are highly toxic to living organisms in the receiving water. Because overdosing (ecological risk) and underdosing (human health risk) are quite common with the use of tablets, long swales/ditches are recommended prior to direct discharge to sensitive waters.

Use of simple liquid sodium hypochlorite (bleach) feeders is more reliable but requires more frequent site visits by operators. These systems employ aspirator or suction feeders that can be part of the pressurization of the wastewater, causing both the pump and the feeder to require inspection and calibration. These operational needs should be met by centralized management or contracted professional management.

3.15.2.1 Process Description

Chlorination units must ensure that sufficient chlorine release occurs (depending on pretreatment) from the tablet chlorinator. These units have a history of erratic dosage, so frequent attention is required. Performance is dependent on pretreatment, which the designer must consider. At the point of chlorine addition, mixing is highly desirable and a contact chamber is necessary to ensure maximum disinfection. Working with chlorinator suppliers, designers should try to ensure consistent dosage capability, maximize mixing usually by chamber or head loss, and provide some type of pipe of sufficient length to attain effective contact time before release. Tablets are usually suspended in open tubes that are housed in a plastic assembly designed to increase flow depth (and tablet exposure) in proportion to effluent flow. Without specific external mixing capability, the contact chamber is the primary means of accomplishing disinfection. Contact time in these chambers (often with added baffles) is on the order of 15 to 20 minutes. The commercial chlorination unit is generally located in a concrete vault with access hatch to the surface. The contact pipe usually runs from the vault toward the next step in the process or discharge location. Surface discharges to open swales or ditches will also allow for dechlorination prior to release to a sensitive receiving water.

3.15.2.2 Design Criteria

Chlorine addition by tablet feeders is likely to be the most practical method for chlorine addition for onsite applications. Tablet feeders are constructed of durable, corrosion-free plastics and are designed for in-line installation. If liquid bleach chlorinators are used, they would be similarly constructed. The contact basin may be plastic, fiberglass, or concrete. Baffles should be provided to prevent short-circuiting of the flow. The contact basin should be covered to protect against the elements, but it should be readily accessible for maintenance and inspection.

To assure adequate pathogen destruction, disinfection should only be used on secondary treated effluent. Primary treated effluent, or septic tank effluent, contains to much TSS for either disinfection devise to adequately remove pathogens.

3.15.2.3 Operation & Maintenance

Whenever disinfection is required, careful attention to system operation and maintenance is necessary. Long-term management, through homeowner-service contracts or local management programs, is an important component of the operation and maintenance program. Typical homeowners do not possess the skills needed to perform proper servicing of these units, and homeowner neglect, ignorance, or interference may contribute to malfunctions.

For chlorination systems, routine operation and maintenance includes servicing the tablet or solution feeder equipment, adding tablets or premixed solution, adjusting flow rates, cleaning the contact tank, and collecting and analyzing effluent samples for chlorine residuals. Caking of tablet feeders may occur and will require appropriate maintenance. Bleach feeders must be periodically refilled and checked for performance. There are no power requirements for gravity-fed systems. Chemical requirements are estimated to be about 5 to 15 pounds of available chlorine per year for a family of four. The contact basin may need cleaning if no filter is located ahead of the unit. Safety issues are minimal and include wearing of proper gloves and clothing during inspection and tablet/feeder work.

3.15.3 ULTRAVIOLET IRRADIATION

The disinfection properties of ultraviolet (UV) irradiation have been recognized for many years. Because the only UV radiation effective in destroying the organism is that which reaches it, the water must be relatively free of turbidity (<5 TPU). Because the distance over which UV light is effective is very limited, the most effective disinfection occurs when a thin film of the water to be treated is exposed to the radiation.

Many commercial UV disinfection systems are available in the marketplace. Each has its own approach to how the wastewater contacts UV irradiation, such as the type of bulb (medium or low pressure; medium, low, or high intensity), the type of contact chamber configuration (horizontal or vertical), or the sleeve material separating the bulb from the liquid (quartz or teflon). All can be effective, and the choice will usually be driven by economics.

3.15.3.1 Process Description

The effectiveness of UV disinfection is dependent upon UV power contact time, liquid film thickness, wastewater absorbance, wastewater turbidity, system configuration, and temperature. Empirical relationships are used to relate UV power (intensity at the organism boundary) and contact time. Since effective disinfection is dependent on wastewater quality as measured by turbidity, it is important that pretreatment provide a high degree of suspended and colloidal solids removal.

Commercially available UV units that permit internal contact times of 30 seconds at peak design flows for the onsite system can be located in insulated outdoor structures or in heated spaces of the structure served, both of which must protect the unit from dust, excessive heat, freezing, and vandals. The actual dosage that reaches the microbes will be reduced by the transmittance of the wastewater. Practically, septic tank effluents cannot be effectively disinfected by UV, whereas biological treatment effluents can meet a standard of 200 cfu/100 mL with UV. High-quality reuse standards will require more effective pretreatment to be met by UV disinfection. No additional contact time is required. Continuous UV bulb operation is recommended for maximum bulb service life. Frequent on/off sequences in response to flow variability will shorten bulb life.

3.15.3.2 Design Criteria

Commercially available package UV units are available for onsite applications. Most are self-contained and provide low pressure mercury arc lamps encased by quartz glass tubes. The unit should be installed downstream of the final treatment process and protected from the elements. UV units must be located near a power source and should be readily accessible for maintenance and inspection. Appropriate controls for the unit must be corrosion-resistant and enclosed in accordance with electrical codes.

3.15.3.3 Operation & Maintenance

Whenever disinfection is required, careful attention to system operation and maintenance is necessary. Long-term management, through homeowner-service contracts or local management programs, is an important component of the operation and maintenance program. Homeowners do not possess the skills needed to perform proper servicing of these units, and homeowner neglect, ignorance, or interference may contribute to malfunctions.

Routine operation and maintenance for UV systems involves cleaning and replacing the UV lamps and sleeves, checking and maintaining mechanical equipment and controls, and monitoring the UV intensity. Lamp replacement (usually annually) will depend upon the equipment selected, but lamp life may range from 7,500 to 13,000 hours. Quartz sleeves will require alcohol or other mildly acidic solution at each inspection.

3.16 SURFACE DISPOSAL (A.A.C. R18-9-E321)

Surface disposal of wastewater is allowable if the wastewater is nominally free of coliform bacterial. These systems cannot be used if the average minimum temperature in any month is 20º F or less or if over 1/3rd of the average annual precipitation falls in a 30 day period.

3.16.1 WHY USE SURFACE DISPOSAL.

Spray irrigation is an efficient way to nourish plants and apply reclaimed wastewater to land. Some spray systems are very similar to potable-water sprinkler systems used to irrigate lawns. Others are specifically designed for agricultural applications. While there are many possible spray system designs, they all work by distributing treated wastewater across the soil surface. Systems should be designed by qualified professionals who have specific experience working with irrigation systems.

Because spray systems apply effluent above-ground, the wastewater must be treated to a high enough level to protect public health and reduce odors. In general, the rule requires that effluent used for surface irrigation meet secondary treatment standards plus disinfection.

3.16.2 DESIGN CRITERIA

With spray systems, therefore, after primary treatment in a septic or trash tank, the wastewater usually goes to a secondary treatment system, and then to a dosing tank or pump chamber. The wastewater is then disinfected with chlorine, ozone, or ultraviolet light before it is stored in a holding tank for later use or just prior to its application to land.

After treatment, filtration, and disinfection, a pump equipped with timers sends the wastewater under pressure through the mains and lines of the spray distribution system at preset times and rates as needed for irrigation. The area to be irrigated must be vegetated and properly landscaped to minimize runoff and erosion.

Chlorination is the most common disinfection method used with spray irrigation. One common chlorinator design accepts chlorine tablets or powder; another doses liquid chlorine into the wastewater. With chlorination, adequate contact time is necessary to allow the chlorine time to kill harmful bacteria and other pathogens.

A holding tank or lagoon is another necessary component in most spray systems, because storage space allows operators to adjust application rates, if needed. In some onsite systems that employ a recirculating sand filter, the recirculation tank serves as the storage tank. However, spray systems in cold or wet climates may need to store 130 days of design flow or more.

Systems can be programmed to adjust application rates for different parts of the field and to shut off automatically during rain or high winds. And some can be operated remotely.

There is a variety of sprinkler designs for irrigating lawns, and landscaping, which are similar to potable-water lawn sprinkler systems.

The sprinklers can be fixed (called solidset) or moveable, buried or above-ground, and some designs are telescoping to adjust the height of application to fit the height of the plants. Other variations exist in the amount of pressure and manner in which the wastewater is released from the sprinklers—examples include full circle, partial circle, gun, and microspray. Different pressure amounts are appropriate for irrigating different plant types. Individual home systems use low trajectory sprinklers to minimize aerosol production.

Fixed, buried sprinkler systems usually are among the most expensive designs to purchase and install, but they have certain advantages. They are less likely to be vandalized or accidentally damaged and they make maneuvering lawn mowers easier. Most spray system designs include valves and controls that allow operators or homeowners to adjust the flow to certain areas of the spray field. Some larger systems have both automated and manual controls.

Unlike traditional irrigation systems whose sole purpose is to deliver water to plants, several additional factors must be considered when managing wastewater irrigation systems. The timing and rate of wastewater application must be designed so that plants benefit as much as possible from the nutrients and other constituents in the wastewater without being overwhelmed by them. In addition, there is the potential that certain wastewater constituents may accumulate in the soil and plants over time and become toxic to the plants, clog the soil, or alter the soil structure.

For example, too much nitrogen can result in nitrate accumulation, but too little can result in reduced plant growth. If evaporation regularly exceeds precipitation, which is true for most of Arizona, too much salt may remain in the soil, which can damage roots. The particular characteristics of the wastewater must be considered in relation to such factors as climate and the individual nutrient requirements of the crops, grass, or landscape plants selected.

In addition, the need to dispose of the wastewater has to be balanced with the needs of the plants during various stages of growth and the hydraulic capacity of the soil and its ability to effectively provide treatment.

If a system is designed and sized primarily for wastewater disposal, the loading rates permitted for the wastewater may be below the irrigation needs of the plants. Therefore, additional water may be required for irrigation with some systems.

3.16.3 OPERATION & MAINTENANCE

The pump, disinfection system, and spray heads in spray irrigation systems require regular maintenance. For example, the chlorine tablets in chlorinators need to be replenished regularly—approximately once per month for home systems. Open pipes and spray heads can become damaged, plugged, or frozen. Any changes in pressure in the system can alter the spray patterns in the field, so spray patterns should be tested to ensure that the system still complies with all setback requirements.

Access to the site from the public must be avoided, which requires signs. In some systems, regular daily or weekly monitoring is needed to check influent and effluent quality, system storage capacity, wind speed and direction, signs of ponding or runoff in the spray field, and depth to water table. Cumulative levels of nutrients, heavy metals, fecal coliforms, and other wastewater constituents must be monitored in the soils (and groundwater) at some sites once or twice per year. Additionally runoff of the wastewater and wastewater that has commingled with precipitation must be avoided, requiring containment burns around the entire irrigation area. These berms are susceptible to erosion and need constant upkeep to assure they are not breached

3.16.4 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.

Advantages:

- When properly designed, installed, and operated, most spray systems provide uniform distribution of wastewater to plants and eliminate discharge to protected waters.
- Above-ground irrigation is needed for some germinating plants.
- Spray irrigation increases levels of nitrogen, phosphorus, and minerals in the soil.
- Above-ground spray system components are easier to inspect, control, and service than subsurface drip irrigation components.
- When performed during the heat of the day it has a cooling effect on some crops and decorative landscape plants.
- Evaporation contributes to the rate of wastewater disposal.

Disadvantages:

- Requires secondary treatment and disinfection.
- Must be enclosed by somewhat intrusive berms not allowing any discharge even during the 10 year 24 hour precipitation event.
- Requires warning signs.
- Cannot be used in colder climates of the state.
- Spray systems generate aerosols, which can pose a threat to public health.
- Wet soil surface promotes weed growth, making some landscaping difficult to maintain.
- Wet soil surface makes weeding, harvesting, and operating lawn mowers more difficult.
- Above-ground spray equipment is exposed to the elements and can be accidentally damaged or vandalized.
- Bacteria tends to survive better in wet, cool soil conditions.

3.17 DRIP SYSTEMS (A.A.C. R18-9-E322)

Drip irrigation systems are an efficient and proven technology to recycle and dispose of wastewater. A drip irrigation system receives high quality wastewater from an advanced onsite wastewater treatment facility and dispenses it through a shallow network of drip tubes and emitters. The system is designed to disperse the wastewater into the soil under unsaturated conditions by pressure distribution and timed dosing. The system reduces the downward percolation of the wastewater by enhancing evapotranspiration to the atmosphere.

3.17.1 WHY USE DRIP IRRIGATION

Drip irrigation can easily be installed on sites with large undulating slopes. It can be installed without disturbing the site as much as trench or bed construction does.

A properly engineered and managed subsurface drip irrigation system using reclaimed water offers many advantages over conventional disposal methods it minimizes health risks associated with exposure to reclaimed water by distributing the effluent below grade. It directly applies the water to plant rootzones and achieves a more manageable balanced water distribution throughout a relatively shallow soil profile.

Drip irrigation systems are considered when high groundwater, shallow soils slowly permeable soils or highly permeable soils are present at the site or when water conservation is needed.

In the past the primary challenges of utilizing subsurface drip irrigation for long term applications have been the potential for internal plugging of the emitter devices and external root intrusuion into the drip tubing.

3.17.2 PROCESS DESCRIPTION

Drip irrigation is the slow and precise application of water, in this case treated wastewater, into a plants rootzone. Drip systems for subsurface wastewater disposal typically consists of flexible polyethylene dripline with large turbulent flow emitters regularly spaced. The line is buried from 6 inches to 12 inches below grade. Wastewater is pumped through the drip lines under pressure, but discharges slowly from a series of evenly-spaced drip emitters. They are fitted with turbulent flow and sometimes pressure-compensating emitter devices.

Systems are engineered to maintain a relatively consistent pressure inside the drip lines, usually about 20 psi. The pressure-compensating emitters allow drip irrigation lines to be installed at different elevations at a site while maintaining a uniform flow.

Because subsurface drip irrigation systems release the wastewater below ground and directly into the plant roots, they irrigate very efficiently and there is little opportunity for the wastewater to come in contact with humans or animals.

By discharging the wastewater into the root zones of plants the water is delivered to the most biologically active soil horizon, which enhances treatment and minimizes the possibility of groundwater contamination. The constant moisture in the root zone also increases the availability of nutrients to plants, reducing the delivery of nitrogen to groundwater.

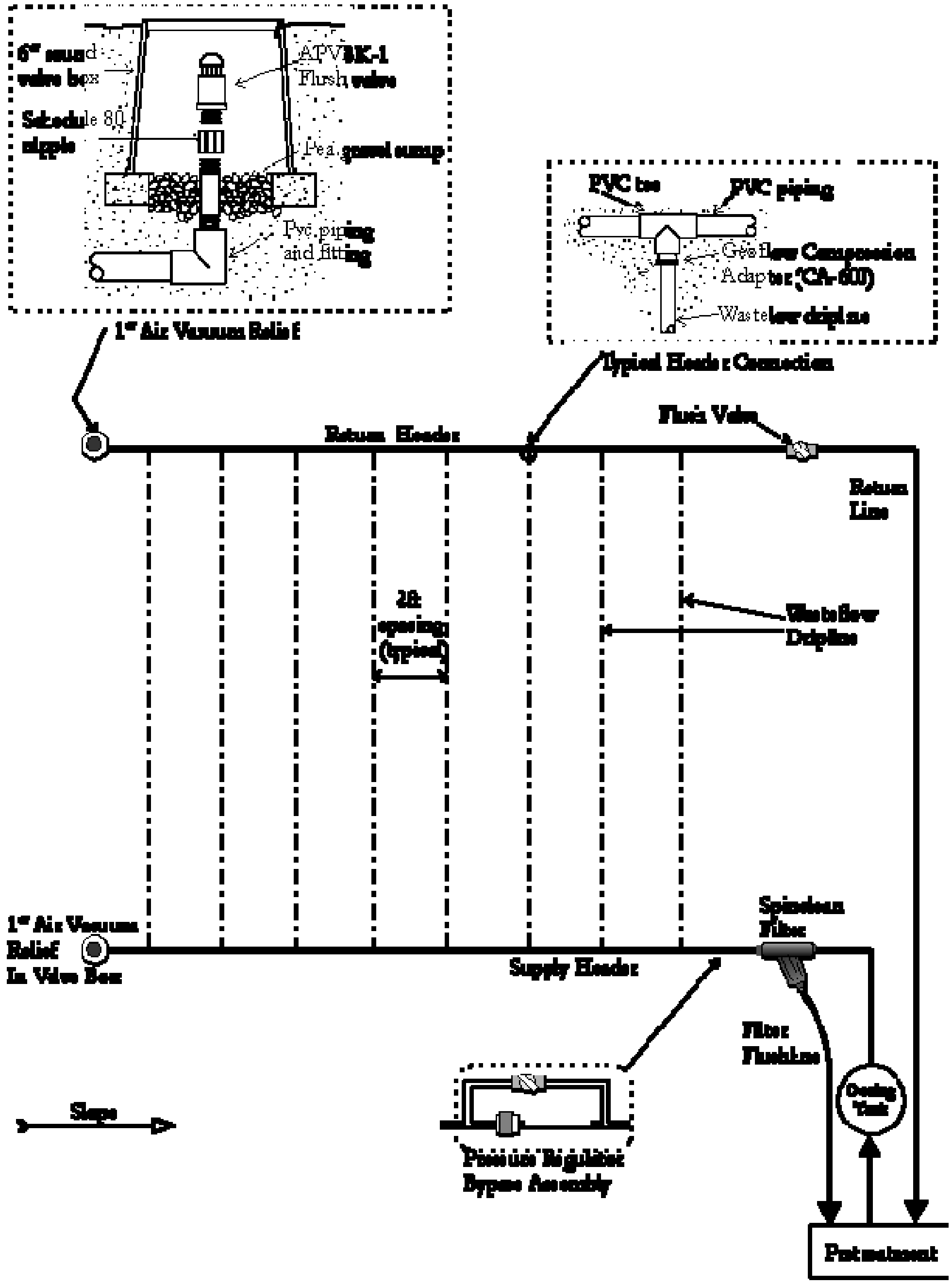
3.17.3 DESIGN CRITERIA

The wastewater must be pretreated prior to drip irrigation to protect public health and the environment and to prevent systems from clogging. Settleable and floatable solids are removed by primary treatment (septic tank or pretreatment tank). Secondary treatment is also required to remove BOD and more solids. In most systems, the treated effluent collects in a pump chamber where it is stored until a predetermined dosing volume or time is reached. All drip systems are equipped with a filtration system before the distribution system to remove small-suspended solid materials that may clog the drip lines or emitters. The size of materials that may pass the filter should be four to six times smaller than the emitter orifice size. The system may include disinfection to protect water resources or public health.

Placement of the drip irrigation lines and emitters are placed at twelve inches below grade, they can be placed as shallow as six inches if there is not a concern of freezing and the effluent was disinfected. Regulations typically require that drip systems be installed an minimum distances from structures, property lines, wells, water resources and groundwater.

The distribution system includes a discharge manifold, a return manifold, drip lines and emitters. A pressure regulator assures that excessive operating pressure or surges do not damage the drip irrigation system. If the system is built on a steep site, several pressure regulators may need to be used to assure equal pressures at all drip emitters. Air vacuum release valves are installed to prevent water and soil being drawnback into the emitters. The drip lines and emitters are spaced at 12 to 24 inches apart, giving each emitter one to four square feet to disperse water. As the drip lines are placed slight variations allow preservation of existing trees and shrubs. The emitters discharge from 0.5 to 2.0 gallons per hour. The system must be designed to flush the irrigation components with wastewater. Piping and valves allow the wastewater to be pumped in a line flushing the system and discharging back to the treatment system. The system can be designed and constructed to automatically back flush the system after a specific number of doses or the system can be built to manually back flush the system when necessary.

The EPA approves the use of chemical trifluralin to prevent root intrusion into the emitters. Some manufactures of drip irrigation systems incorporates the root intrusion chemical barrier directly into the tubing material itself.



Drip Irrigation Field
(Drawing from Geoflow Inc. Design Manual)

3.17.4 OPERATION & MAINTENANCE

Root intrusion into the drip lines and internal clogging from the buildup of sediment, suspended solids, algae and bacterial slime have been diminished greatly by better pretreatment, filtration disinfection, and new improved tubing and emitter designs. Most systems allow for flushing at scouring velocity to remove slime and sediment buildup. If scale (calcium carbonate and salts) buildup develops on emitters and acid treatment may be required.

When emitters clog it affects the pressure inside the drip lines and wastewater distribution in the field. It is very difficult to identify and service buried emitters that clog. Saturation of the soil around emitters can eventually lead to the formation of a biological clogging mat, which can cause system failure.

Filters on drip systems need to be checked and periodically back flushed or cleaned. Back flushing reverses the water flow through the lines and filters to release trapped sediments. As mentioned above systems can be set up to backwash automatically at preset intervals, or operators can do it manually as needed. The wastewater flow needs to be checked periodically to determine if any emitters are plugging.

The impregnated herbicides have a life-span of approximately 15 years. When the herbicides no longer control the growth of algae or stop root penetration the system will have to be removed and replaced. Some manufacturers have the herbicides impregnated into the filter cartridge making it easier to assure adequate herbicide is available.

3.17.5 ADVANTAGES & DISADVANTAGES

Some Advantages and Disadvantages are listed below.

Advantages:

- Can be used in adverse terrain conditions.
- Is associated with water reuse because emitters are typically placed in the rootzone.
- Wastewater is distributed more evenly than spray systems or trenches.
- Ease in construction.
- Can be plowed into soil around objects, such as rocks or trees.

Disadvantages:

- Effluent to drip disposal must be filtered to remove all solids to avoid clogging.
- No storage in trench.
- Emitters can potentially clog, affecting the uniformity of application.
- It is difficult to monitor and correct potential emitter clogging.
- System must be back flushed routinely to avoid clogging of the emitters.
- May be sensitive to extremely cold temperatures.
- The impregnated herbicides have a life span.

4. REFERENCES:

Ball, E. 1995. *Pressure Dosing: Attention to Detail.* Orenco Systems, Inc. Sutherlin, Oregon.

Bounds, T. *Septic Tank Septage Pumping Intervals*. Orenco Systems, Inc. Sutherlin, Oregon.

Brown, L., R. Bartholomew and J. Bale. 2004. *Eljen In-Drain Design Specifications*.

Burks, B. and M. Minnis. 1994. *Onsite Wastewater Treatment Systems.* Hogarth House, LTD. Madison, Wisconsin.

Carlile, B.L. and A. Sanjines. *Subsurface Trickle Irrigation System for On-Site Wastewater Disposal and Reuse.* Geoflow Inc. San Francisco, CA .

Converse. C. 1999. *Mound Systems for On-Site Wastewater Treatment and Dispersal.* University of Wisconsin, Madison, Wisconsin.

Converse, C. and J. Tyler. 1990. *Wisconsin Mound Soil Absorption System Siting, Design and Construction Manual.* University of Wisconsin, Madison, Wisconsin.

Converse, C, E. Tyler and O. Peterson. 1990 *Wisconsin At-Grade Soil Absorption System Siting, design, and Construction Manual*. University of Wisconsin, Madison Wisconsin

Crites, R. and G. Tchobanoglous. 1998. *Small and Decentralized Wastewater Management Systems.* The McGraw-Hill Companies. New York, New York.

H. Henry. 1995. *Intermittent and Seasonal use of the Puraflow Peat Biofilter.* Bord Na Mona, Inc. Greensboro, North Carolina.

Kahn, L, B. Allen and J. Jones. 2000. *The Septic System Owner's Manual.* Shelter Publications. Bolinas, California.

National Small Flows Clearing House. *Pipeline Winter 1996, Vol. 7, No. 1.* West Virginia University, Morgantown, West Virginia.

National Small Flows Clearing House. *Pipeline Winter 1996, Vol. 10, No. 1.* West Virginia University, Morgantown, West Virginia.

National Small Flows Clearing House. *Pipeline Summer 1997, Vol. 8, No. 3.* West Virginia University, Morgantown, West Virginia.

National Small Flows Clearing House. *Pipeline Summer 1998, Vol. 9, No. 3.* West Virginia University, Morgantown, West Virginia.

National Small Flows Clearing House. *Pipeline Summer 1999, Vol. 10, No. 3.* West Virginia University, Morgantown, West Virginia.

National Small Flows Clearing House. *Pipeline Winter 1999, Vol. 10, No. 3.* West Virginia University, Morgantown, West Virginia.

National Small Flows Clearing House. *Pipeline Summer 2001, Vol. 10, No. 3.* West Virginia University, Morgantown, West Virginia.

National Small Flows Clearing House. *Pipeline Fall 2002, Vol. 13, No. 4.* West Virginia University, Morgantown, West Virginia.

Gushiken E., 1993. *Effluent Disposal Through Subsurface Drip Irrigation Systems.* Hawaii Water Pollution Control Association 15th Annual Conference, Honolulu, Hawaii

Solomon, C. 2000. *The Use of Peat Filters in Domestic Wastewater Treatment. Small Flows Quarterly, Winter 2000, Vol. 1, No. 1.* West Virginia University, Morgantown, West Virginia.

Solomon, C., P. Casey, C. Mackne and A. Lake. 1998. *Composting Toilet Systems Fact Sheet.* National Small Flows Clearing House, West Virginia University, Morgantown, West Virginia.

Solomon, C., P. Casey, C. Mackne and A. Lake. 1998. *Evapotranspiration Systems Fact Sheet.* National Small Flows Clearing House, West Virginia University, Morgantown, West Virginia.

Solomon, C., P. Casey, C. Mackne and A. Lake. 1998. *Intermittent Sand Filters Fact Sheet.* National Small Flows Clearing House, West Virginia University, Morgantown, West Virginia.

Solomon, C., P. Casey, C. Mackne and A. Lake. 1998. *Low-Pressure Pipe Systems Fact Sheet.* National Small Flows Clearing House, West Virginia University, Morgantown, West Virginia.

Solomon, C., P. Casey, C. Mackne and A. Lake. 1998. *Mound Systems Fact Sheet.* National Small Flows Clearing House, West Virginia University, Morgantown, West Virginia.

Solomon, C., P. Casey, C. Mackne and A. Lake. 1998. *Recirculating Sand Filters Fact Sheet.* National Small Flows Clearing House, West Virginia University, Morgantown, West Virginia.

U.S. Environmental Protection Agency. 1977. Operations Manual Package Treatment Plants. EPA Office of Water Program Operations. Washington, D.C.

U.S. Environmental Protection Agency. 1997. *Response to Congress On Use of Decentralized Wastewater Treatment Systems.* EPA Office of Wastewater Management. Washington, D.C.

U.S. Environmental Protection Agency. 2002. Onsite Wastewater Treatment Systems Manual. EPA Office of Water Program Operations. Washington, D.C.

Walsh, J. and H. Henry. 1998. *Performance of the Puraflo Peat Biofilter Single Pass and Recirculating Systems.* 2nd Southwest Onsite Wastewater Management Conference and Exhibit Proceedings.