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MODULE 2

Title 5 Setbacks and Separations

What Every Board of Health Should Know

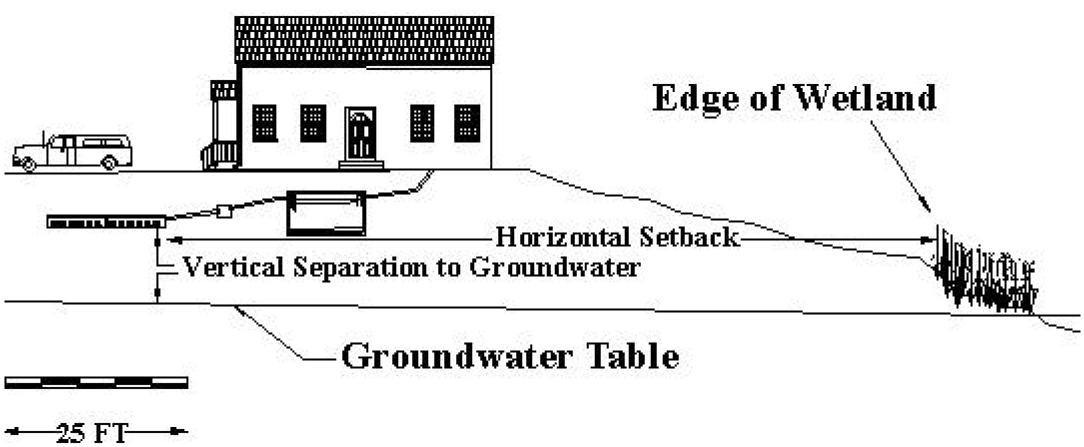
Introduction

Among the most common types of variance requests received by Boards of Health are requests for relief from various setback or separation distances required in Title 5. These horizontal setbacks (as denoted in Section 15.211 Minimum Setback Distances) and vertical separations requirements (as denoted in Section 15.212: Depth to Groundwater), as well as some of the prohibitions on placing septic systems in certain "sensitive" areas are among the most crucial aspects of the code in respect to protecting the public health and the environment.

While the terms "setback" and "separation" when applied to life in general conjure up negative images, in the onsite sewage world these terms merely refer to the position of a septic system relative to a physical feature.

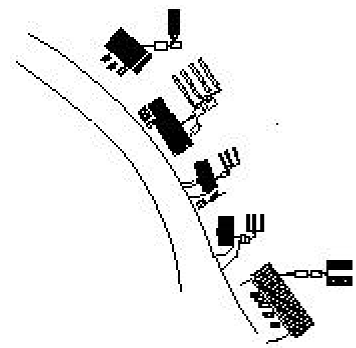
A ***Setback*** (also sometimes referred to as horizontal separation) is the distance from a septic system component to a land-surface feature such as a property line, wetland, private well, public water supply etc. The various requirements for setbacks of septic tanks and leaching systems are listed in 310 CMR 15.211 Minimum Setback Distances.

Vertical Separation (sometimes referred to simply as ***separation***) refers to the distance between the bottom of the leaching facility or soil absorption system and the groundwater. Title 5 requirements in this regard are contained in 310 CMR 15.212 Depth to Groundwater.



This learning module primarily concerns itself with the issue of vertical separation. It hopes to present the technical foundation on which proper vertical separation distances are determined, and to give to you, Board of Health members and agents, information by which you can determine whether a particular variance request from these provision is appropriate for a given situation. **Horizontal Setbacks will be discussed in detail in Module #3.**

A Word about Variances before we go.



You may wonder, as you go through this module "Why am I learning all this stuff?". While it's true that this course is probably showing you more than you ever wanted to know about septic systems (or could ever discuss in polite conversation), consider the following. When someone asks a Board of Health for a variance, they are essentially charged with proving to the Board that granting the variance will not materially affect the public health and further, that the proposed system deficiency is compensated for somehow by an action, design modification or extenuating site detail that provides "a level of environmental protection that is at least equivalent to that provided under 310 CMR 15.000"[1]. How does a Board of Health fulfill their charge to protect the public health and the environment by ensuring that this test is sufficiently met? They either **a)** become savvy enough to understand the principles involved and the technical foundation of those requirements, or **b)** they rely on the proponent's claim that they meet the "test" and hope for the best. If you chose "a", this bud's for you.

So let's get going. We begin first with TREATMENT 101, a discussion of the treatment of effluent as it passes through the soil absorption system. You may wish to review Module 1 before you start, particularly the discussion of treatment in the septic tank. Following the discussion on treatment in the unsaturated zone under the leaching facility, we will discuss groundwater determination as it is carried out under the revised code. Finally, we will summarize how the principles we learned can be brought to bear on variance request from vertical separation (which also as we will see is integrally connected with requests for reduction in leachfield size).

Again - Have Fun!

SEWAGE TREATMENT 101 (PART 2) - LIFE AFTER THE SEPTIC TANK.

As we learned in the first module, a properly functioning septic tank sends liquid wastes (with some finely ground solids - called "suspended solids") to the leaching component of the system. This effluent typically contains high densities of bacteria (> 10^8 per 100 mls of sample), and has the potential to contain pathogenic bacteria and viruses at concentrations capable of transmitting disease. Chemically, the effluent contains mineralized by-products of bacterial breakdown (ammonium, phosphate, sulfates) and a dissolved organic "soup". Pipes and structures convey the septic tank effluent to the soil interface, where the ultimate goal is to spread the effluent out over the entire surface area of the soil surrounding the soil absorption system. Now, let's take the journey of the effluent as it departs the structures of the septic system and passes first vertically through the soil (this Module), and then horizontally away from the site with the groundwater (Module 3).

Biomat - The First Line of Defense

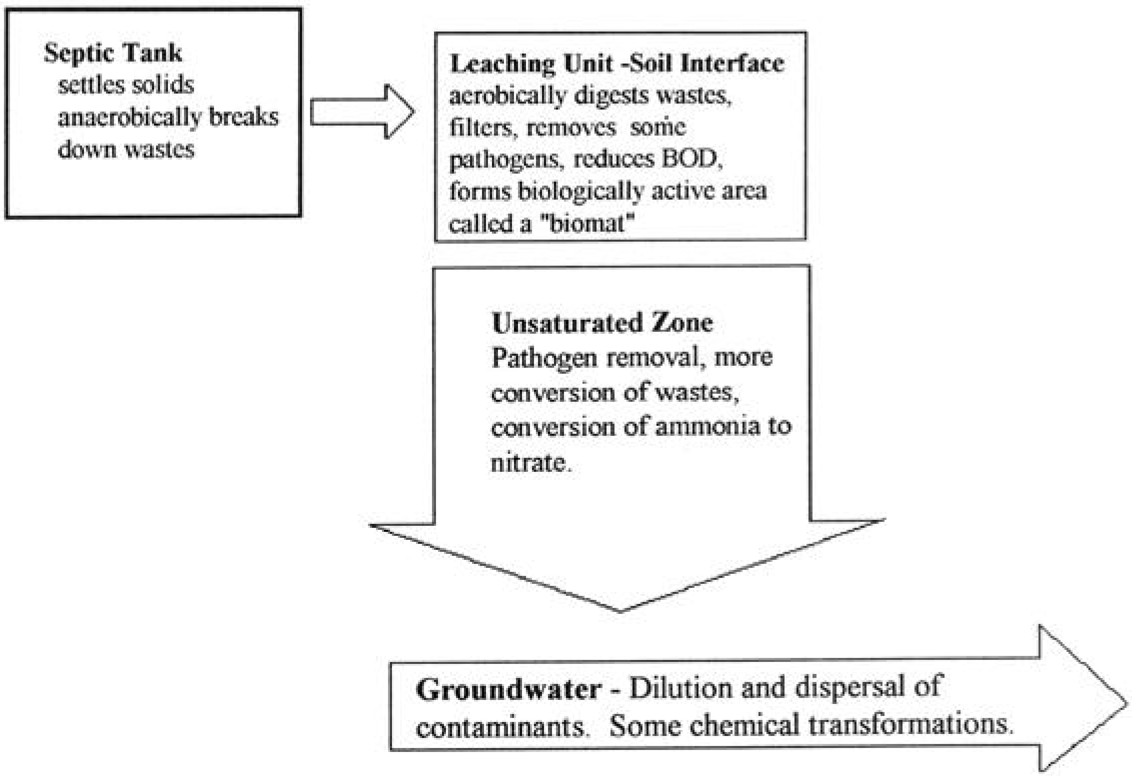
Although it can not do the job of treatment by itself, **the vertical separation between the bottom of the leaching facility and groundwater** (or in some instances an impermeable layer of bedrock) **is the most important characteristic of overall system design for preventing disease transmission**. To understand the truth in this statement, we first need to understand what are the important features in this area that affect treatment and how they are modified with different design changes. So let's start first, where the action is relative to waste treatment - the soil particle surface!

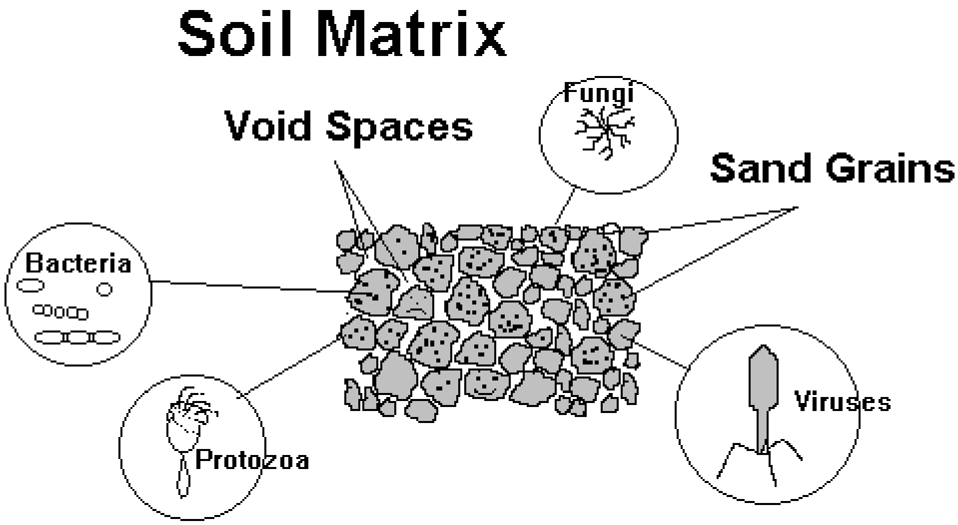
As septic tank effluent is distributed onto the gravel aggregate and the surrounding soil at the leaching facility-native soil interface, it encounters a mini-ecosystem that has developed on each soil grain. In the immediate area where the installed leaching components of the septic system contact the native soil, a relatively dense sewage-digesting community of organisms develops that is known as the biological mat or "biomat" for short. The biomat is a very important feature of a properly functioning system. Ideally, this area, which varies in thickness, contains a diverse community of bacteria, fungi, protozoa (small one-celled animals that eat bacteria), and even nematodes (small wormlike organisms that eat anything they can get). These organisms are not necessarily *pathogenic* (capable of transmitting disease in humans). Many of them are naturally-occurring microbes, species of which have been breaking down larger organic molecules for eons. In fact, if there weren't such organisms, we would be knee high in our own wastes and garbage in no time. These organisms best treat wastes where the conditions are **aerobic** (in the presence of oxygen). The main thing to remember about these treatment organisms is that they live, for the most part, on the soil particle surface. They remove contaminants from the septic tank effluent as it passes over and through their neighborhoods (the grain surface).

The biomat serves two very important functions. Foremost it supports bacteria that breakdown and change wastes into soluble components that can be carried away with the liquid. The protozoan community, made up of mobile and voracious organisms, actively crop the sewage-digesting bacteria, keeping their populations healthy, and as an added benefit also eat many of the *pathogenic bacteria* that come from the septic tank. Many of these pathogenic bacteria following passage through the anaerobic septic tank that is relatively devoid of predators, now find themselves in an environment where they are not adapted to feed, and hence become food themselves. As for the pathogenic viruses? No such luck! Since viruses have no nutritional requirements, they can persist for extended periods until their protein coatings or genetic material is destabilized or broken down. Virus persistence in the biomat is dependent on a number of factors including temperature, pH, moisture content, presence of oxygen etc., and is type-specific. Additionally, the small size of viruses may allow their passage through the biomat into the underlying soil. Viruses will be discussed in detail later.

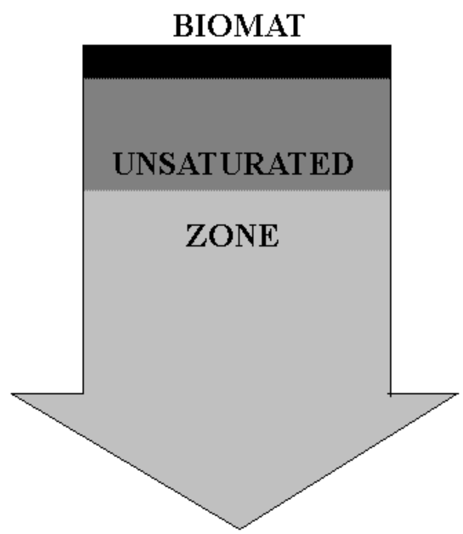
{PRIVATE}Under anaerobic conditions bacteria can not completely break the wastes down, leaving excess material to clog the pore space. In addition, protozoan that would otherwise keep the bacterial community "healthy", have trouble breathing and can not survive.

So, to summarize; the soil beneath a leaching facility is a matrix made up the grains of soil, the void spaces, moisture, and the organisms living on the surface of the soil grains. Treatment of the wastes occurs as it passes over and through the areas where the organisms have colonized. The number of organisms and their diversity depends on, among other factors, the moisture conditions, the amount of oxygen, the amount of food or nutrients, and the acidity.





The second function of the biomat is to provide for unsaturated flow of effluent from the leaching components to the groundwater!



Beneath the biomat in a properly designed leaching facility is at least 4-5 ft of permeable material prior to encountering groundwater. In this zone, in a decreasing gradient away from the bottom of the biomat, is a community of organisms that further break down the wastes aerobically (remember - in the presence of oxygen). The organisms in this area are *thinly distributed over the soil particles*. Many of these organism can not exist in the "harsher" environment of the biomat and rely on the major strength of the sewage to be reduced there[2]. For these communities to do their job properly, *the effluent must pass over them in a thin layer or film.* To support these beneficial communities of sewage digesting organisms, the void space between the soil particles must also allow for the passage of necessary air containing oxygen. When the void spaces between the grains of sand or other soil allows the passage of effluent, and also allows the majority of the space to contain air, we say that the flow through the soil is *unsaturated*. The biomat, which forms a restrictive layer across the leaching component-soil interface evens the flow across the entire infiltrative surface and provides for unsaturated flow beneath the leaching facility. In the process, limited ponding of effluent across the entire infiltrative surface occurs.

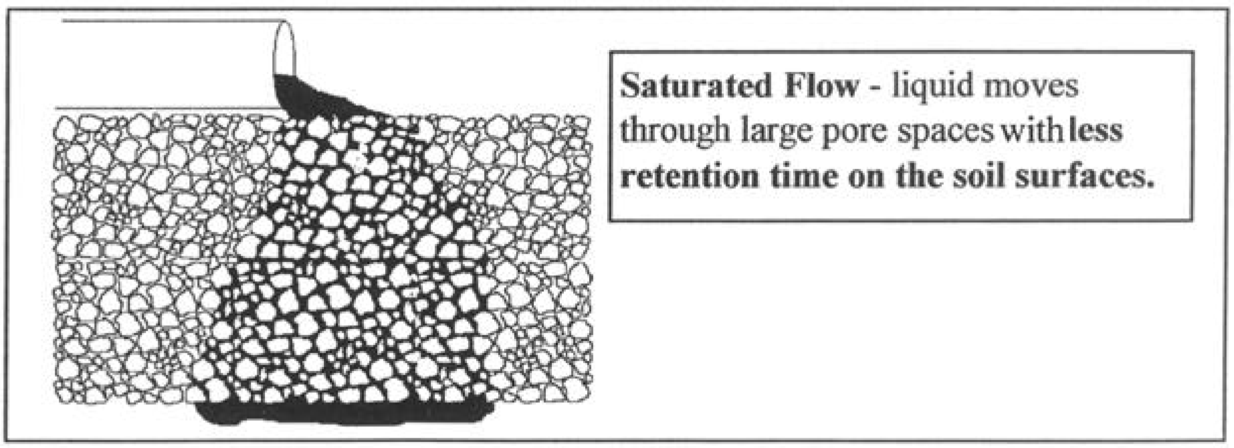
THE OBJECTIVE OF A LEACHING FACILITY IS TO PROVIDE UNSATURATED FLOW OF EFFLUENT TO THE GROUNDWATER

THE OBJECTIVE OF A LEACHING FACILITY IS TO PROVIDE

UNSATURATED FLOW OF EFFLUENT TO THE GROUNDWATER

(YES THIS IS IMPORTANT!)

The reason for this performance objective is that **unsaturated flow of effluent through soils offers superior treatment**. Again, unsaturated flow results in superior treatment because the effluent passes in a thin film over the biologically-active surface of the soil particles where it receives maximum exposure to attached microorganisms. During saturated flow, effluent fills the voids of the receiving soil and allows particulate contaminants (such as bacteria and viruses) to pass untreated through the large passageways between the soil particles. Since most of the biological activity that transforms and treats wastes occurs in the thin surface film of the soil particles, large passageway flow minimizes the treatment.



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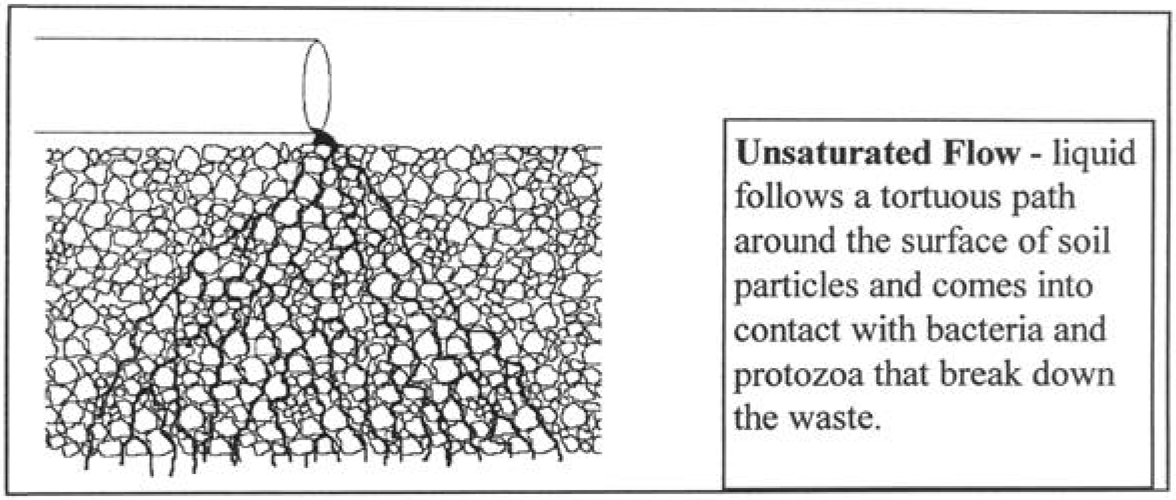
In unsaturated flow, the effluent passes through a tortuous path over the soil particles. Bacteria and protozoa that grow on the soil particles come in contact with the effluent and break the wastes down. **A key thing to remember is that unsaturated flow exposes the effluent to the biologically active sites on the soil surfaces that transform the wastes and reduces the pathogens**.



So, how can we achieve aerobic and unsaturated flow

beneath the soil absorption system ?

It's actually quite simple. Spread smaller amounts of effluent per given area, closer to the surface of the ground where air exchange is more likely. Sound familiar ? It should! Recent revisions to Title 5 requiring shallower profile systems[3] within three feet of the surface[4], with greatly reduced loading rates[5] (Section 310 CMR 15.242: LTAR - Effluent Loading Rates) are designed to encourage aerobic unsaturated flow. The reduction in allowable loading rates is a large step toward recognizing the need for treatment in addition to mere disposal.

Since Unsaturated Conditions Beneath the Leaching Facility Are So Essential to Good Treatment,

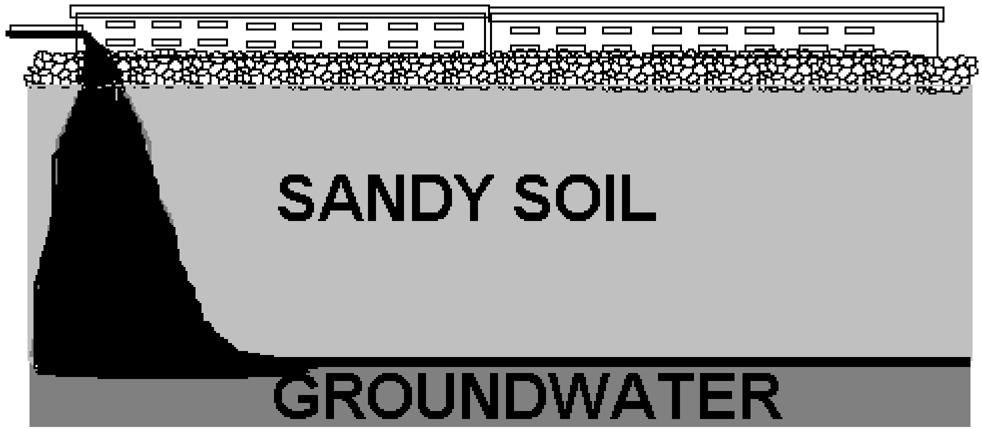
How do Septic Systems that Conform to the Revised Title 5 Promote the Necessary Unsaturated Flow Beneath their Leaching Facility ?

Good Question !

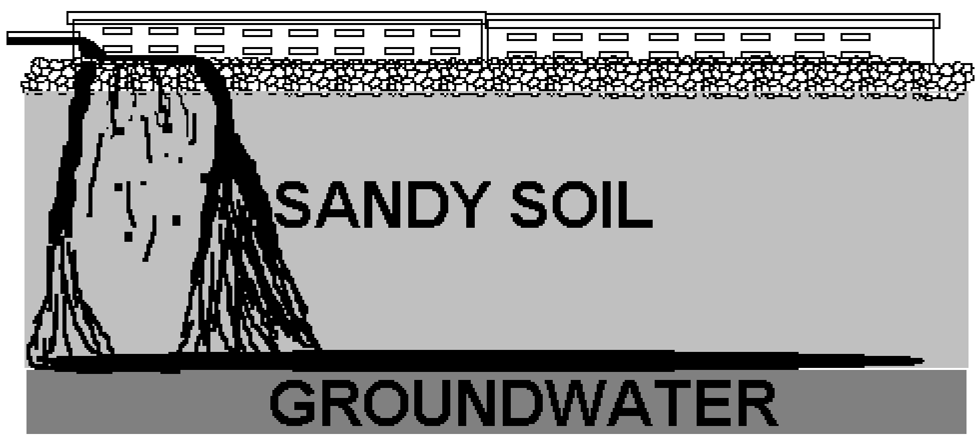
We have seen that in order to get the most out of the soil absorption system relative to treatment, the septic tank effluent must be evenly distributed over the maximum amount of infiltrative surface. Does this happen in a regular gravity-fed[6] leachfield ? Yes and No!

Even in the best constructed gravity-fed system, effluent in a newly-constructed system spills out onto only a limited portion of the infiltrative surface area. As the biomat forms, that limited area becomes somewhat clogged and less infiltrative, and the effluent spills to adjacent areas. This process continues until the entire infiltrative surface of the soil absorption system seals to some extent. This process has been variously called progressive maturation, progressive clogging, progressive biological mat formation, and even progressive "failure" .

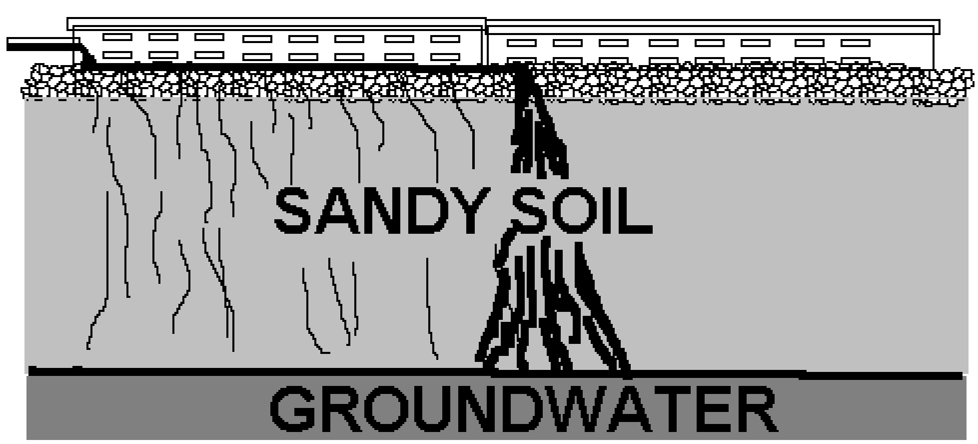
Exaggerated flow pattern of effluent in the start up of a Title 5 system with leaching chambers.



Early stage of biomat formation, still resulting in uneven and locally high hydraulic loading.

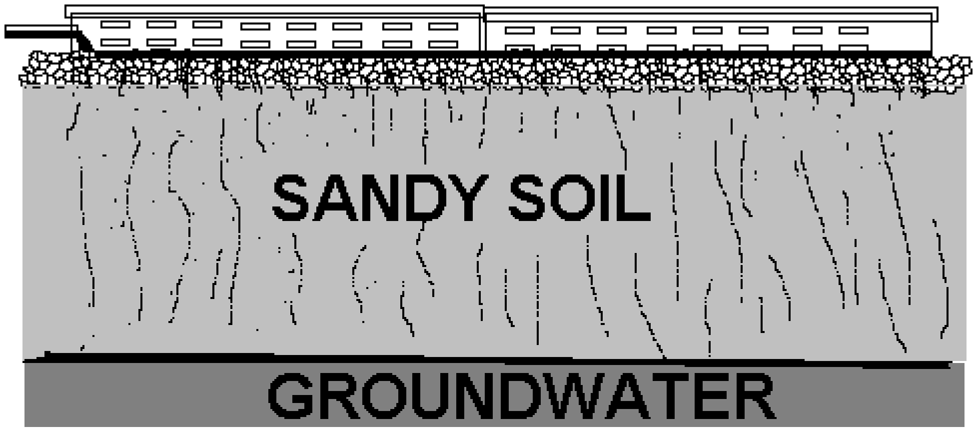


Still later stage of progressive biomat formation, continuing to show some areas of high hydraulic loading. Some flow is evened out by passage through existing biomat.



Idealized final stage of biomat formation. Ideally, the biomat covers the entire infiltrative

surface, evening out the vertical flow to groundwater, yet not being hydraulically restrictive to the point where there is excessive ponding of effluent on top of the biomat.



In gravity-fed systems, unsaturated flows beneath the leaching facility are supposedly maintained by the uniform restrictive action of the biomat. The biomat evens and slows the vertical flow through the system when it completely covers the infiltrative surface. In ideal situations, the continual addition of cells, organisms and byproducts to the biomat is balanced by the breakdown and digestion of dead cell mass and byproducts. Ideally ponding in the system is maintained at a minimum, which promotes the continuance of aerobic conditions. Under these conditions the biomat remains "healthy"; digesting and recycling the dead biomass, at the same rate that new biomass is added during the waste-digestion process. This principle forms the basis of the long term acceptance rate (LTAR) referred to in Section 15.242 LTAR - Effluent Loading Rates.

A logical question arising from this discussion is "How long does it take the biomat to mature?" The answer depends on the strength of the sewage, the soil characteristics, and other factors. Many have speculated that in general six months up to one or two years may be necessary to form a "mature" biomat. What happens in the meantime? Higher hydraulic loadings in certain sections of the system occur until the vertical flows are evened by the biomat, with less residence time of effluent in the treatment zone, and possibly saturated flow to the groundwater.

In some situations, it is unlikely that the previously described scenario of a progressive biomat formation that ultimately results in a stable biomat and even unsaturated flow to the groundwater, will occur. What are these situations ?

Seasonal Homes - In residences used seasonally and having gravity fed leaching components, the beginning of each season will, in essence, be a new starting point for the biomat formation. Higher localized hydraulic loadings will mean less treatment and faster travel times from the bottom of the leaching facility to the groundwater. Together these factors mean less treatment.

High Intermittent Loading Situations - When there are wide variations in the waste loads (volume or strength) to leaching facilities, the flow pattern beneath the biomat can exhibit similar variations. Large intermittent pulses of wastewater can cause localized "breakthrough" in portions of the mat closest to the loading point. Because of this, larger systems require pressure dosing as described below and in Module 1.

Are there any design features that can compensate for the lack of a uniform biomat or intermittent pulses of high volume or high strength wastes? We're glad you asked!

Dosing and Pressure Dosing

Dosing, as we learned in Module 1, is the practice of intermittently applying septic tank effluent to a soil absorption system. The design guidelines are presented in Section 15.252 Dosing. In traditional dosing, the dosed volume is pumped to a distribution box for subsequent forced/gravity flow to the leaching components. Although 4-inch diameter pipe is used most commonly, it has been shown that smaller diameter pipe (minimum allowed by Title 5 is 2-inch[7]) provides more even distribution of effluent to the infiltrative surface. The dosing with alternate resting of this type of system has been shown to reduce the incidence of soil clogging failure and result in unsaturated flow patterns from the leaching facility to the groundwater.

Dosed systems provide better distribution over the infiltrative surface and more even and unsaturated flows from the bottom of the leachfield to the groundwater. Accordingly, when faced with variance requests or local upgrade approval requests relative to leaching area or distance to groundwater in very environmentally sensitive areas, **Boards of Health should consider adopting a policy of requiring a dosed system to alleviate the problems of simple gravity-fed system startup inefficiencies and to maximize use of the treatment surface area**.

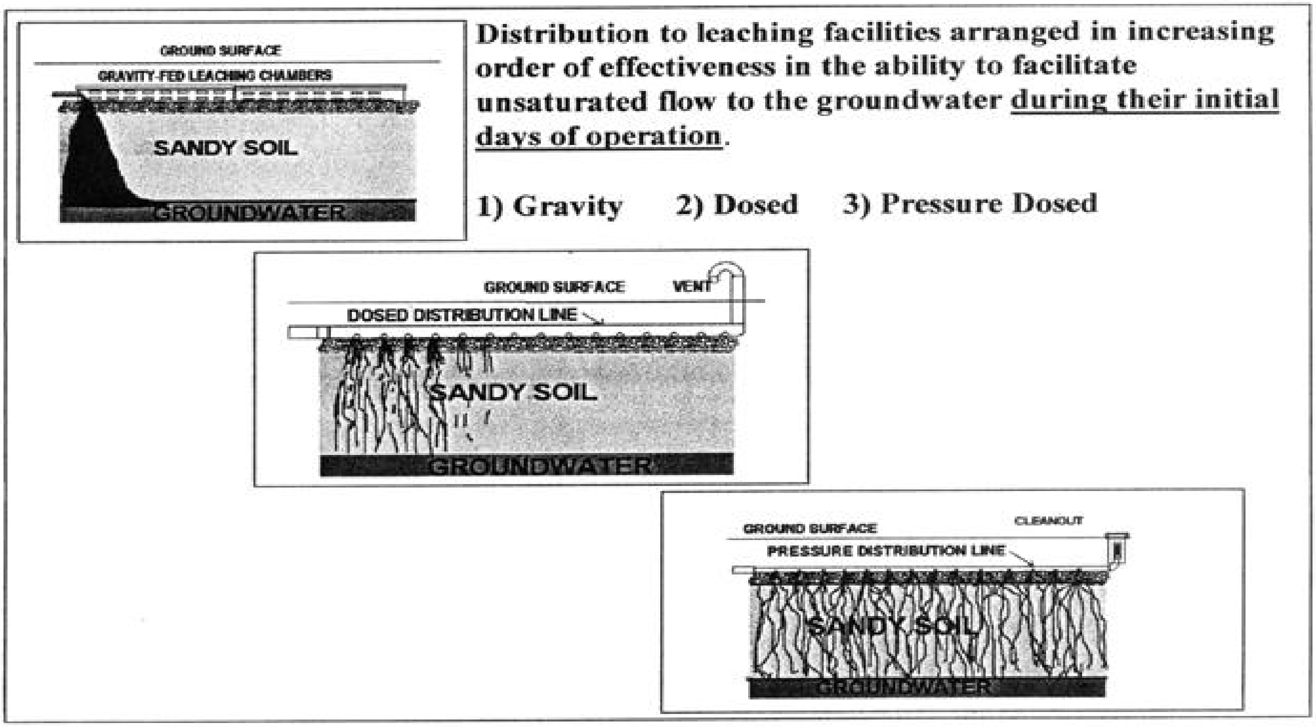
Pressure Dosing - When you really want to get the job done right!

Pressure dosing is distinguished from dosing by the fact that distribution lines distribute effluent under pressure through small (1/4 -1/8") holes. The system is designed to provide an equivalent discharge rate out of each orifice using pressure, as opposed to relying on gravity flow.

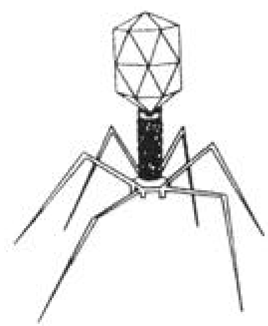
Assuming openings are evenly spaced over the soil absorption system, the infiltrative surface will be evenly loaded. This even loading of intermittently-applied effluent can go a long way in compensating for the lack of the flow-evening qualities of a biomat. In addition, this type of system may offer unsaturated flow in all portions of a leaching facility right from day-1 of operation.

What do other experts have to say ?
In its Technical Evaluation of Title 5, DeFeo, Wait & Associates, Inc. stated

"Dosing and resting of any system is the preferred method of wastewater application. It provides limited hydraulic head to aid infiltration, followed by a prolonged aeration period which promotes biomat digestion and respiration. We therefore recommend consideration be given to requiring dosing facilities in conjunction with leaching systems. We also suggest that consideration be given to the use of smaller diameter pipe for both pressure and gravity distribution of effluent".



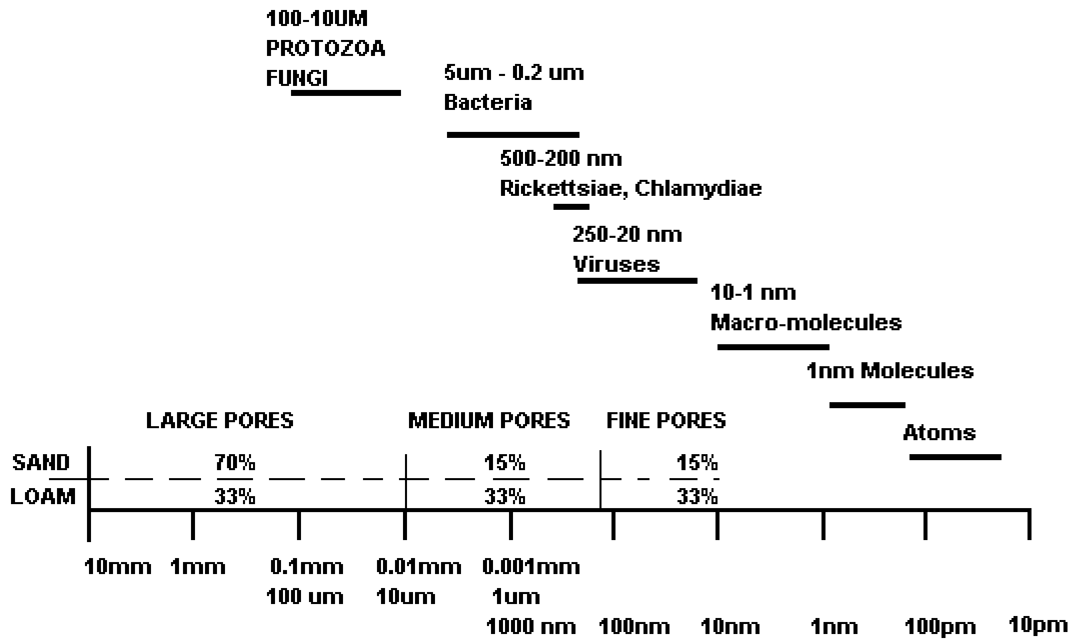
What About Viruses ?



There is perhaps no more controversial subject relative to the treatment of sanitary wastes than that of viruses. **Viruses are mentioned here because the <u>primary treatment site for pathogenic viruses is the unsaturated zone under the leaching facility</u>** (commonly called the *vadose zone*). Once viruses reach the saturated conditions of the groundwater, there are very few mechanisms that work at removing them other than time and distance.

Viruses - visitors of inner space

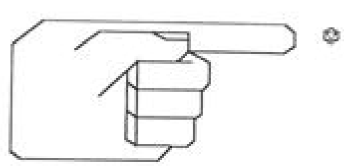
While there are a wide variety of misconceptions, very few people today are unaware of the common aspects of viruses that make them so pervasive. Foremost, they are small.



By the way, the virus depicted on the previous page that resembles a spacecraft, is a typical *bacteriophage* virus enlarged approximately 200,000 times. Bacteriophage viruses attack bacteria such as E. coli. I mention them because many studies use these relatively harmless viruses to determine the treatment efficiency of a septic system (besides, they look neat!).

The small size of viruses make it unlikely that viruses are filtered out of effluent as it passes through the underlying soil. The primary removal mechanism for viruses is ***adsorption***. Don't confuse this term with ***absorption***. ***Ad***sorption is the process by which a substance, in this case a virus, sticks to or adheres to the material it is being passed over or through. The outer coating of a virus (called the capsid) is a proteinaceous material that exhibits an electrostatic charge. This charge causes an attraction to particles of clay, iron oxides (of which there are a lot in our soils on Cape Cod), and other metal oxides. This attraction, along with weaker attractional forces (called van der Waals forces) can hold the virus for as long as conditions are right. If the virus is detained long enough, conditions may develop that actually inactivate the virus by disrupting the protective outer capsid. In unsaturated soils, oxygen present may actually oxidize the protective coating and inactivate the virus. Desiccation or drying out can also destabilize the viral material.

{PRIVATE}**Whoaaah!**



Still having a little trouble putting viruses in perspective? Consider this: The small figure being pointed to is an illustration of a Reovirus. Reoviruses are 70-75 nanometer (10^{-9} meter) viruses responsible for a variety of respiratory and intestinal diseases. This RNA-based virus, shaped like an icosahedon has been enlarged approximately 57,000 times. If a sand grain (0.5 mm about the size of a period on this page) was similarly enlarged, it would be approximately

94 feet high ! The pore space between grains (through which the virus above would travel) would be 13 feet wide ! You, by the way (assuming you are about 5' 10" tall), would be over 60 miles tall !

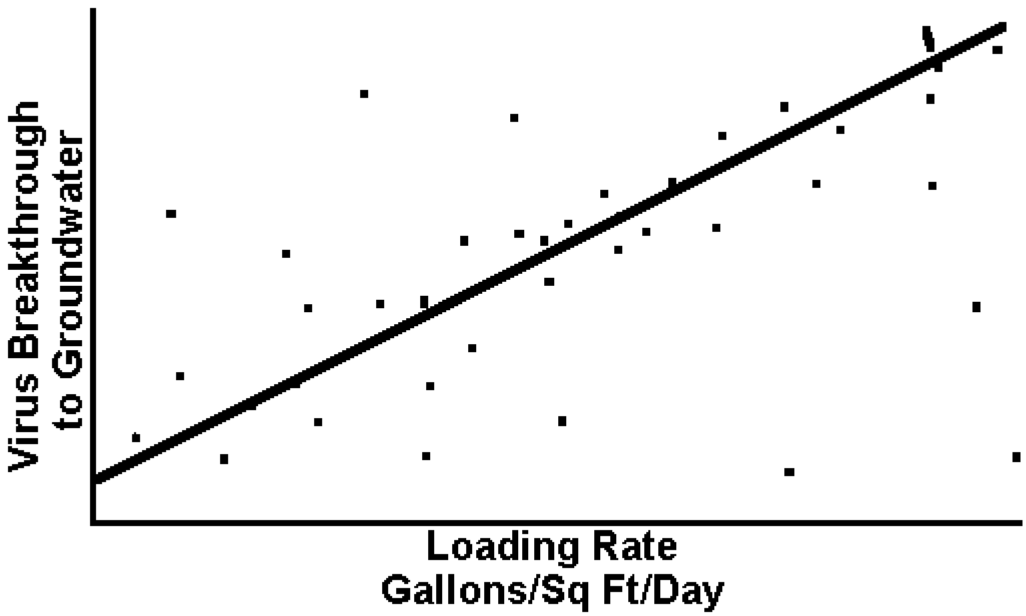
What are some of the other factors that affect virus persistence in the subsurface environment? Although it's not necessary for you to memorize all the factors affecting the survival of viruses in the subsurface environment, the following table is just for the curious among you who simply must know. The Table is reproduced from a 1988 *CRC Critical Reviews in Environmental Control*[8].

{PRIVATE}**Factor**	**Effects on Survival**	**Effects on Migration**
Temperature	Viruses survive longer at lower temperatures	Unknown
Microbial Activity	Some viruses are inactivated more readily in the presence of certain microorganisms; however, adsorption to the surface of bacteria can be protective	Unknown
Moisture Content	Some viruses persist longer in moist soils than dry soils	Generally, virus migration increases under saturated conditions
pH	Most enteric viruses are stable over a pH range of 3 to 9; survival may be prolonged at near-neutral pH values.	Generally, low pH favors virus adsorption and high pH results in virus desorption from soil particles
Salt species and concentration	Some viruses are protected from inactivation by certain cations; the reverse is also true	Virus movement through soils is slowed or prevented by association with soil.
Virus association with soil	In many cases, survival is prolonged by adsorption to soil; however, the opposite has also been observed	Retards movement
Virus aggregation	Enhances survival	Retards movement
Soil Properties	Effects on survival are probably related to the degree of soil adsorption	Greater virus migration in coarse-textured soils; there is a high degree of virus retention to the clay fraction of the soil.
Virus Type	Differentvirus types vary in their susceptibility to inactivation by physical, chemical, and biological factors.	Virus adsorption to soils is probably related to physiochemical differences in the virus capsid surfaces.
Organic Matter	Presence of organic matter may protect viruses from inactivation; others have found that it may reversibly retard virus infectivity	Soluble organic matter competes with viruses for adsorption sites on soil particles

Hydraulic conditions	Unknown	Generally, virus migration increases with increasing hydraulic loads and flow rates

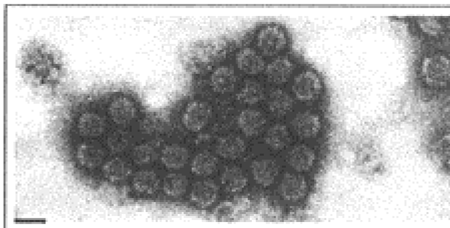
Pulling it all Together - What Does the Virus Information Mean ?

The essence of the virus information relative to the unsaturated zone under a septic system can be summed up in one graph[9], adapted from Yates (1987)[10].



Research summarized by Yates (1987) and others clearly indicates a positive relationship between hydraulic loading rate and the breakthrough of viruses to the groundwater. In 1991, under a grant from EPA, the Buzzards Bay Project commissioned our department to research the literature relative to vertical separation and horizontal setbacks to determine whether there was a technical foundation for increased setbacks (generally 100 ft to wetlands and watercourses) that had been adopted by many towns on the Cape and in the Buzzards Bay Watershed. We determined, using a compilation of studies and a correction factor calculated using a study conducted by Dr. James Vaughn in the similar soils of Long Island[11], that a loading rate of 0.75 gallons per square foot per day (with 5 ft. vertical separation of leaching facility to groundwater), would give reasonable assurance in most situations that viruses would not enter the groundwater. In the event that viruses did enter the groundwater, we recommended that the horizontal setback distance requirement of 100 ft. be maintained. Pleasantly coincidental was the fact that independently a loading rate of 0.74 gal/sq ft./day for sandy soils was adopted in the revised Title 5 in 1995.

Controversy in the Issue of Virus Removal

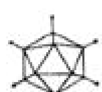


The above image is of a clump of rotaviruses. 500 million of these gastrointestinal goodies can fit on the head of a pin! (ELECTRON MICROGRAPH DOWNLOADED FROM THE INTERNET)

There is considerable controversy regarding the issue of viruses that must be frankly confronted. On the one hand, many contend that public health officials are unduly conservative in this regard, and their insistence on vertical separation and horizontal setback requirements (discussed in the next Module) impose unreasonable cost. Public Health Officials, on the other hand, have the weight of history with polio epidemics of the 1950's, hepatitis outbreaks and periodic and recent outbreaks of Norwalk-virus-related illnesses that compel them to "hold the line". In addition, the adsorption of viruses onto soil is not a permanent phenomena. Intense rain or a dramatic change in the effluent characteristics can cause viruses to desorb and move (be entrained) downward in the soil column toward groundwater. A take-home message one gets from reading the published literature is that there are so many variables associated with virus removal from wastewater, a conservative approach is warranted. Despite the controversy regarding what theoretical removal target should be used, one issue remains clear. Treatment for pathogenic viruses occurs primarily in the unsaturated zone beneath the leaching facility, and maintaining the unsaturated nature of this zone is essential. As Boards of Health are asked for relief from various aspects of Title 5, it is clear that detail surrounding variances from **this** aspect should be carefully scrutinized and only relaxed when all assurances have been made that an equal degree of environmental protection to that provided by Title 5 can be met. Some means to compensate for smaller separations are presented later in context of basic treatment facts.

{PRIVATE**}*Want to learn more about virus persistence in Groundwater ?***

Attached at the end of this module is a collection of reference articles that, although rather dated, may give you an idea of the factors involved in virus survival in groundwater. They were annotated by George Heufelder and Susan Rask as part of another project. They are not mandatory reading for the course, but are presented for the inquisitive among you.



Adenovirus
70-90 nm

A Short Word About Bacterial and Other Pathogens

You may have noticed that we have mentioned very little about the bacterial pathogens. This is because studies conducted in sandy soils most common to our area (including research conducted by our Department in Buttermilk Bay, Bourne under the Buzzards Bay Project), strongly suggest that bacteria are very effectively removed within short (less than 20 ft) distances from a leaching facility located in sand, even if it is close to groundwater. This is also presumably true about other potential pathogens, such as some of the protozoa, since they are orders of magnitude larger and would hence be strained out as effluent percolated through our soils. The danger in this phenomena, however, is that fecal coliform (the majority of which are *Escherichia coli*) are used as fecal indicators in both the shellfish sanitation programs as well as for bathing beach waters. This means that in coastal resource areas where septic systems are prevalent, the fecal indicator may be absent, due to the effectiveness of the soil in retaining them, but the viral pathogens could be present and go undetected. That is, of course, until it the virus is digested with some tasty morsel of shellfish that has filtered water containing viruses.

{PRIVATE**}A word of caution for those reading this course from outside of Barnstable County!**

Bacterial and other pathogens remain an issue in areas shallow-to-bedrock, or areas where fissures in the soil or rock allow for large passageways that connect leaching areas with areas of wells or resource areas.

Ground Water Determination

With a good understanding of the importance of the area between the bottom of the leaching facility and groundwater, only one set of questions remains. Where is ground water? How do we determine ground water elevation? and, How can we account for the seasonal variations in ground water elevation in our septic system designs? Don't worry. As Board of Health members, you will not have to know all the minute detail surrounding ground water determination, but on the other hand, you should have a good idea about the various ways it is determined.

{PRIVATE**}Ground Water** or **Groundwater**
a rose by any other name is still a rose. I will leave it to one of you English or science buffs to tell the rest of us what is right, but the code uses the former term throughout its length, while many publications use the latter form.

First things First - What is Ground Water?

The words "ground water" refers to "water found in cracks, fissures and pore spaces in the saturated zone below the ground surface, including but not limited to perched ground water"[12]. ***Ground-water elevation*** is that elevation below which all available pore space between the soil particles is filled with water as opposed to air. It is also called the ***water table***. Since, as we have stated, the majority of treatment for pathogens occurs in the area below the leaching facility and above the groundwater, it is crucial that the groundwater elevation is accurately determined. To account for the seasonal and year to year differences in groundwater elevation, Title 5 requires that the ***high ground-water elevation*** be used in the design of a leaching facility. This prevents the design and installation of a system in a "dry" year from having the unsaturated zone under the leaching facility reduced below the minimum requirement in a "wet" year. Similarly, in near coastal situations, the high ground-water elevation determination and usage (as opposed to a single observation of groundwater that might not represent the worst case situation), prevents the infringement on the critical vertical separation distance. The methods for determining high ground-water elevation are reviewed later.

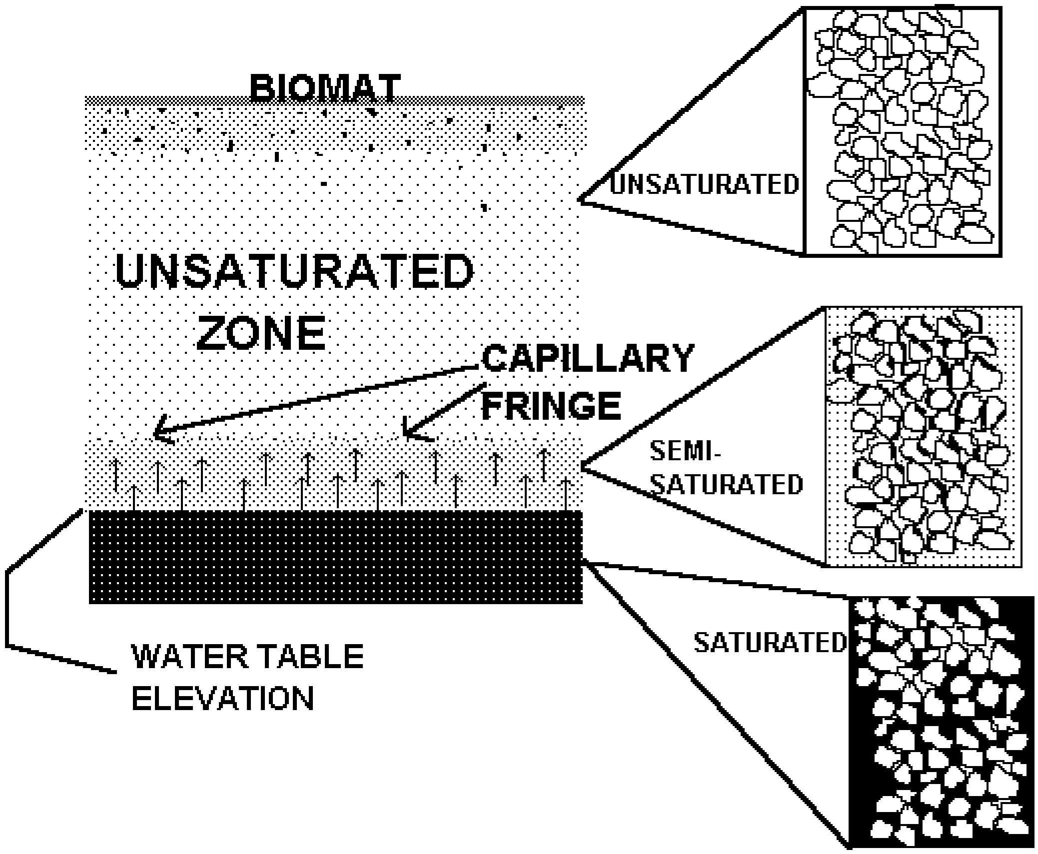
So, How Much Unsaturated Zone Under A System is Enough?

If anyone tells you that they know historically where the vertical separation requirement of 4 ft came from, they probably also have a bridge to sell you. A wide range of values are reported to be effective for the removal of pathogens. The truth is, that pathogen removal is not the exact science we would like it to be, and this is reflected in the variability in states' requirements for vertical separations. There are, however some consistent references in the literature that suggest the appropriateness of the 4 foot vertical separation requirement, and Massachusetts joins at least 19 other states in this requirement. The additional 5-foot requirement in coarse sands and gravel is appropriate considering the literature indicating the reduced ability of coarse-grained sediments to retain bacteria and viruses. In any event, the recent literature and recommendations made in the Technical Evaluation of Title 5 are likely the origin of the four and five foot separation requirement[13] in the revised code.

One More Thing About the Unsaturated Zone or **life in the fringe**

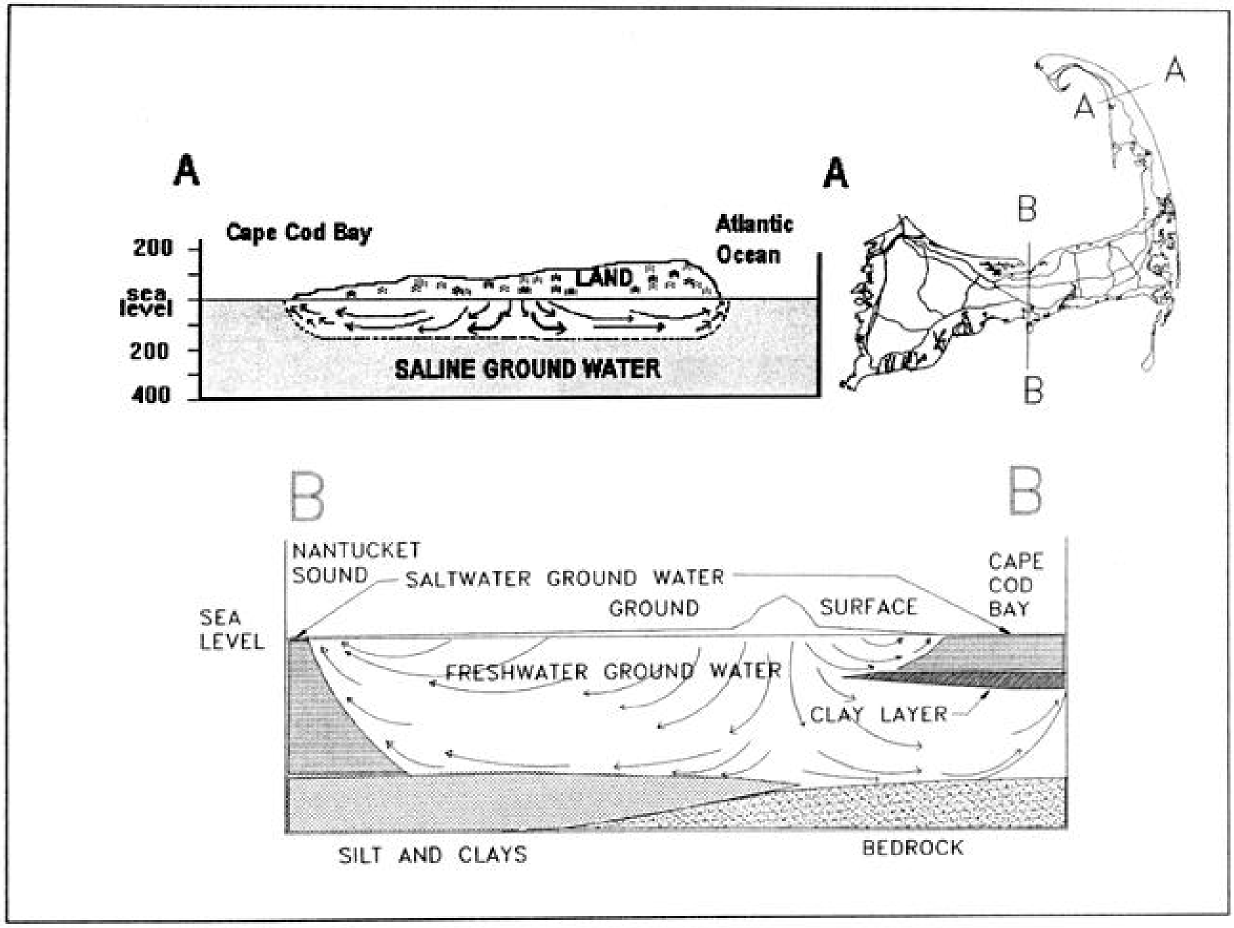
It wouldn't be quite right to leave you with the impression that beneath the leaching facility until you reach groundwater, you can achieve totally unsaturated conditions that are ruinous to pathogens. The fact is that there is an area directly above the water table or groundwater elevation that contains significantly more water than in the majority of the unsaturated zone. This is due to the fact that capillary action wicks water upward. Thus the soil pores directly above the water table may be quite close to saturation in a decreasing gradient with height. The area of not-quite-saturation directly above the water table is called the ***capillary fringe*** . The height at which the capillary tension on the water discontinues to "pull" it upward is different for different soil types. A generalized table is given here.

{PRIVATE**}** **Material**	**Height in meters that water can be drawn upward from water table**
Sand	0.05 - 1
Silt	1 - 10
Clay	>10
Maximum	>35



Groundwater is the result of precipitation (rain and snow) infiltrating the soil. The annual amount of water that actually makes it to the groundwater is referred to as the ***annual recharge***. Where does the rest go ? Well in the hydrologic cycle, some runs off into the ocean, some evaporates, and some is taken up by plants and returned to the atmosphere (a process called ***evapotranspiration***). In Barnstable County, approximately half of the annual precipitation actually makes it to the groundwater.

In some areas of Cape Cod and elsewhere, precipitation recharges a water table that actually sets like a layer or *lens* on top of the salt water table. The figure on the linked page attempts to help you visualize this concept in cross section[14]. The cross section shown is from the area between the A's. The cross section of the area between the B's is a little more complicated because part of the freshwater groundwater table actually is above a confining layer of fine silt and bedrock. This later situation is quite common in other parts of the state (where the groundwater table is confined by bedrock or dense glacial deposits).



A common misconception about the freshwater groundwater on Cape Cod is that it is one big lens. In actuality there are six distinct lenses throughout the Cape that are, to some extent, all hydraulically connected, but recognizably distinct. If you are reading this and live in an area outside of Barnstable County, we would encourage you read information on groundwater from your area. An understanding of groundwater, and how it connects or does not connect with water supplies and other resource areas is extremely important in protecting the public health and the environment.

Groundwater - How do you find it ?

There's an old joke that starts with a musician from out-of -town running through the streets of New York after his cab broke down on the way to a performance. Violin in hand, late for his performance, disheveled and nearly out of breath he stops an old man and gasps "mister, how do you get to Carnegie Hall?". The old man sizes the musician up, looking at the violin case at his side and says "practice my boy, practice". How do you find groundwater? Dig my boy dig!

There are basically three ways to determine that all important high ground-water elevation that is required for septic system design. You can:

1) Observe it (be there at the right time when the groundwater is at its highest),
2) Estimate the high ground water using one of the approved methods outlined in Section 15.103

(3)(c), or
3) Using soil characteristics and reference United States Geological Survey (USGS) reference wells for corroboration.

Observing High Ground Water - Being at the Right Place at the Right Time!

If you are fortunate to be able to schedule your percolation tests for a time of year, and a year where you might expect the highest ground water elevation, this method may be used to make the determination. Generally, this method is used for areas where there is perched water (discussed later), and some communities where perched water tables are prevalent insist on this method. Even in perched water situations, however, this method may not, of itself, give the appropriate level of certainty as to where the maximum high ground water could come.

Estimating the Maximum High Ground Water Using an Approved Method.

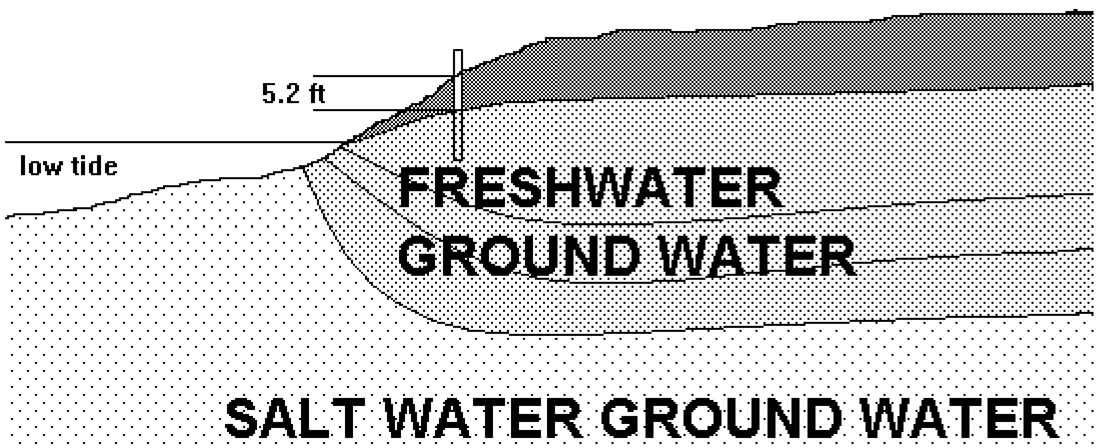
Historical groundwater fluctuations give us the best estimate of the fluctuation we might expect at a particular site. **Incorporating adjustment factors from historical record yield the highest probability that we can maintain the required vertical separation between the bottom of the leaching facility and the groundwater**. In Barnstable County a method has been formulated, using historical water table fluctuations at over 52 wells (nine of which were finally chosen for reference wells). The method is described in detail in the Publication "**ESTIMATION OF HIGH GROUND-WATER LEVELS FOR CONSTRUCTION AND LAND USE PLANNING - A CAPE COD, MASSACHUSETTS, EXAMPLE - UPDATED 1991**" Published by the Cape Cod Commission in cooperation with USGS (Authors Michael H. Frimpter, USGS and Gabrielle C. Belfit, Cape Cod Commission). In summary, the method involves the following steps:

> **STEP 1. Measure Depth-to-Water at the Test Site -** This is normally done in conjunction with the "perc" test. This is only valid if the soils are sandy, so any observation of silt or restrictive layers will invalidate the results.
>
> S**TEP 2. Identify the Representative Index (reference) Well and Annual Water-Level-Range Zone for the Test Site -** The publication referenced above contains four maps with delineations clearly indicating which reference well serves the area where the property in question is located. Using a colored gradient overlay, the maps additionally indicate the *fluctuations* experienced by the groundwater within that area.
>
> **STEP 3 . Determine Current Depth-toWater Level for Index (reference) Well -** These data can be obtained from a number of sources that are referenced in the publication (they are even on the CCC's Web Site). Choose the water level in the reference well for the end of the month closest to when the test was done at your site.
>
> **STEP 4 Determine Water-Level Adjustment -** For this figure, another set of tables provided in the document provide the potential water level rise for any given observation.
>
> **STEP 5 Estimate Depth-to-High-Water Level at Test Site -** This is the easy part. Take the adjustment, subtract it from your observed value at the test site, and away you go. You have an estimated high ground-water value.

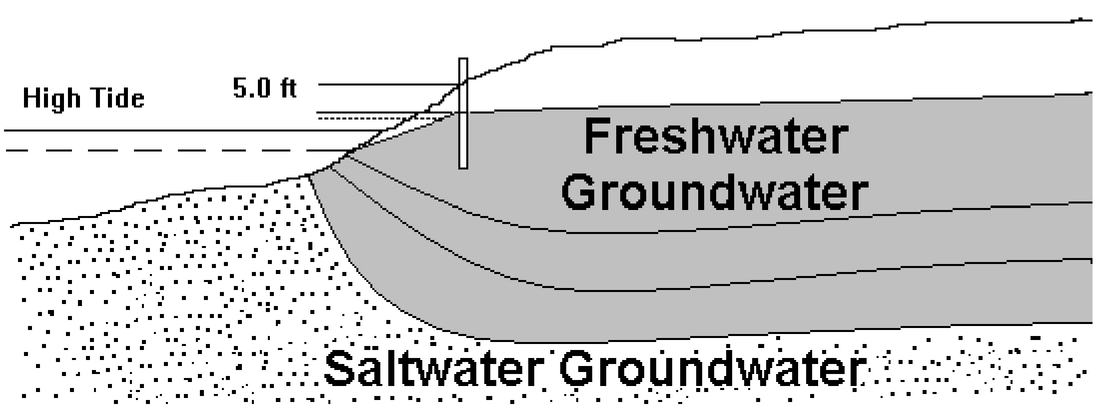
Confused enough? Actually, it is quite simple. Take some time to go over a sample calculation that is provided in the document and I am sure you will get it. In essence, all it is doing is incorporating historical fluctuation trends into a time-fixed observation. Thanks Dr. Frimpter and Ms. Belfit!

Is There Any Time When the Reference Well Adjustment Won't Work?

We're glad you asked! The method previously described is inappropriate to use where the groundwater level is affected by tidal stage. In the nearshore area (within about 3-400 feet) the groundwater is primarily influenced by the changing hydraulic head difference of the tide. The Concept is demonstrated below. In the first illustration we can see a simplified version of what is happening at low tide.



The freshwater groundwater is discharging near the shoreline and the distance from the surface of the ground to the ground water is 5.2 ft. As the tide comes in the hydraulic head difference between the freshwater ground water and the adjacent surface water changes. The resulting head difference slow the exiting ground water, which now actually mounds up a little. The result is a higher freshwater ground-water elevation (distance from the ground surface to the groundwater is 5.0 ft). In many locations, depending on the distance from the shore, the transmissivity of the soil, and other factors, the observed elevation in groundwater will exhibit a lag from the actual high tide. So, the best way to determine maximum high ground water near the shore is to monitor the high groundwater elevation hourly over a tidal cycle during a full moon high tide[15].



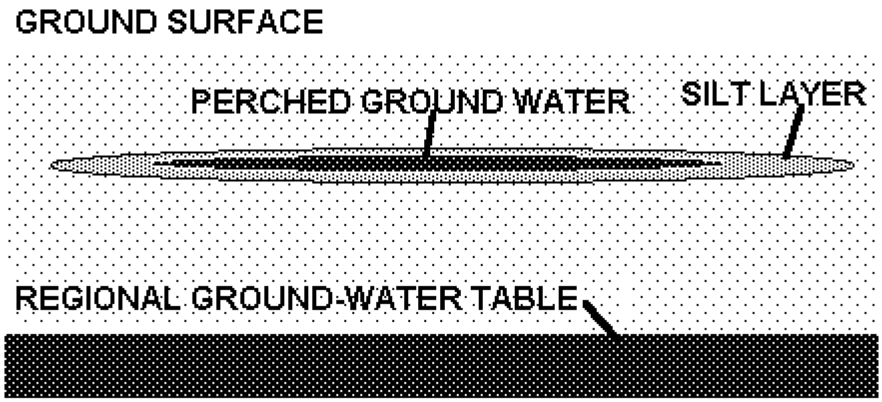
Using Soil Characteristics to Determine Maximum High Ground Water - Down and Dirty!

A substantial change in the Code since the revisions is the requirement that a soil evaluation be performed by a Massachusetts Certified Soil Evaluator. In addition to requiring information on a number of items (See Sections 15.100-15.107), considerable emphasis is placed on characterizing the soils. By using a system of color evaluation called the **Munsell System**, subtle changes in soil color can be noted. Some observed color changes in the soil reveal a water table that fluctuates up and down, creating alternately reduced and oxidized conditions. The resulting color patterns in soils experiencing a fluctuating water table are called ***mottles***. In the Cape's soils, mottles are generally observed as orange or yellowish-red blotches (due to the changing oxidation states of iron with the changing oxidation-reduction conditions), against a gray background. The gray background color is the result of reducing conditions that occur as soil remains saturated for long periods of time. The benefit of using soil observations to determine the depth of the water table is that it allows us to use the "trail" of evidence left behind as water periodically rose to higher elevations. If you get to see an observation hole, however, don't jump too quickly to the wrong conclusion when you see the iron staining. Sometimes on the Cape (especially in Orleans, Brewster and Chatham), I have seen horizontally-oriented streaks of iron staining. These are sometimes caused by a soil inconsistency that simply slows the downward percolating water and results in precipitation of some iron. In general, these phenomena can be distinguished from high ground-water mottles due to their horizontal (vs. vertical or blotchy) orientation to the soil surface.

Special Cases in Ground-Water Elevations

It is not uncommon in some areas of Barnstable County (especially in West Barnstable, Brewster and Orleans) to encounter a water table that is suspended above the regional water table on a confining layer of silt or clay. These water tables are referred to as ***perched water tables***. They are often observed as water weeping from the side of a deep test hole. Closer observation indicates a confining layer of silt or clay just beneath the weep site. The concept of a perched water table is demonstrated on the next page. Perched water tables deserve special attention since the water contained in them is considered groundwater[16] for purpose of leach facility design.

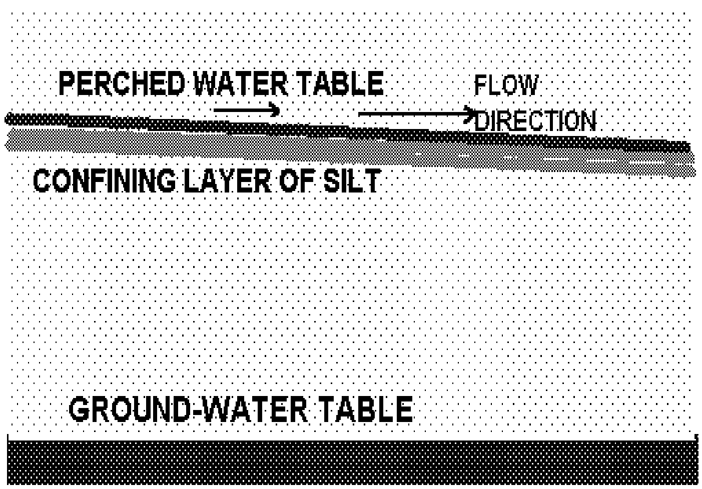
In some situations, where the perched water observed is very limited (a little trickle weeps out of the side of the test hole), the limiting material can be "stripped out" for a distance of five feet around the entire outer perimeter of the soil absorption system[17]. A note of caution here. The "strip out" strategy should only be permitted when the confining layer and the perched water is not extensive. A increased number of test holes (more than two) are often necessary to determine the extent of the confining layer. In addition, care must be taken to assess the extent of perched water. This is done by observing the soil mottling above the confining layer. If the mottling indicates that the depth of perched water gets substantial (greater than 3 inches depth) as indicated by observation or soil mottling, then a simple strip out may not be sufficient to allow the occasional high volumes of perched water to pass to the underlying ground water without hydraulically connecting with the downward percolating effluent from the leaching facility. This would result in saturated flow of the combined flows (perched water and septic effluent) to the ground water; which by now, you know is not a good thing. In cases such as these, the system should be designed using the perched water table, adjusted for observation of any mottles, as the maximum high groundwater.

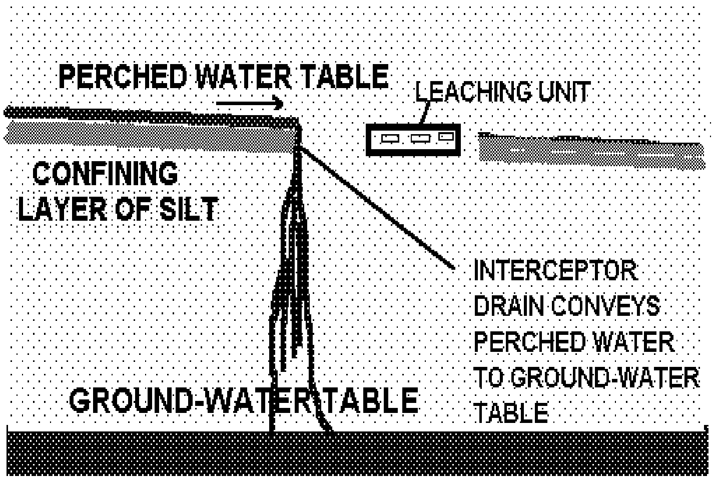


Perched water will not be observed above every confining layer of soil. In some instances, the confining layer is relatively small so that no water collects on top of it. In other instances, the confining layer may have a slope so that percolating water runs off of it. And still in other instances, the confining layer may allow downward percolating water to pass through it at a slower rate.

What to Do If the Extent of Perched Water is Questionably Problematic.

In some situations, and in consultation with the regional office Title 5 technical support person, it may be determined that an interceptor drain can be used to drain away a perched water table (some folks call them "French Drains" don't ask me!, collection drains, perimeter drains or diversion drains).





Interceptor drains are used to convey perched water tables to the underlying regional water table. They are used when the amounts of perched water indicated either by observation or mottling are high enough that there is concern that the downward percolating perched water will hydraulically connect with septic tank leachate and result in less treatment.

The assessment of perched groundwater or confining layers of soil can get pretty tricky. In some instances, the Health Agent and Soil Evaluator must exercise his or her best professional judgment to decide whether the small trickle coming from the side of the test hole is substantial enough to require a design changes that count the perched table as the groundwater elevation. Many agents prefer not to take any chances, and just require a design that uses the perched table as the high ground-water elevation. This is certainly the "safest" and most conservative from the public health point of view. But we all know, there are those questionable calls where a conservative call means substantial expense with questionable return. In this event, remember that the staff at the regional DEP office is available to consult with..

Seasonally-High Ground Water

Another term you may hear is "seasonally-high groundwater". This term is generally applied to groundwater that is evident only seasonally, and to some the term is synonymous with perched water table. The difference between the two is that the term perched water table is usually used in areas where there are coarse soils underlying the restricting layer. Seasonally-high ground water is noted mostly in glacial till soils that may extend to bedrock. Glacial till soils usually have a loose friable surface and subsoil. During the spring snowmelt and rainfall, water percolates through these upper strata, but collects on the dense, poorly draining hardpan beneath. Eventually, the water will percolate through this poorly draining soil, but water is frequently and seasonally observed perched on top of the hardpan. In these situations, the seasonal high groundwater must be considered as the high ground-water elevation for purpose of design. Seasonally-high groundwater fluctuations often exhibit themselves with very obvious mottles, that are evident even during the dry season. In these situations, where the seasonally high groundwater table is near the surface, the system must generally be mounded, using the percolation rate of the fine material underneath.

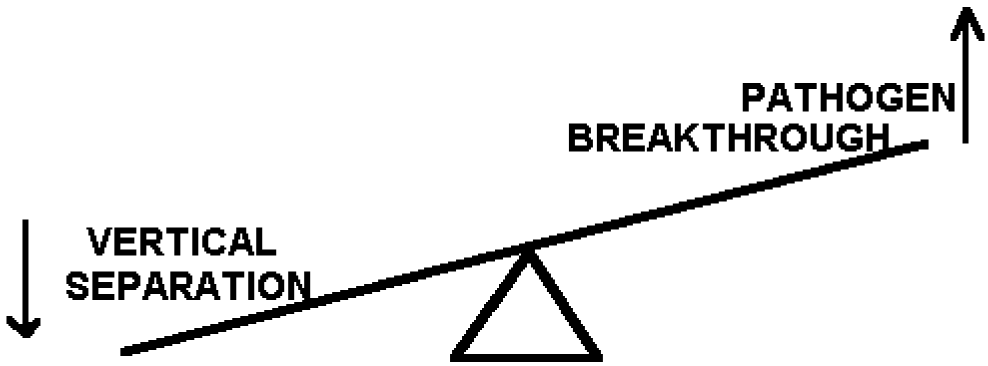
Applying What We Have Learned

Thus far, this module has reviewed the concepts and principles involved in the vertical separation distances between the bottom of the leachfield and the groundwater. The key points that you have hopefully learned are:

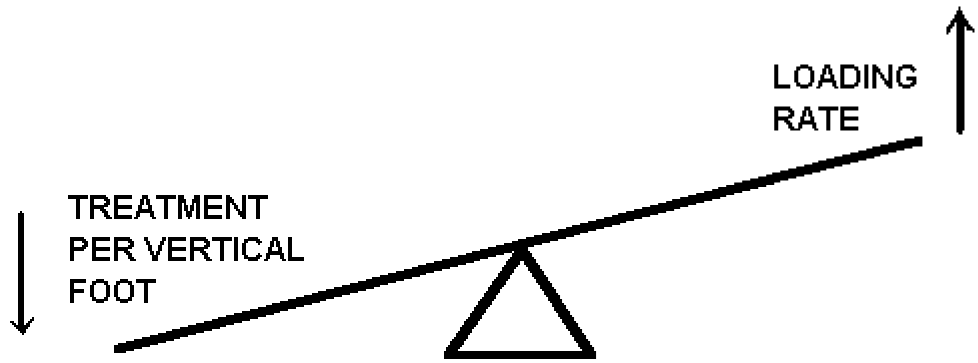
- that vertical separation is the most important feature for the treatment for pathogens and that viruses, in particular, are inactivated in the unsaturated zone under the leaching facility;
- uniform distribution of effluent across the entire infiltrative surface of the leaching facility becomes more crucial for the treatment of pathogens as you situate systems closer to the maximum high ground water;
- in a septic system where the effluent is distributed by gravity alone, the biomat is the primary feature that allows for even and unsaturated flow to the groundwater;
- the absence of a biomat can be somewhat compensated for by providing even distribution of effluent by dosing or pressure dosing;
- the methods for determination of maximum high ground water
- an understanding of perched ground water

By now, you should understand that the vertical separation between the bottom of the leachfield and the groundwater is intimately linked with the loading rate. Remember loading rate is the amount of effluent you disperse over a given area. In Title 5, this is generally expressed in gallons per square foot per day (gal/sq ft/day). This brings us to a very frequent request that Boards of Health are dealing with in the revised code: the local upgrade approval request for either reduction in leachfield (which increases the loading rate by virtue of decreasing the square foot area that the effluent can be dispersed on) or the request to approve a decrease in vertical separation. Notice we said "or". Section 15.405: Contents of a Local Upgrade Approval (subsection 1(i)5)[18] clearly indicate that the approval for <u>both</u> the reduction in vertical separation and the reduction in leachfield size can not be just locally approved (but may be the subject of a variance request). There is a very good reason why request for relief from both vertical setback and loading rate should come under a higher level of scrutiny. The reasons are summed up in the following small table:

{PRIVATE}**ACTION**	**RESULT**
Leaching field size decreases	1)Loading rate in gal/sq ft/day goes up there is less area to take the same flow) 2)Treatment per foot of passage decreases (see graph)
Vertical separation decreases	1) Total treatment decreases because there is less vertical passage

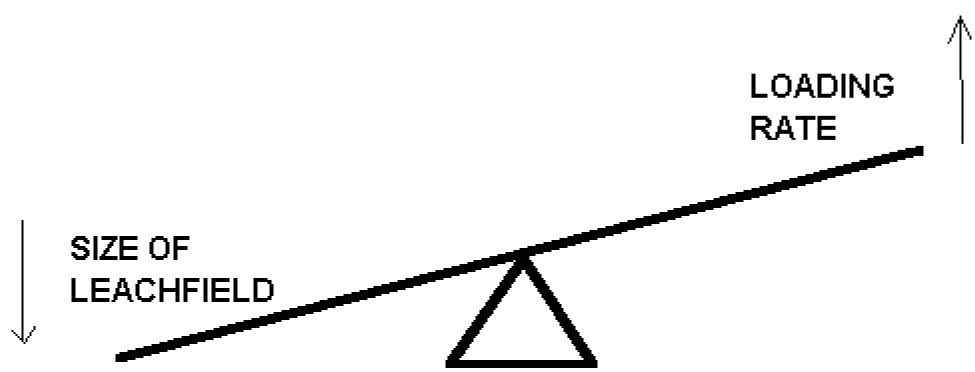


Double Whammy! If we could allow a decreased leaching field (25% reduction allowed under a local upgrade approval described in Section 15.405 (1)(c)), ***and*** a decrease in the vertical separation, we would be getting less treatment per foot of passage ***and*** less feet of vertical



passage.

This information regarding the relationship between leaching field size and vertical separation, should, however, make us feel a little more comfortable about allowing a decrease in the leachfield size (up to 25%) if there is ***greater*** than the required vertical separation. This is because, although we have less treatment per foot of passage with the higher loading rate, the greater vertical separation can compensate by providing more distance for vertical passage before the effluent hits the groundwater. To put it another way, if someone requests a local upgrade approval for decrease leachfield size, the Board of Health can feel a little more comfort that there will be an equal degree of environmental protection afforded by the system, the greater the vertical separation that can be achieved.



What about local upgrade requests for reduction in the vertical separation itself?

Well, we can see from the chart on the previous page, that decreasing the vertical separation can only be compensated for by reducing the loading rate. Decreasing the loading rate can only be done by increasing the leaching area of the system. This would be an unreasonable request by the Board of Health, given the already-more-expansive system requirements under the revised code. So, in consideration of its importance, Boards of Health should insist upon the proper vertical separation, even if it means installing a mounded system.

But what if it is not possible to achieve the vertical separation?

What should a Board require to compensate for decreased vertical separation in situations where the required distance can not be achieved?

Hold on to your seats - that is a complex question!

If the request for decreased vertical setbacks is far and away (greater than 250 day groundwater travel time - or 250 ft on Cape Cod) from any of the resources outlined in Section 15.211: Minimum Setback Distances, then the threat of disease transmission is very limited. This is because, even if some pathogens did make it to the groundwater, their persistence would, within reasonable probability and based on the virus literature, not exceed 200 days (the 50 was added for a safety factor). If it is closer, the Board might want to be assured that higher loading rates could not occur in localized portions of the leaching field and hence increase the probability that viruses could reach groundwater. How could the design engineer ensure that there would be no localized higher loading rates? Remember our discussion of dosing? See page 13 of this module and Module 1. Here, in the situation where there is less vertical separation near a resource, the Board must decide if the situation warrants the extra efforts that will be required to disperse the effluent evenly over the entire leaching facility. The pluses are that pressure distribution will achieve more even loading from day 1 and will hence achieve better treatment. The negative is that the system will undoubtedly require more maintenance and expense. In addition, generally the design and installation requires more oversight since pressure dosed systems are not common as of yet.

Well, I think we have sowed enough confusion for now. The next module deals with horizontal setbacks. In it you will learn how the resources are identified, and those critical landmarks to look out for. The self test that follows should let you know if you have grasped the concepts in this module.