SOIL ABSORPTION BED PERFORMANCE IN ALASKA

AN INVESTIGATION OF ON-SITE WASTEWATER SYSTEM PERFORMANCE

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RESEARCH SUMMARY

PROJECT TITLE SOIL ABSORPTION BED PERFORMANCE IN ALASKA

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OBJECTIVE This project, funded by a grant from the Alaska Science and Technology Foundation, assesses the current status of on-site soil absorption system technology in the Anchorage area.

RESEARCH HIGHLIGHTS Five major subject areas are covered in the report.

(1) Site inspections were conducted at 83 randomly selected sites served by soil absorption beds to assess whether or not this type of system was more prone to failure than other conventional soil absorption system types. Over 50% of these soil absorption beds were found to be either in failure or not operating in a manner that would render them eligible for issuance of a Health Authority Approval certificate. Follow-up inspections revealed a trend towards increasing depth of ponded effluent with time.

(2) A database was compiled containing 235 septic system installations and 832 adequacy tests conducted by one engineering firm in Anchorage over the past 15 years. Analysis of the installation data revealed that trenches can be installed in many locations that might otherwise be favored for beds. Soil absorption beds were found to fail at a significantly higher rate and younger age than other types of systems. Comparisons were made between adequacy test failure rates observed at different times of the year and as testing criteria changed over time.

(3) The report discusses the effects of several factors relevant to soil absorption system performance. Soil grain size is looked at with particular emphasis on the use of filter sand to enhance treatment performance. Recommended filter sand characteristics and available sources in the Anchorage area are identified. The report addresses the role oxygen availability plays in soil treatment performance. Oxygen sensors were installed at several locations and changes in soil oxygen content monitored over time. The effect of soil temperature on treatment performance is discussed, and the report analyzes soil temperature monitoring data collected over a period of several years by middle school students in Anchorage.

(4) The report evaluates the authors' experience with several different

proprietary techniques for remediation of failing septic systems. Some beneficial results have been observed, at least in the short-term, but long-term efficacy is unknown.

(5) Finally, the study evaluates the performance of three different types of advanced on-site wastewater treatment technologies that have been introduced to the Anchorage area starting in the mid-1990s. Several years of performance data for the Intermittent Sand Filter, the "Biocycle" aerobic treatment unit and Orenco's "Reactex" trickling filter is presented in terms of the biochemical oxygen demand, total suspended solids, total nitrogen and fecal coliform of their output. Each of the system types was found to be capable of producing effluent exceeding secondary treatment standards, however they are subject to occasional upsets when poor performance occurs. The report makes recommendations regarding classification of advanced treatment systems in terms of performance, necessary maintenance to ensure continued performance and appropriate design standards in terms of soil application rates and separation distance criteria.

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1. INTRODUCTION

This purpose of this report is to provide an assessment of the current status of on-site soil absorption system technology in Alaska. The project's initial focus on soil absorption bed performance was broadened to evaluate beds as they fit into the range of available technologies for on-site wastewater disposal. This report represents a compilation of the knowledge and opinions regarding soil absorption system performance gained by the authors over several decades of research and practical experience. The last 6 years of research leading up to the production of this report was made possible by a generous grant from the Alaska Science and Technology foundation.

It is hoped that portions of this report will prove useful to persons from a variety of backgrounds, including practicing engineers, regulatory officials, academic researchers and homeowners who rely on a septic system for their personal needs. Its mass appeal will probably be somewhat limited. For those who do not spend their lives immersed in sewage a brief overview of the technology precedes each section to set the context for the research and findings that follow. Wastewater professionals will probably want to skip past these overviews. The intent of this report is to present interesting research findings as well as subjective opinions and recommendations based on the authors' combined years of practical experience as it is to present a polished report meeting rigorous academic publishing standards. Different sections of the report will probably be of interest to different readers.

While this is the final report covering research activities funded by ASTF, the authors hope to periodically update and revise the report as time, finances and further research permit. The authors wish to express their appreciation for the generous assistance of Kyle Brown of Discovery Drilling in fabricating and installing soil-oxygen monitoring equipment. Thanks also to both Kyle and Ellyn Brown and Ellyn's many students at Mears Middle School for collecting and sharing their soil temperature monitoring data. Thanks to Larry Acomb for helpful discussions regarding soil oxygen monitoring. We also wish to express our appreciation for the assistance provided by the members of our committee or advisors, John Kennish and Bob Miller at UAA, Keven Klaweno at ADEC and Jim Cross at MOA DHHS.

1.1 BACKGROUND

In seeking ASTF support of this project the initial goals we identified were as follows:

- To assess whether or not soil absorption beds in Alaska were in fact more prone to failure than other types of systems.
- To assess the various factors which could be causing premature failure of beds and mounds as well as factors that could lead to extended performance.

Based on this analysis to suggest appropriate design and/or regulatory changes that could enhance the longevity of soil absorption systems in Alaska.

While the project title refers to Alaska in general, the primary focus of the study was on soil absorption system performance in the Anchorage area, which is where the majority of Alaskans reside. Due to extreme climatic variations encountered across Alaska, the conclusions of this report do not necessarily apply to other Alaskan locations. Partly as a result of the authors' expressed concerns about problems with soil absorption bed performance, in the past few years there has been a distinct shift away from the installation of "beds", back to the use of "trenches" whenever feasible.

As work on the project evolved, the authors came to realize that simple modifications to the design of beds and mounds was only one of several possible approaches to enhancing the longevity of soil absorption system performance. Concurrently with our work on this project several different forms of advanced on-site treatment and disposal technology were being tested in Anchorage. Some, such as the Intermittent Sand Filter (ISF) are simply higher-tech mounds, whereas others such as the Biocycle and Recirculating Trickling Filter (RTF) are intended to significantly treat the septic tank effluent prior to discharging it into a soil absorption system. These new technologies offered an alternative approach to enhancing the longevity of soil absorption beds. The authors broadened the scope of the original project to evaluate available data on the performance of these advanced systems so as to address their use as an alternative to bed technology. This led us address several other factors relating to the performance of advanced treatment systems including: classification of advanced systems in terms of treatment performance, maintenance needs of advanced systems, and relevant design criteria such as soil application rates, and horizontal and vertical separation distances.

1.2 OVERVIEW OF SOIL ABSORPTION SYSTEM TECHNOLOGY IN ANCHORAGE

Conventional on-site wastewater disposal systems consist of two basic components. The first is a watertight septic tank, typically 1000 – 1500 gallons capacity that receives raw wastewater from the residence and retains it in a quiescent state for at least 24 hours to allow a significant portion of the settleable solids and floatable scum to be separated out from the liquid. The second component is a soil absorption system, which is designed to facilitate the passage of the liquid portion of septic tank effluent into the on-site receiving soils. For frost protection Municipal and State regulations stipulate that soil absorption systems be covered with 3 feet of soil or insulated with 2 inches of foam plus 2 feet of soil.

There are 4 basic types of conventional soil absorption systems that have been used for on-site wastewater disposal in the Anchorage area. The Anchorage Health Department has a database containing installation records on 10,600 soil absorption system installations between 1969 and 1998. Complete data for 1999 has not yet been entered into the version of the database that is made available to the public. Table 1 presents a breakdown of the number of systems by type and year. Figures 1 and 2 provide plots of the yearly breakdown of all installations by type and how it has changed over the years. The following system types are described in the order of their introduction into Anchorage.

1.2.1 Seepage pits

Seepage pits (also called cribs) are constructed either of logs or concrete or steel rings and were the dominant soil absorption system type until the mid 1970s. The crib is a perforated hollow structure that is constructed in the middle of a much larger excavated pit. The space between the crib walls and the outer edges of the seepage pit is backfilled with gravel or other granular. Effluent from the septic tank flows into the open crib structure from whence it seeps through the gravel backfill into the surrounding native soil. Seepage pits are similar in construction to earlier (now illegal) cesspools except that they are preceded by a watertight septic tank. Although their use has largely gone out of favor many seepage pits continue to function well up to today.

Table 1. Municipality of Anchorage Septic System Installation Data, By Year and System Type

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Trench	5	5	17	11	19	27	279	388	481	524	298	307
Bed	4	4	6	4	8	1	5	2	11	5	4	7
W. Drain	2	4	8	8	9	8	10	7	17	48	29	32
Seep. Pit	112	196	215	207	284	332	111	38	25	25	10	16
Other	0	0	0	0	0	0	0	1		1	1	
Total	123	209	246	230	320	368	405	436	534	603	342	362
Trench %	4.1%	2.4%	6.9%	4.8%	5.9%	7.3%	68.9%	89.0%	90.1%	86.9%	87.1%	84.8%
Bed %	3.3%	1.9%	2.4%	1.7%	2.5%	0.3%	1.2%	0.5%	2.1%	0.8%	1.2%	1.9%
W. Drain %	1.6%	1.9%	3.3%	3.5%	2.8%	2.2%	2.5%	1.6%	3.2%	8.0%	8.5%	8.8%
Seep. Pit %	91.1%	93.8%	87.4%	90.0%	88.8%	90.2%	27.4%	8.7%	4.7%	4.1%	2.9%	4.4%
Other %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.2%	0.3%	0.0%

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Trench	561	451	502	356	262	153	96	67	59	83	99	136
Bed	47	71	204	179	127	98	63	39	53	113	88	100
W. Drain	96	124	104	98	50	29	26	31	29	32	29	30
Seep. Pit	22	16	19	9	10	6	2	4		1	1	1
Other	3	3	2	4	3	1	3	3	5	2	1	3
Total	729	665	831	646	452	287	190	144	146	231	218	270
Trench %	77.0%	67.8%	60.4%	55.1%	58.0%	53.3%	50.5%	46.5%	40.4%	35.9%	45.4%	50.4%
Bed %	6.4%	10.7%	24.5%	27.7%	28.1%	34.1%	33.2%	27.1%	36.3%	48.9%	40.4%	37.0%
W. Drain %	13.2%	18.6%	12.5%	15.2%	11.1%	10.1%	13.7%	21.5%	19.9%	13.9%	13.3%	11.1%
Seep. Pit %	3.0%	2.4%	2.3%	1.4%	2.2%	2.1%	1.1%	2.8%	0.0%	0.4%	0.5%	0.4%
Other %	0.4%	0.5%	0.2%	0.6%	0.7%	0.3%	1.6%	2.1%	3.4%	0.9%	0.5%	1.1%

	1993	1994	1995	1996	1997	1998		Total		Average
Trench	225	242	216	220	219	156		6464		215
Bed	95	65	67	22	37	25		1554		52
W. Drain	2		2		4	48		916		33
Seep. Pit		1	2	1				1666		64
Other	2		1	4	0	11		54		2
Total	324	308	288	247	260	240		10654		355
Trench %	69.4%	78.6%	75.0%	89.1%	84.2%	65.0%		0.607		
Bed %	29.3%	21.1%	23.3%	8.9%	14.2%	10.4%		0.146		
W. Drain %	0.6%	0.0%	0.7%	0.0%	1.5%	20.0%		0.086		
Seep. Pit %	0.0%	0.3%	0.7%	0.4%	0.0%	0.0%		0.156		
Other %	0.6%	0.0%	0.3%	1.6%	0.0%	4.6%		0.005		

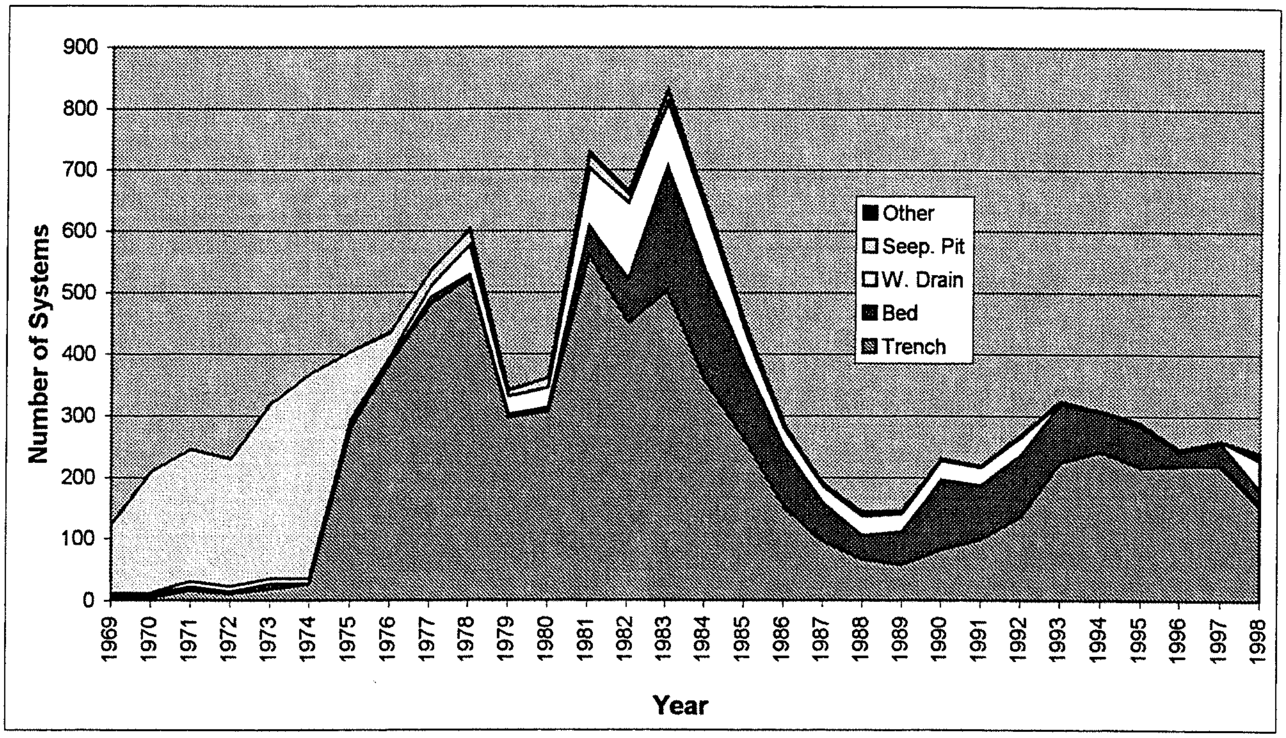


Figure 1. Septic System Installations in Anchorage: Totals of all system types, by year

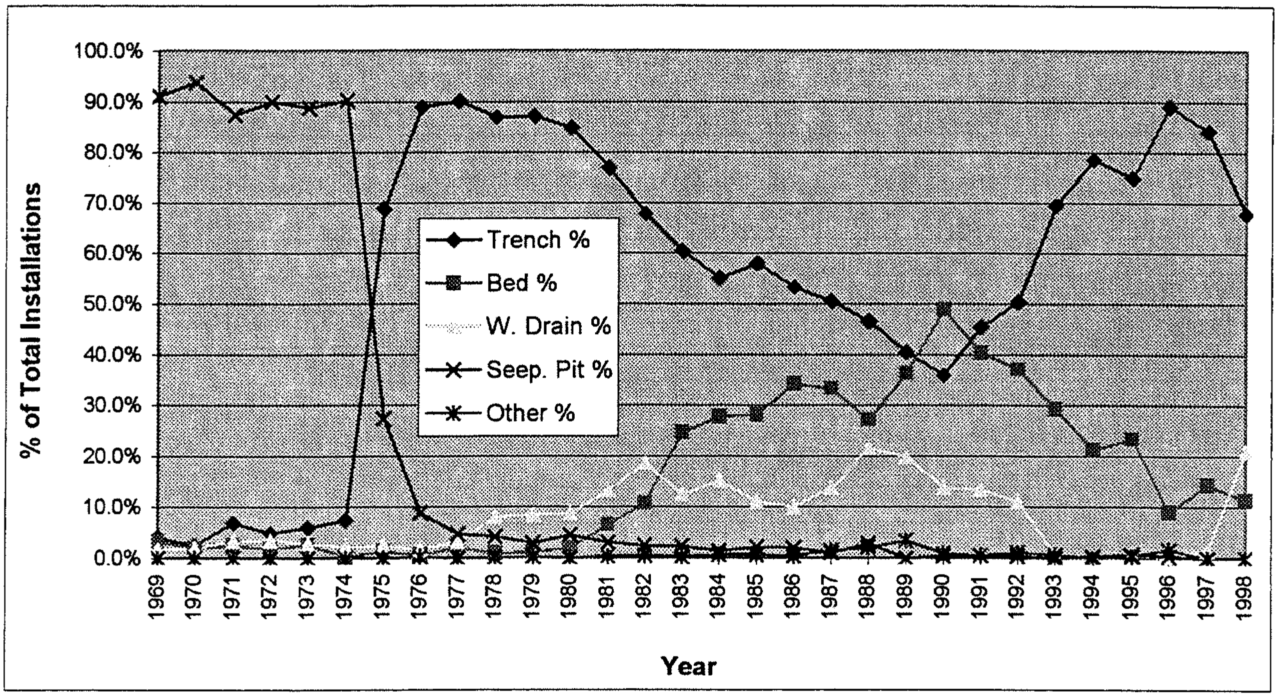


Figure 2. Septic System Installations in Anchorage: Each system type's percent of total, by year

1.2.2 Trenches

Trenches are gravel-filled ditches dug no wider than the width of a backhoe bucket and filled with approximately 5-10 feet of sewer gravel. Because of their greater sidewall-to-volume ratio, trenches became popular in the mid 1970s as a less expensive alternative to seepage pits. Trenches are still the most widely used type of soil absorption system in Anchorage, and are generally installed wherever site conditions permit. Since both seepage pits and trenches rely predominantly on their sidewalls for infiltration into native soil, they can only be used where permeable soils are relatively deep and free of permafrost and seasonal high groundwater. The underlying principle behind these systems is for progressive clogging of the sidewalls. Septic tank effluent ponded in the bottom of the systems gradually increases in depth over time as the sidewalls become increasingly clogged with biomat. Because deep soils are generally poorly oxygenated little bacterial degradation takes place and the primary treatment mechanism is mechanical filtration. Trenches account for a little over 60% of all soil absorption system installations in Anchorage.

In the late 1970s and early 1980s a number of **hybrid** systems (*author's nomenclature*) were installed, consisting of seepage pits plus one or more deep trench fingers radiating outward from the perimeter of the crib. The trenches were usually added as a retrofit to an existing seepage pit to increase its absorption capability. This nomenclature is not used in the Municipal records.

1.2.3 Drainfields

As pressure to develop on-site systems on lots lacking deep permeable soils grew, significant numbers of drainfields became popular starting in the late 1970s. Drainfields are 5-feet wide and typically have 6 inches of gravel under the horizontal distribution pipe. They rely on absorption through their bottom, rather than their sidewalls. This configuration allows construction of a soil absorption system on thinner strata of permeable soils and/or in locations subject to high groundwater levels. Drainfields are readily adaptable to sloping lots as they can be constructed along a natural contour of the land. Where sufficient natural soil exists, drainfields sometimes are be constructed with extra gravel thickness to allow some sidewall absorption as well as through the bottom. Being constructed in shallower soils, the potential exists for the receiving soils to be better-oxygenated soils, which promotes more bacteriological treatment of the effluent.

The MOA installation data shown in Table 1 and plotted in Figures 1 and 2 indicates that virtually no drainfields were installed in Anchorage between 1993 and 1997. This is an error, probably resulting from the fact that drainfields are also sometimes called shallow trenches. Drainfield installations in those years must have been coded as trenches.

1.2.4 Beds

Soil absorption beds, like drainfields, have only 6 inches of effective gravel depth, but are rectangular with typical widths ranging from 15 to 25 feet. Significant numbers of beds began to be installed in the Anchorage area starting in 1981. Because of their greater width, beds must be constructed on relatively flat terrain in order to remain within a thin stratum of permeable soil. Air necessary to oxygenate the receiving soils under the center of the bed must travel horizontally through the underlying soil from the edges of the bed. **Mounds** are a variant of beds constructed at a very shallow depth. They derive their name from the distinctive "mounded" shape of the soil cover that modifies the natural contours of the ground. The receiving stratum for mounds is sometimes built up above original ground level with imported sand. Lift stations are usually necessary to pump effluent up into mounds. A pressurized system allows better distribution of effluent over the surface of the mound.

Unlike seepage pits and trenches, which operate by progressive failure of the sidewalls, the design principle behind beds and mounds is that these types of systems should immediately absorb all the septic tank effluent without ponding. Following a national trend, and also partly because they were considered "higher tech", beds and mounds came into vogue as a preferred soil absorption system design option, starting in the mid 1980s. By 1990 a maximum of 49% of all new soil absorption system installations in Anchorage were classified as beds. Design professionals and regulators generally thought that beds and mounds provided superior biological treatment of effluent and therefore should last a long time before clogging occurred. Within just a few years after their widespread introduction, however, the authors began observing a disturbingly high number of bed and mound failures; sometimes with beds were only a couple of years old. These failures were either overt, as is the case when untreated septic tank effluent starts "daylighting" out onto the surface of the ground, or technical, as is the case when it takes an adequacy test to reveal the presence of excessive quantities of effluent ponded within the bed structure itself. In recent years the popularity of beds has waned to the point that only a little over10% of new installations since 1996 have been beds.

1.2.5 Advanced Systems

Advanced systems (also called "alternative" or "innovative" systems) are the latest on-site wastewater disposal technology, which seeks to overcome the limitations of conventional soil absorption systems. Advanced systems are designed to provide a significant amount of pre-treatment of septic tank effluent to reduce its harmful constituents prior to discharge to a soil absorption system. When operating properly, the higher quality effluent from advanced systems makes possible the use of smaller residual soil absorption systems located closer to sensitive environments. In the 1970s the Health Department did allow a number of aerated septic tanks to be installed in Anchorage. This program was terminated after it became apparent that necessary maintenance was not being performed on those systems. MOA initiated the present advanced system program in 1993. Recent experience with advanced system technology in Anchorage is addressed in Section 6.

1.3 ADEQUACY TESTING OF ON-SITE WASTEWATER DISPOSAL SYSTEMS

An adequacy test is a field test conducted to determine whether or not a septic system is operating in conformance with regulatory requirements. While this sounds straightforward, the determination of what constitutes an adequate system is subjective and testing requirements and procedures have changed over time. The test is now mandatory in conjunction with a title transfer and is used to verify the condition of the septic system for the benefit of a new buyer and/or lender. Because this report uses adequacy test results as a measure of performance, it is important to specify what is meant by a passing or failing adequacy test.

As practiced in Anchorage, the septic system adequacy test is a measure of its hydraulic adequacy only – no assessment is made of its biologic treatment performance. The Municipality of Anchorage's Health Authority Approval (HAA) certificates are based on satisfactory results of an adequacy test conducted by a professional engineer. This requirement ensures that non-passing systems are upgraded whenever a property is sold.

Residential septic systems in Anchorage are sized on the basis of the number of bedrooms in the house. The assumption is that two people occupy each bedroom and that each person uses 75 gallons of water per day, so the septic design requirement is 150 gallons per bedroom per day. In designing a system percolation tests are used to rate the absorption characteristics of in-situ soil in terms of gallons per day per square foot. By multiplying these two numbers the required number of square feet of absorption area for a particular home can be calculated. Soil absorption systems usually consist of a horizontal distribution pipe or pipes underlain by coarse washed gravel that provides an avenue for septic tank effluent to be absorbed into the native soil. The effective absorption area is the total surface area of the interface between the sewer gravel and the in-situ soil. Monitor tubes, consisting of perforated 4-inch diameter pipe extending to the bottom of the sewer gravel, are installed to allow a determination of the depth of ponded liquid in a soil absorption system.

1.3.1 Adequacy Testing Procedures

While no two septic systems are identical, the basic procedures for conducting an adequacy test are as follows: First, the tester must locate the monitor tube(s) in the soil absorption system and measure the fluid depth in them to determine the initial level of any ponded effluent relative to the elevation of the horizontal distribution pipe network. If the fluid level is at or above the level of the horizontal distribution pipe, the system is said to be operating in a "surcharged" condition. Current Municipal guidelines do not allow a surcharged system to be classified as adequate, even if it is able to still accept the wastewater load generated by the residence.

Next, measured quantities of water (typically 500 – 1000 gallons) are introduced into the system through a cleanout pipe usually located upstream of the soil absorption system. While the water is flowing into the system the tester periodically measures the fluid level in the monitor tube(s) and thereby correlates changes in fluid depth to the numbers of gallons of water added. Then, when either the desired number of gallons of water has been added or the fluid level in the monitor tube has risen to the level of the horizontal distribution pipe, the tester stops adding water and starts recording the rate that the fluid level recedes in the monitor tube(s). Using these measurements the tester is able to calculate a short-term absorption rate and extrapolate from that the daily absorption, which he then compares to the design requirements based on the number of bedrooms in the residence. Often these measurements must be made over two or three cycles in order to obtain consistent data that will enable the tester to be confident of the extrapolated rate.

1.3.2 Adequacy Testing Pitfalls

While the above procedures are straightforward in concept, there are a number of pitfalls, particularly with older systems, that can trip up the unwary tester and lead to his making an incorrect adequacy determination. Some of the common pitfalls include: (1) There may not be any monitor tube in the soil absorption system or an existing monitor tube may not extend down to the bottom of the sewer gravel – this can be rectified by having an excavator dig down to expose the surface of the sewer gravel and then drive a perforated steel pipe down to the bottom of the sewer gravel. (2) The perforations in the existing monitor tube may have become clogged over time causing it to appear as though there were more fluid in the system than there really is. The performance during an adequacy test should reveal this, and the monitor tube and other system pipes can often be jetted out and made functional once again. (3) If the residence has been unoccupied for an extended period of time prior to the test the soil absorption system may have mostly dried out so that the addition of a normal dose of water only partially refills it. In this case the measured reabsorption rate of the partially filled system may be very low, causing it to appear that the system is failing. Sometimes it is possible to add even more water (perhaps necessitating a water truck) to more completely refill the system. This may then lead to measurement of an adequate reabsorption rate.

1.3.3 What an adequacy test doesn't determine

There are certain situations in which a septic system may pass an adequacy test but still have problems that are undetected.

Situation 1: The septic system could be installed in soils that are subject to seasonal high water table which usually occurs shortly after breakup. A test conducted any other time of year probably would not reveal this condition. If the soil absorption system is constructed sufficiently downhill of the residence, seasonal flooding might not affect the operational performance of the system from the point of view of the resident even though the system was contaminating the groundwater. Such a condition is not uncommon in Anchorage. Even though such a system may appear to be functionally adequate on the basis of an adequacy test, it is operating in violation of regulations and thus should be classified as a failed system.

Situation 2: Another situation may involve a system serving an unoccupied residence. As mentioned in the previous section, the tester can attempt to duplicate normal operating conditions by adding an unusually large amount of water to refill the system to its usual working level. But, this level is unknown and it is impossible to fully mirror normal operating conditions. After a system has dried out for an extended period of time the composition of the clogging mat may change allowing it to briefly absorb water at a higher rate than normal.

Situation 3: Due to errors made at the time of installation, or if there have been subsequent undocumented modifications, the soil absorption system may not be actually configured as shown on the record drawings. The system could be either deeper or shallower than indicated, or bigger or smaller, and this condition might not be determinable from the monitor tubes and other cleanout pipes. Thus, there could be unknown code violations and/or unknown factors could be skewing the apparent test results. The longer a tester has been conducting tests the more savvy he will become at interpreting performance data, but there is always a possibility that reported adequacy test results will not fully describe the situation. An adequacy test provides a measurement of the absorption system performance on the day of the test, but there can be no guarantee as to how that relates to long-term performance under different conditions.

Situation 4: Unless the septic tank is actually starting to visibly collapse, an adequacy tester has no way of assessing the structural integrity of the septic tank. Most septic tanks installed in the Anchorage area are fabricated out of steel and have a quite limited lifespan, typically 15-25 years. Cast iron septic tank outlet pipes sometimes become obstructed due to corrosion; this may or may not be evident to the person conducting an adequacy test.

2. SITE INSPECTIONS OF 83 RANDOMLY SELECTED BEDS

2.1 FIELD INVESTIGATION

A primary goal of the project was to determine whether or not soil absorption beds in Alaska are in fact more prone to early failure than other types of soil absorption systems. In an attempt to eliminate as many variables as possible the authors conducted inspections of a random subset of all the soil absorption beds in Anchorage. The primary purpose of the inspections was to measure the depth of any fluid that had ponded in the bed. Secondary goals were to measure fluid depths in other standpipes, measure fluid temperatures, and to obtain information on homeowner water use patterns.

To assist us in this effort the Municipal Health Department compiled a list of approximately 1200 soil absorption systems in Anchorage that had been classified as either beds or mounds, along with the names and addresses of the owners of record. Our goal was to conduct field inspections of approximately 100 beds that were a representative subset of all beds in Anchorage. Using a random number generator we selected 150 sites out of these 1200 and sent letters to the owners (with prepaid return envelopes) requesting permission to conduct site inspections. We were disappointed to receive only 73 responses of which 44 owners granted us permission to inspect and 29 denied us permission. Efforts to contact non-responsive owners by telephone were only marginally successful. We then tried to augment the pool of available sites by selecting an additional 90 sites and sending out another 90 letters. We eventually received permission to inspect approximately 90 out of the 240 selected sites.

Not all of the sites for which permission was obtained proved possible to inspect. A few turned out to no longer be served by a soil absorption bed (in most of these cases the bed had failed and had been replaced with a different type of system) and some of the others had no monitor tubes that could be used to determine the amount of any fluid that was ponded in the bed. Ultimately we were able to conduct meaningful site inspections of 83 beds. Since the initial round of inspections we have conducted at least one and sometimes two follow-up inspections on most of the beds.

On the initial site visits to these 83 beds, 48% were found to have fluid depths in excess of 6 inches at the time of our inspection. Unless there were extenuating circumstances, these beds would technically be classified as "failing" according to Municipal Health Department guidelines, without the need to conduct an adequacy test. We did not conduct adequacy tests to determine how many of the remaining 52% were operating satisfactorily. Including the follow-up inspections, we now have performed a total of 160 inspections. On 55% of these inspections fluid depths in excess of 6 inches were measured, meaning they would automatically be classified as in at least technical failure. This higher percentage is probably attributable to the fact that, with no new systems being added to the inspection set, the average age of the selected systems was getting older over the course of our study. Fluid depths in excess of 12 inches were found on 35% of the inspections.

There are several factors that we believe may cause the overall failure rate of beds to be even higher than indicated by the above numbers. The first is that owners who thought their systems might be in failure may have been more reluctant to grant us permission to inspect out of fear that the inspection could precipitate some sort of enforcement action. We sought to alleviate these fears by assuring that no site-specific inspection data would be turned over regulators, but nevertheless mistrust might still exist. Thus our sample may have been skewed towards better performing systems. Secondly, many of the systems were poorly documented and in some cases monitor tubes may not have penetrated to the bottom of the sewer gravel. Thus, measurements of fluid depths in monitor tubes may not always have reflected the true depth of fluid ponded in the beds, causing some that we classified as passing to be actually failing. Thirdly, some of the homes were unoccupied at the time of our inspections, causing the measured fluid depths to be artificially low. Finally, some of the homes that were functioning adequately to handle the wastewater loads imposed by the actual house occupants might not have been able to handle the higher design loads necessary to pass an adequacy test.

Using the data from the 160 site inspections we tried to establish a correlation between fluid depth and age of beds. Figure 3 is a plot of this data with a trend line established by linear regression. While the trend is towards increasing depth with increasing age there is a great deal of scatter in the data making it difficult to have a high level of confidence in the trend line. In looking at this plot one should bear in mind that beds with over 6 inches of fluid are technically in failure, and beds with over 12 inches of fluid are surcharged up into the overlying soil. Since the overlying soil has very little void space for surge capacity these large fluid depths measured in monitor tubes will also tend to fluctuate greatly with small changes in usage.

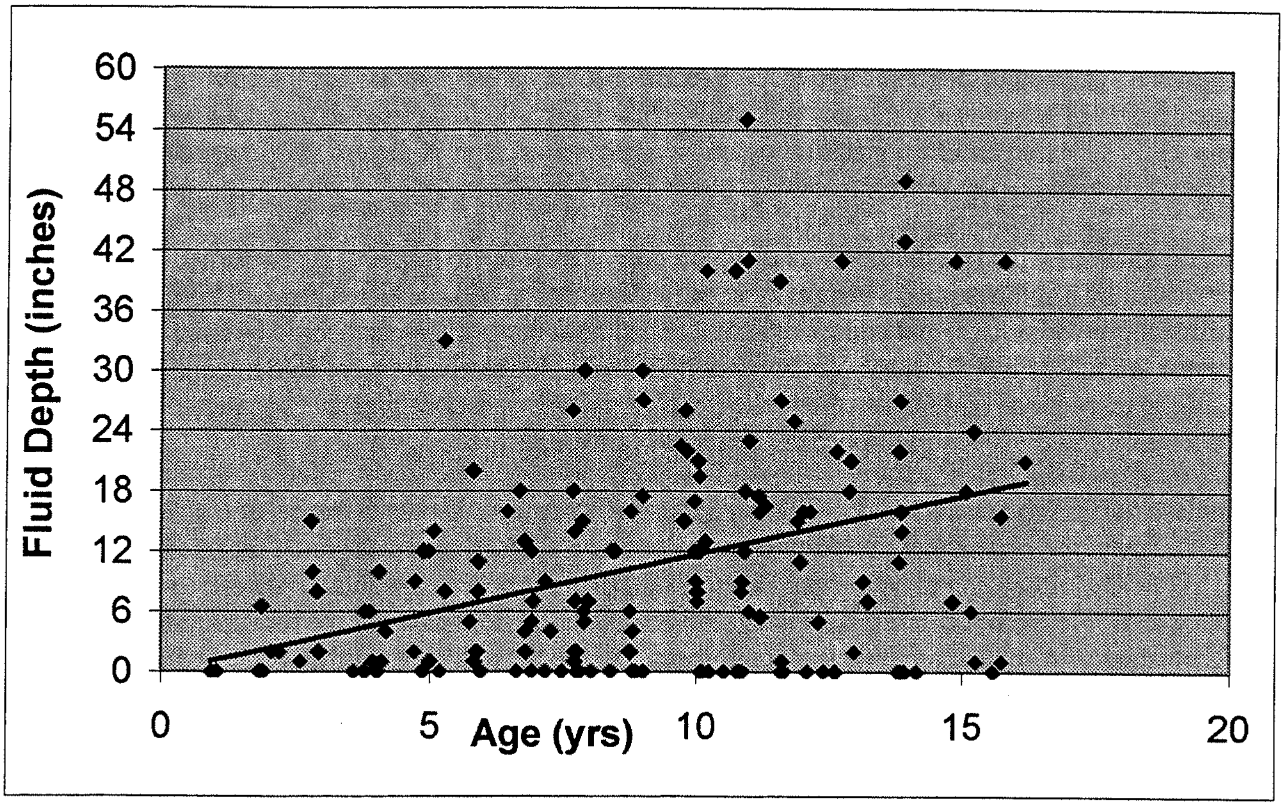


Figure 3. Soil Absorption Bed Fluid Depth vs. Age

A detailed breakdown of the changes in bed fluid depth over time at 65 different locations where we made multiple inspections is provided in Appendix A. At 41of the sites the fluid levels increased; at 11 of the sites the fluid levels remained unchanged or were zero; and at 13 of the sites the fluid levels actually decreased over time. While in the aggregate the trend is obvious, these anomalies illustrate the limitations of relying on random spot inspections when there are so many different factors potentially affecting the measurements.

In conjunction with the initial site inspections we also gathered data on fluid temperatures in each of the septic system components and wherever possible interviewed homeowners regarding their occupancy and water use. The temperature of the septic tank fluid at the 73 locations where we were able to measure it ranged from 41.6°F to 78°F. Since the second coldest temperature was 48°F, it appeared that the lowest temperature must have been taken at a house that had been unoccupied for some time allowing the septic tank fluid to cool to near ambient ground temperature. The average septic tank fluid temperature for the other 72 sites was 61.3°F. We were only able to collect fluid temperatures in the beds at only 23 of these sites, since there had to be at least 6 inches of fluid for our temperature sensor to work. The fluid temperature in these 23 ponded beds ranged from 39°F to 57.4°F with an average temperature of 49.6°F. This illustrates the decrease in temperature with time and distance from the source and also the fact that residual warmth is imparted to the soil around the beds by the fluid passing through it.

During the initial site inspections we interviewed residents of 40 of the homes served by these soil absorption beds. The reported occupancy ranged from 1 to 8 people with an average of 3.5 people per house. We compared these occupancy numbers to the bedroom rating of those houses and found that they had an average of 3.4 bedrooms per house. While we did not have any way of determining actual wastewater flow, it appears that the average actual occupancy was approximately one half of the average design occupancy. Out of the 40 interviews, 18 residents reported having garbage disposal units, 6 had water softeners and 9 had used some sort of septic tank additive. We were unable to establish any statistically significant correlation between any of these parameters and depth of ponding of effluent in the soil absorption beds.

2.2 CONCLUSION

Despite its inherent limitations, the data generated by this spot inspection effort strongly supports the authors' initial hypothesis that soil absorption beds have a poor performance track record in Anchorage. Based on our inspection results it seems safe to conclude that over 50% of the soil absorption systems in Anchorage at any point in time are not functioning in a manner that would qualify them for issuance of a Health Authority Approval (HAA) certificate. This is not the same thing as saying that 50% of the beds constitute a health hazard, since it is clear that a large percentage are able to continue to operate in an overfull condition without backing up or "daylighting" onto the surface of the ground.

3. ANALYSIS OF ONE FIRM'S INSTALLATION AND ADEQUACY TEST DATA

3.1 DATABASE

In order to compare the performance of different types of septic systems the author compiled a computerized database of 235 septic system installations and 832 septic system adequacy test results overseen by his engineering firm between the years of 1984 – 1999. Because this database represents the work of a single engineer following consistent standards and procedures, it allows one to make particularly useful statistical comparisons of septic system construction and performance.

Concerns regarding the validity of a septic system database include the fact that there is a significant variation in the quality of construction of individual systems even within a small geographic area. Different adequacy testers have somewhat different standards and procedures, so even identical systems will not necessarily receive identical evaluations. It is not unusual for soil conditions to vary significantly, even within the span encompassed by a single septic system. Although design standards are prescriptive, homeowner water use patterns are far from homogeneous. Soil absorption system performance is affected by local soil variations as well as actual water use patterns in the residence.

This database was prepared with Microsoft Access. The database is set up with a location form containing generic information about the property and the owner at the time of the first contact. Each location form has one or more sub-forms describing the as-built composition of the septic systems and wells. Finally, each septic system or well sub-form contains further sub-forms incorporating data from each adequacy test.

Data entry proved to be very time-consuming partly because the data had to be extracted from a variety of documents contained within the author's project files. Subjective decisions had to be made in many instances regarding how the data in the project files should best be fit into the standardized format of the database. To avoid overlooking important data and to minimize errors it was necessary to spend time thoroughly reviewing each file to establish a good overview of each project before starting to enter the data.

After the data entry was completed the author used queries to sort the entire body of data on the basis of various parameters, including location, system type, date and adequacy test results. In reviewing the following material it is important to keep in mind that the data represents the records of just one engineer, so the trends observed may or may not parallel the work of others.

3.2 TYPES OF SYSTEMS INSTALLED

Figure 4 compares the number of bed, trench and wide drainfield installations overseen by the author's engineering firm over the past 15 years. This shows that the number of beds installed was low up through 1988, but was followed by a sharp increase over the next four years. In 1991 sixteen out of twenty-three installations, or 70%, were beds. Then, after the author became concerned about the performance of beds, he scaled the number of bed installations back down to only a couple per year, while increasing the numbers of trench installations. From this we can see that to a large extent it is possible to substitute trenches for beds. The trade-off is a combination of a conscious effort to minimize the use of beds, coupled with less stringent regulatory requirements mandating the use of filter sand, which forces the absorption system type to be a bed.

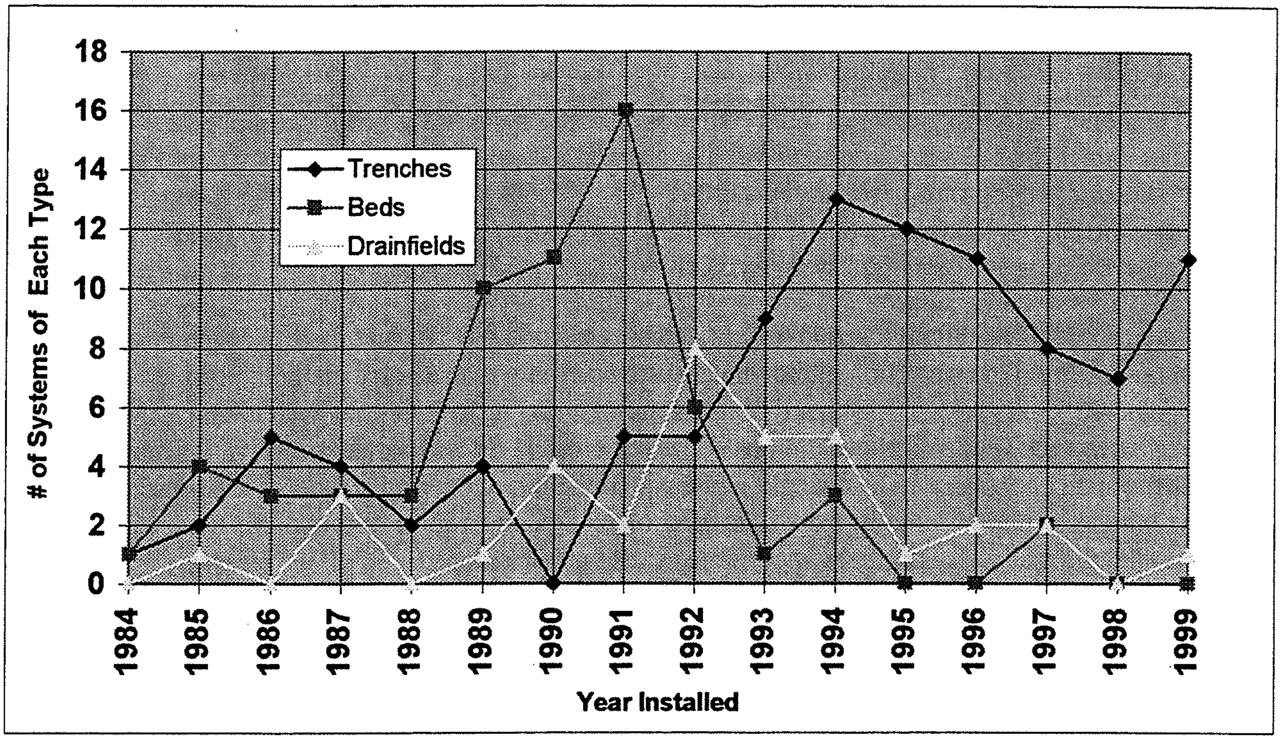


Figure 4. Types of Septic Systems Installed by FTS

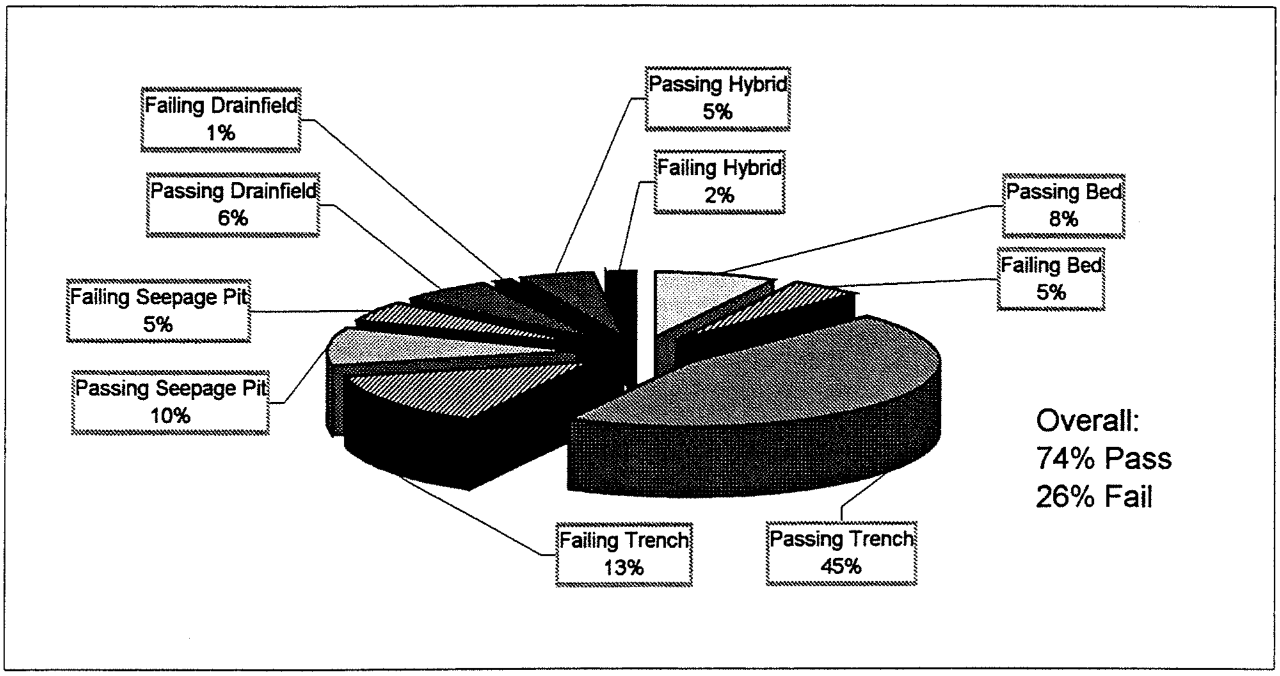


Figure 5. FTS Adequacy Test Results By System Type

3.3 ADEQUACY TEST RESULTS

Figure 5 is a pie chart displaying the breakdown by system type and results of 832 adequacy tests performed by the author's engineering firm over the past 15 years. Although trenches were by far the most common type of system tested, proportionally fewer trenches failed than did beds. In the aggregate 59% of this firm's adequacy tests were done on trench systems vs. 12% on bed systems. These numbers correlate closely with the overall number of beds and trenches that have been installed in Anchorage, i.e. 61% trenches and 15% beds.

Figure 6 illustrates the cumulative age distribution of soil absorption system failures broken down by system type. In this graph the results are normalized to show the percent failure rate of each system type. Each curve has two distinct portions. The initial upward sloping portion spans the range of ages of systems of that type that were in existence during the period covered by the author's tests. The curves flatten out after that age because older systems simply did not exist. The authors hypothesize that, if a significant number of older systems of each type had existed, the initial slopes of the curves would have continued until they reached 100%.

This plot illustrates the fact that **beds** have the highest overall failure rate (38%) and that these failures occur on significantly younger systems than other design types. Although their overall failure rate is much lower (14%), 5ft.- wide **drainfields** have the second steepest failure curve during the first 12 years, when the vast majority of these systems were installed. **Trenches** have a significantly lower failure rate, with very few failures occurring in the first 6 years. Because trenches have been in use for a longer period of time the failure curve continues to climb at a fairly constant rate for the first 18 years. The failure rate curve for **seepage pits** is interesting in that it appears that no failures occur at less than 10 years of age. Actually, this anomaly is explained by the fact the installation of seepage pits was virtually discontinued 10 years prior to the beginning of this engineering firm's tests in 1984, meaning that the pool of cribs available to test is becoming increasingly older. The curve illustrates the fact that many seepage pits continue to function up to an age approaching 30 years.

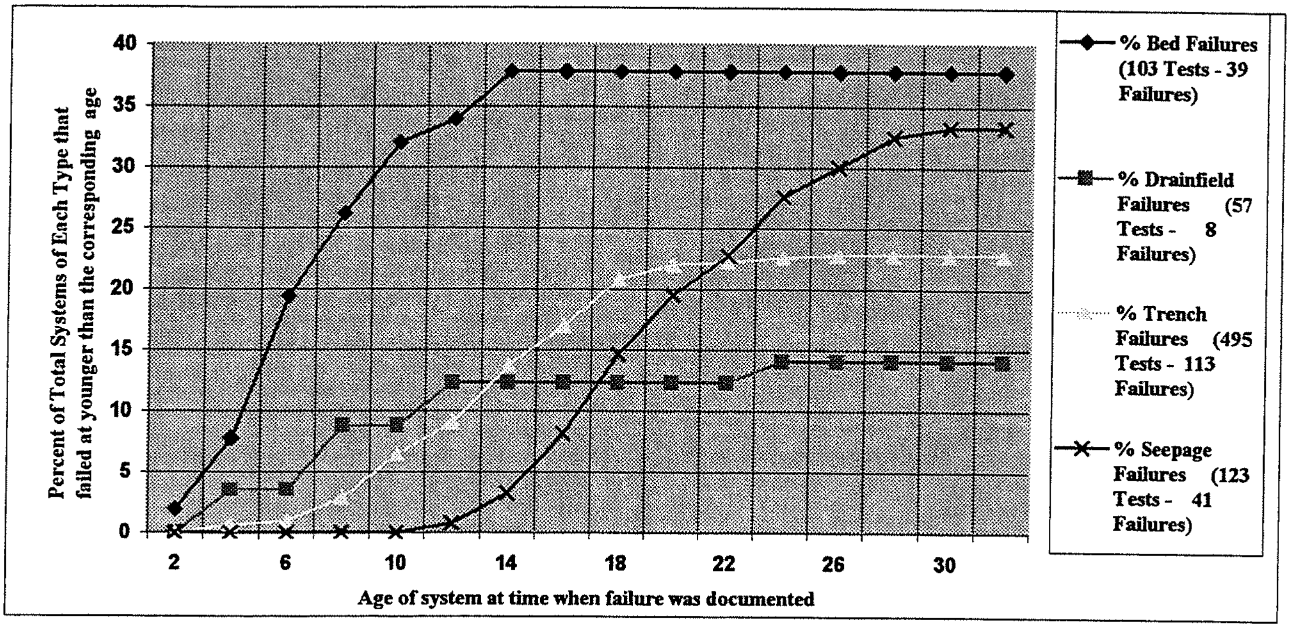
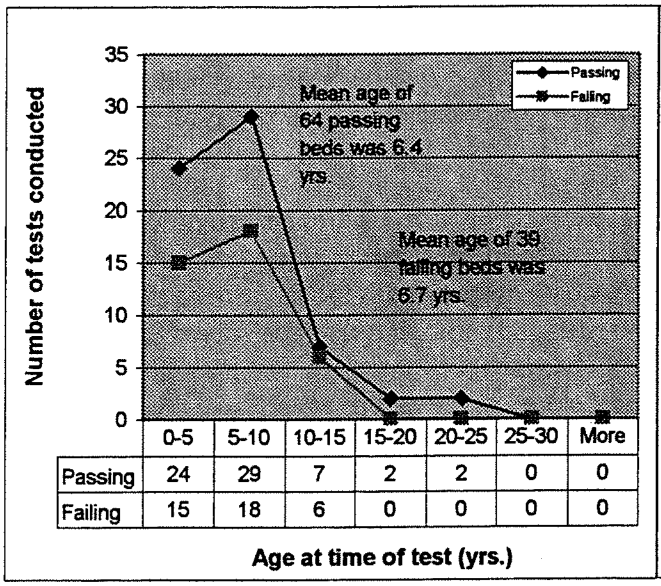


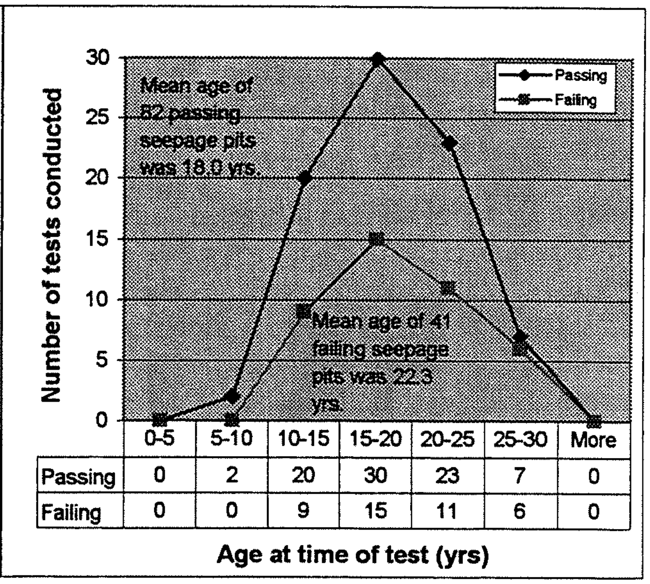
Figure 6. Cumulative Age Distribution of Soil Absorption System Failures by System Type

Figures 7-10 plot the distribution of passing and failing results vs. age for each system type. The trends that are described above are also discernable from these plots.



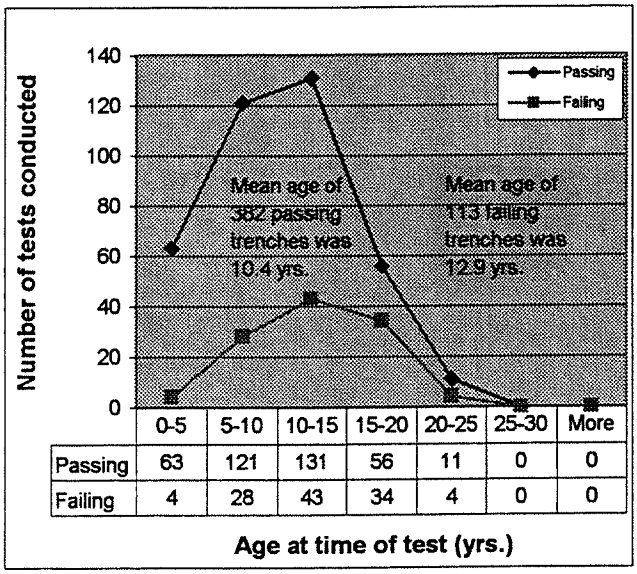
	0-5	5-10	10-15	15-20	20-25	25-30	More
Passing	24	29	7	2	2	0	0
Failing	15	18	6	0	0	0	0

Figure 7. FTS Tests of Soil Absorption Beds



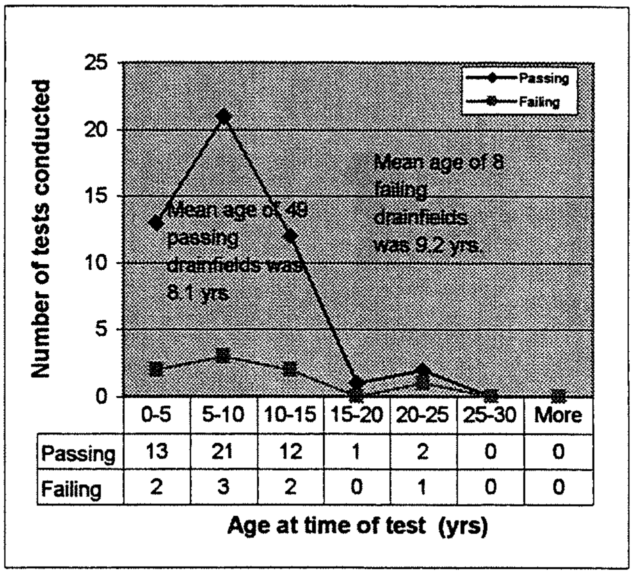
	0-5	5-10	10-15	15-20	20-25	25-30	More
Passing	0	2	20	30	23	7	0
Failing	0	0	9	15	11	6	0

Figure 9. FTS Tests of Seepage Pits



	0-5	5-10	10-15	15-20	20-25	25-30	More
Passing	63	121	131	56	11	0	0
Failing	4	28	43	34	4	0	0

Figure 8. FTS Tests of Trenches



	0-5	5-10	10-15	15-20	20-25	25-30	More
Passing	13	21	12	1	2	0	0
Failing	2	3	2	0	1	0	0

Figure 10. FTS Tests of 5'-Wide Drainfields

Table 2 shows the adequacy test failure rate by system type on an annual basis. The overall failure rate was 26% but there were significant variations from year to year. Older, less stringent requirements for a system to pass an adequacy test probably caused the failure rate to be generally lower prior to 1988. Bed failures peaked between 1991 and 1995 with a maximum of 57% of 14 bed tests failing in 1992. Since 1995 both the number of bed tests and the failure rate has declined.

Finally, table3 displays the adequacy test failure rate by system type broken down by month, irrespective of year. This allows some interesting comparisons, some of which are counterintuitive. One might hypothesize that adequacy tests conducted in April should be most likely to result in failure, due to spring snow-melt. In fact, the April failure rate is near the annual average, and higher failure rates are observed in May and June. This probably reflects the fact that "break-up" often doesn't begin until mid-April and it's effect on groundwater levels may not be felt until extremely late April and extends into May and June. Lower failure rates were observed in July and August when subsurface soils tend to be quite dry.

3.4 CONCLUSIONS

The adequacy testing data supports the authors' initial premise that beds have a poorer performance record than all other soil absorption system types. More beds fail adequacy tests than any other type of system and they do so at a younger age. The tradeoffs between system types reflected in the installation data indicate that in most situations it is possible to come up with design solutions that allow the construction of non-bed systems.

The author hypothesizes that the recent decline in bed failure rate is largely due to the reduction in the number of new beds being installed, many of which are subject to extremely early failure. Those early failing beds have probably now been replaced by either better-designed beds or other types of systems. The fact that a few older beds manage to buck the trend towards premature failure may be a result of these having been constructed in better soils or being oversized or being subjected to a lower loading rate. It has been speculated that some of the older beds that are able to pass adequacy may actually be subjected to seasonal flooding by groundwater. Such periodic flooding could cleanse the bed by flushing out accumulated solids. If so, this is obviously an unacceptable means of prolonging the life of a soil absorption system.

Year	All Systems			Beds			Trenches			Drainfields			Seepage Pits			Hybrid Systems		
	No. of Tests	No. of Failures	Failure Rate	No. of Tests	No. of Failures	Failure Rate	No. of Tests	No. of Failures	Failure Rate	No. of Tests	No. of Failures	Failure Rate	No. of Tests	No. of Failures	Failure Rate	No. of Tests	No. of Failures	Failure Rate
1984	10	4	40.0%	0	0		4	2	50.0%	1	0	0.0%	5	2	40.0%	0	0	
1985	30	2	6.7%	0	0		16	0	0.0%	4	1	25.0%	8	1	12.5%	2	0	0.0%
1986	72	9	12.5%	2	0	0.0%	53	4	7.5%	5	1	20.0%	8	3	37.5%	4	1	25.0%
1987	35	3	8.6%	2	1	50.0%	20	0	0.0%	3	0	0.0%	5	1	20.0%	5	1	20.0%
1988	33	10	30.3%	2	1	50.0%	13	3	23.1%	1	0	0.0%	14	5	35.7%	3	1	33.3%
1989	50	12	24.0%	4	1	25.0%	28	6	21.4%	3	1	33.3%	9	2	22.2%	6	2	33.3%
1990	76	22	28.9%	7	2	28.6%	48	14	29.2%	9	2	22.2%	8	2	25.0%	4	2	50.0%
1991	76	27	35.5%	16	6	37.5%	42	14	33.3%	2	0	0.0%	12	6	50.0%	4	1	25.0%
1992	109	32	29.4%	14	8	57.1%	64	15	23.4%	9	2	22.2%	15	6	40.0%	7	1	14.3%
1993	96	21	21.9%	12	5	41.7%	69	14	20.3%	4	0	0.0%	7	1	14.3%	4	1	25.0%
1994	54	16	29.6%	14	5	35.7%	26	8	30.8%	1	0	0.0%	6	3	50.0%	7	0	0.0%
1995	52	23	44.2%	12	6	50.0%	28	11	39.3%	3	1	33.3%	6	3	50.0%	3	2	66.7%
1996	46	13	28.3%	4	1	25.0%	28	8	28.6%	5	0	0.0%	7	2	28.6%	2	2	100.0%
1997	38	8	21.1%	6	1	16.7%	21	5	23.8%	3	0	0.0%	7	2	28.6%	1	0	0.0%
1998	32	7	21.9%	8	2	25.0%	18	3	16.7%	2	0	0.0%	1	0	0.0%	3	2	66.7%
1999	23	7	30.4%	0	0		15	5	33.3%	2	0	0.0%	5	2	40.0%	1	0	0.0%
Total	832	216	26.0%	103	39	37.9%	493	112	22.7%	57	8	14.0%	123	41	33.3%	56	16	28.6%

Table 2. FTS Adequacy Test Results By Soil Absorption Type and Year Tested

Month	All Septic Systems			Beds			Trenches			Cribs			Drainfields			Hybrid Systems		
	# of Tests	# of Failures	Failure Rate	# of Tests	# of Failures	Failure Rate	# of Tests	# of Failures	Failure Rate	# of Tests	# of Failures	Failure Rate	# of Tests	# of Failures	Failure Rate	# of Tests	# of Failures	Failure Rate
Jan	30	6	20.0%	8	2	25.0%	13	2	15.4%	5	1	20.0%	3	1	33.3%	1	0	0.0%
Feb	60	13	21.7%	7	2	28.6%	34	8	23.5%	10	3	30.0%	6	0	0.0%	3	0	0.0%
Mar	64	15	23.4%	3	0	0.0%	42	8	19.0%	10	5	50.0%	4	0	0.0%	5	2	40.0%
Apr	75	20	26.7%	9	6	66.7%	49	10	20.4%	10	2	20.0%	5	2	40.0%	2	0	0.0%
May	106	35	33.0%	14	8	57.1%	62	17	27.4%	14	6	42.9%	8	2	25.0%	8	2	25.0%
Jun	99	31	31.3%	14	5	35.7%	54	14	25.9%	11	6	54.5%	9	1	11.1%	11	5	45.5%
Jul	93	21	22.6%	12	4	33.3%	58	12	20.7%	14	2	14.3%	3	1	33.3%	6	2	33.3%
Aug	85	16	18.8%	10	2	20.0%	51	8	15.7%	15	5	33.3%	5	0	0.0%	4	1	25.0%
Sep	78	22	28.2%	9	2	22.2%	48	13	27.1%	12	6	50.0%	4	0	0.0%	5	1	20.0%
Oct	63	12	19.0%	8	4	50.0%	31	5	16.1%	15	3	20.0%	6	0	0.0%	3	0	0.0%
Nov	49	16	32.7%	6	2	33.3%	31	10	32.3%	3	1	33.3%	1	0	0.0%	8	3	37.5%
Dec	30	9	30.0%	3	2	66.7%	20	5	25.0%	4	1	25.0%	3	1	33.3%	0	0	0.0%
Totals	832	216	26.0%	103	39	37.9%	493	112	22.7%	123	41	33.3%	57	8	14.0%	56	16	28.6%

Table 3. FTS Adequacy Test Results By Soil Absorption System Type and Month Tested: 1984-1999

4. FACTORS AFFECTING SOIL ABSORPTION SYSTEM PERFORMANCE

4.1 SOIL CHARACTERISTICS

Soil is the most basic component of a soil absorption system. It appears in a variety of forms and is used to perform a variety of functions in the process of treating and disposing of wastewater. The basic function of a soil absorption system is to provide a structure for the passage of partially treated septic tank effluent into the ground. As the effluent passes through soil it receives additional treatment before reaching environments of concern, primarily water sources. The following is a brief overview of the role of soil media and sand in a soil absorption system.

Water Transport: The primary function of the soil media is to transport liquid away from the septic tank in an environmentally suitable way. Since soil is comprised of irregular grains that cannot be packed into a solid mass, pore spaces are left between individual grains through which water can pass. A soil's ability to transport water is largely a function of its grain size and distribution. In general, the coarser the grains and the more uniform their size distribution the greater the ability of a particular soil type to transmit water. Thus, gravels and sands are more effective at transmitting water than are silts and clays.

Oxygen Transport: A secondary function of the soil media is to provide a means of air diffusion through the ground. Air is necessary to provide oxygen for the respiration of bacteria involved in the degradation of the organic and nitrogenous materials contained in the wastewater stream. The same factors that make a soil permeable to water also affect its ability to transmit air, plus there is the added condition that the soil must be unsaturated.

Treatment Environment: The third function of the soil is to provide a suitable physical environment in which treatment of wastewater can take place. The treatment of wastewater in soil is both physical and biological. Physical treatment means filtration to physically stop the passage of solids carried in the wastewater stream while allowing the water to pass on through. The grain size distribution of the media dictates the size of the pore spaces available for transport, which in turn determines the size of entrained particles that are removed from the wastewater stream by the soil media. Graded soil media can also function to distribute trapped particles through a broad zone. With a graduated filter media larger entrained particles are removed first near the surface of the soil while smaller particles pass further into the soil before being stopped by smaller effective pore sizes. Physical filtration can also remove pathogens, be they bacteria or viruses, from the wastewater stream and/or introduce a sufficient time delay that they die off before reaching groundwater. The biologic treatment of wastewater in soil is made possible by the retention of entrained particles from the wastewater stream in the soil matrix either by simple filtration or adhesion onto soil grains. These entrained particles serve as a nutrient source for soil microbes, which consume them and in the process convert them into harmless substances, primarily carbon dioxide and water. Depending on oxygen availability the soil microbes can be either aerobic or anaerobic, however aerobic biodegradation is a considerably faster and more effective process than anaerobic biodegradation.

Frost Protection: A final function of the soil media in wastewater disposal in cold regions such as Alaska is to provide frost protection. The thermal mass and insulative properties of soil serve as a buffer protecting the infiltrative surface and water transport avenues from sub-freezing temperatures during winter.

4.1.1 Soil Classification

Two different approaches to soil classification are of primary relevance to designers of soil absorption systems.

Grain Size and Distribution: The Unified Soil Classification System (USCS) was developed during World War Two for the U. S. Army Corps of Engineers. The USCS classifies soils on the basis of grain size distribution and plasticity and has proven very useful in characterizing the suitability of soils for use in soil absorption systems. This system breaks soil down into four broad categories based on grain size: (1) Cobbles – soil with particles exceeding 3 inches in diameter, (2) Gravel – soil with particles having a diameter exceeding ¼ inch but smaller than cobbles, (3) Sand – soil whose particles are retained on a #200 (approx. 0.08mm) sieve but smaller than gravel, and (4) Silts and Clays – soil with particles smaller than sand. The USCS classification of a soil sample is based on the percentage by weight of particles falling within each of these categories and their subcategories.

Hydraulic Conductivity: The second approach to soil classification applicable to the design of soil absorption systems is the "falling head percolation test" which was developed for the U.S. Public Health Service around 1950. The "perc test" evaluates the saturated hydraulic conductivity of a soil by measuring the rate at which water is able to be absorbed into the soil under standardized conditions. The units used to express "perc test" results are minutes per inch. Although the perc test has been widely criticized, most septic system regulatory agencies have adopted prescriptive regulations correlating perc test results to the sizing of soil absorption systems. Soil is an inconsistent medium and localized variations in soil structure can lead to very different "perc test" results, even for tests conducted in close proximity to each other.

4.1.2 Desirable Soil Characteristics for On-Site Soil Absorption Systems

Soils falling within the general categories of sands and gravels comprise the preferred soil categories for use in soil absorption systems. The pore spaces between loose cobbles are too large to provide necessary filtration. Gravels tend to be extremely permeable and thus function well from a purely physical point of view because they are very resistant to clogging. But, like cobbles, pure gravel provides limited filtration of septic tank effluent and thus limited treatment of the wastewater passing through it. For this reason sand is the ideal soil type for on-site wastewater treatment – providing both excellent water and air transport characteristics and a sufficiently fine grain size distribution for effective filtration and biodegradation to occur. Because of their small pore size pure silts are only slowly permeable and thus require a very large surface area to transport a significant quantity of water. Silty soil conditions are, however, commonly encountered, so it is necessary to be able to design soil absorption systems that function in silty soils. Clays expand when wetted and are therefore impermeable, which renders them unsuitable for construction of on-site soil absorption systems.

4.1.3 Sand Filters

In recent years septic system design professionals have focused considerable attention on the use of artificial sand filters to enhance the performance of soil absorption systems, both in terms of level of treatment and longevity. Soil grain size and distribution within an artificial sand filter is the single parameter affecting the operation of a soil absorption system that can be most effectively controlled by the designer. Sand can be readily manufactured to meet virtually any specification and, although the unit cost of manufactured sand is significantly higher than that of pit-run material, the quantities involved are usually small enough for it not to be cost-prohibitive.

In addition to the USCS classification engineers commonly use a couple of other measurements to quantify properties of sands that are relevant to its performance as a filter material. *Effective grain size* refers to the maximum grain size of the smallest 10% of the sand by weight. In other words, 10% of a sand with an effective grain size of 0.15 mm would pass through a sieve with 0.15 mm holes. *Fines* loosely refers to the fraction of a sample that passes through a #100 sieve. The *Uniformity coefficient* of a sand C_u describes how well graded the sand is. It is defined as the ratio of the maximum diameter of the smallest 60% of a sample to the maximum diameter of the smallest 10% of a sample.

4.1.3.1 Purposes of Sand Filters

Sand filters have been used in Alaska in an attempt to accomplish two somewhat contradictory objectives:

1. Reducing Hydraulic Conductivity: One purpose of installing sand filters is to slow down the rate of water transport through clean soils and thereby promote the formation of an organic mat. In the mid 1980s, regulatory agencies in Alaska and elsewhere became concerned that native soils with rapid "perc rates" might not be providing an acceptable level of treatment to wastewater passing through it prior to its reaching groundwater. This is of particular concern on sites where a shallow water table is overlain by a stratum of highly permeable clean gravelly soil. To address this perceived problem Anchorage wastewater regulations required that 2-foot thick sand filters be installed under all soil absorption systems where the percolation rate of the native soil was faster than 5 minutes per inch. Furthermore, because clean sands also have perc rates faster than one minute per inch, the regulations specified that the filter sand should include up to 15% silt particles to promote the formation of an organic mat. This regulation encouraged the installation of bed type soil absorption systems instead of trenches, because of the impossibility of installing a sand filter sand along the sidewalls of trenches.

In retrospect, sands meeting this specification did their job all too well. Based on the author's research we believe that both the sharp increase in the number of "bed" type system installations and the subsequently noted propensity of beds towards premature failure can be largely attributed to this filter requirement. Like any other in-situ silty soil, the silty sand used in sand filters did promote the rapid formation of an organic clogging mat over the bottom surface of a soil absorption bed. This in turn caused effluent to pond in the bed. The resulting anaerobic conditions at the absorption interface led to a rapid buildup of ponded fluid to depths at or above the level of the distribution pipe network. Although this is contrary to the way beds are designed to work, some beds seem to be able to limp along in this fashion for a number of years. We hypothesize that the dominant avenue of absorption for these beds may be up through the top into the overlying soil, then laterally. In other beds the depth of ponded fluid continued to increase until it daylighted onto the surface of the ground. MOA adequacy test guidelines state that any system with ponded fluid at or above the level of the horizontal distribution pipe network is technically failing.

Revisions to Anchorage's wastewater disposal regulations in 1990 allowed soil absorption systems to be constructed in soils with perc rates as fast as one minute per inch without a sand filter, and also increased the effective grain size of filter sand and reduced the maximum allowable silt content from 15% to 5%. As regulators became aware of the problems associated with premature clogging mat formation in sand filters they started informally allowing systems to be constructed without filters in soils with perc rates faster than one minute per inch so long as the native soil was classified as sand or had a significant silt content. This more liberal interpretation allowed trench designs to be used once again in many situations where beds had briefly been the only option.

2. Optimizing Treatment Environment: A second objective of sand filters is to create an optimum environment in which wastewater treatment can take place. Rather than seeking to slow the passage of water through the filter by promoting the formation of a clogging mat on or near the surface of the filter, the objective here is to prevent the formation of any clogging mat. Absent a clogging mat, the solids entrained in wastewater are more broadly distributed throughout the upper portions of the sand filter. Stripped of its suspended solids by the filtering action of the sand, the uncontaminated liquid portion of the wastewater readily passes on through the remainder of the sand filter and into the receiving native soils. Once the entrained solids are widely distributed in an unsaturated aerobic environment they become a useable food source for naturally occurring soil microorganisms that convert them into harmless gaseous byproducts and water. The goal in designing a sand filter is to determine the optimum grain size distribution and thickness for this to occur. Numerous laboratory and field tests have indicated that a two-foot thickness of most sands is sufficient to remove 99%+ of all contaminants in the wastewater stream, so the focus is really on grain size. Much of the research has been done in conjunction with development of an advanced treatment system, the "Intermittent Sand Filter" (ISF).

4.1.3.2 Specifications for Filter Sand

The original filter sand specified for Wisconsin mounds and used in many intermittent sand filters was ASTM C-33 concrete sand. This specification was apparently chosen because of the widespread availability of concrete sand. C-33 sand is quite fine with an effective grain size of approximately 0.2 mm. The major drawback of concrete sand is the wide range in the allowable amount of very fine material (2-10% by weight passing the #100 sieve). Experience has indicated that concrete sand manufactured with the amount of fines near the low end of the allowable spectrum can work quite well as filter sand and has far less propensity for clogging than C-33 sand with fines approaching 10%. Unfortunately, there is no requirement at all in the C-33 specification governing the amount of material passing the #200 sieve, so it is possible for C-33 sand to have a silt content of up to 10%, which is far too high for good filter performance. In practice washing in addition to screening is usually necessary in order to reduce the amount of fines in filter sand.

In their 1985 Technology Assessment of Intermittent Sand Filters prepared for EPA Anderson, Siegrist and Otis stated that the recommended effective grain size was between 0.4mm and 1.0 mm, coupled with a uniformity coefficient of less than 4.0.

In 1994 Orenco Systems, Inc came up with a recommended sand gradation for their ISFs which they called 4-50 sand (see Figure 11 at the end of this section). This sand is considerably coarser than C-33 sand and has an effective grain size of 0.6 mm. Unfortunately; no plant in Anchorage manufactures sand to this exact specification.

Where high quality filter sand is very expensive, a recommended design strategy would be to use it only in the top 6-12" of the filter where it is most needed, and then to use a less expensive sand such as concrete sand in the bottom portion of the filter where there is less potential for formation of a clogging mat. This creates a "stratified filter" which potentially offers the highest level of performance.

4.1.3.3 Filter Sand Availability in Anchorage

In recent years, both Municipal Health Department regulators and private engineers have devoted a considerable amount of effort to finding available sources of good filter sand and/or encouraging local aggregate suppliers to manufacture it. The biggest problem encountered has been in ensuring quality control. There are sources of pit run sand in Anchorage, specifically the Lake Otis Gravel Pit, which lab tests show can supply extremely clean filter sand, at a very reasonable price. Unfortunately; with pit run material there is no way to guarantee that all the sand loaded onto a truck has the same gradation as a sample from the same source which was tested at a lab. Even with manufactured sands it is difficult to ensure that the plants (particularly the smaller operators) consistently follow the same procedures used in manufacturing the run from which a prior sample was collected and tested. The quantity of sand needed for septic system sand filters in Anchorage is still low enough that it is not a significant factor in most plant's operations. Following is a comparison of potential filter sands that are available in Anchorage.

"C-33 Concrete Sand": This sand is readily available in Anchorage from most aggregate suppliers. Typical sample test results show an undesirably high 6-8% passing the #100 sieve.

"Lake Otis Gravel": Although a pit run material, several samples collected by the author have shown it to be predominantly sand with approximately 1% passing the #100 sieve and 0.7-0.8% passing the #200 sieve. If one could be confident in its consistency, this would be an excellent, inexpensive, filter sand.

"Airport Sand": This sand is manufactured in Anchorage to FAA specifications for wintertime sanding of airport runways. It has less than 0.5% passing the #100 sieve and is an excellent sand for filters, but so far this filter sand has been cost prohibitive at approximately $40 - $60/ton. The grain size distribution for Airport sand is plotted by hand on Figure 11.

"CPP Road Sand": In the mid-1990s this sand was manufactured to a fairly tight standard that called for less than 2% passing the #200 sieve, and in practice was usually nearer to 1%. Recently, the plant's standards seem to have slipped. A recent sample tested in 1999 showed an undesirably high 10% passing the #100 sieve and 3.1% passing the #200 sieve.

"Quality Innovative System Filter Sand": This washed sand has recently become available at a reasonable price and test results show that it has excellent characteristics of less than 2% passing the #100 sieve and less than 1% passing the #200 sieve.

4.1.3.4 Sand Filter Design Recommendations:

Select a sand with minimal content of fines (<2% passing the #100 sieve, and <1% passing the #200 sieve – ideally 0% for both). A washed sand is best. Some pit run sands can be excellent, but it's impossible to guarantee consistency.

Select a coarse sand having a large effective grain size, ideally between 0.4 mm and 1.0 mm.

Select a sand that is well graded for best treatment performance. A stratified filter with a coarser sand overlying a finer sand is even better.

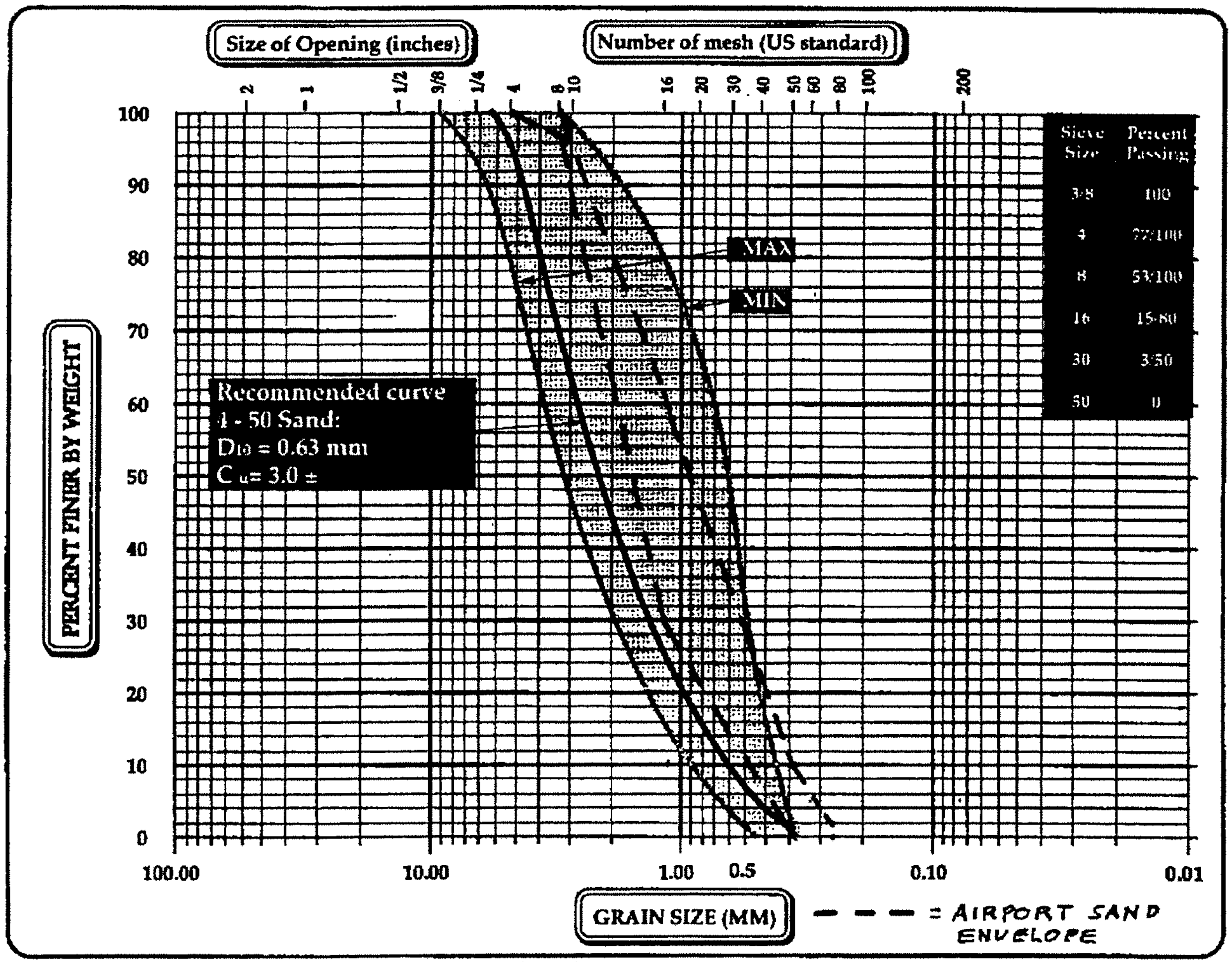
Dose the filter with small pressurized doses distributed over the surface of the filter and spread out over the course of the day to ensure best performance.

Protect the surface of the filter sand from contamination with fines washed out of the sewer gravel by bedding the distribution pipe network in the cleanest washed sewer rock available.

Enhance the aerobic environment in the sand filter by minimizing burial depth, eliminating rigid insulation, and backfilling with granular soil. Mechanical aeration using a small air compressor and an air distribution pipe network is the ideal, but probably cost prohibitive except in an ISF.

ENCO SYSTEMS, INC.
olonial Road Roseburg, OR 97470
503 673-0165

RECOMMENDED SAND GRADATION
FOR INTERMITTENT SAND FILTER SYSTEMS LOADED AT 4 GPD/SQ. FT.



Note: Sand used in intermittent sand filters must be well washed. The presence of excessive fines can cause premature plugging of the filter. Fine aggregate shall be determined using wet sieving procedure. A sample of sand can be sent to OSI for evaluation. Care must be exercised during placement of the sand so that segregation does not occur (pumping sand into the filter in a slurry will cause segregation of the particles). The moisture concentration of the sand must, however, be sufficient to ensure adequate compaction.

Figure 11. Grain Size Distribution for Filter Sand

4.2 SOIL OXYGEN

One of the major goals in the design of an on-site soil absorption system is to create an environment wherein microorganisms can digest the suspended organic matter and break down many of the harmful constituents of wastewater. These microbes occur naturally both in the wastewater stream and in the receiving soils. They utilize the organic materials in the wastewater as a food source and by consuming it convert it predominantly into carbon dioxide gas and water. Pathogens in the wastewater stream also become food and/or die out before reaching groundwater. While both aerobic and anaerobic bacteria exist which can break down organic material, aerobic bacteria do so at a much faster rate. Therefore, an adequate supply of oxygen is essential for microbial decomposition to take place. Oxygen is also necessary to convert organic nitrogen and ammonia contained in septic tank effluent into nitrate form. The following is a brief overview of the role of oxygen in soil absorption system performance.

4.2.1 Oxygen demands for decomposition

The strength (or concentration) of wastewater can be expressed in terms of the amount of oxygen needed to provide for the metabolic consumption of microorganisms necessary to break down the organic (carbonaceous) matter contained in it. This strength is usually expressed as the 5-day biochemical oxygen demand (BOD_5), with the units being milligrams of oxygen per liter of wastewater. Typical residential septic tank effluent in the "lower 48" has a reported BOD_5 of approximately 150 mg/l. The authors have measured significantly higher BOD_5 levels for septic tank effluent in Anchorage, in the vicinity of 200 – 300 mg/l. A 1987 analysis done by Robert Siegrist in Wisconsin found that due to the slowly biodegradable nature of septic tank effluent the long term carbonaceous BOD can be double the BOD_5, or approximately 300 mg/l, for typical septic tank effluent in the "Lower 48"

Nitrogen in septic tank effluent is partially organic nitrogen but primarily in the form of soluble ammonia (NH_3). The combined amount of organic and ammonia nitrogen in septic tank effluent is expressed in mg/l as Kjeldahl nitrogen (TKN). In an aerobic environment autotrophic (nitrogenous) bacteria convert Kjeldahl nitrogen into the more stable nitrate nitrogen form (NO_3). The nitrogenous bacteria oxygen demand of converting ammonia nitrogen to nitrate nitrogen can also be expressed in mg/l as nBOD. Based on the nitrification reaction stoichiometry, nBOD = 4.57TKN. With a typical septic tank effluent TKN strength of 55 mg/l, this translates into an equivalent nBOD of approximately 250 mg/l.

Combining these two, the total oxygen demand to fully treat septic tank effluent may be on the order of 550 mg/l. If a 3-bedroom residence generates 450 gallons per day of wastewater, the amount of oxygen necessary to treat it is 450 gal/day x 3.8 liters/gal x 550 mg-O_2/liter = 940 grams-O_2/day which is the equivalent of a little over 2 lb. of oxygen per day. The density of air is approximately 0.08 lb/ft^3, and air is approximately 23% oxygen by weight. Aerobic microbes can survive breathing air with an oxygen concentration as low as 5%, leaving the other 18% as consumable oxygen. Using these figures one can calculate that the amount of air necessary to be supplied to the soil to support the bacteria = 2 lb-O_2/day x ft^3/0.08 lb.Air x lb.Air/0.18lb-O_2 = 140 ft^3/day which is the equivalent of approximately 0.1-cfm. This number represents the minimum amount of air that must be available (on a continuous basis) in the soil at the infiltrative surface for aerobic treatment of a typical 3-bedroom soil absorption system.

4.2.2 Air transport through soil

The natural processes by which air moves through soil are difficult to quantify. Because soil is a granular material there are open spaces between the soil particles that allow passage of air and/or water. When the soil is unsaturated these pore spaces are filled with air, however if a soil becomes saturated with water the air is replaced with water, preventing oxygen transport. The oxygen content of the air in soil pore spaces near the ground surface is approximately that of atmospheric air of 23% O_2 by weight. As aerobic microbes grow in the soil they consume oxygen and respire carbon dioxide, which reduces the oxygen content of the soil air. Several mechanisms are available to replenish the oxygen content of the soil air, although diffusion is generally considered to be the most important. Since the soil air is not physically separated from the atmospheric air natural diffusion works to restore equilibrium between these two air masses. The size and configuration of the interstitial spaces between the soil particles affect the rate of diffusion. In general, the coarser grained the soil the more readily air is able to diffuse within it. Fine-grained soils such as silts and clays demonstrate much slower diffusion. Calculation of air diffusion within soils involves determination of a "tortuosity" factor reflecting the configuration of interstitial spaces, which in turn leads to the determination of a soil gas diffusion constant.

Convection is another mechanism for air transport in soils. For example, as the barometric pressure fluctuates differential pressure forces are created which tend to pump air into or draw it out of the soil. Temperature changes, wind and rainfall can also stimulate natural air convection within soil. Fluctuating fluid levels within a ponded soil absorption system also act as a pump promoting air convection within the overlying unsaturated soil. In some advanced soil absorption systems an air distribution pipe network is used to mechanically supply air to the vicinity of the infiltrative surface.

The ease with which soil air is able to exchange with atmospheric air decreases with depth in the soil column. The passageways along which the air must pass become long, narrow and tortuous, particularly with fine-grained soils. Friction head loss serves to slow the rate of transport. Partially decomposed organic matter that is in the process of being absorbed through the pores of permeable soil also reduces the pore volume available for air transport. Naturally occurring or man-made impermeable barriers or semi-impermeable barriers or soil strata can greatly inhibit air transport within soil. Rigid insulation installed over a soil absorption bed blocks most of the air transport down through the overlying soil. Saturated conditions such as groundwater or ponded effluent in a soil absorption bed completely stop the flow of gaseous air downward through the soil. If sterile conditions exist soil air deep down below ground surface may contain a significant oxygen content, but aerobic bacteria attempting to live in this zone will soon deplete the oxygen and it cannot be replenished at a rapid rate. This is the situation in the soil adjacent to deep wastewater disposal trenches, meaning that little aerobic decomposition is able to take place. Biologic decomposition within deep trenches is primarily anaerobic and these trenches function primarily as filters, with the fluid level in them gradually rising over time as the soil pores become totally clogged with suspended solids in the wastewater stream.

Much of the current research regarding air transport through soil is being done in conjunction with bioremediation of soils contaminated by hydrocarbons. In this era of total dependence on the continued availability of petroleum produces, coupled with a heightened sensitivity to environmental problems, a lot of money is being spent in this area. There are a number of parallels between oil spill bioremediation and wastewater treatment in soils, but also a number of significant differences. The major difference is that with oil the goal is to eliminate a one-time inadvertent source of contaminants of often unknown extent, whereas with wastewater treatment there is a steady source of deliberately introduced contaminants that must be treated on an on-going basis. With wastewater, the precise location where the treatment should take place is known. But, unlike oil, wastewater also carries with it other non-organic solids that tend to clog up the soil pores in the area where it is most critical to maintain an aerobic environment.

4.2.3 Oxygen monitoring program

One of the major goals of this study was to attempt to measure the soil oxygen content in the vicinity of soil absorption systems to assess its role on the performance of soil absorption beds. We had hoped to be able to measure differences in soil oxygen levels in the vicinity of working and failing beds and compare these to oxygen levels in undisturbed soil and in the vicinity of other types of soil absorption systems. This turned out to be considerably more difficult to meaningfully measure than originally envisioned, and the results obtained were less useful than we had originally hoped.

Instrumentation: A variety of instruments are widely available to measure dissolved oxygen in water, however it is a foregone conclusion that ponded effluent in soil absorption systems is virtually devoid of oxygen and all biologic activity there is anaerobic. We did confirm this fact in numerous ponded beds and septic tanks. Most previous studies that addressed soil oxygen diffusion attempted to do so by measuring the Redox potential of the soil. In this method the oxygen diffusion rate in soil is assumed to be proportional to the electric current between platinum electrodes that are buried in soil and a saturated calomel cell. According to the literature we reviewed this method requires a wetted electrode and so works best in fine-grained damp soils since the surface of the platinum electrode must remain wetted. For this reason the Redox methodology is not particularly adaptable for use in coarse-grained dry soils that are preferred for soil absorption systems.

After considerable searching we located a company (Figaro) that distributes Japanese-made galvanic oxygen sensors which are designed to operate in a dry environment. Figaro's KE series sensor is essentially a lead-oxygen battery that incorporates a lead anode, an oxygen cathode made of gold and a weak acid electrolyte. The current that flows between the electrodes is proportional to the oxygen concentration in the gas mixture being measured. The terminal voltages are read as a signal, with the change in output voltage representing the change in oxygen concentration. While the relationship between O_2 concentration and voltage is quite linear, the exact voltage corresponding to normal atmospheric oxygen concentration is different for each sensor, necessitating that each be calibrated in atmospheric air of known O_2 concentration prior to use for comparative measurements. The KE-25 sensors we used have a life expectancy of 5 years, which makes them ideal for extended monitoring programs. According to the manufacturer small amount of oxygen (2-3 ml/min) is consumed by the operation of the sensor.

The KE series sensors were developed for monitoring combustion gases and medical applications; no reference is made in the manufacturer's literature to soil gas applications. However, Figaro's engineering staff indicated that they did not foresee any problem with our proposed in-soil application. The KE-25 sensors are supplied with quite short leads, which had to be extended in order to permit the sensors to be able to be read while underground. We used a Fluke 73 series multimeter to manually check the KE-25 output voltage at each of our installations on a periodic basis.

Sensor calibration: Although the sensors are all checked at the factory prior to shipment we decided to verify their performance in known low-oxygen environments. For our first test we injected propane gas from a canister through a hose into a sealed 5-gallon plastic container. We suspended a KE-25 sensor inside the container and allowed excess gas to be forced out through a different opening. Within one hour after starting the propane flow the sensor voltage had dropped by over 60%, and after another hour of propone injection the voltage dropped to 20% of the original voltage. The voltage returned to its original level within 1 minute of removing the sensor from the propane environment. It is probable that the slower observed decline in voltage was attributable to mixing and inefficient exhausting of air from the container as propane was being slowly added.

Figaro's literature implies that their sensors will only operate in a gaseous environment. Since we would be burying them in soil there was the possibility that some of the sensors could become inundated with groundwater at certain times of the year. To assess how the sensors might react in such a situation we performed a second calibration check by submerging a KE-25 sensor in an open pitcher of tap water. In this experiment the sensor's output voltage declined rather slowly. 5 hours after it was first submerged the voltage had dropped only 10%. The voltage continued to gradually drop over the next 10 days to less than 7% of the original voltage. Once the sensor was removed from the water container the output voltage gradually increased to 40 % of its original within 4 hours and 95% of its original voltage within 26 hours.

Sensor installations and observed results: Our first two KE-25 sensor installations were as follows: The first was suspended through a sealed cleanout pipe into the air space above the liquid inside a septic tank and the second was suspended through a sealed cleanout pipe into a distribution pipe in an unsaturated soil absorption bed. Our expectation was that these would both show significantly reduced oxygen levels by comparison with atmospheric air. In fact, the sensor in the air above the septic tank showed an oxygen reduction of only about 12% compared to atmospheric, and the sensor in the soil absorption bed distribution pipe showed an oxygen reduction of about 10%. Barring unaccounted for external circumstances this indicates that air diffusion and convection was working to maintain aerobic conditions in these locations. We took concurrent measurements of the dissolved oxygen in the same septic tank with a YSI-55 probe, and these confirmed that the DO in the septic tank remained consistently < 0.5 mg/l. This appears to indicate that there is relatively little transfer of oxygen taking place inside a septic tank from the air above into the liquid. We felt that as long as the caps remained in place only a negligible amount of air should have been able to make it directly into the standpipes through the small holes where the leads penetrated the caps. On the other hand, removing the seal as was necessary to make DO measurements in the septic tank obviously did allow some air exchange while that was happening.

In a first attempt to assess changes in the soil oxygen profile with depth we installed 3 KE-25 sensors in October of 1996 in a hand-dug posthole at depths of 1ft., 2ft. and 3ft. below ground level before backfilling the hole with soil. We expected that there would be a measurable decrease in soil oxygen with increasing depth. These sensors have now been in place for over 3 years. Within 3 months after installation of the sensors the output voltages had decreased by 16% at 1ft., by 12% at 2ft. and by 19% at 3ft. and have remained fairly constant thereafter. From this data we were unable to determine a meaningful correlation between depth and soil oxygen levels. It is possible that the soils that we had excavated in the process of installing the sensors might have been so much disturbed that diffusion was enhanced at all depths. It also is possible that without an abundant food source soil microbes are limited by food availability only, and so do not deplete the soil oxygen, no matter how slowly it is able to be replenished.

In an effort to avoid some of the potential problems associated with our first attempt to assess the soil oxygen profile we worked with Kyle Brown of Discovery Drilling to fabricate two 10-foot long hollow steel probes that could be driven into the ground. Inside each probe we installed strings of 8 KE-25 sensors spaced at 1 ft. intervals. The probes have air intake holes drilled into them at the level of each

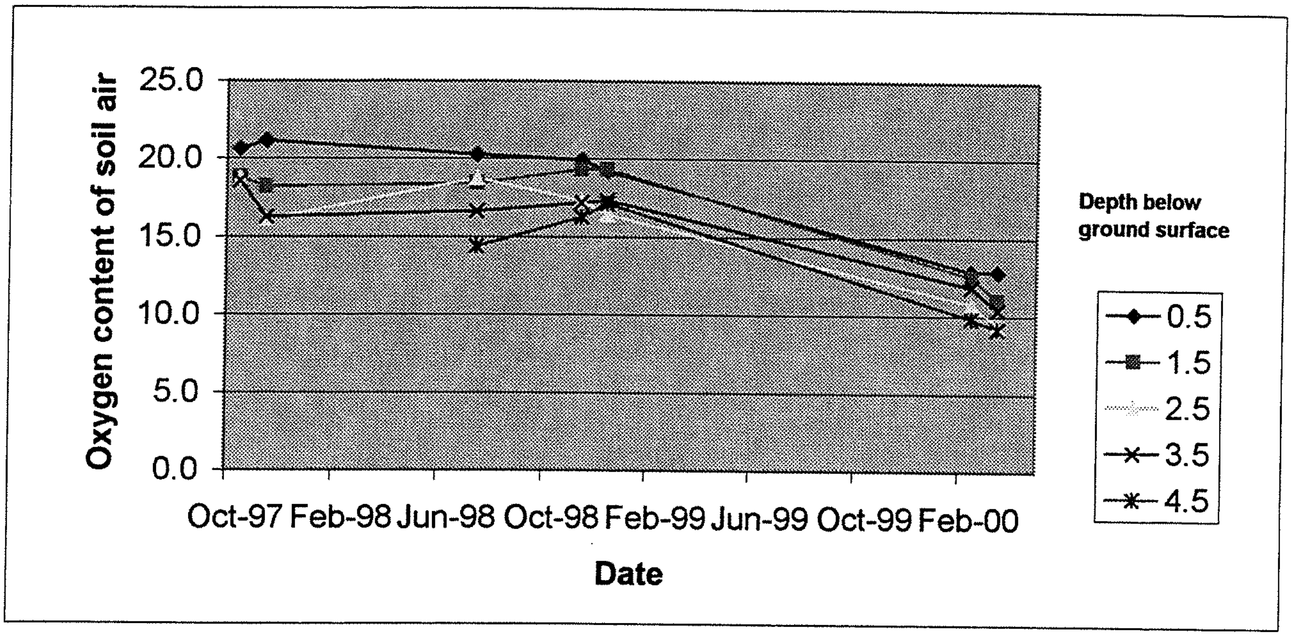


Figure 12. Soil Oxygen Profile through Undisturbed Ground

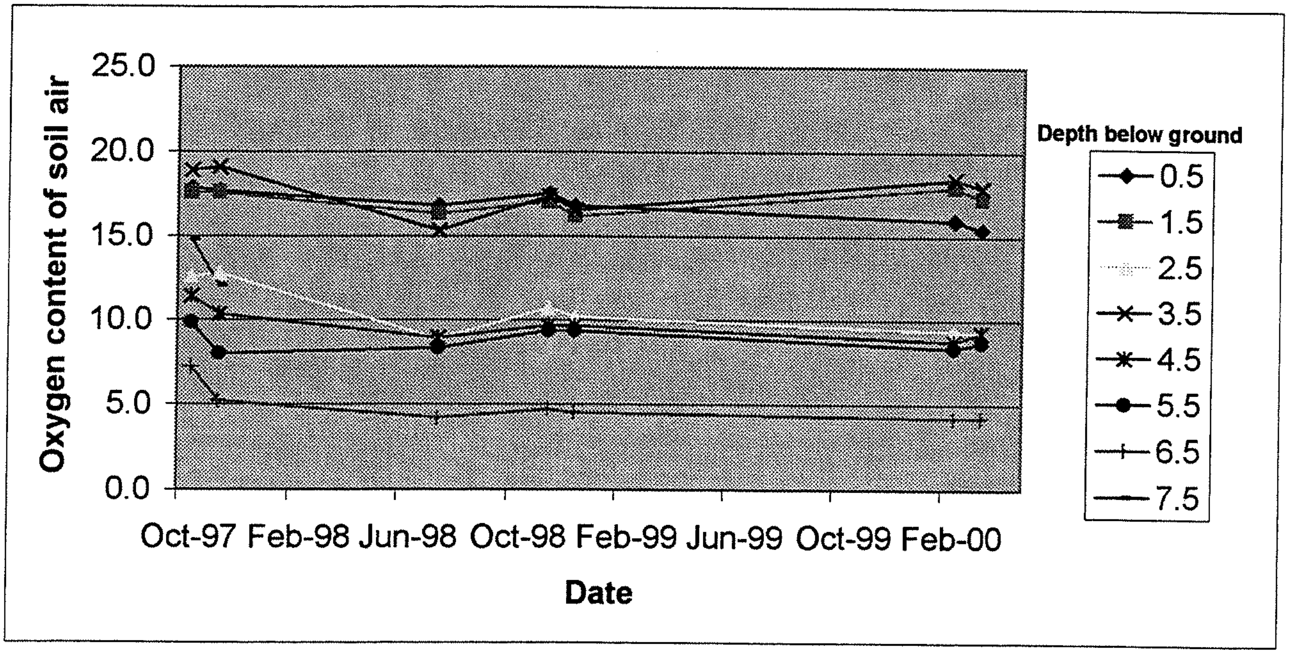


Figure 13. Soil Oxygen Profile through Bed

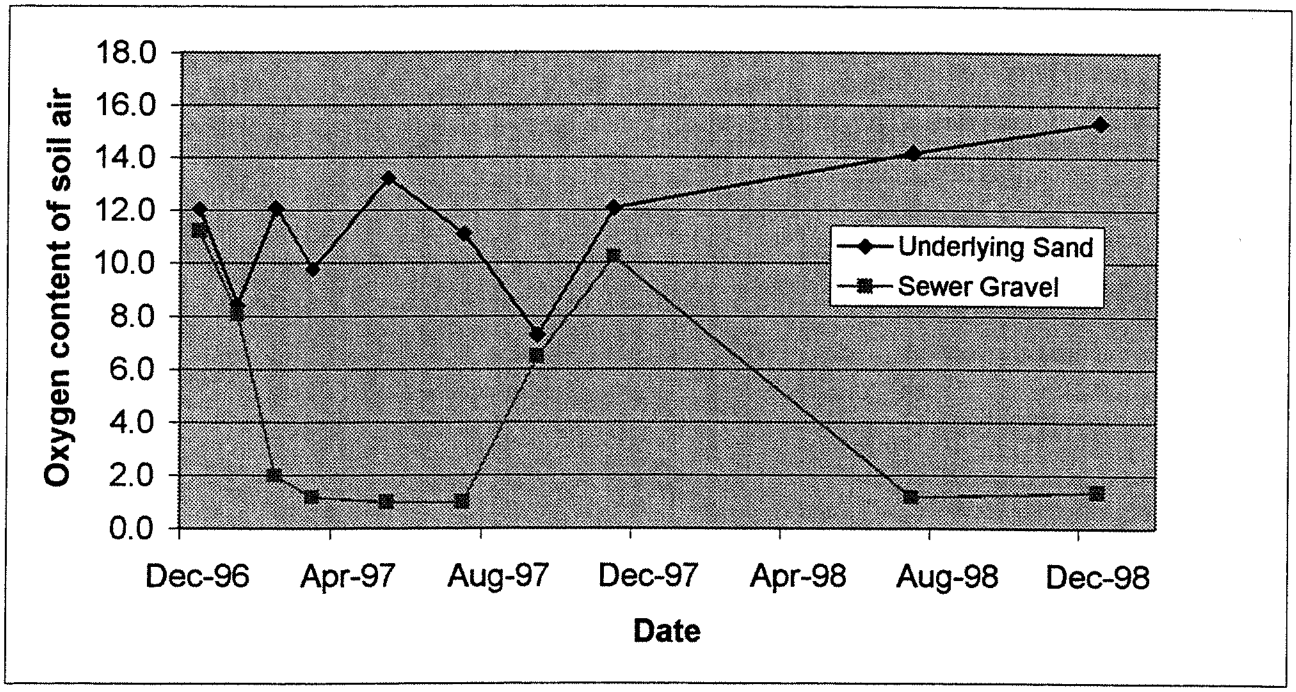


Figure 14. Soil Oxygen in a bed receiving Biocycle effluent

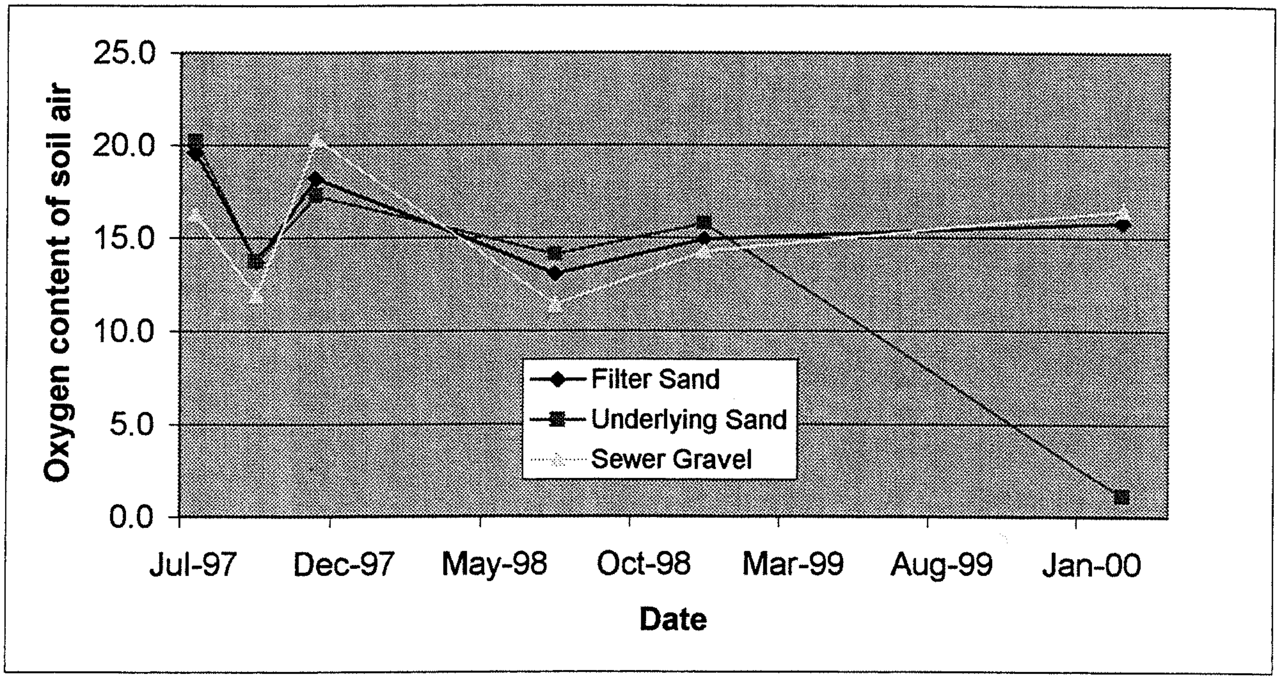


Figure 15. Soil Oxygen in bed receiving septic tank effluent

sensor and expanding foam packing filling the pipe between the air intake holes to prevent air exchange within the vertical shaft of the probe. The idea was that this should avoid problems associated with excavating and replacing soil, and would also create a small open-air plenum surrounding each sensor. We installed these two probes containing sensor strings in October of 1997. The first was driven down through an operating unsaturated soil absorption bed and the second in an area of undisturbed soil adjacent to the bed. The infiltrative surface in the bed is at 4.0 feet below finish grade and the sensor intakes are at 1ft. intervals between 0.5 ft. and 7.5ft. below ground level. Thus, four of the sensor intakes in the bed probe are above the assumed level of the infiltrative surface of the bed and four are below.

Figures 12 and 13 plot the monitoring results from these two oxygen sensor strings in terms of percentage of initial (atmospheric) oxygen at 3 intervals over a 2-year period. The results from both of these are interesting if not altogether in conformance with expectations. Although the readings did jump around a little over time, overall there appeared to be relatively little net change over time after the initial in-situ readings. The sensor string installed through the soil absorption bed showed generally higher O_2 readings above the level of the infiltrative surface (4ft.) than below. This fits with the assumption that the oxygen content of air supplied from above is being depleted by microbial action in the bed. Interestingly, the sensor at 3.5ft., which is located within the coarse imported sewer gravel itself, indicated significantly higher O_2 readings than the sensor immediately above it. The O2 concentrations in the sewer gravel are in the 15-20% range, very similar to those measured in the sensors at 0.5ft. and 1.5ft.. This appears to indicate that reasonably well-oxygenated air is available throughout the sewer gravel in this bed. Of course it is also possible that either this sensor or the one above it is faulty. The sensors below the bed show gradually decreasing O_2 concentrations with depth, as one might expect. The lowest sensor (at 7.5ft.) gave erratic measurements, indicating the possible presence of seasonal groundwater.

The second sensor string, which was installed in nearby undisturbed soil, gave less clear results. The upper four sensors showed relatively high O_2 concentrations of 16-21% for the first year, but significantly lower concentrations on the last two readings taken this year. It is possible that these last readings indicate that the sensors were gradually wearing out or had a partial short. The lower four readings (below 3.5ft.) were initially all zero, indicating either an electrical short or inundation in groundwater. After the first year, however, the 5th sensor started giving readings consistent with the upper four. We installed a perforated monitor tube adjacent to this string to check for groundwater and found it to be consistently at almost 8 feet below ground level, so groundwater inundation does not appear to be the cause of the zero readings.

We also installed KE-25 sensors in two other beds while they were under construction. One of the beds was dosed with effluent from an advanced treatment unit (Biocycle) and the other received gravity discharge from a single-compartment conventional septic tank. The monitoring results for these two systems are plotted in figures 14 & 15. Two sensors were installed in the bed receiving Biocycle effluent; one directly in the sewer gravel and the other in an underlying layer of coarse filter sand. The sensor in the sewer gravel indicated an O_2 content of 11% shortly after installation and then this level fluctuated between 1% and 10% over the next 2 years. This appears to indicate that despite the reduced BOD_5 of the Biocycle effluent the oxygen demand of the microbes in the disposal bed still exceed the rate of oxygen transfer through the overlying soil. The sensor in the imported filter sand underlying the bed indicates a higher oxygen level there, ranging from 8% to 15%.

The bed receiving effluent from a single-compartment concrete septic tank is a deep one with almost 10 feet of soil cover. It was also constructed with a two-foot layer of coarse filter sand between the sewer gravel and the underlying native sand. We installed KE-25 sensors in each of these strata. Over two and a half years of monitoring the sensors in the sewer gravel and the filter sand showed O_2 concentrations ranging between 12% and 20%, which seems to indicate that sufficient oxygen is available in the bed to sustain aerobic microbes. The sensor in the underlying native sand also showed a similar oxygen content, except for the most recent reading where it dropped 1%. At this point we cannot tell if this reflects a sensor failure or a true drop in available oxygen. We plan to continue follow-up monitoring at this site in the future.

Oxygen monitoring conclusions: The results of our oxygen monitoring program were somewhat disappointing in that we were unable to conclusively validate or refute our original hypotheses regarding oxygen availability in soil absorption bed performance in Alaska. On the other hand, we feel that in the process of researching for and conducting these experiments we were able to learn a lot about the role oxygen plays in soil absorption system operation. While the KE-25 sensors are a bit difficult to work with, we still feel that they are probably the most appropriate sensors presently available to researchers. Given the many different variables that can affect the amount of soil oxygen in the vicinity of a soil absorption bed it would be presumptuous to draw broad conclusions from such a limited amount of field data. The most unexpected finding was the apparent absence of a clear attenuation of oxygen content in soil air with increasing depth in undisturbed soil.

4.3 SOIL TEMPERATURE

Temperature is an important factor in soil absorption system performance. Warm temperatures promote the removal of soil moisture through evaporation. This can be a very significant factor where soil absorption systems are constructed at very shallow depths and is often enhanced by moisture uptake though the roots of plants followed by transpiration through green grass and leaves. On the other extreme, frozen soil is impervious to the passage of water, so in a cold climate such as ours in Alaska, soil absorption systems have to be buried a sufficient depth below ground level or insulated to maintain the soil temperature above 32 °F. This necessity for deep burial has the unfortunate side effect of placing the infiltrative surface at a depth where the soil is quite cold year round. Deep soils tend to be less well aerated than shallower soils are, and when rigid insulation is installed for frost protection it provides a further barrier to both evaporation and soil aeration.

The authors could find little research that had been done correlating metabolic rates of aerobic microorganisms involved in the breakdown of organic waste with temperature. It is generally understood that the metabolic rate of most microorganisms slows as the temperature decreases below their optimum temperature. However, different microorganisms have different optimum temperature ranges in which they are metabolically most active. Thus, the biologic oxidation done mesophilic organisms (which fare best at or above 20°C) can also be done by psychrophilic organisms (which thrive at temperatures near 0°C). Some research, such as that done by Murray and Murphy in Fairbanks in 1972, suggests that the biologic oxidation rates of psychrophiles may be comparable to that of mesophiles. If so, then cold soil temperatures alone are not enough to prevent the proper functioning of soil absorption systems in Alaska, so long as they are protected from freezing.

For a particular latitude, the seasonal soil temperature profile is strongly influenced by the effective insulation at and near ground surface as well as by shading and the orientation of the slope of the land relative to south. The organic duff including dead leaves and grasses found in undisturbed sites provides excellent insulation compared with bare dirt or paved areas. Snow cover is an excellent insulator with an R-value approaching that of man-made insulating materials. However, snow cover cannot be relied on because occasional winters can have very cold temperatures preceding the arrival of any snow. Because of the absence of either snow cover or natural organic duff insulation, frost penetration is usually much greater in the soil under roads, driveways and sidewalks. To some extent this can be countered by the installation of rigid insulation in these areas.

The authors were unable to find useful published data on seasonal variations in shallow soil temperature profiles applicable to the Anchorage area. But we were fortunate to learn that Kyle Brown (owner of Discovery Drilling, Inc.) has focused his company's efforts in the area of soil research. Mr. Brown's wife teaches junior high students and was looking for a class project to stimulate her student's interest in science. In late 1996 Mr. Brown installed two thermister strings at Mears Middle School in South Anchorage with sensors spaced at one-foot intervals down to 10 feet and a single sensor at 14 feet. One thermister string was installed under a sidewalk that is kept free of snow in the winter and the other in a nearby forested area that tends to hold its snow cover. Since 1996, successive generations of middle school students have periodically recorded the soil temperatures at two-week to one-month intervals during the school year. Mrs. Brown was kind enough to provide the authors with tabulations of these temperature measurements and we have used Microsoft Excel to plot the data as shown in Figures 16 and 17. With several years of data now compiled it is possible to make a number of interesting observations relevant to soil absorption system operation. Unfortunately, because students collected the data as a class project, no data was collected during the summer months when soil temperatures are probably highest. This lack is not too important for our purposes, since our primary concern is with minimum temperatures.

Both thermister strings showed significant variations in the temperature data collected in different years. We suspect that these differences reflect a combination of differences in mean air temperatures and differences in the amount of snow cover. As expected, the thermister string under the plowed sidewalk documented a greater range of seasonal temperature fluctuations and significantly colder soil temperatures during the winter. Frost penetration under the plowed sidewalk (as determined by temperature readings below 32 °F) varied from 3 to 5 feet during the study period, and minimum soil temperatures of 15 °F were encountered on two of those years at a depth of 1-foot. It is interesting to note that the coldest temperatures at the 1-foot depth were measured in January as might be expected, but the coldest temperatures at the 14-foot depth were not measured in until May. This demonstrates the time lag as deeper soils slowly react to changes in the temperature of the soil above them. Another interesting observation is that while the maximum annual soil temperature swing at the 1-foot depth was 42 °F, the annual temperature swing at the 14-foot depth was attenuated to a 7-degree range between 38 °F and 45 °F. This appears to indicate a convergence on a mean annual soil temperature of approximately 41.5 °F.

The thermister string under the forested area documented a smaller range of seasonal temperature fluctuations and warmer winter soil temperatures. Here the maximum frost penetration was 2 feet and in one of the years (1998) no freezing temperatures were ever recorded, even at the 1-foot depth. There is a similar lag between the coldest temperatures at the shallower depths being recorded near midwinter and the coldest temperatures at deeper depths not occurring until well into the spring. For the forested site the maximum annual temperature swing at the 1-foot depth was 26 degrees, vs. 42 degrees for the plowed sidewalk site. At the 14-foot depth the annual temperature swing was 6 degrees, much closer to the 7 degrees recorded at the plowed sidewalk site.

What are the implications of these soil temperature observations on soil absorption system performance in Alaska? First, it should be recognized that these measurements only reflect the conditions at one location in the Anchorage “bowl” area, in the southwestern part of town and at a low elevation. As such they are probably more representative of conditions encountered in the Sand Lake area and the lower Hillside. Average soil temperatures in the mid and upper Hillside, where a large number of on-site systems are located would undoubtedly be a bit cooler, although the higher probability of early snow cover may ensure equivalent or less frost penetration. Certainly, it has been the experience of the authors of this report that it is not at all uncommon to encounter totally frost free soil conditions when digging test holes in mid-winter in undisturbed areas with good snow cover. Physical freezing of soil absorption systems is almost unheard of in Anchorage. Very occasionally, poorly or non-insulated shallow sewer lines do freeze up where they pass under plowed driveways but that is a relatively easy problem to fix. Generally, the wastewater stream being continually added to a soil absorption system contains enough warm water maintain the soil in the immediate vicinity above the temperature of the surrounding soil. In the course of this study we made spot measurements of the fluid temperatures of any fluid ponded in most of the 100 beds we randomly selected for preliminary assessments. With one exception the temperatures of the ponded effluent were always above 40 °F, and in most cases they ranged from the upper 40’s to the lower

50’s. Based on all of these observations it appears that concerns about potential freezing of soil absorption systems are adequately addressed by present construction procedures.

The question of whether or not appropriate temperatures are being maintained for effective biologic treatment of the septic tank effluent in soil absorption systems in Anchorage remains unresolved. Certainly, there is some evidence, as indicated above, that psychrophilic organisms exist in wastewater and in the in-situ soils that are able to degrade organic wastes at the soil temperatures encountered in Anchorage. The amount of biodegradation that actually takes place in Alaskan soil absorption systems is also unknown, but the available evidence indicates that it is probably more limited by oxygen availability than by soil temperature. To the extent that this is true, it seems probable that reducing the soil cover and/or insulation requirements so as to allow the infiltrative surface to be located in shallower, better aerated soils would enhance soil absorption system performance.

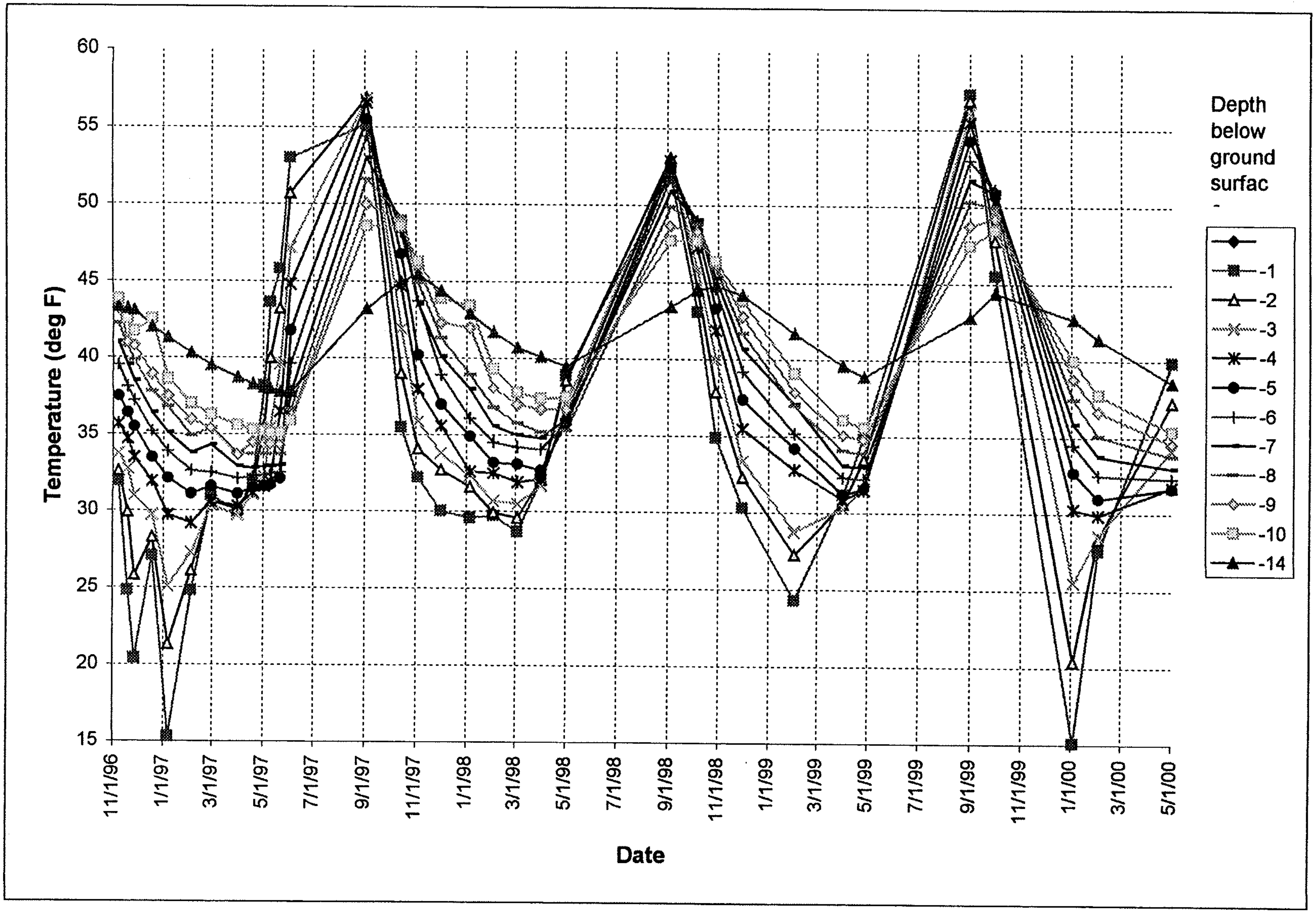


Figure 16. Soil Temperature Under Plowed Sidewalk

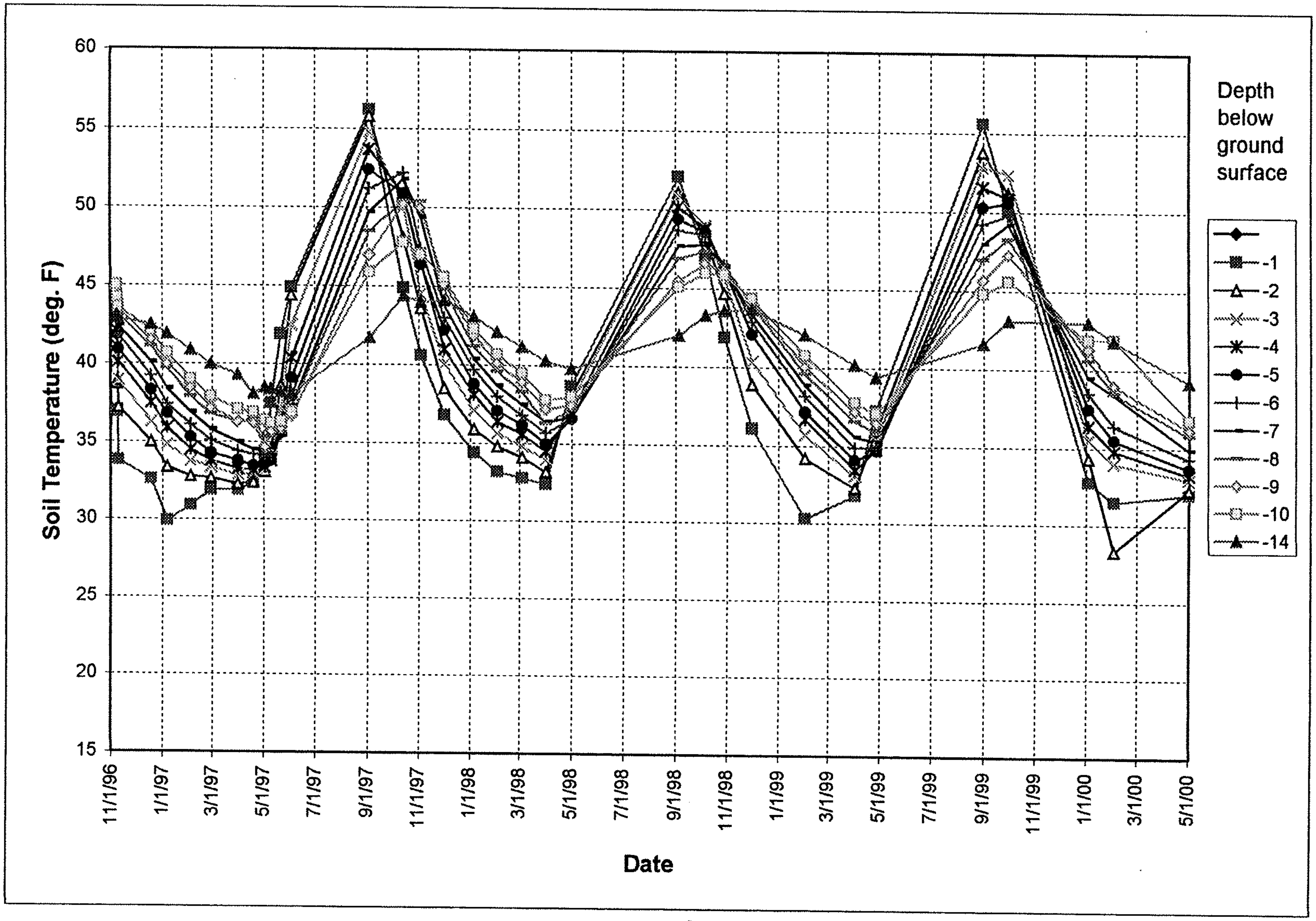


Figure 17. Soil Temperature Under Forested Area

5. REMEDIATION OF FAILING SEPTIC SYSTEMS

All soil absorption systems have a limited service life. When an on-site wastewater disposal system fails an adequacy test or begins to exhibit operational problems it is classified as a failing system. Usually the most cost-effective solution is to install a new soil absorption system, however this can be quite expensive and sometimes it is impossible to find another suitable site on the lot. For these reasons septic system owners often express interest in finding a remediation technique that can restore their existing system to a functional state.

The mechanics behind septic system failure are well known and have been documented through laboratory testing and field testing. The underlying cause of most failures of soil absorption systems is the build-up of an impermeable clogging mat at the interface between the imported sewer gravel and the surrounding native soil. This clogging mat prevents septic tank effluent from being absorbed into the ground at an acceptable rate. Much of the clogging mat consists of organic material that soil bacteria are unable to break down or digest at the rate of deposition. With poor construction practices that result in compaction or smearing of the infiltrative surface the rate of clogging mat formation is accelerated. Once a soil absorption system becomes saturated, the ponded liquid blocks the transmission of oxygen into the soil, causing aerobic soil bacteria to die off. The remaining anaerobic bacteria are much less effective at digesting organic materials and also secrete a slime, so the clogging mat becomes ever thicker and more impermeable.

Under this project split spoon samples of the clogging mat material were collected from the infiltrative surface of several failing soil absorption beds. Other samples were collected and examined by digging into failing beds with a backhoe. The observed color of the clogging mat was a metallic blue-gray, with a very black surface coat. The zone of discoloration was often one to two inches thick, but sometimes extended up to several inches below the soil surface at the gravel/soil interface. The discolored soil usually had a crusty texture indicating that the soil particles had become "cemented" together. Individual pebbles of the overlying sewer gravel were coated with a black anaerobic sludge. While excavating this material a strong odor of rotten-eggs, indicating the presence of hydrogen sulfide. The ponded liquid in failing beds was highly corrosive, causing the shiny steel of a backhoe bucket to turn black almost instantaneously.

It appears that the clogging is caused by two distinct barriers: (1) the black slime on the soil and sewer gravel surfaces, and (2) the cemented soil layer extending downwards from the infiltrative surface. The thickness and hardness of the cemented layer are soil and age dependant. Sandy soils tend to have a relatively thick layer with relatively little cementing whereas fine-grained soil will have a thinner layer, but heavier cementation. The operation of a drainfield can be improved if the sludge can be removed and the cemented soil layer broken apart.

At least three different methods of soil absorption system remediation have been, or are being, offered in Anchorage that claim to break down the clogging mat and thus allow the soil absorption system to function once again as designed. The approaches used to break down the clogging mat range from chemical treatment (hydrogen peroxide) to physical breakup ("Terralift") to bioremediation. The efficacy of these remediation techniques is a subject of debate, and little solid engineering data documenting their performance is available. Perhaps as a reaction to the often exaggerated marketing claims of the purveyors, Municipal and State regulators are skeptical of all techniques. They are concerned that a remediation attempt might have only a short-term beneficial effect which would allow a failing system to pass an adequacy test and be approved only to fail again, thereby transferring the septic system problem from the seller of a property to the buyer. As part of our study on soil absorption bed performance in Alaska we felt it was worthwhile to compile the data we have gathered over the years regarding our experience with these techniques. The following sections discuss our experience with each method.

5.1 HYDROGEN PEROXIDE

Hydrogen Peroxide (H_2O_2) rejuvenation techniques were developed in 1973 and patented under the trade name POROX in 1977. Since the process is patented the exact procedure is not public knowledge. Licensees have reported a high degree of success without defining what success implied. However the technique is not successful in cases where the septic tank is faulty, allowing scum and undigested solids to enter the drain field and where fines have infiltrated the drain rock. A limited field test was conducted in Anchorage in 1981 when three concrete ring seepage pits were treated with 50 gallons of 50% H_2O_2. Two of the systems had failed an adequacy test prior to the treatment. After treatment all three systems showed a substantial improvement. The two failed systems passed the adequacy test immediately after treatment and one year later. Both professional engineers and septic tank pumpers have applied the hydrogen peroxide technique sporadically over the last 20 years. To our knowledge none of these people are or have been POROX licensees. The procedures used in Anchorage are also not known but can it be assumed that the application rate and concentration varies from dumping one or more 50 gallon drums of 50% H_2O_2 directly into the drainfield to diluting the H_2O_2 to 12.5% or less and charging the field in 5-gallon increments over several days.

H_2O_2 is a strong oxidant that causes major agitation of the ponded wastewater due to the release of the oxygen gas. This agitation will break up the crust on the soil surface, but also pull silt and fine soil particles into the drain rock. The biological slime will be oxidized and to some extent so will the accumulated organic materials. In most cases there has been an immediate improvement but long-term benefits have not been documented. As part of this study Mr. Spurkland identified 21 systems that had been treated with H_2O_2. Table 2 contains follow-up data he was able to obtain. Nine of the systems were trenches, six were seepage pits, four were beds and two were drainfields. Twelve of the systems were treated in an attempt to qualify for a HAA certificate, seven to improve their operation, and two as a temporary fix until the systems could be replaced. Three of the twelve systems treated to qualify for HAA's did not pass the subsequent adequacy test. The fact that these three were beds or drainfields may be of some significance. The metal ring seepage pit that was replaced in 1998 was replaced for reasons not related to HAA requirements. Of the 9 systems passing the HAA requirement only one has subsequently been inspected and failed an adequacy test. This system was excavated and it was found that the bottom three feet of the trench had been completely filled with silt. This is probably the result of the H_2O_2 treatment. None of the other passed systems have been replaced which is an indication that the present owners have not experienced operational problems serious enough to necessitate replacement.

Only one of the seven systems that were treated to improve operation has been replaced. This system did not exhibit immediate improvement after the treatment. The septic tank was replaced with a Biocycle in one of the systems but the original seepage pit was retained as the soil absorption system. The two temporary fixes were just that. These two systems were completely replaced within three years of the H_2O_2 treatment.

Table 2. Follow-up Inspections of Septic Systems Treated With Hydrogen Peroxide

ID	Syst. Type	Soil Rtg.	Date Inst.	Gvl. Depth	Fluid Before	Purpose	Trmt.Date	Adeq.Test	Reinsp
1	Bed	305	7/12/84	0.5ft.	Surch.	HAA	5/14/92	Fail 3/92	
2	Drainfield	183	9/8/83	2ft.	Failing	HAA	6/3/93	Fail 1993	
3	Bed	150	10/22/85	0.5ft.	Surch.	HAA	6/18/92	Fail 1993	Repl. 1993
4	Seepage	125	11/1/77	6ft.	Surch.	HAA	11/6/97	Pass 1997	Repl. 1998
5	Trench	125	1/31/84	4ft.	Surch.	HAA	11/20/91	Pass 2/92	
6	Trench	225	7/31/87	8ft.	Surch.	HAA	4/28/98	Pass 5/1/98	
7	Seepage	150	7/31/73	9ft.	Surch.	HAA	3/19/96	Pass 5/96	
8	Bed	115	7/31/81	0.5ft.	16.5"	HAA	5/19/92	Pass 8/92	
9	Bed	150	7/19/88	0.5ft.	Surch.	HAA	5/28/93	Pass 9/93	
10	Trench	150	8/31/81	9ft.	Surch.	HAA	9/27/90	Pass 10/90	
11	Seepage	125	1968	6ft.	Surch.	HAA	6/2/92	Pass 10/93	
12	Trench	125	5/31/77	6ft.	Surch.	HAA	7/31/93	Pass 10/93	Fail 1/99
13	Hybrid	250	6/14/79	6ft.		Improve	9/27/90		
14	Drainfield	150	9/30/88	1ft.	19ft.	Improve	8/11/92		
15	Seepage	85	1970		Surch.	Improve	8/12/92		
16	Trench	125	10/10/81	6ft.	Surch	Improve	6/30/93		
17	Trench	85	10/2/78	5ft.	Surch.	Improve	10/14/94		
18	Seepage	330	1971	12ft.	10ft.	Improve	6/25/96	Pass 7/96	Biocycle 96
19	Seepage	150	1971	6ft.	Surch	Improve	4/13/97	Fail 1997	ISF 1998
20	Trench	330	1982		Overfl	Temp.	5/25/95		ISF 1996
21	Trench	330	5/20/78	6ft.	Overfl	Temp.	6/2/95		ISF 1997

5.2 TERRALIFT

The newest remediation technique being actively marketed in Anchorage is a proprietary system called "Terralift". The first applications of this technique in the Anchorage area were in the summer of 1997, so the long-term efficacy is still unknown. Two different companies in Anchorage are presently offering Terralift treatment of failing septic systems. In essence, the process involves injecting blasts of compressed air mixed with Styrofoam pellets into the soil surrounding a clogged soil absorption. The intended purpose of the compressed air is to aerate and fracture the soil and create a network of cracks that allow the ponded liquid to pass out through the clogging mat into unclogged soil. The stated purpose of the Styrofoam pellets is to prop open the cracks and prevent their rapid reclosing. The companies claim that the injected air also facilitates the growth of beneficial aerobic bacteria, and the treatment regime also includes follow-up bacterial treatment.

In conducting a Terralift treatment, the operator uses a self-powered machine to drive a narrow probe into undisturbed soil adjacent to the septic system through which a single blast of compressed air and Styrofoam pellets is injected. The process is repeated at approximately 4-foot intervals around the perimeter of a clogged soil absorption system. The blasts of compressed air sometimes force small bursts of ponded effluent to spout out through nearby septic system observation pipes. There is little or no disturbance to the property or landscaping. In most cases, any residual effluent that is ponded in the soil absorption system drains away within a few hours.

In several systems where we have monitored the efficacy of Terralift treatments we have noted a decrease in the distance to the bottom of the monitor tube. A possible explanation of this phenomenon is that the blast of compressed air could be blowing fine-grained soils up into the lower portions of the sewer gravel, particularly if the discharge point is directly beneath the system, as would be the case with a bed. This probably renders the technique ineffectual, and perhaps detrimental, for bed systems where the design absorption mode is downwards through the bottom. The following table presents relevant data on nine (9) different Terralift remediation attempts that have been monitored by Flattop Technical Services.

I	System	Installe	Gvl	Pre-	Trtmt.	Adeq. Test	Reinsp.	Reinsp.
1	Bed	6/88	6"	5/97 – 26"	5/17/9	N/A	5/97-0"	8/97-11"
2	Seepage Pit	8/71	9ft.	6/97-fail-	6/19/9	7/97 - Pass	7/97-	11/97-
3	Seepage Pit	9/74	9ft.	N/A	6/19/9	8/97 - Pass	11/97-	2/00-85"
4	Bed	6/85	6"	6/98-fail-	6/10/9	9/98 - Pass	9/98 – 0"	
5	Trench	7/78	72"	9/98 –	9/18/9	11/98 -	11/98–	
6	Trench	6/88	60"	9/98 – 64	10/98	11/98 –	2/00 –	
7	Seepage Pit	10/72	10f	3/99-fail-	5/18/9	6/99 – Pass	6/99 –	2/00 –
8	Trench	4/84	60"	6/99 – 62"	6/20/9	N/A	7/99 – 0"	2/00 –
9	Trench	4/83	96"	7/99 –	8/99	N/A	2/00 –	

It is apparent from these observations that Terralift did have a beneficial effect (at least in the short-term) on the performance of virtually all of these systems. The beneficial effect on the first system (a failing bed-type system) was so short-lived as to be almost worthless. The other bed system passed an adequacy test 3 months after the Terralift treatment was done, but in that situation the actual configuration of the monitor tube was unknown, and recent deep snow prevented a follow-up inspection this year. Based on spot reinspections wherein only the fluid depth in the monitor tube was measured but no adequacy test was conducted, it appears that in several cases some residual benefit was still present as much as 2 years after the Terralift treatment was done.

One problem in attempting to determine the efficacy of a Terralift or other remediation treatment is that most of the systems being treated are relatively old and their construction is often poorly documented. Monitor tubes may or may not extend to the bottom of the sewer gravel. It is also not always clear that the initial problem causing the property owner to consider remediation is actually the formation of an impermeable clogging mat around the sewer gravel. Other problems, including clogging of the distribution pipe network itself or the presence of native soils that were unsuitable in the first place can cause similar failure symptoms for entirely different reasons. Without thorough adequacy tests conducted before and after a remediation treatment is done and without digging up the system it is difficult to pinpoint with confidence either the nature of the problem or the degree of cure.

While it is definitely too early to conclude that Terralift does offer a cost-effective long term remediation option for failing systems, the evidence shows that it should not be dismissed out of hand. Until conclusive data is available documenting long-term performance it is appropriate that the Municipal Health Department remain skeptical of all remediation technologies. On the other hand, we do not see the justification for enacting regulatory roadblocks discourage their use. Septic system owners should be allowed to decide for themselves whether or not the *possible* beneficial effects warrant the substantial cost of this treatment. In light of our somewhat favorable observations to date we recommend that the Health Department endeavor to work constructively with companies offering remediation services to develop a program to monitor the effect on a few carefully selected sites over an extended time period of approximately 5 years.

5.3 ALTERNATING USAGE

A proven passive approach to soil absorption system remediation is to simply stop using the system for an extended period of time. Once wastewater is no longer flowing into a clogged soil absorption system it will gradually dry out. As the system dries out aerobic soil bacteria are able to reestablish themselves and start to break down the organic material in the clogging mat. Numerous cases have been observed wherein once failing systems are able to regain some absorption capability after a period of rest.

The most practical way to take advantage of this phenomenon is to install a diversion valve at the time a replacement system is constructed. The original system is retained in an inactive status. The diversion valve allows the homeowner to divert the wastewater stream back to the original system after a sufficient period of time has elapsed, typically 2-5 years. By doing so, even for a relatively short period of time such as 1 year, the newer replacement system is also given a chance to dry out and rejuvenate itself. In theory, with such alternating usage, the useful lifespan of both soil absorption systems can be prolonged almost indefinitely. While this promising approach to prolonging the life of drainfields has become very popular in Anchorage as a low-cost option at the time a replacement system is installed, the long-term efficacy has not been kept track of in any systematic manner.

6. ADVANCED ON-SITE WASTEWATER TREATMENT SYSTEMS

In 1993 the Municipality of Anchorage Health Department initiated a program allowing the installation of advanced wastewater pre-treatment systems that are designed to produce a much cleaner effluent than conventional septic tanks. To date, three different advanced treatment technologies have been introduced under this program. Because of their much higher cost, advanced systems are usually the option of choice only at locations where installation of a conventional septic system is not feasible. Such locations include those with high groundwater levels, extremely silty soils and/or space constraints. Under this program prototype installations of each type of advanced system were to be monitored for two years to evaluate its performance under Alaskan conditions. The effluent from all of the advanced systems flows into a residual on-site soil absorption system. Because the effluent is far cleaner than septic tank effluent it does not need such a large residual absorption system to prevent the build-up of a clogging mat. Nor, in theory, does it need the same vertical and horizontal separation distances from groundwater, bedrock, surface water or drilled wells to protect them from contamination.

Because advanced system technology is new and represents a potentially viable alternative to soil absorption beds, the authors felt that it warranted a close look under this project.

Based on available sampling data to date, this section compares the performance of three different types of pre-treatment systems currently in use in Anchorage. Their effluents are compared in terms of the widely accepted wastewater quality parameters of BOD_5, TSS, Total Nitrogen, and Fecal Coliform. The sampling data is normalized and plotted allowing conclusions to be drawn regarding relative performance between the three systems, as well as with respect to accepted standards. While there is considerable variation in the sample results between the systems, all were found to produce effluent that exceeds State of Alaska secondary treatment criteria.

6.1 ADVANCED SYSTEMS CURRENTLY USED IN ANCHORAGE

6.1.1 "Intermittent Sand Filter" (ISF).

The first ISF installations in Anchorage were made in 1993. In essence, the ISF is an intermediate component between a conventional septic tank and a residual soil absorption drainfield. The filter itself has an area of 360 square feet and consists of 2 feet of carefully graded coarse sand. It serves both to physically filter septic tank effluent and to provide an optimal medium in which bacteria can grow and break down the organic components of domestic wastewater. Characteristic features typically include a dosing pump that operates on a timer to evenly distribute septic tank effluent over the filter surface, and an air distribution network to oxygenate the filter sand. ISFs can be either lined or bottomless, depending on the location of the residual disposal field, however only lined ISFs can be sampled and tested in terms of the parameters discussed in this section.

6.1.2 "Biocycle"

The Biocycle provides extended aeration treatment and was first installed in Anchorage in 1994. In essence, this system consists of a 1500 gallon, 4-compartment, wastewater treatment package plant that replaces a conventional septic tank. The Biocycle is a proprietary system that has been used widely around the world, particularly in Australia and Ireland. Wastewater treatment in the Biocycle is accomplished in stages consisting of 1) primary settlement, followed by 2) aeration to promote growth of decomposing bacteria on a subsurface plastic medium. This is followed by 3) clarification and finally 4) pumped discharge to the residual disposal field. Settled solids that collect in the clarifier are pumped back into the primary chamber for further treatment.

6.1.3 The "Recirculating Trickling Filter" (RTF or Reactex)

The RTF was first introduced in Anchorage in 1996. Basically, this system consists of a 2-compartment septic tank with a screened vault in the second compartment containing two pumps controlled by floats and timers, followed by an up-flow filter. The first pump intermittently recirculates a portion of the effluent up into a vault containing fibrous material that is located over the first compartment of the tank. Bacterial growth and nitrification occurs in this passively vented vault as the effluent trickles down through the fibrous media. Denitrification occurs in the anaerobic environment of the first compartment of the septic tank. The second pump discharges the tank effluent up through a gravel up-flow filter before it flows on into the residual drainfield. Since initial introduction the supplier has changed the type and configuration of the filter media several times. The latest configuration, which was introduced in late 1998, has a much larger filter media compartment and is now called a "Reactex" system. Because of its significant modifications from earlier RTF installations the monitoring data for the Reactex filter installations (and Reactex tank samples) are plotted separately.

6.2 EFFLUENT QUALITY PARAMETERS USED TO ASSESS PERFORMANCE

The effluent quality parameters that are routinely measured for these systems are as follows:

BOD_5 - The 5-day Biochemical Oxygen Demand, measured in milligrams per liter (mg/l)

TSS - Total Suspended Solids, measured in milligrams per liter (mg/l)

TKN - Total Kjeldahl Nitrogen, measured in milligrams per liter (mg/l)

NO_3-N - Nitrate nitrogen, measured in milligrams per liter (mg/l)

FC - Fecal Coliform bacteria, measured in # of colonies per 100 milliliters (col/100ml)

TKN and NO_3-N are supplementary components of the total nitrogen in wastewater, and represent successive stages in the nitrogen cycle. TKN includes both ammonia nitrogen and organic nitrogen. In the anaerobic environment of a septic tank almost all of the nitrogen is found in the form of TKN. In an aerobic environment Kjeldahl nitrogen is converted into nitrate nitrogen. Since the total amount of nitrogen introduced into the soil from the wastewater stream is the factor of environmental concern, these two parameters have been added to form TN = Total Nitrogen for the purposes of this analysis. TN is also measured in milligrams per liter (mg/l)

6.3 PERFORMANCE DATA:

Figures 18 - 21 (at the end of this section) provide graphical plots of the sample data for each of the parameters. In order to analyze the data using histograms, the total range of measured concentrations for each parameter was broken down into approximately 10 discrete "bins" and then the number of samples falling within each bin for each type of innovative system was determined. The bins for BOD_5, TSS and TN consist of linear increments, while the bins for FC consist of logarithmic increments. The number of samples in each bin was then normalized into percentages, so that the total for all bins adds up to 100% for each innovative system type, irrespective of the number of samples collected. A smoothed curve was then created connecting the respective sample percentages in each bin for each innovative system type. The four figures display the resultant comparisons between the three types of innovative systems in terms of BOD_5, TSS, TN, and FC. For comparison purposes, typical values for untreated septic tank effluent in Alaska are also indicated on each figure, as well as the State of Alaska secondary treatment standards, where applicable.

Important Note: Since the goal of a pre-treatment system is to reduce the concentration of each of the sample parameters, the data distribution curve for the most effective system in terms of each parameter will have the high point of its performance curve furthest to the left; the least effective system will have its high point furthest to the right. Because the data exhibits a fair amount of scatter, with occasional high readings significantly affecting the mean, it is felt that the median value is often a better descriptor of typical performance.

6.3.1 BOD_5

As illustrated on Figure 18, the ISF appears to be significantly more effective than the other advanced systems in terms of BOD_5 reduction with a median effluent concentration of 2 mg/l. The Biocycle, RTF and Reactex also provide good BOD_5 reduction also with median effluent concentrations of less than 20 mg/l. There is a lot of scatter in the range of BOD_5 output for these systems, and due to occasional "hiccups" a few of the samples from each of these systems were significantly higher. It should be noted that all of the measured BOD_5 concentrations represent a significant reduction from a typical BOD_5 concentration of 300 mg/l for untreated septic tank effluent. These concentrations are also significantly below the 30-mg/l arithmetic mean of BOD_5 over a 30-day period necessary to meet State of Alaska secondary treatment criteria.

6.3.2 TSS

Based on the performance date illustrated in Figure 19, the ISF also appears to be the most effective in terms of suspended solids reduction. The ISF sampling data has a median TSS value of 2.8 mg/l. The Biocycle, RTF and Reactex systems all have median TSS sample concentrations of less than 15 mg/l. There is a lot of scatter in the range of TSS output for these systems, and due to occasional "hiccups" a few of the samples from each of these systems were significantly higher. All of these measured TSS concentrations represent a significant reduction from a typical TSS concentration of 80 mg/l for untreated septic tank effluent and are well below the 30-mg/l arithmetic mean of TSS over a 30-day period necessary to meet State of Alaska secondary treatment criteria.

6.3.3 TN

As illustrated on Figure 20, the Reactex with up-flow filter system is the most effective in terms of total nitrogen reduction with median TN concentrations of less than 15 mg/l. The earlier RTF units and even the Reactex tank without an up-flow filter show almost as good TN performance. The Biocycle ranks next with a median TN of 27 mg/l and the ISF offers the least total nitrogen reduction with a median output of 42mg/l. It should be noted that all of the systems significantly reduce TN from the typical level of 80 mg/l found in conventional septic tank effluent. There are no residual nitrogen criteria in the State of Alaska secondary treatment standards.

6.3.4 FC

Table 21 indicates that in terms of fecal coliform reduction the ISF also does the best job, with a median of only 5 colonies per 100 ml. While significantly higher, the fecal coliform counts in effluent from the Reactex, Biocycle and RTF range up to a median of 14,000 colonies/100m. It should be noted that all of these represent reductions of over 98% from the fecal coliform count of untreated septic tank effluent, which is typically over 1,000,000 colonies per 100 ml. The Reactex tank without an up-flow filter has a median FC count of 87,000 colonies per 100 ml. There are no residual fecal coliform criteria in the State of Alaska secondary treatment standards.

6.4 DISCUSSION OF THE PERFORMANCE DATA

The sampling data demonstrates that all of the advanced systems are capable of providing a significantly cleaner effluent on average than is obtained from conventional septic tanks, and in fact the effluent almost always exceeds State of Alaska secondary treatment standards. As a result of their different designs, each of the systems does relatively better in terms of some of the wastewater parameters than others. For example, the output from the ISF is usually the lowest in terms of BOD_5, TSS, and FC, but it is highest in terms of TN. It would be subjective to assign a relative importance to the various wastewater parameters. BOD_5 and TSS have historically been the parameters most commonly used to measure the performance of treatment systems, and they are the only ones that are even addressed in the State of Alaska secondary treatment standards.

In recent years, however, a lot of concern has been focused on nitrogen, due to the proven relationship between nitrates in drinking water and methemoglobinemia in infants. The RTF and Reactex systems do the best job in terms of total nitrogen reduction. In Anchorage whenever public or private drinking water supplies are tested for potability a nitrate test is included. The vast majority of well water samples collected in Anchorage in recent years are significantly below the accepted nitrate standard of 10 mg/l. There are many potential sources of nitrate in drinking water, both man induced and natural, and it is very difficult to establish a correlation between nitrates from wastewater and elevated nitrate levels in drinking water. Nevertheless, anything that can be done to reduce one known source of nitrate contamination is a definite plus.

Fecal coliform (FC) is another parameter for which no wastewater standard exists, and because of the wide variation in individual counts their significance is difficult to interpret. Coliform bacteria are not harmful in themselves; they are, however, easy to detect and their presence indicates conditions which could support much more harmful organisms which are almost impossible to detect. While the ideal would be 0 colonies in a wastewater sample, this is only occasionally achieved (most notably in the ISF), and it should be kept in mind that even a seemingly high count of 20,000 colonies per 100 ml represents a 98% reduction from the fecal coliform count of typical septic tank effluent.

6.5 BIOMAT FORMATION IN ADVANCED TREATMENT UNIT DISPOSAL FIELDS

When the Municipality of Anchorage introduced its "Advanced System" program in 1993 the assumption was that, because of their significantly higher cost, these systems would mostly be installed in locations where conventional systems could not be installed, primarily because of tight soils or high groundwater conditions. While most conventional soil absorption systems fail because biomat formation eventually prevents sufficient infiltration into native soils, it was assumed that the much cleaner effluent emanating from advanced systems would not lead to biomat formation. A biomat may develop on the filter surface of an improperly functioning ISF, but once wastewater has passed through the filter the effluent contains such low levels of BOD_5 and TSS that biomat formation is highly unlikely. The effluent from the Biocycle and the Reactex units contains somewhat higher, but still low, levels of BOD_5 and TSS.

The authors have monitored a selection of early ISF and Biocycle installations with these concerns in mind. Because of the relatively recent introduction of the Reactex system we have not monitored any of these systems, but based on effluent characteristics we expect that biomat formation will parallel that of the Biocycle. We expected that if biomat formation were to occur it would not become noticeable until after several years of operation.

Short of digging up a soil absorption system to visually inspect the infiltrative surface, the only indication of biomat formation is the gradual build-up of fluid depth in a monitor tube. However, fluid build-up in a residual disposal field can also be a result of inundation by high groundwater, which makes it difficult to pinpoint the cause.

Municipal and State regulations specify that the bottom of any soil absorption system should maintain a 4-foot vertical separation from "seasonal high ground water". It is generally accepted that seasonal high groundwater occurs during or immediately after spring break-up, and that a second high groundwater condition occurs in the fall when rainfall tends to be high. Design guidelines call for groundwater determination to be made on the basis of a 7-day monitoring period following excavation of a test hole. The absence of groundwater in a test hole in mid-summer is no guarantee that groundwater will not occur during break-up. When a test hole is excavated during a dry period, the groundwater determination may be arbitrarily adjusted to allow for possible higher levels during break-up. In a few areas with significant know groundwater level fluctuations the Health Department may require monitoring through the spring or fall high groundwater periods before issuance of a construction permit.

When advanced systems are installed to replace a failing conventional system, monitoring groundwater through one of the high seasons may not be a viable option, yet these systems are often installed in groundwater problem areas. The result is a significant potential for seasonal groundwater infiltration into the disposal field.

6.5.1 ISF Monitoring

Table 4 in Appendix B presents the author's monitoring results at nine sites with ISFs. Three of these systems were installed in 1994, four in 1995, one in 1996 and one in 1998. Four of the systems are bottomless, meaning that effluent flows directly down from the filter into the underlying soil, which makes it impossible to monitor for biomat formation or groundwater. The remaining 5 systems have residual drainfields with six inches of sewer gravel. Monitoring was conducted in the spring when groundwater levels tend to be near their seasonal highs.

Theoretically a water level buildup should not be observed in either the drainfield or on the filter surface. A water buildup in the drainfield could be an indication of either groundwater intrusion or of ponding caused by biomat formation. A water buildup on the filter surface is a strong indication of biomat formation.

The water depths observed may be deceptive. Both the filter and the residual absorption systems are designed with 6 inches of pea gravel or sewer gravel. Water depths up to 6 inches relate directly to the amount of water that is ponded. Water depths greater than 6 inches indicate only that the filter or field is flooded. When the water level is above 6 inches, small quantities of additional water will cause the level to rise rapidly in the monitor tubes because all available voids in the gravel are already full of water. A water depth in excess of 6 inches in the filter may cause the excess effluent to drain back into the lift station.

Both ISF#1 and ISF#2 have been observed with inoperable air supplies. The air compressors have been replaced, but the authors had no way of knowing how long the air supply had been shut off. The absence of air may accelerate the rate of biomat formation, particularly on the filter surface, but also in the residual drainfield. ISF#1served a family with small children,, and the wastewater load it received was probably substantially higher than the wastewater load received by ISF#2 which serves a professional couple without children and who are away a lot. The remaining 7 ISF installations did not have consistent ponding of water either on the filter or in the drainfield.

6.5.2 Biocycle Monitoring

Table 3 in Appendix B presents monitoring results observed by the author at twelve Biocycle installations over a three-year period. Five of these systems were installed in 1995 and seven in 1996. A majority of the residual absorption systems were 5-foot wide drainfields with 6-inch effective depths of sewer gravel.

Two of the systems were observed in May of 2000 to have more than 6 inches of water in the drainfields. This may indicate either biomat formation or groundwater intrusion. The remainder of the drainfields have always been dry or observed with only a small amount of fluid, which would be an indication of a recent discharge from the treatment unit. While the data is limited, these monitoring observations seem to indicate that rapid biomat formation is not a serious problem with any of the advanced treatment systems.

6.6 ADVANCED TREATMENT SYSTEM CONCLUSIONS AND RECOMMENDATIONS:

The testing data shows that advanced treatment systems (when properly installed and operated) can and do produce an effluent that is much cleaner than conventional septic tank effluent. As should be expected with any biological process, each of the system types experiences occasional “hiccups” wherein performance falls short of expectations. With regular inspections and maintenance these problems can be corrected and good performance restored. Based on this demonstrated performance the authors recommend that local regulators actively encourage the continued use of these advanced systems as well as the introduction of other comparable systems. The authors also recommend that a long-term monitoring program be instituted at representative sites served by each type of advanced system.

Over the past year the Municipal Health Department, in conjunction with its Technical Review Board, has initiated the development of an addendum to its wastewater code pertaining to advanced treatment systems. To efficiently administer these new regulations the Health Department will need to develop and maintain necessary expertise in-house. This will necessitate that appropriate user fees are instituted to pay for the program's administration. The following are the authors' recommendations regarding the development of a regulatory framework for advanced treatment systems in Alaska.

6.6.1 Goals

Goals that the authors recommend be used to guide the development of new regulations for advanced systems:

To encourage the use of the best available technology for on-site wastewater disposal

To make sure that this technology can perform as designed in Anchorage's climatic conditions

To ensure that appropriate maintenance is done to keep the systems operating as designed

To provide for the generation of appropriate user fees necessary to sustain the program

To avoid unnecessary regulatory and financial burdens on the users

To avoid the possibility of arbitrary regulatory bias for (or against) specific technologies or vendors

6.6.2 Classification of Advanced Treatment Systems

Much of the effort to date on the development of advanced treatment system regulations as been devoted to formulating classifications based on performance. This is a very important first step in that a lot of the remainder of the regulations should be differentiated between classifications. The current draft provides for three different classifications of advanced treatment systems. These can be loosely described as: *Secondary treatment systems* (Category II) whose effluent achieves levels of <30 mg/l for BOD_5 and TSS, *Enhanced secondary treatment systems* (CategoryIII) whose effluent achieves significantly lower levels of <10 mg/l for BOD_5 and TSS, and *Nitrogen reducing systems* whose effluent achieves significantly reduced levels of <20 mg/l for total nitrogen.

The authors feel these are a reasonable set of classifications that describe distinct levels of performance, but are a little concerned about the implicit need to develop three corresponding sets of design criteria. The authors recommend that, rather than selecting slightly different performance criteria as is done in the current draft, the existing DEC criteria for secondary treatment be used for the first classification.

In looking at the performance data it appears that the ISF is the only system tested to date whose effluent quality fits into the enhanced secondary treatment category. Although there are differences between the two, both the Biocycle and the Reactex filter fit into the secondary treatment classification. The Reactex tank without an up-flow filter does not appear to quite meet secondary treatment standards. The Reactex with up-flow filter is the only system that fits into the nitrogen reducing classification.

6.6.3 Maintenance Requirements For Advanced Treatment Systems

Advanced systems are significantly more mechanically complex than conventional septic tank/soil absorption systems. Because of their cleaner effluent they are able to justify reduced separation distances and higher application rates without compromising public health. But, the high quality effluent of advanced is dependent on all their mechanical components operating as designed. As with any complex system, there is a tendency for mechanical components to break down or to cease to function as intended, particularly in a cold climate such as Alaska. Some malfunctions cause an alarm to go off which prompts the homeowner to get the system serviced; however in other cases the system may cease to operate as designed without the homeowner even being aware. If a malfunction causes deterioration of the quality of the effluent it could lead to premature failure of the reduced-size residual drainfield and/or discharge of primary quality effluent with improper horizontal and vertical separation distances.

To minimize the potential for malfunctioning systems to remain unrepaired, a regular inspection and maintenance program is essential. ***Proper maintenance is probably the most important issue relating to advanced wastewater treatment systems and is also the most difficult to ensure.*** The authors recommend that regulatory agencies require that prior to issuance of a permit for any innovative system an on-going agreement must be signed with a qualified maintenance contractor ensuring that the system will be inspected and maintained by a trained repairman at set intervals. Provisions need to be included ensuring that the maintenance responsibilities are transferred to subsequent owners of the property. Provisions also need to address the possibility that the maintenance contractor goes out of business or ceases to perform the required maintenance.

The authors recommend that a generic set of maintenance requirements applicable to all advanced systems be included in the regulations. These requirements should address the frequency of maintenance inspections (every 3 or 6 months would be our recommendation), the types of components that should be inspected, any on-going sampling requirements, reporting procedures, and consequences of failure to perform the necessary maintenance. Since the responsibility for monitoring maintenance compliance will fall upon the regulatory agencies, there will need to be some sort of a user fee to support this program.

6.6.4 Design Standards For Advanced Treatment Systems

The soil application rates and separation distance standards in the existing wastewater ordinances were developed to ensure that the effluent from conventional septic tanks does not pose a contamination risk to wells and surface waters. In order to optimize the use of advanced systems there is a need to set new design standards that take into consideration the higher effluent quality of advanced systems and allow for correspondingly higher soil application rates and smaller separation distances. The authors urge regulators not to look upon adoption of different design standards as waivers to the existing standards for conventional septic systems, but rather to view them as appropriate new standards for an advanced technology.

6.6.4.1 Soil Application Rates for Residual Disposal Field Sizing

For conventional septic tank effluent Municipal and State regulations allow variable soil application rates ranging between 0.3 and 1.2 gallons per day per square foot, based on perc test results. Up until recently the Municipal Health Department has allowed ISF and RTF/Reactex effluent to be applied at a rate of either 2.0 or 4.0 gpd/sq. ft. depending on whether the perc rate is slower than or faster than 30 minutes per inch. On the other hand MOA has allowed Biocycle effluent to be applied at only double the rate of septic tank effluent, or 0.6 – 2.4 gpd/sq. ft.

At an April, 2000 work session the MOA On-Site Technical Review Board adopted the following soil application criteria for advanced wastewater treatment systems. These new criteria recognize that biomat formation is more of a limiting factor in coarse-grained soils than it is in fine-grained soils.

Percolation Rate (Minutes/Inch)	Conventional Septic Tank Effluent	Secondary Treatment (Category II)	Enhanced Secondary (Category III)
<1	1.0 gpd/sq. ft. with filter	4.0 gpd/sq/ ft.	6.0 gpd/sq/ ft.
1-5	1.2 gpd/sq/ ft.	4.0 gpd/sq/ ft.	6.0 gpd/sq/ ft.
6-15	0.8 gpd/sq/ ft.	3 gpd/sq/ ft.	5 gpd/sq/ ft.
16-30	0.6 gpd/sq/ ft.	2.0 gpd/sq/ ft.	4.0 gpd/sq/ ft.
31-60	0.45 gpd/sq/ ft.	1.0 gpd/sq/ ft.	2.0 gpd/sq/ ft.
61-120	Not allowed	0.5 gpd/sq/ ft.	0.5 gpd/sq/ ft.

From a functional viewpoint, the wastewater parameters that relate to drainfield sizing are BOD_5 and TSS, since these determine the probability and rate of biomat formation. The nitrogen in wastewater is in a dissolved form and therefore does not contribute to the formation of a biomat.

We feel that the present 2.0/4.0 gpd/sq. ft application rates are appropriate for effluent from enhanced secondary treatment systems, only. We are a little uncomfortable with the present practice of using these high application rates for the Reactex filter system because of its significantly higher levels of BOD_5 and TSS.

For effluent from secondary treatment systems (which includes both Biocycle and RTF/Reactex filter systems) we recommend an intermediate schedule of application rates as follows: 4.0 gpd/sq. ft. for receiving soils with a measured perc rate of less than 5 minutes/inch, 2.0 gpd/sq. ft. for receiving soils with a measured perc rate of 5 - 30 minutes/inch, and 1.0 gpd/sq. ft. for receiving soils with a measured perc rate of 30 - 120 minutes/inch.

We recommend that effluent from nitrogen reducing systems be applied at the rate corresponding to its BOD_5/TSS classification.

6.6.4.2 Vertical Separation Distances For Residual Disposal Field Design

For conventional septic tank effluent the vertical separation distance requirements are 4 feet from seasonal high water table and 6 feet from impermeable soil or bedrock. The purpose of this vertical separation requirement is to provide a thick layer of unsaturated soil in which will filter out harmful microorganisms as the effluent percolates through it. Thus, the parameter of concern in setting vertical separation standards should be the fecal coliform count. Municipal and State environmental agencies presently allow effluent from an ISF to be discharged as close as 2 feet from a seasonal high water table and 4 feet from impermeable soils. This really does not represent any relaxation of existing standards at all, because the ISF incorporates a 2-foot thick sand layer within itself. The RTF and Reactex prototype systems have been granted the same 2-foot reduction in separation distance requirements on the arguable contention that the saturated gravel in the up-flow filter provides the equivalent level of microorganism removal as downward flow through 2 feet of unsaturated soil. The Biocycle has been granted no reduction in vertical separation distance requirements, despite the fact that its effluent quality in terms of BOD_5, TSS, and fecal coliform is cleaner than, the RTF/Reactex effluent. The authors feel that the quality of the effluent is what should be germane to a decision on reduced separation distance standards, not the process through which the innovative system achieves that effluent quality.

The 4-foot vertical separation distance requirement for conventional septic tank effluent to groundwater is quite conservative – many other states require either 2 or 3 feet. Research indicates that virtually all microorganisms are removed as septic tank effluent percolates down through 2 feet of unsaturated soil. The authors have never understood the rationale (if any) behind the 6-foot vertical separation requirement from bedrock or impermeable soils for effluent from conventional septic systems. Most other states use the same requirements for groundwater and bedrock. If 4 feet is an adequate distance to treat septic tank effluent before it reaches groundwater, then it should be adequate for bedrock or impermeable soils as well.

For effluent from secondary treatment systems, because of the greatly reduced fecal coliform counts (98% reduction), it is the authors' opinion a vertical separation of 2 feet between the bottom of the residual disposal drainfield and either seasonal high surface water or impermeable soils or bedrock for any of the systems should be adequate from a public health viewpoint. The authors share the concern expressed by others regarding the potential impact of malfunctioning systems. However, we believe these concerns should be addressed through adoption of appropriate maintenance requirements before an advanced system type is approved for general use.

6.6.4.3 Horizontal Separations

For conventional septic tank effluent the horizontal separation distance requirement is 100 feet from either private drinking water wells or surface water. The purpose of the horizontal separation distance requirement is primarily to eliminate the possibility of overland flow of untreated effluent from a failing system ever reaching a sensitive environment. This distance was arbitrarily chosen in an effort to provide a conservative buffer to protect water supplies from primary contamination. Since the pollutant load of the effluent from advanced systems is reduced by a factor of three to ten or more over conventional septic tank effluent, the authors feel that a lesser horizontal separation distance requirement is appropriate. While it is impossible to establish horizontal separations on a scientific basis, the authors feel that for secondary treatment systems a 50 % reduction from separation distance requirements for conventional septic systems is conservative, considering the much higher quality effluent. The authors feel that adoption of such a standard will go a long way towards fostering appropriate use of this technology. Due to the fact that the cleaner effluent promotes rapid infiltration, the required 50-foot separation for conventional septic tank effluent from slopes exceeding 25 % should not apply to advanced systems.

6.6.5 Recommended Procedures For Adequacy Testing of Advanced Systems:

The criteria and procedures used to perform adequacy tests on conventional septic systems do not apply to advanced systems in several respects. Now that there are a significant number of advanced systems operating in the Anchorage area it becomes increasingly important to agree upon standardized testing procedures for these new types of systems. In the case of a bottomless ISF it is impossible to measure the absorption capability of the residual disposal field, since there is no separate residual disposal field. The most important thing is the need to inspect the mechanical components to verify that they are all working properly. Proper operation should be verified through a combination of an engineer's inspection coupled with proof that the system has been routinely serviced. In the case of the ISF the inspector should verify that there is no fluid ponded on the surface of the filter. For all advanced systems where it is feasible, effluent samples should be collected and tested for BOD_5, TSS, TKN, NO_3-N, and FC, and a determination made that the test results for each fall within acceptable limits. The inspection should also verify that the residual disposal field is operating properly and is not surcharged.

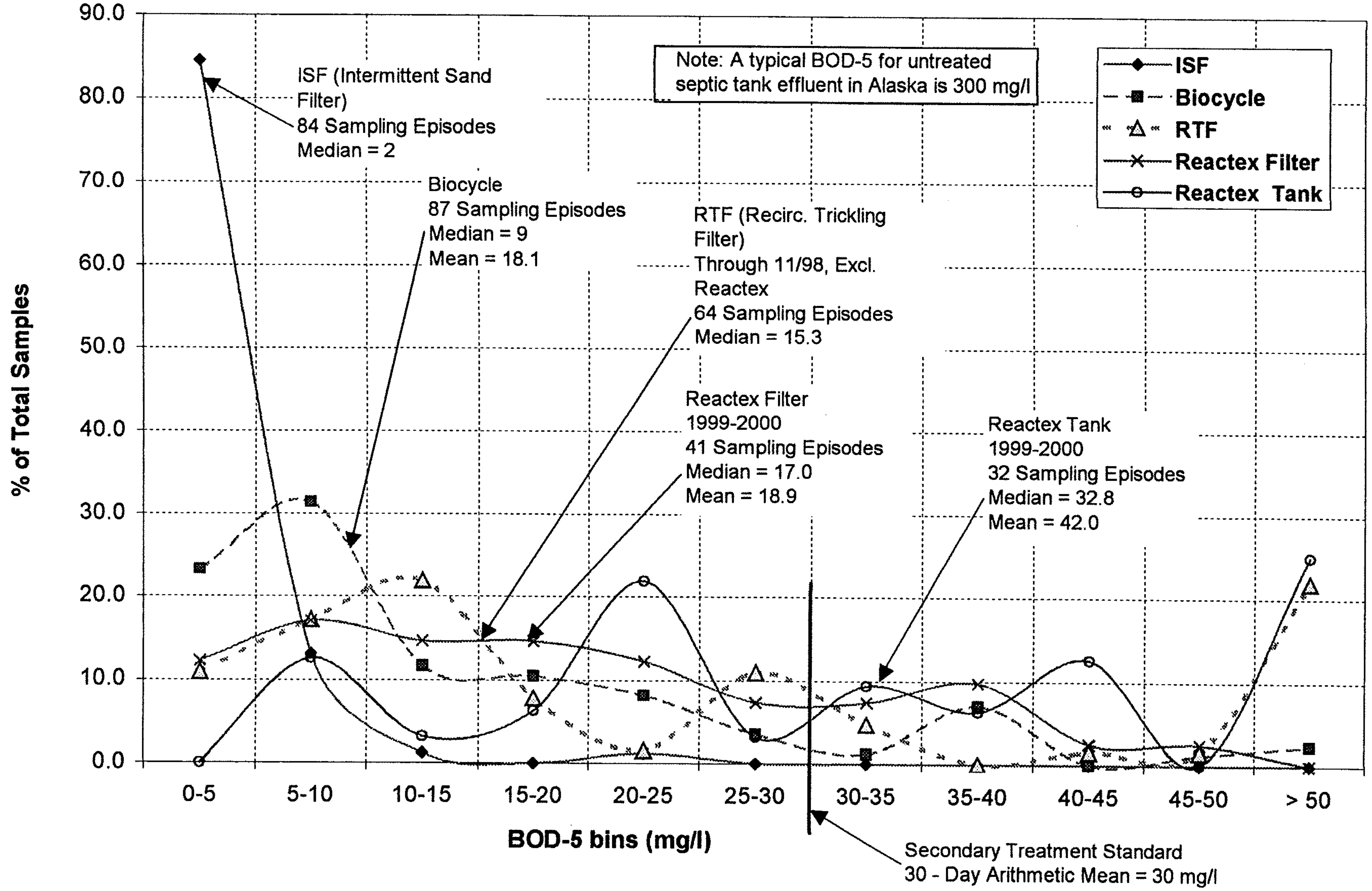


Figure 18. BOD5 Sampling Data for Advanced Treatment Systems

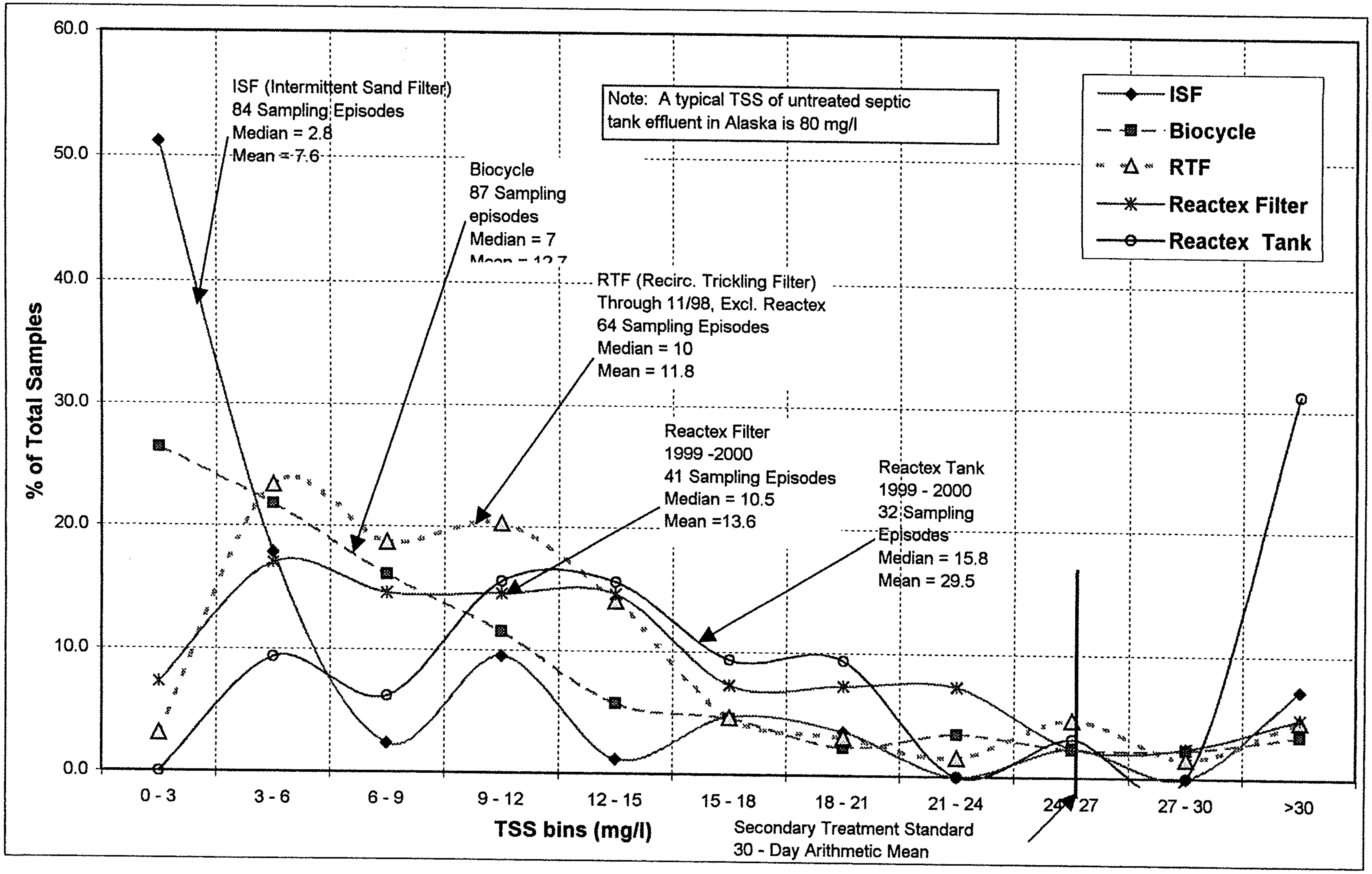
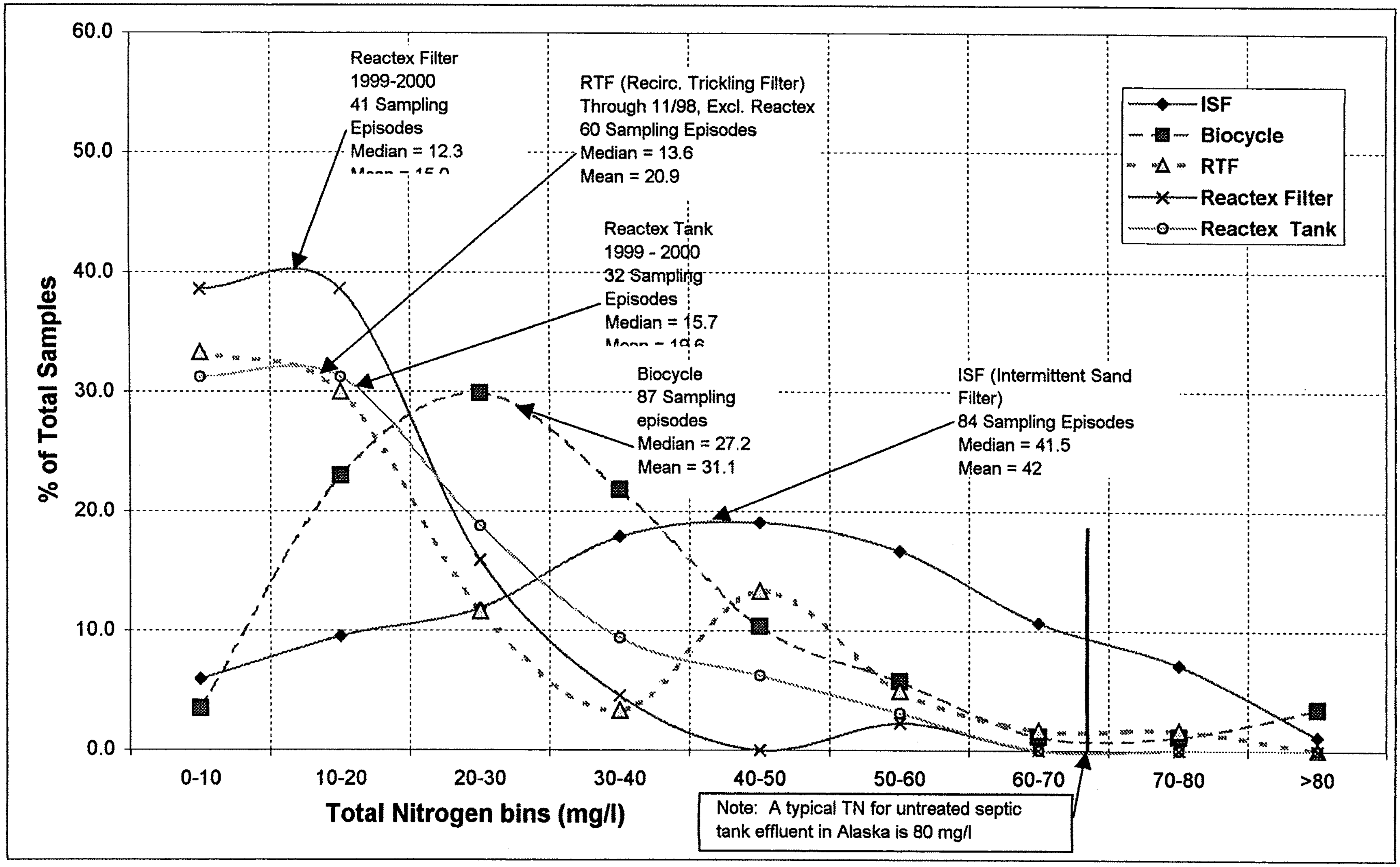


Figure 19. Total Suspended Solids Sampling Data for Advanced Treatment Systems



Reactex Filter
1999-2000
41 Sampling
Episodes
Median = 12.3

RTF (Recirc. Trickling Filter)
Through 11/98, Excl. Reactex
60 Sampling Episodes
Median = 13.6
Mean = 20.9

Reactex Tank
1999 - 2000
32 Sampling
Episodes
Median = 15.7

Biocycle
87 Sampling
episodes
Median = 27.2
Mean = 31.1

ISF (Intermittent Sand
Filter)
84 Sampling Episodes
Median = 41.5
Mean = 42

Note: A typical TN for untreated septic
tank effluent in Alaska is 80 mg/l

Figure 20. Nitrogen Sampling Data for Advanced Treatment Systems

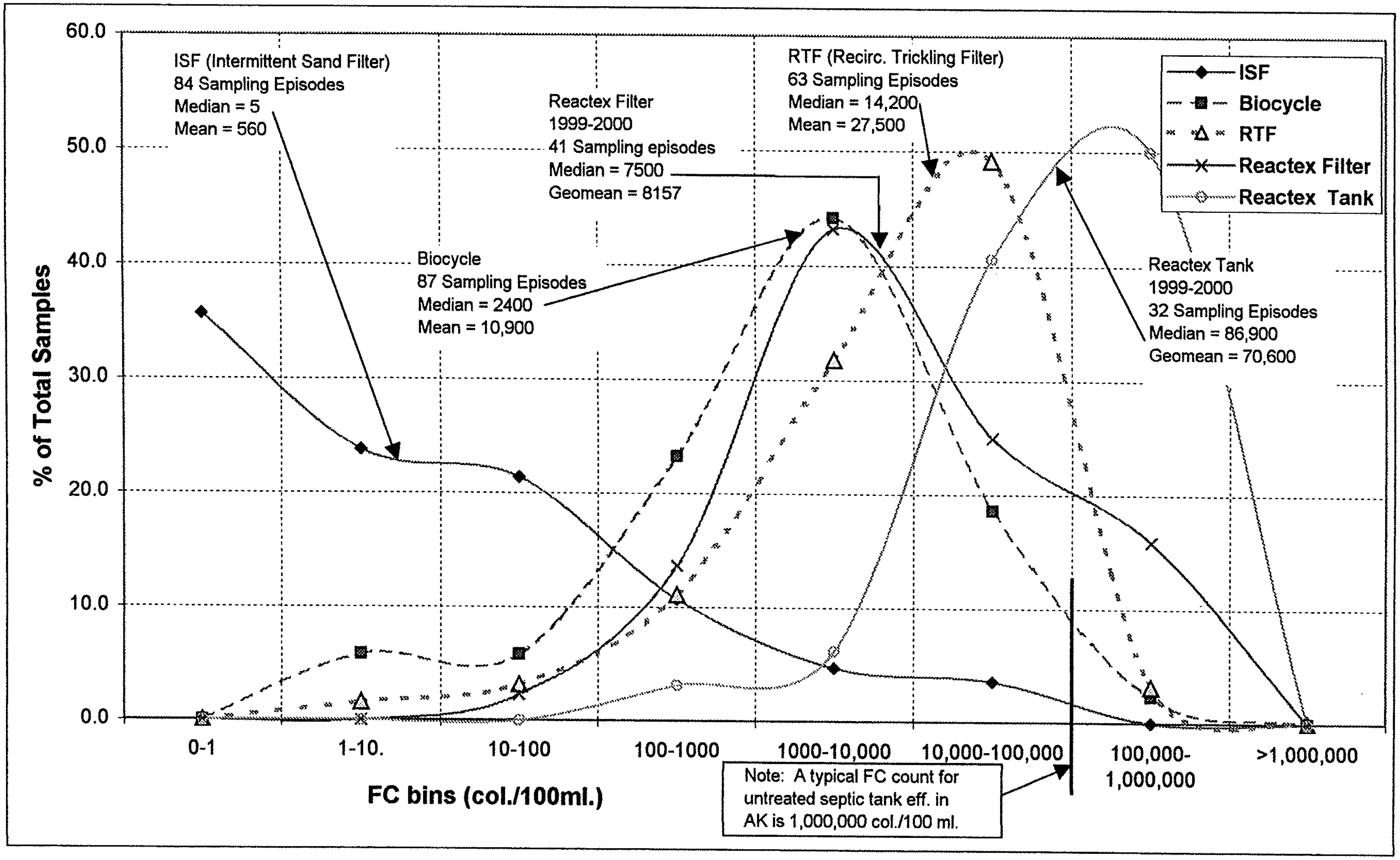


Figure 21. Fecal Coliform Sampling Data for Advanced Treatment Systems

APPENDIX A: SOIL ABSORPTION BEDS IN ANCHORAGE: CHANGES IN FLUID DEPTH

Site ID	Gravel Dep. (in.)	Insp. Date	Age (yr.)	S.T. Fluid Depth (in.)	S.T. Fluid Temp (in.)	Bed Fluid Depth	ΔFluid Depth in.)	ΔTime (yr.)	Change (in/yr.)
190	6	10/ 3/94	3.8	27	67.6	0			
	6	6/17/98	7.5	33	67.0	0			
						0		3.7	0
255	6	8/ 2/948.8	55	50	6				
	6	6/16/98	12.6	52	65.5	22			
						16		3.9	4.130
215	6	7/28/94	5.9	48	60	8			
	6	6/17/98	9.8	49	62.2	26			
						18		3.9	4.626
193	6	9/28/94	9.0	52	58.3	27			
	6	6/17/98	12.7	57	61.3	41			
						14		3.7	3.762
253	6	8/17/95	8.1	46		0			
	6	6/25/98	10.9	19		55			
						55		2.9	19.24
246	6	8/17/95	12.0	46.5	57.7	11			
	6	6/25/98	14.8	47	55.8	7			
	6	6/ 1/9915.8			1				
						-10		3.8	-2.63
251	6	8/17/95	6.9	49	67.5	12			
	6	6/25/98	9.8	50	49.0	15			
	6	6/ 1/9910.7			40				
						28		3.8	7.384
257	6	8/ 1/941.9	47	60	6.5				
	6	6/25/98	5.8	46	58.8	5			
	6	6/ 1/996.7			18				
						11.5		4.8	2.378
207	6	8/17/95	10.0	50	75.4	21			
	6	6/25/98	12.9	50	56.1	21			
	6	5/25/99	13.8			22			
						1		3.8	0.265
258		7/28/942.6	50.5	70	1				
		6/19/986.5	54	64	16				
						15		3.9	3.850
218	6	8/ 1/9410.0	48	64	7				
	6	6/23/98	13.9	49	70.5	0			
						-7		3.9	-1.79
200	6	6/13/95	10.8	49	62.6	0			
	6	6/25/98	13.8	49	53.2	11			
						11		3.0	3.623
201	6	8/ 4/944.9	50	66.6	12				
	6	6/25/98	8.8	50		16			
	6	6/ 1/999.7			22.5				
						10.5		4.8	2.175
185	6	9/29/94	10.2	56	60.8	40			
	6	6/19/98	13.9	67	59.2	49			
					9	3.7		2.417	
186	6	9/30/94	12.0	39	58.3	16			
	6	6/19/98	15.7	39	51.8	15.5			
						-0.5		3.7	-0.13
259	6	8/29/94	10.1	50	52	12			
	6	6/19/98	13.9	51	54.1	0			
						-12		3.8	-3.15
235	6	6/13/95	10.9	49	64.2	9			
	6	6/23/98	13.9	85	72.3	43			
						34		3.0	11.22

Site ID	Gravel Dep. (in.)	Insp. Date	Age (yr.)	S.T. Fluid Depth (in.)	S.T. Fluid Temp (in.)	Bed Fluid Depth	ΔFluid Depth in.)	ΔTime (yr.)	Change (in/yr.)
260	6	8/ 1/94	7.7	45	68	18			
	6	6/23/98	11.6	56	55	27			
							9	3.9	2.310
261	6	8/ 1/94	10.0	48	59	12			
	6	6/23/98	13.9	48	48	14			
							2	3.9	0.513
220	12	8/ 9/94	11.2	47	60.4	17.5			
	12	6/26/98	15.1	47	52	18			
							0.5	3.9	0.128
262	6	8/ 1/94	1.8	49.5		0			
	6	8/ 5/98	5.8	50	59	1			
	6	5/25/99	6.6			0			
							0	4.8	0
189	6	10/ 3/94	5.3		66.6	33			
	6	6/19/98	9.0			30			
							-3	3.7	-0.80
263	6	7/28/94	7.0	50	60	7			
	6	6/17/98	10.9	50	51.6	8			
							1	3.9	0.257
264	6	8/ 2/94	10.3	50.5	69.3	0			
	6	6/25/98	14.2	51	56.8	0			
							0	3.9	0
280	6	8/24/95	6.0	50	60.1	0			
	6	6/10/98	8.8	50	66.1	2			
							2	2.8	0.714
267	6	8/ 5/94	9.0	48	56	17.5			
	6	6/23/98	12.9	51	52.5	18			
	6	6/ 1/99	13.8			27			
							9.5	4.8	1.969
266	6	8/ 2/94	11.0	48	59	41			
	6	6/25/98	14.9	49	51.3	41			
	6	6/ 1/99	15.8			41			
							0	4.8	0
269	6	3/31/95	5.2	53		0			
	6	6/18/98	8.4	51	64.9	0			
							0	3.2	0
245	6	5/16/95	8.5	49	55	12			
	6	6/10/98	11.6	50	56.3	39			
							27	3.1	8.791
241	6	6/13/95	11.2	47	66	16			
	6	6/ 1/99	15.2	47	67	6			
							-10	4.0	-2.51
270	6	8/ 1/94	2.9	46	75	8			
	6	6/23/98	6.8	49	77.7	13			
	6	6/ 1/99	7.7			14			
							6	4.8	1.240
202	6	6/13/95	6.9	49	62.8	5			
	6	6/23/98	10.0	46	65.1	17			
							12	3.0	3.960
224	6	8/ 8/94	12.3	48	63	5			
	6	6/23/98	16.2	58	64	21			
							16	3.9	4.127

Site ID	Gravel Dep. (in.)	Insp. Date	Age (yr.)	S.T. Fluid Depth (in.)	S.T. Fluid Temp (in.)	Bed Fluid Depth	ΔFluid Depth in.)	ΔTime (yr.)	Change (in/yr.)
236	6	6/13/95	4.7	48	58.5	2			
	6	6/23/98	7.7	49	57.2	2			
							0	3.0	0
272	6	8/16/94	1.0	46	68.2	0			
	6	6/16/98	4.9	47	58.8	0			
							0	3.8	0
233	6	5/16/95	7.9		59.5	30			
	6	6/16/98	11.0	19	57.9	6			
							-24	3.1	-7.77
216	6	9/ 1/94	10.1	57		19.5			
	6	6/16/98	13.9	55	57.2	16			
							-3.5	3.8	-0.92
194	10	9/28/94	10.1	48	59.4	0			
	10	6/16/98	13.8	49	47.8	0			
							0	3.7	0
250	6	5/16/95	7.8	51	56.7	2			
	6	6/19/98	10.9	51	62.1	0			
							-2	3.1	-0.64
254	6	6/13/95	2.8	53	61.5	15			
	6	6/23/98	5.8	51	64	20			
							5	3.0	1.650
214	6	8/17/95	0.9	44	65.5	0			
	6	6/25/98	3.8	45	65.7	6			
	6	6/ 1/99	4.7			9			
							9	3.8	2.373
273	6	7/29/94	3.9	50	60	1			
	6	6/19/98	7.8	50	58	0			
							-1	3.9	-0.25
192	6	9/28/94	7.2	48	64.6	9			
	6	6/17/98	10.9	50	55.9	12			
							3	3.7	0.806
274	6	7/29/94	7.7	57		1			
	6	6/17/98	11.6			1			
							0	3.9	0
275	6	8/ 5/94	7.8	51		0			
	6	6/25/98	11.7	51	62.1	0			
	6	6/ 6/99	12.6			0			
							0	4.8	0
195	6	9/28/94	8.4	52	54	12			
	6	6/16/98	12.2	56	49.5	16			
							4	3.7	1.075
239	12	5/16/95	2.8	51	54.5	10			
	12	6/19/98	5.9	55	58	11			
							1	3.1	0.323
234	6	5/16/95	1.9	28	51.4	0			
	6	6/16/98	5.0	40	62.6	12			
							12	3.1	3.886
225	6	7/28/94	5.0	45		1			
	6	8/ 3/98	9.0	45		0			
							-1	4.0	-0.24
242	6	5/16/95	10.0	51	55.9	8			
	6	8/ 3/98	13.2	48		7			
							-1	3.2	-0.31
198	6	8/17/95	10.0	48.5	54.9	9			
	6	8/ 5/98	13.0	48		2			
							-7	3.0	-2.35

Site ID	Gravel Dep. (in.)	Insp. Date	Age (yr.)	S.T. Fluid Depth (in.)	S.T. Fluid Temp (in.)	Bed Fluid Depth	ΔFluid Depth in.)	ΔTime (yr.)	Change (in/yr.)
276	6	8/ 1/94	4.0	41	54	0			
	6	5/25/99	8.8			0			
							0	4.8	0
206	6	5/16/95	8.8	49	65.4	4			
	6	6/19/98	11.9	52	72.5	15			
							11	3.1	3.553
230	6	8/ 1/94	6.9	38	50	0			
	6	6/25/98	10.8	38	40.8	0			
							0	3.9	0
278	6	6/13/95	2.0	47	56.5	2			
	6	6/23/98	5.1	46	60.1	14			
							12	3.0	3.960
208	6	5/16/95	2.2	42		2			
	6	6/17/98	5.3	43		8			
							6	3.1	1.941
227	6	7/28/94	4.1	40	58	1			
	6	6/17/98	8.0	40	59	7			
							6	3.9	1.542
188	6	9/30/94	4.2	24	64.8	4			
	6	6/17/98	7.9	24	61.3	15			
							11	3.7	2.960
210	6	8/17/95	12.4	48	62.4	0			
	6	6/23/98	15.3	48	60.8	1			
							1	2.9	0.350
191	6	9/30/94	7.3	49	60.6	4			
	6	6/17/98	11.0	50	58.3	23			
							19	3.7	5.114
228	12	7/28/94	11.3	57	63	16.5			
	12	6/19/98	15.2	63	63.5	24			
							7.5	3.9	1.925
231	12	8/10/94	7.7			7			
	12	6/17/98	11.6	55	46	0			
							-7	3.9	-1.81
199	6	8/17/95	12.6	59	67.5	0			
	6	8/ 5/98	15.6			0			
							0	3.0	0
232	6	8/ 2/94	2.9	50	56	2			
	6	6/16/98	6.8	50	61	4			
							2	3.9	0.516
248	6	6/13/95	10.1	50	41.7	0			
	6	6/23/98	13.2	51	59.7	9			
							9	3.0	2.970
Average Total Change							5.20		

APPENDIX B: ADVANCED TREATMENT SYSTEM MONITORING

Table 3. Biocycle Monitoring Data 1994-2000

	Installation Date	Absorption Type	Percolation Rate	Inspection Date	Water in Field
Bio#1	1995	Bed w/2 ft F.S. 6" rock	100	June 1997	0"
				May 1998	0"
				May 1999	5"
				May 2000	12"
Bio#2	1995	Bed w/4ft F.S. 6" rock	30	June 1997	0"
				May 1998	0"
Bio#3	1995	Bed w/1 ft F.S. 6" rock	30	June 1997	2"
				May 1998	2"
				May 2000	1"
Bio#4	1995	5-Wide w/12" rock	5	June 1997	0"
				May 1998	0"
				May 2000	0"
Bio#5	1995	Trench w/5 ft rock	15	June 1997	36"
				May 1998	5" Trench
				June 1998	0" Bed
				May 2000	0" Bed
Bio#6	1996	5-Wide w/36" rock	3.6	June 1997	0"
				May 1998	12"
				May 2000	3"
Bio#7	1996	Trench w/5' of rock	6	June 1997	0"
				May 1998	0"
				May 2000	0"
Bio#8	1996	Mound w/2 ft F.S., 6" rock	2	June 1997	0"
				May 1998	2"
				May 1999	0"
				May 2000	0"
Bio#9	1996	5-Wide w/6" rock	5	June 1997	0"
				May 1998	0"
				May 2000	0"
Bio#10	1996	Bed w/2 ft F.S. 6" rock	2	June 1997	0"
				May 1998	0"
				May 2000	0"
Bio#11	1996	5-Wide, 6" rock	<5	June 1997	0"
				May 1998	0"
				May 2000	0"
Bio#12	1996	5-Wide, 6" rock	4	June 1997	3"
				May 1998	3"
				May 1999	3"
				May 2000	12"

Table 4. Intermittent Sand Filter System Monitoring 1994-2000

System ID	Installation Date	Absorption Type	Percolation Rate (minutes/inch)	Inspection Date	Water Depth Absorption Field (in.)	Water Depth on Filter (in.)
ISF#1	1994	5-Wide, 6" rock	10	June 1997	7.5	
				May19 98	17	
				May 1999	25.5	8.5
				May 2000		10
ISF#2	1994	5-Wide, 6" rock	3.6	June 1997	0	
				May 1998	0	
				May 1999	0	3
				May 2000	0	2
ISF#3	1994	5-Wide, 6" rock	40	July 1998	0	
				May 1999	2.5	
				April 2000	0	
ISF#4	1995	Bottomless	3	May 2000		2
ISF#5	1995	Bottomless	<30	June 1997		6.5
				May 1999		6
				May 2000		0
ISF#6	1995	Bottomless	<30	June 1997		0
				May 1998		0
				July 1998		0
				May 2000		0
ISF#7	1995	Bottomless	<30	June 1997		0
				July 1998		0
				May 2000		0
ISF#8	1996	5-Wide, 6" rock	<30	June 1997	0	
				July 1998	0	
				May 2000	0	
ISF#9	1998	5-Wide, 6" rock	<1	July 1998	0	
				May 2000	0	

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