PROCEEDINGS
SECOND WORKSHOP ON HOME SEWAGE DISPOSAL IN COLORADO

Edited by
Robert C. Ward

September, 1975

ENVIRONMENTAL RESOURCES CENTER

Colorado State University
Fort Collins, Colorado

Information Series No. 20

PROCEEDINGS

SECOND WORKSHOP ON HOME SEWAGE DISPOSAL IN COLORADO

Edited by

Robert C. Ward
Agricultural Engineering Department
Colorado State University

Held at the
Student Center
Colorado State University
September 17, 1975

Sponsored by: Environmental Resources Center at Colorado State University
Colorado Department of Health
In cooperation with: Colorado Environmental Health Association
(Colorado) Cooperative Extension Service
Environmental Protection Agency, Region VIII

The publication of this report was supported in part by the Water Quality Control Division of the Colorado Department of Health and funds made available under PL 88-379, The Water Resources Research Act of 1964, through the Office of Water Resources Technology, U. S. Department of Interior.

Available from Environmental Resources Center

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INTRODUCTION

The following proceedings were developed from the Second Workshop on Home Sewage Disposal sponsored by the Environmental Resources Center at Colorado State University and the Colorado Department of Health. The first workshop was held in 1972 and dealt mainly with problem definition. This second workshop was organized to up date people in Colorado on : (1) work being done in Wisconsin on the Small Flows Project underway there; (2) curent research activities and regulating thinking in Colorado; and (3) the thoughts of Dr. J. T. Winneberger, a well known consultant in the home sewage disposal field.

Through the generous assistance of the speakers, the proceedings contain a large amount of specific design information on the systems discussed. As a result of this detail, it is hoped that the proceedings can be used to rapidly disseminate the research findings reported on herein.

Successful execution of the workshop was greatly assisted by Hancor, Inc. of Findlay, Ohio; Jet Aeration Co. and its distribution in Colorado; and the contribution by each speaker of his time and effort. Hopefully the proceedings have captured a measure of this success and are, consequently, able to pass it on to those not in attendance.

Robert C. Ward

SECOND WORKSHOP

ON

HOME SEWAGE DISPOSAL IN COLORADO

September 17, 1975
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Sponsored by: Environmental Resources Center, Colorado State University, Colorado Department of Health

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PROGRAM

8:00 a.m.	Registration, Student Center
MORNING SESSION	Room 228, Student Center
8:45 a.m.	"Welcome" - Norman A. Evans, Director, Environmental Resources Center, Colorado State University
9:00 a.m.	"Review of the Wisconsin Small Flows Project" - Richard J. Otis, Project Coordinator, Civil and Environmental Engineering Department, University of Wisconsin
9:35 a.m.	"Mound System Design Principles" - James C. Converse, Agricultural Engineering Department, University of Wisconsin
10:10 a.m.	Break - sponsored by Jet Aeration Company
10:30 a.m.	Panel Discussion on "What's Happening in Colorado" - moderated by R. C. Ward, Agricultural Engineering Department, Colorado State University

Panel:

E. R. Bennett, Civil and Environmental Engineering Department, University of Colorado, Boulder 80302

J. C. Ward, Civil Engineering Department, Colorado State University, Fort Collins 80523

D. C. Hall, USGS, WRD, Colorado District, Building 53, Denver Federal Center, Denver 80225

J. A. Danielson, State Engineer's Office, Division of Water Resources, 1845 Sherman Street, Denver 80203

P. Arell, Region VIII, Environmental Protection Agency, 1860 Lincoln Street, Denver 80202

12:00 noon	Lunch, West Ballroom, Student Center Luncheon address presented by John R. Bermingham, Colorado Land Use Commission
AFTERNOON--	Room 228 Student Center
1:30 p.m.	Workshop Discussion - led by T. J. Winneberger, Septic Tank Consultant, Berkeley, California (Dr. Winneberger's appearance is made possible by Hancor, Inc., of Findlay, Ohio)
3:00 p.m.	Break - sponsored by Jet Aeration Company
3:20 p.m.	Continuation of Workshop Discussion led by Dr. Winneberger
5:00 p.m.	Adjourn

Jet Aeration Company is represented in Colorado by:

Industrial Denver Company, Denver

Carmack Motors, Durango

El Paso Precaste Concrete, Colorado Springs

ON-SITE DISPOSAL OF SMALL WASTE FLOWS

The University of Wisconsin's Small Scale Waste Management Project

R. J. Otis[1]

INTRODUCTION

The safe disposal of wastewaters from single family dwellings, motels, restaurants, laundries and other establishments not connected to central sewerage is a complex and serious problem. Wastewaters contain many substances that are undesirable and potentially dangerous. Pathogenic bacteria and infectious viruses are often present which cause such diseases as typhoid fever, cholera, dysentery, poliomyelitis, infectious hepatitis and several parasitic infections. Some of these can be fatal. Putrescible organic matter, toxic chemicals and nutrients of nitrogen and phosphorus are also found in wastewater which can result in the deterioration of the environment.

Sewers solve the problem in the urban areas. The wastewaters are collected and transported away from the source to a central plant where it can be treated before disposal. Trained operators are present at the treatment works to see that the waste is properly treated. Also, access to the point of effluent discharge to a receiving stream is controlled. This minimizes the danger to public health.

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[1] Sanitary Engineer, Department of Civil and Environmental Engineering, University of Wisconsin, Madison, Wisconsin.

Publications listed in this paper may be obtained by writing to the Small Scale Waste Management Project, Room 1, Agriculture Hall, University of Wisconsin, Madison, 53706.

In the rural setting, however, the advantages of a community system are not available. Wastes must be treated and disposed of at the source. If failure of any type occurs, the owner can be in immediate danger and he usually lacks the knowledge or the money to repair the system. Therefore, it is important to develop improved methods of on-site liquid waste disposal that are more effective to lessen the public health hazards to the rural population.

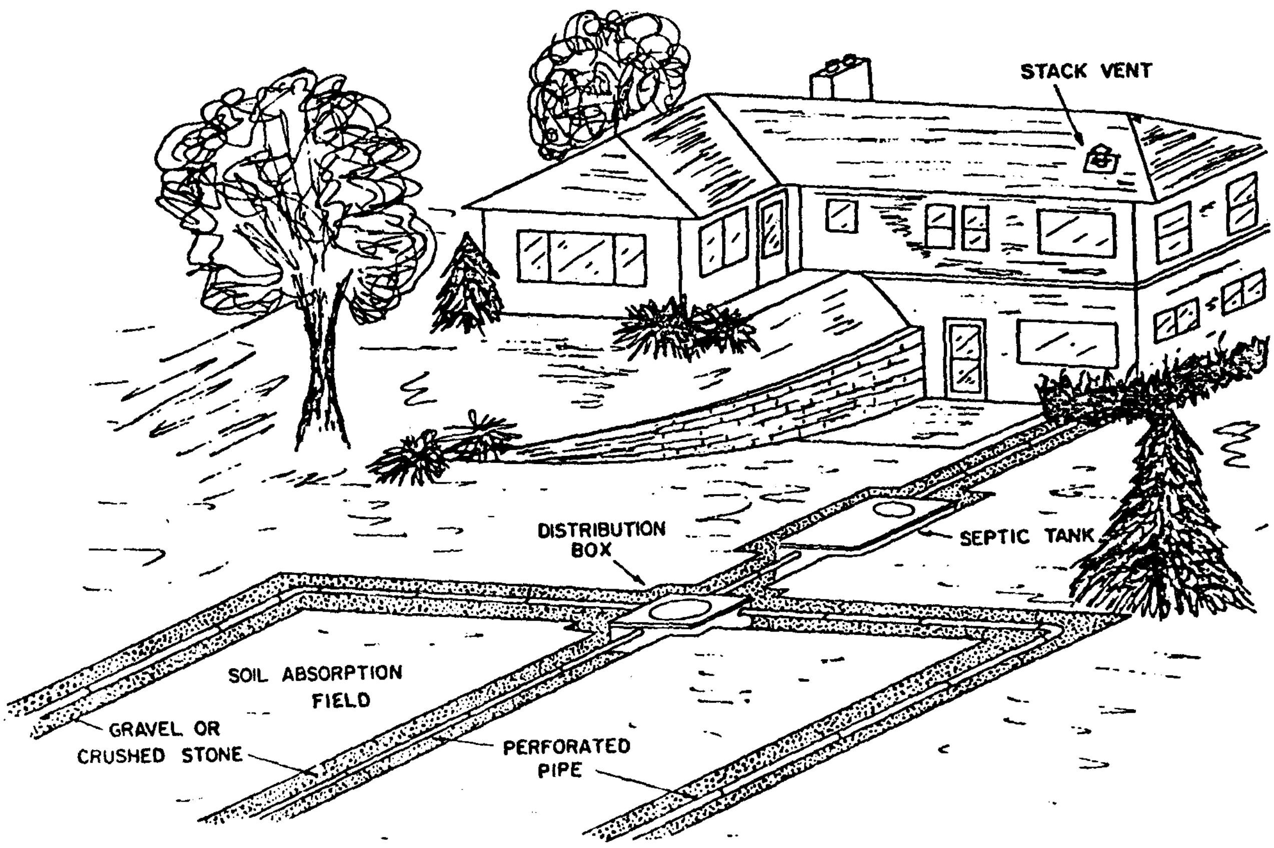

Figure 1. A Typical Household Tank System

<u>The Septic Tank-Soil Absorption System</u>

The most common method of on-site liquid waste disposal is the septic tank system. The conventional septic tank system is made up of two components: the septic tank, used to provide partial treatment of the raw waste and the soil absorption field or pit where final treatment and disposal of the liquid discharged from the septic tank takes place (Figure 1). Both are installed below the ground surface.

Unfortunately, the septic tank system has a bad reputation for failure. Failure usually manifests itself by surface seepage of the partially treated septic tank effluent or by sewage back-ups in the plumbing fixtures due to a clogged soil absorption field. Since the system is near the home or establishment, the seepage is usually readily accessible to playing children and pets. A more serious type of failure, however, is less obvious. It occurs when there is insufficient or unsuitable soil below the absorption field to properly purify the septic tank effluent before it reaches the groundwater. This results in contamination of the nearby wells used as water supplies by bacteria, viruses and chemical pollutants. This type of failure often goes unnoticed until an illness occurs.

The causes of failure do not seem to be due to inherent shortcomings of the septic tank soil absorption system itself, but rather its misapplication and misuse. Where the soils are suitable for installation, the septic tank-soil absorption field is an excellent method of on-site disposal of wastewaters. If the soil is moderately permeable, unsaturated to a depth of 4 to 5 feet and not located on excessive slopes, the system has been shown to provide trouble-free operation for up to 20 years or more, However, development is not restricted to areas with these optimal site conditions. The Soil Conservation Service estimates that only 32% of the total land area of the United States has suitable soils for the installation of septic tank systems[2] (Figure 2). Thus, systems are often installed where they have little chance of success. Also, even in areas considered to have suitable soils, failures often occur because of poor design, installation or maintenance. Clearly, there is a need to understand how a septic tank system works, why it fails and what alternative systems might be employed in unsuitable areas if the public health and environment is to be protected in the rural areas.

Objectives of the Small Scale Waste Management Project

The growing concern about water pollution, the danger to public health and the inhibition of regional economic development due to inadequate on-site liquid waste disposal system led to the commitment of the University of Wisconsin to study the management problems associated with small waste flows. Extensive research by Weibel, Bendixen, Coulter and others at the Public Health Service in the late 1940's and by McGauhey and Winneberger at the

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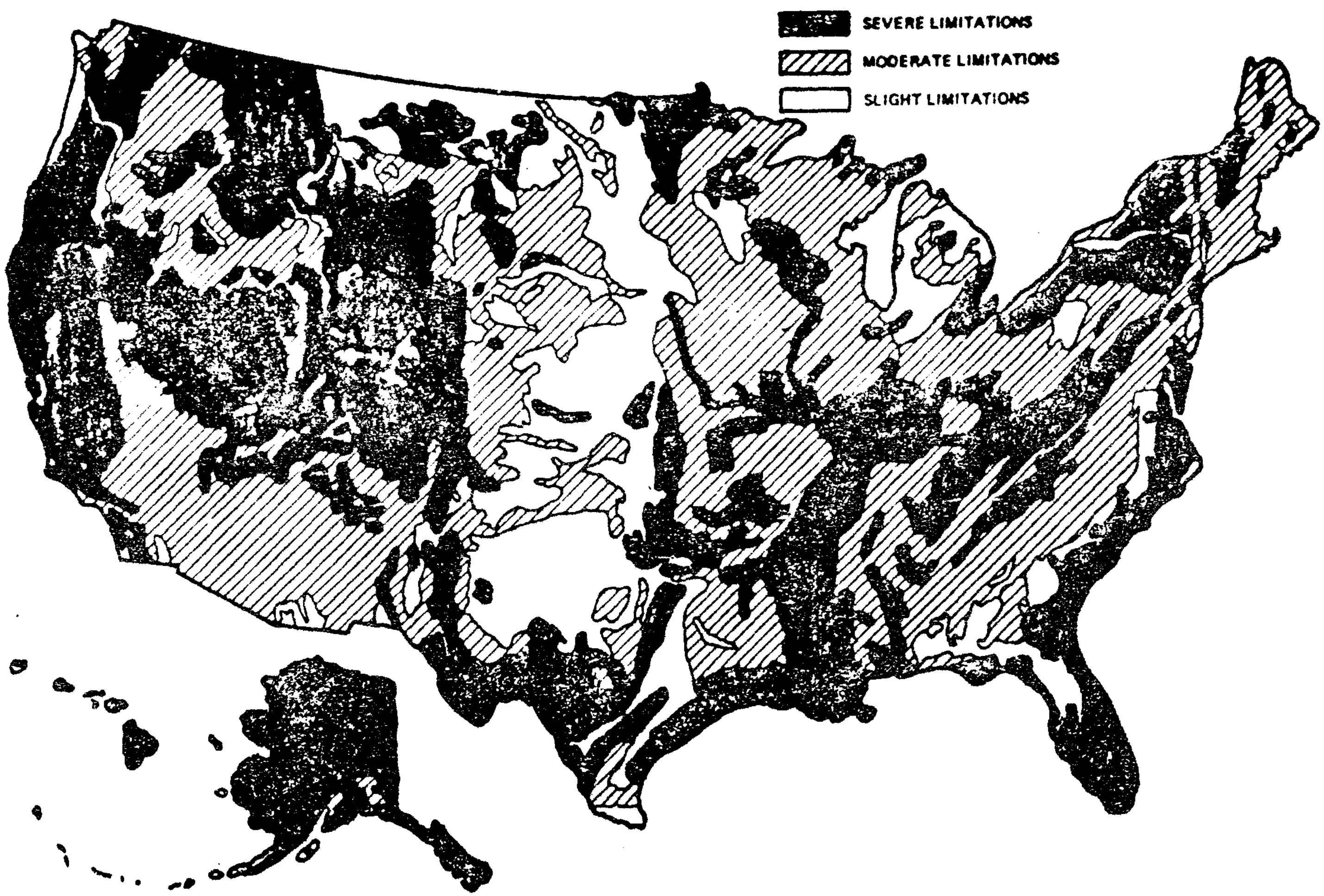
[2] Wenk, V.D., "Water Pollution: Domestic Wastes," A technology assessment methodology prepared for the Office of Technology, PB 202778-06 Vol. 6, MITRE Corporation (June, 1971).

Figure 2

DISTRIBUTION OF SOIL LIMITATIONS FOR SEPTIC TANK OPERATION

(Data from Wenk 1971)



University of California-Berkeley in the late 1950's provided much of the basis for today's practices. However, many questions still remain unanswered. To answer some of these questions, the Small Scale Waste Management Project was organized.

The Wisconsin Geological and Natural History Survey, University of Wisconsin-Extension has been studying the problem since 1969 with initial support from the Wisconsin Department of Natural Resources. The Upper Great Lakes Regional Commission has provided funding to the University of Wisconsin-Extension from July, 1971 to present to demonstrate alternative on-site disposal systems. Special research funds have been appropriated by the State of Wisconsin since November, 1971 to the College of Agriculture and Life Sciences, University of Wisconsin-Madison. Additional funds were granted to the Water Resources Center, University of Wisconsin-Madison in December, 1973 by the U.S. Environmental Protection Agency. The Small Scale Waste Management Project grew out of an integration of these activities.

The objectives of the project are:

1. To determine and understand the causes of failure of septic tank systems.
2. To develop improved methods of site characterization, design and construction techniques for on-site disposal of wastewaters.
3. To develop improved methods of management of on-site systems.
4. To investigate the implications to land use planning of improved technology.

I. The Use of Soil As A Treatment and Disposal Medium For Wastewater

I-A. Infiltration and Liquid Movement Through Soils

The success of the septic tank-soil absorption system for disposal of wastewater on-site depends upon the ability of the soil surrounding the absorption area to accept and treat the liquid effectively. The soil must absorb all the septic tank effluent discharged to it daily and purify it as it moves through the soil. Both of these functions are directly related to the hydraulic characteristics of the soil which are governed by pore geometry of the soil material. Failure occurs if either of these functions are not achieved.

I-A.1. Morphological and Physical Characterization of Soil Porosity

Soil is a mixture of solid particles and voids. The size, shape and arrangement of the particles and voids comprise the structure of the soil. It is this structure that determines how liquid will move through the soil.

Two levels of soil structure have to be distinguished when when considering soil porosity, they are primary and secondary. The primary structure is formed by the packing arrangement of the individual soil particles which form packing pores between them. The secondary structure is made up of aggregated soil materials in which primary particles are combined into larger compound natural units, called peds, which are separated by natural or planar voids Larger pores or channels formed by roots or animals may occur inside or between peds.

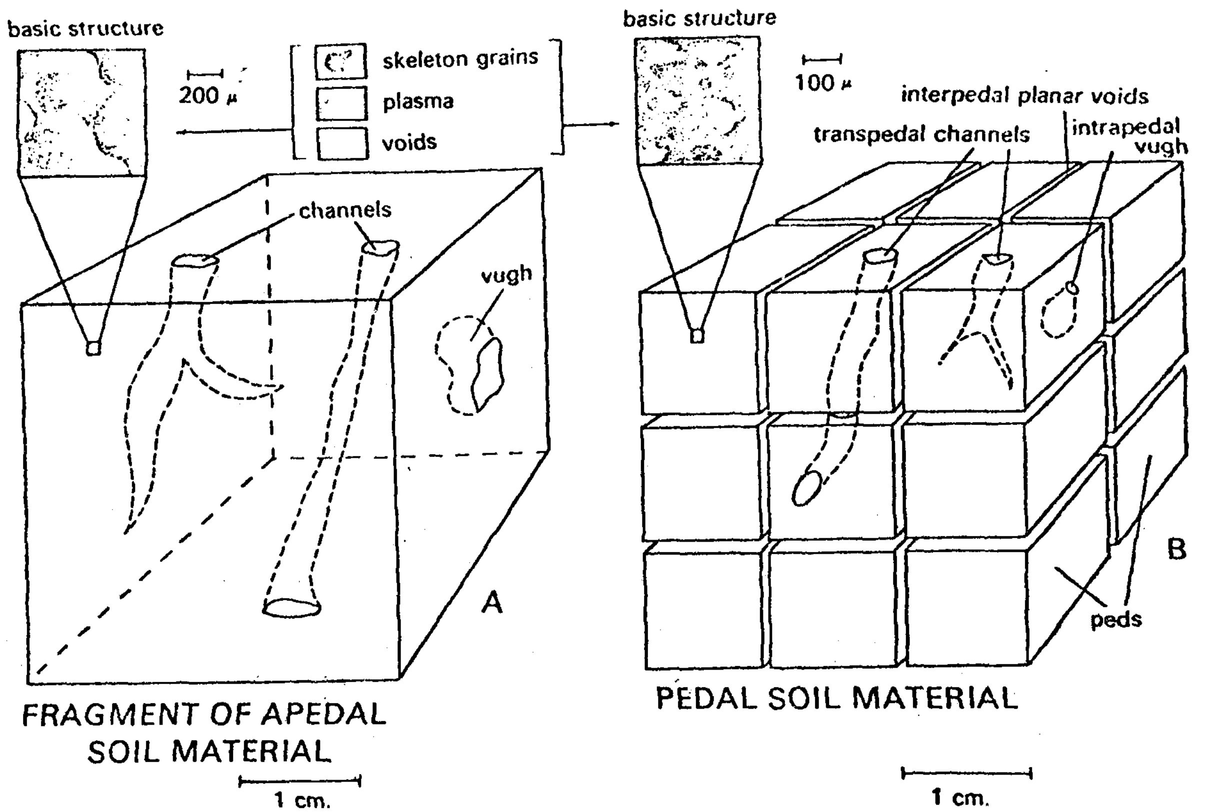


Figure I-A.1. Schematic Representation of a Pedal (right) and Apedal Soil Material (left). (Bouma, Anderson, 1973)

Bouma, J. and J.L. Anderson, "Relationships Between Soil Structure Characteristics and Hydraulic Conductivity," Field Soil Water Regime, Soil Science Society of America, (1973) pp. 77-105.

I-A.2. Physical Characteristics of Water in Soil Materials.

The pores within the soil can be conceptualized as a bundle of capillary tubes of various diameters. These tubes will conduct water upward as well as downward. The direction of flow will depend on the potential gradients within the soil.

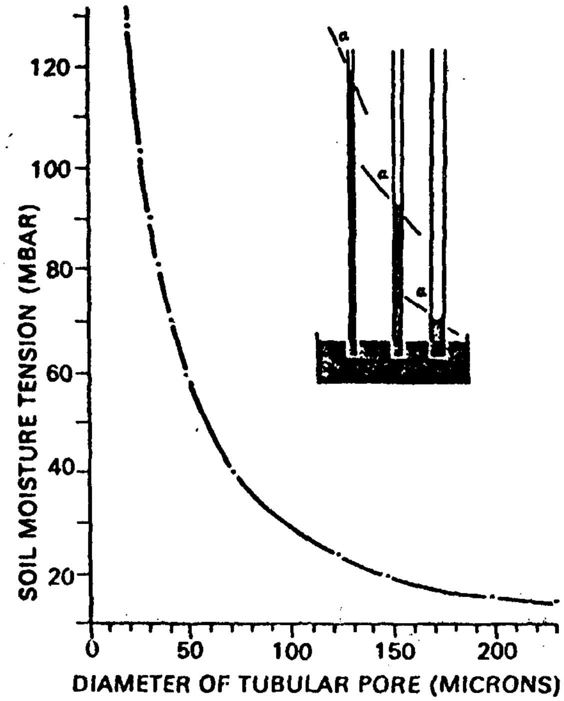


Figure I-A.2.a Graphical Expression of the Relationship Between Tubular Pore Size and Corresponding Soil Moisture Tension. (Bouma et al., 1972)

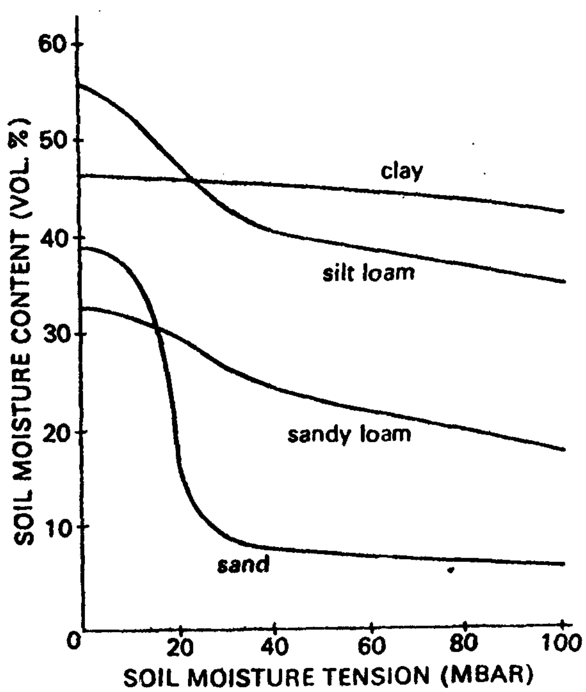


Figure I-A.2.b. Soil Moisture Retention Curves, Relating Soil Moisture Content to Moisture Tension, for Four Different Soil Materials (Bouma, et al., 1972)

Two components primarily determine the potential gradient and therefore the direction and rate of flow of water under a soil absorption field. They are the gravitational potential and the matric potential. The gravitational potential is due to the force of gravity pulling the water downward toward the center of the earth. The matric potential refers the force exerted on the water under negative pressure resulting from capillary and adsorptive forces due to the soil matrix. This force is referred to as soil "suction" or "tension." It can "pull" water downward, upward or sideward.

At saturation, all the pores are filled with water and the tension is zero. The only force acting on the water is gravity. As the soil drains, however, the tension begins to increase as progressively smaller pores empty. The largest pores empty first since the capillary force they exercise becomes insufficient to retain the water against the tension applied. The rate of decrease of water content in a soil sample upon increasing tension is characteristic for each soil material, since it is a function of its pore size distribution. Most of the pores in sand are relatively large that will drain at relatively low tensions whereas the pores in clays release only a small volume of water because of their very small size.

Bouma, J., W.A. Ziebell, W.G. Walker, P. Olcott, E. McCoy and F.D. Hole, Soil Absorption Septic Tank Effluent - A Field Study of Some Major Soils of Wisconsin, University Extension and Geological and Natural History Survey, Bulletin 20, University of Wisconsin-Madison (1972), 235 pp.

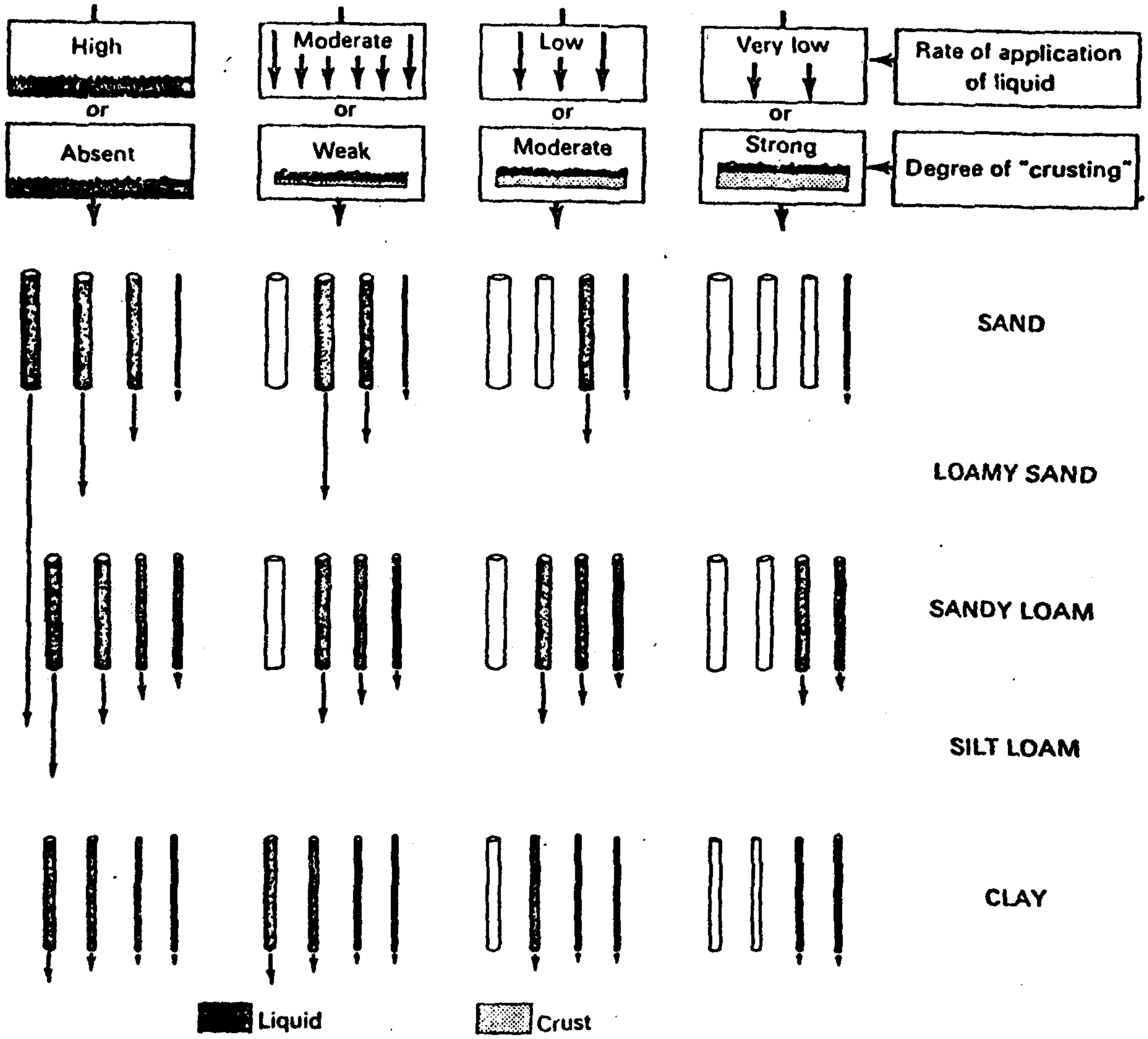


Figure I-A.3.a. Schematic Diagram Showing the Effect of Increasing the Degree of Crusting or Decreasing the Rate of Application of Liquid on the Rate of Percolation Through Three "Soil Materials," (Bouma *et al.*, 1972)

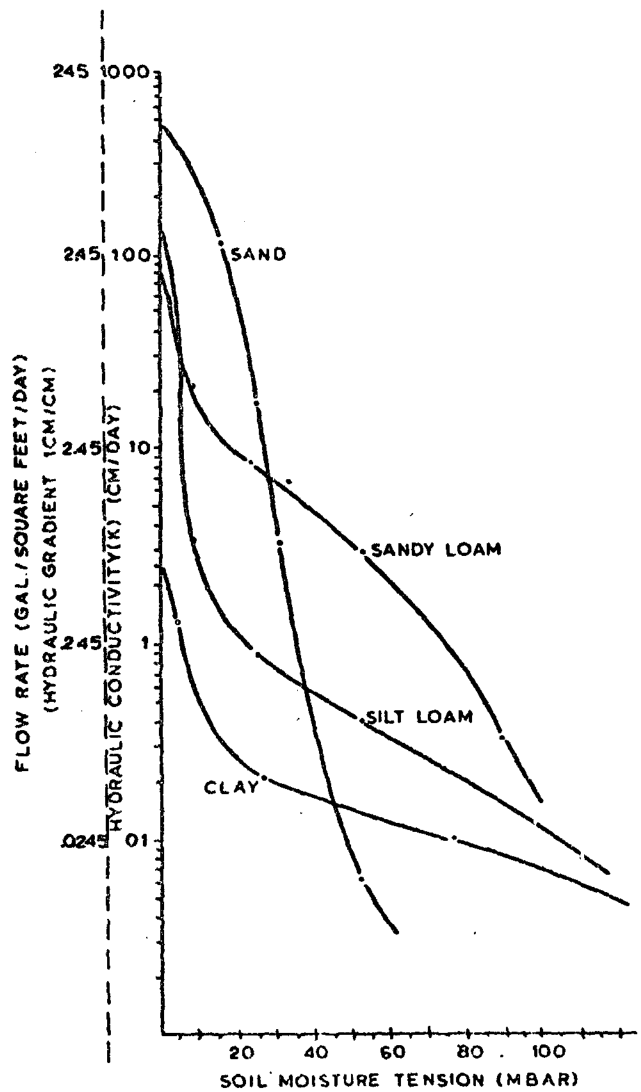


Figure I-A.3.b. Hydraulic Conductivity (K) As A Function of Soil Moisture Tension Measured *in situ* With the Crust-Test Procedure. (Bouma et al., 1972)

Bouma, J., F.G. Baker and P.L.M. Veneman, Measurement of Water Movement in Soil Pedons Above the Water Table, University of Wisconsin-Extension, Geological and Natural History Survey, Information Circular Number 27, (1974), 114 pp.

I-A.3. Liquid Movement in Soils

At a given moisture content, the liquid flow rate through a soil can vary considerably with varying potential gradients. The hydraulic conductivity, K, however is defined as the flow rate at unit gradient and can, therefore, be considered a characteristic value for a given soil. The measured K values for different soils will vary widely due to the different pore size distributions in the soils. Coarse porous soils have a relatively high saturated hydraulic conductivity, K_{sat}, but drops strongly with increasing tension. Fine porous soils have a relatively low K_{sat} but the flow rate decreases more slowly with increasing tension.

I-B. Flow Phenomena Around Seepage Fields

Results obtained from monitoring operating soil absorption systems in several different soils indicate the occurrence of unsaturated soil conditions below and along side the system while the effluent is ponded inside. This condition is due to the presence of an impeding layer or clogging mat at the infiltrating surface.

I-B.1. The Process of Pore Clogging

Studies by several investigators indicate that physical and biological mechanisms are the primary causes of soil clogging. Systems that fail within a year or two have probably been poorly constructed. Rapid absorption of liquid by soil depends upon a suitable soil structure being maintained to keep the soil pores open. Poor construction techniques can destroy it. In systems that clog biologically, the clogging seems to start at the point of inlet and progress down the length of the bed.

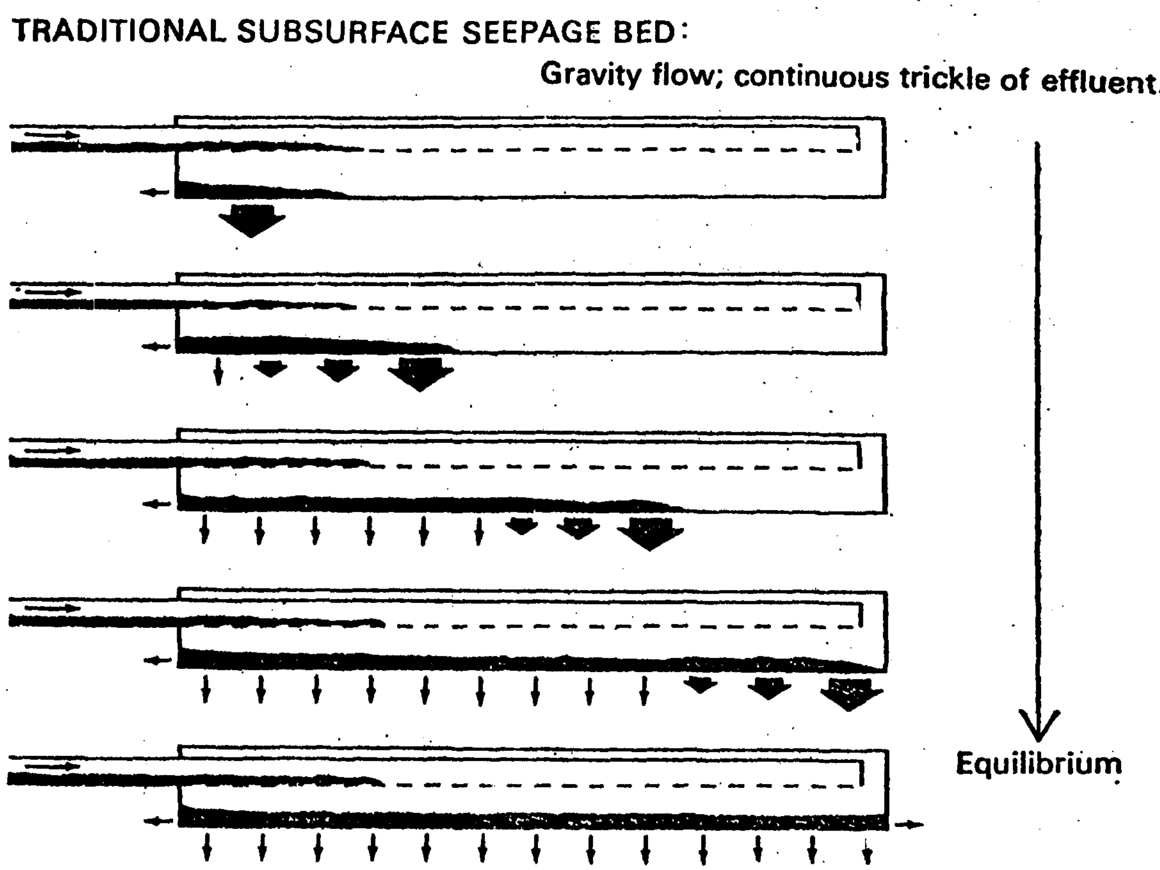


Figure I-B.1. Progressive Crusting of the Infiltrative Surfaces of Subsurface Seepage Beds. (Bouma et al., 1972)

Daniel, T.C. and J. Bouma, "Column Studies of Soil Clogging in a Slowly Permeable Soil as a Function of Effluent Quality," Journal of Environmental Quality, 3, 5 (1974) pp. 321-326.

Magdoff, F.R. and J. Bouma, "The Development of Soil Clogging in Sands Leached with Septic Effluent," Home Sewage Disposal, Proceedings of the National Home Sewage Disposal Symposium, ASAE Publication Proc-175 (December, 1974).

I-B.2. The Significance of Unsaturated Flow

Flow of liquid in unsaturated soil proceeds at a much slower rate than in saturated soil because flow occurs in the finer pores only. The matric potential begins to play a role. This slows the rate of infiltration into the soil but it is advantageous from the viewpoint of purification. Septic tank effluent is purified by the process of filtration and absorption which is enhanced in unsaturated soils because average distances between effluent particles and the soil phase decrease while time of contact increases. Very high moisture tension below heavy crusts in seepage beds would be most favorable from a viewpoint of soil filtration, but this would require inordinately large seepage areas to dispose of the effluent. A compromise must be made.

Otis, R.J., J. Bouma and W.G. Walker, "Uniform Distribution in Soil Absorption Fields," Groundwater, 12, 6 (November-December, 1974).

Converse, J.C., J.L. Anderson, W.A. Ziebell and J. Bouma, "Pressure Distribution to Improve Soil Absorption Systems," Home Sewage Disposal, Proceedings of the National Symposium on Home Sewage Disposal, ASAE Pub. Proc-175 (December, 1974).

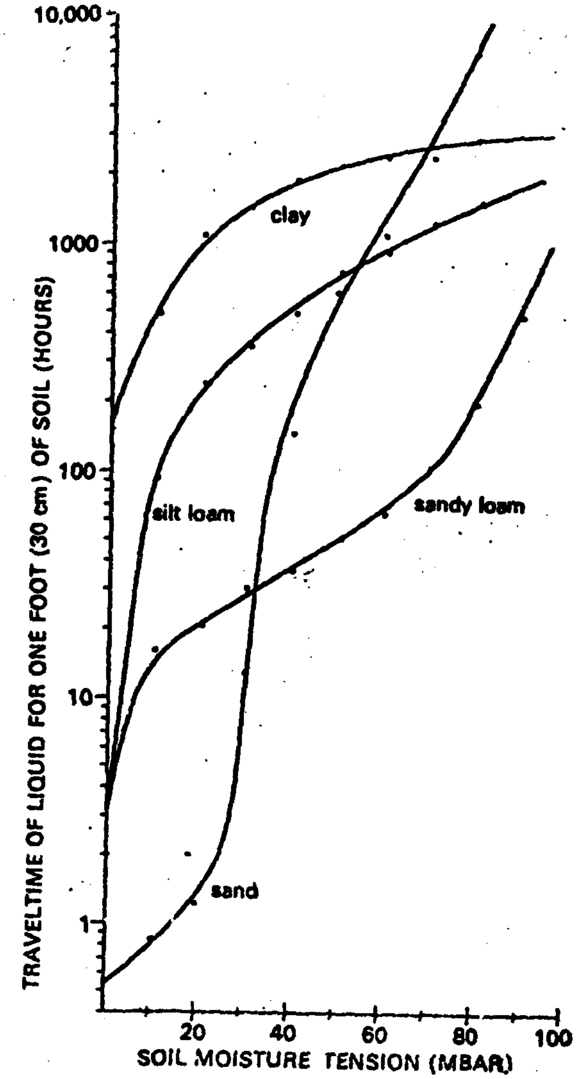


Figure I-B.2. Traveltime of Liquid for One Foot of Soil at Different Soil Moisture Tensions, Calculated for Four Soil Materials (Bouma et al., 1972)

I-C. Wastewater Renovation Capabilities of Soil

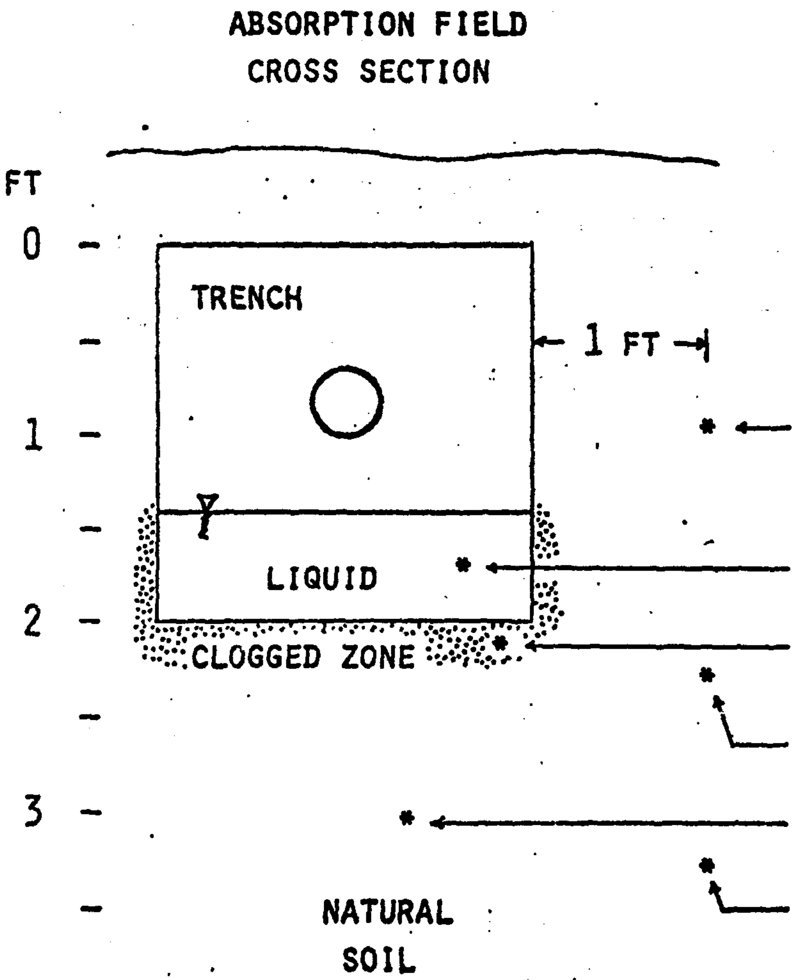
A principal constraint on liquid waste disposal is the purification of the liquid before it reaches potable or recreational waters. Organic matter, chemicals and pathogenic organisms and viruses that are not removed prior to application in the soil must be removed by the soil material. Numerous studies have shown that under the proper conditions, the soil is an extremely efficient filter.

I-C.1. Bacteriological and Viral Removal by Soil

Field monitoring of operating septic tank-soil absorption fields show that 2 feet of natural soil is sufficient to reduce bacterial populations in septic tank effluent to background levels. The greatest removal occurs within the clogging mat at the infiltrative surface. If this mat is poorly or unevenly developed, bacteria tend to slip through. This is illustrated by bacteria counts made within the clogged zone from a 6 week old system (Black River Falls) and a 7 year old system (Adams County). In the young system, pathogenic indicators were found as much as 15 cm below the trench. Hydraulic overloading can also result in penetration of pathogens.

Similar results have been obtained in studies of virus removal. Septic tank effluent innoculated with more than 10^5 plaque forming units (PFU) of polio virus type I and applied to 2 feet of medium sand removed all virus except 1 PFU at a loading of 1.24 gpd/ft^2 over a period of more than one year. When loading rates were increased to 12.4 gpd/ft^2 virus breakthrough occurred.

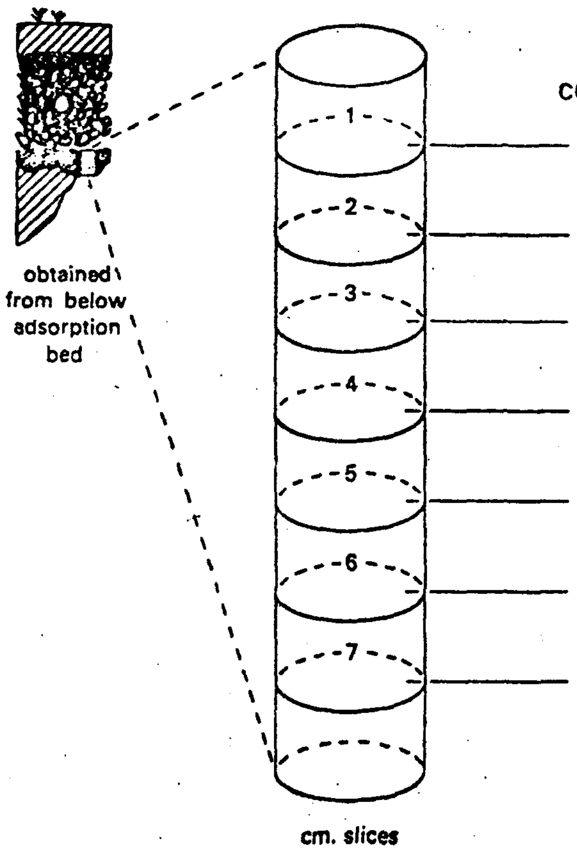
Bouma, J., W.A. Ziebell, W.G. Walker, P. Olcott, E. McCoy and F.D. Hole, "Soil Absorption Septic Tank Effluent - A Field Study of Some Major Soils of Wisconsin," University Extension and Geological and Natural History Survey, Bulletin 20, University of Wisconsin-Madison (1972)



BACTERIA/100 MLS OR PER 100 G OF SOIL

FECAL STREPTO-COCCI	FECAL COLIFORMS	TOTAL COLIFORMS	TOTAL BACTERIA x 10^7
< 200	< 200	< 600	0.6
160,000	1,900,000	5,700,000	3.0
54,000	4,000,000	23,000,000	4,400
< 200	17,000	23,000	6.7
< 200	< 200	< 600	3.7
< 200	700	1,800	2.8

Figure I-C.1.a. Cross-section of an Absorption Field in Sandy Soil With Typical Counts at Various Points in the Field (Ziebell, 1975)



Slice (cm)	Black River Falls: Total Coliform	Black River Falls: Fecal Coliform	Black River Falls: Entero-coccus	Black River Falls: Total Bacteria	Adams: Total Coliform	Adams: Fecal Coliform	Adams: Entero-coccus	Adams: Total Bacteria
1	60	2	50	85×10^4	5×10^4	X	X	27×10^6
2					3×10^4	X	X	3×10^6
3	14	4	12	11×10^5	2×10^2	X	X	2×10^5
4					X	X	X	2×10^5
5	**	**	**	10×10^4				
6								
7	2	**	**	20×10^5	X	X	X	1×10^5

BLACK RIVER FALLS and ADAMS: BACTERIAL COUNTS IN CLOGGED ZONE (per gram of soil)

** organism not detected, < 6 /gram per plate (triplicate platings of each sample)

X organism not detected, <10/ gram per plate (triplicate platings of each sample)

Figure I-C.1.b. Bacterial Counts in Soil Samples Taken in the Clogged Zone (7 cm) of the Systems in Black River Falls and Adams County (Ziebell, 1975)

Ziebell, W.A., "Removal of Fecal Bacteria from Wastewater of Individual Homes During Treatment by Conventional and Experimental Methods," M.S. Thesis, Department of Civil and Environmental Engineering, University of Wisconsin-Madison (1975).

Otis, R.J., J. Bouma and W.G. Walker, "Uniform Distribution in Soil Absorption Fields," Groundwater, 12, 6 (November-December, 1974).

Converse, J.C., J.L. Anderson, W.A. Ziebell and J. Bouma, "Pressure Distribution to Improve Soil Absorption Systems," Home Sewage Disposal, Proceedings of the National Symposium on Home Sewage Disposal, ASAE Pub. Proc-175 (December, 1974).

Green, K.M. and D.O. Cliver, "Removal of Virus from Septic Tank Effluent," Home Sewage Disposal, Proceedings from the National Home Sewage Disposal Symposium, ASAE Pub. Proc-175 (December, 1974).

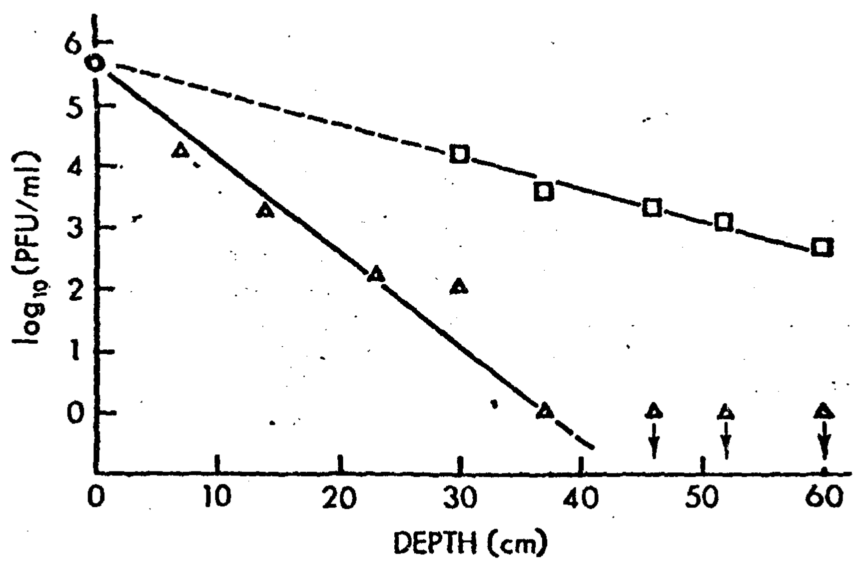


Figure I-C.1.c. Penetration of Poliovirus into a 60 cm Conditioned Sand Column at Room Temperature. Fluid Samples (▲ 5 cm (850 ml) Dose, ◻ 50 cm (8.5 l) Dose, • Input Titer, ↓ < Indicated Value). (Green and Cliver, 1974)

I-C.2. Chemical Transformation and Removals by Soil

Nitrogen and phosphorus discharged in wastes can enter ground or surface waters in quantities that are harmful. Nitrogen, in the form of nitrate, can cause deaths of infants due to methemoglobinemia when it is in drinking water above concentrations of 10 mg-N/l. There are many reports of high concentration of nitrate in wells adjacent to septic tank systems.

Nitrate moves freely through the soil though some denitrification does occur where a carbon source in an anaerobic environment occur. While the total nitrogen in septic tank effluent is nearly 80% ammonium and 20% organic nitrogen, it is quickly converted biologically to nitrate in the unsaturated soil immediately below the clogging mat in the seepage field. If anaerobic conditions occur in the subsoil, nitrification does not occur and nitrogen will remain in the form of ammonium. Ammonium is readily adsorbed by the soil material and will not migrate.

The phosphorus is stored in the soil due to adsorption reactions. Phosphates appear to be precipitated as calcium, aluminum or iron phosphates. Where there exists high water tables, very coarse sand and gravel, or where the seepage bed has been loaded heavily over a long period of time, concentration of phosphates above 5 mg-P/l have been observed.

Walker, W.G., J. Bouma, D.R. Keeney and P.G. Olcott, "Nitrogen Transformation During Subsurface Disposal of Septic Tank Effluent in Sands: Part II Ground Water Quality," Journal of Environmental Quality, 2, 4 (October-December, 1973).

Walker, W.G., J. Bouma, D.R. Keeney and F.R. Magdoff, "Nitrogen Transformations During Subsurface Disposal of Septic Tank Effluent in Sands: Part I. Soil Transformation," Journal of Environmental Quality, 2, 4 (October-December, 1973).

Dudley, J.G. and D.A. Stephenson, "Nutrient Enrichment of Ground Water from Septic Tank Disposal Systems," Inland Lake Renewal and Shoreland Management Demonstration Project Report, University of Wisconsin, Madison (November, 1973).

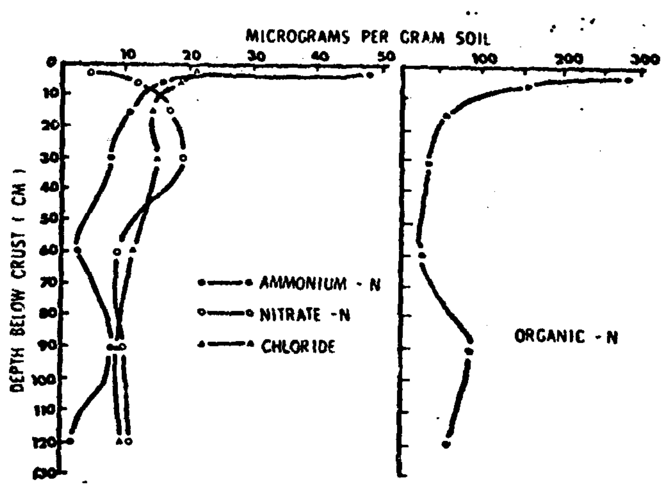


Figure I-C.1.d. Concentrations of NH_4-N, NO_3-N, and Cl in Unsaturated Soil Below the Crust at a System in Sand (Walker et al., 1973)

II. Estimation of the Infiltrative and Percolative Capacity of the Soil

Several factors are usually considered in the selection of a site for on-site disposal. The percolative capacity of the soil, slope, depth to groundwater and bedrock, and evidence of freedom from flooding are the traditional factors considered. Of these, the percolation test is the most deceptive. It is subject to wide variation and has only a very indirect relationship to the performance of a soil absorption system.

II-A. The Percolation Test

The percolation test is based on the assumption that the ability of a soil to absorb sewage effluent over a prolonged period of time can be predicted by its initial ability to absorb clean water. However, because it relies on an empirical relationship between the percolation rate measured and the design loading rate and because of its variability it can lead to errors in design. Variability between tests run in the same soil have been shown to be as great as 50%.

Bouma, J. "Evaluation of the Field Percolation Test and An Alternative Procedure to Test Soil Potential for Disposal of Septic Tank Effluent," Soil Science Society of American Proceedings, 35, 6 (December-November, 1971).

II-B. The "Crust" Test

Because the soil below most absorption systems is unsaturated, the flow rate through the soil will be governed by the soil's unsaturated hydraulic conductivity of a soil at many different soil tensions from which curves can be drawn (See Figure I-A.3.b.). Knowing what tension can be expected below a mature bed, a rational design loading can be selected.

Soil Type	Loading Rate (Bottom Area Only)	Comments
Sands	1.2 gpd/ft^2	Dose 4 times/day Equal Distribution
Sandy Loams, Loams	0.72 gpd/ft^2	Dose/time/day Equal Distribution
Silty Loams, Some Silty Clay Loams	1.2 gpd/ft^2	Dose/time/day Shallow Trenches
Clays, Some Silty Clay Loams	0.24 gpd/ft^2	Shallow Trenches

Bouma, J., D.I. Hillel, F.D. Hole, and C.R. Amerman, "Field Measurement of Unsaturated Hydraulic Conductivity by Infiltration Through Artificial Crusts," Soil Science Society of America Proceedings, 35, 2 (March-April, 1971).

Bouma, J. and J.L. Denning, "Field Measurement of Unsaturated Hydraulic Conductivity by Infiltration Through Gypsum Crusts," Soil Science Society of America Proceedings, 36, 5 (September-October, 1972).

Bouma, J., "Unsaturated Flow During Soil Treatment of Septic Tank Effluent," Journal of Environmental Engineering, ASCE, (1975) (in press).

III. Maintaining the Infiltrative Capacity of the Soil

If a system is to operate satisfactorily for a reasonable length of time then the infiltrative capacity of the soil must be maintained. This requires that proper design, construction and maintenance procedures be followed.

II-A. Sizing the Soil Absorption Field

II-A.1. Estimation of Flow

Small waste flows are intermittent and subject to wide variation. The number of persons contributing to the flow can vary from day to day which can have a profound effect on the daily volume of waste. A survey of eleven homes showed the average flow to be 43 gpd/capita with the greatest flow contribution from the laundry and bathing events. Estimation of flow from public buildings and commercial establishments is more difficult. A study to be completed by December, 1976 is presently underway to determine the daily average and peak flows from various types of establishments.

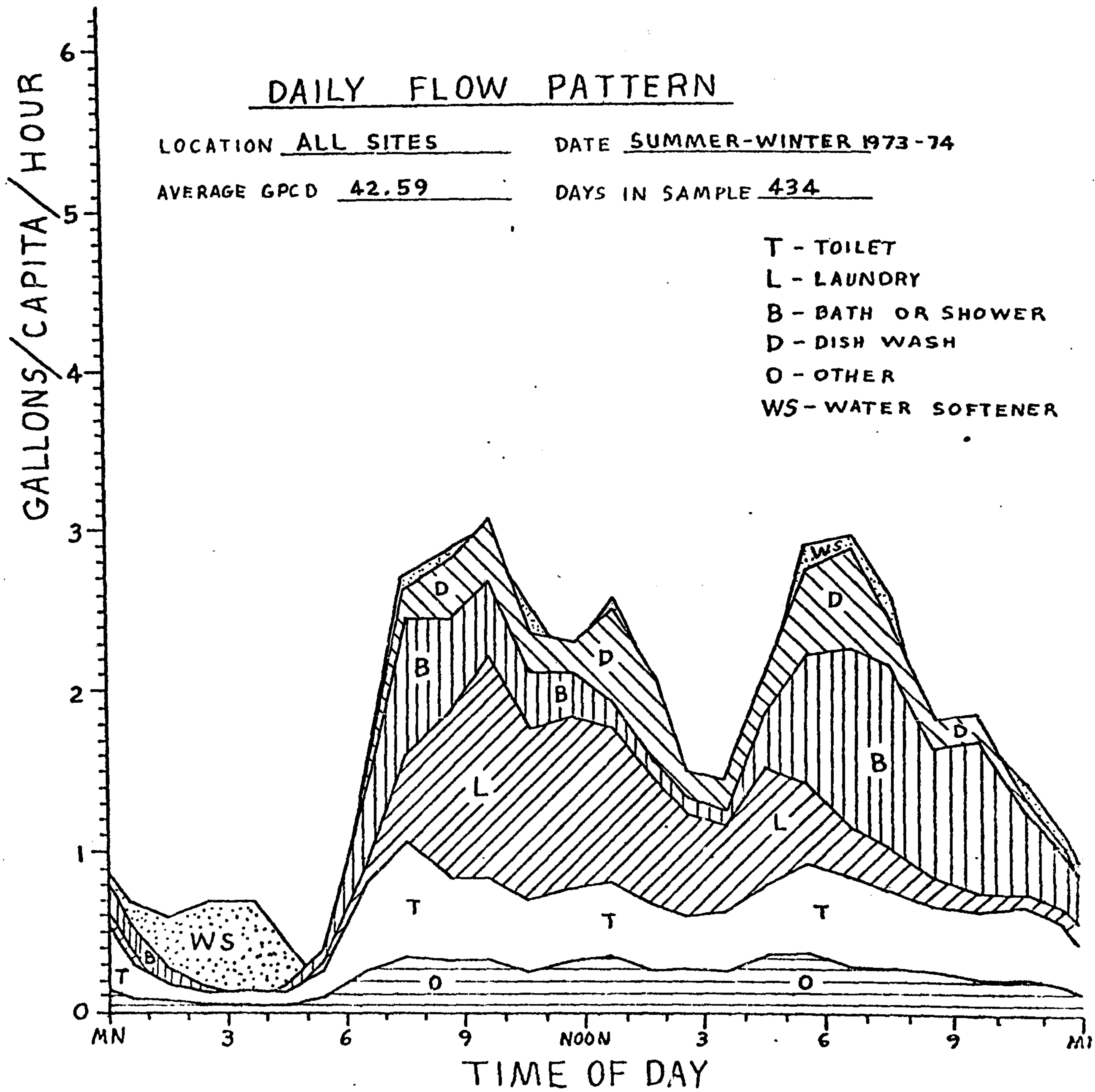


Figure III-A.1. Average Daily Flow Pattern From Eleven Rural Households (Witt, 1974)

Witt, M.D., "Water Use in Rural Homes," Small Scale Waste Management Project publication, University of Wisconsin, Madison (1974).

Witt, M.D., R. Siegrist and W.C. Boyle, "Rural Household Waste Characterization," Home Sewage Disposal, Proceedings of the National Home Sewage Disposal Symposium, ASAE pub Proc-175 (December, 1974).

III-A.2. Sidewall vs. Bottom Area

Results from monitoring moisture tensions in absorption systems in sands indicate that significant quantities of effluent are absorbed by both the bottom and sidewall areas. For the mid-west, the comparison of both rates is in favor of the bottom areas because of changes in moisture tensions that occur during the wet seasons. The horizontal potential gradients can be reduced to levels lower than the vertical potential gradients because of relatively low natural drainage rates. However, maximizing the infiltrative area through the use of sidewalls is certainly recommended.

Bouma, J., "Unsaturated Flow During Soil Treatment of Septic Tank Effluent," Journal of Environmental Engineering, ASCE, (1975) (in press).

Otis, R.J. and J. Bouma, "Notes on Soil Absorption Field Construction for Septic Tank Systems," Small Scale Waste Management Project, University of Wisconsin, Madison (June, 1973).

III-B. Distribution of Liquid Over the Infiltrative Surface

The conventional 4 inch perforated pipe used to distribute the septic tank effluent over the absorption field has been shown to provide poor distribution whether the liquid is allowed to flow by gravity or is pumped. In sands and weakly structured soils such as sandy loams and loams, this type of distribution may cause failure due to local overloading. Overloading a new system in sands may result in groundwater contamination while in weakly structured soils early clogging may occur. Pressure distribution systems were developed as a solution. Such systems combine uniform distribution with dosing. Field studies indicate that they perform satisfactorily and are beneficial.

Converse, J.C., "Distribution of Domestic Waste Effluent in Soil Absorption Beds," Transactions ASAE, 17, 2 (1974).

Converse, J.C., J.L. Anderson, W.A. Ziebell and J. Bouma. "Pressure Distribution to Improve Soil Absorption Systems," Home Sewage Disposal, Proceedings of the National Home Sewage Disposal Symposium ASAE pub Proc-175 (December, 1974).

Otis, R.J., J. Bouma and W.G. Walker, "Uniform Distribution in Soil Absorption Fields," Ground Water, 12, 6 (November-December, 1974).

Bouma, J., J.C. Converse, J. Carlson and F.G. Baker, "Soil Absorption of Septic Tank Effluent in Moderately Permeable Fine Silty Soils," (1975) (Submitted ASAE).

Bouma, J., "Unsaturated Flow During Soil Treatment of Septic Tank Effluent," Journal of Environmental Engineering, ASCE, (1975) (in press).

III-C. Construction Practices

Probably the greatest cause of early failure of soil absorption systems is poor construction practices. Often the soil pores which are needed to conduct the liquid away are sealed shut during construction due to compaction or puddling. Not all soils are susceptible to this destruction. Soils with high clay contents are easily puddled while sands are not affected. By improving construction techniques, it is possible to minimize the damage to the soil. The following recommendations are made:

1. Work in clayey soils only when the moisture content is low.
2. Do not drive on the exposed infiltrative surface with construction equipment.
3. Build shallow systems.
4. Remove any smeared or compacted surfaces to re-expose the open pores.
5. Schedule work such that the infiltrative surface is not left exposed for more than a day.

Otis, R.J. and J. Bouma, "Notes on Soil Absorption Field Construction for Septic Tank Systems," Small Scale Waste Management Project, University of Wisconsin, Madison (June, 1973).

Bouma, J., "Using Soil for Disposal and Treatment of Septic Tank Effluent Following the Current Health Code," Small Scale Waste Management Project, University of Wisconsin, Madison (1974).

III-D. Modifying the Treated Wastewater Characteristics

Higher quality effluents may enhance soil infiltration, reduce the dependence on soils for final treatment or eliminate the need for soils altogether.

III-D.1. Modifying the Wastewater Source

Water use reduction and waste segregation are two methods of improving the quality of the effluent. If the total flow is reduced there is less liquid to be disposed of. It may be accomplished through water conservation or water recycle. Waste segregation is a method of reducing the waste strength. Non-water carriage toilets reduce the total BOD up to 22% and 68% of the

Table III-A.1. Mean Wastewater Concentrations From Household Events, mg/l (Witt, Siegrist, Boyle, 1975)

Parameter \ Event	Fecal Toilet Flush	Nonfecal Toilet Flush	Garbage Disposal	Kitchen Sink Usage	Automatic Dish Washer	Clothes Washer-Wash	Clothes Washer-Rinse	Bath/ Shower
BOD_5 U	610	330	1030	1460	1040	380	150	170
BOD_5 F	330	200	240	800	650	250	110	100
TOC U	500	220	690	880	600	280	100	100
TOC F	220	160	370	720	390	190	72	61
TS	1500	910	2430	2410	1500	1340	410	250
TVS	1090	610	2270	1710	870	520	180	190
TSS	880	320	1490	720	440	280	120	120
TVSS	720	260	1270	670	370	170	69	85
TOT-N	210	140	60	74	40	21	6	17
NH_3-N	84	27	.9	6.	4.5	.7	.4	2
NO_3-N	.9	1.1	0	.3	.3	.6	.4	.4
TOT-P	38	14	12	74	68	57	21	2
ORTHO-P	16	10	8	31	32	15	4.	1
TEMPERATURE	66°F	66°	71°	80°	101°	90°	83°	85°
FLOW[1]	4.3	4.3	3.8	4.8	12.0	15.7	14.4	13.0
NUMBER OF SAMPLES	32-40	24-37	4-7	7-11	13-15	24-27	24-28	18-24

[1] Flow values were determined in the wastewater quality study and are in gallons. Liters = 3.8 x gallons.

total nitrogen as well as 20% of the total flow. However, the wastes which remain are not harmless and must be disposed of properly. They contain 80% of the BOD and high concentrations of pathogenic indicators.

Witt, M.D., "Water Use in Rural Homes," Small Scale Waste Management Project publication, University of Wisconsin, Madison (1974).

Witt, M.D., R. Siegrist and W.C. Boyle, M. ASCE, "The Characteristics of Rural Household Wastewater," Draft Submitted for Publication in the ASCE Journal of the Sanitary Engineering Division, (1975).

III-D.2. Modifying Treatment

Another method to improve the effluent quality is to provide better treatment. Field and laboratory studies of septic tanks and small extended aeration units have shown that the aerobic units achieve better BOD removals than septic tanks but the suspended solids concentrations in the effluents are nearly identical. Septic tanks were more stable, however. Field studies of sand filters are still in progress but the results indicate that sparkling effluents with BOD and suspended solids concentrations below 10 mg/l may be possible.

Otis, R.J., W.C. Boyle and D.K. Sauer, "The Performance of Household Wastewater Treatment Units Under Field Conditions," Home Sewage Disposal, Proceedings of the National Home Sewage Disposal Symposium, ASAE Proc-175 (December, 1974).

Otis, R.J. and W.C. Boyle, "Performance of Single Household Treatment Units," Journal of Environmental Engineering Division ASCE, (1975) (in press).

Sauer, D.K., "Intermittent Sand Filtration of Septic Tank and Aerobic Unit Effluents Under Field Conditions," M.S. Thesis, Department of Civil and Environmental Engineering, University of Wisconsin, Madison (1975).

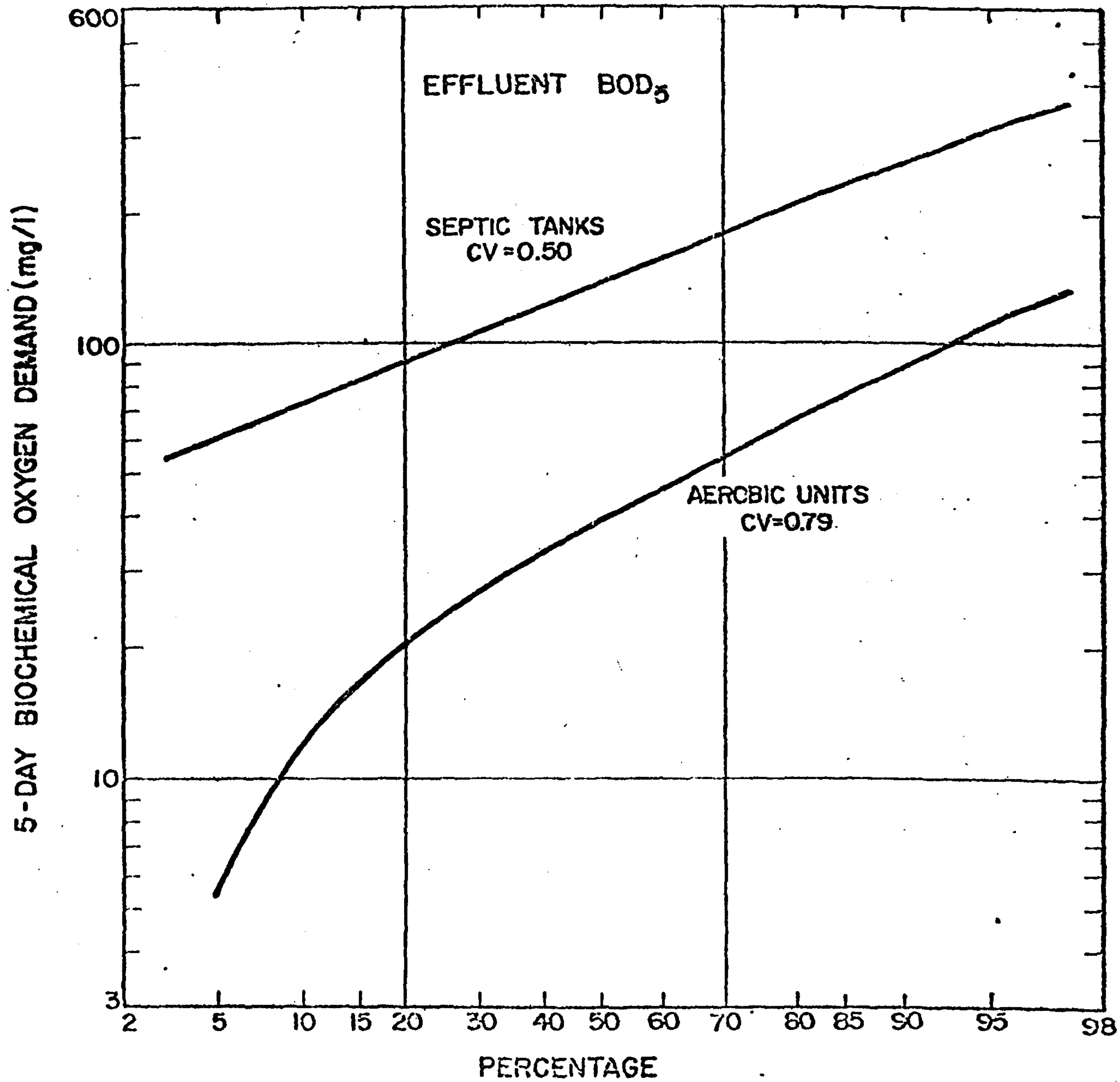


Figure III-D.2.a. Comparison of Septic Tank and Aerobic Effluent BOD_5 (Otis and Boyle, 1975)

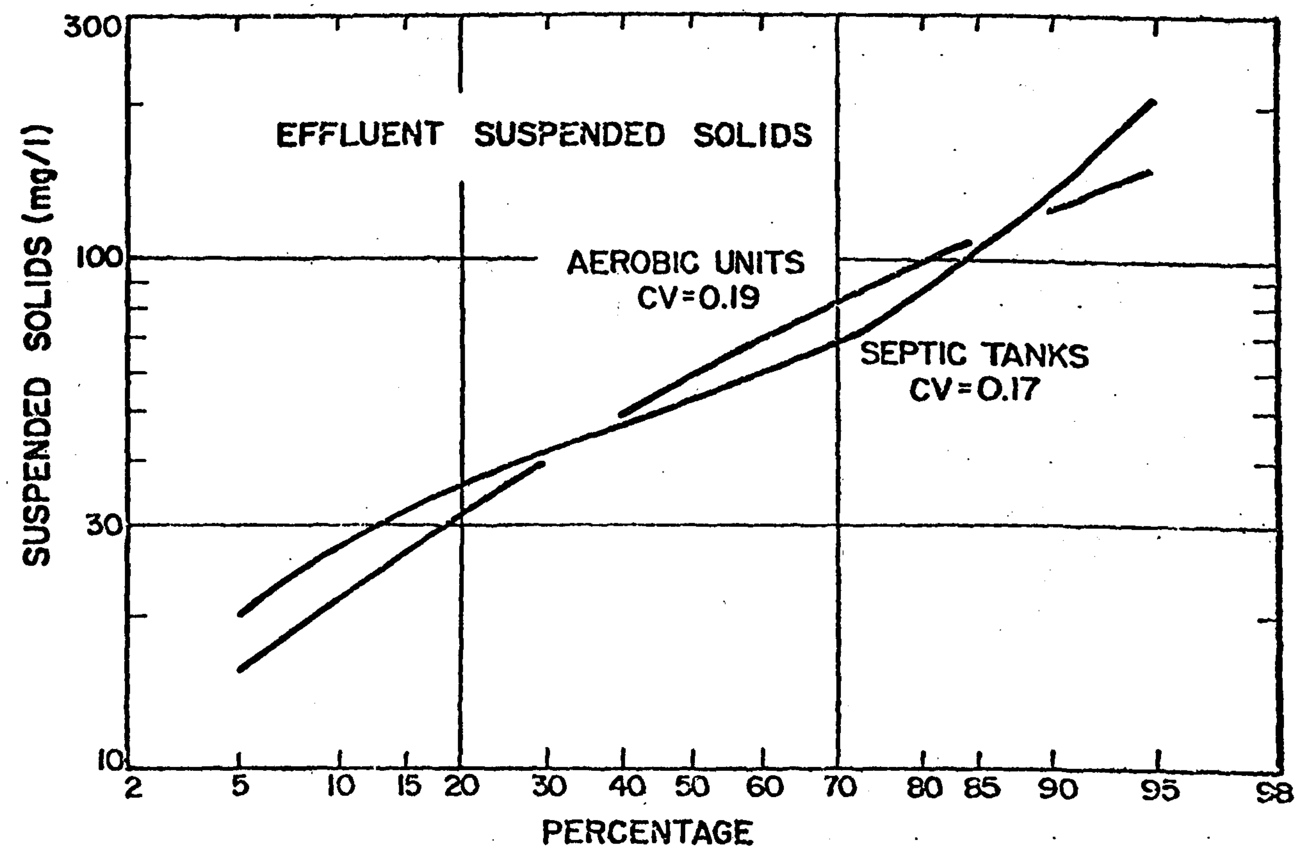


Figure III-D.2.b. Comparison of Septic Tank and Aerobic Unit Effluent Suspended Solids (Otis and Boyle, 1975)

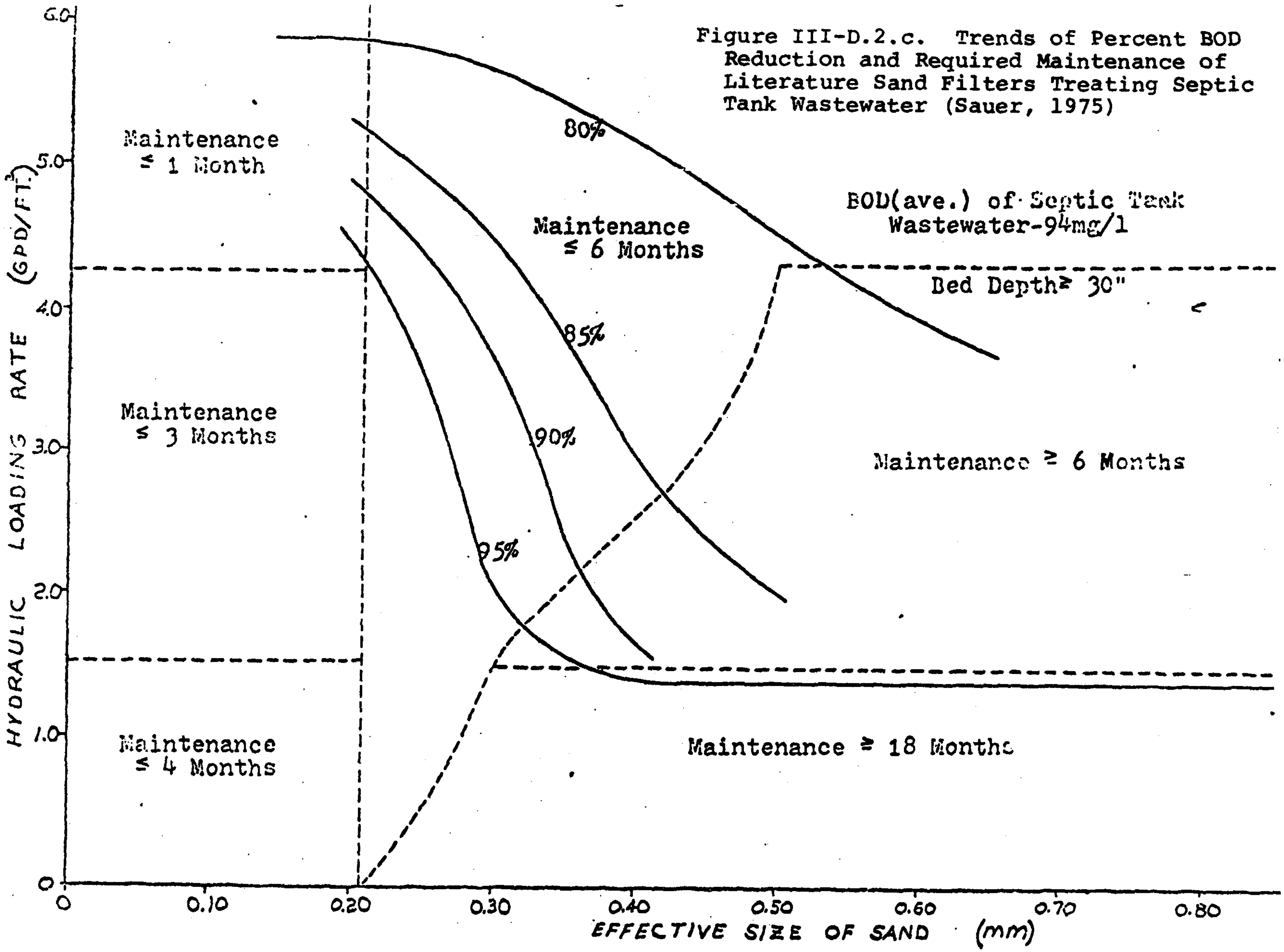


Figure III-D.2.c. Trends of Percent BOD Reduction and Required Maintenance of Literature Sand Filters Treating Septic Tank Wastewater (Sauer, 1975)

III-D.3. Soil Pore Clogging Potential of Various Effluent Qualities

Improved effluent quality does not seem to significantly increase the infiltrative capacity of the soil. Studies in which septic tank and aerobic unit effluents were applied to undisturbed columns of a silt loam showed a more severe clogging occurred in the columns loaded with aerobic effluent. No clogging in cores loaded with tap water. Characterization of the suspended solids in both effluents showed they did not differ significantly in concentration but the aerobic unit waste did have smaller particle diameters. The smaller particles seemed to clog the soil with depth creating a more effective barrier to flow. These studies are continuing.

Daniel, T.C. and J. Bouma, "Column Studies of Soil Clogging in a Slowly Permeable Soil as a Function of Effluent Quality," Journal of Environmental Quality, 3, 4 (April, 1974).

IV. Alternate Systems for Problem Soils

The conventional septic tank-soil absorption field is not a suitable system of wastewater disposal in every soil regardless of the precautions taken. However, with the knowledge gained about the capabilities of soil materials to absorb and purify wastewater, alternate systems can be proposed (See Converse, this conference).

Bouma, J., "Innovative On-Site Soil Disposal and Treatment Systems for Septic Tank Effluent," Home Sewage Disposal Proceedings of the National Home Sewage Disposal Symposium ASAE Proc-175 (December, 1974).

Bouma, J., J.C. Converse, R.J. Otis, W.G. Walker and W.A. Ziebell, "A Mound System for On-Site Disposal of Septic Tank Effluent in Slowly Permeable Soils With Seasonally Perched Water Tables," Journal of Environmental Quality, 4, 3 (July-Sept., 1975) pp. 382-388.

Converse, J.C., R.J. Otis, J. Bouma, W.G. Walker, J.L. Anderson and D.E. Stewart, "Design and Construction Procedures for Mounds in Slowly Permeable Soils With Seasonally High Water Tables," Small Scale Waste Management Project, University of Wisconsin, Madison (April, 1975).

Converse, J.C., R.J. Otis and J. Bouma, "Design and Construction Procedures for Fill Systems in Permeable Soils With Shallow Creviced or Porous Bedrock," Small Scale Waste Management Project, University of Wisconsin, Madison (April, 1975).

Bouma, J., J.C. Converse and F.R. Magdoff, "A Mound System for Disposal of Septic Tank Effluent in Shallow Soils Over Creviced Bedrock," Proceedings of the International Conference on Land Management for Waste Management, Ottawa, Canada (October, 1973).

Magdoff, F.R., D.R. Keeney, J. Bouma and W.A. Ziebell, "Columns Representing Mound-Type Disposal Systems for Septic Tank Effluent. II. Nutrient Transformations and Bacterial Populations," Journal of Environmental Quality, 3, 3 (July-September, 1974).

V. Alternative Systems Not Dependent on Soil and Site Columns

There will always be some situations where the soil cannot be used for the ultimate disposal of wastewater. For these situations, systems not dependent on soil are necessary. Current field and laboratory studies are investigating treatment schemes that will produce effluents that are suitable for surface discharge. A typical scheme seems to be a septic tank followed by sand filtration with nitrogen removal and disinfection. Only low cost, low maintenance systems are being investigated. Evapotranspiration was considered but found not to be viable in the midwest. It would have application in drier climates, however.

Tanner, C.B. and J. Bouma, "Evapotranspiration as a Means of Domestic Liquid Waste Disposal in Wisconsin," Small Scale Waste Management Project, University of Wisconsin, Madison (February, 1975).

VI. Management of On-Site Wastewater Disposal Systems

VI-A. Regulation and Control

From a review of the regulatory schemes used by many states, means for improving regulation of on-site systems have been made. Three phases in the life cycle of an on-site system have been identified. They are the installation phase, operation phase and the failure phase. In each, one or more problems can arise which need regulation to prevent public health hazards. Some of the suggestions made may not be possible in all states and some may require the enactment of enabling legislation.

Stewart, D.E., "Legal Planning and Economic Considerations of On-Site Sewerage Systems," Home Sewage Disposal, Proceedings of the National Home Sewage Disposal Symposium ASAE Proc-175 (December, 1974).

VI-B. Land Use Implications

The introduction of new technology in on-site waste disposal raises a host of questions about land use and other types of land development. Regional planning commissions should have the capabilities to understand the new technology and its possible impact on land use plans. In two case studies, it has been shown that alternate systems can threaten planning goals such as preservation of natural areas. Planning agencies must have the capabilities to determine which areas are most vunerable and work hard to protect them.

Amato, P.W. and H.D. Goehring, "Land Use and Policy Implications in a Three County Wisconsin Area," Small Scale Waste Management Project, University of Wisconsin, Madison (April, 1974).

Water Resources Management Workshop, "Groundwater Quality Door County, Wisconsin: An Assessment of the Institutional and Physical Constraints on Economic Development, Recreational Growth and Groundwater Quality," Institute for Environmental Studies, University of Wisconsin, Madison (May, 1973).

VII. Application of On-Site Disposal Methods to Small Communities

On-site techniques could be employed on a large scale to serve clusters of homes and commercial establishments in low density rural communities where central sewage is ill-suited. Several on-site systems could serve a single community rather than a central sewer system. To ensure success ·ˆh a method, central management would be necessary. A project is underway to demonstrate such a facility for an unincorporated community in northern Wisconsin. Preliminary estimates indicate that a savings of up to 35% can be realized. Implementation of this plan is anticipated in 1976.

Otis, R.J. and D.E. Stewart, "An Alternate Wastewater Facility for Communities in Rural America," Small Scale Waste Management Project, University of Wisconsin, Madison (September, 1975).

DESIGN AND CONSTRUCTION PROCEDURES FOR MOUND OR FILL SYSTEMS

by

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Today I would like to discuss with you the design of individual home sewerage disposal systems that have been recently developed in Wisconsin. The systems are referred to as mound or fill systems and are used where conventional soil absorption systems cannot be installed.

We currently have three design packages of which only one will be emphasized today and will appear in the proceedings. It describes the design and construction procedures for a system over creviced bedrock with a minimum amount of topsoil.

The status of these packages right now is that we have installed a number of these systems and have come up with a design criteria. We, at the University, have supervised construction and know that we can make these systems work. Now we are at the stage with the State regulatory officials of putting these systems out in the field on somewhat of a limited basis, but not under our supervision. Our objective is to see if the contractor and the sanitarian can follow the design guidelines. Then, after about one or two years of operation, we will follow up and see what some of the problems are and at that time make the necessary modifications in our design packages.

This morning what I'd like to do is briefly go through the design Then I would like to go through the step by step construction of one of these systems.

The system that we are going to be spending all our time on this morning is the permeable soils with shallow, creviced or porous bedrock.

Here we're talking about a percolation of the topsoil anywhere from 3 to 60 minutes per inch, depth to groundwater in our case is greater than 5 feet, and depth to bedrock greater than 2 feet. We're still holding out for a little topsoil on the system as a factor of safety. We aren't recommending that these systems go directly on bedrock. We want some topsoil on it. If its a foot or two feet, we're not quite sure yet. After some further studies we may change it to a foot of topsoil. Also, as far as slope is concerned, we are going up as high as 12% slope provided that the soil has a percolation rate of 3 and 29 min/in which indicates a fairly permeable soil. For soils with percolation rate 30-60 min/in, then we are reducing the slope to 6% because there may be some seepage, or some lateral movement of liquid in these heavier soils. At a 12% slope and with heavier soils, we may get a breakout at the toe of the system.

Before I get into the details, I want to mention two other packages we have available because there may be some applications for these in this state. The first package deals with slowly permeable soils with percolation rates of 60-120 min/in, depth of groundwater greater than 2 feet. Depth to bedrock greater than 5 feet and slope less than 6%. Our people at the State Department of Public Health who have regulatory control, at this point in time, will not allow these systems on new construction. It's primarily just a replacement type of system. They want to get a little more experience with this system because they feel that this is their biggest problem and this sytem will have the highest failure rate, as far as surface seepage is concerned.

The other package is for permeable soils with high water tables. Here we're talking about a system for soils with percolation rates of less than 60 min/in, depth to groundwater greater than 2 feet; depth to bedrock greater than 5 feet and slopes criteria the same as for the creviced bedrock system described previously.

Returning to the creviced bedrock package, the following description is from our package write up. Please note that the system described herein was designed from research findings conducted over a four year period. It contains the best available information on design to date. Further research findings will undoubtedly result in design modifications and changes. Therefore, this system should still be considered experimental until further information is available to change its status.

Description of Fill System

The conventional method of liquid waste disposal for homes in unsewered areas is the septic tank-subsurface soil absorption field. However, many areas have soils or site characteristics that are unsuitable for absorption of liquid wastes. As a result, states often do not allow on-site disposal systems to be installed because of inevitable failure which creates public health hazards and nuisances.

permeable soil over creviced bedrock constitute a major group of problem soils because inadequate soil is available to purify percolating liquid waste before it reaches the open crevices in the bedrock which are directly leading into the groundwater. To overcome these limitations, the absorption field can be raised above the natural soil by using a suitable fill material. This increases the amount of soil available for percolation, and with uniform application of effluent purification will be adequate by the time the percolating effluent reaches the groundwater. The procedure of waste application has been shown to be crucial to proper functioning of the fill system. Much emphasis will, therefore, be placed on installation of a pressure distribution system which insures uniform distribution. (For more details on the fill system, the pressure distribution system, and bacteriological and virological purification, see references as listed in the back. As with any soil absorption system, the success of a fill system depends upon proper siting, design and construction. Each is discussed in detail.

NECESSARY SOIL AND SITE CHARACTERISTICS

Fill systems may be used for safe and effective disposal of septic tank effluent in many areas now considered unsuitable for on-site disposal. This bulletin discusses the design and construction of fill systems in areas with the following characteristics:

1. SOIL PERCOLATION RATES: 3-60 min./in. in natural soil on top of the bedrock, (bottom of percolation test hole at 12 in. depth).

   Soil permeability characteristics can better be expressed in terms of the hydraulic conductivity. Studies in many different Wisconsin soils have shown that at least four types of hydraulic conductivity can be distinguished (see Bouma, 1975).

   At this time insufficient data are available to utilize the hydraulic conductivity criterion for testing soil permeability. After more measurements are made, different soil types (series) will be listed in terms of their hydraulic conductivity characteristics. Until this information is available soil permeability is expressed by percolation rates.

2. DEPTH TO GROUNDWATER: greater than 5 ft.

   Problems with on-site waste disposal in shallow sites over creviced bedrock follow from inadequate purification due to rapid percolation through the creviced rock. Groundwater levels are generally present somewhere in the creviced bedrock. Problems resulting from groundwater being too close to the absorption system which may occur when solid bedrock underlies the system, are discussed in other bulletins.

3. DEPTH TO BEDROCK: greater than 2 ft. (If more than 5 ft., the conventional system can be used if other factors are satisfactory.)

4. SLOPE: less than 12 percent (percolation rates 3-29 min/in.)
   less than 6 percent ((percolation rates 30-60 min/in.)

   Fill systems of the type discussed require somewhat more stringent slope specifications than conventional systems because effluent will have to move through the fill into the topsoil. Slopes exceeding 6 percent could, under adverse conditions result in lateral flow over the original soil surface and could lead to surfacing of only partly purified effluent. This danger would be particularly evident in the more slowly permeable soils, and that is why slope restrictions are more severe for the latter soils.

5. FLOOD PLAINS: Construction in flood plains is not recommended.

DESIGN

The design of the fill system is based upon the expected daily wastewater volume it will receive and the soil characteristics. It must be sized such that it can accept the daily wastewater flow without causing surface seepage or groundwater pollution. The total basal area of the mound must be sufficiently large to conduct the effluent into and through the soil covering the creviced rock. The seepage system inside the mound can have any shape desired. Usually a seepage bed will be most suitable. One design is offered for a wide range of soil permeabilities (3-60min/in). Experimental data of the Small Scale Waste Management Project have demonstrated that purification by in-situ soil is necessary in addition to purification provided by the sand-fill. Generally more permeable loamy soil can be expected to be less efficient as a purifier than is a more slowly permeable clayey soil, and it could be argued that perhaps less sand-fill would be necessary over more slowly permeable soils. However, effluents can sometimes short-circuit through clayey soils which have cracks and crevices and a fill thickness of 2 ft., therefore, is necessary for all conditions.

The design of a fill system includes six steps. They are: (1) flow estimation, (2) design of the absorption bed, (3) dimensioning the fill system, (4) checking limiting conditions, (5) design of the distribution system, and (6) sizing the dosing chamber.

1. ESTIMATION OF DAILY FLOW

Research has shown that 50 gal. per person per day is a good estimation of daily p capita water use (Siegrist, Witt and Boyle, 1974). However, this figure should not be used for sizing any soil absorption system. The number of occupants in a house may change either due to growth of the family or through selling the house.

It is recommended that daily flow be estimated by using 150 gpd per bedroom. Two occupants per bedroom contributing 75 gpd each is assumed to arrive at this figure. The advantage of using this guideline is that it provided a good factor of safety and it allows for unusually high flow which occasionally occur.

Estimated Daily Flow (gpd) = No. of Bedrooms x 150 gpd

2. DESIGN OF ABSORPTION BED

A clean, medium sand is used as the fill material in construction of the fill system. A gravel filled seepage bed is constructed within this. As in any seepage bed, a clogging mat will ultimately develop at its bottom. The ultimate infiltration rate through this zone has been shown to be 5 cm/day or 1.23 gpd/ft.^{2}. Therefore, one consideration must be to insure that sufficient bed botton area is available for the design flow.

Design of the bed proceeds through the following steps:

a. Determine bed bottom area required.

$$\text{Area (ft.}^2\text{)} = \frac{\text{estimated daily flow (gpd)}}{\text{infiltration rate of fill (1.23 gpd/ft.}^2\text{)}}$$

b. Select the bed width and length desired.

Usually a square design is preferable, but variations can be made as long as uniform distribution of the waste can be maintained.

c. Bed depth.

The bed should be deep enough such that where filled with gravel there still remains sufficient void space more than the estimated daily flow. Trench depths below the distribution pipe invert of 9 in. is recommended. The crown of the pipe should be covered by an additional 2 in. of gravel.

Trench depth (below invert) = 9 inches

3. DIMENSIONING OF FILL SYSTEM

The bed is constructed in the sand fill. At least 2 ft. of fill between the bed bottom and the natural soil surface must exist to provide adequate purification of the effluent. If built on a slope, the down slope side of the bed will require more than 2 ft. of filling underlying it. Over the top of the bed, at least 1.5 to 2 ft. of fill must be placed to prevent freezing and to allow runoff. The minimum height at the center of a fill system, therefore, is about 4.5 to 5 ft. above the original elevation depending on fill system width and slope of ground.

The side slopes should be stable but sufficiently steep to promote runoff. Slopes up to 3:1 (3 ft. run, 1 ft. rise) can be used. If the fill system is built on the side of a slope, the down slope or toe of the fill system should gradually blend in with the natural slope of the landscape and not result in a sharp slope change.

4. CHECKING LIMITING CONDITIONS

The basal area of the fill system below and down slope from the bed, excluding the side slopes, should be sufficiently large for the natural soil to absorb the estimated daily wastewater flow. For systems built on level ground the entire basal area can be included. A check should be made using the final dimensions of the system and the infiltration rate of the least permeable soil horizon below the system. In soils with percolation rates of 3 or 29 min/in, an infiltration rate of 1.24 gpd/ft.^{2} should be used while in soils with rates of 30 to 60 min/in. a rate of 0.74 gpd/ft. should be used. Usually the fill system is of sufficient size. If not, additional fill should be used to extend the slopes on the down slope portions of the system

5. DESIGN OF DISTRIBUTION NETWORK

Uniform distribution is necessary within the fill system to prevent local overloading in the absorption bed. If not uniformly applied, the fill system will not be utilized and inadequate purification may result as has been demonstrated.

Pressure distribution has been shown to do a better job than conventional

4 in. perforated pipe of uniform application of septic tank effluent over a large area (Converse, 1974). Pressure networks usually consist of a central solid 2 in. diameter pipe with 1 in. diameter laterals perforated with the 1/4 in. diameter holes. The laterals are mounted in the manifold using the tee-tee construction and the ends are capped (see Fig. A-1). Laterals should not expend more than 20 ft. from either side of the manifold. Schedule 40 or 80 PVC pipe is used throughout.

Sizing the pump is very critical to the functioning of this system. Adequate pressure must be maintained to ensure good distribution and to prevent clogging. A general rule of thumb for 1, 2, 3, bedroom size systems is to select a pump able to pump at least 25 gpm at a total head equal to the elevation difference between the pump and the distribution system, the friction lost from the pump to the inlet of the distribution system at the minimum flow rate, and 2 psi at the inlet of the distribution system. For larger systems a flow rate of 30 gpm is recommended. A submersible pump of at least 1/3 to 1/2 horsepower is recommended. (See Pump Selection under Site Preparation and Construction.)

6. SIZING PUMPING CHAMBER

Dosing the bed once or twice a day is recommended for the optimal functioning of the fill system. The pumping chamber should be designed to have a minimum pumping capacity during each pump cycle equal to the estimated daily volume of waste. In case of pump failure, an additional volume of approximately one day's capacity should be provided above the high water alarm switch, which must be on a separate circuit from the pump and have an audio or visible alarm in the house.

EXAMPLE PLANS

Example plans have been developed for the 1, 2, 3, and 4 bedroom homes for level, and sloping site which are included in Appendix A of this publication. These are intended for the person who does not want to develop his own system, but is able to adapt one of the example plans to his site. For the engineer or designer who wants to design his own, he can use the procedure outlined in the previous section. An example design is worked out step by step in Appendix A.

SELECTION OF FILL MATERIALS

The fill material below the seepage trenches in the fill system should preferably have a sand texture according to the USDA Soil Conservation Service classification. (This implies at least 25 percent very coarse, coarse and medium sand with diameters between 2.0 and 0.25 mm, and less than 50 per cent fine or very fine sand with diameters between 0.25 and 0.05 mm.) The sand does not have to be washed. In fact, some content of fines is desirable. Use of sandy materials with significantly higher contents of silt and clay (for example: sandy loams) is not recommended because of a higher potential for clogging. Fill material is often obtained in sandpits, where clayey layers are, of course, unsuitable for fill materials to be used for percolation.

The fill material on top of the seepage bed should preferably be more clayey to allow plant growth due to a higher water-holding capacity and increased runoff due to a more compact structure. If available, excavated clayey material from the site itself can be used. Good quality topsoil should be placed to a depth of 6 in. on top of the fill to promote good vegetation cover.

TYPE OF EQUIPMENT NEEDED

For constructing the fill system it is necessary to use a crawler type tractor with a blade and bucket. A blade is superior over a bucket in leveling and movement of fill and in forming the bed. The bucket is used to place the gravel in the bed. A wheel tractor will rut up the plowed area during the initial phases of sand placement. This will result in compaction and possible channeling of liquid to the edge of the system. Also, it will not do a satisfactory job in leveling, forming sloping sides and forming the bed. Therefore, a wheel tractor should not be used when constructing the mound.

SITE PREPARATION AND CONSTRUCTION

The following steps, if followed in sequential order, will minimize future problems and give a satisfactory operating fill system.

Septic Tank and Pumping Chamber

The septic tank will be sized and installed according to your State Administrative Code. The pumping chamber for a 1, 2, 3, and 4 bedroom house should be 500, 500, 750 and 750 gal. capacity, respectively. Dosing will be done once or twice a day but will vary depending on water usage and pumping chamber diameter. The extra capacity of the pumping chamber is for reserve storage in case of pump failure or electrical outage. A 4 in. line will connect the septic tank to the pumping chamber. A 2 ft. riser and manhole cover on the pumping chamber will extend 6 in. above the final surface grade with an 18 in. vent pipe. The ground surface can slope up to the top of the riser. This rise in elevation is necessary to eliminate any surface water entering into the pumping chamber. Immediate access to the tank is necessary for pump servicing (Fig. 1).

Pump Selection

The following steps, if followed, should result in proper sizing of a pump for the system. It is better to oversize the pump rather than to undersize it. Undersizing will result in poor distribution and build-up of slime in pipes resulting in clogged holes.

1. Select the pump based on its performance curve (total head vs. capacity) and not on its horsepower rating. Pumps having similar horsepower ratings do not always have the same performance curves.
2. Determine the total head for the pump by summing the elevation difference between the pump and the distribution system, the friction loss at minimum flow rates between pump and distribution

inlet and 2 psi pressure at the distribution inlet.

3. The pump capacity for the 1, 2 and 3 bedroom systems must be designed for at least 25 gpm while the 4 bedroom systems must be designed for at least 30 gpm.
4. Select the pump from performance curves that will give the minimum capacity for the designed total head (i.e. 25 gpm at total head determined).
5. Support the pump about 6 to 8 in. off the floor. A concrete block will be satisfactory (Fig. 1).
6. A quick disconnect, such as a union, should be attached between the pump and the pipe leading to the fill system.

Distribution Systems

The distribution systems are made using scheduled 40 or 80 PVC pipe of the proper diameter which is dependent upon the system in question. The holes are made using a 1/4 inch drill. The holes should be drilled in a straight line along the length of the pipe. This can best be accomplished by placing a 1 in. x 1 in. angle iron on the PVC pipe and marking a line along the length of the pipe. Holes should be drilled straight into the pipe and not at an angle. This is best accomplished by holding the drill in a vertical position while the pipe is in a horizontal position. Build the system according to the example plans shown in Appendix A.

Fill System

1. Locate a suitable site which is either a level surface or one that has a slope of less than 6 percent (12 percent for soils with percolation rates between 3-29 min/in.). The level site is preferred; however, in most situations there is only one choice.
2. Pick an example plan sized for the house and topography conditions (Appendix A) or design the system for the site (see example in Appendix A).

Stake out the site with the orientation of the mound (length, width directions) such that the bed, if rectangular, will perpendicular to the direction of slope. In addition to setting corner stakes, set reference stakes back 10 ft. from corner stakes, because the corner stakes will more than likely be moved during construction (Fig. 2).

4. For fairly level sites, measure the average ground surface elevations directly below where the bed is to be located and reference this to a bench mark for future use. For the sloping surface, measure the average ground surface elevation where the upper edge of bed is to be located and reference this to a bench mark for future use. This is necessary to determine the elevation of the bottom of the bed after placement of the fill.
5. Determine where the pipe from pumping chamber connects to the distribution system in fill system.
6. Trench and lay the pipe from pumping chamber to fill system area. Cut and cap it about 1 ft. below the surface. The pipe can be laid below frost line or it can be laid on a uniform slope back to the pumping chamber so that it drains after each pumping. This is to be done before plowing to avoid compaction of the plowed area (Fig. 3).
7. Plow the area enclosed by the corner stakes of the fill system using a mold board plow or disk and plow or disk perpendicular to the direction of surface slope with plow throwing soil upslope. Plow or disk to a depth of 4 to 5 in. Disking is also necessary in very permeable soils to break up the vegetative cover. Use as large a plow as possible to reduce the number of driven-in furrows which results in compaction of the subsoil. NOTE: For soils with percola-

tion rate 30-60 min/in., plow soil only when the moisture content is low to avoid compaction and puddling. If a fragment of soil occurring approximately 4-5 in. below the surface can be easily rolled into a wire, the soil should not be plowed or disked, since the moisture content is too high. If, on the other hand, the soil is friable or dry and falls apart when rolling it into a wire, the soil can be plowed because the danger of causing compaction and puddling is minimal. Once compaction and puddling occurs, it reduces the ability of soil to accept water, thus increasing the chance of failure. Once plowing or disking is complete, keep all vehicular traffic off the plowed area. Try to avoid the occurrence of a long period between plowing and construction. If it rains after plowing is completed, wait until the soil dries out before the start of construction. Immediate construction after plowing is highly preferable.

8. Using the set back reference stakes, reset the corner stakes and relocate the bed areas by staking the boundary. Extend the pipe from pumping chamber above the top of the bed elevation. Determine the bottom elevation for the bed making sure that the bottom is level. This elevation would be a minimum of two feet above the average surface elevation determined in step 4 (Fig. 4).
9. Place the medium textured sand around the edge of the plowed area by dumping it on the plowed area, but keep the wheels of the dump truck off the plowed area. Wheel tracks in the plowed area will lead to compaction and ruts in the plowed area. This may allow the effluent to flow in the ruts, which could result in seepage (Fig. 4).

10. Using a crawler tractor with a blade, move the sand around into place. Try to keep at least 6 in. of sand under the tracks to

minimize compaction of the plowed layer.

11. Place all the sand needed in the fill system, which will be to the top of the bed. Shape the sides to the required slopes (Fig. 5).
12. With the blade of the crawler form the bed. The sand walls will stay sufficiently stable. Make sure the bottom of the bed is level. Some hand shovel leveling will be required (Fig. 6).
13. Using a bucket on the crawler, dump the stones in the bed by traveling up the side slope. Level the stones off to the desired elevation (9 in. above the bed bottom) (Fig. 7).
14. Lay the distribution pipe in the rock taking care to lay it level with holes downward. Remove dips and rises which occur in the pipe. Connect the manifold pipe to the pipe from the pumping chamber. The manifold should be sloped slightly toward the pipe from the pump so that it will drain. Using a shovel, cover the pipe with about 2 in. of stones. Do not drive on the distribution pipe (Fig. 8).
15. Permanent markers of durable material must be placed at the end of each distribution lateral.
16. Place straw or marsh hay 3 to 4 in. deep (uncompacted) over the top of the bed (Fig. 9).
17. Reslope and smooth the sides and top center of the fill system. Do not drive on top of the bed, as you will damage the distribution system.
18. Place soil on the top of fill system to a depth of 1 ft. above the top of the bed in the center of fill system, and to a depth of 6 in. at the outside edge of the bed. This soil may be subsoil if it is not a heavy clay or glacial till full of rocks and boulders.

19. Place 6 in. of good topsoil on top of fill material (step 17) over the entire area of fill system. This will raise the elevation at the center of the system and at the outside edges of the bed 1.5 ft. and 1 ft. above the top of bed elevations, respectively.

20. Landscape the fill system by planting grasses on the surface. Grasses that will tolerate dry summer periods are recommended. Vegetative cover such as 90 percent birdsfoot treefoil and 10% timothy may be desirable if the fill system is not manicured. If manicuring is desired, a combination 60 percent bluegrass, 30 percent creeping red fescue and 10 percent annual rye grass may be the desired vegetative cover. Shrubs placed at the foot and up the slope on the sides and ends are also recommended. Do not place shrubs directly on top of the fill system as roots may interfere with the distribution system (Fig. 10).

QUESTIONS AND ANSWERS

Question: What does it cost?

Answer: That is hard to determine, because it is dependent upon how far you have to haul fill material. Our systems are costing between $3,000 and $4,000. This includes the total system.

Question: How about freezing?

Answer: Freezing has not been a problem. We have placed thermocouples in the system to measure temperatures. We do have freezing conditions in the distribution system but the distribution system drains after every pumping, so no freezing problem. You do not put a check valve on the pump to keep the pipe from the pumping chamber full. If you do, freezing will occur at the inlet to the distribution system.

Question: Does the mound freeze?

Answer: Well, it depends on the snow cover. At times we do get freezing in the upper layers, but since the distribution system drains it has not been a problem.

Question: Are dosing and pressurizing the distribution system critical to the performance?

Answer: Yes, we think it is, at least in the initial stages of the system. Once the bed has crusted over and liquid is ponded, then dosing is not critical. However, it appears that crusting will not develop as fast at the sand fill-rock bed interface with dosing once or twice a day as it will if the conventional 4 inch pipe with gravity flow is used. With the conventional pipe, the liquid will exit out the holes at the lowest elevation regardless where it is in the bed. It is this point where most of the septic tank effluent will concentrate. This overloading will result in saturated conditions and purification will not be satisfactory. Crusting will develop at this point and progress over the rest of the sand fill-rock bed interface. We confirmed this by examining several systems in Door County, Wisconsin where the conventional distribution system was used. We found that where the liquid was concentrated in one area we had coliform and fecal bacteria passing through the fill to the bedrock.

Now for the heavy soil system, purification is not a problem. The problem is seepage out the toe of the mound. For this system the bed is long and narrow instead of square as in the creviced bedrock. If the liquid is concentrated in one area of the mound there will most likely be seepage at the toe because of the concentrating effect. Here again distribution throughout the length of the bed is necessary to avoid this concentrating effect.

Question: Can you use smaller holes than 1/4 inch?

Answer: We haven't, but T. Winneberger indicates that he has.

Question: When you have a heavy soil under your mound, how do you design to avoid breakouts?

Answer: On a heavier soil, our basal area down slope is the most critical and, of course, on a slope you have only one area to work with. On a very flat area, you have more area to work with as the liquid will move in both directions. The bed area in these systems is long and narrow and you will have up to three trenches. The design for these systems is discussed in our package entitled "Design and Construction Procedures for Mounds in Slowly Permeable Soils."

Question: What is the length of the mound?

Answer: For a 3 bedroom home on heavy soils we will have 3 parallel trenches running along the slope. Each trench will be 41 feet long by 3 feet wide and spaced 15 feet apart. There will be approximately 15 feet for slope on each end. Thus the mound will be approximately 71 feet long.

The 15 foot spacing between the trenches is for liquid absorption before it reaches the downslope trench. In this system the liquid will move vertically and laterally downslope. Plowing the soil avoids the abrupt change from sand to topsoil, thus allowing for easier passage of liquid into the topsoil and helping to avoid seepage at the toe.

Question: What do you do with an area where you have broken down sandstone rock and you can't plow?

Answer: A broken down sandstone? You don't have any topsoil on top of it?

Comment: Very little.

Answer: I would not recommend putting this system there. Because, we feel for groundwater protection that we want at least a factor of safety of at least 1 foot soil, but at this time are requiring 2 feet until we get more experience with it. We have areas in Wisconsin that do not have the required topsoil depth and I am sure you do also. Maybe after further research we can reduce this topsoil depth requirement.

Question: In that situation, couldn't you bring in some looser soil?

Answer: That is a possibility.

Question: Could you comment further on the no soil situation?

Answer: One thing that I would like to say is that this research was done under Wisconsin soil and climatic conditions and Colorado conditions are different. I believe we are at the stage of technology transfer where we would take our technology and transfer it to Colorado. This would require installing some systems in Colorado on an experimental basis and do research on them. It would not require doing the basic research as we have done, but it would require evaluating some actual size systems with modifications necessary for Colorado conditions. In Wisconsin we are now in this second experimental stage. This stage involves installation of systems under minimum supervision and in different topography conditions. Colorado should be doing this type of research so the technology can advance under Colorado conditions. However, this takes a commitment by the State and the necessary funds to carry on a scientific research project.

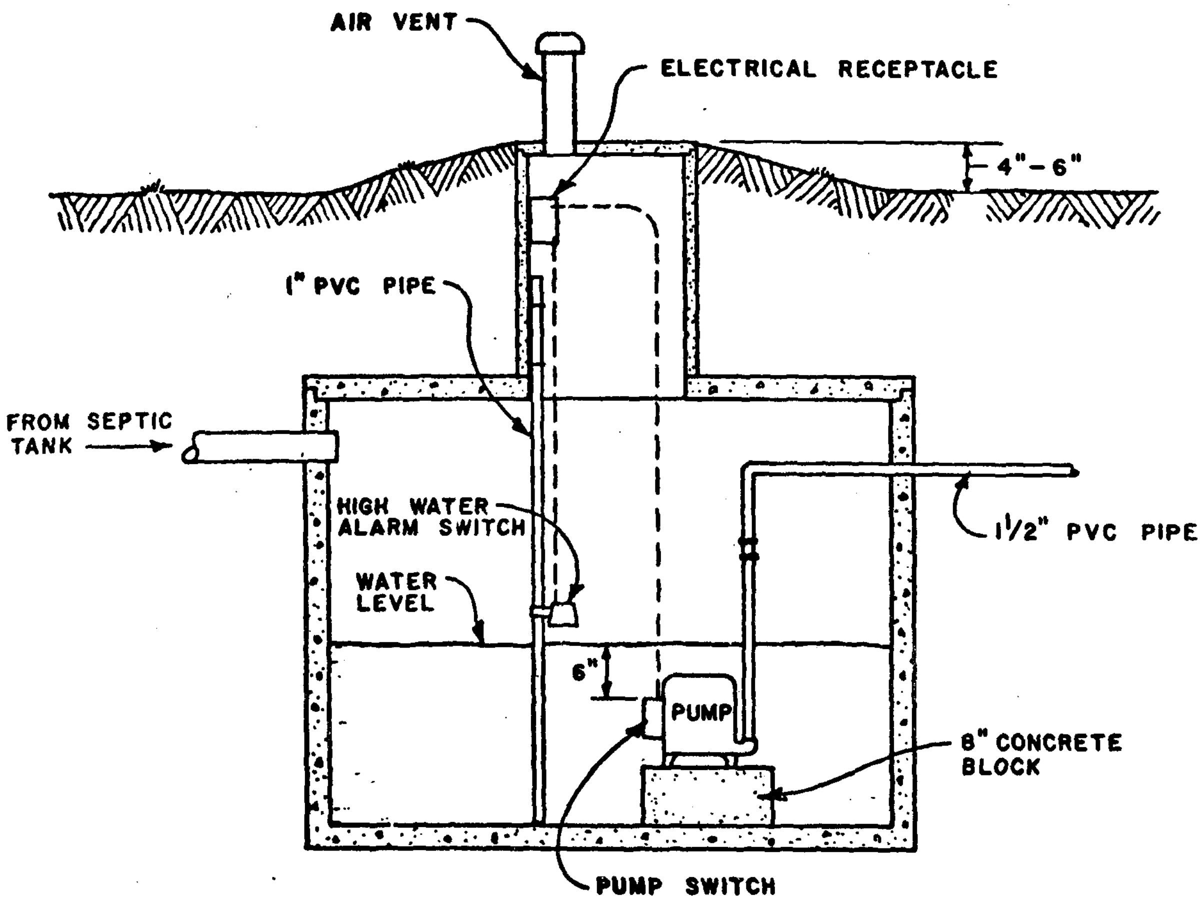

Fig. 1. A cross section view of pumping chamber. If pump has a removable pressure switch, it may be desirable to place it on the same support rod as the high water alarm switch. It can be easily removed if it needs replacing.

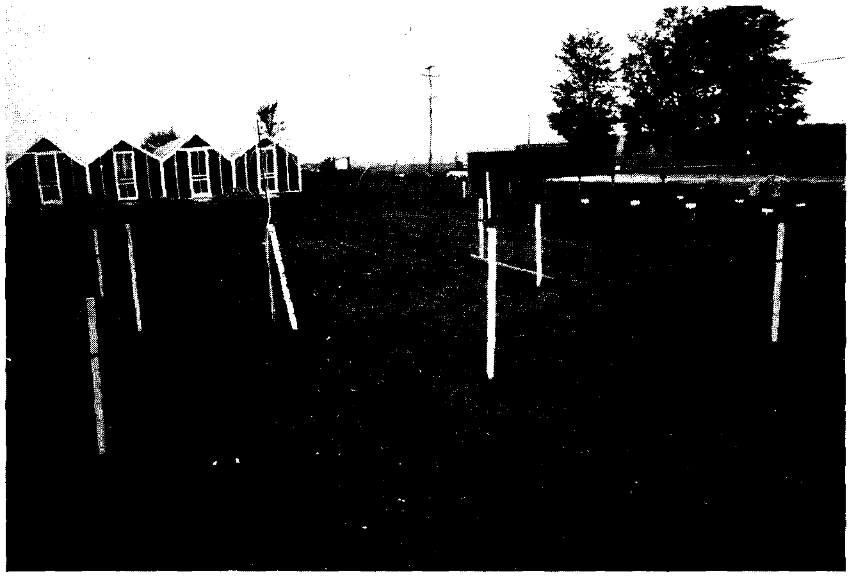

Fig. 2. Lay out the boundary of the fill system and the bed within the fill system. Take the necessary elevations in the fill system before plowing. These elevations are used to locate the bottom of the bed. Locate where the pipe from the pumping chamber will be placed. This pipe connects to the distribution system in the bed.

Fig. 3. Trench and lay the pipe from the pumping chamber to the fill system. Normally a $1\frac{1}{2}$ to 2 in. PVC, schedule 40 or 80, pipe is recommended.

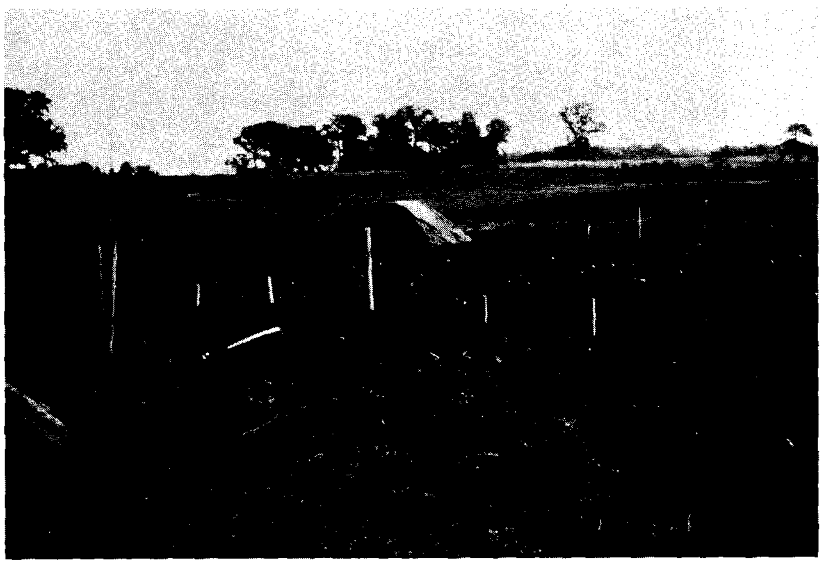

Fig. 4. A view of the fill system after plowing or disking. Re-stake the boundary and area for bed. Sand has been placed along the edge of plowed area. (NOTE: This picture was taken from an installation other than the fill system, but shows the procedure to follow.)

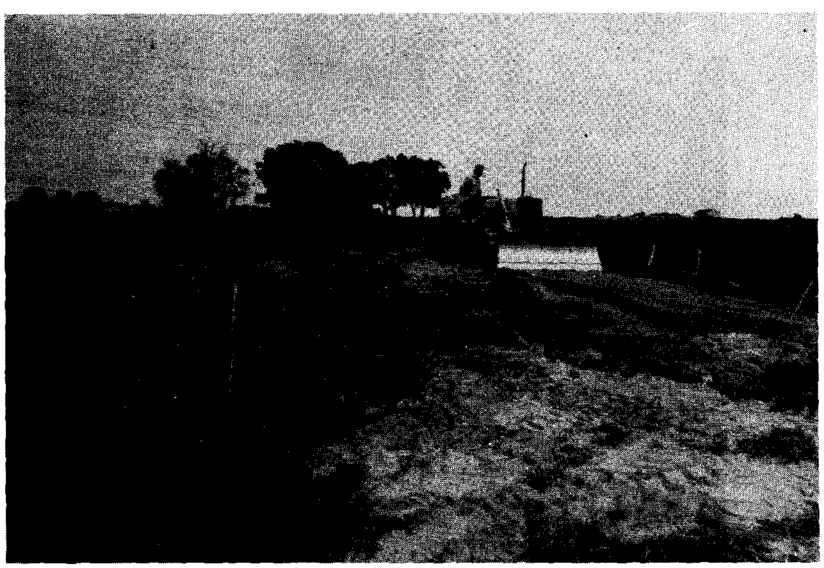

Fig. 5. Place sand to the required depth and shape sides with a crawler tractor. (This picture was taken from another project, but shows the proper procedure.)

Fig. 6. Placement of bed in the fill system. This can be done with crawler tractor with blade. Bottom must be level, thus requiring some hand leveling.

Fig. 7. Place the stones in the bed to a depth of 9 in. and level the stones.

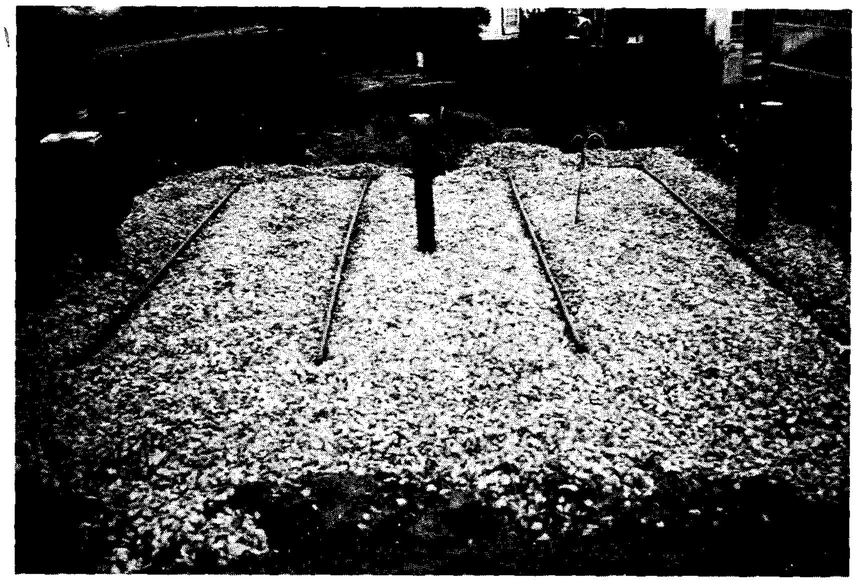

Fig. 8. Lay the distribution pipe on the stones, taking care to lay the laterals level. Slope the manifold slightly toward the inlet pipe. Remove dips and rises in laterals. Cover distribution system with 2 in. of stone. Do not drive on top of distribution system.

Fig. 9. Place 3 to 4 in. of straw or marsh hay (uncompacted) on top of stones.

Fig. 10. View of finished fill system.

PANEL DISCUSSION - WHAT'S HAPPENING IN COLORADO

Moderated by

Robert C. Ward
Agricultural Engineering Department
Colorado State University

Robert C. Ward--The purpose of this panel discussion is to familiarize everyone with what is happening in Colorado. You will note that the other speakers in the program were ones that have come from out of state. The people on this panel are in-state and are resource people who can be reached more easily than the out-of-state speakers. We would like to have each of these panel members briefly review their particular work in the area and how they envision their activities being related to sewage disposal.

On the panel are researchers and regulatory people involved in all aspects of individual home sewage disposal - some more directly than others. The first speaker is Dr. Ed. Bennett from the Civil and Environmental Engineering Department at the University of Colorado, who has been working with individual systems in a research capacity now for a number of years. We would like for Ed to briefly go over some of the work he's been doing and familiarize us with it.

E. R. Bennett--A three year study at the University of Colorado has been completed. The objectives were to determine some of the flow patterns, waste strength characteristics and treatment methods for individual home wastes. With help from the City of Boulder, recording meters were installed on several homes. The study was somewhat limited in size and included six homes. An effort was made to select the homes to represent different types of families with different water use characteristics. Records were kept in the home showing who used the water and for what function. The individual uses were then correlated with the amounts read from the recorder charts. The results obtained were presented as time distributions of flows through the day and these were fairly similar to the ones reported for a larger study conducted at the University of Wisconsin. The home flows were found to be widely varying and the average use per person was 45 gal. per day. This was further defined in terms of household use as 60 gallons used in the home for family purposes, 40 gallons per day for adults and 20 gallons per day per child.

The measurement of pollutional strength of home wastewaters involved sampling all of the different cycles of each home fixture such as the washing machine, dishwasher, sink, bath, toilet and garbage grinder, and measurement of the common pollutional parameters. It was found that the toilet wastes and garbage grinder were the largest contributors to the pollutional flow. These fixtures contributed about three quarters of the pollutional values while producing only about one third of the flow. The grey waters from the shower, dishwasher, washing machine and sinks contributed only one quarter of the pollutional load and resulted in about two thirds of the flow.

Field evaluations of different types of home wastewater systems were made in the Boulder area. These included septic tanks (including percolation tests), aerobic units, and E-T systems. A brief consideration of some of the water savings devices was also presented.

Another part of our study was devoted to evaluation of treatment methods for grey waters and examining the potential for reuse, particularly for use in the toilet. The grey waters were found to contain primarily soap wastes and that very little of the hard to degrade biological materials were present. It was found using aerobic type units (plain aeration for four days) that the organic pollutant reduction was about 80 percent. The use of filtration as a means of clarifying the sewage was found to be not very successful, neither with the raw sewage nor with the biologically treated sewage. The use of activated carbon for the removal of organics was found to be fairly effective with raw sewage, producing approximately 65 percent organics removal. Carbon adsorption used in conjunction with the biological treatment resulted in approximately 95 percent removal of the organic pollutants present and produced effluent BOD's in the range of 5 milligrams per liter.

This research is essentially finished, and we are now concentrating our work in the area of evaporation systems for home wastewater disposal. This includes studies of evapotranspiration beds and mechanical evaporation systems. The research involves an evaluation of where evaporation systems can be used on a nationwide basis and development of the design criteria to match those climatic conditions.

Robert C. Ward--The next speaker is Dennis C. Hall, with the U. S. Geological Survey of Denver, who has been associated with Warren E. Hofstra, down there for a number of years. Together they have been performing groundwater studies in Jefferson County and as I understand have begun to initiate studies elsewhere. So I would like for Dennis to briefly review with you some of the work they have done and some of the plans they have.

D. C. Hall--First, I want to explain what the U. S. Geological Survey does. The Survey is basically a factfinding organization that does two types of studies: federally funded studies and studies cooperatively funded with federal, state and local agencies. The cooperative type of study is what I've been involved with. At the present time there are three cooperative county studies of interest to this workshop. In the Park and Teller Counties study, which is principally staffed by personnel from our Pueblo office, relations between ground and surface water quality and sewage treatment are being investigated. In the Boulder County study that I'm involved with and that is just getting started, ground and surface water quality is being investigated. In the Jefferson County study, the first part of which was completed about a year ago, ground and surface water quality was investigated. A continuation of that study is now underway. Results of the Jefferson County study to date have been published in Colorado Water Conservation Board Basic-Data Releast 36, "Hydrogeologic and water-quality data in Western Jefferson County, Colorado" and in Colorado Geological Survey Bulletin 36, "Geologic control of and quality of water in the mountainous part of Jefferson County, Colorado." Warren E. Hofstra is the senior author on both reports.

A few results of the studies in the Jefferson County area follow. A 2-year study in the mountainous part of Jefferson County (an area of about 300 square miles) was done in cooperation with the Jefferson County Planning Commission and the Colorado Geological Survey. About 750 wells and 25 surface water sites were examined for various pollution indicators.

Surface water was generally of good quality (dissolved solids about 100-200 mg/l or milligrams per litre) except in instances below public sewage outfalls. Although we haven't sampled lately, it is my understanding that the sewage facilities above the sampling sites are now functioning properly and the quality of the effluent has been improved. Surface water did usually contain some coliform bacteria.

In groundwater, there were some instances where concentrations of chemical constituents exceeded existing drinking water standards.

However, the groundwater is generally of good quality based on dissolved-solids concentration. Most groundwater samples had a dissolved-solids concentration ranging from 100 to 300 mg/l compared, for example, to the water in the South Platte River below Denver that contains 1,000-2,000 mg/l of dissolved solids. About 20 percent of the wells were found to contain two or more colonies of total coliform bacteria per 100 ml (millilitres) of water. About 3 percent of the wells had one or more colonies of focal coliform bacteria per 100 ml of water. These appeared to be isolated occurrences rather than community-associated occurrences. This was not the case for nitrates. About 5 percent of the wells sampled had nitrite plus nitrate as nitrogen exceeding 10 mg/l, the maximum concentration recommended by the Colorado State Health Department for drinking water. Wells with high nitrate were found to be related nitrates usually found to be in communities. That is, by mapping nitrate concentrations, the higher concentrations plotted around developed communities. It appears that although bacterial contamination of wells is short-lived and therefore does not usually spread to more than one well, nitrate is more persistent in the water and may build up under and around communities.

A water budget has also been calculated. The amount of groundwater in storage in the study area was estimated and is about equal to surface runoff for the year. Recharge to the groundwater was estimated to be about 40 percent of the annual precipitation. The annual evaporation and transpiration of precipitation was estimated to be about 10 times higher than the amount of water in storage in the ground.

About one-fourth of the wells were shallow wells (alluvial wells), about three-fourths were deeper wells in fractured crystalline rock, and as might be expected, somewhat higher concentrations of total coliform bacteria were found in the shallow wells. About 35 percent of these wells were contaminated compared to 19 or 20 percent of the total wells sampled. No statistical correlation between the occurrence of high nitrate and the occurrence of total coliform bacteria in the wells was found.

There was a good correlation between different chemical constituents (nitrates, chlorides, and dissolved solids). Several other factors were investigated, such as aquifer types, distances between wells and leach fields. We'd like to find out more about these relations. We didn't really get all the answers we had hoped to, and that's one of the reasons for the continuation of the Jefferson County study that we are doing now.

We are now investigating three communities with varying lot sizes and trying to do a more in-depth study rather than the general area-wide approach we used earlier. In the recently completed study and in the current study we are trying to get some idea of the relations between the density of the homes in the communities and the quality of the groundwater.

Robert C. Ward--The next speaker is Dr. Jerry Danielson from the State Engineer's Office. With the increased interest in evapotranspiration systems, it is becoming increasingly apparent to a number of us that there is a potential for conflicting goals - safe home sewage disposal (E-T systems) vs. the state water rights in Colorado. So I thought it quite appropriate to have someone from the State Engineer's Office to update us on some current thinking along these lines.

J. A. Danielson--Every panel needs a villain, so I thought about wearing a Texas University hat. I always have to tell this story. I had thought of telling one about politicians, but I see John Bermingham here. Politicians have a way of, you know, bobbing up to the surface every so often. You never know when they might be up there when we need a few dollars from the legislature; therefore, I will speak about the poor old public health engineer who had all of eastern Tennessee as his area to cover. The guy was working about 18 hours a day, conscientious as all engineers are, doing what he could to help these people out with their water quality problems. He happened to be in this one little town, rather isolated up in the hills of Tennessee, and this old, old mountaineer came up and indicated he had a water quality problem; in fact, his well water was making his kids sick, his wife sick and everybody else sick. He wondered if the poor old engineer could come and take a look at his problem. Well, the guy allowed as that was what he got paid for, and so he proceeded to go with the gentleman to look at the situation. They drove about 15 miles over rutty, bumpy roads and finally stopped the pickup and got on an old mule. They rode about two more miles through the hills on this trail and came to where the old mountaineer lived. An old shack - barn, really - not much to look at. The guy's problem became apparent rather quickly, because he had arranged his water supply disposal system in such a manner that the cesspool was upgradient - uphill of the well. The engineer pointed this out to him, and said this is the source of your pollution. So the old engineer went back and about a year later, he was back out in the same little mountain town. He looked over in front of the general store and there sat the old mountaineer looking pretty healthy, so he thought he'd walk over to him and see how the results came out. He walked up to him and asked if he had done anything. The guy stood there, spit a little tobacco in the dirt, hit the guy right in the side, knocking the engineer down. The old engineer lay there a little bit, thought about it, and asked what in the world had gone wrong? I spent a whole day, went out to your farm, helped you with your problem and the next time I see you, you knock me down in the middle of the street. The old mountaineer looked at him and said, "You're not so smart. The minute I moved that cesspool, my well ran dry!"

All of you being in the sanitation business, you probably anticipated that. How does a state engineer get involved in home sewage disposal? I think you have to look first at what is a state engineer's job. Statutorily, it is to administer all of the waters of the State of Colorado. Without a water supply, you don't have a home sewage disposal problem. So, we're concerned more about the supply that's coming in and what the effect of certain disposal systems do to that supply. Colorado is a state which has adopted the system of prior appropriation with respect to water rights. This means that the first guy on a stream to use the water is entitled to the use. Each user receives his water based on the first point in time that he put the water to use. Unfortunately, we don't have an unlimited supply of water in the state. In the South Platte Basin, we use our water about two and a half times. In the Arkansas, we use it about three and a half to four times. That is the virgin runoff is used about four times before what's left flows into Kansas. So, we do have a water shortage. Every stream in the state is governed by at least one interstate compact. Not only do we have a responsibility to water users in-state, but over half the water originating in the state has to flow downstream under interstate compact to lower basin states. So we are very concerned with retaining the supply and meeting those compacts. Now these are all very large-magnitude problems. How does one home sewage disposal system enter into it. Well, one doesn't, particularly, but we're in the process now of reviewing Senate Bill 35 which was the initial subdivision or land use control bill passed. A subdivision in the San Luis Valley envisions plotting over 11,000 lots, each to be served by an individual well; each to have a home sewage disposal system. Now we begin to see where we get concerned, because depending on the type of home sewage disposal system, we can be looking upwards of 8-10 thousand acre feet of water a year being depleted from the Rio Grande River. Any of you who are familiar with the Rio Grande compact know that theoretically we owe the states of New Mexico and Texas about 750,000 acre feet of water. We are in debt that much. We shoot, under a Supreme Court mandate, to meet the delivery on each and every year, with a variation not exceeding 10,000 acre feet over the limit. We're dealing in terms of a million acre feet of runoff at Del Norte this year. We're trying to distribute that water to Colorado users so that we only over deliver to New Mexico 10,000 acre feet. If all of a sudden we have an 11,000 lot subdivision come up and start depleting the system 10-12, (if there's any irrigation, 20,000 acre feet), you see the kind of problem this creates in the water rights area.

Just two other things I wanted to talk about. We get involved in the area which you are concerned with here under Senate Bill 35 wherein we review subdivision plans for all subdivisions plotted in the state from the aspect of their water supply, both quality and quantity, the physical supply and the legal availability of water. There's another contingent that says you can go ahead and develop your subdivision but you must, if you're going to use a groundwater source, replace to the hydrology system the amount of water that you deplete. If we're going to evaluate the program, the subdivision, we've got to know what it's form of treatment will be. Is he going to go strictly to evaporative system? If so, we have 100 percent consumption. The amount of water he has to replace (put back in the system) is much larger than if the subdivision is suited to a septic tank-leachfield type of approach. So we get involved from the subdivision aspect.

Another very important way we get involved is by the fact that Colorado has seen fit to define, at last count, seven different kinds of wells, water wells, depending on the amount they produce, depending on source, depending on use of the water. One that was brought into existence a few years ago, House Bill 1042, was what we call an in-house use only well. This well represents a very radical departure from the whole approach that case law has taken with respect to water rights. Always before, if you went out to get a water right decree, it was encumbent on you to show before the court that you were not going to injure a senior vested right.

House Bill 1042 created an in-house use only well with the presumption that there was no damage done to the system, no depletion. Here again we can see the type of sewage disposal systems that receive the effluent from this well will greatly influence the amount of water returned to the hydrologic cycle by that particular well. When you get 11,000 of them operating together, it becomes very significant. The legislature put a little hooker in this House Bill 1042. It says the effluent from use inside the house (not irrigation, not washing the car, not watering the horse) must be returned to the same hydrologic system from which it came. There is no effluent from an evaporative system. If a county sanitarian is sitting there and a guy comes in for a building permit and says, "Look, I've got my well permit from the state engineer," the sanitarian says, "Yea, but you have some groundwater problems on your site and you're going to have to go to an evaporative system." The next visit the guy will get is one from the water commissioner who tells him shut the well off because you're violating the terms of your permit. This is something I think is very important to the county sanitarian. That's all I have. If you have any questions further, I'd be glad to answer them.

Robert C. Ward--The next speaker is Paul Arell from the Environmental Protection Agency in Denver. The reason that we invited someone from the EPA up to the meeting today is due to some of the decisions that are being made with respect to the Three Lakes Water and Sanitation District. The district proposed constructing a very large and elaborate system with federal aid, and EPA is now reanalyzing the situation and the result may be that a scaled down system may be installed. What are some of the ramifications for individual wastewater disposal systems in an area where only small central systems are presently installed to serve existing population centers?

P. Arell--The area we're talking about for those who are not familiar with it is the drainage arising off the west slope of the Continental Divide southwest of Rocky Mountain National Park. The area includes Grand Lake, which is the largest natural lake in the state, Lake Granby and Shadow Mountain Reservoir -- all part of the Colorado-Big Thompson Project. The area is under intense pressure for development of recreation facilities (second homes, condominiums, ski resorts, etc.). Less than two percent of the drainage area is in private ownership; the balance being National Park Service, U. S. Forest Service, or Bureau of Land Management lands. There is a National Recreation Area Proposal for the Three Lakes area which will affect the future potential of the area for development of water oriented recreation. The area is presently served by one central wastewater treatment plant near the community of Grand Lake and a large number of septic systems, many of which are inadequately installed and maintained. The National Park Service also operates a treatment facility in the "Islands" area between Shadow Mountain Reservoir and Lake Granby.

A condensed history of the situation shows that the concern for the water quality of the Three Lakes area originated in the late 1940s with the filling of Shadow Mountain Reservoir and Lake Granby. Nuisance conditions had been reported beginning in 1954. During the late 1960s concern for the quality of the lakes had reached a focal point and both the Federal Water Quality Administration, a predecessor agency of the EPA, and the Colorado Water Pollution Control Division were involved in water quality studies of the lakes.

In the late summer of 1969 the Federal Water Quality Administration conducted a one week study of the area and concluded that the point source discharges and septic tank contamination were the cause of the water quality problems in the lakes. A recommendation was made for the formation of a regional district to treat the wastes and/or remove them from the drainage area. The study found that 68 percent of the phosphorous entering the lakes came from the Grand Lake treatment plant and septic tanks. In 1971 the Three Lakes Water and Sanitation District was created by a special act of the Colorado Legislature and given the responsibility to study the problem and come up with a regional solution. Incidentally, I believe this to be the only sanitation district to have been formed by the State Legislature. In 1973, a regional plan was formulated by the District and it called for a massive collection and transmission system to exit all wastes from the drainage area. This proposal included some vacuum sewer lines under the lakes and an aerated lagoon-percolation pond system below the Lake Granby dam near the Colorado River. The price tag on the proposal at that time was somewhere around 5-1/2 to 6 million dollars, and state and federal grant money would be needed. It should be noted that there are only a small number of permanent residents in the area and large influxes of tourists during the summer. It appeared there would be difficulty in the locals raising their 25 percent share of the cost of such a large project. Also in 1973 a draft environmental assessment on the project submitted by the District to EPA raised the issue of the validity of removing all the wastes from the basin and the relative magnitude of the non-point source pollution from land development activities which would be accommodated by the large excess capacity in the sewage collection and treatment facilities. At that time EPA determined that an environmental impact statement should be prepared on the proposed project prior to funding of construction because of the secondary impacts of the system as well as other issues.

In the spring and fall of 1974 EPA went back for another intensive study of the sources of pollution coming into the lakes. What we were trying to determine was the impact of the point sources (treatment plants) versus the non-point sources (land development, road and home construction activities, septic tank leachate, irrigation and grazing practices). This field study involved sampling during the high spring runoff period which the 1969 study did not take into account. The 1969 study had been conducted in late summer and quite different results were found at this time. The 1974 study indicated that there had been an improvement in the general water quality of the lakes and no numerical violations of the Class A water quality standard were found. It was concluded that point sources contributed only 7 percent of the phosphorous and 2 percent of the nitrogen reaching the lakes.

The non-point sources were found to contribute 93 percent of the phosphorous and 5 percent of the nitrogen. It was conservatively estimated that 29 percent of the total phosphorous and 5 percent of the total nitrogen reaching the lakes is contributed by non-point sources resulting from land use practices. Land use changes such as recreation developments, roads, construction activities and agricultural activities were identified as the primary cause of water quality degradation.

EPA felt that construction of the proposed collection, transmission and treatment facilities would do little to improve water quality of the lakes without a program of land use controls to protect water quality. The excess capacity of the proposed system might induce growth of the area, increase the non-point sources and therefore outweigh any benefits gained by removing the wastewater from the basin. The proposed system was therefore rejected by EPA. Other matters of concern were possible water rights problems caused by exit of the wastewater from the basin and questionable technology (under-lake vacuum lines).

Although septic tank systems were shown to be improperly placed and maintained in some parts of the study area, the magnitude of this problem was not contributing to any violation of water quality standards. Strict enforcement of the county's septic tank regulations would be acceptable to EPA in conjunction with providing central collection and treatment for certain areas which are known contributors to health hazards. What this would consist of would probably be a new or improved treatment facility for the community of Grand Lake area and a new treatment facility for the area between Shadow Mountain Reservoir and Lake Granby.

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The EPA's counter proposal was that the District go back and evaluate a scaled down collection system, strict enforcement of septic tank regulations, positive moves towards control of land uses contributing to the water quality degradation and construction of two wastewater treatment plants which would be located in the existing growth centers and possibly discharge to the lakes.

It therefore does appear that individual home systems will have a future in the District, especially in the more outlying areas, for some time to come.

R. C. Ward--The next speaker will be Dr. John Ward of the Civil Engineering Department here at CSU, who, for the past three years, has been doing some work on a total evaporation system which could be applied to our mountain situation.

J. C. Ward--In the mountainous areas, as you are probably aware, oftentimes the topsoil is very shallow (the soil depth is less than the frost depth). Essentially useless are the conventional leach fields or leaching system, because this leads to the almost immediate contamination of nearby water wells. So, the requirements of the regulatory agencies in these areas are generally that the person must install a vault at the cabin, and every single gallon discharged must be discharged to this vault and hauled away by tank truck. These costs can be as much as 10 cents per gallon, so that's a pretty prohibitive cost. In such situations, the alternatives won't be cheap either.

We built a number of pilot scale solar wastewater evaporation units at elevations ranging from about 5,200 feet to about 10,700 feet, and one full scale unit at an elevation of about 8,200 feet. Figure III-5 shows the plan and elevation views of the full scale unit. The cabin served by this unit was actually a modular home. Two families used this cabin for weekends, vacations, and that sort of thing. One of the families was a retired couple, so it did get a fair amount of use. We used a conventional septic tank to settle out the suspended solids, and, more important for our purposes, to skim off the floating grease

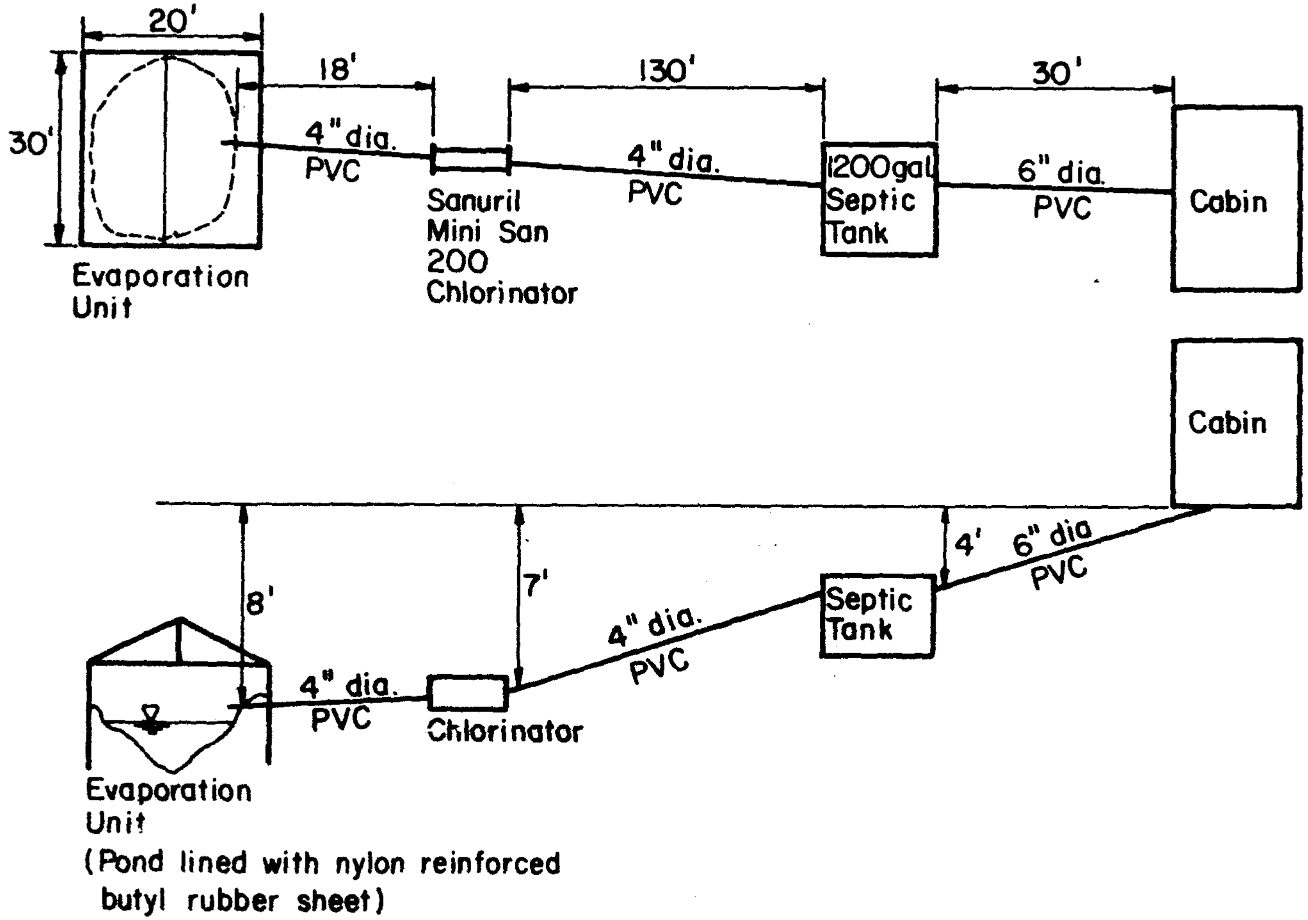

Figure III-5. Layout of Wastewater Disposal System at Site B and so forth. This you would have with any system any place. Figure I-1 shows the sort of septic tank used.

Inititally we had some odor problems. The people that lived in this cabin (owned it) had the most sensitive noses of any people I know. One of the things that we tried (that didn't work) was a chlorinator. We also tried copper sulfate and that did not work either. We found that common formaldehyde solved all our problems. Formaldehyde cleared up everything, and there were no more odor problems after addition of 5 gallons of formaldehyde.

Figure IV-2 is the evaporation unit. We intentionally undersized it so that we could be sure that we would always have some water there to evaporate. We felt we were undersizing it (I'm not so sure we did), but at least we always had water to evaporate. The transparent cover is 20 ft. wide and 30 ft. long. The important thing here is that the solar wastewater evaporation pond is covered with a transparent (to solar radiation) roof that lets solar radiation through and keeps out rain and snow. If you don't do this, of course, it's a hopeless situation. Precipitation in the mountains equals or often exceeds the evaporation rate.

Another advantage of this transparent cover is that it cuts down the heat loss associated with long wave radiation so that more solar energy is converted to evaporated water. We used a nylon reinforced butyl rubber liner to insure ourselves of no leakage from the system. Figure IV-2 is a contour map of the actual pond that was installed. The pond itself had overall dimensions of about 24 ft. long and 15 ft. wide. It was not very deep. Even at the center, it was only about 3 1/3 ft deep. So it wasn't very big. One reason why it wasn't much bigger than this is that we had to dynamite the excavation. In the

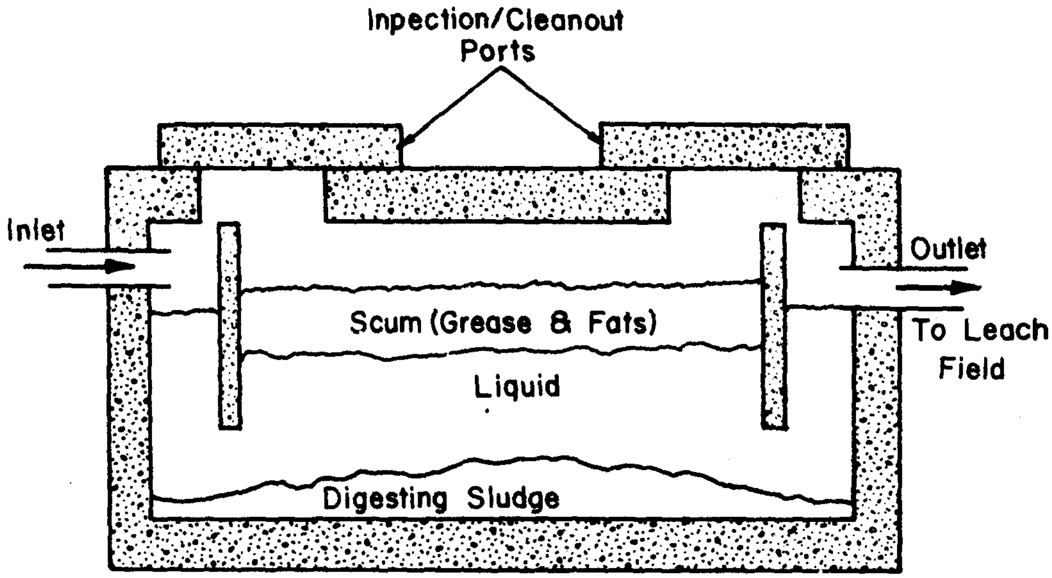

Figure I-I. Septic Tank

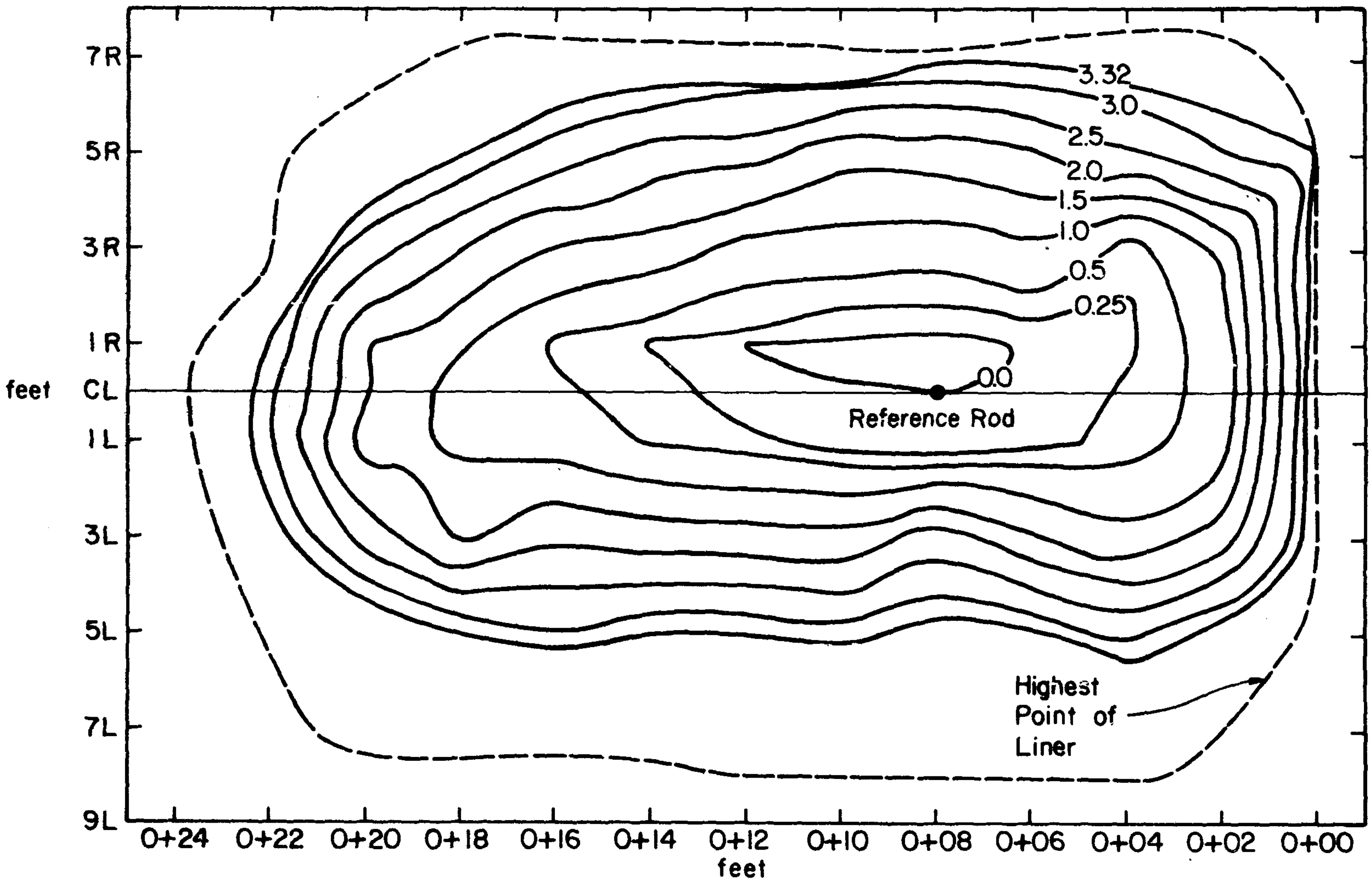

Figure IV-2. Contour Map Full Scale on Line Unit at Site B

Red Feather Lakes area, you have to dynamite to put in post holes. This is about the best we could do without extensive rock blasting. It's not a very large pond.

Figure VII-23 shows part of the test data. The actual water consumption at the cabin was as much as 44 gal per day. One way to reduce the consumption, of course, is to use a recirculating water closet.

As shown in Figure VII-22, the dissolved solids do build up with time of operation, but they would have to build up to quite substantial levels before they would have a significant effect on evaporation rates. The mineral residue may have to be hauled out from time to time, but certainly not as often as would be the case if one hauled out 100% of the cabin effluent.

From Figure VII, you can see that we tested a number of materials for the roof. Glass is the best material, but due to breakage, is probably out of the question. A number of plastic and plastic reinforced with fiberglass materials were also examined and their solar properties were compared to glass (the best). We selected a plastic reinforced with fiberglass that seemed the most durable. The temperatures are often too cold to permit use of ordinary plastic.

Mass transfer coefficients and average water temperatures were determined at four sites:

1) 5,200 feet elevation (Fort Collins, Colorado)
2) 8,200 feet elevation (Red Feather Lakes, Colorado)
3) 8,600 feet elevation (Storm Mountain above Drake, Colorado)
4) 10,700 feet elevation (Breckenridge, Colorado)

Figure VII-10 shows the annual variation in mass transfer coefficient as a function of time of year at the 5,200 feet elevation site. Even though the mass transfer coefficient for water evaporation is a function of wind velocity, this figure shows that an annual average

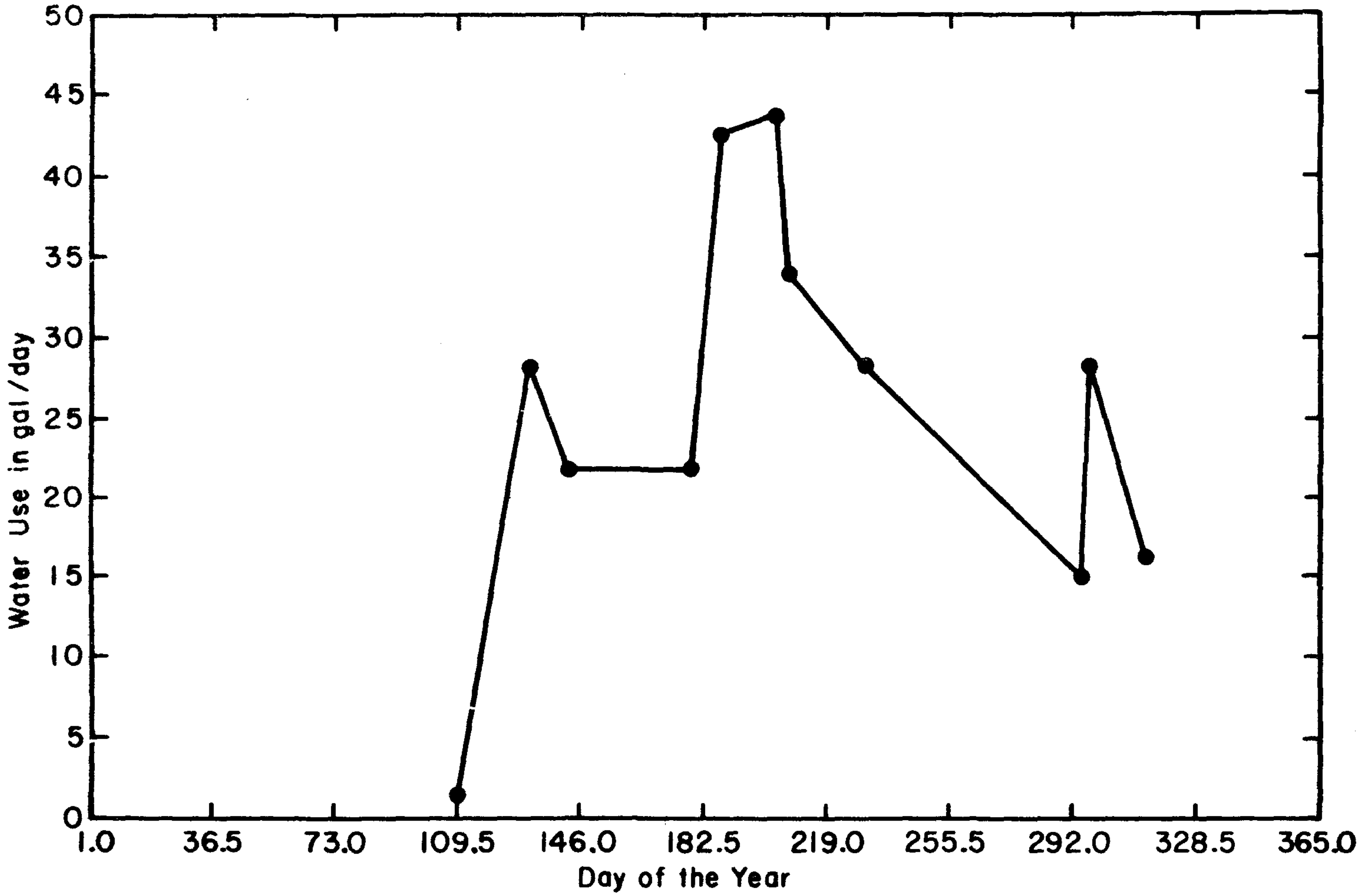

Figure VII-23. Water Consumption at Red Feather Lakes, Site B

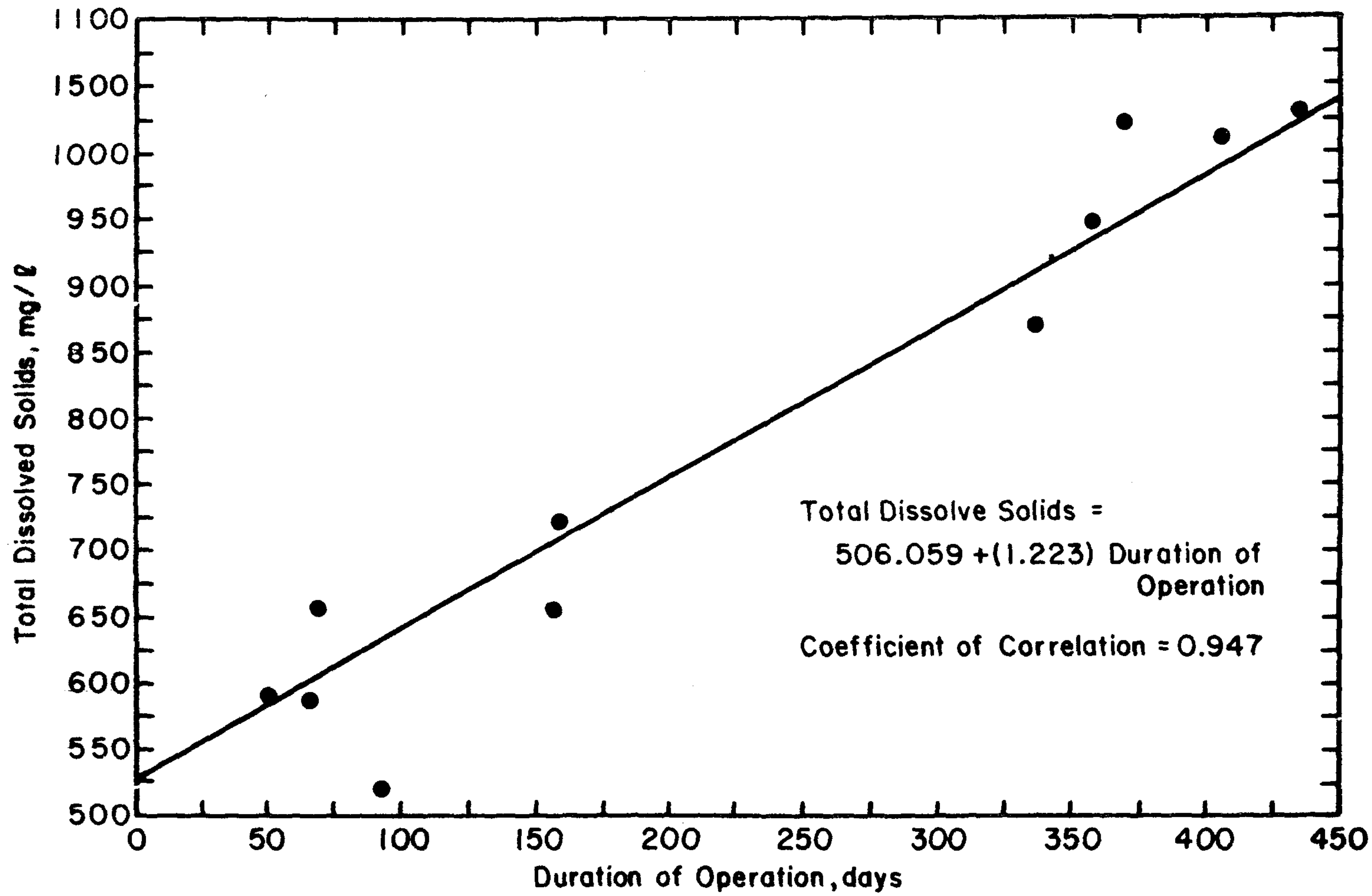

Figure VII-22. Total Dissolved Solids Versus Duration of Operations

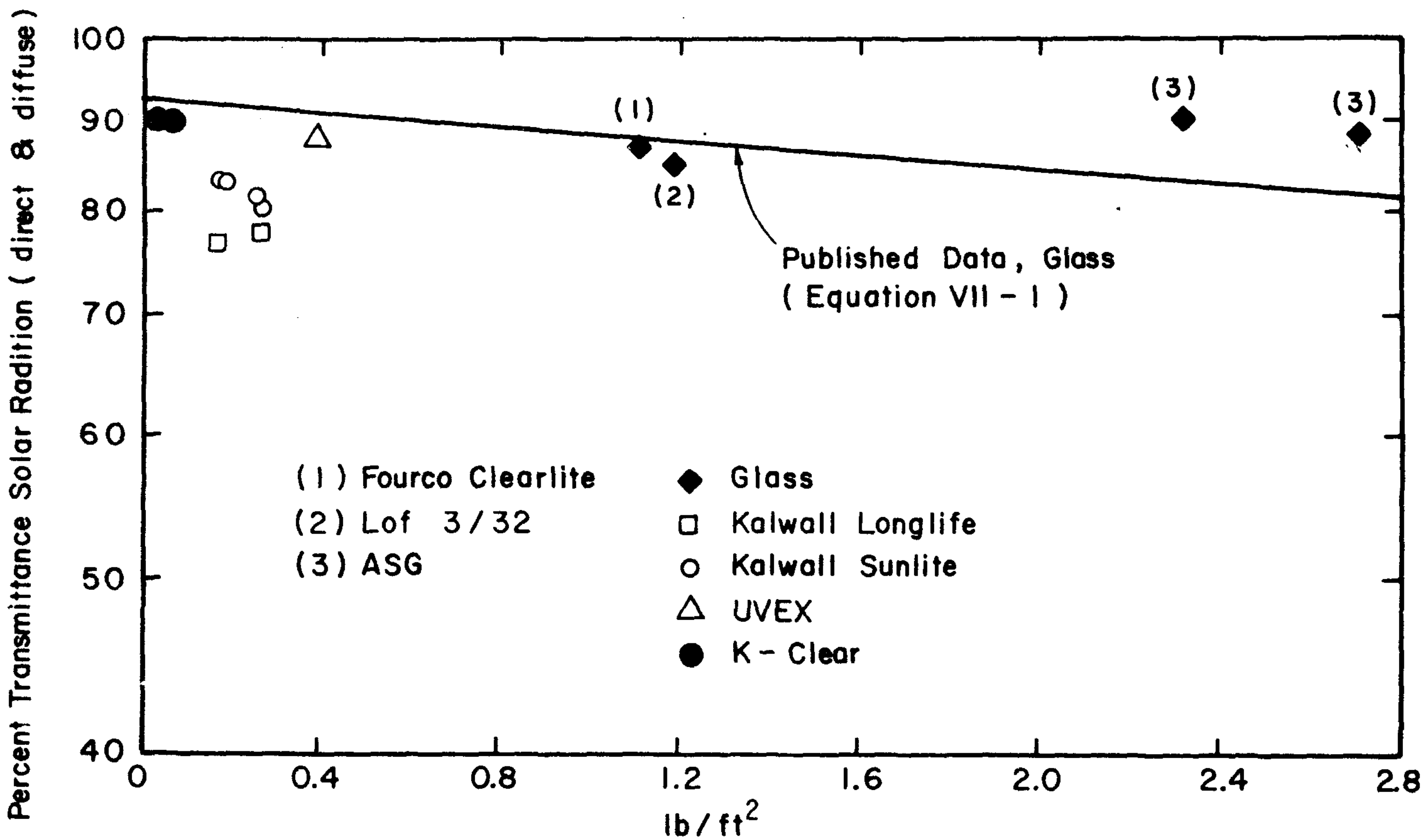

Figure VII , Solar Radiation Transmittance (direct and diffuse) of Various Materials, Experimental Results

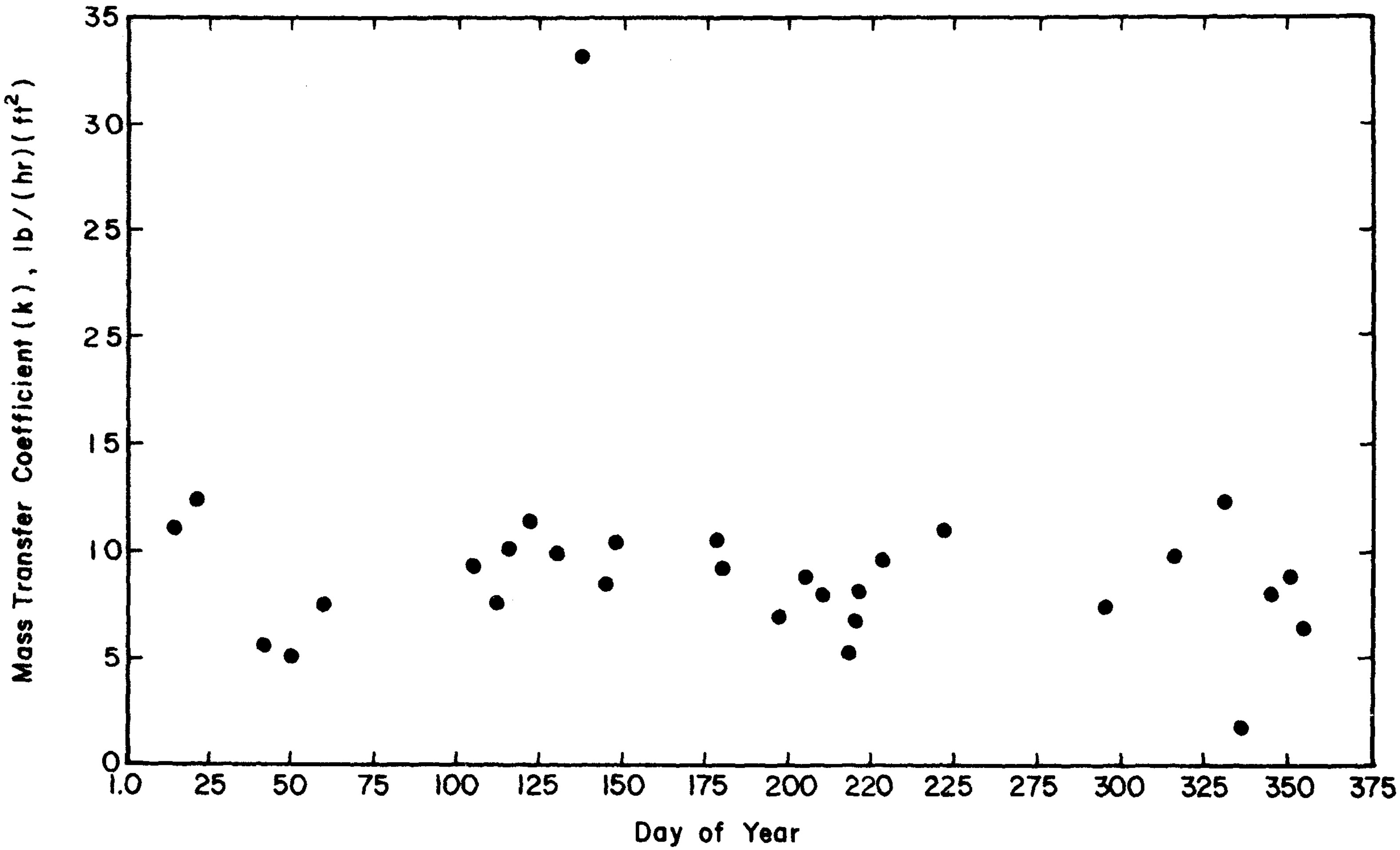

Figure VII-10. Mass Transfer Coefficient (k) vs Day of Year, Site A - Covered value could be used year round without significant error.

Figure VII-20 shows the not unexpected result that the annual average water temperature ($\overline{T}_w$) decreases as elevation increases. This factor, taken alone, indicates that water evaporation rates will also decrease with increasing elevation.

Figure VII-13 shows the fraction of the incident solar radiation (q_s) converted to evaporated water (represented by the energy loss from the water surface because of evaporation, q_e). Clearly this fraction (the ratio q_e/q_s) decreases with increasing elevation primarily because of greater convective heat losses.

Figure VII-24 shows the annual variation of water temperature at the 5,200 feet elevation site (x=1 for January 1). Water surface temperatures would have been much lower year round without the transparent precipitation interceptor reducing long wave radiation heat losses.

Figure VII-7 shows the observed water evaporation rate at the 5,200 feet elevation site as a function of time of year. Fortunately water evaporation rates are greatest during periods of highest recreation home use thereby carryover wastewater storage requirements.

The work I have reported on was supported in part by funds provided by the United States Department of the Interior, Office of Water Research and Technology, as authorized by The Water Resources Act of 1964 and pursuant to grant agreement numbers 14-31-0001-3806, 14-31-0001-4006, and 14-31-001-5006.

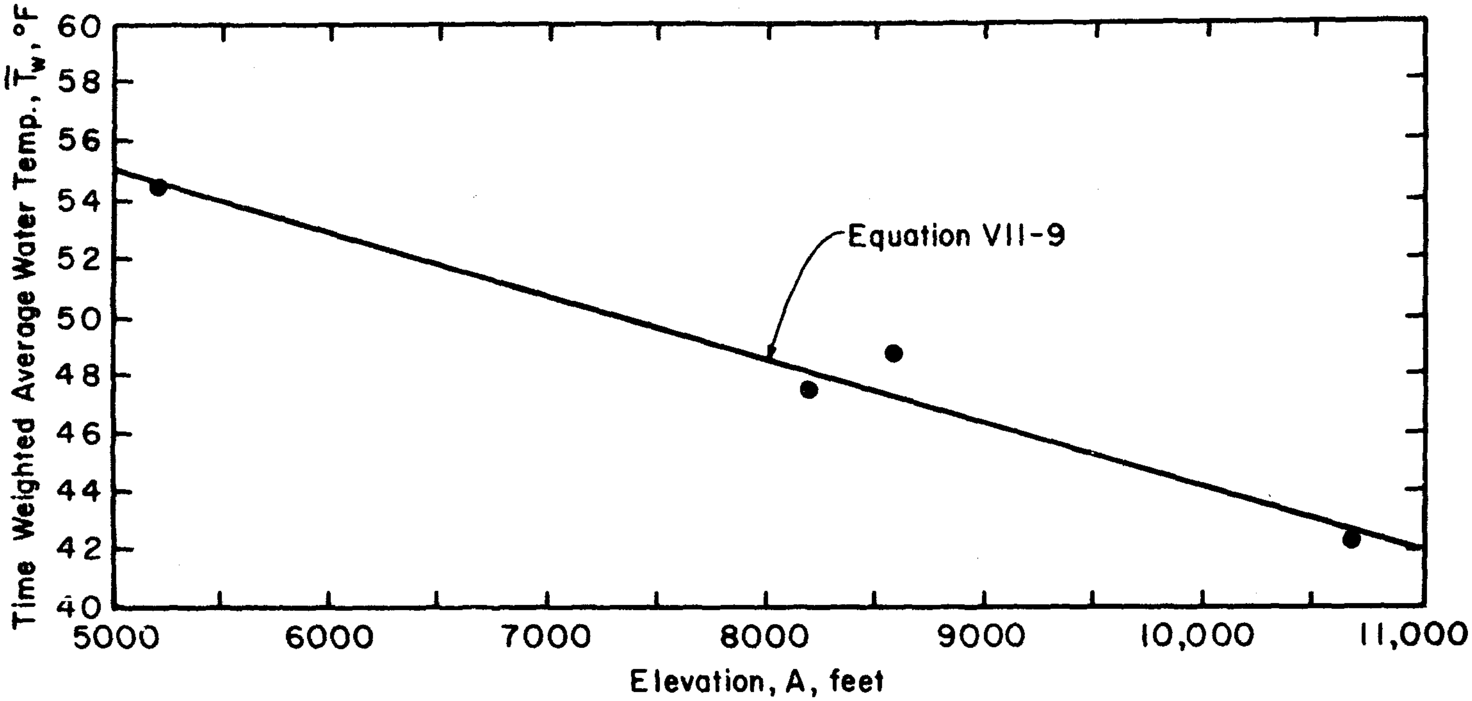

Figure VII-20. Time Weighted Average Water Temperature, $\overline{T}_w$, Versus Elevation, A

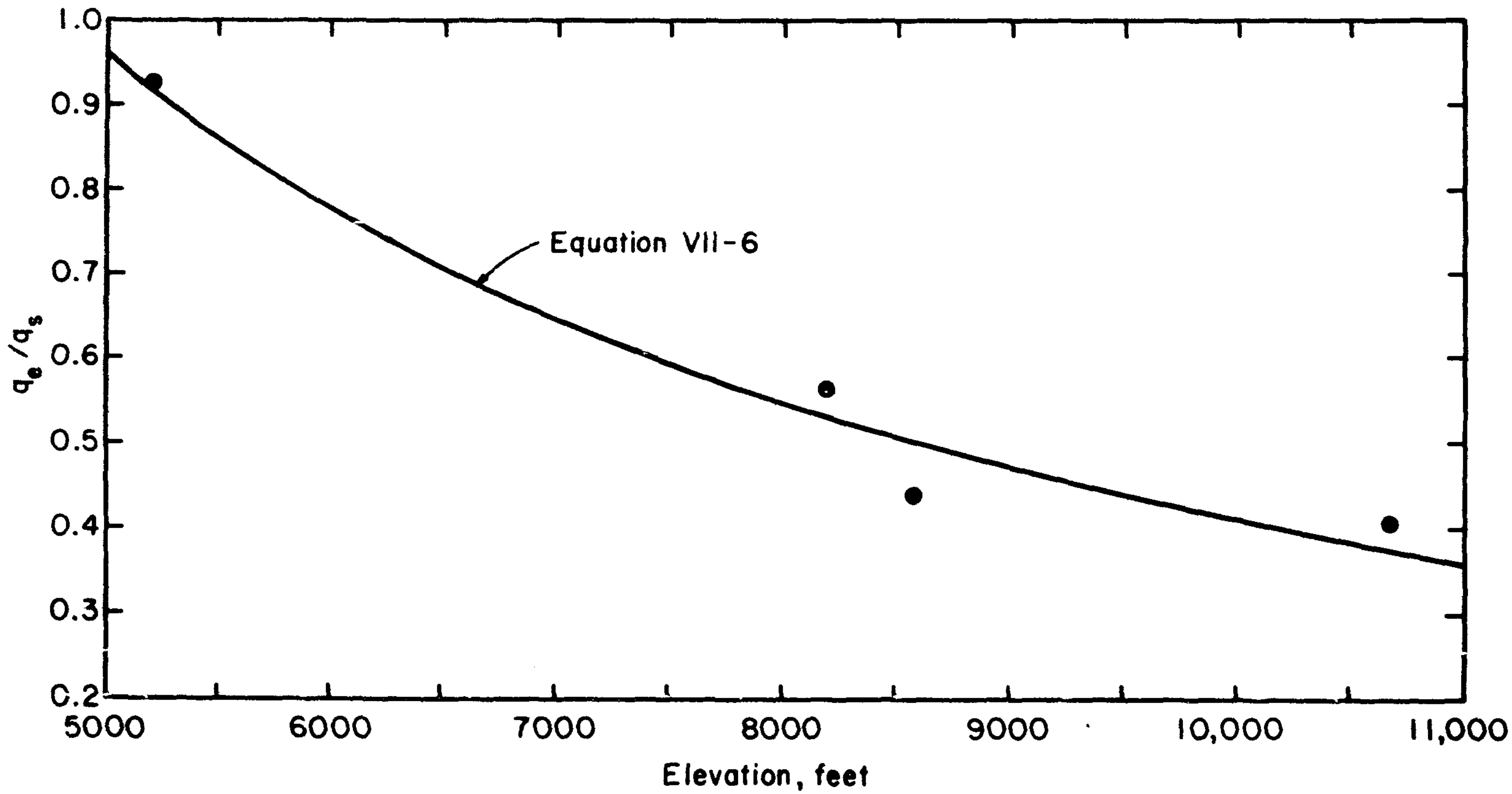

Figure VII-13. Energy Loss Due to Evaporation, q_e / Energy Input Due to Solar Radiation, q_s, Versus Elevation

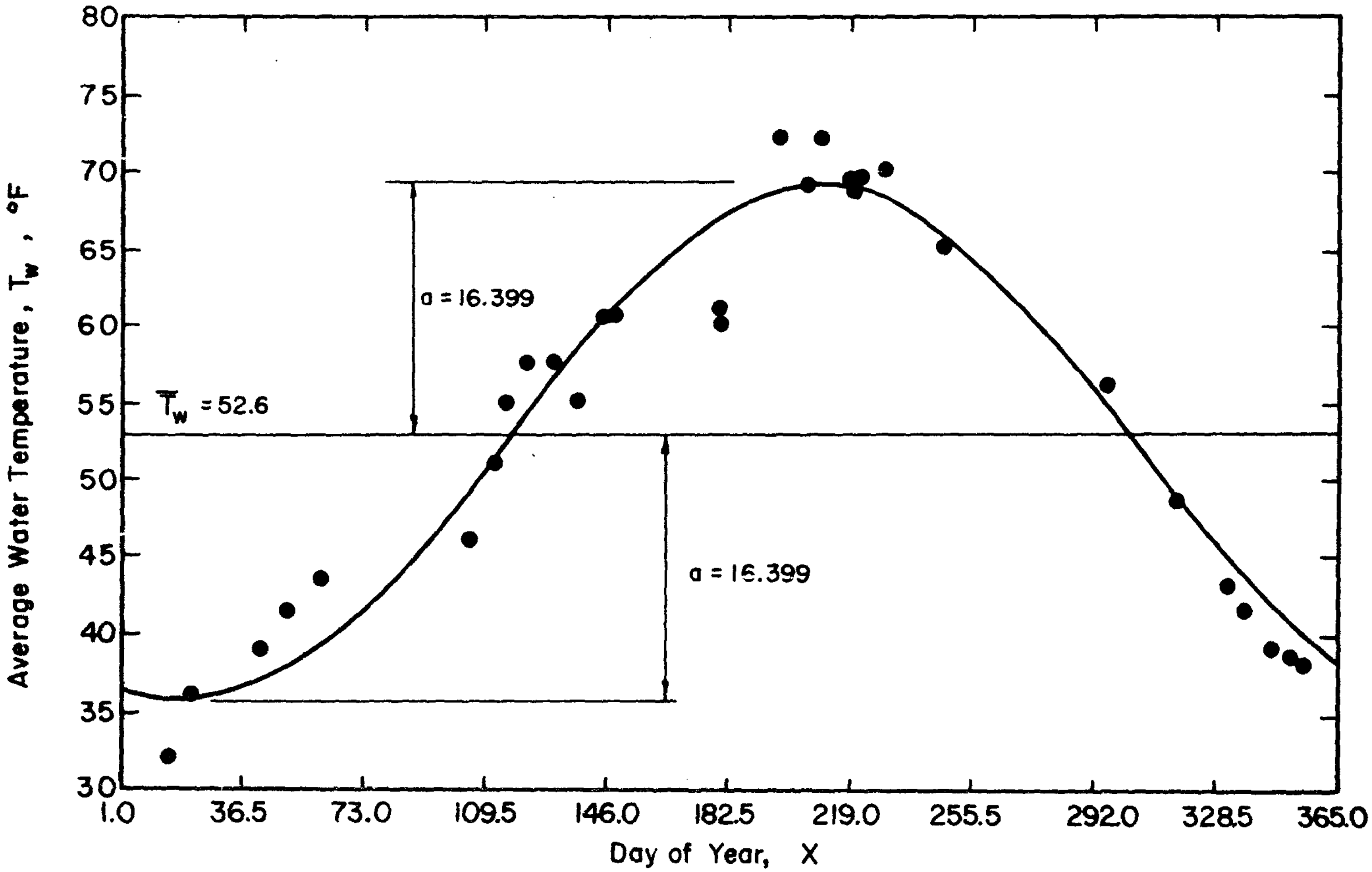

Figure VII-24. Average Water Temperature vs. Time of Year, Site A - Covered

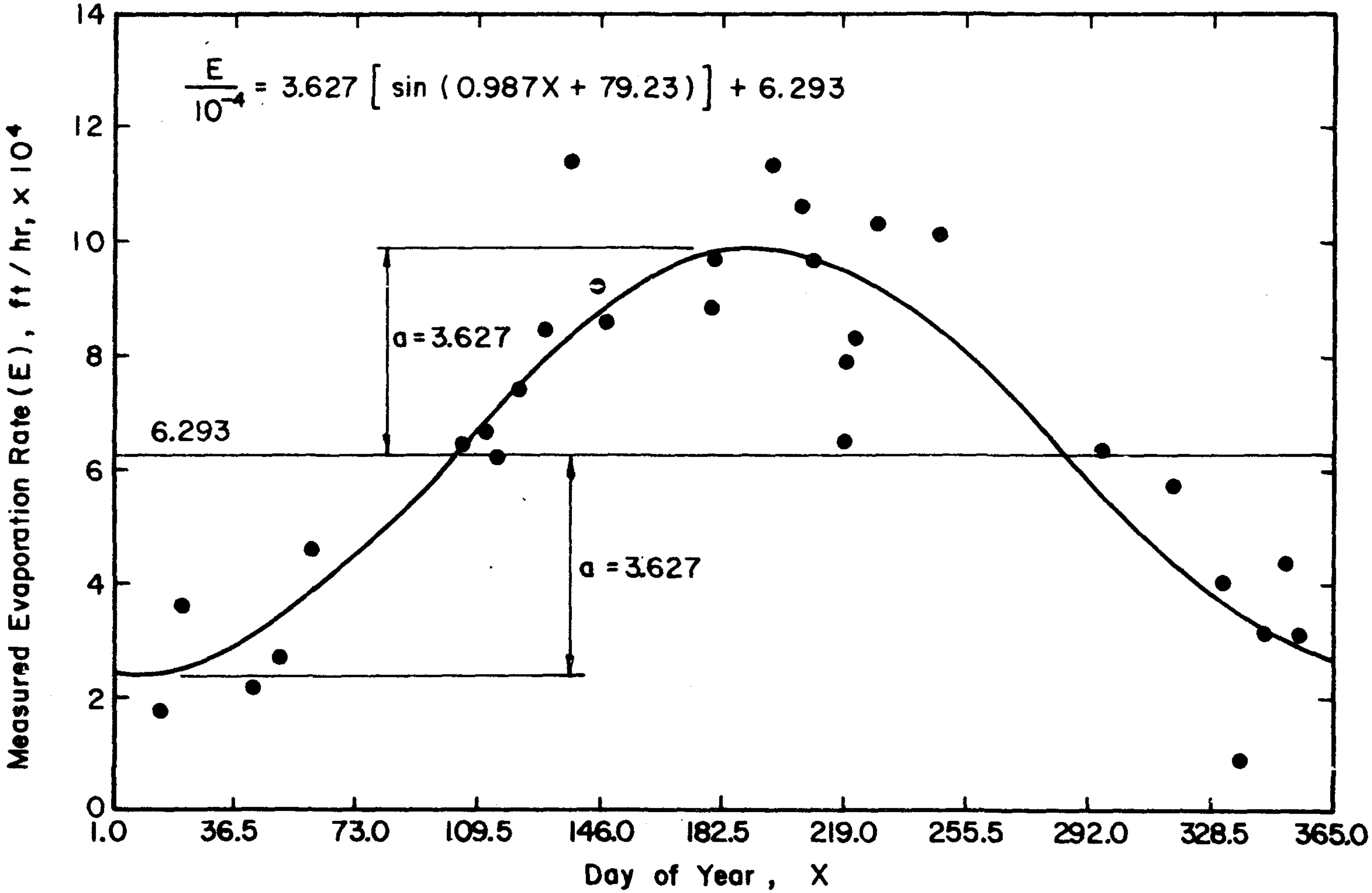

Figure VII - 7. Measured Evaporation Rate vs. Day of Year, Site A - Covered Unit. (see Table VII - 29)

WORKSHOP DISCUSSION

Led by

Dr. J. T. Winneberger
Septic Tank Consultant
(Sponsored by: Hancor, Inc., Findlay, Ohio)

Summary of Salient Points

Informal, oral communications are delivered with voice inflections and gestures. Complete meanings cannot be contained in writing alone. The following brief points are intended to convey the gist of the more detailed presentation.

Attempts to control the future through planning cannot obligate future generations. Those people will ignore documented directives, but cannot ignore physical reality of what has been constructed in accordance with those directives. Planners could be effective by identifying the planning implications of on-site wastewater disposal practices as compared to public collection systems. Each makes possible a totally different kind of community.

Where development booms, it might be feasible for local authorities to collect a "Feasibility Fee". It would provide revenues for acquisition of private consultants to assist authorities with shock loads. Without such funded assistance, local authorities see input out of proportion from consultants to private interests.

Septic tanks and sewers are simply devices, but they are frequently confused with private versus public management, The real issue of septic tanks versus sewers when a community seems to be poorly served by the former, is not a matter of devices. Rather, the real question is, "when has a community developed such that public management of all wastewater disposal practices is needed."

Formation of public entities to be responsible for septic-tank practices has been accomplished many places in California and perhaps elsewhere. Through public responsibility much improved septic-tank practices can be achieved at great savings for the public and to the delight of planners interested in maintaining low-density developments.

Technology of on-site wastewater disposal is not a part of normal engineering curricula. Sewering is. Through natural inclination to apply one's training to a problem together with rewards which sewer contracts bring, engineers can be predicted to advise public sewerage collection systems wherever money may exist for such projects. The engineer is in the truest sense of the expression, "in conflict of interest", when he advises a community on methods of managing waste disposal problems when that engineer (or other business friends) stand to gain if a sewer project is advised and undertaken. That conflict of interest might be removed by disqualifying the engineer performing "feasibility studies" from bidding on sewer work recommended. Involved local authorities are also in somewhat a position of conflict of interest if their workloads are lessened by abandoning on-site disposal systems in favor of a community sewer. It is doubtful that authorities whose pay was directly related to the number of functioning septic-tank systems in their area, would promote public sewers.

Sanitary surveys are meaningless if they only report functioning versus non-functioning septic systems. Meaningful surveys speak to lifespans of systems, technical errors of past practices, and benefits realistically to be realized through new, and improved septic-tank practices. See: "Sanitary Surveys and Survival Curves of Septic-Tank Systems"; Jour. Env. Health 38 (1) : 36; July/Aug 1975.

The percolation test is an empirical tool. Because of its empiricism there is only one valid test procedure. It has been described in the Appendix to : "Correlation of Three Techniques for Determining Soil Permeability"; Jour. Env. Health 37 (2) : 108-118; Sept/Oct 1974.

Research work at the University of California and the University of Wisconsin independently demonstrated that soils respond (clogging) equally to effluents from a septic tank, and from aeration devices. Disposal fields should, therefore, be constructed equally large to serve whichever device is used.

There is a need for a manufactured, indestructible, light-weight septic tank of superior design. Customary baffles crossing the middle of tanks cause short-circuiting. Baffles should run in the direction of the length of the tank. It is practical to construct baffles dividing a tank into three compartments, each running along the length of the tank. See: Septic Tank Practices; Dr. Peter Warshall, P. O. Box 42, Elm Road, Bolinas, California 94924; or, Procedures and Regulations for Individual Waste Disposal Sysytems; Bolinas Community Public Utility District, P. O. Box 348, Bolinas, California 94924.

Authorities interested in permanent as opposed to temporary septic-tank practices have found it practical to require construction of two disposal fields. Each is to serve one year while the alternate field rests. District management can best accomplish alternation of fields. A homeowner may alternate his fields yearly, but more commonly he may not. Still, there is considerable value in having an alternate field installed. Among other benefits, the alternate field provides an instant repair when the first field has been used to exhaustion. At that time, the homeowner would be more likely to begin alternating his fields.

Distribution pipes in fields can be smaller than 4-inches in diameter and serve quite well. Two-inches diameter might be practical if it becomes available. It is also unnecessary to attempt leveling distribution pipes or placing them on a specified grade. It is only necessary that the distribution pipes be below the invert of the septic tank overflow and be about 4-inches away from any soil wall. The primary function of the distribution pipe in trenches and pits is providing continuity which could be disrupted by soil blockages in gravel backfillings.

Deep disposal pits too frequently claim human lives, either during construction or from failure at a later date. Human lives could be saved by insisting that disposal pits be gravel-filled as trenches are and a distribution pipe should be placed from top to bottom of each pit.

Persons interested in recommendations for improved practices for subsurface wastewater disposal systems are directed to: Current and Recommended Practices for Subsurface Waste Water Disposal Systems in Arizona; J. T. Winneberger and J. W. Klock. Rept. No. ERC-R-73014. Tempe, Ariz.: Eng. Res. Center, Coll. of Eng. Sci., Ariz. State Univ., July 1973.

Control Through Planning?

Everywhere I travel I hear people discussing plans..land planning, land use, rules and regulations and things. Those are things that mankind does to rationalize what he intends to do at the time. He formalizes these things on paper. Nothing on paper, however, seems to govern mankind's behavior. Paper plans help one man do something to another one, but when there are enough people together, paper's change.

I have alot of faith in physical reality. The population of the Pacific Ocean is amazingly small compared to Los Angeles. And it probably will remain that way because it just isn't physically possible to populate the Pacific Ocean.

The EPA finally discovered that if a large sewer was installed somewhere, growth occurred. Amazing information! It's so obvious! Another thing that ought to be equally obvious hasn't really come to the light of day. Not every place in this country can limit growth while producing children. It can't be done. So it seems to me that one of the most practical things to do would be to govern what's going to happen anyway.

Sanitarians are getting into planning and planners are welcoming their input. In some counties in California sanitarians are assigned to planning commissions. The septic tank system (the onsite waste disposal system) or community sewer, whichever device is chosen, is bound to affect planning. If you put in one kind of device at the onset you pretty well determine what the future is going to be.

Let me put that another way. I can look at different communities and I'll tell you if they have, or if they have not septic tanks. If I see a cabin out on the side of a hill I know well it's not sewered up. If I got to downtown Denver I would be very surprised to find a septic tank system. Those waste disposal devices have alot to do with planning and if we don't recognize that we are in real trouble. Planners love to, on paper, have all these things happening, but there isn't any way on earth that you can provide a man, at least in California, with a half acre, three-quarters acre or such lot with sewers, roads, underground utilities and the rest. It can't be done. He can't afford it. If we want to have houses very close together, one right after the other, it's going to be nigh impossible to put septic tank systems in. So, planners should recognize the profound effects each of these devices has. It's pretty rare for the planner to realize these effects of physical, truly simple, reality.

Feasibility Fee

California went through a subdivision boom. Suddenly a sanitarian was faced with a subdivision proposed bigger than the county seat. He was expected to approve it and there wasn't any way on earth he could get out and check out the soil situation. None! He didn't have a staff! In many cases he lacked the technical expertise needed to handle the job. I don't mean that as a negative remark. Most people that deal with sanitarians know that they handle more than one kind of thing. Restaurants are one part of it, dog bites, chasing people down who pick skunks to make pets of them, or something like that. They have a huge variety of things to do besides look at septic tank systems. They have to be general practitioners. Also, the sanitarian in California typically is a man who came from some other field of study and didn't study sanitation as such at a University. In any case, the sanitarian was no match for the subdividers ability to bring in lawyers, engineers, geologists, and other crews of people. These people could cover several sections of land and come in with a report. The sanitarian was one heck of a spot to disagree with or check work. His requirements were also skimpy. He may not have felt too good about things, he usually didn't, but he was in no real position to do anything about it. So, subdivisions were approved with very little work. It would have helped if a fee arrangement had existed. For example, maybe a developer could come in, say, with 2,000 lots and a fee was collected. It could be called a feasibility fee. That would allow the sanitarian immediately to have enough money at hand to put his own group of experts to work. He would then have the ability to evaluate the site from his point of view. Something like that would have made sense. Subdividers, by the way, would have welcomed such an occurrence.

They are people who want to do the right thing. They don't know what that is always. So they satisfy county regulations. Many would have welcomed just simply forking out so much money, and then knowing they would have an answer. In many cases, perfectly honest engineers worked for subdividers and brought in reports. He was always dealt with suspicion, because the sanitarian was in a defensive spot. The sanitarian hadn't been there. Some would go in the field and have a heck of a time following thefield crew. It was really a bad situation that didn't have to be. So feasibility fees would help.

Question: When you suggest this type of fee are you saying that rather than having a subdivider present his geologic report and the health department present one that would be better for the subdivider to take these fees and give them to the health department who would then in turn contract out the geologic, hydrologic, and those types of studies? In other words, one report by the health department rather than having two different conflicting reports.

Answer: Yes, let me explain. Usually when a subdivision is planned by the developer, he figures on so many bucks for that kind of work. He usually finds out what the requirements are and then he figures out so many bucks to satisfy those requirements. He gives them to a consultant. He chooses a consultant on the basis of costs. The consultants know that they are competing with other consultants.

They don't want to beef up the cost and maybe do the job that needs to be done. They want the job even if they don't get enough money to do it right. What I suggested was the possibility that those monies be extracted from the developer, who could care less, really. He just wants the work done. Those monies could then hire consultants who were responsible to government and to the public. They would have a whole lot more freedom, believe me, than working for a subdivider.

Comment: Yea, that's what I was trying to get at. I thought you were suggesting two redundant studies rather than just one study.

Answer: That would be an out. Now, supposing the report didn't make sense to the subdividers. You don't want to take his rights and privileges away. He certainly has a right to hire anyone he wants to represent his interests and to disagree. And that very well could be an outcome in many situations depending on what the results were and so forth. The point I was making is right now health departments are in a position of judging a mass of work they couldn't possibly oversee. The work was done by a person who is not responsible to anybody but the developer. See, it's just a big heavyweight the developer brings in; the local guy hasn't got one of his own. I just tossed it (feasibility fee) out as a thought. I don't believe anybody does it.

Question: In order to initiate a program like this, say at the county level, it would have to be written in as an ordinance to the county commissioners?

Answer: I don't know how to do it legally. It's a lawyers problem; but I would imagine if you put your mind to it I'm sure the government could figure out a way to extract a fee. I don't think it would be too difficult; but nobody bothered to do it.

Comment: I think it is an excellant idea, because then when you've got an organization like the US Army or the Post Office Department or the Highway Department wanting to rip up the landscape and they've got an army or a battery of lawyers (like they did down here in Boulder)-they wanted to run that North-South freeway- we have means to react. Now what you're talking about is that the developer would have to pay the opposition's side, which is expensive. I think it would be an excellent idea, because when a school like this wanted to expand out into that field and somebody out there didn't like it; the school has to pay its expenses at the same time as theirs; and if you did something like this, we'd absolutely stop development cold.

Answer: It might not. I think what I'm trying to do is point out is that there is a real disparity in your adversary situation; a guy wants to do something,another guy does not. The guy in the judgemental position, really doesn't have the muscle power at his command that the other guy does. It's causing a lot of unnecessary regulations. A subdivider wants a good subdivision. He's not in and out, and don't kid yourself about that; somebody's left holding the bag. I have picked up alot of the loose bags, working with these guys; they don't get all cash. They want a good development, but they had an unfair advantage that they probably don't want. I think government needs a fair shake. I think it would be to the public's interest. Maybe it wouldn't be, I don't know.

I simply think the technical man representing the public would probably be in better shape if he had more cash to work with. I think what we're discussing isn't competence, I think what we're discussing is shock loading. You know a guy sitting in his office one day may be having half the county subdivided next week. I think that that's what we're discussing. Anyway, the feasibility fee is an idea I offer to you to think about.

Delegation of Problems

There's another thought that I might give you. In California, sanitarians sometimes run into real first class "bad" lot situations. The lot may be not much bigger than a quarter of this room. I've seen lots 50 by 50, lots of them. Little tiny lot; you really have an impossible situation. So what does the sanitarian do? He figures, well you know, if I let them in here, sure as Hell sewage is going to be running down the street and guess who's going to hear about it? There's got to be a way out, and by gosh there is. The sanitarian would be only too pleased to approve your lot if you bring in an engineer's plan so he could hang responsibility on the engineer.

We've been doing that for years. The engineer falls for it because he sees himself as a rescuer. And he may not realize what a trap has been set for him by the sanitarian. So he will try. He'll do his best, and, in California, he'll collect maybe a 600 dollar fee-more if he goes to a lot! If the system doesn't work, the engineer can be sued. I knew an engineer who was sued. The legal fees amounted to $30,000. Still, he lost and had to buy a $40,000 lot-for a $600.00 fee! That sad story I see in many places.

Public Management of Septic-tank Systems

Septic tanks and sewers are nothing more than engineering tools. Now, they ought to be, but they're not. If I say that area has sewer; everybody sort of breathes a sigh of relief. Sewage is no problem. If it is a septic tank area; you get all sorts of bad thoughts.

The reason is that the sewer is a professionally managed device. It doesn't matter what the quality of the effluent is coming out of the plant. The plant may be a group of weeds by the river. Whatever it may be, there is somebody responsible and so its professionally managed. The septic tank is not. It is privately managed. It is up to the individual homeowner to be the operator. So when you're really discussing septic tanks and sewers; you confuse things in your mind, most people do. They confuse management with devices. Septic tanks weren't invented by the devil. They are a perfectly suitable device. They do all sorts of things. They cannot, however, make up for deficiencies caused by gross negligence. The tanks keep getting bigger and bigger each year. I think we're up to 2,000 gallons in some areas. That's because nobody pumps them out and we hope to make tanks so big they will store virtually everything. So a device being incompetently managed is hurting the device. Septic tanks are poorly thought of. We run around like mad trying to prove septic tanks are polluting underground waters or something like that to get rid of them. But we don't really realize that what we're trying to get rid of is not the septic tank system, it's the private management problem. The sanitarian has the headache of all responsibility of that device. Sure he's responsible, but he's not responsible to get out there with a shovel and start fixing it up.

The need for professional management has caused, at least in California, the advent of professional management. We have districts that design, manage, maintain, etc., septic tanks, or sewers, or whichever. The responsibility the districts are charged with is to get rid of the waste waters. And then how they do it is up to the engineers. Public management of septic-tank systems is worth alot of thought. Here's Colorado struggling along trying to figure out what to do about home sewerage disposal. There's a real need to get districts going. I've always realized that if these things were ever going to stand a chance, they had to be inexpensive(they are) and they had to become publicly managed. It's economically feasible to do that.

I can describe an occurrence to give you some feeling for how this happens. In El Dorado County, California, where a subdivision of about 1800 lots was pretty well underway. The sales program was underway and development was proceeding. Right smack in the middle of all this, the State Regional Water Quality Control Board suddenly said you couldn't discharge septic tank systems in that area. Which meant there was no way to continue that development. Local authorities in the local health department were pretty well embarrassed over the midnight raid of the state. Right in the middle of it the subdivider representing all the people who had purchased lots, was willing to do something. He immediately hired people to leap in and do what they could. The key to the problem was to create more government. The Georgetown Divide Public Utilities District, supplying water to the subdivision, wanted the subdivision to remain alive. They were already supplying water so they took on the responsibility for all waste disposal practices. A considerable undertaking. This creation of an entity to be legally responsible (to collect a tax, all the rest of it) bailed out that subdivision. The state authorities said OK, if things still don't go well there, we know who to go after. The Public Utility District's attitude was, that's alright, sure as heck if we find technical problems with individual systems that we can't solve, we have authority to go ahead with sewers. We have the law with us and we can do anything we want with it. And it bailed out everybody. That subdivision has been there since 1970 and its worked out very well.

It occurs to me that a sanitary district which takes care of a bunch of septic tanks systems is practical in Colorado. I'm sure it would be but it may not be too easy to get started. It's something that subdividors would start or be required to do. By required, I mean they either went that way or they did not get approvals.

In Reno, Nevada, where I'll be in October, the county authorities have charged the Health Department with responsibility of checking into district management of the whole county. We have County management in some California counties; the concept is spreading.

Someday all waste disposal practices will be considered public responsibility. When that day comes, I think we'll find alot of improvement. In the short run, we're going to have to suffer with quite alot of problems, of course, because we don't have people who specialize in technology to do this work. For awhile I could see district management at wits end. Surely enough when demands become impossible the district manager would have the money to hire specialists to come in and help with the special problem. He'll have enough money to do that. He may make some mistakes. Initially he may put in devices that just don't work.

There's a need for a growth of technology. Why don't engineers study septic tank systems? It's obvious; there is no way to pay them! With district hiring people, I think you'll find more interest.

Out in California they're interested in great big systems. Lately there is quite alot of interest in the big systems. It's an indication that things may change.

Question: Would a varying fee be set up to reflect different siting conditions?

Answer: You are getting into the economics of management. It is a personal opinion as to how it should be done. What I'm pointing out, at least technically, supposing you have 2,000 people paying money to keep this program going, and alot (or 2 or 3) is a real problem. Rather than deny the owner use of the lot, it's be a pittance to pump and carry wastes away.

It's to everbody else's advantage, you see, if you want to look at it that way. There's no reason to sewer up the whole town because of one place. It's cheaper to pump one guy's place than it is to sewer up the whole town. Public management opens up a world of possibilities we really haven't thought about. It would be for him, but not for a whole district's support.

This thought of district control changes the whole picture. We're so accustomed to going first to septic tanks, then when the community gets older, we have problems all over the place and we don't know what to do about them, then we start pushing for sewers. Sewers are usually too expensive, when the community is already there. The sewer goes in, if you get enough pressure. It's an unpopular job. Then after the sewer is in, everybody subdivides his lot and you get a whole different community (this way megalopoles are born)! It's a process we've been going through, It's not really satisfactory to anybody.

Sewering Up

This gets me into another field of prejudices. This business of sewering up. It's not uncommon in California to have a study made of an area to see what should be done with the waste disposal practices. So funds are spent to hire an engineering firm to tell them what to do. These firms look into their tool kit and determine that sewers are needed. They study the feasibility of sewers from every point of view. They'll get out and test soils to make sure they can dig them. At the end of it all, they'll end up advising a sewer system. Maybe it will cost more than the assessed evaluation of all the property involved. And when you take a look at what they have to say about septic tanks, it's fairly simple.They never studied them. The septic tank as an engineering tool has been completely lost. The engineer advising a sewer is in my mind in a conflict of interest situation. Now legally, perhaps he is not, but if I rewarded man for advising me to do something I shouldn't be too surprised if he advises me to do it. If an engineer studies an area and decides that public sewers are needed, he stands to make a fortune by doing the job---sewering it up.

Another part of it is certainly honest enough. The engineer doesn't know how to study septic tank situations. Usually health departments are called upon to speak about problems in a community. They'll make a real heroic effort to go to the community and they'll run around to see how many systems are working and how many are not. This is called a sanitary survey. Let me explain it this way. Say I have a septic tank system. This morning I noticed it isn't working so good in my back yard. Before I came here I called up a contractor. He's out there fixing it up. But supposing I'm like I really am. I notice its running off onto the neighbors and nobody there to tell me what to do about it. Rather than coughing up the cash to do it now, I notice it's downwind, and I leave it alone for a little while till I get around to fixing it up. Now which situation is more likely to have me classified by the sanitary survey as a problem. Obviously the latter. If I take my time about getting it fixed up, there's far more chance that somebody might come by and say, gee, you do have a problem now. I notice that sanitary surveys generally bring up information like one in five isn't working. It's usually pretty close to that. Surveys do not have much to do with soils or septic tanks or anything else. What we've done is measure the procrastination of mankind.

Septic tank systems have life spans, the subsurface disposal fields systems have lifespans. If you go to the homeowner, and ask him how the septic tank system has functioned, you'll collect information on length of time the system served. Such pieces of information can be used to formulate survival curves. This has been published in the Journal of Environmental Health. These are known procedures. The techniques are known; they're simple and it makes sense to do this in any area being looked at for sewage disposal. And it makes sense to find out whether or not the area was generally a problem area or not.

With respect to information on the systems, the question to ask isn't does it work or not; the question to ask is how long did it work before you had troubles. If you had troubles at all. Those pieces of information I think would be vital to any engineer who is honestly deciding whether septic tank practices are useful or not. If you look at it economically what does it cost, how many years service did you get out of something you've bought. Things like that. It's really honest engineering information. They need to collect it, but they don't know how! As far as I know these techniques are not widely known. People just don't know how to do it. It's not taught in school. As far as I know the Journal of Environment Health now carries the only widely spread publications. These techniques were spread by the United State Public Health Service in the 50's and 60's too, I think, but nothing much came of it. Pretty much you see sanitary surveys which do not really give you engineering information. It may be meaningful to a health authority to know that one system in five isn't working. That's meaningful! But from the engineering point of view, it doesn't mean a thing.

If the survival curve is put together by a person who really knows what he's doing, he will also, during the collection of information, get a pretty good notion as to where systems work, where they don't and why, and what to do about them. Then when he comes up with recommendations for practices, you will find need to sewer a certain area, and there are areas where you do not.

There is no reason why the subsurface disposal field cannot last as a method indefinitely. Right now we design systems to be temporary. Our codes call for temporary systems. Most county codes start out the same way by saying septic tanks are no good, and sewers are great, but if you must have a septic tank, this is how to do it.

But this business of sewering up has gotten to be a real problem. A friend of mine recently back East told me that somebody had added up all the costs of projected projects of sanitary engineers all over this country and the total exceeds the national debt. Colorado's not the only state that's after free money. Everybody wants free money and the money is almost worthless now.

The EPA is just beginning to realize they can't afford all these various projects and so they are trying to find ways to say no to projects. They are really getting pretty darn fussy and selective. What's really involved in some of the turn downs that have occurred lately is that the EPA can't afford it. There's a limit to the amount of money that can be poured into these things. I knew good and well that sooner or later the economy would have its way. We cannot afford to sewer up the entirety of this country and if we ever did we couldn't afford the outfall to dump into the middle of the Pacific Ocean safely. It just can't be done.

Percolation Tests

The percolation test is a rather blunt tool. However, it is the best thing we have; its practical, and probably going to be around for a long time. The percolation test could be a good tool; there's nothing wrong with it as such. But it's very rare that I see an actual percolation test performed. More usually, the guy digs a hole in the ground and pours water in it, and watches the water go away. He times this, and then calculates the rate that he calls a percolation rate, regardless of the size of the hole, the depth of the filling, or the way the hole was treated or whatever, so when I hear somebody talk about a perc rate of 60 min. the inch, I wonder what they did to get that figure. The percolation test is a real rubber tape measure. The percolation test has fallen into disrepute because it just isn't uniform.

The percolation test is an empirical tool. It was devised by Henry Ryon about 1926. He did it in a certain way. He dug a hole in the ground (one foot square), and poured water in it 6" deep. He measured the length of time it took for one inch to go away. Now we know from research that if you change that hole and make it narrower, like 4 ins., you get a terrifically different rate. If you fill the hole deeper, it goes in faster. Hydraulic head has something to say about that.

If you change the physical conditions, you change the number you end up with.

So the percolation test for soils was performed in a certain way. If you perform it that certain way you should end up with a number about like what Henry Ryon would. After he devised the percolation test, he related it to sewage leading rates of disposal fields.

We used Ryons' table of loading pretty well over the country. We kept the table of loadings, because it's harder to change numbers without knowing you're doing it, but practically everybody I run into has his own variety of perc test.

The percolation test, I think could be a useful tool. It needs to be performed in a standard fashion, and I cannot overemphasize the need for standardization of the percolation tests. If you've got to perform the tests at all, they should be practical. There is no point in requiring a test that a guy cannot perform. And it ought to be simple because many people who perform percolation tests have other things to do than study percolation tests all their life. If you're going to use Henry Ryons' table of loading rates of soils (how big should the system be, how many square feet per bed, etc.) you may as well use his test; it was simple.

Question: What is your feeling about aeration versus the septic tank?

Answer: It's simple enough. I look at it from an economic point of view. If a soil clogs up as rapidly with aerobically treated sewage as it does with septic tank effluent, I see no other alternative than to select the cheaper of the two devices. It's always a septic tank.

Research in California showed that septic tank effluents and effluents from an aerobic device acted alot alike. The work in

Wisconsin reported this morning said the same thing. The only disagreement I've run into outside of manufacturers of the devices has come from Professor Lank of Connecticut. He says one effluent is a bit better than the other. But if you'll take a look at his arithmetic, the difference is not as much as you find with a contractor in the field. You think, you got a trench 80' long, it's not all that accurately built! Apparently, people feel differently about sewage; more so than soil. I wish I could make people with aerobic devices feel better. Most of them don't enjoy hearing me say these things. Nonetheless, I never advise the use of an aerobic treatment device for practical reasons. I couldn't in clear conscience do it.

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September 17, 1975

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REFERENCES

(References can be obtained from Small Scale Waste Management Project, 1 Ag Hall, University of Wisconsin-Madison, Madison, Wisconsin 53706.)

1. Description of the fill system described in this bulletin:

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