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Title: SUBSURFACE DISPOSAL OF DOMESTIC SEPTIC EFFLUENT IN A HAPLOXERALF SOIL IN SOUTH-WESTERN OREGON

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Experimental Drainfields

Standard subsurface sewage disposal systems, gravity loaded and 60 cm deep on slopes above 15% did not show signs of effluent surfacing after 14 months of operation. However, subsurface signs of failure were found on both the experimental sites and on older drainfields established in identical soils. Evidence included fecal coliforms in the groundwater nearby, ferrous compounds in trenches, and trench ponding. Lateral movement of coliforms over an undisturbed restrictive layer under high-intensity short duration rainfall does occur.

Penetration of fractured rock by drainfields may result in coliform contamination some distance from the site.

Low pressure dosing of drainfield trenches appeared to prevent ferrous compound buildup.

Curtain drains installed in fractured rock do not function as effectively as ones installed in a soil restrictive layer and may not be effective for a standard size field on steeper slopes.

Effluent volume monitoring indicated that figures currently used by Oregon's Department of Environmental Quality to size drainfields may need revision.

Piezometers

Six different soils were evaluated on the basis of their suitability for drainfields. Water table fluctuation was monitored for three years. Permeability, as determined by structural strength, porosity and slope were determining factors in a soil's ability to transmit water rapidly.

The position of the long term high water table could not always be determined by soil mottling. Geomorphic position was equally important in assessment of drainage capability.

Subsurface Disposal of Domestic Septic Effluent in a Haploxeralf Soil in Southwestern Oregon

by

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SUBSURFACE DISPOSAL OF DOMESTIC SEPTIC EFFLUENT IN A HAPLOXERALF SOIL IN SOUTHWESTERN OREGON

PART ONE: EXPERIMENTAL DRAINFIELDS

INTRODUCTION

This thesis subject was chosen after a survey of the available literature revealed that most published studies related to the performance of in situ drainfields were restricted to surveys of drainfields of varying ages (Wert, 1969) or involved drainfield facsimiles such as columns or lysimeters (McKee and McMicheal, 1964). However, a sand column can incorporate only a very limited number of the variables operating in a normal drainfield. Surveys of installed drainfields cannot tell after the fact just what the soil conditions were prior to installation, how the soil varied throughout the trench length, whether the pipe and distribution boxes were laid level in a level trench, and whether soil compaction occurred during the cover operation. They usually do not provide records of the actual volume of effluent going into a system over a period of time. In many systems this varies markedly over the years, due to vacations, part-time babysitting and homes that are either rented or subject to a large turnover in owners.

The last item is very important in a nation as restless as ours.

Therefore, sanitarians in the State of Oregon, operating under the Department of Environmental Quality Subsurface Sewage Disposal Rules (1975), design drainfields based on the following interrelated points:

1) Number of bedrooms, at 568 liters per bedroom. The rule of thumb is to use a standard three-bedroom figure or more, recognizing the fact that the average family is composed of at least two adults and two children. Hence, the drainfield is very often oversized and underutilized a fair share of its lifespan. This may also account for a sudden failure when a house changes hands from a retired couple to a large family.

2) Soil texture, outlined in two charts, one incorporating depths of soil to a restrictive layer from 75.0 cm to 180 cm or more, and the other for soil depths to an impervious layer from 60 to 165 cm. Sidewall area for each soil texture ranges from 13.9 sq. meters per 568 liters daily waste for a sandy loam to 30.7 sq. meters for a silty clay. Clay textures are considered unuseable unless they have a low to moderate shrink-swell potential combined with a moderate to strong structure as rated by the Soil Conservation Service for a particular series.

3) Slope-depth relationship, as demonstrated by one or more testpits in the area of the prospective drainfield. This rests directly on the sanitarian's assessment of whether he is dealing with a

restrictive or impervious layer, a matter of subjective judgment. If the layer is "impervious" (absorbs fluid at less than 0.009 cm per hour as defined by Department of Environmental Quality Rules, 1975), the soil depth must be no less than 90 cm on a 12 percent slope and at least 180 cm on a 25 percent slope. A "restrictive layer," defined as capable of absorbing fluid at a rate of 0.009 to 0.5 cm per hour by the Department of Environmental Quality Rules, 1975, must have a minimum depth of soil of 75 cm on a 12 percent slope, ranging up to 120 cm on a 25 percent slope. No system is installed on a slope exceeding 25 percent unless the area is defined as "rural"[1/] and no hazard to public or private water supply can be anticipated if effluent should surface. This is based on the assumption that any system installed on a slope exceeding 25 percent can be expected to surface, coupled with the difficulty that a backhoe may have in operating on a slope of this steepness.

Interpretation and enforcement of DEQ Rules tends to concentrate housing development on lands that are gentle in slope and have relatively deep soils. Even a cursory inspection of private land available for development of rural homesites in western Oregon

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[1/] Rural areas are defined by Department of Environmental Quality Rules as areas designated by the county and approved by the Department that do not meet minimum standards as defined by the Rules but would not appear to pose a public health hazard or cause degradation of public waters if a subsurface sewage disposal system were installed.

reveals that such lands are either under cultivation and zoned for farm use or are already built on. After years of concentration of home building on valley floors, most of the land now available is located on hillslopes exceeding 15 percent slope and usually possesses less than the minimum soil depths required by the Rules.

In Douglas County, these sloping shallow soils commonly occur in the Oakland-Sutherlin, Jory-Bellpine and Willakenzie-Bellpine associations (USDA-SCS, 1974). The Oakland-Sutherlin association comprises 104,121 hectares in the county or 7.9 percent of the total. The Jory-Bellpine association extends over 6,916 hectares or 0.5 percent of the total. The Willakenzie-Bellpine association covers 98,682 hectares or 7.5 percent of the county.

Other associations which meet the same criteria for slope-depth relationship include the Bellpine-Hazelair and the Philomath-Hazelair-Dixonville. These are excluded from consideration here due to high shrink-swell potential and/or highly restrictive clay layers, coupled with shallow depths to fractured bedrock.

The five described associations comprise a significant part of the land still available for development in Douglas County. Similar soils are typical of foothills bordering the Willamette Valley and Southwest Oregon valleys. The County is experiencing the same growth as the rest of western Oregon and is hard pressed to provide adequate housing to meet demand. The county is zoned to protect the remaining Capability Class I and II agricultural land and to produce orderly growth on the remaining private lands, which are minor in proportion to the extent of Federal, State and private timber lands belonging to large corporations. The percentages of lands in the public sector are (Valde, 1973):

(1) Federal lands - 665,769 hectares of 50.8% of the total county.

(2) State lands - 19,600 hectares or 1.5% of the total county.

(3) County lands - 7,971 hectares or 0.6% of the total county.

All other lands (618,018 hectares or 47.1% of the total) are in the private sector, but of these lands, the forest industry owns 281,267 hectares, which may generally be assumed to be unavailable for housing development. Therefore, of a total of 1,311,358 hectares, only 25.7 percent or 336,752 hectares are possibly available for development at present. There is the further restriction that of the 336,752 hectares left, 212,468 hectares are listed as being commercial forest land held for cutting by farmers and other miscellaneous private interests. In summation, of the entire county, only 124,284 hectares or 9.5 percent is available for housing, set aside for agriculture, or is presently developed. Therefore, this was a pertinent area in which to test the hypothesis that soils presently considered unuseable by the State criteria could be used for drainfields, and to collect data on installations that were completely supervised from original soil inspection to covering of the lines.

PURPOSE AND OBJECTIVES

The purpose of this study was to monitor the performance of drainfields installed according to the standards prescribed in the Rules promulgated by the Department of Environmental Quality for the State of Oregon.

The specific objectives of the study were:

1. To evaluate presently used criteria for determining drainfield failure and the creation of a public health hazard.

2. To develop enough information to determine whether trenches could be installed at shallower depths and steeper slopes than are presently allowed under the Rules.

3. To assess the efficiency of curtain drains (French or interceptor) above hillside drainfields.

4. To determine the validity of data concerning average household effluent volumes and effluent chemistry.

5. To determine if dosing of drainfields would improve performance.

LITERATURE REVIEW

In the relatively brief history of the septic tank-drainfield method for disposal of man's biological wastes, we have gone from the blythe assumption that the earth can absorb all and rebound for more to the realization that our soil resources have very finite limits with reference to waste disposal. Thus we have progressed from Ryon's simple percolation test (Olson, 1964) to Bouma's sophisticated crust test procedure (Bouma and Denning, 1972), soil fabric pore analysis and various morphometric measurements. We have, in effect, moved from the assumption that soils do not vary much to the decision that we must examine every waste disposal site in detail.

Drainfields, with or without septic tanks, came into use as soon as houses became equipped with running water in the early 1900's. Apparently not until 1928, when Henry Ryon devised the percolation test to deal with the problems he saw and dealt with in New York, was there any attempt to classify soils as to their ability to absorb sewage effluent. Ryon appears to have been aware that his procedure was applicable only within a small area which he knew thoroughly. Following this pioneering effort, other procedures evolved. First, however, there was the long stretch of time, some 25 years, in which Ryon's curves were the only test used. Not until housing density increased to the point where failing drainfields were increasingly frequent and traceable to domestic water pollution on a large scale was there any recognition of the size of the problem developing. With environmental concern increasing in the 1960's, public health officials began to give more consideration to increasing numbers of failing drainfields, with the attendant public health hazards of surfacing effluent and water pollution. Ryon's curves, long inadequate, no longer sufficed for accurately determining potential drainfield sites.

In the past sixteen years different procedures have been proposed for measuring the ability of soil to transmit drainfield effluent. Measuring the permeability of small soil cores is and has been one of the most convenient methods used, but it suffers from some deficiencies. One is that the permeability of the core is inversely proportional to the core length (Anderson and Bouma, 1973). Secondly, it is frequently not representative of the soil conditions in the field where pore continuity has a major effect and, lastly, results have often lacked reproducibility.

A second procedure is the Bouwer double tube method reviewed by Bouma, Baker and Veneman (1974). This apparatus functions much like a double ring infiltrometer, except the systems are closed. Several investigators have used this procedure, including Wert (1969), who found it less variable than the Ryon test but still producing a wide range of values. Bouma (1971), comparing the double tube test with the field percolation test found the mean coefficient of variability of the double tube method was 0.25 for a variety of soils and conditions. The double tube test also has the disadvantage of measuring only saturated permeability.

The instantaneous profile method, which measures both saturated and unsaturated permeabilities, was developed by Bouma, Baker and Veneman (1974). The technique involves saturating a plot of soil and measuring the rate of free drainage to establish conductivity curves. The chief advantage is assessing a soil's drainfield potential in situ. The disadvantages are inapplicability to layered soils and steeper slopes, the time required to produce low moisture contents, and the high variability at low moisture contents.

Bouma and Denning's (1972) crust test, developed at the University of Wisconsin, measures one-dimensional hydraulic conductivity of soil in situ and both saturated and unsaturated conductivities. It has the chief advantage of being fairly inexpensive in both labor and time plus the ease of applicability to small sites. Its coefficient of variation, at least in a study of two different fine-silty soil series, is 0.37 (Baker and Bouma, 1976). This technique has potential for making soil groupings based on measurable moisture transmission characteristics and could contribute much to relating different soils for similar use and management.

Finally, a soil's ability to absorb and transmit effluent may be estimated in the field. A soil scientist inspects the soil profile in several pits on the proposed drainfield site, makes additional soil borings, assesses geomorphologic features, assesses drainage, and uses vegetative evidence to predict suitability of soils for effluent disposal. Bouma (1973, 1974a, 1974b) advocates the use of soil survey information for identification of relatively homogenous soil areas that will respond to a defined method of disposal in the same way. Whether the required precision is possible without on-site inspection remains to be seen. However, the approach recognizes the importance of morphological assessment of soils by soil scientists and usefulness of the soil survey.

Oregon's subsurface rules and regulations have evolved from reliance on percolation tests to a recognition of the use of soil profile examinations to determine occurrence of high water tables and to prescribe design criteria. In other states, such as Wisconsin, soil research aimed at quantifying drainfield requirements is accelerating. Efforts there are focused on improving installation practices, the education of installers and the general public in this regard, and attempting to determine and describe the causes for failure of standard installations.

Poor installation practices are a primary cause of early drainfield failure, especially on suitable soils. McGauhey and Krone (1967) list physical causes of soil clogging as compaction, smearing of surface, and migration of fines during vibration of dry surfaces and during rainfall. Construction methods for seepage beds, requiring driving of heavy equipment on the bottoms, leads Bouma (1975) to recommend trench construction primarily to prevent such compaction. Common use of gravity systems that use 10 cm distribution pipe with closely spaced holes results in loading which leads to creeping failure, as discussed by McGauhey and Krone (1967). Investigation of pipe size, dosing of effluent, and pressure distribution of effluent has received much attention from Wisconsin in the last five years, both for standard type systems (Otis, Bouma, and Walker, 1974) and for innovative techniques such as mounds (Bouma, Converse, Ziebell, Magdoff, 1974). On the critical parameter of loading, Bouma (1975) has developed a series of four conductivity types, keyed to soil textural classes as shown in Table 1. Recommended operating conditions, based on this research, are abstracted by Otis (1976).

Bouma (1975) also states emphatically that the data on which the chart is based do not support the hypothesis suggested by McGauhey and Winneberger in 1964 that sidewalls are more effective as infiltrative surfaces than bottom areas.

Much work has been done on the identification of the chemical and biological processes leading to clogging of drainfields (McGauhey and Krone, 1967). The different types of clogging, usually

Table 1. Maximum Permeable Loading Rates of Septic Tank Effluent Recommended for Different Soil Types (Otis, 1976).

Soil Texture	Loading Rate (Bottom area only)	Operating Conditions
Sands	5 cm/day	4 doses/day; equal distribution
Sandy loams, loams	3 cm/day	1 dose/day; equal distribution
Some porous silt loams and silty clay loams	5 cm/day	1 dose/day; shallow trenches
Clays, some compact silt loams and silty clay loams	1 cm/day	shallow trenches

interrelated in system failure, are chemical (flocculation and deflocculation), biological and organic (suspended solids deposition and subsequent decomposition by bacteria, producing slimes and gels), humus formation (favored in an anerobic environment) and interaction between organic matter and soil, affecting soil properties.

Some innovative methods for cleaning clogged zones have been suggested, ranging from the standard resting to allow return of aerobicity (not endorsed by all researchers) to such treatments as addition of hydrogen peroxide (Harken, Jawson and Baker, 1976) and dosing (Bouma et al., 1972; Bouma, Converse and Magdoff, 1974; McGauhey and Krone, 1967).

Sizing of absorption surfaces cannot be separated from loading or the degree of required purification of effluent. In Oregon it is based strictly on soil texture with wide ranges of recommendations being offered, depending on the degree of treatment expected. Lawrence (1973) has suggested that septic tanks often do not produce treatment beyond primary settlement of solids and some minor reduction of BOD, leaving most systems undersized from the start. However, the common tendency is to oversize systems as a "safety factor". Gravity loading, which leads to unequal distribution, appears to contribute to failures regardless of the size of the system (Bouma et al., 1972; Otis, 1976). The surfaces of the trenches nearest the distribution boxes become coated with clogging ferrous compounds, which slowly extend toward the end of the trench as effluent must travel further to dissipate through the distribution holes in the pipe. The surfaces of the trench are seldom subjected to a sufficient head of effluent to achieve complete penetration of the entire drainfield, nor is subsequent drying permitted with return of aerobic conditions in the portion inundated. Therefore, small systems, overloaded by present standards, could possibly be much more efficient and longer-lived, so long as the design incorporated textural considerations coupled with equal distribution (Table 1).

Unsuitable soils, increasing pollution and the desire for higher density development have led to consideration of alternative systems, which have received a large amount of attention in the past few years. The offerings have ranged from completely waterless systems such as the Clivus Multrum to aerobic units with or without evapotranspiration beds and mounds. The ET bed (Bernhart, 1973) has been tried in various forms all over the country. Tanner and Bouma (1975a, b) demonstrate conclusively that the sealed bottom ET systems have no possible chance of working except in climates where evapotranspiration exceeds precipitation almost year round and temperatures seldom drop below freezing. However, it should be noted that Bernhart never advocated closed bed systems.

Bouma, Baker and Veneman (1974) and Bouma _et al_. (1972, 1975) have emphasized the use of mounds, fills and other somewhat unorthodox ideas (Vepraskas *et al.*, 1974) during their work in Wisconsin. This may be easily understood considering the problem soils in the area, the generally low slopes (0-12%) and the abundance of medium-size sand for construction of filter beds. In any case, Bouma and his coworkers have done much to advance the state of knowledge concerning systems other than standard trenches and seepage beds. Though the technology may not transfer intact to other parts of the country, the data have provided needed insight to the problems and the possibilities.

PHYSICAL ASPECTS OF STUDY AREA

Douglas County, located in southwestern Oregon (Figure 1), extends from sea level at the Pacific Ocean to 2797 meters at Mt. Thielsen in the Cascade Mountains. It includes the entire Umpqua River drainage basin. The basin interior is oriented around a long north-south trending alluvial valley with elevations between 90 and 450 meters. Within the basin many short, discontinuous valleys containing most of the level land and population centers are traversed by the Umpqua River and its tributaries. To the south, the Umpqua River drainage is separated from the Rogue River basin by a divide of the Klamath Mountains which reaches almost 2200 meters in elevation. To the north, the Calapooya hills, reaching elevations of 460 meters, separate the Umpqua and Willamette drainage basins. To the west is the Coast Range, rising to 760 meters and to the east are the Cascade Mountains which reach heights of more than 2700 meters.

The extreme eastern edge of the county lies in the Cascade Mountains with peaks ranging from 1310 to 2797 meters. The ridges and mountains that form the boundary of the Umpqua basin restrict wind movement and cause the high precipitation producing the forest wealth of the county.

The valley floors of Douglas County are comprised of

DOUGLAS COUNTY OREGON

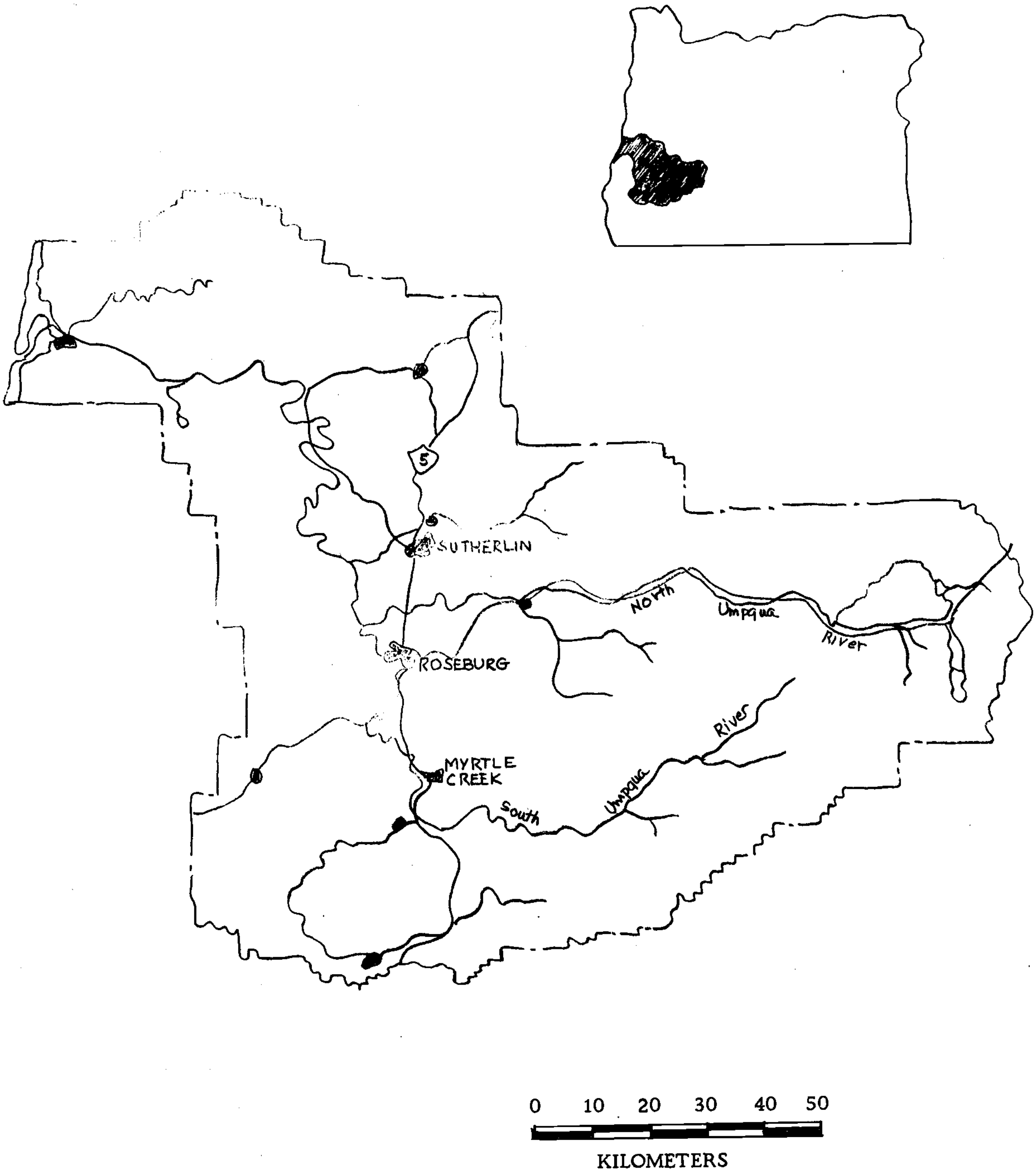

Figure 1. Geographic location of the study area.

alluvial material of Pleistocene and Recent age. This material is variable in texture, coarse-fragment content, degree of weathering, and lithology. Basalt and related volcanic rocks of Eocene age underlie the uplands in the vicinity of Roseburg, Elkhead, and Drain. Sedimentary rocks of Eocene age make up most of the remaining area. They are part of the Roseburg Formation (Baldwin, 1974) consisting of thinly bedded, alternating strata of mudstone, sandstone and siltstone.

The Cascade Mountains are made up almost entirely of basic volcanic rocks, including lava, tuff, and breccia. These rocks of late Eocene to late Miocene age have been warped, faulted, and altered. Uplift occurred in two stages. The amount of uplift varies from a few dozen meters along the western margin to as much as a few hundred meters along the axis of the range.

The rocks of the Coast Range are mostly sandstone, mudstone, and siltstone of Eocene age, generally part of the Tyee formation. Slip scars and landslide debris suggest that mass movement has been important in the formation of the regolith.

The Klamath section is an area of generally resistant rocks of Jurassic and Cretaceous age that have been leveled by erosion, uplifted a few hundred meters and then dissected by two or more later cycles of erosion. The sedimentary rocks and igneous rocks have been altered by heat and pressure in varying degrees.

Douglas County has a temperate maritime climate, with dry, moderately warm summers and wet mild winters. The varying topography produces considerable ranges in the climate, depending on elevation and aspect.

An outstanding characteristic of the county's climate, in common with most of western Oregon, is the seasonal distribution of precipitation. About 60 percent occurs during the November through February storm season while only 10 percent occurs from June through September.

The average annual precipitation is as low as 60 cm in the valley portions of the county but increases rapidly with elevation to over 250 cm in parts of the Coast Range in the western portion of the county. Below 600 meters elevation, most of the precipitation occurs as low intensity rainfall. The proportion of precipitation that occurs as snow increases from about 2 percent of the total on the valley floors to 50 percent at 1500 meters and about 75 percent at 2100 meters. Winter snow accumulations are extensive in much of the Cascades and are an important source of summer streamflow. Summer precipitation in the county is limited to occasional light rainstorms and thunderstorms and frequently there are periods of from 60 to 90 days with no rainfall.

The prevailing winds are from the north and north-west during the summer and from the south and south-west during winter storm periods. Wind velocities are moderate; the highest wind velocity every recorded at Roseburg was 64 Kph.

Seasonal temperature variations are relatively small in the valley area of the county. Winter temperatures below -12^{o}C. and summer temperatures above 38^{o}C. are rare. Maximum temperatures at Roseburg during the four summer months normally range from 23 to 29^{o}C., although temperatures as high as 41^{o}C. have been recorded. The average minimum January temperature is 0.8^{o}C. Some freezing of short duration occurs in the valley every winter. Temperatures in the Cascades are generally cooler and seasonal variations greater than elsewhere in the county.

The frost-free season in most of the valley areas of the county is from April to October, a period of 190 to 220 days.

The soils of Douglas County are described in nineteen associations (USDA-SCS, 1974) ranging from deep well-drained soils on coastal terraces with undulating to steep slopes to cold, well-drained, shallow to moderately deep, gently sloping to very steep soils developed from igneous rocks of the High Cascades.

The associations are grouped into seven major types. Group #IV, containing the most soils, is described as being found in areas dominated by well-drained to moderately well-drained shallow to deep, gently sloping to very steep soils developed from sedimentary and igneous rocks of the Middle Umpqua foothills and mountains.

Of the five associations included in this group, two were selected for investigation as potential soils for future housing development; the Oakland-Sutherlin and the Willakenzie-Bellpine. The soil described at the Sutherlin experimental site is classified as a Willakenzie (Appendix A).

Group #VI, areas dominated by somewhat excessively drained to moderately well-drained, shallow to deep, strongly sloping to very steep soils developed from sedimentary, metamorphic, and igneous rocks of the Klamath Mountains, contains three associations, one of which was also chosen for study as a future drainfield site. This was the Josephine-Beekman-Colestine, which includes the moderately deep Speaker series described at the Clark's Branch experimental site.

Sutherlin Experimental Site

The first site was located in the area just west of the town of Sutherlin, Oregon, in a valley occupied by the confluence of Green Valley and Calapooya Creeks. It is the approximate center of an area designated as the Calapooya Creek Syncline of the Roseburg Formation (Baldwin, 1974), a recent redefinition of the old Umpqua or lower Umpqua Formation. The formation in the specific area of the experimental site is described by Baldwin as one of the two most continuous sedimentary sections of the Formation and is composed of "approximately 2,438 meters of sedimentary beds composed of dark-gray tuffaceous siltstone grading upward into more rhythmically bedded sandstone and interbedded siltstone."

The topography of the area is that of low rolling hills disected by creeks flowing west to the Umpqua River. The soils are included in the Oakland-Sutherlin association (USDA-SCS, 1974) and are similar to those found on the high terrances and surrounding hills of alluviated valleys, such as the Camas and Lookingglass Valleys. They are classified as Haploxeralfs, characterized by loam or silty clay loam.A horizons over silty clay loam Bt horizons and moderately deep to deep to sedimentary bedrock. Another associated soil is Nonpareil (Dystric Xerochrept), which is loamy and shallow over sedimentary bedrock.

These soils are moderately well to well-drained with permeability ranging from moderate in the Nonpareil to moderately slow in the Oakland and very slow in the Sutherlin. Typically, these soils form a toposequence--Nonpareil occupies ridges and steeper slopes, Oakland is on intermediate slopes, and Sutherlin is on pediment footslopes and terraces. .

The Willakenzie-Bellpine association is also described in Group #IV and has similar morphology to the Oakland-Sutherlin association. The Willakenzie series is an Ultic Haploxeralf and has a silty clay loam A horizon over a silty clay loam Bt and is moderately deep over siltstone. It falls in the conductivity type III category (Bouma, 1974a), as do Nonpareil, Oakland and Sutherlin. Based on the profile description and associated lab data, this series provided the best fit for the soil at the Sutherlin site. (See profile description and modal profile in Appendix A for Willakenzie series.) The Willakenzie is well-drained with moderately slow permeability and corresponds to the Oakland series in the described toposequence.

Clarks Branch Experimental Site

The second site was located 16.1 km south of Roseburg and 2.4 km east of the Clarks Branch-Round Prairie interchange with Interstate 5. It is situated at 244 meters elevation on 26% slope on the side of a slightly dissected drainageway, which joins Clarks Branch flowing to the South Umpqua one mile away. The aspect is south-southeast. The bedrock of the area is Pre-Tertiary sediments (Baldwin, 1974), of rhythmically bedded sandstone and siltstone, probably allied to the Days Creek Formation. The site lies midway between two northeast-southwest trending fault lines. The terrain is that of rolling uplands covered with Douglas-fir mixed with madrone. In the cleared areas, grass and forbs compete with poison oak and wild rose for the available water on the mostly shallow, loamy soils. Slopes are generally over 30 percent on the pediment backslope. There is moderate erosion evident when the soils are cleared for pasture or houses and not reseeded before the winter rains.

The soils of the area are shown as the Oakland-Sutherlin association and the Josephine-Beekman-Colestine association (USDA-SCS, 1974).

The Speaker taxajunct soil described at the experimental site has a light colored, loam A horizon over a brownish to reddish loam Bt horizon and is moderately deep to fractured siltstone. This soil fits Conductivity Type II (Bouma, 1974a). It differs somewhat in texture from major soils of the two associations described above. It is similar to the Rosehaven and the Speaker series, both Ultic Haploxeralfs, but has less clay than either, and also differs from Rosehaven in the depth to bedrock, and the colors of the Bt. Both series have moderately slow permeability and are well-drained. (See soil profile descriptions of the experimental sites and modal profiles for Rosehaven and Speaker in Appendix A.)

METHODS AND MATERIALS

Introduction

Criteria for selection of the two experimental sites included: soils typical of southwestern Oregon with similar profile and slope characteristics, considered marginal by the Department of Environmental Quality for drainfields; proximity to an operating septic tank to provide household effluent; and the owner's permission for access to install and monitor the site. An extensive search was required to locate willing co-operators for this project, especially when the county has so recently been required to enforce the current Rules for drainfield site selection. The tightening of requirements, the accompanying inspections, applications and fees have produced a general atmosphere of suspicion of motives whenever a stranger is interested in a homeowner's drainfield. Consequently, many interviews of homeowners at likely sites were required to produce even a few possibilities. This was coupled with the lack of a detailed soil survey in the county, which made it necessary to personally inspect many areas before two that were sufficiently similar and on the desired soils could be located. Eventually, two such sites were located and experimental drainfields were designed to duplicate effluent loading of standard systems.

Installation of Experimental Sites

The chief consideration in the selection of the experimental sites, after selecting the desired soils and finding similar sites for replication, was the availability of household effluent. This was necessary in order to test the drainfields under conditions related to normal drainfield use. Therefore, functioning systems which could supply effluent were required. Drainfield dimensions were determined by the size of the suitable soil area available, slope considerations, separation from the original drainfield, location of trees interfering with installation, and the mechanics of the pumping equipment used to divert effluent from the old drainfield to the experimental field.

The chief problem in the design and installation of the system was the need to divert a measured portion of the household effluent going to the original drainfield to the experimental field. This was accomplished by installing a sump at each site consisting of a 190 liter paint drum, coated with asphalt emulsion, into which all the septic tank effluent was diverted. Two sump pumps, equipped with one set of mercury float valves, were installed in the sump. One pump was connected to the original system and one to the experimental system. The float valves were wired to a control box designed to switch operation from one pump to another, delivering three-quarters of the daily effluent to the old system and one-quarter to the experimental, in the case of the Sutherlin system and one-half for the Clarks Branch system. This delivered exactly the same amount per square foot of effective sidewall as in the original standard drainfield but the amount varied from day to day as it would in a normal field.

Automatic counters were wired into the pump switching assembly to record the number of times the pumps operated. These could be manually reset each time the systems were inspected. Calibration of the pumped volume in each sump, times the numbers of dosings, equalled the volume flowing to each drainfield.

A curtain drain (Figure 2) was installed at the Sutherlin site perimeter of the experimental site to prevent contamination by effluent from the old drainfield entering the new, since there was a total distance of about 12 meters between the old field's bottom line and the top line of the new. The curtain drain was dug into the fractured siltstone to a total depth of 1.2 meters at the deepest point directly upslope from the center of the new drainfield, and was slowly tapered off to ground level some 15 meters downslope and to the side of the drainfield. On the other side, at the other end of the line, a 1.8 by 1.5 by 2.4 meter deep sump was dug into the siltstone, filled with sand and equipped with a capped sample well, uncased (Figure 3).

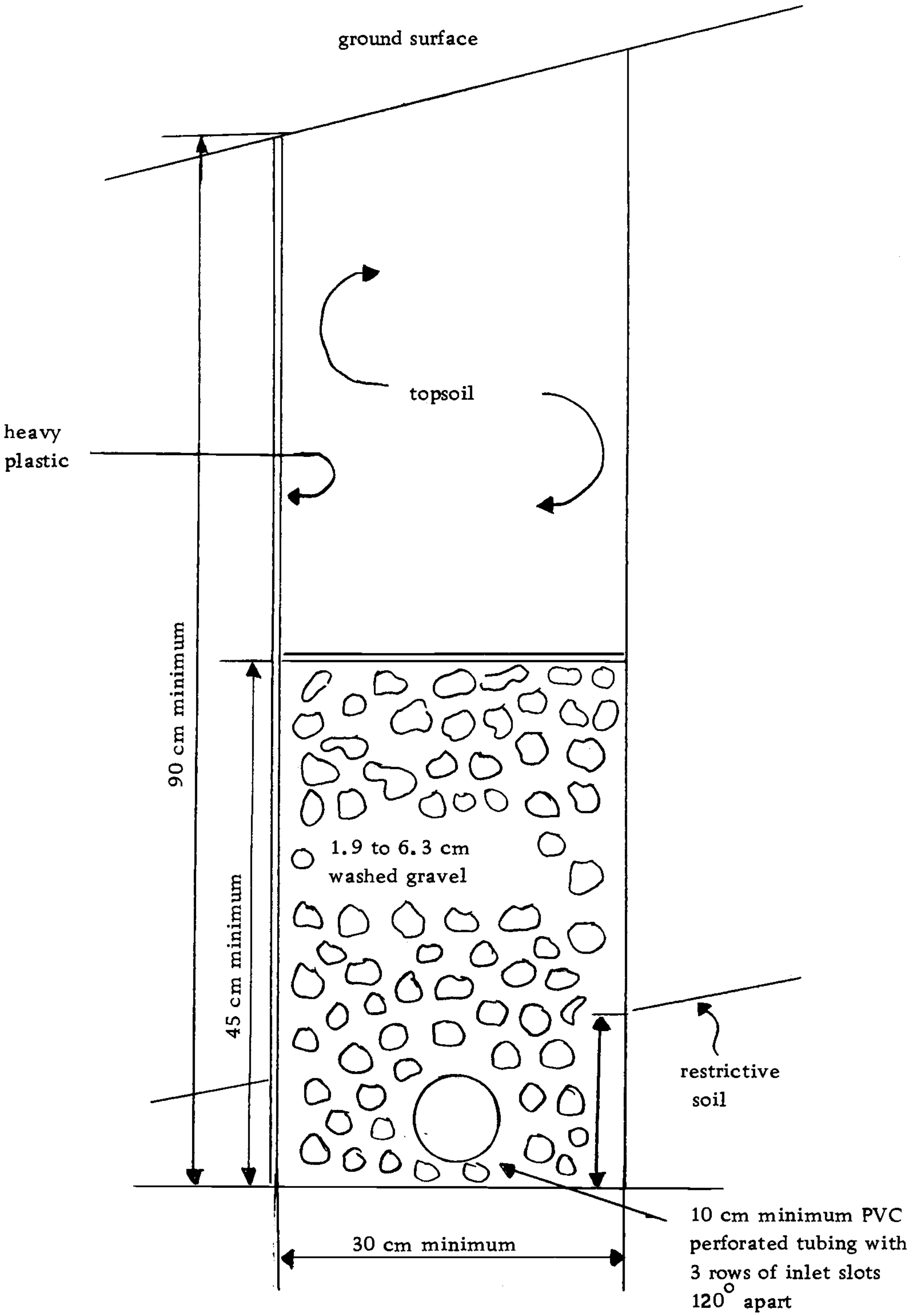

Figure 2. Curtain drain design.

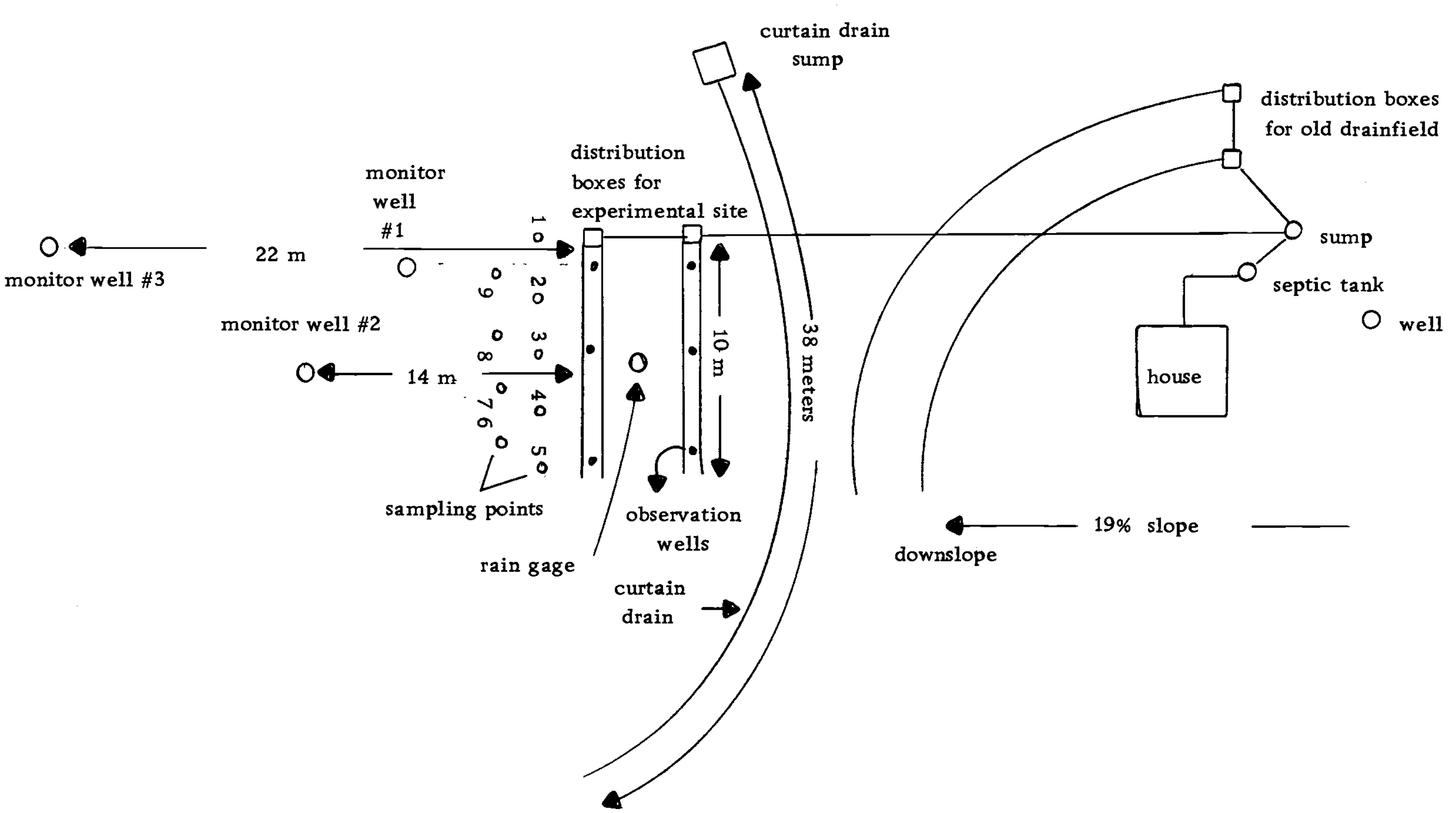

Figure 3. Arrangement of Sutherlin experimental drainfield with respect to original drainfield.

It should be noted that the original drainfield at Sutherlin was one year old at this time and appeared to be functioning properly.

The drainfield trenches at each site were excavated by conventional backhoe method, 0.61 meters deep and with as uniform grade as possible to meet the standard of less than 5 cm of fall per 30.48 meters set up by the Rules of the Department of Environmental Quality. The trenches at the experimental sites were dug by the best qualified backhoe operators as determined by the County Sanitation Department, operating free of other commitments and checked with a good surveyor's level. However, even with the most careful supervision and frequent checking, it proved to be difficult to meet the standard for allowable fall in all the lines. The resultant figures, surveyed after completion of the trenches, added up to a total fall of 4.2 cm in the upper trench at Clarks Branch, 3 cm in the lower, and slight dips and rises in the total 16.76 meter length (Figure 4). At the Sutherlin site, total fall in the top trench was 5.7 cm and 4.2 cm in the lower, combined with dips and rises (Figure 5) in the 10.67 meter length.

The trenches were dug without regard for penetrating any restrictive layer or the fractured siltstone below (Figure 6). The trenches were bedded with 5 cm of drainfield rock, the flexible 10 cm PVC distribution pipe with 1.25 cm perforations was laid with the holes downward in the trench. In the Sutherlin site the pipe

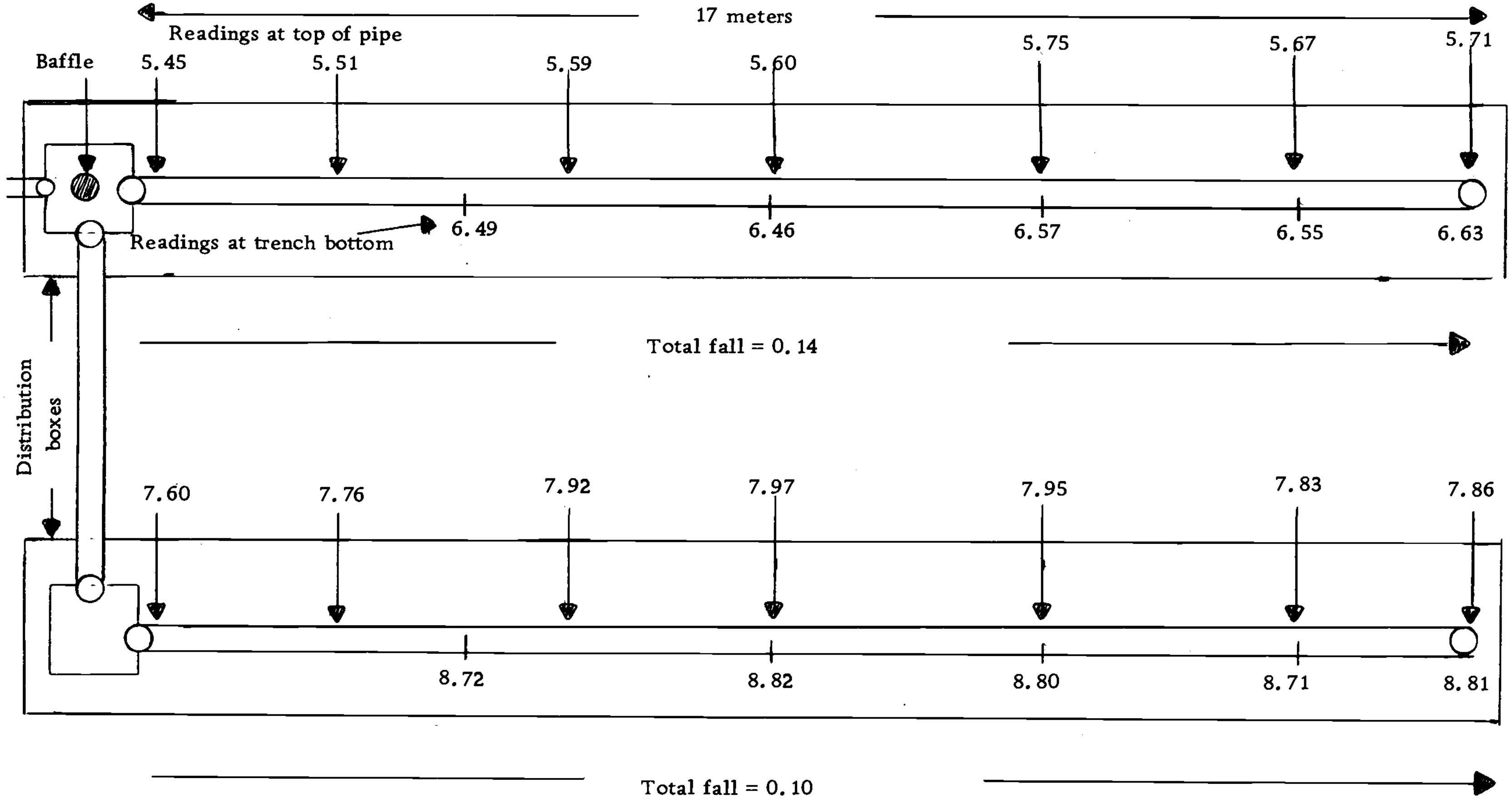

Figure 4. Diagram of drainfield construction - Clarks Branch site.

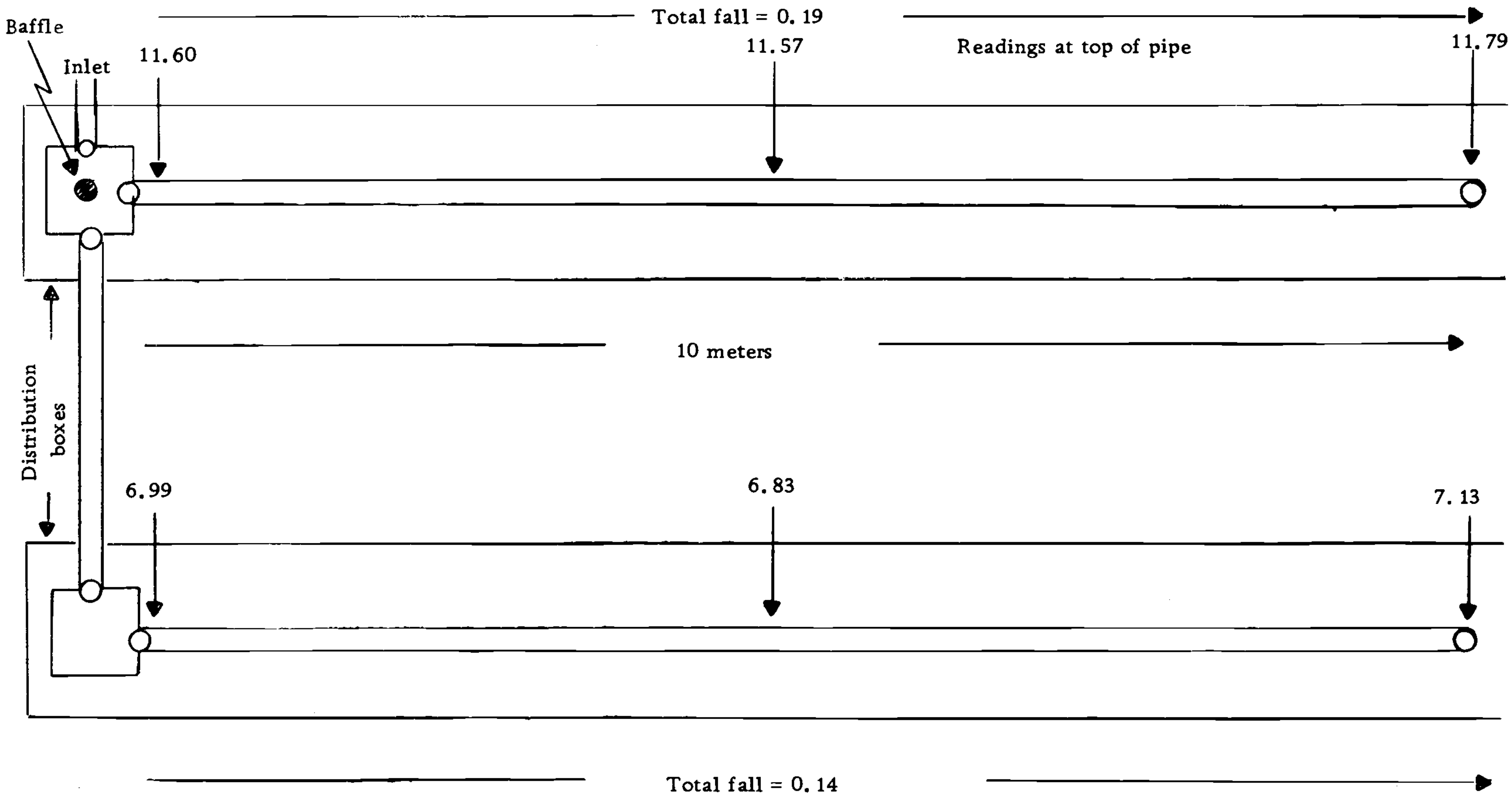

Figure 5. Diagram of drainfield construction - Sutherlin site.

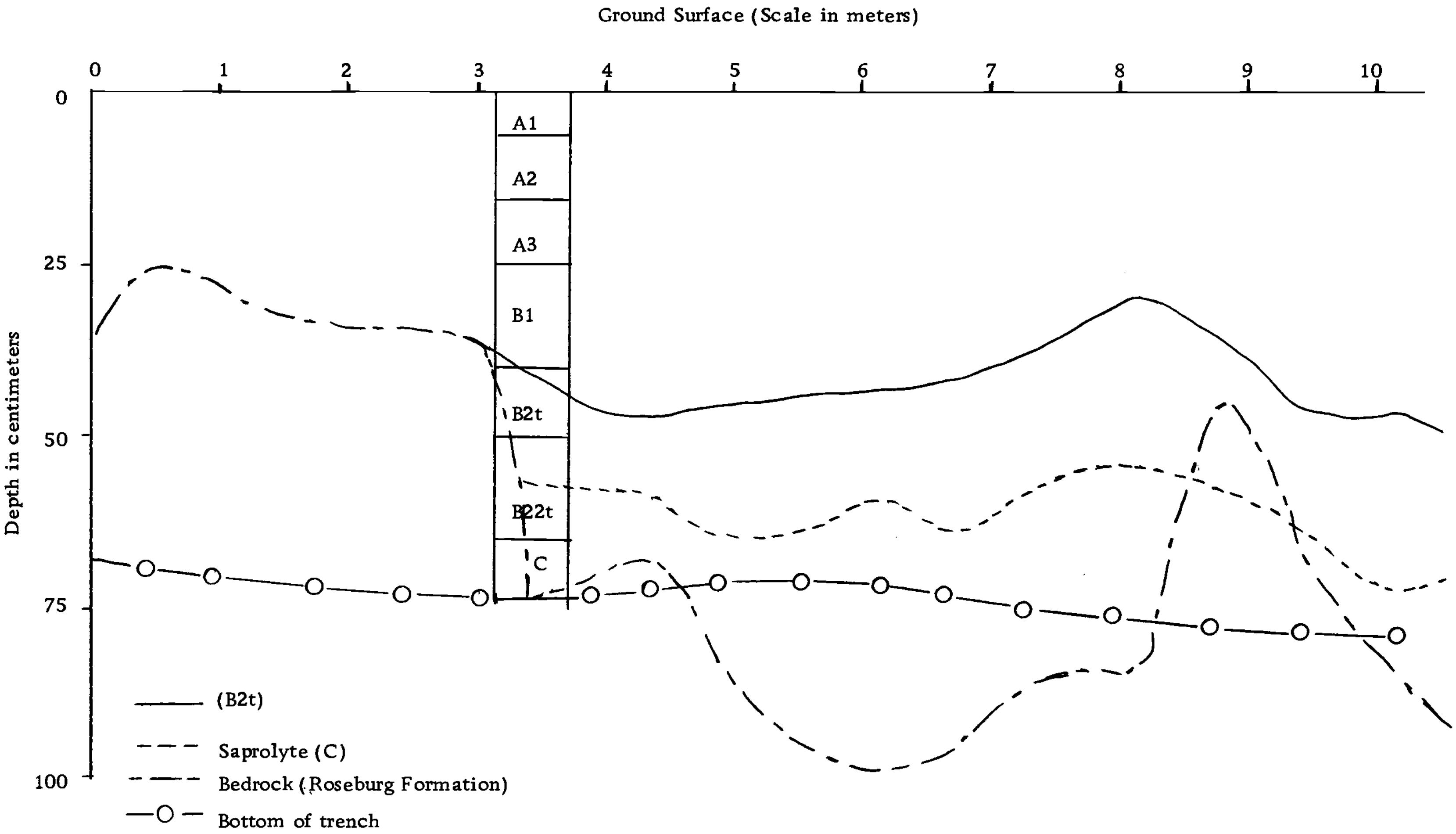

Figure 6. Cross-section of upper trench at Sutherlin with location of described soil profile.

was laid with 0.5 cm of fall in each trench. At Clarks Branch site, the pipe was laid with 0.65 cm of total fall. However, both pipes showed dips and rises after being partially buried with drainfield gravel. It was impossible to lay the pipes perfectly level with mechanized equipment.

Fifteen cm of regulation drainfield rock (1.9 - 6.3 cm. diameter gravel) covered the perforated plastic pipe. Then it was covered with untreated building paper and backfilled with on-site material. The distribution boxes were left open but covered with plywood enclosures to allow inspection for settlement and allow for sampling of effluent.

Since the systems were partially pressurized due to effluent being delivered by a pump in increments, only a baffle at the first distribution box was required to accomplish equal flow.

Effluent levels in the distribution trenches of the experimental drainfields were monitored through 1.5 cm PVC conduit installed to bedrock. Three conduits were placed in each trench, spaced at 3-meter intervals. The center point was on the upslope side of the distribution pipe, and the first and last points were on the downslope side.

Both drainfields were equipped with piezometer wells of 7.5 cm. PVC conduit, slotted by a saw blade up to 45 cm. from the bottom. The conduit was installed in auger holes drilled to the saprolyte layer in each drainfield. Winter inspection of the two areas by auger showed that no restrictive layers were present and maximum saturation occurred in an approximately 7.5 cm. layer directly above the saprolyte. Between this layer and unweathered bedrock the soil was markedly below field capacity. It was assumed that any evidence of bacterial movement from the drainfields would be found in the soil water carried downslope in the saturated zone. All conduit was sunk to this layer, sealed with backfill and a grout sleeve (which was mounded slightly on ground surface to divert precipitation from the well) and fitted with a tight PVC cap. The sampling points were located in a pattern calculated to intercept the major avenues of subsurface flow in all areas (Figures 3, 7).

Soil and water samples were taken from October 1975 to April, 1976. This period represents conditions of maximum saturation.

The water samples were obtained by bailing with a disposable paper cup attached to an aluminum rod if water levels were sufficient to allow this procedure. If only minimal amounts were available, a small hand suction pump hooked to a sterile 100 ml Nalgene collection flask equipped with sterile Nalgon tubing was used to withdraw whatever sample was obtainable. Unfortunately, this situation was often the case and turbid samples were a frequent occurrence.

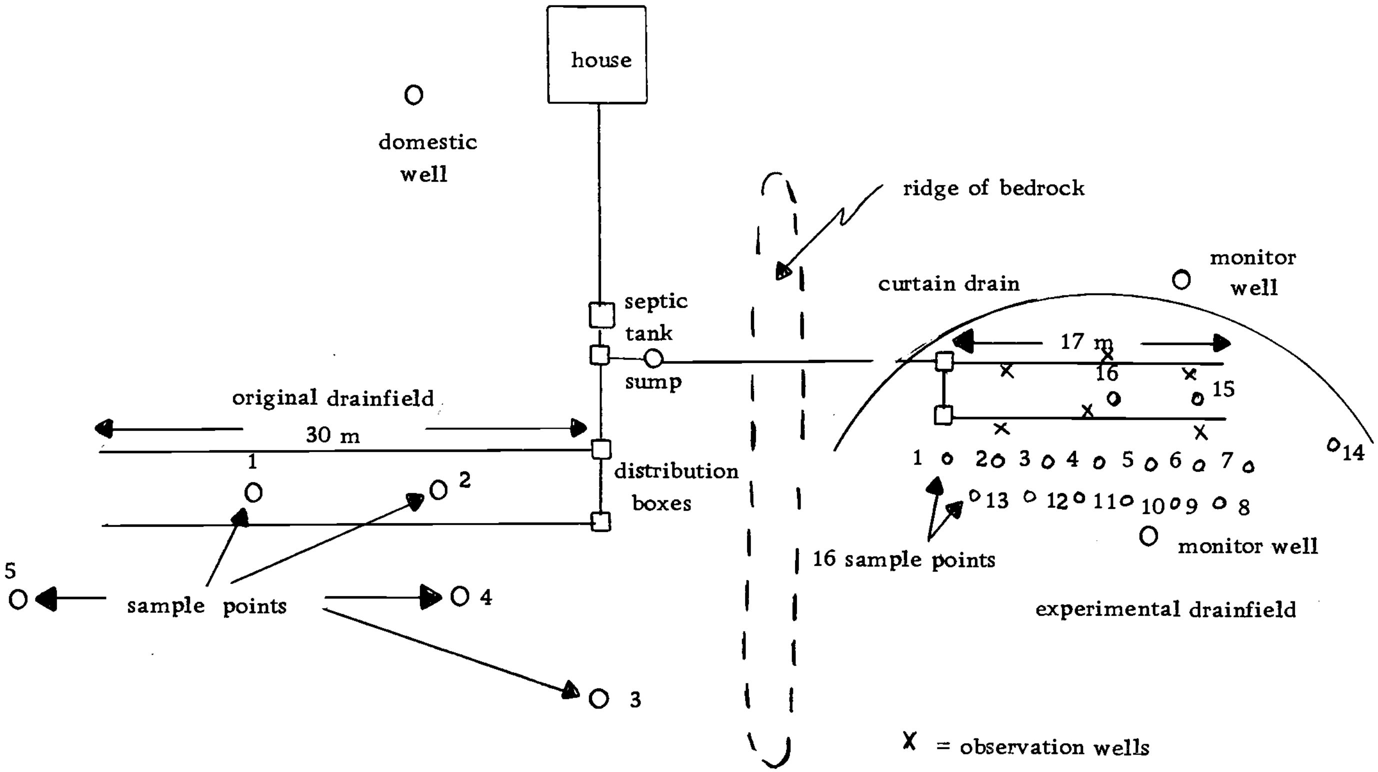

Figure 7. Arrangement of Clarks Branch experimental drainfield with respect to old drainfield.

The tubing extended to within 1.25 cm of the restrictive layer and allowed sampling of very small amounts of soil solution. It also reduced the turbidity associated with other methods tried for sampling, as it was found that large amounts of suspended material hampered microbiological assessment of the sample. The above described sample apparatus was also small enough when installed that it was possible to remove soil samples from the bottom of the pipe with an Oakfield soil sampler for microbiological analysis when the soil solution dropped below the end of the tubing.

Soil samples were also collected from the drainfield ground surfaces with sterile tongue depressors for bacteriological analysis.

Downslope from the sample points at the Sutherlin site three deep monitoring wells were dug by a backhoe at the time of the drainfield installation. The upper two were dug into fractured siltstone between 1.3 and 2 meters. The well farthest downshope was dug to the limits of the backhoe's reach, approximately 3 meters deep through soil and extended into a gleyed silty clay layer. The pattern of the wells was staggered to assure intercepting the path of the subsurface flow from the drainfield. Each well was equipped with a maximum-minimum water level recorder, with a sampling apparatus as described above. The pipes were perforated as described above to a height of 60 cm from the bottom of the well, backfilled in place, tamped and insulated from surface seepage by a layer of heavy black plastic covering the total of the disturbed ground and sealed to the pipe with duct tape. The plastic was covered with soil to hold it in place and the top of the pipe was grouted for extra protection.

At the Clarks Branch site, it was noted that the original drainfield appeared to be failing, as evidenced by extremely heavy vegetation at the end of the lower trench and surfacing effluent.

This system was installed by the owner six years previously, before Douglas County began a formal permit system. Therefore, no diagram of the system exists and no inspection was made of the lines before covering to insure that they and the distribution boxes were level. The owner stated that the lines were put in with a hand level, which is unreliable for the accuracy required to insure the lines do not fall more than 5.1 cm in every 38.1 meters, as per the regulations. Therefore, excessive fall in the lines and/or unequal distribution may have caused the failure.

The soil, inspected with a hand auger, had approximately 76 to 89 cm of loam over a band of clay loam some 10.2 cm thick over saprolyte with a texture of coarse sandy loam. The slope is 20%. The soil profile is similar to the Speaker taxajunct, of the adjacent experimental site. The saprolytic material has been observed to be uniformly dry or slightly moist in heavy rainfall conditions and not saturated at any time of the year. This indicates that most, if not all, of the rainfall and effluent entering the soil is traveling downslope in and over the restrictive clay loam B3 layer. To remove the new drainfield from any possible influence by the failing drainfield, the new site was located some 61 meters to the northeast, separated from the old field by a rise of ground with very shallow soils, separating two minor drainages within the same watershed. The site was laid out where the slope averages 26% and the soil depths ranged from 50 to over 100 cm deep along a cross slope transect (Figure 7). Parent material and sub-surface configuration of the bedrock contact was similar to that of the Sutherlin experimental site (Figure 3). The rock at each site yielded readily to the backhoe and genuinely hard (non-rippable) bedrock was not encountered.

The new experimental drainfield was made one-half the size of the old drainfield, consisting of two 15 meter lines, providing 11.14 sq. meters of effective sidewall.

A curtain drain (Figure 3) was dug at a distance of 1.83 meters upslope from the top line and curved around the perimeter of the drainfield, daylighting at both ends below the drainfield. The east end was left open to check on the efficiency of the drain and screened to prevent entry of small animals.

The sump was installed, as described previously, with an electrically operated counter-switching box, delivering half the effluent to each drainfield. Since the effluent had to be pumped upslope and then down, a vacuum breaker was installed in the 3.1 cm line to prevent siphoning.

Sampling points were installed on both the new drainfield and on the old, both between lines and below them (see Figure 7). These were driven through the restrictive layer and penetrated the saprolyte below. The sample points were positioned to intercept the subsurface drainage pattern as evidenced by the topography. All were equipped with nalgon tubing as described previously for sample withdrawal.

<u>Bacteriological Analyses Procedure</u>

All soil and water samples were transferred immediately to 20 ml vials of prepared lactose broth equipped with Durham tubes and brom thymol blue indicator. The lactose broth vials were prepared as follows:

Beef extract	3.0 gms
Peptone	5.0 gms
Lactose	5.0 gms
Distilled water 1 liter	

Brom thymol blue indicator stock solution: 0.016 gm/l. of 1:1 95% ethanol and water.
Add 1 ml. of the stock solution per 100 ml of lactose broth.

The media was poured into the 20 ml vials, loosely capped and autoclaved to sterilize. They were stored at 4°C. until used. Sterile procedure was used as much as possible in the field to transfer the samples to the vials. One gram of soil or 1 ml of water was added to the vials. They were immediately recapped and inverted several times to distribute the sample. The vials were incubated for 24 hours at 37°C. and inspected for gas production and/or color change of the indicator. If no change had occurred or only one of the possible changes had occurred, the vial was incubated for another 24 hours at the same temperature. All vials were considered as positive if gas production occurred within 48 hours.

The combination of lactose broth and brom thymol blue indicator makes the test fecal coliform specific (Standard Methods, 1971), and it is unlikely that any number of false positives could occur. To reduce the number of false positives still further, the vials were run in conjunction with some other type of test such as M-FC broth on a Millipore filtration, with EMB plates, or with MPN serial dilutions. In no case were any of these tests positive while the lactose vials were negative. The composition of Eosin Methylene Blue Agar and M-FC broth (Standard Methods, 1971) is as follows:

Levine's Eosin Methylene Blue Agar (EMB)	
Peptone	10 gms
Lactose	10 gms
K_2HPO_4	2 gms
Agar	15 gms
Eosin Y	0.4 gms
Methylene blue	0.065 gms
Distilled water	1000 ml

Millipore-Fecal Coliform Broth* (M-FC)	
Tryptose	10 gms
Polypeptone	5 gms
Yeast extract	3 gms
Sodium chloride	5 gms
Lactose	12.5 gms
Bile salts No. 3	1.5 gms
Distilled water	1 liter
Analine blue	0.1 gms

*Must be rehydrated in distilled water containing 10 ml of 1% rosolic acid in 0.2 N NaOH.

EMB plates were pre-incubated at 37°C. overnight, then innoculated and incubated for 48 hours at 37°C. Fecal coliform counts were based on colonies with green metallic sheen on EMB.

M-FC broth plates were incubated at 44.5°C. for 24 hours. All blue raised colonies were counted as fecal coliforms.

Random water samples were also plated on EMB as a check, using 1 ml of sample pipetted on to the plate and rotated to distribute.

A bulk soil sample was also taken for microbiological analysis from the #1 well at the old drainfield at the Clarks Branch site in April, 1976. The soil was weighed moist and dispersed in 0.5% Difco peptone diluent with 0.05% Na_2CO_3 and 0.2% NaCl. A 1:10 dilution was made and 0.1 ml pipetted on an EMB plate for a 1:100 dilution.

All water samples having sufficient volume (20 to 100 ml) were inspected via the Millipore filter method (Standard Methods, 1971). This consists of filtering a sample aliquot of water through a 0.45 micron sterile Millipore filter under vacuum suction, transferring the filter to a plate containing 2 ml of M-FC broth, sealing the plate, inverting it and placing it in a water bath held at 44.5°C. for 24 hours.

All turbid samples were shaken well before withdrawing an aliquot for filtration. Most were restricted to 10 ml if the turbidity was easily visible to the eye when the sample was held to a direct light. Lengthy filtration was required to process the sample if this volume was exceeded.

All M-FC plate results were cross checked by innoculating a lactose broth vial and incubating for 24 hours at 37°C. Theoretically, the 44.5°C. incubation temperature for the plates is more specific for fecal coliforms and less subject to false positives. In no case was this found to be untrue. No plate was found to be positive without a positive lactose vial for acid and gas. The reverse, of course, was not true, as was to be expected considering the amount of turbidity that was routinely encountered.

RESULTS AND DISCUSSION

Sutherlin Experimental Site

Each family occupying the house at the Sutherlin site was averaged separately on the basis of effluent volumes produced. The maximum average liters per day to the experimental system was 284.6 at startup, and the minimum was 100.3 l/day during the summer of 1975. From October 1975 to the conclusion of the project, the average was 123.0 liters per day.

The center (C) and right (R) observation points installed in the trench bottoms in the upper distribution line on the Sutherlin site were equally deep (86 cm) yet the readings differed on several occasions. Both were empty 44% of the time that readings were made (Table 2). From the middle of May through August the center was consistently dry while the right occasionally contained fluid. This was a period of variable effluent volume and little or no rainfall. Two cm of rain in August did not produce liquid in the center point, lacking effluent in the lines, but a record high volume of effluent (403 l/day) the next month produced 12.5 cm (measured from the trench bottom) of fluid in this observation point while the right was dry. This was maintained more or less until the volume of effluent dropped to 103 l/day with 2.7 cm of rainfall. At this point, sludge

Table 2. Compilation of Observation Point Levels in Upper and Lower Trenches, Seven Day Precipitation Prior to Measurement and Effluent Volumes to the Sutherlin Experimental System, March 28, 1975 through April 28, 1976.

Date	Upper Trench L[a/] (cm above trench bottom)	Upper Trench C[b/]	Upper Trench R[c/]	Average of Readings	Lower Trench L (cm above trench bottom)	Lower Trench C	Lower Trench R	Average of Readings	Ppt. preceding 7 days (cm)	Average Effluent Volume in liters/day
Two adults - two children										
March 28	10.0	5.0	1.25	5.4	20.0	0.0	10.0	10.0	7.5	383.4
April 6	11.25	0.0	17.5	9.6	21.25	0.0	7.5	9.61	1.35	280.5
April 16	8.75	3.75	22.5	11.7	15.0	0.0	1.25	5.4	2.58	228.6
April 24	8.75	10.0	26.3	15.0	17.5	0.0	6.25	7.9	2.08	Vacant
Two adults										
May 5	10.0	8.75	30.0	16.3	21.25	0.0	5.0	8.8	1.48	121.0
May 13	2.5	0.0	2.5	1.7	10.0	0.0	5.0	5.0	1.43	48.8
May 20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.53	Vacant
May 27	3.75	0.0	0.0	1.3	10.0	0.0	0.0	3.3	0.60	67.4
Two adults - two children										
June 6	11.25	0.0	0.0	3.8	16.25	0.0	0.0	5.4	0.00	121.9
June 12	12.5	0.0	27.5	13.3	20.0	0.0	0.0	7.0	0.00	250.2
Two adults										
June 26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	46.6
July 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	45.0
August 20	5.0	0.0	0.0	1.7	5.0	0.0	0.0	1.7	1.93	-----
Two adults - two children										
September 15	11.25	12.5	0.0	7.9	20.0	0.0	0.0	7.0	0.48	402.7
September 25	10.0	15.0	0.0	8.3	20.0	0.0	0.0	6.7	0.00	196.1
September 28	8.75	7.5	0.0	5.4	13.75	0.0	0.0	4.6	0.00	210.4

Table 2. Continued.

Date	Upper Trench L[a]	C[b]	R[c]	Average of Readings	Lower Trench L	C	R	Average of Readings	Ppt. preceding 7 days (cm)	Average Effluent Volume in liters/day
	(cm above trench bottom)				(cm above trench bottom)					
Two adults - one child										
November 3	11.25	0.0	0.0	3.8	20.0	0.0	0.0	6.7	2.70	103.3
November 13	10.0	12.5	0.0	7.5	17.5	0.0	0.0	5.8	4.65	121.9
November 24	10.0	0.0	0.0	3.3	15.0	0.0	0.0	5.0	3.98	53.4
December 3	2.5	0.0	0.0	0.8	10.0	0.0	6.25	5.4	5.77	-----
December 19	7.5	5.0	7.5	6.7	15.0	6.25	7.5	9.6	0.73	238.1
January 16, 1976	12.5	17.5	17.5	15.8	21.25	0.0	18.75	13.3	3.05	143.8
January 23	12.5	12.5	17.5	14.2	20.0	0.0	0.0	6.7	0.31	124.5
January 30	10.0	12.5	20.0	14.2	21.25	0.0	0.0	7.1	0.16	146.1
February 6	15.0	12.5	20.0	15.8	20.0	0.0	5.0	6.7	0.0	158.6
February 13	12.5	17.5	30.0	20.0	22.5	0.0	0.0	7.5	0.31	133.6
February 24	7.5	0.0	0.0	2.5	15.0	0.0	0.0	5.0	3.59	78.3
March 8	13.75	0.0	30.0	14.6	25.0	0.0	0.0	8.3	3.75	107.1
March 17	13.75	15.0	27.5	18.8	22.5	0.0	0.0	7.5	0.31	104.1
March 25	13.75	20.0	32.5	22.1	23.75	0.0	7.5	10.4	6.86	111.7
April 1	13.75	18.75	32.5	21.7	25.0	0.0	11.25	12.1	2.03	109.1
April 8	5.0	0.0	0.0	1.7	13.75	0.0	17.5	10.4	0.0	90.1
April 14	11.25	13.75	7.5	10.8	20.0	0.0	0.0	6.7	1.40	105.2
April 28	13.75	17.5	20.0	17.1	23.75	0.0	0.0	7.9	2.03	97.7

[a] End of trench nearest distribution box.

[b] Center of trench.

[c] End of trench farthest from distribution box.

was observed in the trenches with a probe inserted in the wells. In the next week (November 13) with 4.65 cm of rainfall and 122 l/day, effluent was again observed in the center well while the right was dry. During the weeks of November 24 and December 3, with very little or no effluent volume but with 9.75 cm of rain, both points were still devoid of effluent.

In the third week of January, 1976, sludge was again found in connection with a reading in the center observation well in the upper trench. It followed a total of 16.5 cm of precipitation in the preceding thirteen days. The volume of effluent at this point was only 20% above average but coupled with high intensity--short duration precipitation, anerobic conditions appeared to prevail and saturated trenches filled with ponded fluids resulted.

This situation prevails through March and April with only a few deviations.

The center well on the lower trench only contained fluid once--after nine months of use. This occurred under low rainfall conditions and moderate volumes (238 l/day) of effluent. However, the second highest seven-day precipitation had occurred in the previous two weeks. This response may reflect the buildup of a clogging mat, since previous high levels of effluent and high rainfall at startup of the system failed to produce an equivalent response.

Sludge or ferrous compounds were formed in the upper trench during the dry period described above. It is suspected that the temperatures may have been too cool for rapid microbial action and hence the clogging mat persisted (McGauhey and Krone, 1967). Though rainfall remained below average during the last of February and through most of March, effluent levels remained high in the upper trench, accompanied by sludge evidence which persisted through April. The lower trench developed the first evidence of ferrous compounds in March but it did not persist, or was not detectable, beyond the end of the month.

It appears that rainfall influenced trench levels of fluid but there are a few anomolous points. The recording of the appearance and disappearance of the sludge with an aluminum rod inserted in the wells may not be wholly accurate, barring opening the trenches every week. Considering the high effluent levels when no rainfall has fallen for weeks, it may be safe to assume the clogging zone is there. However, the levels also may reflect a recent dosing of the field, since there is no way to ascertain precisely how long it was between pumpings. However, considering the small amount (86 liters) pumped each time, it is quite certain that no single dosing could produce levels of 30 cm or more in the trench ends unless the amount of fall in the lines did not allow equilibration.

The following conclusions may be drawn from Figure 8, a graph of averaged effluent levels for both the upper and lower

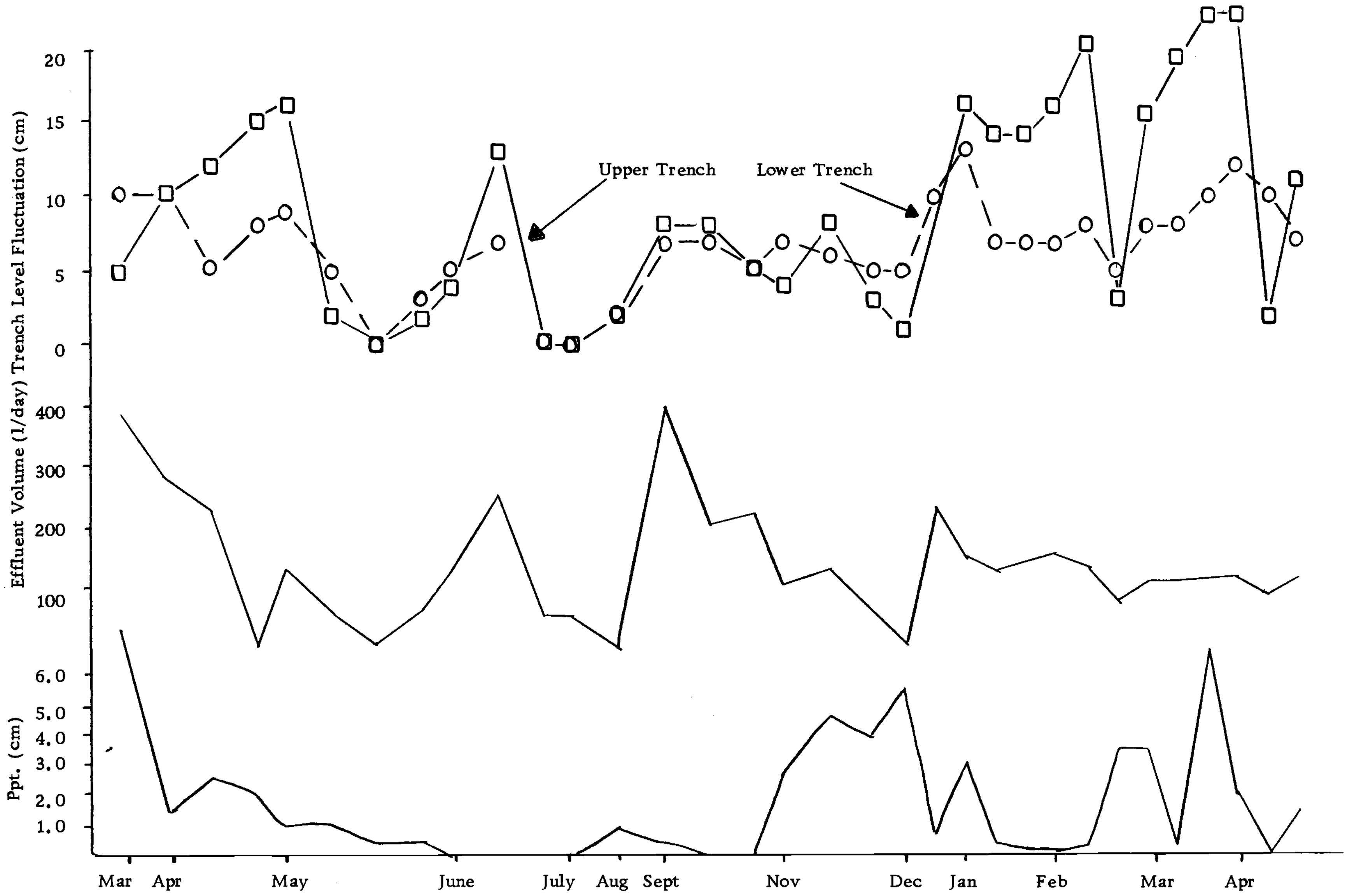

Figure 8. Observation point levels in trenches, seven-day Ppt. and effluent volumes, Sutherlin.

trenches, compared with average volume per day and precipitation.

The curve for the lower trench appears to roughly follow the volume curve.

The curve for the upper trench has no discernible correlation to either variable for the first few months of operation. Thereafter, it can only roughly be compared with volume of effluent and precipitation.

Clarks Branch Experimental Site

The effluent volume measurements at this site were divided into three groups. The first group, averaging 340 l/day, included the measurements from initial startup of the system in March, 1975 to June 26, 1975, just prior to a three week vacation taken by the family occupying the house at the site.

Upon their return it was found that the house well pump had to be pulled and repaired. The well static head was also low and water useage by the family was severely curtailed. Therefore, the second group of measurements, averaging 228 l/day from August 5, 1975 to December 8, 1975, showed a significantly lower average volume than the first group.

During December, the house was put on a community water supply but the combination of costlier water and continued low pressure lowered water consumption even further. Hence the third and last grouping averaged 189 l/day.

The total average volume of the three groups was 252 l/day. After initial startup, both the upper and lower trench had a slight but persistent ponding which increased in volume until both trench ends were some 20 to 27.5 cm deep in fluid, as contrasted to levels of 2.5 and 12.5 cm nearest the distribution boxes. The upper trench showed the greatest inequity in distribution consistent with its greater fall. This ponding may also have been a response to several large rainstorms, closely spaced, and an increasing inability of the curtain drain to effect diversion of a major part of the subsurface flow. However, considering what 2.5 cm of rain on the drainfield areas equates with in volume (2602 liters over 102 square meters) then 16 cm of rain over eleven days on the same area equates with 16,653 liters or more than seven times more rain than effluent per day. It is perhaps surprising that the level of fluid in the trenches was not higher. In addition, the soil on the east side of the drainfield, where the trenches end, is somewhat deeper (Appendix B) and forms one side of a topographically defined drainageway. Hence, increasing fluid levels in the trenches from west to east may reflect the position of the drainfield in part of the local recharge collection pattern.

Table 3 shows that the lower trench's center observation point recorded a level only once. Because one or both of the wells at the

Table 3. Compilation of Observation Point Levels in Upper and Lower Trenches, Seven Day Precipitation Prior to Measurement of Levels and Effluent Volumes to the Clarks Branch Experimental System, March 14, 1975 through May 12, 1976.

Date	Upper Trench L[a/]	Upper Trench C[b/]	Upper Trench R[c/]	Average of Readings	Lower Trench L	Lower Trench C	Lower Trench R	Average of Readings	Ppt. preceding 7 days (cm)	Average Effluent Volume in liters/day
	(cm above trench bottom)				(cm above trench bottom)					
March 14	3.75	5.0	2.5	3.8	2.5	0.0	1.25	1.25	0.25	-----
March 20	5.0	0.0	2.5	2.5	10.0	0.0	7.5	5.8	2.47	-----
March 28	2.5	8.75	27.5	12.1	12.5	1.25	20.0	11.3	3.83	352.8
April 6	0.0	7.5	11.25	6.3	7.5	0.0	12.5	6.7	0.64	143.1
April 15	2.5	10.0	27.5	13.3	10.0	0.0	6.25	5.4	0.62	255.5
April 24	5.0	6.25	25.0	12.1	10.0	0.0	12.5	4.2	0.42	304.3
May 5	7.5	5.0	6.25	6.3	1.25	0.0	13.75	5.0	0.45	Septic tank pumped
May 13	5.0	8.75	28.75	14.2	11.25	0.0	12.5	7.9	0.07	391.0
May 20	15.0	8.75	25.0	16.3	11.25	0.0	15.0	8.8	0.30	393.6
May 27	7.5	10.0	25.0	14.2	5.0	0.0	25.0	10.0	0.10	401.2
June 6	10.0	10.0	30.0	26.7	5.0	0.0	10.0	5.0	0.0	306.6
June 12	25.0	12.5	30.0	22.5	5.0	0.0	7.5	4.2	0.0	414.1
June 26	6.25	10.0	27.5	14.6	3.75	0.0	7.5	3.8	0.19	437.2
July 10	Vacation - no levels									
July 23									0.1	
August 5	0.0	0.0	0.0	0.0	7.5	0.0	0.0	2.5	0.09	135.5
August 20	3.75	2.5	0.0	2.1	11.25	0.0	0.0	3.8	0.0	301.7
September 15	7.5	1.25	0.0	2.9	6.25	0.0	0.0	2.1	0.05	255.5
September 25	0.0	0.0	0.0	0.0	5.0	0.0	0.0	1.7	0.0	224.8
October 7	5.0	0.0	0.0	1.7	10.0	0.0	0.0	3.3	0.6	222.6
October 29	10.0	6.25	0.0	5.4	10.0	0.0	0.0	3.3	2.2	250.6
November 18	10.0	7.5	15.0	10.8	10.0	0.0	21.25	10.4	2.75	209.7
December 8	13.75	10.0	18.75	14.2	13.75	0.0	13.75	9.2	3.5	219.9
December 19	2.5	2.5	11.25	5.4	6.25	0.0	5.0	3.8	2.45	Malfunction[d/]

Table 3. Continued.

Date	Upper Trench L[a/]	C[b/]	R[c/]	Average of Readings	L	C	R	Average of Readings	Ppt. preceding 7 days (cm)	Average Effluent Volume in liters/day
	(cm above trench bottom)				(cm above trench bottom)					
January 23, 1976	0.0	0.0	0.0	0.0	0.0	0.0	5.0	1.7	0.0	
January 30	0.0	0.0	0.0	0.0	0.0	0.0	17.5	5.8	0.18	
February 6	0.0	0.0	0.0	0.0	5.0	0.0	0.0	1.7	0.0	
February 13	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.8	0.35	
February 25	2.5	3.75	8.75	5.0	11.25	0.0	0.0	3.8	2.97	194.2
March 9	7.5	6.25	6.25	6.7	11.25	0.0	0.0	3.8	0.70	198.3
March 17	5.0	5.0	5.0	5.0	12.5	0.0	2.4	4.2	0.09	297.9
April 1	12.5	12.5	27.5	17.5	12.5	0.0	17.5	10.0	4.01	213.9
April 8	5.0	0.0	5.0	3.3	12.5	0.0	7.5	6.7	0.0	95.0
April 14	10.0	5.0	5.0	6.7	12.5	0.0	5.0	5.8	0.87	161.6
April 28	6.25	6.25	18.75	10.4	10.0	0.0	0.0	3.3	2.62	197.2
May 12	3.75	3.75	0.0	2.5	10.0	0.0	0.0	3.3	0.0	157.0

a/ End of trench nearest distribution box.

b/ Center of trench.

c/ End of trench farthest from distribution box.

d/ Inlet pipe broken to septic tank - no effluent to system.

ends of the trench contained liquid on every observation date (excepting days when no effluent was in the system) data from the center well seem to be anomolous. Figure 4 shows a slight dip at this point, both in the trench and in the distribution line. Therefore, some ponding should have resulted there. It is possible the port became clogged very early or it was not driven deep enough to record levels comparable to the other observation wells. The data recorded from the central observation point on the upper line lend credence to this last possibility. This point was driven deeper than the points at either end of the trench (93 cm versus 74 and 90 cm) while the lower line's center observation point was driven 65 cm deep, versus 73 and 83 cm at either end.

The upper trench data reflect a response to fluctuating effluent levels through the month of June until effluent ceased entirely in July. The cessation of rainfall did not appear to affect ponding levels (Figure 9). The lower trench levels did not appear to have any discernible pattern. Ponded levels in the trench fluctuated differently from those in the upper line.

Flow was interrupted by pumping of the septic tank on May 5. On this date, ferrous oxide compounds were noted for the first time in the end of the lower line nearest the distribution box. The FeO persisted until the system was given a resting period during a three week family vacation in July.

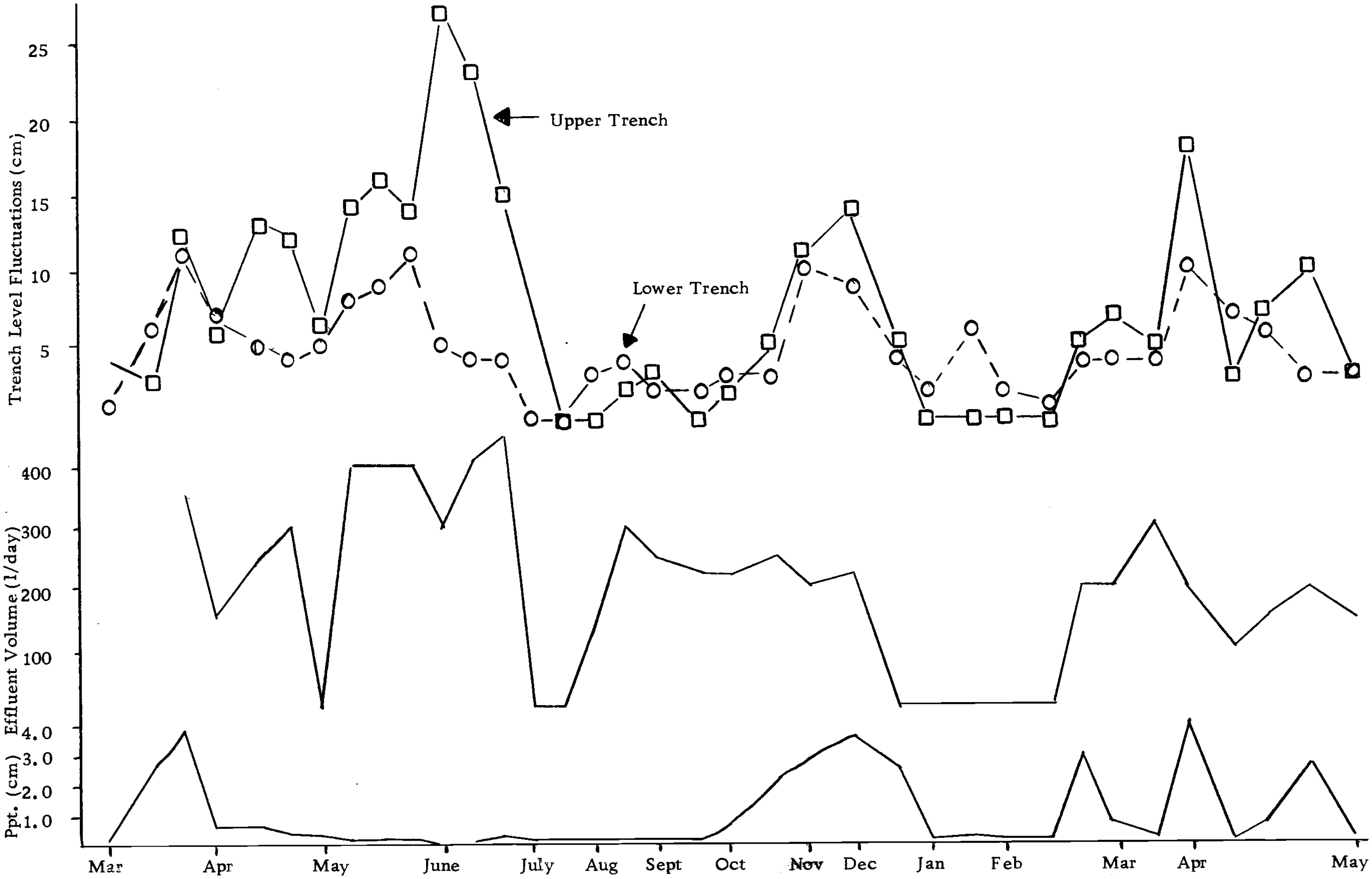

Figure 9. Observation point levels in trenches, seven-day Ppt. and effluent volumes, Clarks Branch.

After resumption of use of the system in the last week of July, a normal loading pattern was observed until November 18. Ferrous compounds appeared in the lower line within two months then disappeared until the first week of December and persisted until the end of January when the lines were completely devoid of effluent due to a malfunction. Effluent levels were persistently lower than the established average for the rest of the experiment due to reduced water levels to the household.

At the end of January, after effluent flow had ceased completely due to a clogged septic tank inlet, the upper line was completely dry. Seasonal precipitation accumulated to that point was 37.5 cm, 10 cm of which had come in the previous two weeks. Recharge probably was occurring, yet the curtain drain was able to prevent groundwater entering the upper line. The lower line, however, contained 17.5 cm of fluid ponded in the end, indicating that once the soil has become saturated, the curtain drain is incapable of diverting subsurface flow completely from the lower part of the drainfield. The data suggest that the curtain drain protects only half to three quarters of the drainfield (51 to 77 sq. meters) on this 26% slope from normal subsurface flow.

Effluent resumed flowing to the bed in February, after a lapse of about one month. The drainfield reassumed approximately the normal loading pattern except that the end of the upper line became ponded by the end of the month. But for some weeks, the "dry season" pattern held. This may have been caused by a low volume of effluent (57% of average) and a period of very low rainfall extending from the middle of January to the middle of February with only light rains (7.25 cm) during the latter part of February. The upper line did not pond until this rain had fallen during the previous week. Clogging compounds, which indicate a return to anerobic conditions appeared in the lower line concurrently with ponding.

Effluent levels during March (Figure 9) were consistently low (about 5 cm) in both trenches. There was no ponding in the upper trench but effluent was ponded in the first third of the lower trench. Sludge had disappeared from both trenches. Rainfall was limited to several large rains in the last part of the month. Because there was very little rainfall (Figure 9) during the early part of March, effluent must have been absorbed at a rate equal to application, and unsaturated flow must have prevailed, thus maintaining an aerobic environment.

Flooding of the trenches during the first week of April was a response to heavy rains in late March. Effluent volumes during this period did not differ substantially from early March values. The effluent levels dropped sharply in the first week of April, simultaneously with the ending of rainfall, and reduction of effluent volume to 36% of normal. Then they rose back to levels that were 17% above average as a temporary curtailment of water pressure to the household was ended. Effluent levels in late April and early May returned to normal loading patterns except for April 28 when deep ponding was noted at the end of the upper trench, due to a high intensity storm just previous to measurement.

Evaluation of the data lead to three major conclusions. The first concerns drainfield installation. It may not be possible, using mechanized equipment, to excavate a perfectly level trench or one that meets the standard laid down by the current Rules (5 cm of fall/ 30 meters). This is especially true when dealing with fractured rock such as the siltstone encountered at both sites. Only hand excavation could approach the precision required. It is necessary to assume most trenches do not meet standards.

Also, every effort was made to lay the distribution lines straight and level, but light flexible PVC has a tendency to bounce when heavy drainfield rock hits it during the burial process, making it very difficult to lay a perfectly level line. It also demonstrates how easily even a well designed and carefully installed drainfield can fail or function improperly. Perhaps a heavier material would be easier to control in this situation, such as rigid PVC or bituminous fiber.

The second conclusion concerns the effectiveness of a curtain drain on steep slopes. Only the upper line, with the second line laid as close as present regulations allow (3 meters), was protected, and even it appeared to be influenced by subsurface flow during heavy rains.

The presence of fluid ponded in the end of the lower line at Clarks Branch during the December-January malfunction (Table 3) cannot be the result of effluent. Instead, it appears to be mostly subsurface flow of precipitation, supporting the hypothesis concerning the limited sphere of influence of the curtain drain. This limit may also be related to the fact that the curtain drain was installed in fractured rock and not in a soil layer. Fractured rock is quite permeable, as is recognized by the current Rules. It will not collect and divert water as a fine textured soil layer will do.

The third conclusion concerns the pattern of occurrence of clogging compounds. Only one reason could explain the absence of ferrous compounds in one of the two trenches at each experimental site. At the Sutherlin site, the line bringing effluent from the sump to the first distribution box pointed downslope or toward the distribution box on the second line (Figure 3), while the line at Clarks Branch (Figure 7) pointed cross slope, or toward the upper line. Therefore, a different line at each site was under partial pressure. The effluent line was only partially baffled from the lines toward which it was pointed. Therefore, every time a dose of effluent surged into the first distribution box, part of it immediately flowed into the line toward which it was pointed. This would effect an immediate, if only slight, innundation of the entire line. The other line was fed entirely by gravity, even though it too would be somewhat affected by the pump surge. This line, in both cases, accumulated ferrous compounds very early and they persisted more or less through the life of the experiment. Oxygenation of the effluent as it swirled and surged through the distribution box and the line may also have helped produce aerobic conditions in one of the two lines at each site.

Bacteriological Analyses

The primary purpose of the microbiological investigation was to determine the zone of influence with regard to fecal coliforms of the experimental drainfields. Samples of soil and water were taken in and near both experimental fields during the year of their operation. Samples were also taken in and near the original drainfield installed six years previous at the same location as the Clarks Branch experimental drainfield but separated from it by a rocky ridge.

The Sutherlin experimental drainfield was sampled three times during March and April of 1976 (Table 4). Only water samples were taken on the first two dates, March 26 and April 1. However, only a few of the sample points held retrievable water. These all revealed confirmed positives for points #4, #5 and #7 (Figure 3) immediately

Table 4. Bacterial Analysis for Fecal Coliforms--Sutherlin Site--New Drainfield (see Figure 3 for Sample Point Location).

Sample Point	Date	Type of Sample	MFC	Lactose
4	March 26	turbid water	$2x10^2$/100 ml	positive
5		turbid water	1/100 ml	positive
7		turbid water	$2x10^3$/100 ml	positive
5	April 1	turbid water	13/100 ml	positive
1	April 8	moist soil[a]	negative	positive
2		moist soil	9/gm of soil	positive
3		moist soil	TNTC[b]	positive
4		moist soil	5/gm of soil	positive
5		moist soil	negative	positive
6		moist soil	negative	positive
7		moist soil	negative	positive
8		moist soil	TNTC	positive
9		moist soil	negative	positive

[a] 1 gm of soil incubated in a lactose vial for 5 days at 37°C--then entire contents (20 ml) filtered for test.

[b] Too numerous to count (plate overgrown).

below the drainfield. On April 8, 1 gm of moist soil was collected from each point to incubate for 5 days in lactose vials at 37°C. The contents were then passed through a Millipore filter and incubated for 48 hours. Points #2, #3, #4 and #8 in the same area were confirmed positive for fecal coliforms. All others were negative on Millipore filters, though positive in the lactose vials.

The three deep piezometers located downslope from the drainfield (Figure 3) were sampled from January through April (Table 5). Only once was piezometer number two found with bailable water. This occurred immediately after 6.03 cm of rain had fallen in a four day period. The resulting plate was overgrown in 24 hours with fecal coliforms. The other two wells showed a water level response that seemed keyed to their positions (Figure 3) relative to the drainfield as rainfall fluctuated through the winter. Well #1, closest to the drainfield, showed presumptive (both gas and lactose produced) positives both on January 17, after two days without rainfall, and on January 23 after nine days without rain. Well #3, 15 meters downslope from the lower line, was negative on both occasions. Both were negative on February 24 but these tests are not considered reliable due to the small sample size. On March 25, after 6.86 cm of rain, all three wells were positive for fecal coliforms, showing very high counts. On April 1, #1 was negative while #3 exhibited a much reduced count from the previous

Table 5. Bacterial Analysis for Fecal Coliforms--Sutherlin Site--Monitor Wells Below New Drainfield (see Figure 3 for Well Location).

Sample Point	Date	Type of Sample	MFC	Lactose	EMB
1	Jan. 17	water		positive	
3		water		negative	
1	Jan. 23	water		positive	
3		water		negative	
1	Feb. 24	water			negative
3		water			negative
1	March 25	turbid water	1.5×10^3/100 ml	positive	
2		turbid water	TNTC[a]		
3		turbid water	64/100 ml		
1	April 1	clear water	negative		
3		turbid water	3/100 ml	negative	
1	April 8	clear water	1/100 ml	positive	
3		clear water	1/100 ml	positive	

[a] Too numerous to count (plate overgrown).

sampling. On the last sampling, on April 8, both wells produced confirmed positives of 1/100 mg, down from a maximum of 1.4 x 10^3/100 ml on March 25th.

The Clarks Branch experimental drainfield was sampled from November 18 through April 13 (Table 6). The sites were sampled on separate days to allow re-sterilization of a limited number of sample containers.

Presumptive positives were recorded for sample points #7 and #14 (Figure 7), both turbid water samples, on January 23. Though it was not raining at this date, fairly steady rainfall had been recorded to this point--normal winter precipitation for southern Oregon. On February 25, after nearly four weeks of very little rain, only moist soil was available for sampling at all but one point. One gram samples were collected and incubated in lactose vials at 37°C. Only point #2 was completely dry and not sampled. Only three of the remaining fifteen points were negative--#5, #9 and #14.

On March 26th, just after 4.75 cm of rain in three days, most of the points held retrievable water. All samples analyzed were on both lactose and Millipore filters. The lactose samples were uniformly positive; the Millipore all negative but one--point #16 located between the distribution lines. The count was 2/100 ml. The turbid water, in which bacteria tend to adhere to clay and silt

Table 6. Bacterial Analysis for Fecal Coliforms--Clarks Branch--One Year Old Drainfield (see Figure 7 for Sample Point Location).

Sample Point	Date	Type of Sample	MFC	Lactose	EMB	MPN
3	Nov. 18	turbid water		negative		
6		clear water		negative		
6	Dec. 8	clear water		negative		
7		clear water		negative		
8		clear water		negative		
9		clear water		negative		
7	Jan. 23	turbid water		positive		
9		turbid water		negative		
14		turbid water		positive		
15		turbid water		negative		
1	Feb. 25	moist soil		positive		
2		no sample				
3		moist soil		positive		
4		moist soil		positive		
5		moist soil		negative		
6		moist soil		positive		
7		moist soil		positive		
8		moist soil		positive		
9		moist soil		negative		
10		moist soil		positive		
11		moist soil		positive		
12		moist soil		positive		

Table 6. Continued.

Sample Point	Date	Type of Sample	MFC	Lactose	EMB	MPN
13	Feb. 25	moist soil		positive		
14		moist soil		negative		
15		moist soil		positive		
16		turbid water		positive		
3	March 26	turbid water	negative	positive		
4		turbid water	negative	positive		
6		turbid water	negative	positive		
7		turbid water	negative	positive		
8		turbid water	negative	positive		
9		clear water	negative	positive		
15		clear water	negative	positive		
16		clear water	2/100 ml	positive		
3	April 1	clear water	2/100 ml	positive		
5		clear water	negative		negative	positive
6		turbid water	negative	negative		
7		turbid water	negative	negative		
8		turbid water	negative	negative		
9		clear water	negative	negative		
10		turbid water	negative		negative	positive
14		turbid water	negative		negative	positive
1	April 8	soil		positive		
2		soil		negative		
3		soil		positive		
4		soil		positive		

Table 6. Continued.

Sample Point	Date	Type of Sample	MFC	Lactose	EMB	MPN
5	April 8	soil		negative		
6		soil		positive		
7		water	negative	negative		
8		turbid water	negative	positive		
9		soil		negative		
10		soil		positive		
11		soil		positive		
12		soil		positive		
13		soil		positive		
14		water	negative	positive		
15		turbid water	negative	positive		
16		soil		positive		
1	April 13	incubated soil sample	negative			
3		incubated soil sample	negative			
4		incubated soil sample	negative			
6		incubated soil sample	negative			
8		incubated soil sample	negative			
10		incubated soil sample	negative			

Table 6. Continued.

Sample Point	Date	Type of Sample	MFC	Lactose	EMB	MPN
11	April 13	incubated soil sample	4/gm of soil			
12		incubated soil sample	negative			
13		incubated soil sample	4/gm of soil			

and not filter properly, may account for the lack of confirmed positives on points farther removed from the drainfield.

On April 1, confirmed positives were obtained on #3, #5, #10 and #14. Several large rainstorms in the previous 10 days had saturated the soil after low rainfall, enabling coliforms to again reach the periphery of the drainfield. The counts were low but confirmed present.

On April 8, all points were sampled for 1 gram of soil or water. All water samples were negative on Millipore filters, though presumptive positives were recorded for #8, #14 and #15. Of the remaining soil samples, only #2, #7 and #9 were negative on lactose. These samples were incubated for five days and then filtered through Millipore filters and incubated at 44.5°C. Of these samples 11 and 13 were positive. Therefore, after 7 days without rain, the only fecal coliforms are found in the lower line of sample points, 6.1 meters from the lower distribution line. This implies that coliforms should be found in the upper line of sample points also; sampling procedures may not have been adequate.

The old drainfield at Clarks Branch was sampled from January 23 through April 13 (Table 7 and Figure 7). No water was available until #5 contained some on January 23. The other points were sampled for soil for comparison. Only #5 recorded a presumptive positive. Samplings on January 30 and February 6

Table 7. Bacterial Analysis for Fecal Coliforms--Clark Branch Site--Five Year Old Drainfield.

Sample Point	Date	Type of Sample	MFC	Lactose	EMB	MPN
1	Jan. 23	moist soil		positive[a]		
2		moist soil		negative[b]		
3		moist soil		negative		
4		moist soil		negative		
5		water		positive		
1	Jan. 30	well dry				
2		well dry				
3		water		negative		
4		moist soil		negative		
5		moist soil		negative		
1	Feb. 6	well dry				
2		well dry				
3		moist soil		negative		
4		moist soil		negative		
5		moist soil		negative		
1	Feb. 25	moist soil		positive		
2		well dry				
3		water		negative		
4		moist soil		negative		
5		water		negative		

Table 7. Continued.

Sample Point	Date	Type of Sample	BFC	Lactose	EMB	MPN
1	March 26	turbid water	10/100 ml	positive		
2		well dry				
3		turbid water	negative[c]	positive		
4		turbid water	negative	positive		
5		turbid water	negative	positive		
1	April 1	clear water	40/100 ml	positive	negative[d]	positive[e]
2		turbid water	negative		negative	positive
3		clear water	negative		negative	positive
4		clear water	negative		negative	positive
5		turbid water	negative		negative	positive
1	April 8	soil	negative	negative	negative	
2		soil	negative	negative	negative	
3		soil		negative		
4		soil		negative		
5		clear water	1/100 ml			
6		clear water	negative	positive		

Table 7. Continued.

Sample Point	Date	Type of Sample	MFC	Lactose	EMB	MPN
1	April 13	incubated lactose vial	negative			
3		incubated lactose vial	negative			

a/ Positive for the lactose vial means that both acid and gas production occurred within 48 hours from the start of incubation or that at least gas production occurred.

b/ Negative for the lactose vial means that neither acid nor gas production occurred within 48 hours from the start of incubation.

c/ Negative on M-FC media for the Millipore filter technique means no colony growth within 24 hours at 44.5°C. or less than 1 colony per 100 ml of sample.

d/ Negative on Levine Eosin Methylene Blue media means no colony growth in 24 hours at 37°C.

e/ 2 tubes of double strength lactose were innoculated with 10 ml. of water sample, 4 tubes of single strength lactose were innoculated with 2 portions of 1 ml. sample each and 2 portions of 0.1 ml. sample each. Positive samples showed gas production in all 6 tubes.

were negative. On February 25, a lactose positive was recorded on #1 in the center of the drainfield. On March 26th, lactose positives were recorded on all points except #2 (dry) and confirmed on #1.

On April 1, positives were recorded on all points after heavy rain, comparable to results on the new drainfield.

On April 8th, only sample point #4 confirmed positive.

The two dates of confirmed positives on sample point #1 (Figure 7) of the original drainfield (Table 7) would be expected for a drainfield this old except that the owner had excavated the distribution box to the first line in the summer of 1975 and discovered that the box had settled, feeding all the effluent straight to the lower line and accounting for the surfacing at the end of this line. He corrected the problem with a baffle which allowed equal distribution to both lines. Therefore, the upper line had only been in any actual use for some four months. Since this qualifies as a new line, it might be either that the fecal coliforms found at sample point #1 represent a portion of the system that has not yet equilibrated with the soil and that it cannot effectively filter effluent until some mat had developed or most of the effluent is flowing straight to the end of the line. If the former, it coincides with the results from the new drainfield in the same soil conditions and with what other investigators have found for loamy soils of this type (McGauhey and Krone, 1967).

If the latter, effluent in appreciable amounts, reaching a point 18.3 meters from the first distribution box, indicates that the lines were not level when they were installed. The slope of the distribution line probably exceeded the recommended value of 5 cm/30 meters. Excessive line slope could allow effluent to reach the end of the lower line within one year after the system was installed (personal communication from owner).

Sample point #5, which was installed 6.1 meters from the end of the failing lower line and was set in an apparent drainage channel, provided only presumptive positives for fecal coliforms. There was no confirmed positives. This would seem to provide some evidence against longevity of fecal coliforms in soil (Mallman and Litsky, 1951). This area had been saturated with coliforms from essentially untreated effluent for four to five years. No strong evidence of contamination exists now.

The fecal coliform confirmed positive at sample point #4, located 6.7 meters below the lower line (Figure 7) might be expected of a drainfield line that has been receiving effluent for five years. Surprisingly, the count is low, and it appeared after a week of dry weather. Samples taken seven days previously after 3.0 cm of rain in two days were negative. This suggests that new coliforms coming directly from the system require time, even under saturated conditions, to travel downslope.

The two presumptive positives on sample point #3, located 9 meters downslope from the lower line, offers only tenuous evidence for the presence of fecal coliforms this far downstream from the drainfield. No confirmed positives were obtainable for this point.

Overall, the data indicate that the original drainfield at Clarks Branch is functioning fairly well, considering the defects in installation and the resultant overloading of the lower line.

Classifying the data on the basis of dates of collection and confirmed positives gives a very clear picture of lateral flow of bacteria under the impetus of a strong subsurface flow induced by heavy 24 hour precipitation (records of the Douglas County Watermaster). Steady rain did not produce the same evidence of bacterial travel. Heavy rains early in December did not produce the same evidence, perhaps because full saturation conditions had not yet been achieved or there were fewer than 1/100 ml of coliforms in the samples taken. However, on March 26th after rains varying from 4.75 to 6.03 cm on both sites in 4 days, all showed confirmed positives for fecal coliforms. On April 1, with no heavy precipitation recorded, subsurface flow was still strong enough to produce confirmed positives on all sites, though the counts were much reduced. On April 8th, two weeks after the last major precipitation, all sites still recorded confirmed positives. Either coliforms can survive for considerable time if moisture is present or lateral flow persists after two weeks without precipitation.

GROUND WATER AND EFFLUENT CHEMICAL CHARACTERIZATION

Procedure

Effluent samples were taken from the dosing chambers just ahead of the drainfield distribution boxes, since this most closely represented the actual quality being delivered to the drainfield. Two samples were taken on each drainfield, one in the fall of 1975 and one in the spring of 1976, to determine if change in ground water quality, as related to household water quality, had a noticeable effect on septic tank effluent quality. Groundwater samples were taken at the same time from outside household faucets (deep ground water untreated by softeners or additives). Samples were analyzed for 5 day BOD (spring samples only), suspended solids, nitrates, nitrites, ortho phosphate, pH and specific conductivity (Table 8) at a commercial water laboratory.

Results and Discussion

Chemical characteristics of typical septic tank effluent are shown in Table 9. Effluent chemical quality depends on the type of the wastes (whether laundry and kitchen wastes are added), the number of people in a house and the age of the occupants (Lawrence, 1973; Otis, 1976). Consequently, though a table of such average

Table 8. Composition of Effluent and Groundwater for Sutherlin and Clarks Branch Experimental Sites for 1975-1976.

	Sutherlin Effluent		Clarks Branch Effluent	
	Fall, 1975	Spring, 1976	Fall, 1975	Spring, 1976
BOD 5 days	--[a]	221	--[a]	373
Suspended solids	72 mg/l	49 mg/l	38 mg/l	105 mg/l
Nitrates	<0.05 mg/l	0.03 mg/l	0.31 mg/l	0.37 mg/l
Nitrites	0.20 mg/l	<0.01 mg/l	0.13 mg/l	<0.01 mg/l
Ortho Phosphate	0.25 mg/l	4.2 mg/l	2.95 mg/l	31.0 mg/l
pH	7.5	7.3	7.2	7.1
Specific conductivity microhoms/cm	1280	1280	1060	1200
Range of total dissolved solids	704-896[c]	704-896	583-742	660-840

Table 8. Continued.

	Sutherlin Groundwater		Clarks Branch Groundwater	
	Fall, 1975	Spring, 1976	Fall, 1975	Spring, 1976
Suspended solids	52 mg/l	1.0 mg/l	1.0 mg/l	< 1.0 mg/l
Nitrates	<0.05 mg/l	0.11 mg/l	0.14 mg/l	<0.05 mg/l
Nitrites	0.04 mg/l	< 0.01 mg/l	< 0.05 mg/l	< 0.01 mg/l
Ortho Phosphate	0.02 mg/l	< 0.02 mg/l	0.02 mg/l	0.02 mg/l
pH	6.6	8.4	7.6	7.3
Specific Conductivity microhms/cm	290[b/]	432	1550	3100
Range of Total dissolved solids	160-203 mg/l	238-302 mg/l	853-1085 mg/l	1705-2170 mg/l

[a/] Not analyzed at this time.

[b/] Measures the total concentration of ionizable substances in water at 25°C. Ions commonly measured are bicarbonate, calcium, carbonate, magnesium, nitrate, potassium, sodium and sulfate.

[c/] It has been established that the specific conductivity may be multiplied by a factor ranging from .55 to .70 to calculate mg/l total filtratable residue or total dissolved solids for waters within a pH range of 6-9 units. U.S.P.H.S. Drinking Water Standards, 1962, gives 500 mg/l as a safe limit (Standard Methods, 1971).

Table 9. Typical Composition of Domestic Sewage (Metcalf and Eddy, 1972). (All values except settleable solids are expressed in mg/liter.)

Constituent	Concentration		
	Strong	Medium	Weak
Solids, total	1200	700	350
Dissolved, total	850	500	250
Fixed	525	300	145
Volatile	325	200	105
Suspended, total	350	200	100
Fixed	75	50	30
Volatile	275	150	70
Settleable solids, (mg/liter)	20	10	5
Biochemical oxygen demand, 5-day, 20 C.	300	200	100
Total organic carbon (TOC)	300	200	100
Chemical oxygen demand (COD)	1000	500	250
Nitrogen, (total as N)	85	40	20
Organic	35	15	8
Free ammonia	50	25	12
Nitrites	0	0	0
Nitrates	0	0	0
Phosphorus (total as P)	20	10	6
Organic	5	3	2
Inorganic	15	7	4
Chlorides	100	50	30
Alkalinity (as $CaCO_3$)	200	100	50
Grease	150	100	50

values is included for reference (Metcalf and Eddy, 1972), the limitations of their reliability should be kept in mind.

Results of the analyses of effluent and groundwater are given in Table 8. The 5 day BOD for Sutherlin effluent is well within the range given by Metcalf and Eddy (1972), though that for Clarks Branch effluent seems somewhat high. Suspended solids in the Sutherlin effluent are also within the range given, but the 1976 Clarks Branch analysis is again quite high, though Salvato (1958) reports a value of 101 mg/l. Nitrates for both systems are high. There was no substantial difference noted between the fall-spring determinations for either system. Nitrates are also high for both systems compared to values given by Metcalf and Eddy (1972), and they decrease markedly from fall to spring. Both pH and specific conductivity fluctuated very little.

The fluctuations in quality for both effluent and groundwater may be due to the small number of samples as well as to different positions in the recharge cycle.

Groundwater data for both systems showed no apparent seasonal pattern except for specific conductivity and dissolved solids, both of which approximately doubled from fall to spring.

Sutherlin groundwater never exceeded or even closely approached limits given by the U. S. P. H. S. Drinking Water Standards (Standard Methods, 1971) for all parameters analyzed.

Clarks Branch groundwater far exceeded the standard for total dissolved solids (500 mg/l) but was acceptable in other respects except for a strong odor of hydrogen sulfide. This may indicate bacterial contamination of the well (due to inadequate casing) and resultant decomposition of organic matter present in the sedimentary materials in which the well was drilled.

Firm conclusions are difficult to draw because of the small number of samples and different locations within a soil-landscape system. The increase of suspended solids and specific conductivity from fall to spring indicates normal drawdown of groundwater before recharge occurs. The rise in nitrates for the Sutherlin system may indicate well contamination from inadequate casing, since the well was not cased to hard rock. Also, effluent from the treatment plant is used to irrigate Sutherlin Knolls golf course, which adjoins the property on which the well is located. It is possible that the combination of effluent and fertilizer applied to the golf course is penetrating to the groundwater. The rise in specific conductivity measures ions such as nitrate, sulfate, and potassium.

EFFLUENT VOLUME MONITORING

Purpose

Automatic counters were installed on both systems of both experimental drainfields in order to determine the exact amount of effluent being delivered. Therefore it was possible to compare the accumulated volume data with those found in the published literature.

Literature Review

Lawrence (1973) describes an experiment in which two households were studied in order to determine septic tank efficiency in the treatment of effluent. One household with six occupants generaged flows of 704 liters per day or 117 liters per day per person. Laundry wastes were included. The second household with five occupants generated flows of 927 liters per day or 186 liters per day per person. Laundry wastes were excluded. The difference in volumes probably arises because the first household was on a private well with hard, high iron water and the second was on a softened municipal supply.

Otis (1976) cites a figure of 163 liters per day per person, derived from a study of eleven rural homes (all presumably on domestic wells).

Bernhart (1973) gives an average flow for a North American household as 750 liters per day or 200 liters per person per day for an average family of 3.7 persons, where garbage grinders and automatic washing machines are not used. He adds that the flow will increase 30% if washing machines are used. He cites other figures of 370 to 550 liters/person/day as being the norm that is used for most volume calculations in the literature and points out that these are based on flow quantities from city water supplies divided by population.

Results and Discussion

The measured values for the households used in this study show the expected wide range in variation (Table 10). The Clarks Branch household, which is on a small community water supply and pays by the gallon for its water, used only 105 liters per person per day. This is 11% lower than the lowest figure reported by Lawrence (1973). It is also 196% below the average figure calculated for the Sutherlin household, which is on a domestic well. It seems reasonable that cost has some effect in this regard. Lawrence's figure of 117 liters/per/day compares favorably with this, though low water consumption is influenced by different circumstances (poor water quality).

The Sutherlin household (Table 10), which experienced a succession of renters for half the time of monitoring and then a transition to an owner, shows a very wide range of values. A family of four (two adults and two children) averaged 246 l/person/day, while three people (two adults and one small child) produced 159 l/person/day. Two adults produced 133 l/person/day. The number of children seems to influence consumption markedly in this case. The first figure of 246 l/person/day closely approaches Bernhart's (1973) figure of 260 l/person/day and far exceeds all the other referenced figures, even when they include three or four children (Lawrence, 1973). Low consumption is not related to single factors such as age of occupants, number of children, or water quality alone. But, when taken together and combined with cost, it may be easier to predict what the water consumption could be. Otis' figure of 163 l/person/day seems to be representative. The figure cited by the Department of Environmental Quality of 568 liters per bedroom seems excessive when compared with the fact that both of the households studied have three bedrooms and should therefore have produced 1703 liters per day on the average. Neither approached it by more than 20%. The conclusion appears to be that, based on effluent volume, Oregon Department of

Table 10. Effluent Volumes Calculated for Households on Experimental Drainfields with Literature Comparisons.

Site	Number of people	Total liters/day	Total/person/day
Clarks Branch (on community water supply)	2 adults, 3 children	528	105
Sutherlin (domestic well	2 adults, 2 children	1139	284
	2 adults, 2 children	1079	269
	2 adults, 2 children	757	186
	2 adults, 1 child	477	159
	2 adults	265	133
Lawrence, 1973 (domestic well)	2 adults, 4 children	704	117
Lawrence, 1973 (city water)	2 adults, 3 children	927	186
Otis, 1975 (domestic wells)			163
Bernhart, 1973	3.7 people	975	264

Environmental Quality standards for sizing are over conservative. By contrast, Bernhart (1973) cites a value of 1160 liters per day for a three bedroom house which seems to be much closer to the mark. However, this figure does not include laundry wastes, which would increase it 30% (Bernhart, 1973) or up to 1508 liters per day. If these figures are anywhere near correct, drainfield sizing practices need to be examined much more closely and perhaps reevaluated.

PART TWO: GROUND WATER STUDY ON SELECTED SOILS AS RELATED TO MORPHOLOGIC EVIDENCE OF RESTRICTIVE LAYERS

LITERATURE REVIEW

Several studies have been done in recent years relating soil profile morphology and measured water table levels. One study relates profile colors identifying drainage class, i. e. mottling described at different depths in related series, of a drainage sequence with the height and duration of water tables and investigates the genesis of drainage-related characteristics (Boersma, Simonson and Watts, 1972; Simonson and Boersma, 1972). Another study by Wert (1969) sought to relate the same drainage sequence to suitability of the soils for subsurface sewage disposal. A study by Vepraskas, Baker and Bouma (1974) demonstrated that despite the presence of gleyed subsoil colors in a Mollic Hapludalf, the profile was actually saturated for very short periods of time, making it possible to install a seepage bed below a silt loam cap without the possibility of lateral flow even under high rainfall conditions. What all these studies had in common was the use of gleyed and/or mottled colors to describe the nature of saturation in a profile. Other factors must be taken into account, as this study demonstrates.

Other water table studies are directed toward the discovery of relationships between profile morphology and percent time of saturation in order to deduce principles of soil genesis. This approach is demonstrated by Daniels, Gamble and Nelson (1971) who dealt with the functional relationship between depth of water table, distance from the edge of a geomorphic surface, and soil morphology related to genetic development of a profile.

The following study incorporates these ideas and additional techniques from a study by van Heesen (1970) in which measured fluctuations of the water table were presented on soil maps in the Netherlands. It demonstrates that while gleyed colors are useful, they are not the only factor to be considered in determining the level of a high water table in a specific profile. Some ideas were suggested as to the reasons for the absence of discernible development of gleyed colors in a soil that is still saturated a large part of the year.

GROUND WATER MONITORING PROGRAM

A program intended to compile background information for use by the Environmental Sanitation Department of Douglas County was initiated in the fall of 1973. Seasonal water table fluctuations were monitored in selected soils to more closely determine their suitability for use as drainfields under the rules promulgated by the Department of Environmental Quality, 1975.

A variety of soils were selected for which there was a definite question as to the position of the actual winter time high water level. Questions involved the presence or absence of a "restrictive" layer and mottling or whether the soils were well-drained enough to counteract their position in an area known to have a high regional water table. Although some of the soil profiles did not indicate poor drainage, it was felt that their position in the landscape might produce an effective high water table. The Sutherlin site was used to demonstrate, as the profile indicated, that a perched water table existed for much of the year.

Fifteen sites were originally selected. Through vandalism and availability of monitoring personnel these were reduced to six with sufficient data to draw some conclusions.

METHODS AND MATERIALS

The wells[2/] were installed by boring a hole to maximum auger extension (1.52 meters) or to shallower impenetrable rock with a three-inch auger. A three-inch perforated PVC pipe was cut to proper length, the top one-third section of holes covered with duct tape to prevent contamination of the well by surface runoff, and driven into the prepared hole. The soil surface-pipe interface was sealed with mortar or a quick-setting grout. The top was fitted with a three-inch PVC cap, drilled to allow a 0.625 cm aluminum rod to be inserted. The rod was cut to fit each individual well, allowing several cm to protrude through the cap. An aluminum cup, made to fit the rod and slide freely upon it, was put on the rod in an inverted position as a float below the cap. Sections of 0.625 cm Teflon tubing were positioned above and below the cup as maximum-minimum markers. A piece of nylon fishing line was attached to the bottom edge of the cup through a hole and a lead sinker tied on the lower end, enabling removal of the rod for readings without disturbing the position of the cup or markers. The line was run through a small hole bored in the side of the PVC cap and a metal washer tied to it as a handle. Triangular

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[2/] John Collins, U.S. Army Corp of Engineers, Vicksburg, Mississippi, is credited with the design of the following apparatus.

pieces of aluminum were cut the diameter of the pipe and placed at the top and bottom of the rod to keep it centered, prevent it from sliding into the bottom of the well and keep the well cap from sliding down the rod when the apparatus was removed from the well. Set collars were used to keep the plates in place. The aluminum rods were rubbed smooth with fine steel wool and sprayed with silicon to allow free travel of the cup as the water table rose and fell. With this apparatus (Figure 10), the position of the water table at the time was recorded, as well as the maximum and minimum levels of the water table between readings. This apparatus was found very satisfactory in simplicity of assembly and maintenance. The only problem was the fouling of the rod by deposits precipitating from the ground water. This required disassembly of the apparatus, steel wooling the rod, re-siliconing and reassembly. Only a few required this more than twice a winter. Vandalism and occasional destruction by heavy equipment was the greatest problem. Horses and cows are also very attracted to these installations and had to be fenced out.

The soils at the sites which were eventually selected and monitored continuously were described in the summer of 1975. The descriptions are included in Appendix A with the appropriate graph of water levels plotted with precipitation data for each well included in Appendix C.

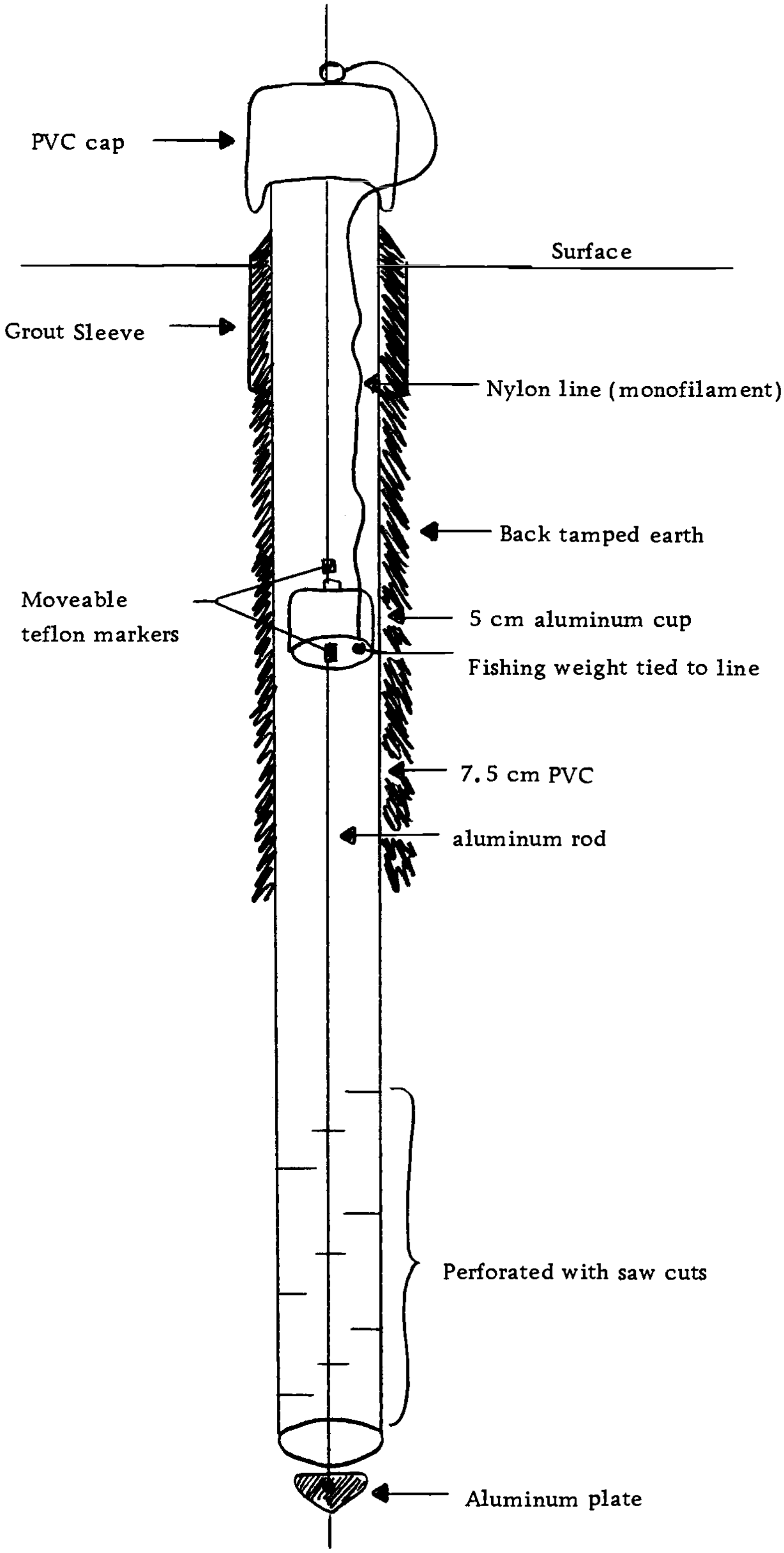

Figure 10. Monitor well apparatus.

The precipitation data were derived from weather stations close by the sites, monitored by the county. If the site was located midway between weather stations, an average was taken.

RESULTS AND DISCUSSION

Water table data is summarized in Figure 11 and Table 11. Had a subsurface sewage system been installed in any of these soils, the amplitude of the peaks and troughs of groundwater fluctuations would have been modified. The water table would have risen sooner, remained higher through the winter season and retreated more slowly through the spring and early summer.

Two wells were installed in the Speaker-like soil at the Clarks Branch experimental drainfield. One was placed above the curtain drain and one directly below the lower line of the drainfield. However, data were acquired only from the uppermost well, because the lower piezometer never contained water in the two years of data collection.

The Speaker soil was only slightly less well drained than the Dixonville soil (Figure 11). Although Dixonville (fine family) contains more clay than the Speaker (fine loamy family), the reduction in permeability that may be expected as clay content increases is more than compensated for by well developed structure. Dixonville has strong subangular blocky structure, whereas the Speaker-like soil has weak to moderate subangular blocky structure. Both soils have about the same visible pore and root distribution. Other than a difference in slope (26% for the Speaker-like and 18%

Table 11. Average Percent of Time the Water Table was Above the Indicated Depth During the Winter Months of December Through June on the Six Soils Series Tested.

Month	Series	Slope	Depth cm.						
			15.0	30.0	45.0	60.0	75.0	90.0	120.0
December	Speaker-like	26%	0.0	0.0	0.0	0.0	100.0	100.0	100.0
	Dixonville	18%	0.0	12.5	12.5	25.0	37.5	50.0	-----
	Rosehaven	5%	11.1	55.6	66.7	77.8	77.8	100.0	100.0
	Sutherlin	8%	7.1	21.4	50.0	92.9	92.9	92.9	92.9
	Packard	3%	44.4	55.6	55.6	88.9	88.9	100.0	100.0
	Coburg	3%	8.3	16.7	41.7	83.3	91.7	100.0	100.0
January	Speaker-like		0.0	0.0	0.0	0.0	100.0	100.0	100.0
	Dixonville		0.0	0.0	10.0	20.0	20.0	60.0	-----
	Rosehaven		46.2	53.8	69.2	76.9	100.0	100.0	100.0
	Sutherlin		37.5	62.5	93.8	100.0	100.0	100.0	100.0
	Packard		46.2	69.2	92.3	100.0	100.0	100.0	100.0
	Coburg		54.5	81.8	90.9	100.0	100.0	100.0	100.0
February	Speaker-like		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dixonville		9.1	9.1	9.1	9.1	18.2	81.8	-----
	Rosehaven		25.0	50.0	50.0	50.0	75.0	75.0	100.0
	Sutherlin		27.3	27.3	54.5	100.0	100.0	100.0	100.0
	Packard		25.0	37.5	50.0	62.5	100.0	100.0	100.0
	Coburg		25.0	50.0	75.0	100.0	100.0	100.0	100.0
March	Speaker-like		8.3	8.3	16.7	25.0	75.0	91.7	100.0
	Dixonville		5.3	5.3	5.5	21.1	26.3	52.6	68.4
	Rosehaven		15.0	35.0	35.0	50.0	75.0	90.0	100.0
	Sutherlin		28.0	28.0	68.0	88.0	100.0	100.0	100.0
	Packard		31.6	42.1	68.4	78.9	94.8	94.8	100.0
	Coburg		43.8	62.5	93.8	100.0	100.0	100.0	100.0

Table 11. Continued.

Month	Series	Slope	Depth cm. 15.0	30.0	45.0	60.0	75.0	90.0	120.0
April	Speaker-like		0.0	0.0	0.0	12.5	100.0	100.0	100.0
	Dixonville		0.0	0.0	0.0	0.0	6.3	25.5	-----
	Rosehaven		0.0	5.3	31.6	63.2	89.5	94.8	100.0
	Sutherlin		4.5	4.5	59.1	86.4	95.5	95.5	100.0
	Packard		6.3	37.5	56.3	87.5	100.0	100.0	100.0
	Coburg		15.8	26.3	47.4	100.0	100.0	100.0	100.0
May	Speaker		0.0	0.0	0.0	0.0	0.0	100.0	100.0
	Dixonville		0.0	0.0	0.0	0.0	16.7	66.7	-----
	Rosehaven		0.0	0.0	8.3	50.0	75.0	100.0	100.0
	Sutherlin		0.0	0.0	33.3	50.0	66.7	83.3	100.0
	Packard		0.0	0.0	6.7	40.0	60.0	73.3	100.0
	Coburg		0.0	0.0	14.3	50.0	92.9	100.0	100.0
June	Speaker		----	----	----	-----	-----	-----	-----
	Dixonville		----	----	----	-----	-----	-----	-----
	Rosehaven		----	----	----	-----	-----	-----	-----
	Sutherlin		0.0	0.0	0.0	0.0	0.0	33.3	77.8
	Packard		0.0	0.0	0.0	0.0	0.0	75.0	75.0
	Coburg		0.0	0.0	0.0	0.0	0.0	0.0	0.0

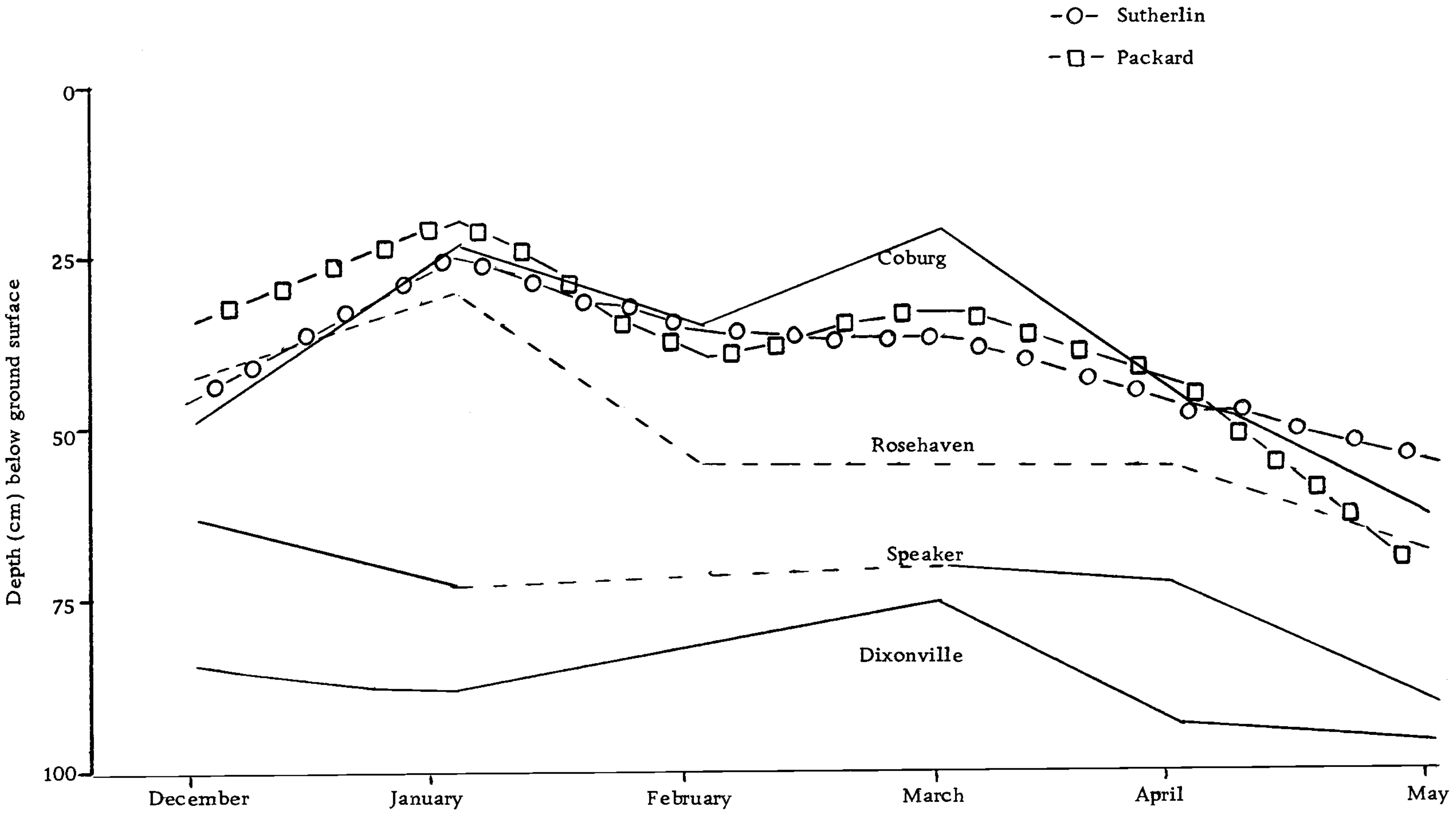

Figure 11. Seasonal fluctuations of water tables on six soils in Douglas County, Oregon, based on three years data.

for Dixonville), the differences in ability to absorb and transmit water rapidly are structure, clay content and, possibly, underlying rock characteristics.

Another point of interest is related to the difference in rainfall between the two sites. The Dixonville site, located 2.4 km west of Roseburg on the Garden Valley road, received 21.6 cm of precipitation more than the Speaker-like site, as measured during the fall and winter of 1974-75. Both sites were located on south-aspect slopes under very similar vegetative cover. Also, the Speaker-like site was located on a slope that was almost completely cleared of vegetation prior to the second winter of readings and seeded to grass. Enough sheet and rill erosion occurred to demonstrate increased runoff, indicating reduced infiltration of the profile. If anything, this should have lowered water table levels.

In summation, the strongly structured, moderately permeable and fine textured Dixonville profile over fractured basalt bedrock was on the average more freely drained than the Speaker-like profile of the same depth over fractured siltstone and coarser textured but much weaker in structure.

The third-ranked soil, based on the completed study, is the Rosehaven series, quite similar to the Speaker but deeper and located on a lesser slope (5%, as opposed to 26%). This site may receive more water as it lies in a broad depression which most likely channels subsurface and surface runoff.

Rosehaven has strong structure, moderate permeability and clay films in the clay loam B2t. There is a restrictive layer at 65 cm where the structure becomes massive. The profile was moist when the pit was described in August. The soil is described as being well drained.

The rainfall is assumed to be the same for this site as it was at the Speaker-like site 0.4 km away on the same general slope. Reference to water table fluctuation (Appendix C) shows that the line follows the general trend of rainfall quite well, even though the recording station used is some 13 km away. It should be noted that unless rainfall is measured on the same watershed that the well is described on and on a similar aspect, measured rainfall several km away may have very little relation to the actual rise and fall of the water table in the profile. Furthermore, it is recognized that some delay in response of a hydrograph, whether in a soil profile or on a stream, is natural.

For the majority of the winter the Rosehaven site is obviously the intermediate situation between well and poorly drained.

When the Rosehaven piezometer data were ranked against the other five, it was noted that December and May were both somewhat askew. There are several possibilities to explain both months. Both times they are at less than full saturation conditions, when the water table is either rising or falling. Especially in December, low levels of both the Sutherlin and the Coburg gravelly substratum wells (Appendix C), may be reflecting a delayed hydrologic response or a greater subsurface reservoir area that must be recharged. In December, the Coburg soil may be able to drain fast enough to keep up with rainfall flowing into the basin in which it is located. After this, in January through May, water simple cannot pass fast enough through the profile to keep the water table as low as it is on the Rosehaven site. In this case, the position of the soil in relation to a high regional ground water table determines its drainage characteristics.

The data substantiate the earlier judgement that internal drainage in Packard, Sutherlin and Coburg gravelly substratum soils is more restricted than in the other soils. Packard is a Pachic Haploxeroll in the loamy-skeletal family. It has weak to moderate structure and a relative (based on a marked difference in texture and structure) restrictive layer at 25 to 60 cm. Mangans on ped faces below 60 cm in the C horizon are evidence of reducing conditions. The pedon is moderately deep and is developing in alluvial gravels.

Sutherlin is an Ultic Haploxeralf, fine-loamy over clayey family, and moderately deep. The structure is moderate and evidence of a perched water table is seen in the bleached and mottled horizon directly overlying the massive clay IIC horizon at the 60 cm depth.

The Coburg gravelly substratum soil is a Pachic Ultic Argixeroll, fine family. It is similar to the Packard intergrade soil in terms of structure but lacks the high gravel percentage above the substratum. Morphological evidence of restricted drainage is indicated by mottling at approximately the same depth as the appearance of mangans in the Packard profile. The Packard is classified as well drained while the Coburg and Sutherlin are considered moderately well drained. Mottles instead of mangans may indicate a longer period of saturation than that occurring on the Packard site or they may indicate a differing chemistry of the soil water due to mineralogy at the site. The data (Figure 11, Table 11) would seem to support the former.

The profiles of Packard, Sutherlin and Coburg gravelly substratum demonstrate very similar responses to rainfall with the Packard well showing a faster response time to precipitation at the beginning of the winter season than the Coburg under identical conditions (the wells are located within 0.4 km of each other east of the town of Sutherlin). The Sutherlin series piezometer, receiving approximately 15 cm less rain, is intermediate between them.

The Sutherlin site and the Packard site, though different in morphology, follow each other closely in water table fluctuation from December to April. In May the Packard and the Coburg show a more rapid drop in water table than the Sutherlin site, probably due to higher conductivity of the coarser-textured subsoil. The perching effect of the Sutherlin IIC is obvious when the months of April and May are compared for the three wells. The morphology of the two sites with the highest water table, Packard and Coburg, does not indicate that water is perched seasonally. The measured water tables, however, provide the major evidence. The presence of water tables can be explained by landscape position and subsurface geology. Both soils are situated in the lowest part of a regional water table, in a valley described as the Calapooya River syncline. This valley is filled deeply with sediments with an essentially flat floor. The Calapooya River has filled the valley with mixed alluvium, producing soils that range from heavy clays to loamy skeletal soils. The more permeable soils are located at random throughout the landscape and do not constitute the majority. Weakly developed, gravelly soils, such as the Packard and Coburg sites, may be "leaks" in the clayey fabric of the valley floor. It is the nature of alluvium to be laid down in layers or lenses, some extensive, some minor. The surface gradient to the Calapooya River from these sites is so gentle as to be almost incapable of removing very much water over a short time. Perhaps it is remarkable that the water table is not higher than it was measured. The answer as to why it is not may lie in these "leaky" spots of porous soils--gravels, sands and loams. If water passes through these spots rapidly, and they provide the major outflow from the saturated soils, it may provide some support for the thesis of Daniels, Gamble and Nelson (1971) that B horizon genesis may be closely related to water table position. They found shallow water tables associated with thin A2 horizons, low contrast mottling and weak B horizon development. Deep water tables were associated with thick A2 horizons and well developed B horizons, with no mottling. The lack of mottles or other evidence of perched water tables must be explained by a lack of reducing conditions, even though the soil is saturated. Perhaps the rate of flow through these profiles is fast enough that the water remains aerated. Iron and manganese remain oxidized and are not translocated through the profile. Indeed, 31 meters away, in a very similar profile, bright chroma mottles are evident. The unmottled soils apparently do not have a clay lens below them near enough to perch water and slow drainage.

CONCLUSIONS

The major conclusion drawn from these data is that in some instances when soil interpretation is employed in order to assess suitability of a soil for use in building purposes, the geomorphology and hydrology are as important as is the profile description. In the case of the Sutherlin soil, morphology provides a correct assessment. This soil retains a perched water table well into the summer, even though recharge to it is not major and a well-established gradient exists to the Umpqua River, approximately a mile distant. The bleached and mottled horizon above the IIC is ample evidence of the position and duration of the water table during a large part of the year and the interpretation is easy to make. In the better drained Dixonville, Speaker and Rosehaven soils, morphological evidence more or less corresponds with water table behavior. All could easily be interpreted correctly by a soil scientist. In the Packard and the Coburg soils, had the profiles been judged by themselves alone, some erroneous conclusions could have been made. Under present Rules, as defined by the Department of Environmental Quality, the sites would probably have been approved for subsurface disposal unless the need for monitoring had been recognized. Yet three years of data show water tables too shallow to meet requirement of the Rules. These soils are somewhat poorly to poorly drained during the winter months and would have a regional water table intercepting subsurface trenches from December to May. In fact, every well-drained site but the Dixonville, would be unsuited under current Rules due to the depth to saprolyte or a "restrictive" layer. Yet, the evidence is that the Dixonville, Speaker and Rosehaven never maintain a perched water table for any marked length of time and could probably absorb and transmit larger amounts of moisture than they now accommodate, providing the necessary filtration and unsaturated conditions required for bacteriological cleansing of sewage effluent.

CONCLUSIONS

Experimental Drainfields

Standard subsurface sewage disposal systems that are gravity loaded and have distribution lines 60 cm deep, located on slopes steeper than specified by Oregon's Department of Environmental Quality for the soil depth available, did not show any signs of effluent surfacing after 14 months of operation. There were, however, subsurface signs of failure in both older established drainfields and newer experimental drainfields. The evidence included concentrations of fecal coli in groundwater in excess of 1/100 ml, deposition of ferrous compounds in trenches, and ponding of effluent. This includes both old and new drainfields. It was not possible to define the furthest extent of drainfield influence, but under conditions of intense, short-duration rainstorms, and given an intact restrictive layer such as encountered at Clarks Branch, lateral movement in both time and distance of coliforms is considerable. If the trenches are inundated by the water table for a length of time, considerations of soil permeability, sizing, dosing, etc. are all secondary and coliforms continue to move downslope. However, once drier weather sets in, coliforms disappear and cannot move beyond the immediate drainfield as long as saturated conditions do not exist.

If drainfield trenches penetrate fractured rock, movement of coliforms may extend far beyond the actual drainfield. At the Sutherlin site, fifteen meters downslope from the lowest line, piezometers showed coliform counts whenever intense short duration rains occurred. These counts could only be coming from the drainfields above. Low pressure dosing of the distribution lines in both experimental drainfields distributed effluent evenly to all absorption surfaces. No sludge concentrations formed in the lines subjected to direct flushing and aerobic treatment conditions were maintained throughout the observation period.

Conclusions relative to curtain drain installation and efficiency are mixed. Curtain drains installed in fractured rock do not function as efficiently as ones installed in restrictive soil layers. The fractured rock at these sites is not a restrictuve layer and should not be considered as such. Also, on steeper slopes above a normal two or three line drainfield, the drainfield area will not be protected from subsurface flow.

Effluent characterization emphasized the need for more data to compare with published figures. Large ranges occurred in all components of the effluent. Nitrates and nitrites were both high compared with the cited literature figures. Analysed parameters for effluent and groundwater showed no confirmed seasonal pattern.

Effluent volume monitoring revealed a discrepancy from standard figures used to size drainfields by sanitarians under current rules. Volumes may depend on water cost and quality as well as other considerations. However, even the heaviest use of water on a domestic well did not reach more than 86% of the standard figure of 568 liters/bedroom used by current Rules. All others were much lower.

Piezometers

Six very different soils were evaluated on the basis of their suitability for drainfields. Water table fluctuation monitored for three years revealed that permeability, as measured by structural strength, porosity and slope were the determining factors in a soil's ability to transmit water rapidly. Textural considerations had little bearing.

The loamy skeletal soils located on level ground and showing little evidence of impeded drainage were found to be almost continuously saturated during the winter. No drainfield could function in these soils and lateral spread of contaminants would be a certainty. The poor drainage may be the result of position in a regional collection point and not controlled by the soil's permeability, but the conclusion remains that, in this case, geomorphic position far outweighs all other considerations of mottling, depth to restrictuve layer and permeability.

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APPENDICES

APPENDIX A

SOIL PROFILE DESCRIPTIONS AND SOIL CHEMICAL CHARACTERIZATIONS FOR EXPERIMENTAL SITES

SPEAKER SERIES

The Speaker series is a member of the fine-loamy, mixed mesic family of Ultic Haploxeralfs. Typically, Speaker soils have dark brown silt loam A horizons and reddish brown silty clay loam Bt horizons over weathered schist at about 35 inches.

Typifying pedon:		Speaker silt loam - forested
01	0-7.5 cm	Dark brown (10YR 3/3 silt loam, brown (10YR 5/3) dry; moderate fine subangular blocky structure; slightly hard, friable; slightly sticky, slightly plastic; many fine and medium roots; many very fine tubular pores; 15 percent partially weathered pebbles; slightly acid (pH 6.1); clear, smooth boundary. (2 to 4 inches thick).
B1	7.5-27.5 cm	Dark yellowish brown (10 YR 4/4) silt loam, light yellowish brown (10YR 6/4) dry; weak medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; many fine and medium roots; many very fine tubular pores; 10 percent partially weathered pebbles; medium acid (pH 5.8); clear smooth boundary. (4 to 10 inches thick).
B2t	27.5-87.5 cm	Reddish brown (5YR 5/4) silty clay loam, yellowish red (5YR 5/6) dry; moderate fine subangular blocky structure; hard, firm, sticky, plastic; common medium and coarse roots; common very fine tubular pores; common moderately thick clay film; 15 percent weathered pebbles; medium acid (pH 5.6); gradual wavy boundary. (10 to 30 inches thick).
C	87.5-92.5 cm	Weathered schist with thin dark red (2.5YR 3/6) clay films in fractures.

Range in Characteristics: Depth to bedrock and thickness of the solum range from 20 to 40 inches. Rock fragments range from 10 to 40 percent pebbles in the A and B1 horizons and 10 to 35 percent pebbles in the control section. Bleached sand and silt coatings are common on faces of peds in the upper part of the B horizon in some pedons. The A horizon has hue of 10YR and 7.5YR, value of 3 or 4 moist and 4 to 6 dry, and chroma of 3 or 4 moist and dry. It is silt loam, gravelly loam, or loam. The Bt horizon has hue of 7.5YR or 5YR, value of 4 or 5 moist and 5 thru 7 dry, and chroma of 4 thru 6 moist and dry. It is silty clay loam, gravelly clay loam or gravelly loam with 25 to 35 percent clay and 10 to 35 percent weathered pebbles. There are few to common moderately thick clay films in this horizon.

Drainage and Permeability: Well drained; medium to rapid runoff; moderately slow permeability.

Date described: October 25, 1974

CLARKS BRANCH EXPERIMENTAL SYSTEM SOIL PROFILE

Series: Speaker taxadjunct (Ultic Haploxeralf)

A	0-12.5 cm	Dark brown (7.5YR 4/4) loam, light yellowish brown(10YR 6/4) dry; moderate very fine subangular blocky structure; hard, friable, slightly sticky, slightly plastic; common very fine discontinuous horizontal inped simple open tubular pores; plentiful fine roots; abrupt wavy boundary. Bulk density: 1:65.
B21t	12.5-30 cm	Dark brown (7.5YR 4/4) loam, light yellowish brown (10YR 6/4) dry; weak to moderate very fine subangular blocky structure; hard, friable, slightly sticky, slightly plastic; many micro discontinuous horizontal inped simple tubular pores; very few medium and few fine roots; many medium ant tunnels thru peds; few thin clay skins on ped faces; distinct wavy boundary, reaction slightly acid (pH 6.2). Bulk density: 1.65.
B22t	30-47.5 cm	Dark brown (7.5YR 4/4) loam, light yellowish brown (10YR 6/4) dry; weak to moderate very fine subangular blocky structure; hard, friable slightly sticky, slightly plastic; pores as described above; few coarse and plentiful medium roots; common thin clay skins on ped faces; clear wavy boundary. Bulk density: 1.68.
B3	47.5-6.25 cm	Yellowish red (5YR 4/6) loam, light brown to reddish yellow (7.5YR 6/5) dry; moderate very fine subangular block structure; slightly hard, friable, slightly sticky, slightly plastic; many fine continuous random exped dendritic open interstitial pores; few medium roots; faint stone line and scattered gravels; abrupt wavy boundary. Bulk density: 1.86.
C	62.5-75 cm	Saprolytic pebbly conglomerate. Bulk density: 2.00.
R	75 + cm	Clean fractured siltstone.

Location:	C. A. Mihevc property, 51 Clarks Branch Rd., Myrtle Creek, Oregon. NW 1/4, SE 1/4, Sec. 1, T 29 S R 6 W.
Site Description:	Located on a sidehill terrace above a dissected stream valley on a convex slope. The terrain is moderately steep. Elevation is 244 meters. Aspect is south-southwest and the slope is 18-26%. The vegetation is grass. The parent material is Pre-Tertiary sediments.
Drainage and permeability:	The profile is well-drained and the permeability is moderate. Ground water is deep. The root distribution is as follows: 0-25 cm: fine, 25-55 cm: medium; 55 + cm: coarse
Stoniness:	Class 0.

Particle Size Analysis and Chemical and Physical Data for Profile Described at Clarks Branch Experimental Site.

	Horizon				
	A	B21t	B22t	B3	C
Depth (cm)	0. -12.5	12.5-30.0	30.0-47.5	47.5-62.5	62.5-75.0
% 2 mm	5.74	4.19	6.56	12.57	19.27
Very coarse 2-1 mm	2.75	1.33	3.23	4.53	4.48
Coarse 1-.5 mm	5.60	5.70	6.25	6.35	8.14
Medium .5-.25 mm	6.64	7.09	7.37	7.33	8.37
Fine .25-1 mm	14.38	15.34	15.07	15.19	17.09
Very fine .1-.05 mm	15.17	15.82	15.37	16.23	15.34
Total sand %	44.54	45.28	47.29	29.63	53.42
Coarse 0.05-0.02 mm	16.35	15.38	15.80	15.96	14.52
Fine 0.02-0.002 mm	22.11	21.85	20.81	19.42	16.40
Total Silt %	38.46	37.23	36.61	35.38	30.92
Clay 0.002 mm %	17.00	17.49	16.10	14.99	15.66
Extractable Cations (Meq. per 100 g. soil)					
Ca	6.8	5.5	6.4	7.2	9.0
Mg	1.7	1.7	2.8	3.6	4.5
Na	.13	.15	.17	.13	.15
K	.46	.33	.27	.24	.22
Exchange H^+	7.0	5.6	5.6	5.2	5.4
Moisture Tension					
.33 ATM	23.17	18.33	17.96	17.90	16.98
15. ATM	7.24	7.17	7.24	7.06	7.86

WILLAKENZIE SERIES

The Willakenzie series is a member of the fine-silty mixed, mesic family of Ultic Haploxeralfs. Typically, Willakenzie soils have a dark brown silty clay loam A horizon and a dark brown silty clay loam Bt horizon overlying fractured partially consolidated siltstone at depths of about 36 inches.

Typifying pedon:	Willakenzie silty clay loam - oak-native grass pasture
A1 0-10 cm	Dark brown (7.5YR 3/2) silty clay loam, brown (7.5YR 5/3) dry; weak medium and fine subangular blocky structure; hard, friable, slightly sticky, slightly plastic; many fine roots;many very fine pores; very few fine concretions; medium acid (pH 6.0); clear smooth boundary.
B1 10-30 cm	Dark brown (7.5YR 3/4) silty clay loam, strong brown (7.5YR 5/6) dry; moderate medium and fine subangular blocky structure; hard, friable, sticky, plastic; many fine roots; many, very fine pores; medium acid (pH 6.0); clear wavy boundary.
B21t 30-45 cm	Dark brown (7.5YR 4/4) silty clay loam, strong brown (7.5YR 5/6) dry; weak medium parting to moderate fine and very fine subangular blocky structure; hard, friable, sticky, very plastic; many fine roots; common very fine and fine pores; few thin clay films in pores and on some surfaces of peds; medium acid (pH 6.0); clear smooth boundary.
B22t 45-65 cm	Dark brown (7.5YR 4/4) silty clay loam, strong brown (7.5YR 5/6) dry; weak medium subangular blocky parting to moderate fine subangular blocky structure; firm, very sticky, very plastic; common fine roots; many very fine pores; few thin clay films on faces of peds; medium acid (pH 5.0); gradual wavy boundary.
B23t 65-80 cm	Dark brown (7.5YR 4/4) silty clay loam, strong brown (7.5YR 5/6) dry; weak medium and fine parting to moderate very fine subangular blocky structure; firm, very sticky, very plastic; common fine roots; many very fine pores; many thin clay films; strongly acid (pH 5.4); abrupt wavy boundary.
IIC1 80-90 cm	Yellowish red (5YR 5/6) silty clay loam, weak fine angular blocky structure; friable, very sticky, very plastic; few fine pores; common thick films on the rock fragments; 80 percent siltstone fragments; very strongly acid (pH 4.7); abrupt smooth lower boundary.
IIC2 90-135 cm	Hard fractured partially consolidated siltstone bedrock.

Range in Characteristics: Depth to a paralithic contact and siltstone and sandstone bedrock ranges from 50 to 100 cm with 75 to 100 cm the most common. Solum colors are generally in the 7.5YR hue, but range to 5YR in the lower part of the B horizon and 10YR in the A horizon. The A horizon has value of 2 or 3 moist and chroma of 2 or 3 moist and dry. It is loam, clay loam, or silty clay loam. The B2t horizon has value of 5 to 6 dry and chroma of 4 moist in the upper part and 4 through 6 moist in the lower part and 4 through 6 throughout dry. It is clay loam or silty clay loam with 27 to 35 percent clay and less than 15 percent coarser than very fine sand in the upper 50 cm of the argillic horizon. In some pedons, the lower part of the argillic horizon is heavy silty clay loam or silty clay. The clay films range from few to many thin in the B2t horizon, and commonly become thick continuous in the fractures of the bedrock. Weathered rock fragments in the B horizon range from none to 25 percent. The fragments are crushable.

Drainage and Permeability: Well-drained; slow to rapid runoff; moderately slow permability.

Date described: November 1, 1974

SUTHERLIN EXPERIMENTAL SYSTEM SOIL PROFILE

Series: Willakenzie (fine-silty, mixed, mesic Ultic Hapoxeralf:

A1	0-6.25 cm	Dark brown to brown (10YR 4/3) silt loam, dark yellowish brown (10YR 4/4) dry; moderate very fine granular structure; loose, nonsticky, nonplastic; abundant micro vertical roots; clear smooth boundary. Bulk density = 1.71.
B1	6.25-15 cm	Dark yellowish brown (10YR 4/4) heavy silt loam, yellowish brown (10YR5/4) dry; moderate fine subangular blocky structure; hard, firm, slightly sticky, slightly plastic; abundant very fine vertical exped roots; common very fine continuous horizontal exped simple tubular pores; clear wavy boundary. Bulk density - 1.67.
B21	15-25 cm	Dark yellowish brown (10YR 4/4) silty clay loam, yellowish brown (10YR 5/4) dry; moderate fine subangular blocky structure; hard, friable, sticky, plastic; pores as described; roots as described; clear smooth boundary, Bulk density = 1.58.
B22t	25-50 cm	Dark yellowish brown (10YR 4/4) silty clay loam, yellowish brown (10YR 5/4) dry; moderate very fine and fine subangular blocky structure; firm, friable, sticky, very plastic; roots and pores as described; many thin clay films; clear smooth boundary. Bulk density = 1.65.
B23	50-65 cm	Dark yellowish brown (10YR 4/4) silty clay loam, light yellowish brown (10YR 6/4) dry; moderate medium subangular blocky structure; hard, friable, slightly sticky, plastic; roots and pores as described; abrupt wavy boundary. Bulk density = 1.72.
C	65-75 cm	Saprolytic material, silt loam texture, few small coarse fragments. Bulk density = 1.74.
R	75+ cm	Hard fractured siltstone.

Location: Frandsen property, Rt. 2, Box 8405 Sutherlin, Oregon. NW 1/4, SE 1/4, Sec. 18, T 25 S, R 6 W.

Site description: Located on a convex hillslope above a small drainageway. Terrain is gently rolling. Elevation is 134 meters. Aspect is south-southwest and the slope is 19%. The vegetation is grass, poison oak, wild rose and Scotch broom. The parent material is the Roseburg Formation.

Drainage and: The profile is well-drained and permeability is moderate. Ground water is deep.

Stoniness: Class 0.

Particle Size Analysis, Chemical and Physical Data for Profile Described at Sutherlin Experimental Site.

	Horizon					
	A1	B1	B21	B22t	B23	C
Depth (cm)	0-6.25	6.25-15	15-25	25-50	50-65	65-75
% 2 mm	--	--	--	0.39	--	5.33
Very coarse sand 2-1 mm	0.46	0.25	0.43	0.25	0.23	0.32
Coarse sand 1-.5 mm	1.43	0.93	0.87	0.98	0.96	1.40
Medium sand .5-.25 mm	2.14	1.77	1.66	1.77	1.77	2.16
Fine sand .25-1 mm	6.86	5.65	5.10	5.33	5.76	6.20
Very fine sand .1-.05 mm	11.22	9.29	8.29	8.62	8.85	8.66
Total sand %	22.11	17.89	16.35	16.95	17.57	18.74
Coarse silt .05-.02 mm	21.78	18.95	16.46	16.76	16.79	18.57
Fine silt .02-.002 mm	35.55	35.87	34.44	34.13	35.34	36.86
Total silt %	57.33	54.82	50.90	50.88	52.13	55.43
Clay .002 mm	20.56	27.29	32.75	32.18	30.30	25.83
Extractable Cations (Meq. per 100 g soil)						
Ca	6.4	5.5	5.9	5.2	5.0	6.2
Mg	3.0	2.8	3.3	3.6	3.9	5.3
Na	.17	.17	.15	.17	.17	.19
K	.62	.43	.39	.32	.19	.21
Exchange H+	12.4	12.6	12.8	12.7	11.5	10.8
Moisture tensions						
.33 ATM	31.03	28.45	28.68	29.26	28.00	27.08
15. ATM	9.59	9.97	11.84	11.64	10.80	11.12

Date described: June 30, 1975

Series: Dixonville (fine, mixed, mesic Pachic Ultic Argixeroll).

A1	0-5 cm	Dark brown (7.5YR 3/2) light silty clay loam, dark brown (7.5YR 4/3) dry; moderate medium platy structure; slightly hard, friable, sticky, plastic; few very fine roots; many micro continuous horizontal and vertical tubular pores; abrupt smooth boundary.
B1	5-15 cm	Dark yellowish brown (10YR 3/4) heavy clay loam, moist and dry; strong very fine subangular blocky structure; slightly hard, friable, sticky, plastic; few very fine roots; very few continuous vertical, horizontal and random inped pores; common simple exped pores; gradual wavy boundary.
B21t	15-20 cm	Dark brown (7.5YR 3/2) light clay, dark yellowish brown (10YR 3/4.5) dry; strong very fine subangular blocky structure; slightly hard, friable, sticky, plastic; few very fine roots; many continuous random vertical and horizontal pores; few, thin clay skins; organic stains on ped faces; clear smooth boundary.
B22t	50-85 cm	Dark yellowish brown (10YR 3/4) heavy clay, dark brown (7.5YR 3.5/2) dry; strong fine subangular blocky structure; hard, friable, sticky, very plastic, few very fine roots, few micro and very fine pores; continuous thin clay skins.

Location: Property of Mr. Darley Ware, Rt. 2, Box 405, N.W. Garden Valley Rd., Roseburg, Oregon. NW 1/4, NE 1/4, Sec. 10, T 27 S, R 6 W.

Site Description: Located in pastureland on dissected topography in rolling uplands on a toeslope. Parent material is basalt colluvium. Slope is 18% and the aspect is west-southwest.

Drainage and permeability: The profile is well-drained and permeability is moderate. There is a marked discontinuity in permeability at 50 cm. where it becomes slow. Profile was dry to 52.5 cm. - moist below.

Stoniness: Class O.

Date described: August 13, 1975

Proposed series: Rosehaven (fine loamy, mixed, mesic Ultic Haploxeralf)

A1	0-20 cm	Very dark grayish brown (10YR 3/2) loam, grayish brown (10YR 5/2) dry; strong fine subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; abundant micro roots; common coarse fragments; common very fine discontinuous vertical tubular inped pores; clear smooth boundary.
B1	20-35 cm	Very dark gray (10YR 3/1) clay loam, dark grayish brown (10YR 4/2) dry; strong medium subangular blocky structure; slightly hard, firm, sticky, plastic; plentiful very fine, abundant fine and few medium roots; few micro pores; many small and few large coarse fragments; clear smooth boundary.
B2t	35-65 cm	Very dark brown (10YR 2/2) clay loam, dark brown (10YR 3/3) dry; organic stains on ped faces; strong medium subangular blocky structure; slightly hard, firm, sticky, plastic, plentiful fine and few medium roots; many thin clay films; few micro pores; clear smooth boundary.
C	65-137.5 cm	Dark grayish brown (10YR 4/2) clay loam, dark yellowish brown (10YR 4/4) dry; massive structure; friable, sticky, very plastic, very few very fine roots; common medium clay films; few pores.

Location:	Wagontire Road, Clarks Branch, Oregon. NE 1/4 SE 1/4, Sec., 1 T 29 S R 6 W.
Site description:	Located on a sidehill terrace above an incised drainage on gently sloping rolling uplands. Vegetation is pasture grasses and forbs. The parent material is mixed sedimentary and igneous rock. Slope is 5% and aspect is south-southeast. Elevation is about 300 meters.
Drainage and permeability:	The profile is well-drained and moist at 52.5 cm. Permeability is moderate and the ground water is deep.
Stoniness:	Class O.

Date described: August 5, 1975

Series: Packard Intergrade (loamy skeletal Pachic Haploxeroll)

A1	0-5 cm	Dark brown (10YR 3/3) loam, dark yellowish brown to dark brown (10YR 4.5/3) dry; moderate fine subangular blocky structure; slightly hard, very friable, slightly sticky, slightly plastic; plentiful very fine roots, very few vertical and horizontal simple tubular pores; 5 percent gravels; abrupt, smooth boundary. Rapid permeability.
B1	5-25 cm	Dark brown (7.5YR 3/2) gravelly light silt loam, brown (10YR 5/3) dry; weak very fine subangular blocky structure; hard, friable, slightly sticky, plastic; plentiful very fine roots; very few vertical and horizontal simple tubular pores; 17 percent fine gravels; clear smooth boundary. Moderate permeability.
B21t	25-60 cm	Dark yellowish brown (10YR 3/4) gravelly clay loam, dark reddish brown 5YR 3/3) dry; moderate fine subangular blocky structure; slightly hard, friable, sticky, very plastic; very few, fine roots; many very fine and fine continuous horizontal and vertical simple tubular pores; common thin clay films; 20 percent fine gravels; clear smooth boundary. Slow permeability, constituting a restrictive layer.
C	60-82.5 cm	Dark brown (7.5YR 4/3) very gravelly heavy clay loam, dark yellowish brown (10YR 4/4) dry; moderate fine subangular blocky structure; slightly hard, friable, sticky, plastic; few very fine discontinuous pores; mangans and many moderately thick clay films on ped faces; 50 percent medium and coarse gravels; diffuse wavy boundary.

Location: Property of Mr. Edward Bohr, Fair Oaks Rd., Sutherlin, Oregon. NW 1/4, NW 1/4, Sec. 7, T 25 S, R 4 W.

Site description: Located in pasture bottomland on swell and swale topography. The parent material is alluvium. The slope is 0-3%.

Drainage and permeability: The profile is moderately well-drained and permeability is moderate to moderately slow. Ground water is deep.

Date described: July 10, 1975

Series: Coburg Intergrade gravelly substratum (fine Pachic Ultic Argixeroll)

Ap	0-17.5 cm	Dark yellowish brown (10YR 3/4) light silt loam, brown (10YR 5/3) dry; moderate very fine subangular blocky structure; hard, very friable, slightly sticky, plastic; common fine roots; mico pores; 1 percent pebbles; abrupt, smooth boundary.
B	17.5-50 cm	Dark yellowish brown (10YR 3/4) light clay loam, dark brown to brown (10YR 4/3.5) dry; weak very fine subangular blocky structure; slightly hard, friable, sticky, plastic; plentiful roots; common very fine pores; 1 percent pebbles; smooth clear boundary.
C	50-87.5 cm	Brown to dark brown (7.5YR 4/4) clay loam, dark yellowish brown (10YR 4/4) dry; faint mottles; weak medium subangular blocky structure; hard, very friable, slightly sticky, plastic; very few fine roots; few, moderately thick dark reddish brown (5YR 3/3) clay films in pores; abrupt boundary (1 percent pebbles)
IIC	87.5-110 cm	Brown to dark brown (7.5YR 4/4) gravelly clay loam, dark yellowish brown (10YR 4/4) dry; faint mottles; very weak very fine subangular blocky structure; very friable, slightly sticky, slightly plastic; 17 percent gravel.

Location:	Hoffman property, Rt. 1, Box 116, Sutherlin, Oregon. NW 1/4, NW 1/4 Sec. 7, T 25 S, R 4 W.
Site description:	Located in a hayfield on swell and swale topography. The parent material is mixed alluvium and the slope is 0-3%.
Drainage and permeability:	The profile is somewhat poorly drained and permeability is moderately slow. There is moisture evident at 67.5 cm. but the ground water is deep.
Stoniness:	Class 1.

Date described: July 25, 1975

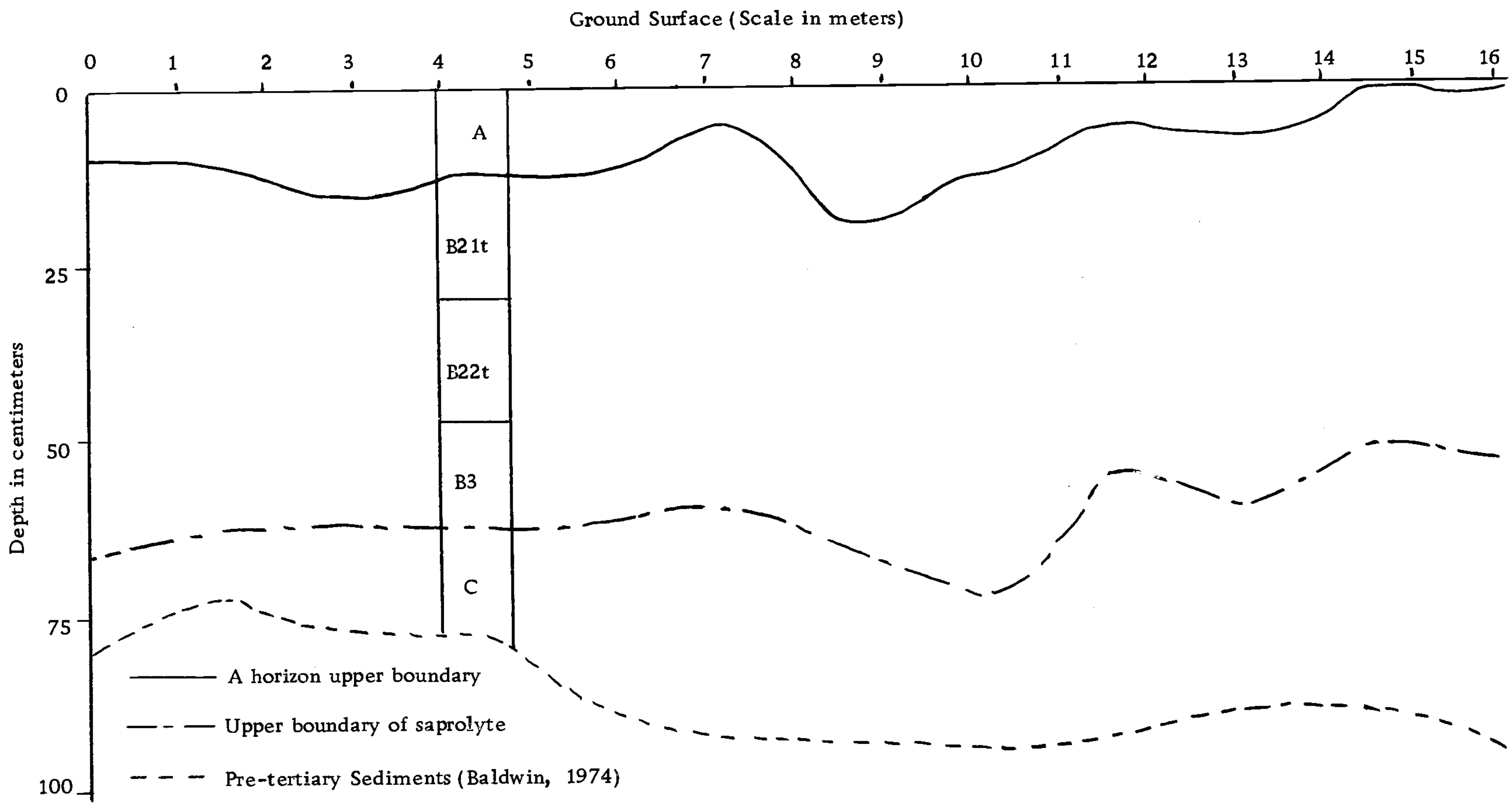
Series: Sutherlin (fine-loamy over clayey, mixed, mesic Ultic Haploxeralf)

A11	0-15 cm	Dark yellowish brown (10YR 3/4) silt loam, light yellowish brown (10YR 6/4) dry; moderate very fine and fine granular structure; soft, friable, slightly sticky, slightly plastic; many very fine and fine roots; common very fine and fine discontinuous interstitial pores; clear smooth boundary.
A12	15-27 cm	Dark brown (7.5YR 4/4) silty clay loam, strong brown (7.5YR 5/6) dry; moderate medium and coarse subangular blocky structure; slightly hard, firm, slightly sticky, slightly plastic; common fine and very fine roots; common medium and fine discontinuous tubular pores; few thin sand and silt coatings on ped faces; clear smooth boundary.
B21	27-40 cm	Dark brown (7.5YR 4/4) silty clay loam, strong brown (7.5YR 5/6) dry; moderate coarse and medium subangular blocky structure; slightly hard, firm, slightly sticky, slightly plastic; common fine and very fine roots; common fine and medium discontinuous tubular pores; silt coatings in peds and on ped faces; few black (10YR 2/1) manganese strains; few yellowish red (10YR 5/8) variegations; clear smooth boundary.
B22t	40-60 cm	Dark brown (7.5YR 4/4) heavy silty clay loam, brown (7.5YR 5/4) dry; common fine yellowish red (5YR 5/6) and reddish yellow (5YR 6/8) variegations; weak medium prismatic and moderate fine and medium sub-angular blocky structure; slightly hard, firm, sticky, plastic; few, very fine roots; common very fine and fine discontinuous interstitial and tubular pore; common thin clay films on ped faces and lining pores; common thin silt coatings on ped faces and in pores; common black (10YR 2/1) manganese stains; abrupt smooth boundary.
IIC1	60-90 cm	Dark yellowish brown (10YR 4/4) silty clay, light yellowish brown (10YR 6/4) dry; light yellowish brown (10YR 7/2) and reddish yellow (7.5YR 6/8) mottles; weak coarse prismatic structure parting to moderate medium and coarse subangular blocky; very hard, very firm, very sticky, very plastic; few very fine roots concentrated along vertical faces of peds; few very fine discontinuous tubular pores; few slickensides; many thick clay firms on ped faces; gradual smooth boundary.
IIC2	90-148 cm	Dark yellowish brown (10YR 4/4) silty clay, light yellowish brown (10YR 6/4) dry; many large prominent light brownish gray (10YR 6/2) and reddish yellow (7.5YR 6/8) mottles; moderate coarse prismatic structure parting to moderate medium and coarse subangular blocky; very hard, very sticky, very plastic; few very fine roots; few very fine discontinuous interstitial pores; many thick clay films on ped faces; few slickensides.
IIICr	148 + cm	Conglomerate sandstone.

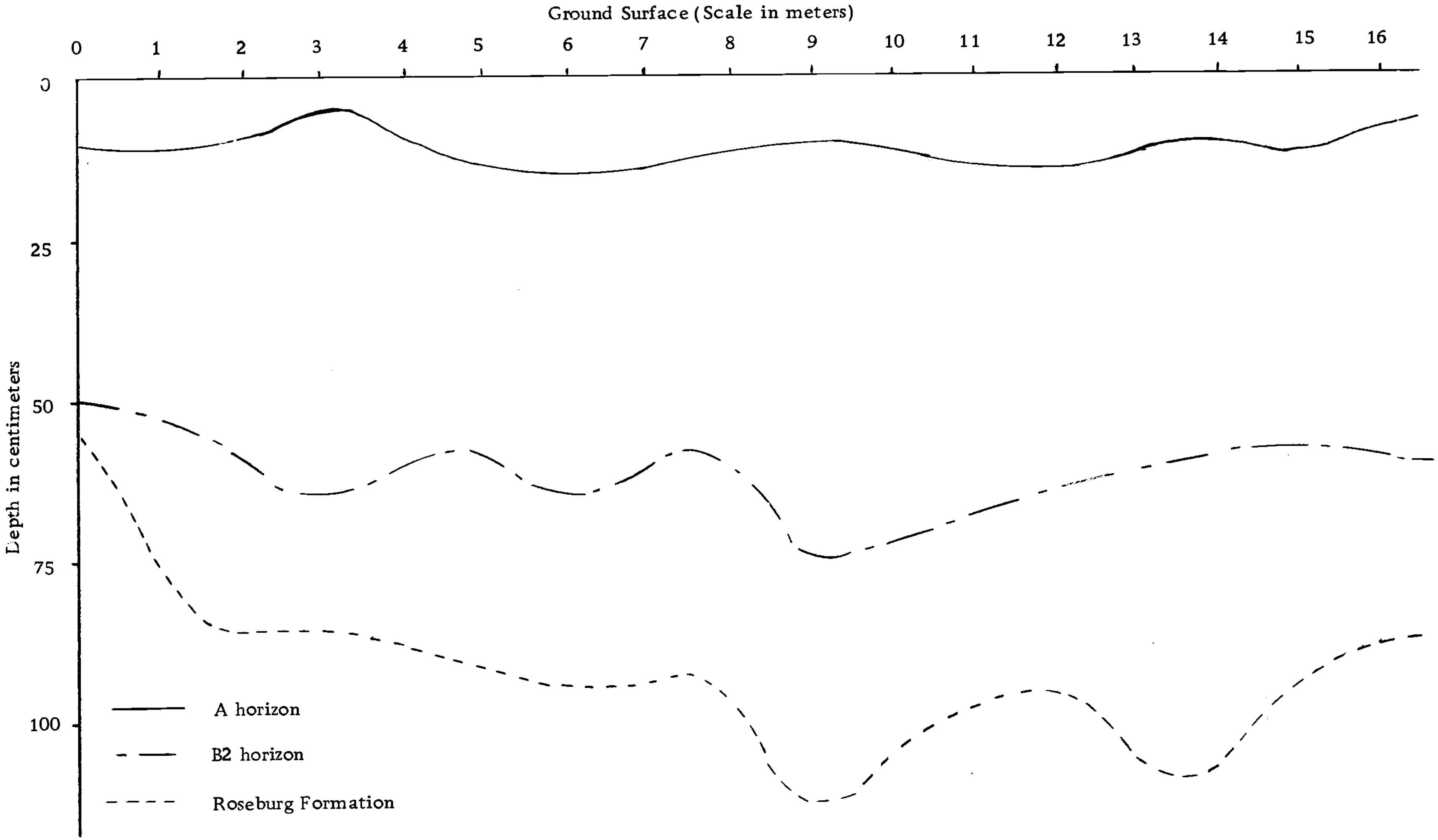
Location:	Property of River Bend West Estates Corporation, approximately one-half mile east on Youngs Lane, north side of road in hayfield, NW 1/4, SE 1/4, Sec. 13, T 26 S, R 7 W.
Site description:	Located in a hayfield on smooth rolling uplands, terrace position above a poorly defined drainage. Parent material is colluvial over the IIC from conglomerate sandstone. Slope is 5% and the aspect is south.
Drainage and permeability:	The profile is moderately well to somewhat poorly drained and permeability is moderately slow to very slow in the discontinuity. Profile was dry.
Stoniness:	Class O.

APPENDIX B

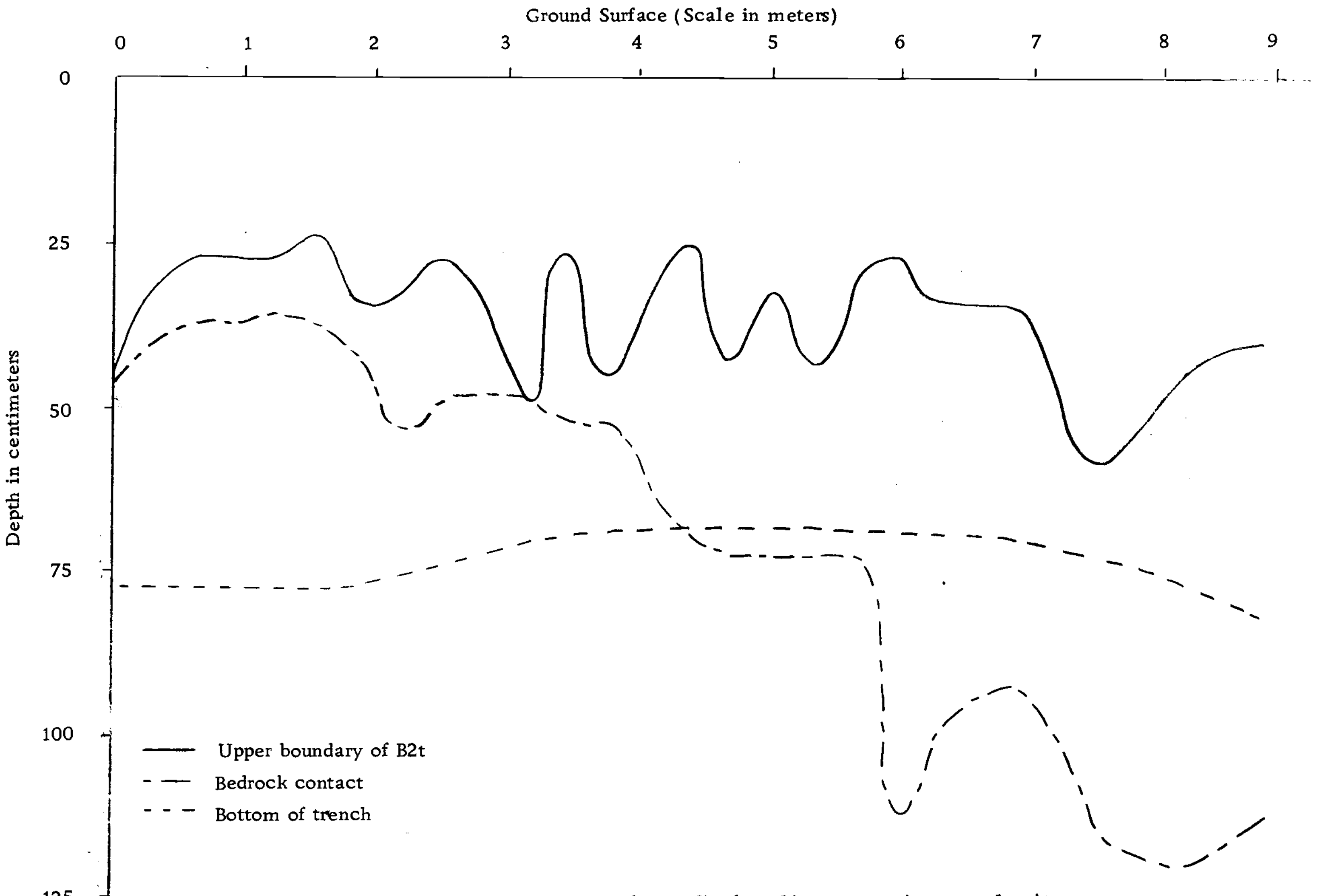
CROSS-SECTIONS OF TRENCHES AT EXPERIMENTAL SITES



Cross-section of lower trench at Clarks Branch with location of described soil.



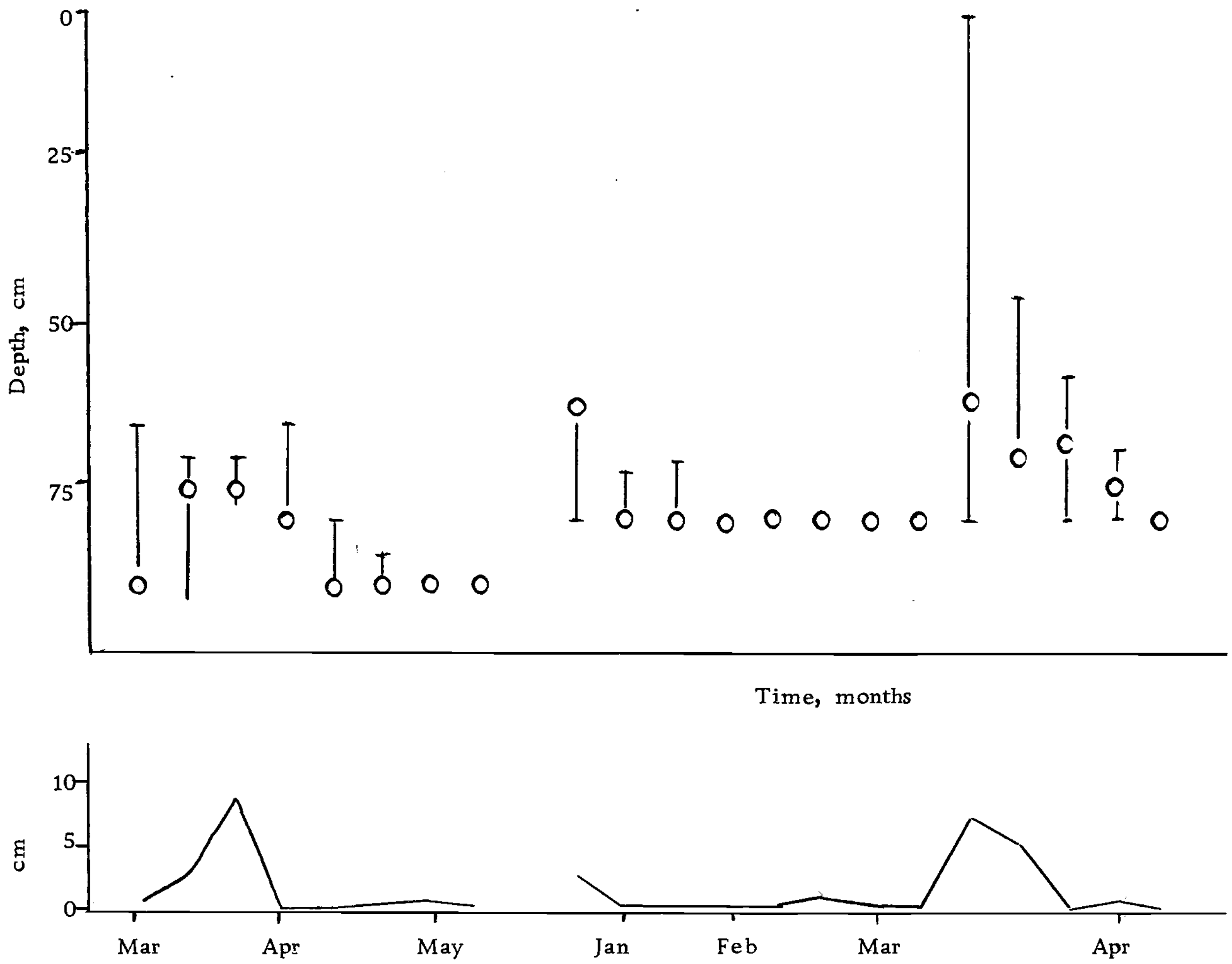
Cross-section of upper trench at Clarks Branch experimental drainfield



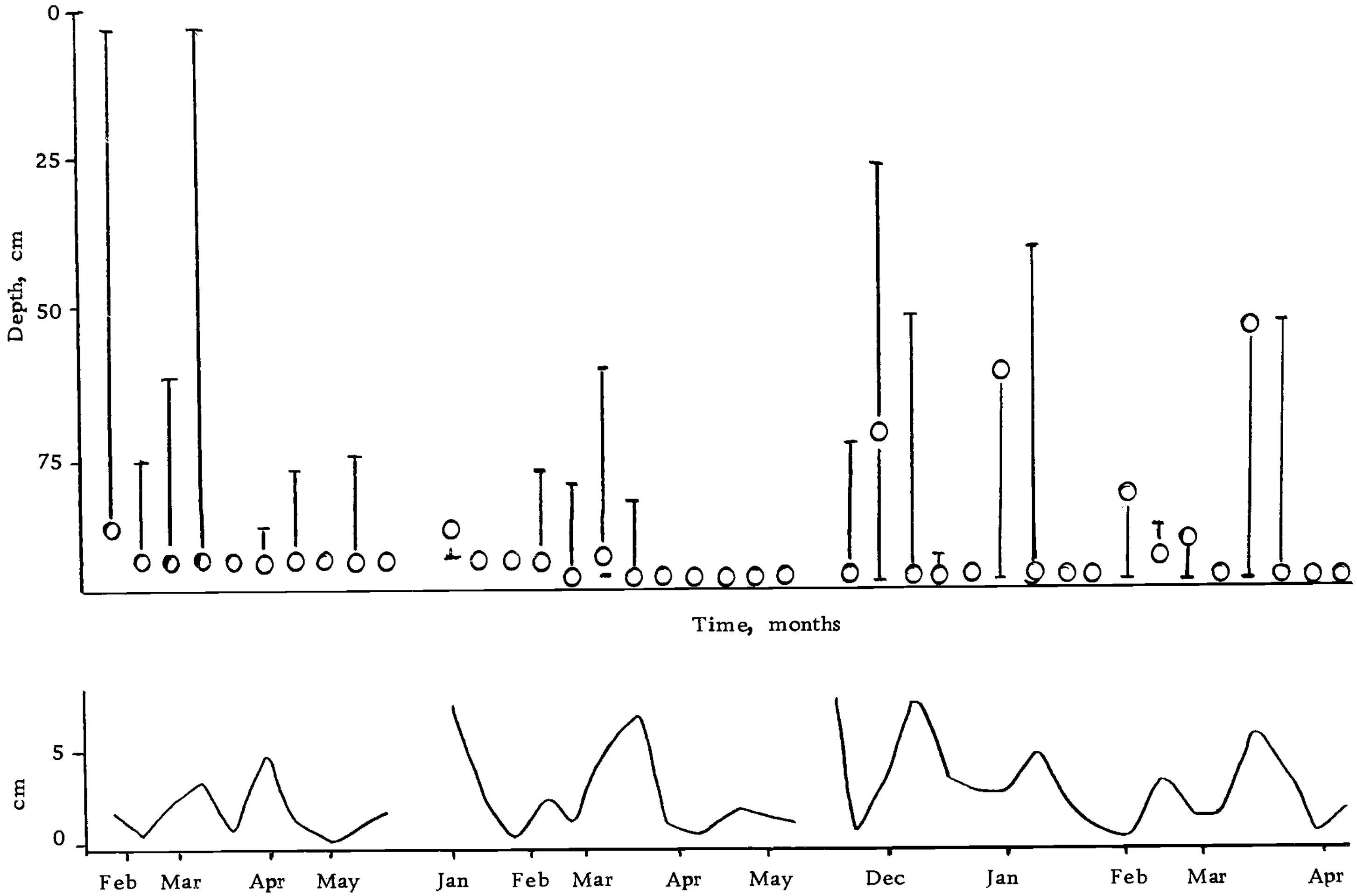
Cross-section of lower trench at Sutherlin experimental site.

APPENDIX C

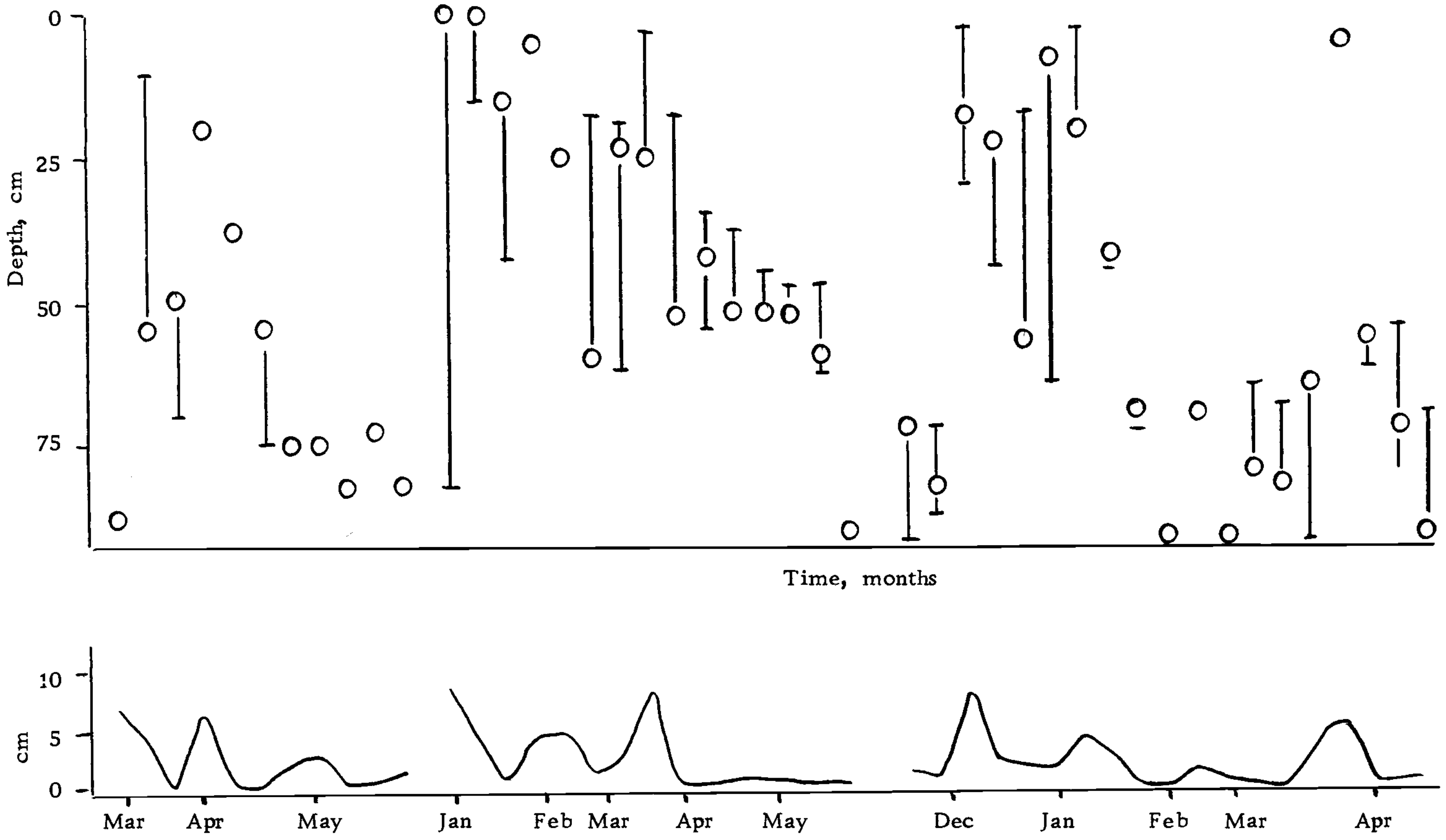
GRAPHS OF WATER TABLE FLUCTUATION AT GROUND WATER MONITORING SITES



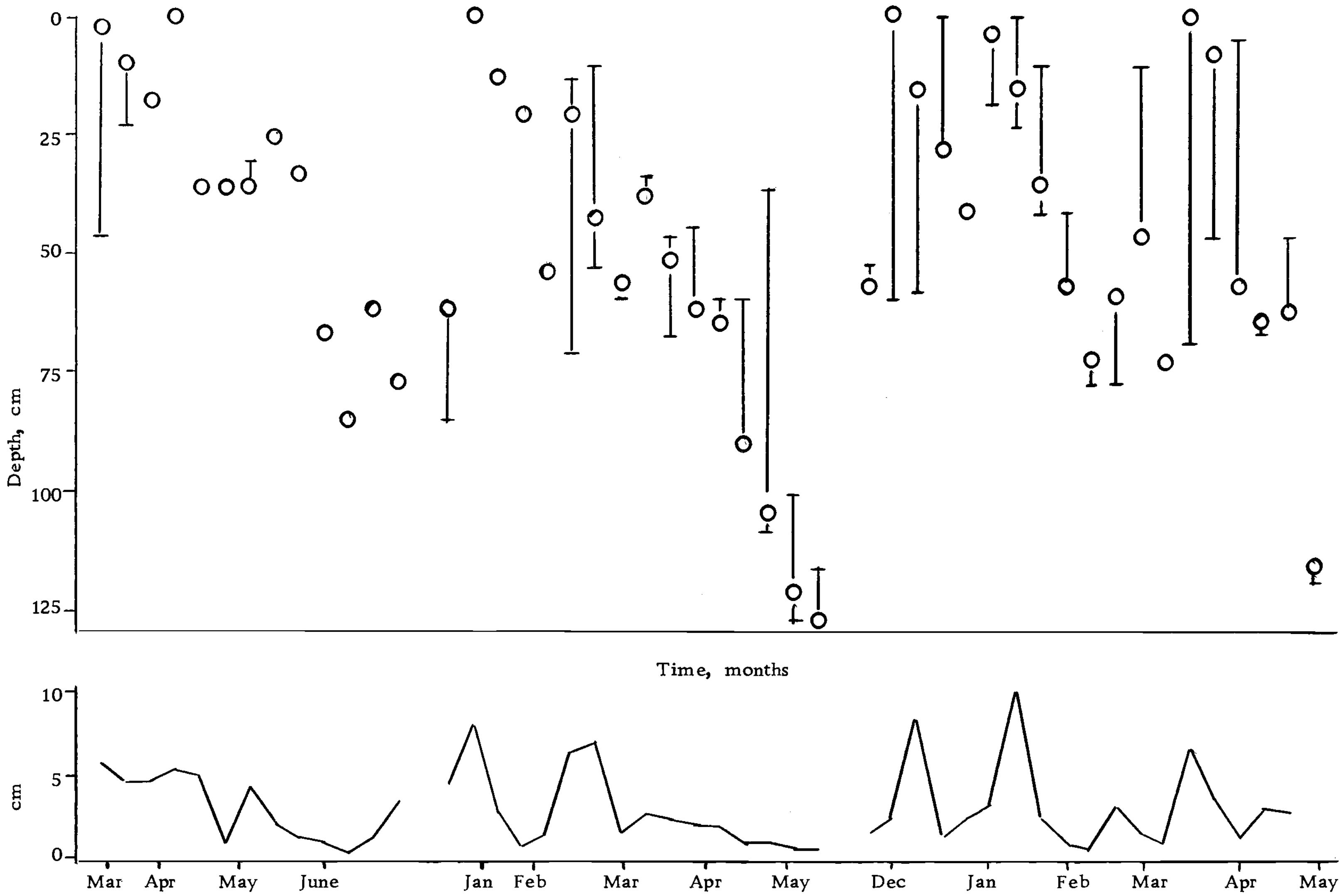
Graph of monthly water table and precipitation fluctuations on a Speaker taxajunct over two rainy seasons, spring 1975 and spring 1976.



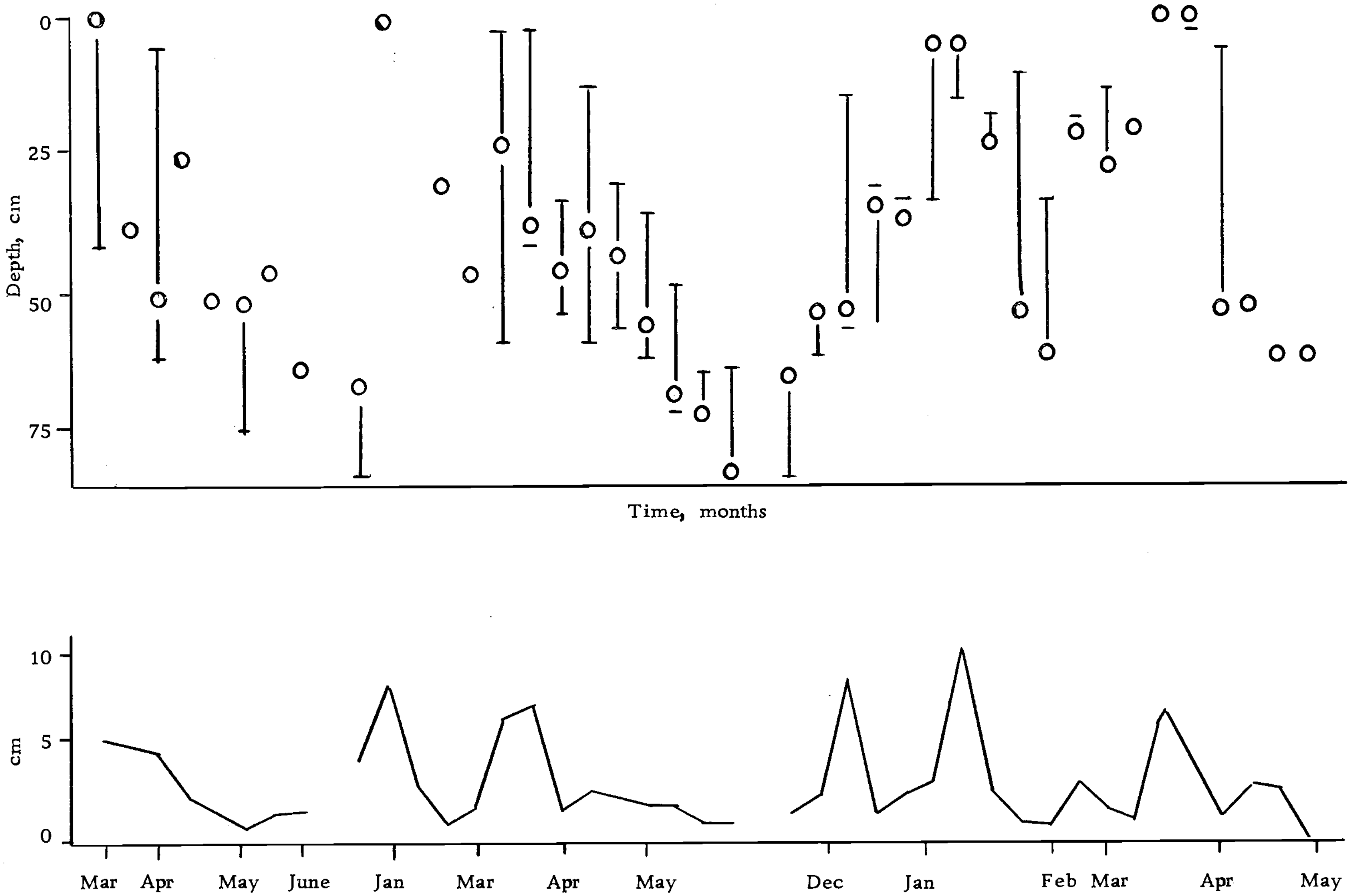
Graph of monthly water table and precipitation fluctuations on a Dixonville series over three rainy seasons, spring 1974 through spring 1976.



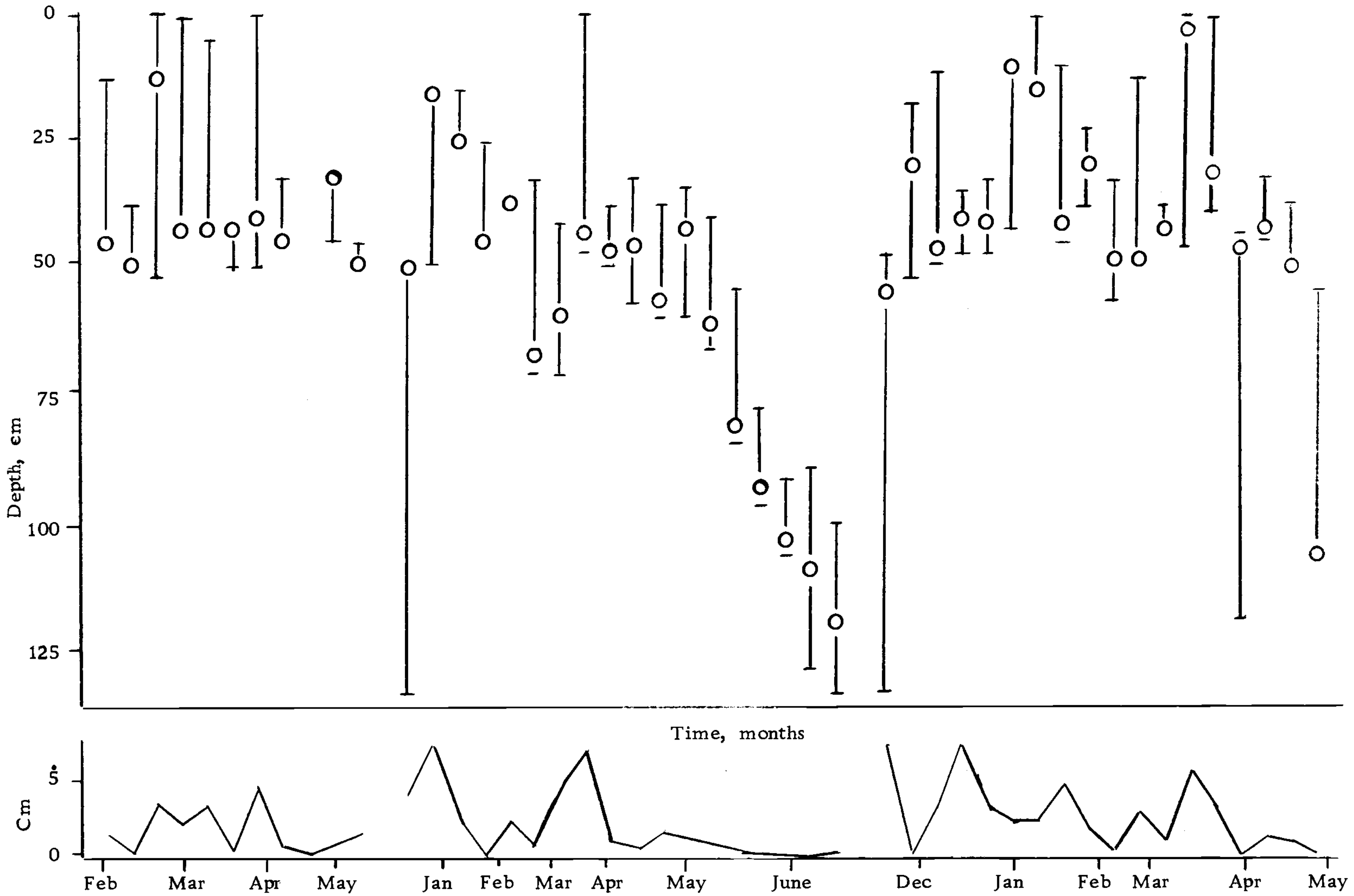
Graph of monthly water table and precipitation fluctuations on a Rosehaven (proposed) series over three rainy seasons, spring 1974 through spring 1976.



Graph of monthly water table and precipitation fluctuations on a Packard intergrade over three rainy seasons, spring 1974 through spring 1976.



Graph of monthly water table and precipitation fluctuations on a Coburg gravelly substratum series over three rainy seasons, spring 1974 through spring 1976.



Graph of monthly water table and precipitation fluctuations on a Sutherlin series over three rainy seasons, spring 1974 through spring 1976.