Arkansas Water
Resources Center

DISPOSAL OF HOUSEHOLD WASTEWATER IN SOILS OF HIGH STONE CONTENT (1981-1983)

Research Project Technical Completion Report B-060-ARK

Publication No. 103

December 1983

Prepared by:
E.M. Rutledge, C.R. Mote, D.T. Mitchell,
M.S. Hirsch, M.D. Harper, H.D. Scott
and C.L. Griffis
Departments of Agronomy
Agricultural Engineering
and Civil Engineering
University of Arkansas
Fayetteville, Arkansas 72701

Prepared for the United States Department of the Interior

Arkansas Water Resources Center
112 Ozark Hall
University of Arkansas
Fayetteville, Arkansas 72701

DISPOSAL OF HOUSEHOLD WASTEWATER IN SOILS OF HIGH STONE CONTENT (1981-1983)

E. M. Rutledge, C. R. Mote, D. T. Mitchell, M. S. Hirsch
M. D. Harper, H. D. Scott and C. L. Griffis

Departments of Agronomy, Agricultural Engineering
and Civil Engineering
University of Arkansas
Fayetteville, Arkansas 72701

Publication No. 103

December, 1983

Research Project Technical Completion Report B-060-ARK

The work upon which this report is based was supported in part by federal funds provided by the U. S. Department of the Interior, as authorized under the Water Research and Development Act of 1978, as amended, through annual cooperative program agreement 14-34-0001-1204.

Arkansas Water Resources Research Center
University of Arkansas
Fayetteville, Arkansas 72701

ABSTRACT

DISPOSAL OF HOUSEHOLD WASTEWATER IN SOILS OF HIGH STONE CONTENT

Four experimental filter fields were constructed with built-in monitoring equipment in Nixa soils. These soils contain many chert fragments and a fragipan about 60 cm below the soil surface. The fragipan restricts downward movement of water and is the design-limiting feature.

The four filter fields were:

1. A "standard" filter field, 76 cm deep. The bottom of the trench was in the fragipan.
2. A "modified standard" filter field, 30 cm deep. The bottom of the trench was above the fragipan.
3. A "modified pressure" filter field, 40 cm deep. The bottom of the trench was above the fragipan. In addition, a pressure-distribution system was used to insure uniform distribution of effluent in the trench. Inadvertently, this field was installed in a different soil, and the results cannot be compared directly with the other three.
4. Another "modified pressure" filter field with the bottom of the trench only 6 cm below the soil surface.

Observation of these systems confirms that placing filter fields higher in the soil above the hydraulically limiting horizon results in improved hydraulic performance. The presence of the fragipan amplified the adverse effects attributable to climatic stress. The seepage beds which are higher in the soil profile are able to handle the effluent load and climatic load with less danger of surfacing.

In order to study renovation of the wastewater, chemical analyses were performed on water samples taken from the seepage beds and from the soil near the seepage beds. Analyses were performed for total organic carbon (TOC), ammonia, and nitrate.

TOC measurements confirmed that significant reductions in organic carbon occurred within the beds. A reduction in TOC of approximately 50% was found to occur in every case. Further reductions in TOC were found to occur as the wastewater passed through the soil near the seepage beds. The reductions amounted to another 30% to 40% beyond that accomplished in the beds, and usually occurred within 60 cm of the beds.

Ammonia measurements showed that small reductions occurred within the beds of the "standard" system and the "modified standard". In both systems, the reductions amounted to 10% to 15%. Such reductions could not be shown in the other two beds, since water seldom ponded in them long enough for samples to be taken. In every system, however, significant reductions in ammonia concentration occurred as the water passed through the soil next to the seepage beds. These reductions amounted to 80% to 90%.

Changes in the concentration of nitrate were not as clear cut as were the other changes observed. The amount of nitrogen contained within the filter field was not determined. In some cases, nitrate concentrations increased with distance from the seepage beds. In other cases, nitrate concentrations decreased with distance. This apparent anomaly was probably the result of variations in the rates of nitrification and denitrification in the systems. Nitrification results in an increase in nitrate concentration, and denitrification results in a decrease. In general, there was a significant reduction in the total of ammonia plus nitrate concentrations with increasing distance from the seepage beds.

E. M. Rutledge, C. R. Mote, D. T. Mitchell, M. S. Hirsch, M. D. Harper, H. D. Scott and C. L. Griffis

Completion Report to Geological Survey, U. S. Department of the Interior, Reston, VA December 1983.

KEYWORDS -- Septic Tank Systems/Filter Fields/Soil Adsorption Systems/Effluent Renovation/Septic Tank Effluent Treatment/Fragiudults/Loamy-Skeletal Soils/Soils-Stony/Climatic Stress Periods.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF FIGURES
(Continued)

I. INTRODUCTION

The disposal of human wastes is a matter for concern to those who deal with environmental problems and to those who deal with public health problems. In communities with populations great enough to pay the cost, central treatment facilities have been developed and standardized. For smaller communities and for individuals, however, on-site wastewater disposal is the only practical solution.

Regulatory agencies have attempted to define a "standard" system for on-site disposal of wastewater, but variations in soil and climate have caused a disturbingly high failure rate, even in those systems which have been constructed according to the standards. It is the purpose of this report to present an evaluation of some alternative filter field designs in operation on particularly troublesome soils, the Nixa series.

The most outstanding features of the Nixa soils are the high content of chert fragments throughout their depths and the fragipan which occurs about 60 cm below the soil surface. The fragipan restricts the downward movement of water and is the design-limiting feature for septic tank filter fields.

These soils are not well suited for agriculture, but are desirable for housing sites, if the wastewater disposal problem can be overcome.

The objectives of the project that generated the information presented in this report were:

1) To continue the study of the "standard" filter field de-

scribed in the previous report. (Rutledge et al., 1983).

2) To continue to study the "modified standard" filter field described in the same report.

3) To install and monitor the performance of two additional filter fields similar to the "modified standard", but utilizing a pressure distribution system to insure uniform distribution in the trenches.

4) To measure soil water movement and effluent purification in all four of the filter fields in the Nixa soils.

II. LITERATURE REVIEW

a. Introduction

The disposal of domestic wastewater was a matter of concern in earlier times primarily because of public health problems. Domestic wastewaters contain bacteria, viruses, protozoa, and helminths pathogenic to humans. These infectious agents are widely distributed, occur in high numbers in untreated domestic wastes and are a potential health hazard. As a result, outbreaks of diseases such as typhoid, cholera, and dysentery that are now known to be associated with contaminated water were quite common. It was not, however, until more recent times that the connections between wastewater and communicable diseases were made. It was out of concern for the public well-being that methods for disposal of wastewater were developed.

Today wastewater treatment technology has developed along two directions. For people who live in large communities or cities, household wastewater is collected by municipal sewer lines and transported to a central treatment plant. There the sewage is treated or purified to certain pathogenic concentrations, depending upon the sophistication of the treatment systems. Subsequently, the treated effluent is introduced back into the hydrological cycle usually by dumping the effluent in a nearby stream.

For those approximately 16.6 million, or 25 percent, of the household (Cooper and Rezek, 1977) in the U.S. which are located in rural areas, the cost of a centralized collection system is prohibitive. For them disposal of wastewater must be accomplished on site. The most popular and best known method for wastewater disposal in this manner is the septic tank filter field system. This system is composed of two components, the septic tank and the filter field. Septic tanks are buried concrete or plastic receptacles, designed to receive wastewater from a household.

The primary purpose of the septic tank is to protect the soil absorption field from becoming clogged by solids suspended in the raw wastewater. It does this by serving as a settling chamber. Inside the tank, anaerobic equilibrium conditions exist, so that the heavy materials settle to the bottom producing a sludge layer, and the lighter materials float to the top. The light materials, which are known as scum, are converted from gelatinous to non-gelatinous forms. This serves to reduce further the clogging potential of the solids remaining in suspension. Under ideal conditions a reduction of about 40 percent of the biological ozygen demand (BOD) occurs in the septic tank. However, high concentrations of pathogenic bacteria and nitrogen and phosphorus remain in the effluent discharged from the tank.

The filter field is an area of soil which ideally is used for the uniform distribution and renovation of the wastewater. Conventional filter fields consist of level seepage beds at shallow soil depths. These seepage beds usually have approximately 25 to 35 cm of gravel in the bottom with the remainder of the bed up to the ground level backfilled with soil. Dimensions of the seepage bed system range from 0.3 to 1.5 m in depth and from 0.3 to more than 0.9 m in width.

In many instances the conventional filter field system will not function properly because of soil or site limitations. Sites having shallow soils, perched water tables, steep slopes, flooded areas, and small lot sizes dictate the use of an alternative system (EPA, 1980). The data presented in Table 1 are optional systems that may function for certain site constraints. It should be noted, however, that the less soil-dependent an alternative system is, generally the higher the cost and, in many cases, the poorer the treatment (Pound and Crites, 1973).

b. Hydraulic Characteristics of Filter Fields

The soil is a physically, chemically, and biologically active system. Soil has a great capacity for receiving and renovating domestic wastewater from septic tanks and is one of the three natural reservoirs where toxic pollutants can accumulate. The potential of a soil site for wastewater treatment may be determined in part by the soil's physical and chemical characteristics. Because these

Table 1. Selection of disposal methods under various site constraints.[1]

Method	Site Constraints									
	Soil Permeability			Depth to Bedrock		Depth to Water Table		Slope		
	Very Rapid	Rapid-Moderate	Slow-Very Slow	Shallow	Deep	Shallow	Deep	0-15%	5-15%	>15%
Trenches		X	X		X		X	X	X	X
Beds		X			X		X	X		
Pits		X			X		X	X	X	X
Mounds	X	X	X	X	X	X	X	X	X	
Fill Sys.	X	X	X	X	X	X	X	X	X	X
Sand-Lined Trenches or Beds	X	X	X		X		X	X	X	X
Artificially Drained Systems		X			X	X		X	X	X
Evaporation Infiltration Lagoons		X	X		X		X	X		
ET Beds or Trenches (lined)	X	X	X	X	X	X	X	X	X	X

---

[1] Design Manual, EPA, 1980.

characteristics vary with location, a general formulation of any kind is difficult (Tare and Bakel, 1982).

Bouma et al. (1983) concluded that the capacity of various land areas to accept, conduct, and renovate liquid wastes varies widely and good methods for determining these capacities are of crucial importance when evaluating land suitability for liquid-waste application. Many methods are available for measuring soil hydraulic characteristics and for calculating soil moisture regimes. However, there is as yet no generally accepted procedure for defining the capacity of a soil to accept, conduct, and renovate liquid wastes. They attributed this to the following factors:

1) Some widely applied methods for estimating soil permeability such as the percolation test have limited applicability because of their poorly defined physical interpretation.
2) Many modern methods for measuring soil hydraulic conductivity are unsuitable for widespread application because they are cumbersome and costly.
3) The dynamic character of the processes involved has oftentimes been ignored, as research was focused on obtaining one characteristic value for a given soil. Examples include one percolation rate or one saturated hydraulic conductivity value or even one average K value over the entire area of waste application. This value usually is inadequate for analyzing transient processes in unsaturated soil that occur during intermittent application of waste.

4) Modern simulation methods for soil water flow are based upon flow theory, which requires the presence of a nonswelling soil without continuous macropores. Many soils have different *in situ* properties.

5) Emphasis has traditionally been placed on disposal rather than on the purification of wastewater movement. Excellent disposal may be associated with poor purification due to high fluxes of water and short travel times. Both aspects are equally important and should be considered together when defining optimal application regimes.

Recent research at several locations has shown much more rapid and extensive movement of solutes through soil than expected (Simpson and Cunningham, 1982; Thomas and Phillips, 1979). These reports have suggested that large interconnected pores account for much of the water and wastewater flow through the soil under near saturated conditions. Rapid flow of water through channels in the soil may lessen the renovating capability of the soil because of the reduced surface area and reduced contact time. For example, Simpson and Cunningham (1982) examined a transect of 15 pits in a Typic Hapludalf that had a wastewater irrigation system operating for 15 years. Morphological investigations of the pit transects revealed that the channels were vertically oriented, variable in size, had inverted cone-shaped bodies that had low bulk densities and were much less firm than the surrounding soil. The channels were three dimensional and not perfectly vertical. They were found in both the irrigated and nonirrigated areas but generally were wider and had greater volumes in the irrigated areas. Field observations indicated that flow through the channels was rapid and much more rapid than laboratory measurements indicated.

Many researchers have reported that a crust may develop at the soil-seepage bed interface in filter fields and may cause the septic system to fail. Bouma et al. (1974) stated that this crusting phenomenon may originate from biochemical, chemical, or physical processes at the interface. Some researchers such as Allison (1947) and McCalla (1950) have reported that microbial cells alone caused the formation of the mat. They made their conclusions on infiltration studies of wastewater in soil columns. In Allison's experiments sterile and non-sterile water was applied to sterile and non-sterile soil. The only treatment which did not exhibit a characteristic decline in infiltration rate was the sterile water, sterile soil combination. McCalla concluded that microorganisms were responsible for reducing percolation rates in soil in two ways: first, by producing by-products such as gases, organic materials, and slime that impeded water movement into soil, and second, by deteriorating agents responsible for stabilizing soil structure.

Other researchers have disputed the possibility that microbes alone were responsible for the formation of the crust. Winneberger et al. (1960) proposed that anaerobic activity on soil organic matter was the determining factor. They based their conclusions on investigations showing that clogging was not inhibited by applying aerated sterile water to soil columns. Jones and Taylor (1965) also thought anaerobic conditions were the true culprit for biological crusing. They measured the effects of intermittent dosing versus continuous ponding of septic tank effluent on sand columns. Their results showed that crust formation developed 3 to 10 times faster in an anaerobic environment than when resting cycles were allowed. It was also determined that those columns having dosing cycles exhibited loss in infiltrative capacity in three phases. The first phase was attributed to blockage of the pores by the organics, the second phase was evidenced by small changes in hydraulic conductivity over a period of several weeks, and a third phase involved clogging which proceeded at a relatively rapid rate until some minimum value was reached. This value, they concluded, was dependent upon the original hydraulic characteristics of the soil.

Kropf et al. (1975) found that infiltration rates of constantly ponded soil columns remained higher than those subjected to intermittent dosing. They postulated that earlier researchers failed to account for the higher organic loads which serve to accelerate clogging (Laak, 1970) in those columns that were constantly ponded. Thus, more effluent had infiltrated those units which were inundated than those which underwent intermittent dosing.

These crusts usually are effective in reducing the transport of large populations of bacteria present in the wastewater. The infiltration of water across the seepage-bed soil interface controls the overall acceptance rate. If crusting has occurred, the acceptance rates are controlled by the hydraulic conductivity of the biological mat. If crusting has not occurred, the acceptance rate is controlled by the hydraulic properties of the soil. The acceptance rate will be equal to the overall hydraulic conductivity of the soil in the system times the hydraulic gradient, i.e., Darcy's law. Hydraulic conductivity (K) is the transport coefficient which is dependent upon the soil water content and the soil water matric potential. Under saturated conditions K is considered constant. Under unsaturated conditions K varies in an exponential relationship with soil water content or matric potential. Not only is the K - water content relationship complex, but the variability in flow rates makes any quantitative measurement of the *in situ* hydraulic properties of the filter field difficult.

c. Water Quality of Filter Fields

The second factor important to the performance of filter fields is the quality of the water as it enters the hydrologic cycle. According to Pettyjohn (1983), it is essential to describe differences between natural quality and man-influenced quality. Background concentrations of pollutants may, however, fluctuate between fairly wide limits during short intervals. The severity of ground water pollution is related to the characteristics of the waste or leachate, i.e., its volume, composition, concentration of the various constituents, time rate of release of the constituents, the size of the area from which the contaminants are derived, the density of the leachate, and others (Pettyjohn, 1983).

The fate of inorganic N and P compounds in the disposal of domestic wastewaters is of great general interest. Particular emphasis has been placed on N transformations because of the potential for NO_3 contamination of ground waters which may eventually be used for domestic or municipal water supplies. Concern arises from the risks of methemoglobinemia in infants who ingest waters containing excessive concentrations of NO_3 and NO_2. Accelerated eutrophication of surface waters with subsequent algal blooms and O_2 depletion also demand attention. Reneau et al. (1977) monitored changes for four years in NH_4, NO_2, and NO_3 around a septic tank filter field. The soil was a Plinthic Paleudult which has a very slowly permeable plinthic horizon. They found that NH_4 in solution decreased with distance from the seepage bed in the direction of ground water flow. They attributed this to adsorption and nitrification. Concentrations of NO_2 and NO_3 did not change significantly with distance above the plinthic horizon, but did accumulate in the plinthic material approximately 1.27 m from the drainfield. They attributed this to the inhibition of nitrification adjacent to the filter field caused by the high oxygen demand and general anaerobic conditions present. Conditions within the plinthic horizon were unfavorable for denitrification. In a similar study P accumulations were found to decrease with distance from the septic tank seepage bed. Movement of septic tank effluent had not appreciably altered the quantities of "fixed" P or the distribution of P fractions at any distance sampled in the systems.

Starr and Sawhney (1980) monitored a 6-year-old septic system drainfield for the vertical movement of N and C. The soil had a coarse sand texture and a low cation exchange capacity of 2 meq/100 g. They found that effluent ponded in the seepage bed within 24 hours after it was directed to that trench and that the effective infiltration rate was about 100 times less than the saturated hydraulic conductivity of the drainfield. They attributed this decreased infiltration to the development of a slime layer on soil surfaces. The soil at depths of 15 and 30 cm below the seepage bed became saturated within a few days and remained so as long as the trench was in use. The soil at greater depths remained unsaturated throughout. Approximately 100 days were required to develop steady state with respect to ponding depth and concentrations of N and C in the soil solution. In both years of the study about 25 percent of the influent N was mineralized. Differences in concentration were attributed to rainfall. Concentrations of NO_3 greater than 25 to 30 ug/ml were frequently found below the 90 cm depth during the year of the lowest rainfall, but concentrations of NH_4 were found below this depth during the year of the highest rainfall. Phosphorus movement from the seepage bed occurred in both the downward and in the horizontal directions (Sawhney and Starr, 1977). Soil solution concentrations at equal distances below and beside the seepage bed had similar P concentrations. They concluded that shallow soils with high or perched water tables would likely permit undesirably large P additions to the groundwater. Resting of the system regenerated P sorption sites in the soil and allowed the soil to remove additional P from wastewater over a longer period.

Another important aspect of the water quality of the wastewater is the microorganism content and distribution. Reneau et al. (1977) determined the distribution of total and fecal coliform bacteria in three coastal plain soils in Virginia over a 3-year period. These soils are considered as only marginally suitable for septic tank installation because the restricting soil horizons result in perched water tables. They found large reductions in both total and fecal coliform bacteria in the perched ground waters above the restricting horizons as distance from the seepage bed increased. This was attributed to dilution, filtration and dieoff as the bacteria moved through the natural soil system. Thus, the restricting horizons in the soil served to reduce the vertical movement of these indicator organisms.

Viraraghavan (1978) also studied the distribution of indicator microorganisms downslope from the end of a septic tile. He found that the indicator organisms coliform, fecal coliforms and fecal streptococci exhibited a declining trend in concentration with distance away from the septic tile in the direction of groundwater flow. Due to the fluctuating water table the concentration of these bacteria at 15.25 m from the seepage bed was high, and this condition was attributed to the lack of sufficient unsaturated soil near the seepage bed. He concluded that there can be no arbitrary rule governing the distance that is necessary for safety between a seepage bed and a source of water supply in a shallow aquifer. Many factors such as slope, direction and level of groundwater, and soil permeability affect the removal of microorganisms through their travel in the unsaturated soil and in the groundwater.

III. METHODS AND MATERIALS

a. Description of the Study Area

The Ozark Highlands of southern Missouri, northern Arkansas, and northeastern Oklahoma are characterized by three step-like geomorphic surfaces. These surfaces successively increase in elevation southwestward across the 300-m Salem Plateau, the 400-m Springfield Plateau, and the 600-m Boston Mountain Plateau. All rocks exposed in this area are of sedimentary origin and range in age from Oridivician to Carboniferous (Croneis, 1930). In general, the oldest beds are exposed in the northern and the youngest along the southern extremities.

1. Location, Geology, Geomorphology

A suitable area for this study was found in the western portion of northern Washington County, Arkansas, approximately 3 km northeast and 6 km northwest of the communities of Savoy and Wheeler, Arkansas, respectively. The study area lies within the Springfield Plateau.

The Springfield Plateau is underlain mainly by rocks of Mississippian age (Thornbury, 1965). In Arkansas, the northeast facing Eureka Springs Escarpment serves to form the boundary between the Salem and Springfield Plateaus. The scarp reaches a thickness of 120 m near Eureka Springs but becomes progressively less well-defined toward the east. Most of the plateau stands between 300 and 450 m above sea level, but at several places, including the Fayetteville quadrangle, prominent erosional remnants of the Boston Mountains may rise 70 to 200 m higher above the general surface (Croneis, 1930; McDonald et al., 1975).

The surface topography of the Springfield Plateau is rather rough, particularly near its northern border, where streams cut to the Eureka Springs Escarpment and to the south where erosional remnants are most prominent. In many areas, however, the surface is only gently undulating. This surface feature is most conspicuous in the area surrounding Fayetteville and is referred to in the literature as "prairie" (Croneis, 1930; Thornbury, 1965).

Most of the surface rocks of the region belong to the Boone formation, which is approximately 90 m thick in central Washington County (Frezon and Glick, 1959). All the limestones of the Boone formation above its lower member are nearly pure calcium carbonate and, therefore, very soluble in water. In addition, chert is found in nearly all horizons of the Boone formation above the St. Joe limestone member (Croneis, 1930). Therefore, as the limestone weathers, the insoluble chert is left behind as surface and sub-surface deposits. Such deposits are widespread over the Springfield Plateau. Much of the unweathered chert is dense, hard, compact, and brittle and has concoidal fracture, but some is relatively soft and occasional pieces can be broken by hand.

Associated also with the relatively high solubility of the Boone formation, is the occurrence of solution valleys that dissect much of the area leaving long, narrow, nearly level ridges that are truncated by the steep slopes of the solution valleys. These valleys are strikingly uniform in width and are nearly straight. According to Croneis (1930), these valleys are so characteristic of the Springfield Plateau that they may be used as a criterion of that physiographic province.

2. Soils

Three soil associations are recognized on the Springfield Plateau of Washington County (Harper et al., 1969). These soils developed predominantly under hardwood vegetation and are underlain by silty or clayey materials, cherty limestone, or alluvium derived from these sources.

The soils in the immediate study area are within the Clarksville-Nixa-Baxter association. The Clarksville soils occur on the steep slopes of the solution valleys and account for approximately 45 percent of the association (Harper et. al., 1969). They are 50 to 90 percent chert with a grayish-brown or brown very cherty silt loam surface texture that is 15 to 30 cm thick and strong-brown to pale-brown very cherty silt loam subsoil. The Baxter soils also occur on the hillsides and account for 15 percent of the association. Their surface layer is grayish-brown or brown very cherty silt loam 15 to 30 cm thick and the subsoil is dark-red to yellowish-red cherty clay or cherty silty clay. Approximately 20 percent of the association is composed of the Nixa series. These soils developed on long narrow ridge-tops from residuum derived from cherty limestone. They are deeply developed and occur on slopes that range from nearly level to moderately steep. The surface layer is very dark grayish-brown and the subsurface layer is brown, very cherty silt loam about 26 cm thick. The upper part of the subsoil is light yellowish-brown, very cherty silt loam about 26 cm thick underlain by a compact, brittle fragipan of yellowish-brown, mottled, very cherty silt loam. Because of the fragipan horizon, the Nixa soil is considered very slowly permeable to water. As a consequence, these soils have a severe limitation to accommodate septic tank filter fields.

b. Experimental Site Characteristics

Table 2 contains the official series description of the Nixa soils. The main soils at the experimental site are similar soils to the Nixa soils. The experimental site is situated near the crest of a ridge (Figure 1). The steepest slope is northeast to southwest across the site. The experimental filter fields are positioned so that the ground slope is less than 3.6 percent.

An abbreviated description of the soil of filter field 01ST76 and 02MG30 is given in Table 3. A detailed description of this soil, which was sampled and described from a pit between filter fields 01ST76 and 02MG30 (Figure 1), is given in Appendix Table A-1. An abbreviated description of the soil of the 10MP40 filter field, which was described about 2 m east of the 10MP40 seepage bed, is given in Table 4. The soil of the 11MP06 filter field, which was described about 2 m southwest of the seepage bed, is described in Table 5.

The soil of the 01ST76 and 02MG30 filter field (Table 3) differed from Nixa soils (Table 2, as noted in Appendix Table A-1), in

Table 2. Official series description of Nixa soils.[1]

The Nixa series consists of moderately well drained, very slowly permeable soils on upland ridgetops and sideslopes of the Ozark Highlands. They formed in loamy residuum weathered from cherty limestone. Slopes range from 1 to 20 percent.

Taxonomic Class: Loamy-skeletal, siliceous, mesic Glossic Fragidults.

Typical Pedon: Nixa very cherty silt loam on a 4 percent slope in forest. (Colors are for moist soil unless otherwise stated.)

A1--0 to 5 cm; Very dark grayish brown (10YR 4/2) very cherty silt loam; weak fine granular structure; friable; common fine roots; few fine pores; 40 percent by volume chert fragments 1 to 10 cm in diameter; strongly acid; clear smooth boundary. (0 to 8 cm thick).

A2--5 to 28 cm; Brown (10YR 5/3) very cherty silt loam; weak fine subangular blocky structure; friable; common fine and medium roots; common fine pores; 40 percent by volume chert fragments 1 to 10 cm in diameter; strongly acid; gradual smooth boundary. (13 to 25 cm thick).

B1--28 to 56 cm; Light yellowish brown (10YR 6/4) very cherty silt loam; weak and moderate medium subangular blocky structure; friable; common fine and medium roots; few fine pores; 60 percent chert fragments 2 to 10 cm in diameter; very strongly acid; gradual wavy boundary. (13 to 36 cm thick).

Bx--56 to 112 cm; Yellowish brown (10YR 5/4) very cherty silt loam; common medium distinct strong brown (7.5YR 5/6), light brownish gray (10YR 6/2), and few fine yellowish red (5YR 5/6) mottles; weak fine subangular structure; firm and brittle; 70 percent by volume chert fragments 2 to 15 cm in diameter; common fine pores; thin patchy clay films on faces of peds and on chert fragments; few fine roots in gray streaks; few dark concretions; black stains on chert faces; very strongly acid; gradual wavy boundary. (25 to 76 cm thick).

B2t--112 to 183 cm; Mottled 50 percent yellowish red (5YR 4/6), 30 percent strong brown (7.5YR 5/6), and 20 percent light brownish gray (10YR 6/2) very cherty silty clay loam; weak medium angular blocky structure to massive; firm; slightly brittle; 80 percent by volume weathered chert fragments up to 15 cm in diameter; few fine pores, thin continuous clay films on faces of peds and chert fragments; very strongly acid.

Type Location: Marion County, Arkansas; 6.6 km north on Arkansas-14 from junction of U.S. 62 on right side of highway, NW1/4SE1/4SW1/4 sec. 21, T. 19 N., R. 16 W.

Range in Characteristics: Depth to the fragipan is 36 to 61 cm. Depth to unconsolidated chert beds is 61 to 122 cm and depth to con-

Table 2. Official series description of the Nixa soils. (continued)

solidated bedrock is over 152 cm. The soil is strongly acid or very strongly acid throughout except where surface layers are limed.

The A1 horizon has hue of 10YR, value of 3 or 4, and chroma of 2. The A2 horizon has hue of 10YR, value of 5 or 6, and chroma of 3 or 4; value of 5, and chroma of 2. The Ap horizon of cultivated areas has hue of 10YR, value of 4 or 5, and chroma of 3; value of 5, and chroma of 4. Texture of the A horizon is very cherty silt loam, cherty lilt loam, or cherty loam.

The B1 horizon has hue of 10YR, value of 5 or 6, and chroma of 4 or 6; value of 5, and chroma of 3. The fine-earth fraction is silt loam, silty clay loam, clay loam, or loam with a very cherty modifier. Chert content ranges from 35 to 76 percent.

An A2 horizon, if present, has hue of 10YR, value of 5 and 6, and chroma of 2 or 3, and in some pedons, has mottle of lower chroma. Texture is very cherty silt loam or very cherty loam. Clay content is less than that of the B1 horizon.

The Bx horizon has hue of 10YR, value of 5, and chroma of 4 or 6; value of 6, and chroma of 6; hue of 7.5YR, value of 5, and chroma of 4 or 6, and mottled in shades of brown, gray, or red. The fine-earth fraction is silt loam, silty clay loam, loam, or clay loam with a very cherty textural modifier. The Bx horizon has 40 to 75 percent chert.

The B2t horizon has hue 2.5YR or 5YR, value of 3, 4, or 5, and chroma of 4, 6, or 8, or mottled in shades of red, brown, or gray. The fine-earth fraction is clay, silty clay, or silty clay loam with very cherty textural modifier. This horizon contains 50 to 85 weathered chert fragments or is discontinuous bedded chert with closely spaced vertical fractures and cracks and horizontal seams 1 to 10 cm in thickness.

Drainage and Permeability: Moderately well drained. Runoff is medium to rapid. Permeability is very slow.

Use and Vegetation: Used mainly for forest and pasture but a small amount is used for cropland. Native forests were mainly of post oak, blackjack oak, and hickory.

Distribution and Extent: Arkansas, Kentucky, Missouri, Oklahoma, and possibly Tennessee. The series is of large extent, probably of 150,000 acres.

National Cooperative Soil Survey
U.S.A.

---

[1] National Cooperative Soil Survey, 1977.

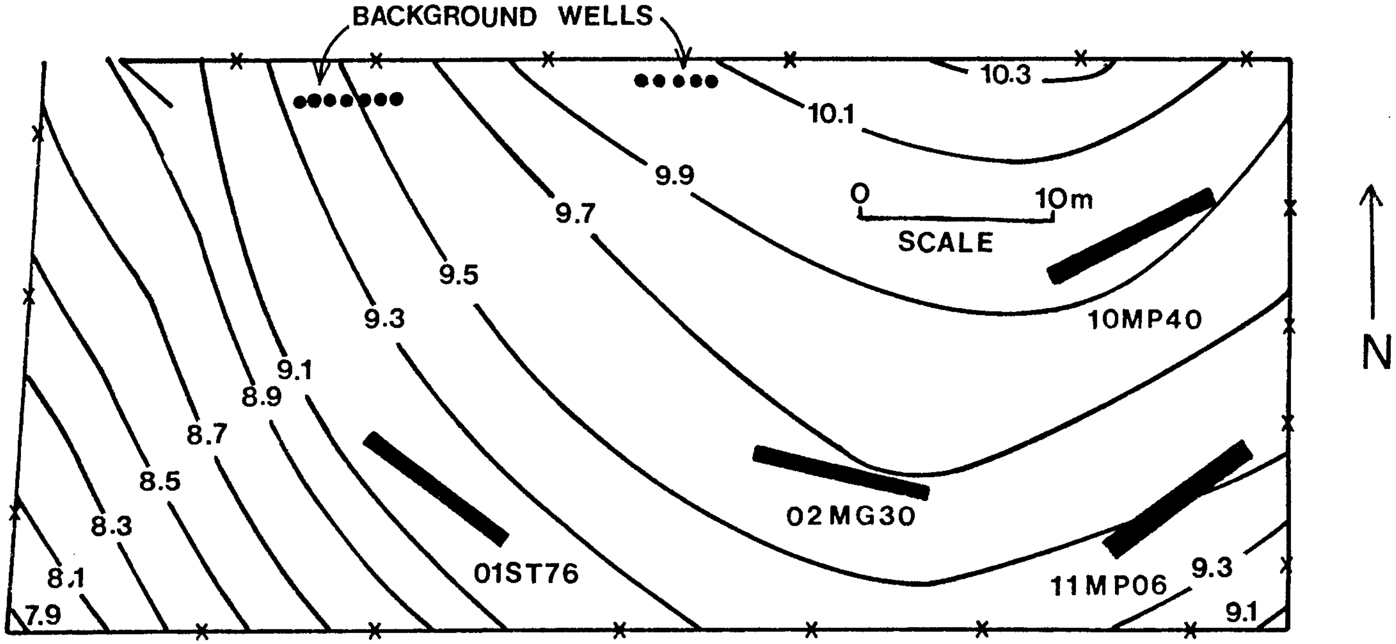

Figure 1. Topographic map of the experimental site with locations of the four experimental filter fields and background wells.

Table 3. Abbreviated pedon description for the soil of filter fields 01ST76 and 02MG30.

Ap	0-13 cm Yellowish brown (10YR 5/4) cherty silt loam; common coarse and medium dark brown (10YR 4/3) mottles; weak medium and fine subangular blocky structure; 30 to 40% by Vol. chert fragments.
E	13-31 cm Yellowish brown (10YR 5/4) cherty silt loam; weak medium subangular blocky structure; 30 to 40% by Vol. chert fragments.
Bt1	31-44 cm Strong brown (7.5YR 5/6) cherty silt loam; common medium brownish yellow (10YR 6/6) mottles; weak to moderate medium subangular blocky structure; 35 to 40% by Vol. chert fragments.
Bt2	44-59 cm Strong brown (7.5YR 5/6) cherty silty clay loam; common medium yellowish red (5YR 4/6), few medium brownish yellow (10YR 6/6), few fine light gray (10YR 7/2) mottles; moderate medium and fine angular blocky structure; 30 to 35% by Vol. chert fragments.
Btx1	59-76 cm Yellowish red (5YR 4/6) cherty silty clay loam; common medium yellowish brown (10YR 5/4) mottles; moderate fine angular blocky structure; 40 to 50% by Vol. chert fragments.
Btx2	76-91 cm Red (2.5YR 4/6) cherty silty clay loam; few fine light brownish gray (10YR 6/2) mottles; moderate fine angular blocky structure; 40 to 50% by Vol. chert fragments.
B't	91-218 cm Dark red (2.5YR 3/6) clay; common coarse red (2.5YR 4/6) and a few medium strong brown (7.5YR 5/8) mottles; moderate fine and medium angular blocky structure; 30 to 40% by Vol. chert fragments.

---

[1] A detailed description is presented in Appendix Table A-1.

Table 4. Abbreviated pedon description for the soil of filter field 10MP40.

Ap	0-12 cm Brown (10YR 4/3) silt loam; moderate medium granular structure; friable; many roots; approximately 55% by Vol. chert fragments up to 10 cm across.
E1	12-20 cm Yellowish brown (10YR 5/4) silt loam weak medium subangular blocky structure; friable; many roots; approximately 50% by Vol. chert fragments up to 10 cm across.
E2	20-34 cm Pale brown (10YR 6/3) silt loam; many coarse 10YR 3/4 mottles; weak medium subangular blocky structure; friable; approximately 60% by Vol. chert fragments up to 12 cm across.
Ex	34-45 cm Light yellowish brown (10YR 6/4) silt loam; common medium and coarse 10YR 6/2 mottles; moderate medium angular blocky structure; firm, brittle; approximately 80% by Vol. chert fragments up to 20 cm across.
BEx/Btx	45-65 cm Strong brown (7.5YR 5/8) silt loam or silty clay loam (80% of horizon) with many coarse 10YR 7/2 mottles; moderate medium and fine angular blocky structure; firm, brittle; approximately 85% by Vol. chert fragments up to 25 cm across; some horizontal seams 10YR 6/2 about 1 cm thick overlying 2.5 YR 3/6 silt clay. 20% of horizon is dark red (2.5YR 3/6) silty clay with common gray and yellowish brown mottles; moderate medium and fine angular blocky structure; firm, brittle; about 85% by Vol. chert fragments up to 25 cm across.

minor ways which are not expected to have influenced the performance of the septic tank filter fields. Therefore, this soil was a similar soil to Nixa soils and is referred to as a Nixa soil. The soil of the 10MP40 filter field (Table 4) differed from Nixa soils by having Ex and BEx/Btx horizons rather than BE and Btx horizons. Also, the fragipan of this soil came to within 34 cm of the surface which, although within the range for Nixa soils, would retard drainage from seepage beds in the E or Ex horizons. Therefore, the soil at filter field 10MP40 was not a similar soil to Nixa because of differences in horizons and the shallow fragipan. The soil of the 11MP06 filter field (Table 5) differed from Nixa soils only in minor ways; mainly in containing slightly more chert in the BE and BTx horizons and in having redder colors in the BTx horizon. These minor differences should not affect the performance of filter fields. Thus, the soil of the 11MP06 filter field was a similar soil to the Nixa soils and is referred to as a Nixa soil.

In summary, the soils of filter fields 01ST76, 02MG30, and 11MP06 are Nixa soils, and the performance of these filter fields can be directly compared. The soil of filter field 10MP40 is not a Nixa soil, and the performance of this filer field cannot be directly compared to that of the other three filter fields.

c. Filter Field Design

1. Description of Filter Field Identification

Four different experimental filter fields were installed and monitored. In order to keep track of the information obtained

Table 5. Abbreviated pedon description of the soil of filter field 11MP06.

Ap	0-12 cm Dark grayish brown (10YR 4/2) silt loam; moderate medium granular structure; friable; approximately 45% by Vol. chert fragments up to 10 cm across.
E1	12-24 cm Light yellowish brown (10YR 6/4) silt loam; weak medium subangular blocky structure; friable; approximately 45% by Vol. chert fragments up to 10 cm across.
E2	24-40 cm Yellowish brown (10YR 5/4) silt loam; weak medium subangular blocky structure; friable; approximately 70% by Vol. chert fragments up to 15 cm across.
BE	40-45 cm Yellowish brown (10YR 5/6) heavy silt loam; common medium 10YR 6/2 mottles; moderate medium subangular blocky structure; firm, somewhat brittle; approximately 80% by Vol. chert fragments up to 25 cm across.
Btx	45-64 cm Yellowish red (5YR 5/6) silty clay loam; many coarse 10YR 7/2 and many coarse strong 7.5YR 5/8 mottles; moderate fine angular blocky structure; firm; brittle; approximately 85% by Vol. chert fragments up to 20 cm across.

from each filter field a labeling system was developed. The system used to describe each filter field is explained below. A typical name of a filter field is described as follows:

11AA22

The first two numbers are the number of the filter field. For instance, 01 would refer to the first filter field designed and 02 would refer to the second filter field designed. The next letters refer to the type of filter field. Letters most commonly used were ST, MG, and MP. ST stands for a standard gravity system and MG and MP refer to a modified gravity and modified pressure, respectively. They were modified by placing the seepage bed near the soil surface. The last two numbers relate how far below the soil surface the bottom of the seepage bed was located in centimeters.

2. Filter Field 01ST76

As the name indicates, 01ST76 was the first filter field designed and was a standard gravity filter field with the bottom of the seepage bed 76 cm below the soil surface. The name standard was used because this type of system filter field is considered as the standard design by the Arkansas Department of Health (1977). The seepage bed was constructed in a 60-cm wide trench and positioned in the soil as shown in Figure 2. The seepage bed consisted of a perforated (with holes at 4 and 8 o'clock), 10-cm diameter, plastic sewer and drain distribution pipe surrounded by crushed limestone as shown in Figure 2. Crushed limestone was placed 30 cm deep throughout the 9-m length of the seepage bed. Untreated building paper was placed on top of the limestone and the trench was backfilled with native soil.

3. Filter Field 02MG30

The second filter field designed was 02MG30, a modified gravity filter field with the bottom of the seepage bed located 30 cm below the soil surface. This filter field was installed (Figure 3) in the same manner and with the same materials as the 01ST76 filter field with the exception that the bottom of the seepage bed was only 30 cm below the soil surface instead of 76 cm and that 25 cm rather than 30 cm of crushed limestone surrounded the distribution pipe. The soil cover was only 5 cm thick rather than 46 cm as in the 01ST76 filter field.

4. Filter Field 10MP40

The 10th system designed was 10MP40, which was installed in a trench 60 cm wide and 9 m long. The bottom of the seepage bed was located 40 cm below the soil surface (Figure 4). Effluent was distributed in the seepage bed under pressure through 18 holes 0.32 cm in diameter drilled in the bottom of a nominal 1.5-inch schedule 40 PVC pipe. The holes were spaced at an interval of about 51 cm, beginning at a distance of about 25 cm from one end. The distribution pipe was surrounded by 30 cm of crushed limestone then covered with untreated building paper and finally with 10 cm of soil.

5. Filter Field 11MP06

Filter field 11MP06 was constructed in a trench of the same dimensions as the previous systems and utilized a pressure dis-

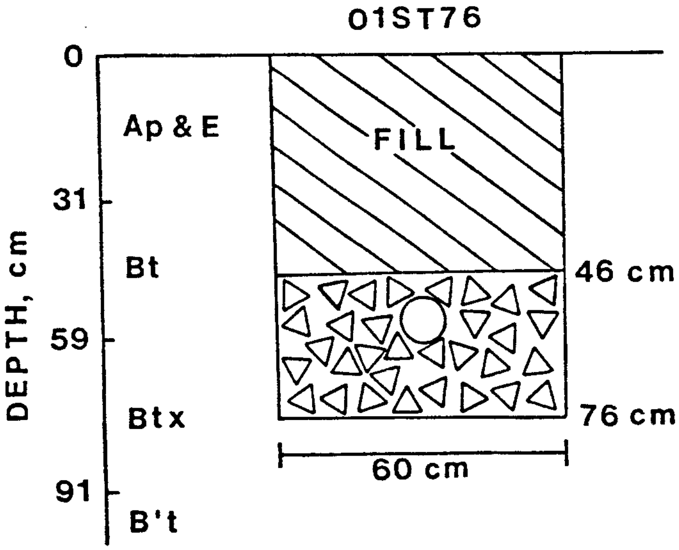

Figure 2. Position of the 01ST76 seepage bed within the soil.

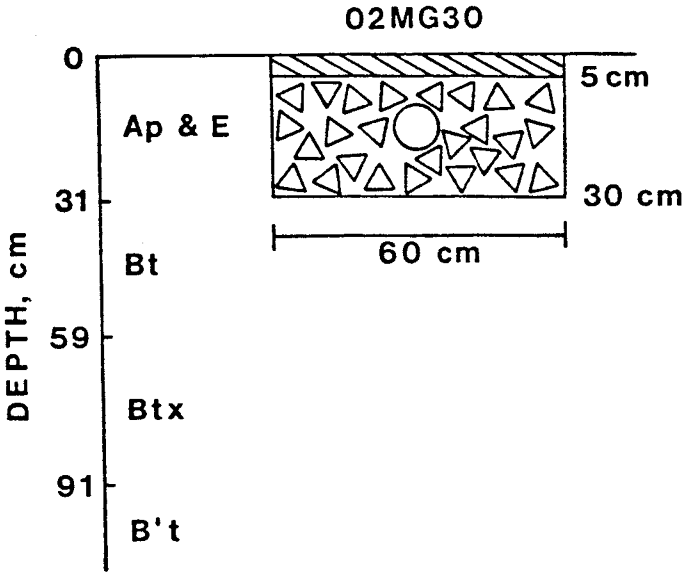

Figure 3. Position of the 02MG30 seepage bed within the soil.

tribution pipe like the one used in 10MP40. The bottom of the seepage bed, however, was located only 6 cm below the original soil surface (Figure 5). Again, the distribution pipe was surrounded by 30 cm of crushed limestone and covered with untreated building paper. Finally, the paper was topped with 15 cm of soil. The seepage bed extended about 40 cm above the original soil surface, unlike the other filter fields which were flush with the surface.

6. Effluent Delivery

Figure 6 shows the location of the experimental filter fields and the experimental effluent collection and distribution system with respect to the existing septic system. The system used to deliver septic tank effluent to the experimental filter fields is illustrated in Figure 7. A 1900-liter concrete tank which served as a septic tank effluent reservoir (sump) was installed in the line between the existing septic tank and the gravity filter field serving a single family residence. A standard, shallow-well, centrifugal domestic-water-supply pump and pressure tank was used to pump the effluent from the sump, through the control valves and meters, and to the experimental filter fields. A pressure tank maintained the pressure on the delivery system between 100 and 210 kPa. A strainer with a 50-mesh screen served to remove particles from the effluent before it reached the flow meter. PVC-body needle valves (1.3 cm) were used to control flow rates to experimental filter fields 01ST76 and 02MG30. Kent Polymer PSM water meters, rated for flow rates of 0.95 to 76 liters per minute, were used to measure the flow of effluent.

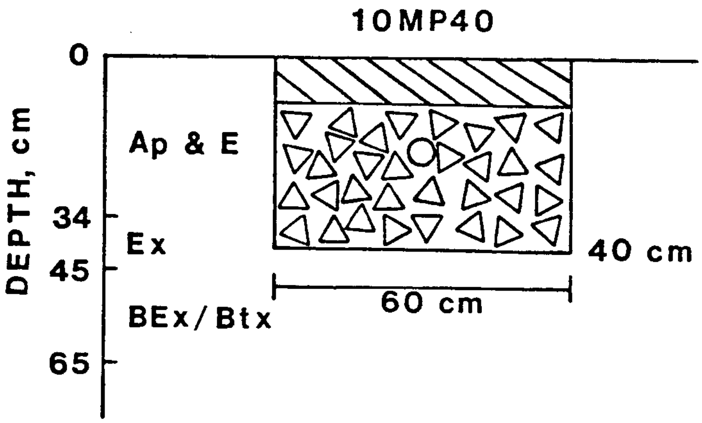

Figure 4. Position of the 10MP40 seepage bed within the soil.

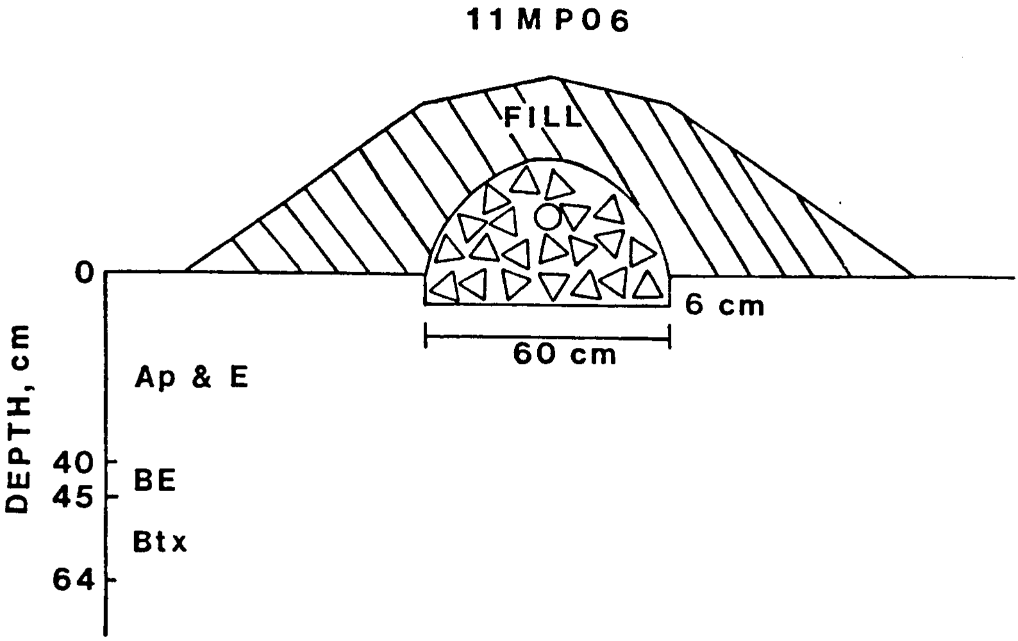

Figure 5. Position of the 11MP06 seepage bed within the soil.

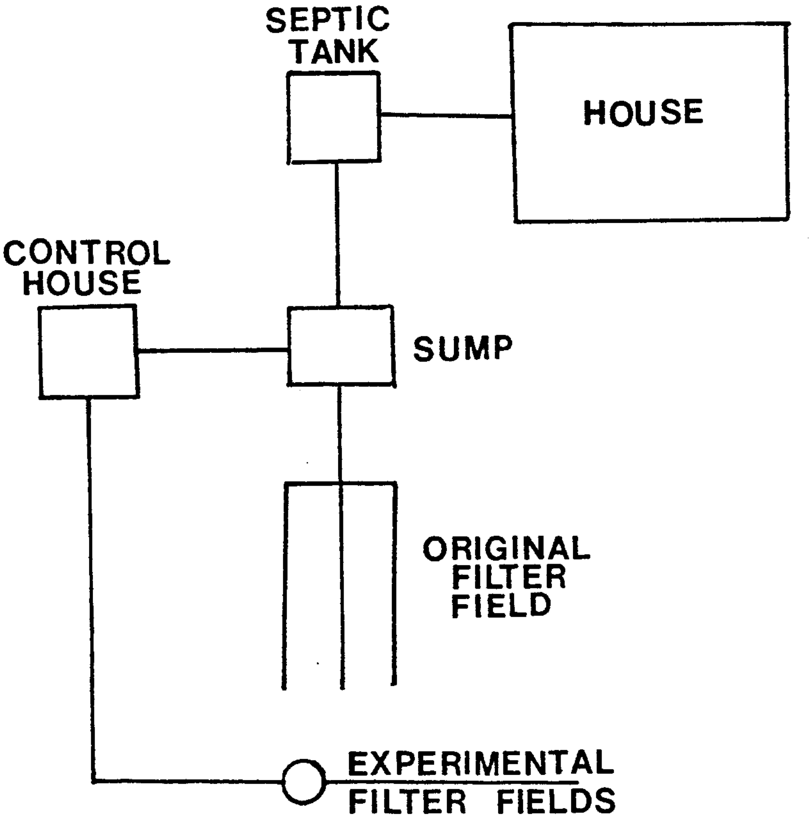

Figure 6. Location of experimental filter fields and equipment with respect to the existing septic system.

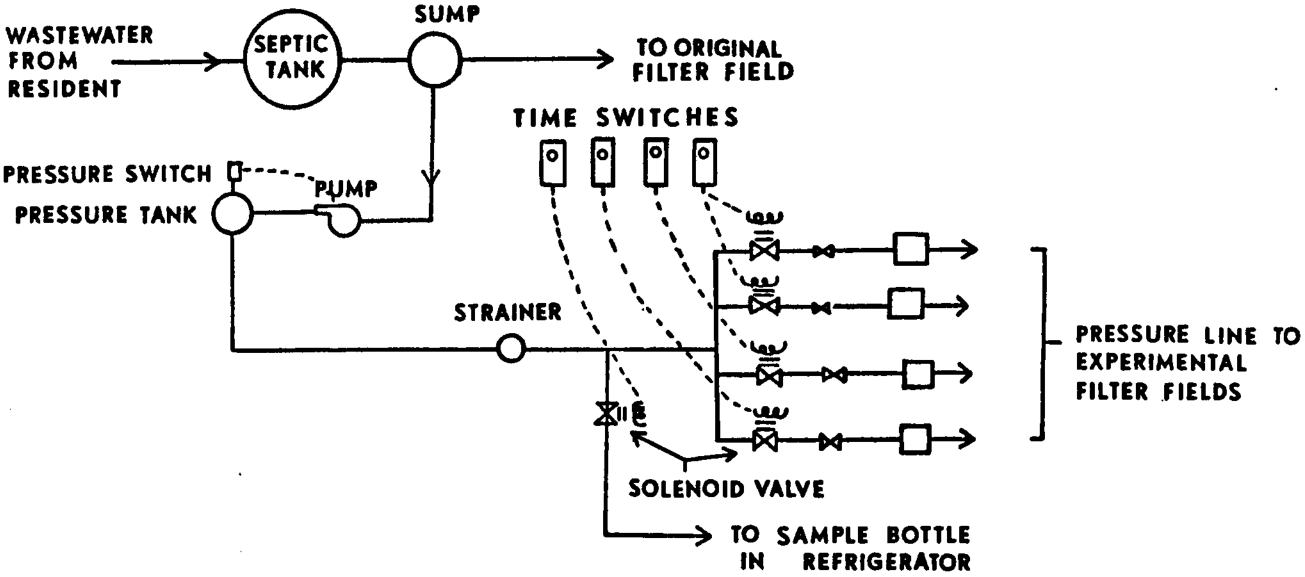

Figure 7. Schematic of effluent delivery system.

The septic tank effluent was delivered to each system by a nominal 0.5-inch black polyethylene pipe. A pressure dissipation chamber, as shown in Figure 8, was installed on the inlet end of each of the seepage bed distribution lines for systems 01ST76 and 02MG30 to ensure gravity distribution.

The application of the effluent to experimental filter fields 01ST76 and 02MG30 was controlled by a time switch which caused a solenoid valve in each pressure line to open for approximately 30 seconds per hour. The rate of flow during the time the solenoid valve was open was regulated by manual adjustment of the needle valves so that approximately 81 liters per day was applied to each of the seepage beds.

The application of effluent to the dosed filter fields, 10MP40 and 11MP06, was also controlled by a time switch connected to a solenoid valve. The valve to system 10MP40 was open for five and one-half minutes daily, and the valve to system 11MP06 was open for six minutes daily. Each system received about 81 liters of effluent per day.

d. Environmental Monitoring

Precipitation was initially recorded approximately twice per week from a simple rain gauge to which a small amount of oil was added to minimize evaporation. An automatic recording rain gauge was installed on May 22, 1981, and utilized thereafter.

e. Laboratory techniques

1. Soil Properties

A Nixa soil, located about midway between the 01ST76 and the 02MG30 filter field was described (Appendix Table A-1) and sampled

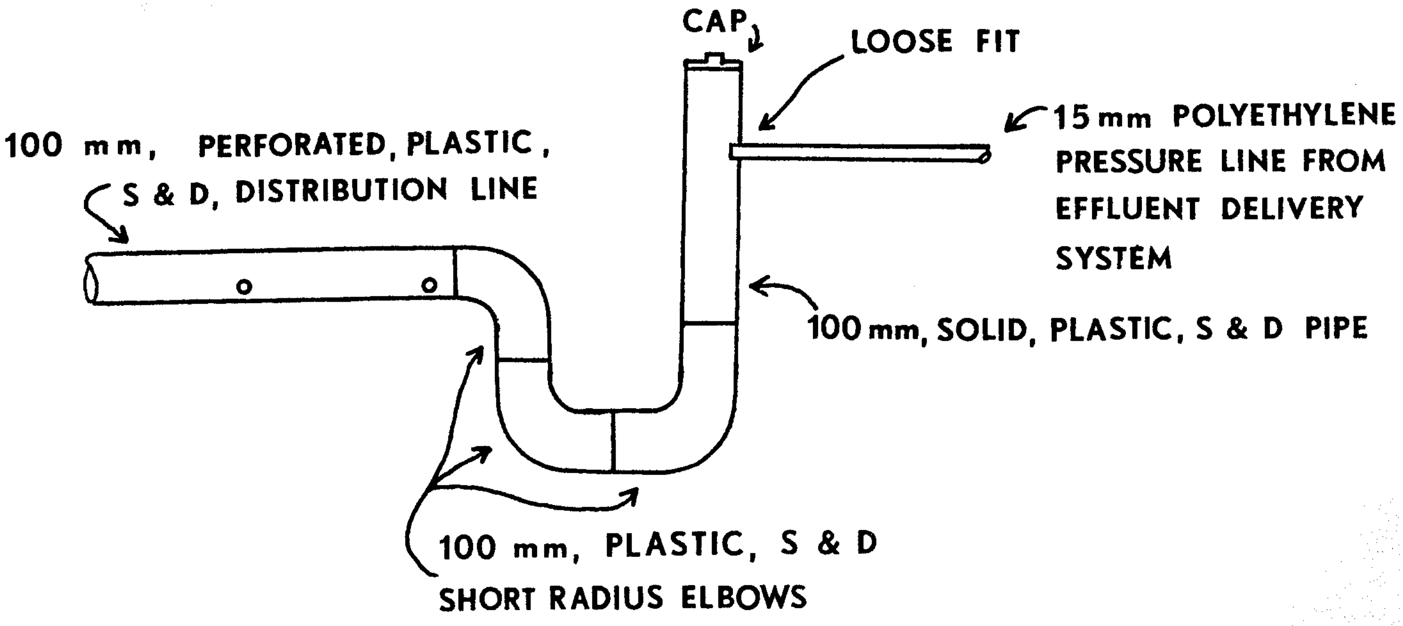

Figure 8. Illustration of effluent dissipation chamber.

by horizons or subhorizons. The bulk samples of soil were allowed to air dry and then were ground to pass a 2-mm sieve. Material greater than 2 mm was discarded. The ground sample was retained for analysis.

A. Particle Size: The ground soil was dispersed with a malt mixer using reagent grade sodium hexametaphosphate buffered to a pH 8.2 as the dispersing agent. No pretreatment was used on any of the samples. The hydrometer method described by Day (1956) was used to determine the amount of clay, fine silt, and medium silt. The sand was dry sieved, fractionated and weighed. The coarse silt was determined by difference.

B. pH: The pH of the soil samples was determined from a 1:1 soil-water suspension (method 8C1a;Soil Survey Staff, 1972).

C. Organic Carbon: Organic carbon was determined by dry combustion according to method 6A2b in Soil Survey Investigations Report No. 1 (Soil Survey Staff, 1972).

D. Extractable Bases: The extractable bases were determined by leaching a 10-g soil sample with 100 ml N pH 7.0 ammonium acetate (method 5A6; Soil Survey Staff, 1972) and determining the concentration of K, Ca, Mg, and Na in the leachate by atomic absorption (methods 6Q2b, 6N2e, 6O2d, and 6P2b; Soil Survey Staff, 1972).

E. Extractable Acidity: The extractable acidity was determined by a triethanolamine-barium chloride method (method 6H1a; Soil Survey Staff, 1972).

Note: All laboratory analyses performed on the soil samples were run in duplication or until duplication tolerances were met. All data are reported on an oven dry basis.

2. Water Quality

Water samples were collected from the wells located in and around the experimental seepage beds using a manual vacuum pump. The day before water samples were to be collected, water depths were measured and the wells containing water were pumped dry to allow infiltration of a fresh sample for the following day's collection. The samples were drawn into 1-liter Nalgene bottles and then placed in an ice chest until delivery to the laboratory. Once in the laboratory, 100 ml of the sample was filtered through a GF-A Glass Fiber Field and then stored in a refrigerator. The unfiltered portion of the sample was analyzed for total organic carbon and the filtered portion was analyzed for ammonia nitrogen, nitrate nitrogen, and chlorides.

A. Total Organic Carbon: The total organic carbon content of each sample was obtained using procedure number 505 from the 15th Edition of Standard Methods while employing a Beckman 915-B Total Organic Carbon Analyzer. Values are recorded as mg/1 TOC.

B. Ammonia Nitrogen: Ammonia values were obtained following procedure number 417B from the 15th Edition of Standard Methods with the aid of a Perkin-Elmer Double Beam Spectrophotometer set at 425 nm. The concentration of ammonia is expressed as N in mg/1.

C. Nitrate Nitrogen: The concentration of nitrate was determined using the cadmium reduction method for water and wastewater with Hach Chemical's NitraVer V Nitrate reagent. The results from the colorimetric procedure were obtained using a Bausch and Lomb Spectronic 20 Spectrophotometer with the wavelength set to 525 nm. The concentration of nitrate was expressed as N in mg/1.

D. Chloride: Chloride concentration was determined following procedure number 407A from the 15th Edition of Standard Methods. Chloride values are expressed as mg/1.

f. Water Measurements

Observation wells were used to monitor ground water depths. Wells were installed at two background locations (Figure 1 & Table 6) and in and around all four experimental seepage beds (Figures 2, 3, 4, and 5 & Table 6).

The wells, which were backfilled in a manner that essentially eliminated flow between the well and the undisturbed soil, acted as piezometers (indicators of water pressure at the intake). The depth to water in the wells was interpreted as depth to free-water in the soil. Such an interpretation for piezometers may include an error, the magnitude of which increases as the downward rate of water movement increases in a given soil. Since water moves slowly downward in Nixa soils, the error in depth to free-water interpretations is assumed to be minimal.

Depths to water in the wells were measured with an ohmmeter attached to a PVC tube that was marked at 1-cm intervals. (Figure 9). The tube was lowered into the well until electrical leads at the end of the tube contacted the water. When the ohmmeter needle deflected, the depth to water was read from the scale on the tube.

Table 6. Location and specifications of filter field and background wells.

Well I.D.	Distance from				Type of well construction[3]
	Inlet[1] end	Soil[2] surface	Center of bed	Edge of bed	
	----------------cm----	--------------	--------------	--------------	
			01ST76		
1A1	396	76	91N	61N	1
1A2	457	91	76N	46N	1
1A3	531	106	106N	76N	1
1B1	305	76	91S	61S	1
1B2	350	91	91S	61S	1
1B3	396	106	76S	46S	1
1C1	670	76	15N	-15N[4]	2
1C2	594	91	106N	76N	1
1C3	625	106	137N	107N	1
1D1	670	76	15S	-15S	2
1D2	533	91	121S	91S	1
1D3	579	106	152S	122S	1
1E1	670	60	83S	53S	3
1E2	579	75	55S	25S	3
1E3	428	90	66S	36S	3
1G1	670	60	261S	231S	3
1G2	670	60	456S	426S	3
1G3	670	60	761S	731S	3
			02MG30		
2A1	396	30	15N	-15N	2
2A2	410	45	60N	30N	1
2A3	442	60	167N	137N	1
2B1	396	30	15S	-15S	2
2B2	381	45	76S	46S	1
2B3	366	60	121S	91S	1

Table 6. Location and specifications of filter field and background wells. (continued)

Well I.D.	Distance from Inlet[1] end	Soil[2] surface	Center of bed	Edge of bed	Type of well construction[3]
	cm	cm	cm	cm	
02MG30					
2C1	686	30	91N	61N	1
2C2	716	45	91N	61N	1
2C3	702	60	91N	61N	1
2D1	690	30	91S	61S	1
2D2	701	45	76S	46S	1
2D3	731	60	91S	61S	1
2E1	807	76	35S	5S	3
2E2	852	91	44S	14S	3
2E3	897	106	45S	15S	3
2E4	552	76	60S	30S	3
2E5	507	91	60S	30S	3
2E6	446	106	68S	38S	3
2E7	291	52	48S	18S	3
10MP40					
IE1	250[1]	40	0	-30	4
IW1	550	40	0	-30	4
XE1	350	50	0	-30	5
XE2	300	65	0	-30	5
XW1	650	51	0	-30	5
XW2	600	67	0	-30	5
NE1	350	45	65	35	5
NE2	300	60	65	35	5
NE3	300	60	110	80	5

Table 6. Location and specifications of filter field and background wells. (continued)

Well I.D.	Distance from Inlet end[1]	Soil surface[2]	Center of bed	Edge of bed	Type of well construction[3]
	----------	---------- cm	----------	----------	
			10MP40		
SE1	350	45	65	35	5
SE2	300	60	65	35	5
SE3	300	60	110	80	5
NW1	650	45	65	35	5
NW2	600	60	65	35	5
NW3	600	60	110	80	5
SW1	650	45	65	35	5
SW2	600	60	65	35	5
SW3	600	60	110	80	5
			11MP06		
IE1	250	6	0	-30	4
IW1	550	6	0	-30	4
XE1	350	26	0	-30	5
XE2	300	50	0	-30	5
XW1	650	27	0	-30	5
XW2	600	51	0	-30	5
NE1	350	0	65	35	5
NE2	300	53	65	35	5
NE3	250	30	65	35	5
NE4	300	60	110	80	5
SE1	350	0	65	35	5
SE2	300	50	65	35	5
SE3	250	30	65	35	5
SE4	300	60	110	80	5

Table 6. Location and specifications of filter field and background wells. (continued)

Well I.D.	Distance from Inlet[1] end	Soil[2] surface	Center of bed	Edge of bed	Type of well construction[3]
	------	------cm------	------	------	
			11MP06		
NW1	650	0	65	35	5
NW2	600	60	65	35	5
NW3	550	30	65	35	5
NW4	600	60	110	80	5
SW1	650	0	65	35	5
SW2	600	60	65	35	5
SW3	550	30	65	35	5
SW4	600	60	110	80	5
			BACKGROUND		
F1		15			6
F2		15			6
F3		30			6
F4		30			6
F5		46			6
F6		46			6
F7		61			6
F8		61			6
F9		76			6
F10		76			6
F12		91			6
F14		120			6
F16		200			7

Table 6. Location and specifications of filter field and background wells. (continued)

---

[1] Locations of wells in 10MP40 and 11MP06 are measured from the east end rather than the inlet end of the seepage bed.

[2] Refers to depth of intake.

[3] Types of well construction

1. Electrical conduit (2.5 cm) pipe with three 0.6 cm intake holes 30 cm above the bottom of the pipe which was improperly sealed. Holes backfilled with tamped Nixa soil.

2. Electrical conduit (2.5 cm) pipe with three 0.6 cm intake holes 30 cm above the bottom of the pipe which was properly sealed. Holes backfilled with tamped Nixa soil.

3. Electrical conduit (2.5 cm) pipe with open ends. Holes backfilled with tamped Nixa soil.

4. PVC (3.2 cm) pipe with open ends. Intake end is footing made from one-half of "T" with added plexiglass as a base. No special backfilling.

5. PVC (3.2 cm) pipe with open ends. Holes backfilled with gravel to 10 cm above end, then concrete to within 12 cm of surface, then to surface with soil material.

6. Electrical conduit (2.5 cm) pipe with open ends and three 0.6-cm holes 2, 4, and 6 cm from the bottom. Holes backfilled (bottom to top) with 10 cm of sand, 5 cm of bentonite clay and then to the surface with "off-the-shelf" redi mix concrete.

7. PVC (3.2 cm) pipe with open ends. Holes backfilled as in No. 6 above.

[4] Negative numbers indicate wells are within or below the bed.

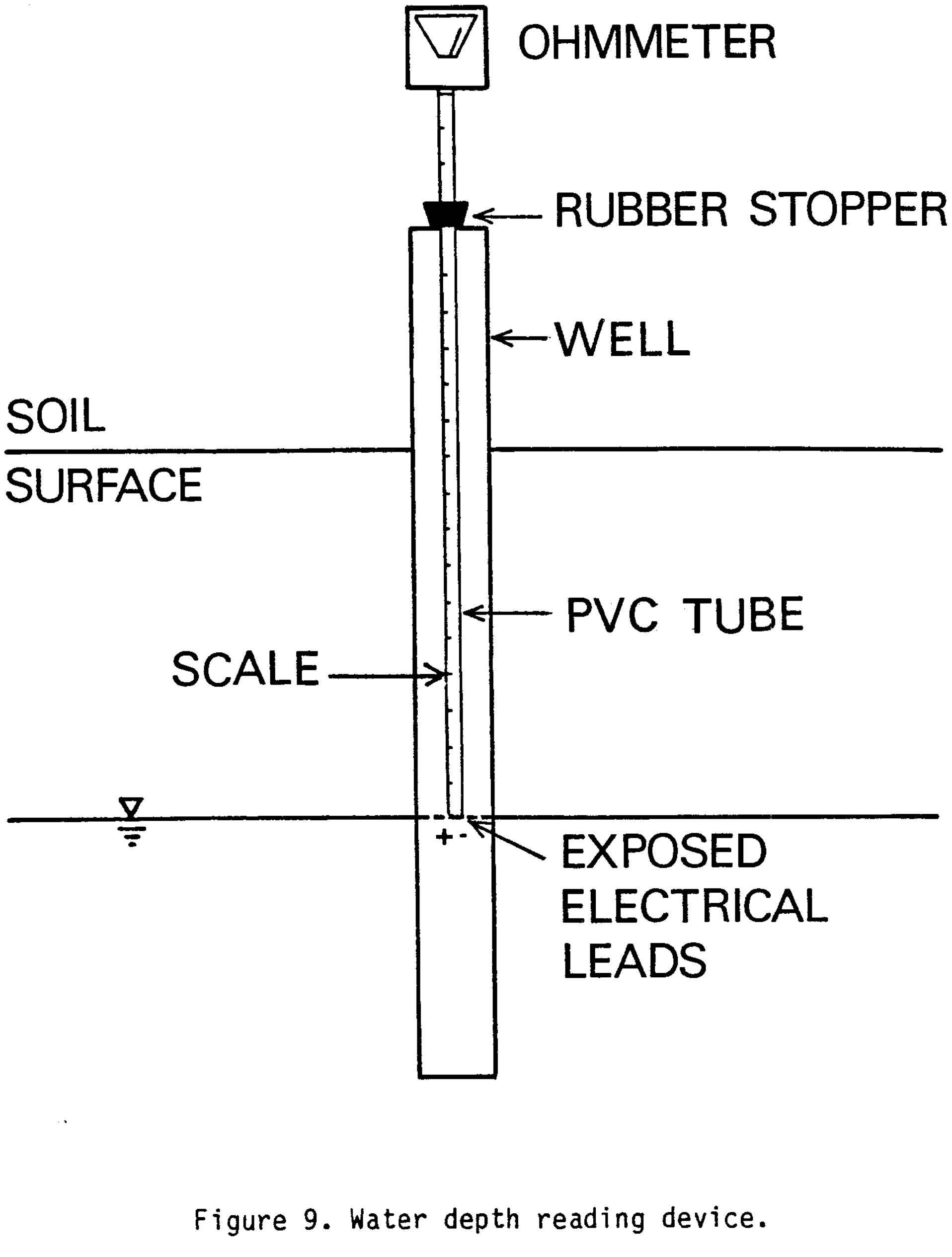

Figure 9. Water depth reading device.

IV. RESULTS AND DISCUSSION

a. Soil Evaluation

Nixa soils within the experimental area (Tables 3 and 5 and Appendix Table A-1) had high chert contents, 30 to 85% by volume, and a well-developed fragipan which frequently started about 45 to 60 cm below the soil surface. Because of its slow rate of water movement, the fragipan is the design limiting feature of these soils for septic tank filter fields. Morphological features indicated the presence of a seasonal water table in the horizon above the fragipan as well as within and below the fragipan (Appendix Table A-1). The Nixa pedons (actually similar soils to Nixa) which are discussed in more detail in the Methods and Materials chapter, differed from soils of the Nixa series in minor ways. These minor differences from Nixa soils are not expected to have significantly influenced the performance of filter fields 01ST76, 02MG30, and 11MP06. The soil of the 10MP40 filter field was not a Nixa soil because of differences in horizons and the shallow fragipan. Therefore, the performance of this filter field is not directly comparable to that of the other three filter fields.

Morphological evaluation indicated rapid or moderate rates of saturated hydraulic conductivity (Ksat) through the Ap, E, BE, and Bt horizons above the fragipan and low rates of hydraulic conductivity through the fragipan (Btx, BEx/Ex, and Ex horizons) and B't horizons below the fragipan of the Nixa soils. Percolation times (Table 7) were variable in four test holes. These data indicate that two test holes passed the requirements of the Arkansas Department of Health (1977) and two failed the requirement of a percolation time equal to or less than 18 min/cm after 4 hours of presoaking. Ransom (1976) showed that percolation times in Nixa soils were highly dependent upon the presence or absence of a seasonal water table. He showed that, when a seasonal water table was present, water did not drain from the test holes. Data presented in Table 7 were obtained in the absence of a seasonal water table.

Table 7. Percolation times of Nixa soils in the experimental site.[1]

Location	Percolation time (min/cm)	
	4 h presoak	24 h presoak
1	16	32
2	NM[2]	NM
3	24	24
4	9	24

[1] Data from Stafford (1979)

[2] NM - No water movement detected

Stafford (1979) conducted a more quantitative evaluation of the Ksat of the various horizons (Table 8) of the Nixa soils (Table 3 and Appendix Table A-1). His data, like the percolation test data, showed considerable variability. Although these data are in general agreement with the morphological evaluation in that the upper horizons (Ap, E and Bt) showed considerably higher rates of hydraulic conductivity than the lower horizon (Btx and B't), the variability among replications was high. In an attempt to identify sources of variability, Stafford (1979) used dye in the water in the determinations of Ksat in replication number 3. The dye studies indicated that boundary flow sometimes occurred between the infiltrometer and the soil. This flow may account for some of the higher rates of water movement. The dye also indicated that water moved mainly through the gray seams along the prism faces within the fragipan (Appendix Table A-X). Since the range in spacing of gray seams within the fragipan exceeded the diameter (25 cm) of the infiltrometer, the instrument was not large enough to obtain a representative measurement of the saturated hydraulic conductivity of the fragipan horizons.

Table 8. Saturated hydraulic conductivities of selected horizons of Nixa soils at the experimental site.[1]

	Ksat (cm/day)			
Horizon	Rep 1	Rep 2	Rep 3[2]	Mean
Ap	350	120	200[2]	220
E	240	11	160[2]	140
Bt2	130	2	24[2]	52
Btx1	56	<1		29
Btx2	32	3		18
B'tl	19	<1		10

[1] Data from Stafford (1979). Measurements made on the Nixa soil described in Table 3 and Appendix Table A-1.

[2] Dyed for identification of flow pathways.

Stafford (1979) evaluation of the Nixa soils for filter fields, which primarily consisted of calculation of steady state moisture profiles, showed that seepage beds placed in the upper horizons (Ap, E, and Bt1) and loaded at a rate of 1.5 cm/day, would have a better chance of success than those placed in lower horizons. In order to facilitate comparison, all filter fields were loaded with approximately 1.5 cm of effluent per day.

b. Climatic Conditions

The weather during the experimental period (Tables 9 and 10) showed, as usual, considerable variation from long-term means. (Since Savoy is only 15 km from Fayetteville and in a similar geomorphic setting and because there are no long-term climatic data for Savoy, the climatic means for Fayetteville are used for comparison.) Most notable among the deviations in rainfall was the period of below normal rainfall which extended from October of 1980 through May of 1981. Shorter periods of 2 months or more of below normal rainfall occurred in November and December of 1981, February, March and April of 1982, August and September of 1982, January, February and March of 1983, and June, July, August and September of 1983. Significant periods of above normal rainfall were less frequent. Although several months had above normal rainfall, November and December of 1982 had the greatest deviation above the norm. In general, rainfall was below normal during the experimental period with FY-81, FY-82 and FY-83 receiving 74, 82 and 84% of the normal rainfall for Fayetteville.

Temperatures during the period of experimentation were nearer the long-term means (Table 10). Only 4 months had both mean maximum and mean minimum temperatures which deviated from the 30-year

Table 9. Monthly rainfall at Fayetteville and at the experimental site.

Month	Precipitation (cm)								
	30-year mean[1] (Fayetteville)			Fayetteville[2]			Experimental site Savoy, AR		
	Total	one year in 10 will have							
		Less than	More than	FY-81	FY-82	FY-83	FY-81	FY-82	FY-83
October	9.0	2.6	16.1	6.6	15.3	7.9	4.6	17.5	6.1
November	8.2	1.7	14.1	4.9	3.2	18.8	5.7	2.8	16.2
December	6.5	1.5	12.3	4.8	1.6	23.7	6.8	1.5	22.8
January	6.5	1.7	13.9	1.7	6.6	2.6	1.4	10.6	3.7
February	7.7	2.2	12.1	4.2	2.3	3.1	3.5	2.6	0.5
March	8.5	3.9	15.1	17.0	5.0	4.8	6.6	4.9	3.8
April	12.1	5.8	18.1	10.1	6.6	14.3	5.4	3.8	14.8
May	15.2	5.9	26.0	13.5	17.3	12.0	8.6	11.8	11.4
June	12.9	1.9	21.0	20.3	34.6	11.5	15.8	20.7	6.2
July	9.2	2.1	16.8	15.1	9.4	2.0	10.4	11.3	5.1
August	8.6	2.3	16.2	13.0	4.1	4.3	10.6	3.2	3.5
September	10.4	2.2	23.3	5.6	2.9	2.7	5.0	3.8	2.2
Year	114.8			116.8	108.9	107.7	84.4	94.5	96.3

[1] Harper et al., 1969.

[2] NOAA, 1980-1983

Table 10. Monthly temperatures at Fayetteville.

Month	Temperature (°C)							
	30-year Means[1]		FY-81[2]		FY-82[2]		FY-83[2]	
	Max	Min	Max	Min	Max	Min	Max	Min
October	23	9	21	6	17	9	22	7
November	15	2	16	2	17	3	16	3
December	10	-1	11	-1	8	-3	11	1
January	9	-2	9	-5	7	-7	6	-3
February	11	-1	11	-2	7	-1	11	0
March	16	3	15	3	16	4	14	3
April	21	8	24	11	19	12	16	5
May	25	13	21	11	25	15	23	11
June	30	18	29	19	26	15	26	15
July	33	19	31	22	29	21	32	20
August	33	19	29	19	31	20	35	20
September	29	14	28	15	28	14	29	15

---

[1] Harper et al., 1962.

[2] NOAA, 1980-1983.

means by more than 2 degrees centigrade. Of these 4 months, April of 1981 had both mean maximum and mean minimum temperatures above the long-term mean. June of 1982, April of 1983 and June of 1983 had both mean temperatures below the long-term means.

c. The 01ST76 Filter Field

The 01ST76 filter field was constructed to approximate the standard filter field as defined by the Arkansas Department of Health (1977). It had its lower (horizontal) interface 76 cm below the surface and was loaded with approximately 1.5 cm of effluent per day. Effluent was added hourly in a manner to approximate gravity distribution.

1. Performance

The seepage bed of the 01ST76 filter field was continuously ponded with effluent throughout the experiment (Appendix Table A-6). Data in Figure 10 provide an overview of the performance of this filter field during the experiment. In Figure 10, the inbed depths are the average of depths from the soil surface to the effluent in two wells (Appendix Table A-6) and the exbed well depths are an average of depths to free-water in three exbed wells 61 cm outside the seepage bed (Appendix Table A-6). When one or more of the three exbed wells was dry, no mean exbed value existed. All subsequent discussion of inbed and exbed free-water depths will refer to these mean values.

The data trends in Figure 10 show that both the inbed and exbed free-water depths were not constant but varied during the three years

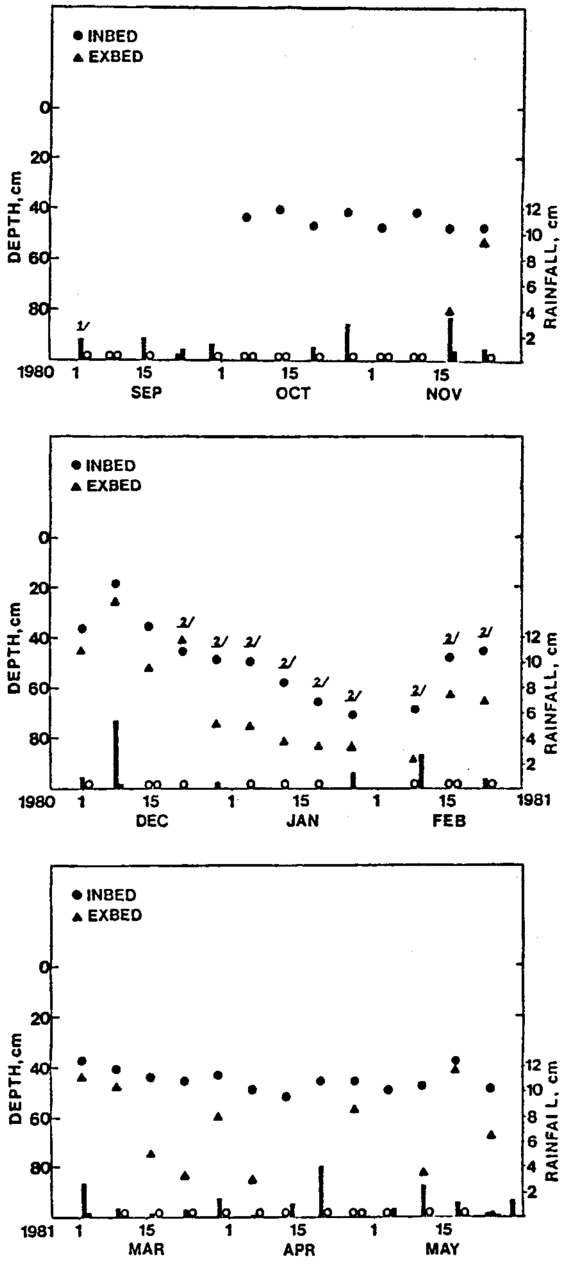

Figure 10. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 01ST76 filter field.

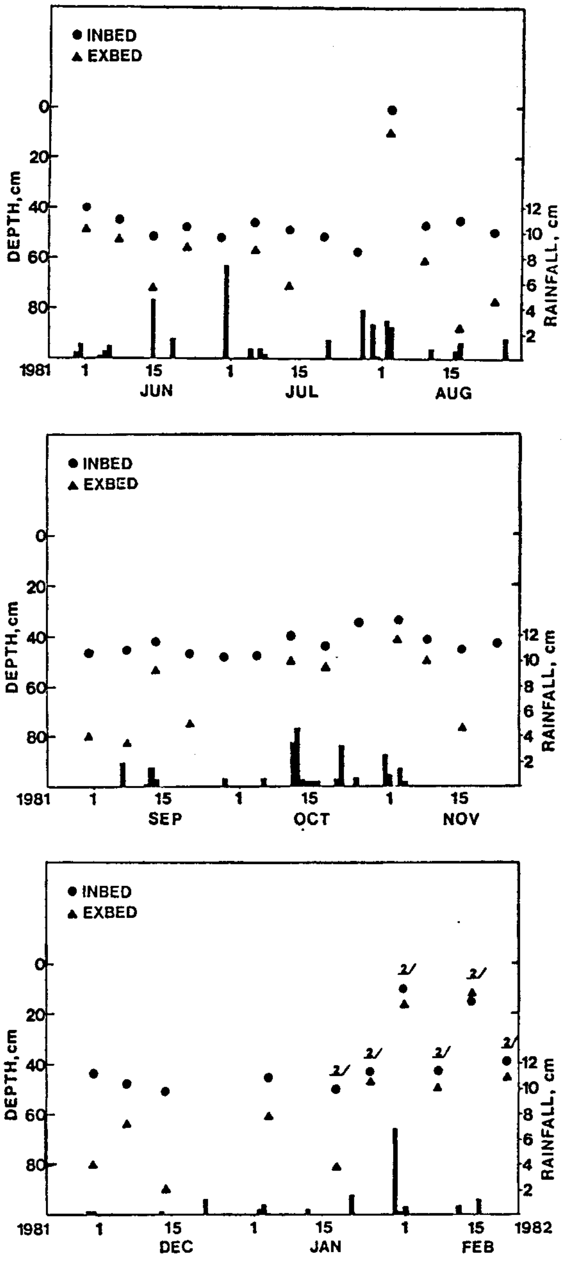

Figure 10. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 02MG30 filter field, continued.

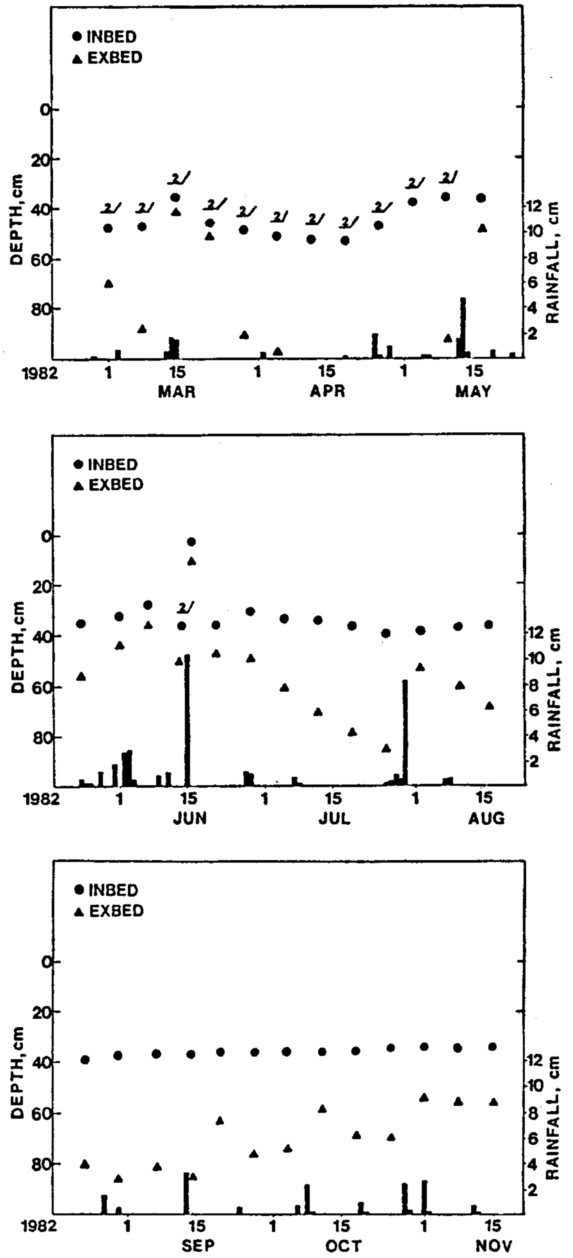

Figure 10. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 02MG30 filter field, continued.

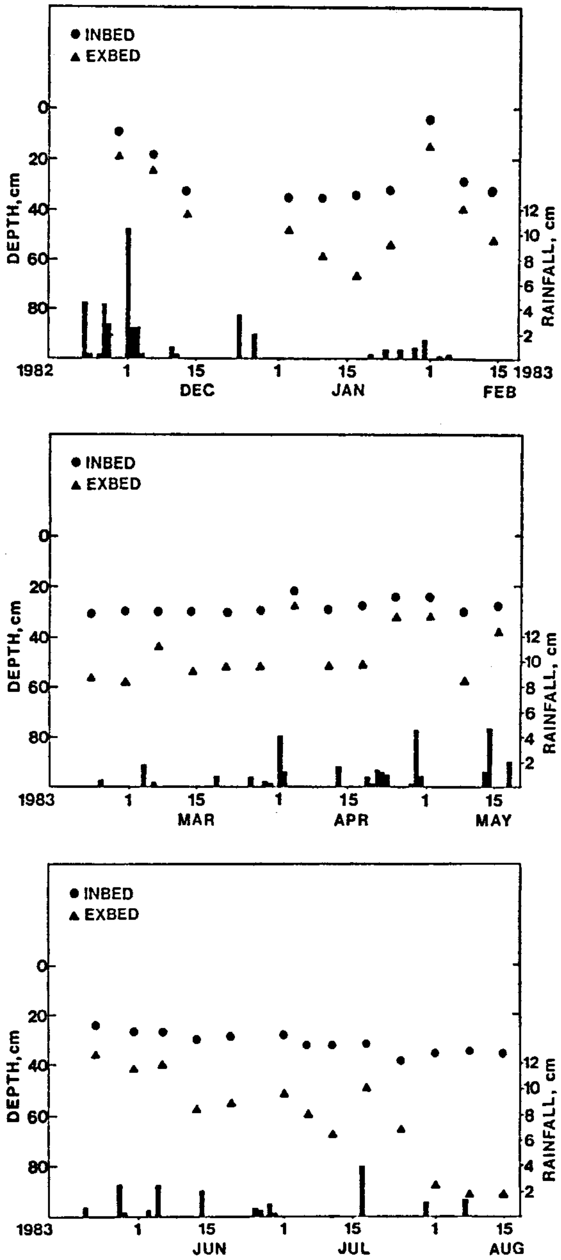

Figure 10. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 02MG30 filter field, continued.

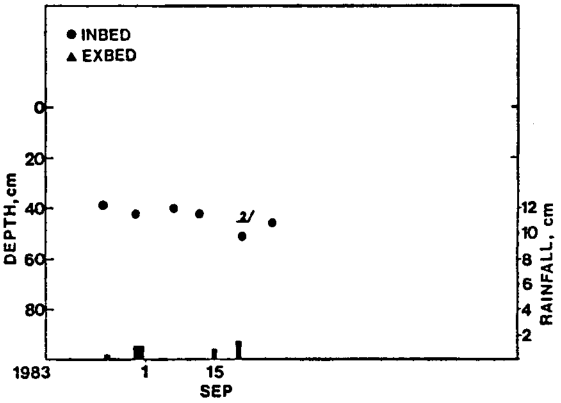

Figure 10. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 02MG30 filter field, continued.

[1] Rainfall values are cumulative since the previous observation through May 22, 1981 when an automatically recording raingauge was installed. Daily values are reported after May 22, 1981. An "o", used only during the period of cumulative raingauge use, denotes no rainfall since the previous observation.

[2] Data influenced by malfunction of the effluent delivery system. Details of effluent delivery are given in Appendix Table A-3.

of the experiment. Qualitative evaluation indicates both depths were responding to climatic variations. When the climate, through rainfall and/or evapotranspiration (ET), caused a high hydraulic load on the soil (a so-called "wet period" or "stress period") the inbed effluent and exbed ground waters were both nearer the soil surface and vice versa.

October through May of FY-81 was one of the dryer periods of the experiment. During this period exbed wells were frequently dry and most inbed water depths were 40 cm or greater. (The exbed and inbed depths for December 22, 1980 through February 23, 1981 should not be considered since the delivery system was malfunctioning during this period.) Maximum depths of inbed effluent for FY-81 were between 50 and 54 cm and occurred in April, May, June, July and August of 1981. Inbed depths of 54 cm occurred on both June 29 and July 20 of 1981. The maximum inbed depth of 59 cm on July 27 is assumed to be erroneous since it occurred only once and is noticeably deeper than other readings.

Maximum rise of inbed effluent during FY-81 was to the soil surface on August 3, 1981 (Figure 10). On that date one inbed well showed effluent 1.2 cm below the soil surface and the other inbed well indicated effluent 0.2 cm above the soil surface. Thus, although no effluent was observed on the surface, we conclude that effluent in 01ST76 surfaced briefly on that date. This surfacing followed 13 cm of rainfall which occurred between July 28 and August 3. No rainfall occurred between August 4 and August 10 at which time the inbed depth was 48 cm; thus, the system rapidly dissipated the high hydraulic load of August 3.

Analysis of the performance of 01ST76 during FY-82 is complicated because a hole developed in the effluent delivery pipe between the meter and the seepage between January 8 and 15, 1982, and was not discovered and repaired until April 23, 1982. There is no way to know the exact amount of effluent delivered to the bed during this period and thus, the data from January 8 through May 10 are of little value and will not be discussed.

Depths of inbed effluent were between 50 and 52 cm on November 23 and December 7, 1981. The maximum inbed depth for FY-81 was 53 cm on December 14, 1981. These inbed lows seem to be a direct reflection of rainfall since November and December of 1981 received 2.8 and 1.5 cm of rainfall, respectively. Maximum rise of inbed effluent was to within 3 cm of the surface on June 16, 1982. This rise followed 11 cm of rainfall on June 15. No rainfall occurred between June 16 and June 21 at which time the inbed effluent depth was 37 cm.

The maximum depths of inbed effluent during FY-83 were 43 cm on August 30, 44 cm on September 12, and 47 cm on September 27 of 1983. The inbed depth was lower on September 21, 1983 but this point is invalid for comparison because of a malfunction of the effluent delivery system. The rainfall (Table 9) in July, August and September of 1983 was considerably below normal.

The maximum rise of inbed effluent during FY-83 was to within 4 cm of the soil surface on February 1, 1983. This rise followed 3 cm of rainfall which occurred between January 29 and 31. A small amount of rainfall, 0.3 cm, occurred between February 1 and February 8 but by February 8 the inbed effluent was 29 cm below the soil surface.

During each of the 3 fiscal years (FY-81, FY-82 and FY-83) inbed effluent depths dropped to 47 to 54 cm below the surface in response to periods of low rainfall with or without high ET. These maximum inbed depths are comparable to maximum yearly inbed depths of about 51 cm which occurred between May, 1978 and September 1980 (Rutledge, et al., 1983).

The minimum depth of inbed effluent during the 3 fiscal years was to 0 cm in FY-81, 3 cm in FY-82, and 3 cm in FY-83. Thus, the filter field surfaced in FY-81 (although no effluent was observed on the surface) and nearly surface in FY-82 and FY-83. However, it is notable that in each year the inbed effluent rose in response to rainfalls and rapidly dissipated following the maximum rise. The rapid dissipation of effluent from the upper part of the seepage suggests, as reported earlier (Rutledge, et al., 1983), that this portion of the seepage bed had a high saturated hydraulic conductivity and was not crusted because it contained effluent for only short periods each year.

The maximum rise of inbed effluent to the surface in FY-81 and to near the surface in FY-82 and FY-83 compares to maximum rises to 11 and 12 cm below the surface (Rutledge, et al., 1983) for this seepage bed between May, 1978 and September 30, 1980. Also, the maximum rises occurred in August of FY-81, June of FY-82 and February of FY-83. These dates indicate that the February-March-April stress period may not be as important as previously reported (Rutledge, et al., 1983).

2. Crusting

The crust which frequently forms at the seepage bed-soil interface has been discussed by many researchers. This crust reduces the rate of effluent movement from the seepage bed to the adjoining soil. Since there are no nondestructive methods of directly measuring crust growth, many workers have assumed that reductions in rates of effluent movement from the seepage bed when hydraulic gradients were comparable were the result of crust growth. We also assume this to be the best indirect indicator of crusting and suggest that comparison between periods of yearly low inbed values provides the best approach.

Since effluent loading rates were essentially constant, inbed effluent depths were a function of rainfall additions, ET losses, interface hydraulic conductivity, and the hydraulic gradient between the seepage bed and the adjoining soil. When periods of negligible rainfall and relatively comparable ET rates are compared, the variables are reduced to the interface hydraulic conductivity and the hydraulic gradient. During relatively dry periods the exbed waters are deep and the hydraulic gradient[1] is large. Earlier research (Rutledge et al., 1983) showed that inbed depths were not related to exbed depths in this filter field after exbed depths became greater than 59 cm. Therefore, during such periods inbed depths are mainly a function of hydraulic conductivity and changes in hydraulic conductivity are assumed to be a function of crusting. The previous study on this filter field showed yearly low inbed depths of 51 cm in July 1978, 51 cm in October 1979, and 51 cm in September of 1980. This report has shown yearly low inbed depths of 54 cm in June and July of 1981, 53 cm in December of 1981, and 47 cm in September of 1983. Although the ET for the December 1981 period was not likely as great as during the other periods, the general trend of these values does not suggest a reduced rate of flow from the seepage bed and thus implies crusting is not occurring to a significant extent.

3. Water Quality

Filter field 01ST76, a standard septic tank filter field, was sampled by way of 12 wells interspersed throughout the field. The vertical and horizontal locations of these wells are given in Table 6 of the Methods and Materials section. The water quality analyses of this system are presented graphically for the various parameters for wells equidistant from the bed and for the inbed wells.

A. Total Organic Carbon: The TOC was reduced as the septic tank effluent passed through the bed into the soil. The term composite sample refers to a small sample of the septic tank effluent that was collected each hour as the seepage bed was loaded. These samples were refrigerated and composited over a 24-hour period just prior to obtaining water samples from the filter field wells. The TOC of the two inbed wells, 1C1 and 1D1, varied with the TOC in the composite; however, their values usually were similar to each other. The TOC values of these two inbed wells were always considerably less than the composite.

The TOC values of the inbed wells were averaged and plotted along with the composite. As Figure 11 shows, nearly 49 percent of the TOC applied to the seepage bed was reduced in the seepage bed before any soil percolation occurred. Similar seepage bed treatment of TOC has been reported earlier for this filter field (Hirsch et al., 1983).

Wells 1A1 and 1B1 are both located 61 cm from the edge of the bed horizontally, and in the same vertical plane as the bottom of the bed. A further reduction of TOC was observed in these two wells, when compared with the TOC in the samples taken from the bed. TOC concentrations in the bed were about 50 to 80 mg/l, and passage through 61 cm of soil resulted in a significant reduction in TOC. As shown in Figures 12, 13, 14, and 15, however, little improvement in TOC levels occurred with passage through even more soil.

B. Ammonia: As Figure 16 illustrates, the concentration of ammonia changed little in the seepage bed itself. The composite had between 60 and 85 mg/l ammonia as N through June of 1982. Then it began to decrease at a nearly constant rate to about 30 mg/l at the time this project ended. This change in water quality of the influent is also shown in the TOC of the composite indicating a weaker septic tank effluent. The inbed wells had an ammonia concentration generally 5 to 10 mg/l below the composite, indicating some nitrification was occurring in the beds.

When ammonia concentrations from exbed wells are compared to the inbed and septic tank concentrations, reduction of ammonia concentration in the soil is clearly seen (Figures 17-21). Infiltration of the wastewater into the soil produced a water with generally about 2 mg/l

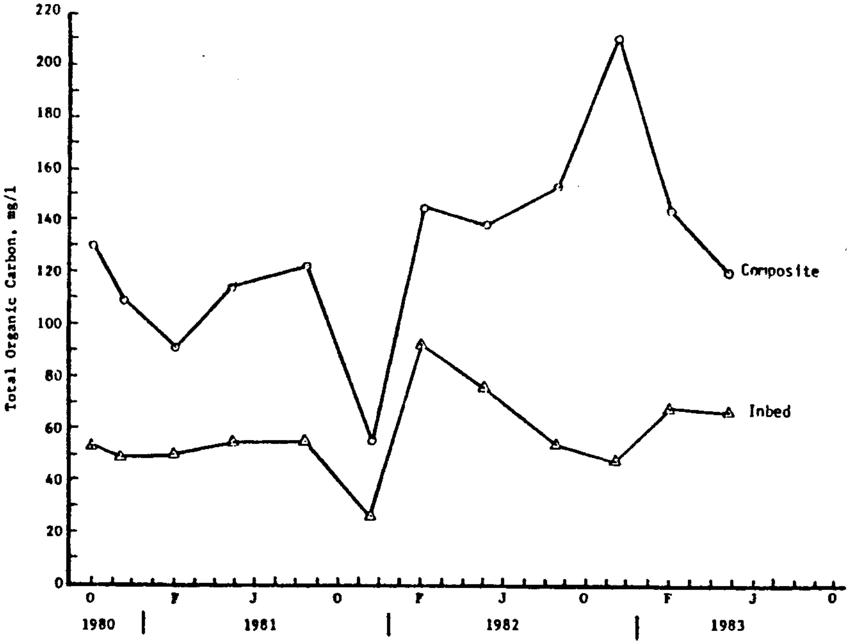

Figure 11. TOC of the composite and inbed wells of the 01ST76 filter field.

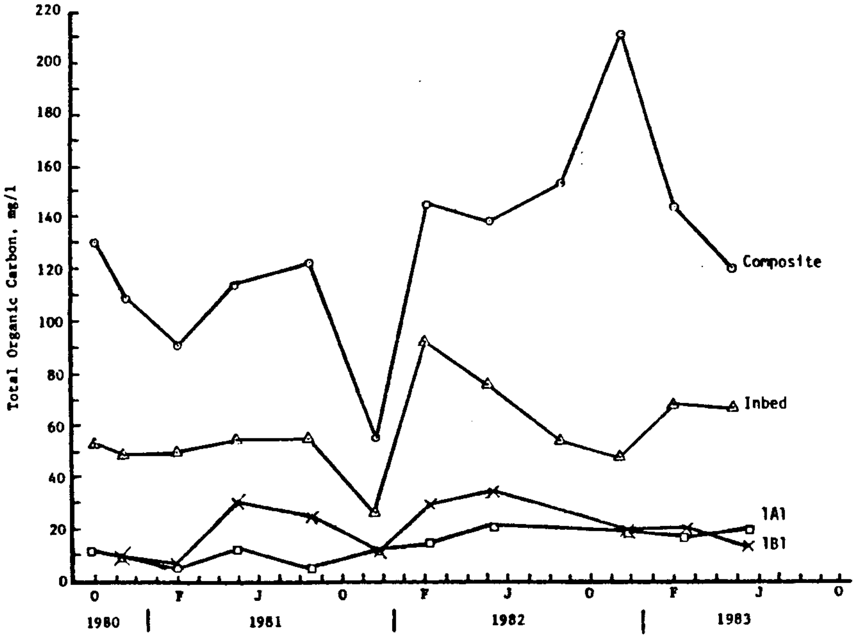

Figure 12. TOC of two exbed wells 61 cm horizontally from 01ST76 filter field bed.

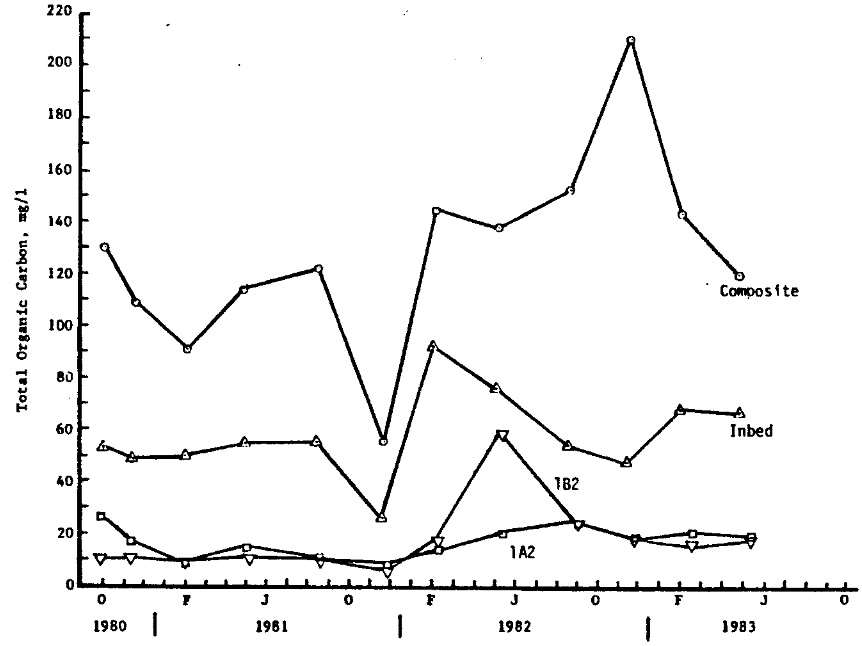

Figure 13. TOC of exbed wells 46 and 61 cm horizontally and 15 cm vertically from 01ST76 filter field bed.

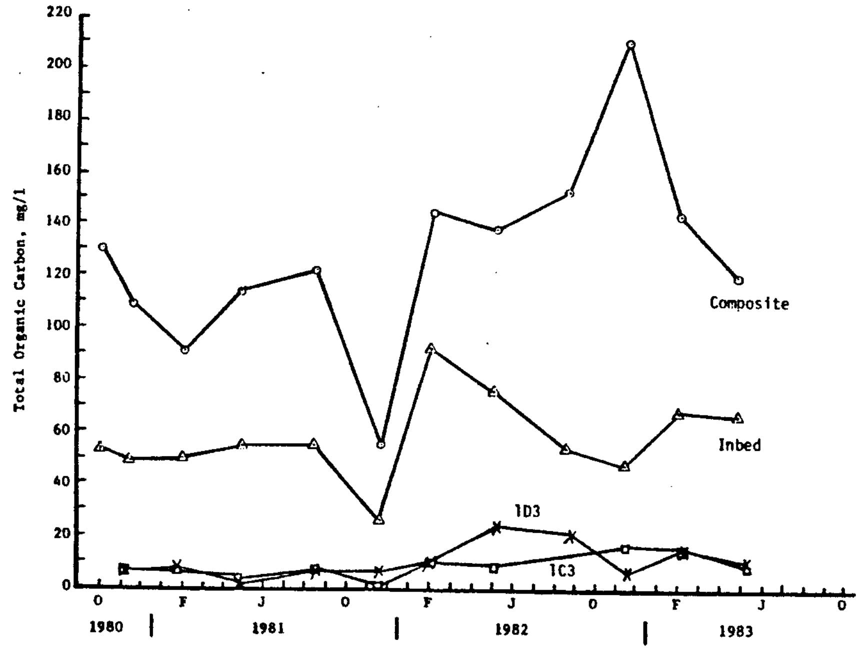

Figure 14. TOC of exbed wells 107 and 122 cm horizontally and 30 cm vertically from 01ST76 filter field bed.

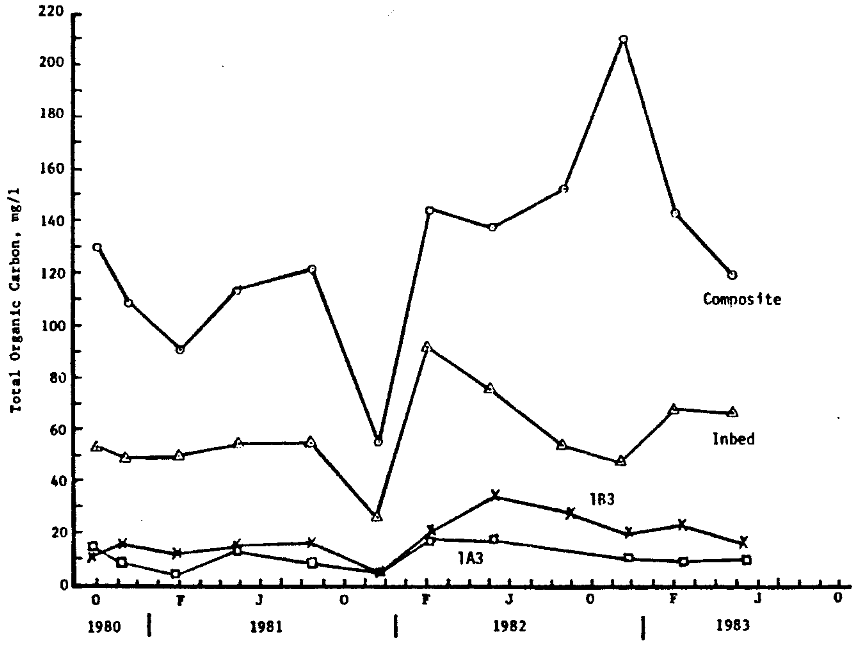

Figure 15. TOC of exbed wells 46 and 76 cm horizontally and 30 cm vertically from 01ST76 filter field bed.

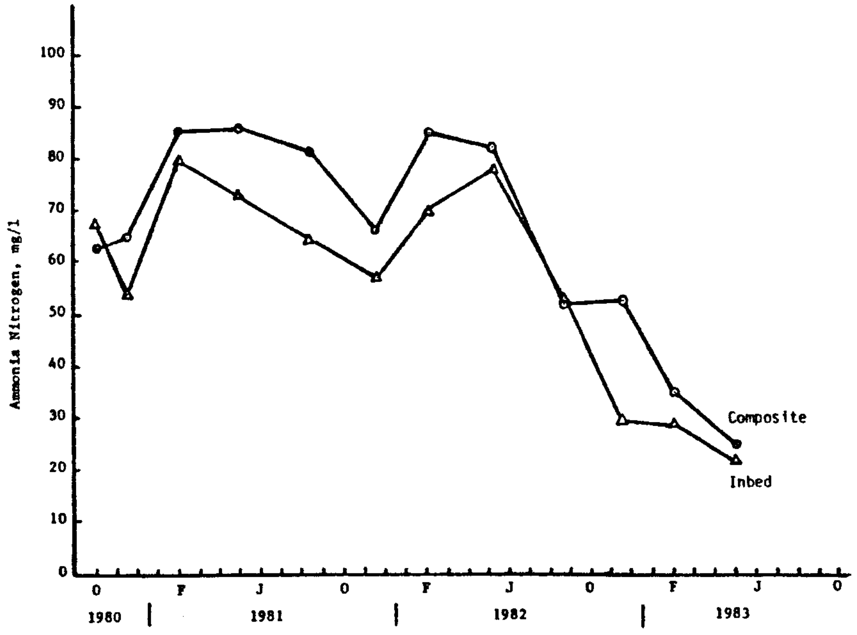

Figure 16. Ammonia in the composite and inbed wells of the 01ST76 filter field.

ammonia. This degree of treatment was achieved consistently by passage through soil 30 cm vertically of soil. However, as seen in Figures 17 through 20, a great reduction in ammonia concentration occurs after passage from the bed into the soil, and in all exbed wells sampled the ammonia concentration generally was reduced to less than 15 mg/l.

C. Nitrate: The conversion of ammonia to nitrate is an aerobic biochemical process. Thus, the presence of low ammonia concentration often less than 1 mg/l, and high nitrate concentrations, sometimes exceeding 10 mg/l, in all well samples leads to the conclusion that the wastewater quality was improved through biochemical treatment upon passage through the soil and that nitrification was essentially complete. The inbed well data in Figure 22 show low nitrate levels, and therefore, little nitrification has occurred in the seepage bed. Figures 23 through 27 show higher nitrate concentrations, particularly during the winter months, corresponded to low concentrations of ammonia, demonstrating nitrification in the filter field. The ammonia and nitrate concentration combined exceeded 60 mg/l in the composite during the first 2 years of this study but, as shown in Figure 28, only about 10 mg/l or less of the combined inorganic nitrogen showed up in the exbed wells in the filter field. Some denitrification probably took place in the gravel bed of the filter field because the inorganic nitrogen concentrations of the inbed wells were always considerably less than that of the composite.

D. Chloride: As mentioned before, chloride concentra-

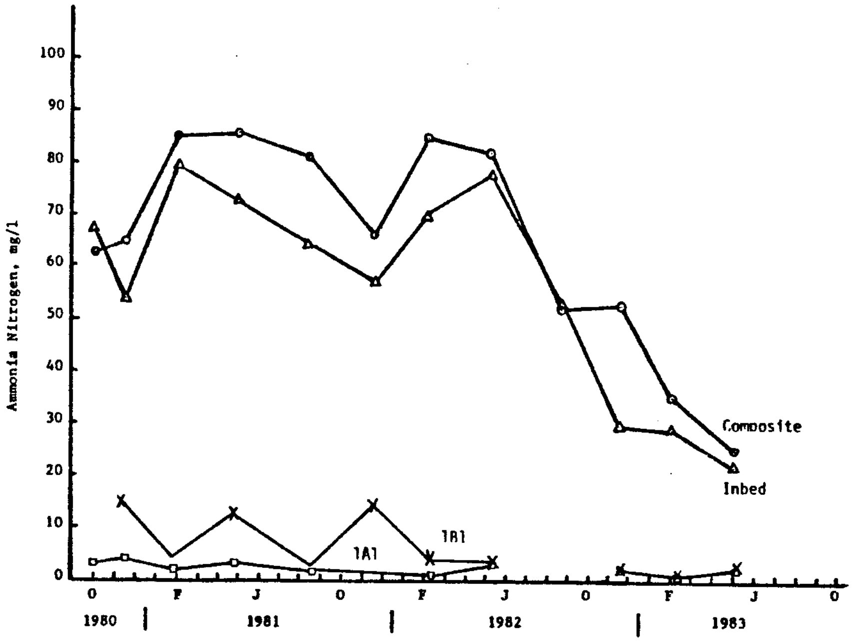

Figure 17. Ammonia in exbed wells 61 cm horizontally from the 01ST76 filter field bed.

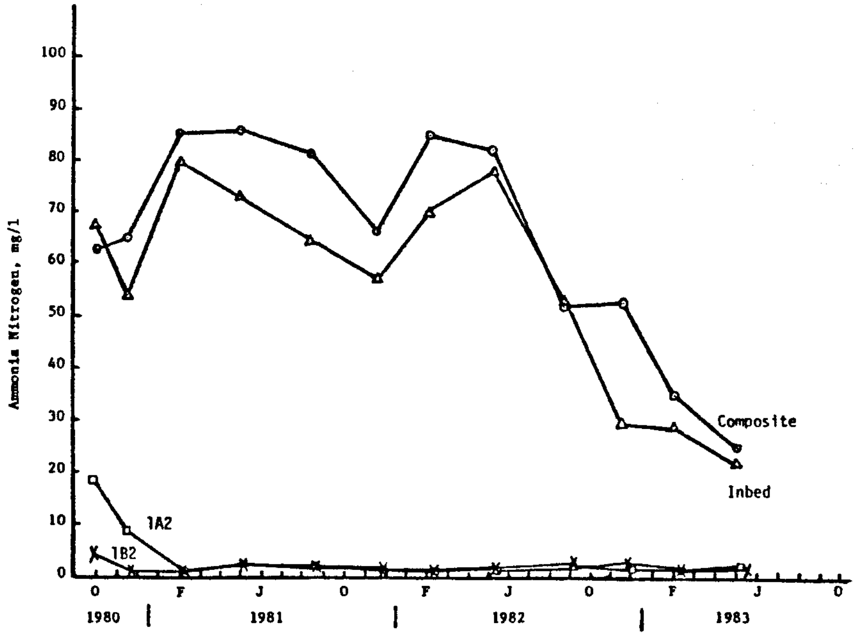

Figure 18. Ammonia in exbed wells 46 and 61 cm horizontally and 15 cm vertically from 01ST76 filter field bed.

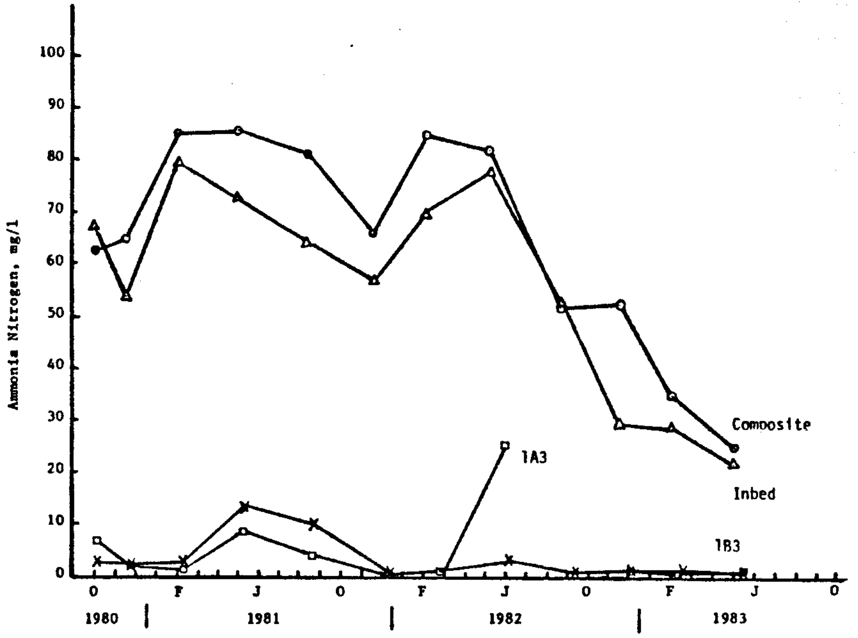

Figure 19. Ammonia in exbed wells 46 and 76 cm horizontally and 30 cm vertically from 01ST76 filter field bed.

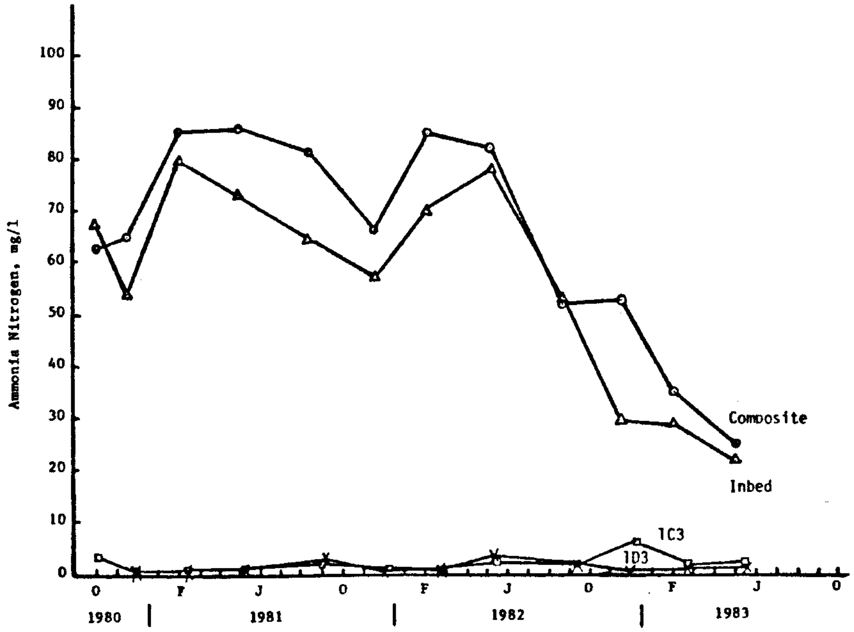

Figure 20. Ammonia in exbed wells 107 and 122 cm horizontally and 30 cm vertically from 01ST76 filter field bed.

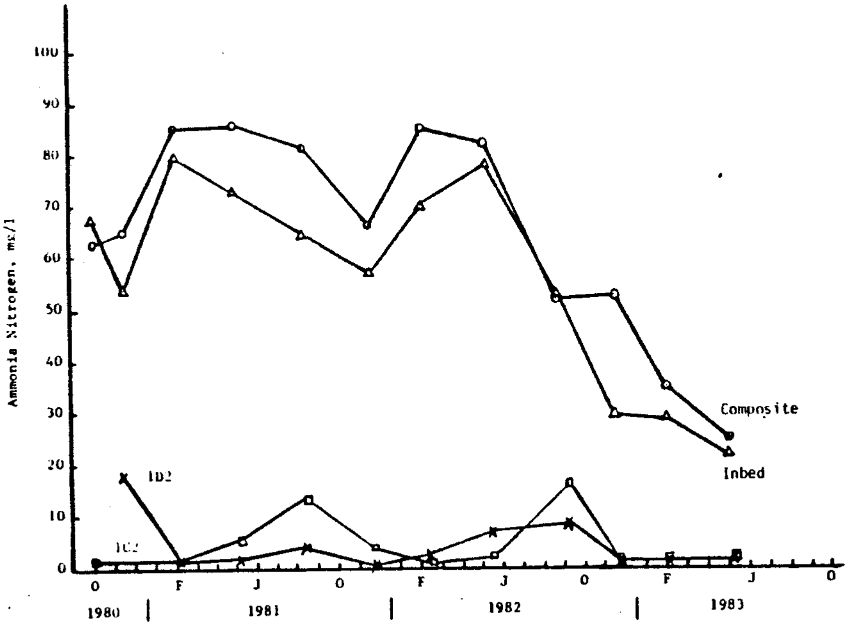

Figure 21. Ammonia in exbed wells 76 and 91 cm horizontally and 15 cm vertically from 01ST76 filter field bed.

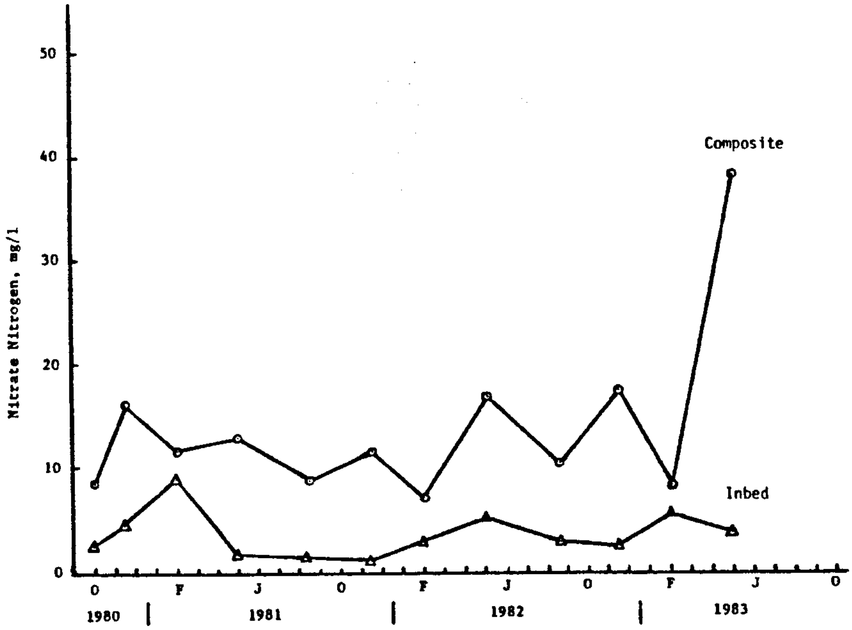

Figure 22. Nitrate in the composite and the inbed wells of the 01ST76 filter field.

tions were observed in an effort to detect groundwater dilution during wet weather periods. Figure 29 shows that the chloride concentrations in the inbed wells were always close to the concentrations in the composite samples. Thus, no significant dilution occurred, and biochemical activity must have caused the TOC and nitrogen effects discussed.

d. The 02MG30 Filter Field

This filter field was constructed with its seepage bed-soil interface only 30 cm below the soil surface. It was loaded with approximately 1.5 cm of effluent per day. Effluent was added hourly in a manner to approximate gravity distribution. This filter field, 02MG30, was comparable to 01ST76 except that it was placed higher in the soil; its lower interface was at 30 cm rather than at 76 cm in the case of 01ST76.

1. Performance

The seepage bed of the 02MG30 filter field was not continuously ponded with effluent throughout the experiment (Appendix Table A-7) as was the seepage bed of 01ST76, but effluent was in the bed on many occasions. Data in Figure 30 provide an overview of the performance of this filter field with time and changing climatic conditions. The inbed depths are the average of two inbed wells (Appendix Table A-8) and the exbed depths are the average of two exbed wells 61 cm outside the seepage bed (Appendix Table A-8). When one or both of the inbed wells were dry, no point is plotted in Figure 30.

The inbed and exbed free-water depths (Figure 30) varied con-

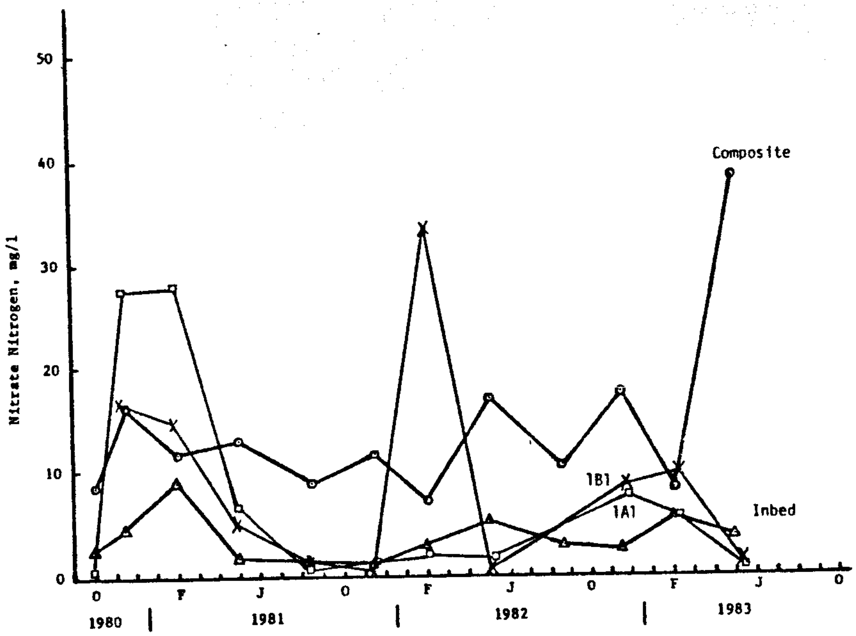

Figure 23. Nitrate in exbed wells 61 cm horizontally from 01ST76 filter field bed.

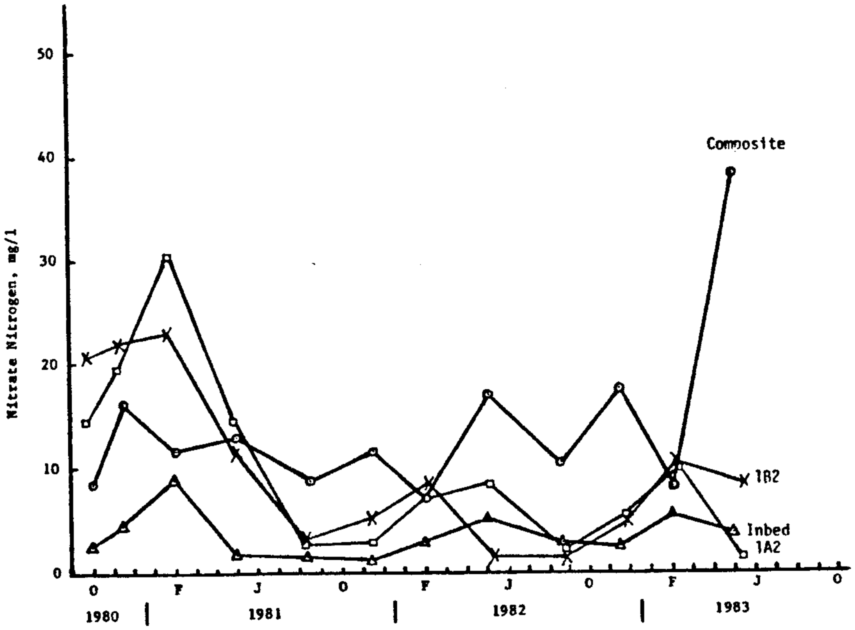

Figure 24. Nitrate in exbed wells 46 and 61 cm horizontally and 15 cm vertically from 01ST76 filter field bed.

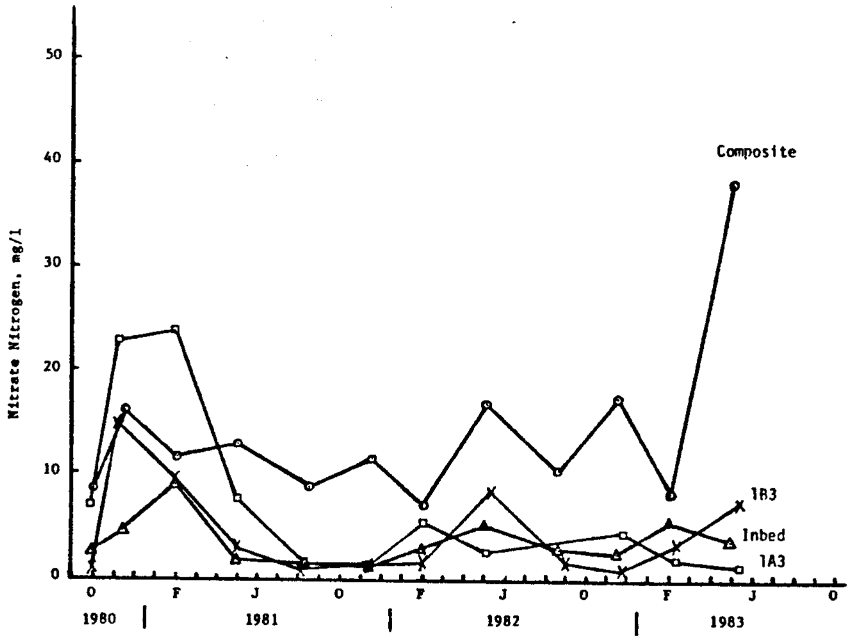

Figure 25. Nitrate in exbed wells 46 and 76 cm horizontally and 30cm vertically from the 01ST76 filter field bed.

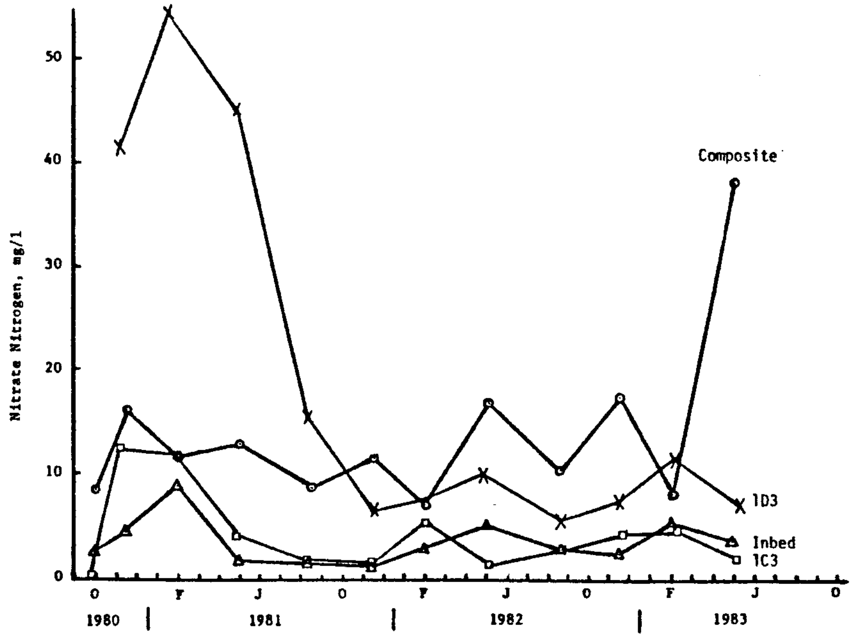

Figure 26. Nitrate in exbed wells 107 and 122 cm horizontally and 30 cm vertically from the 01ST76 filter field bed.

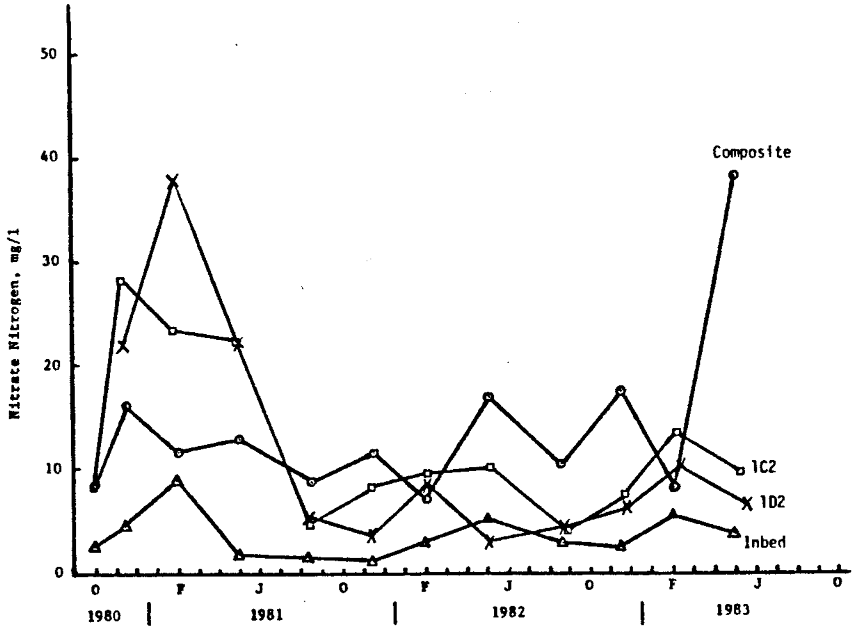

Figure 27. Nitrate in exbed wells 76 and 91 cm horizontally and 30 cm vertically from 01ST76 filter field bed.

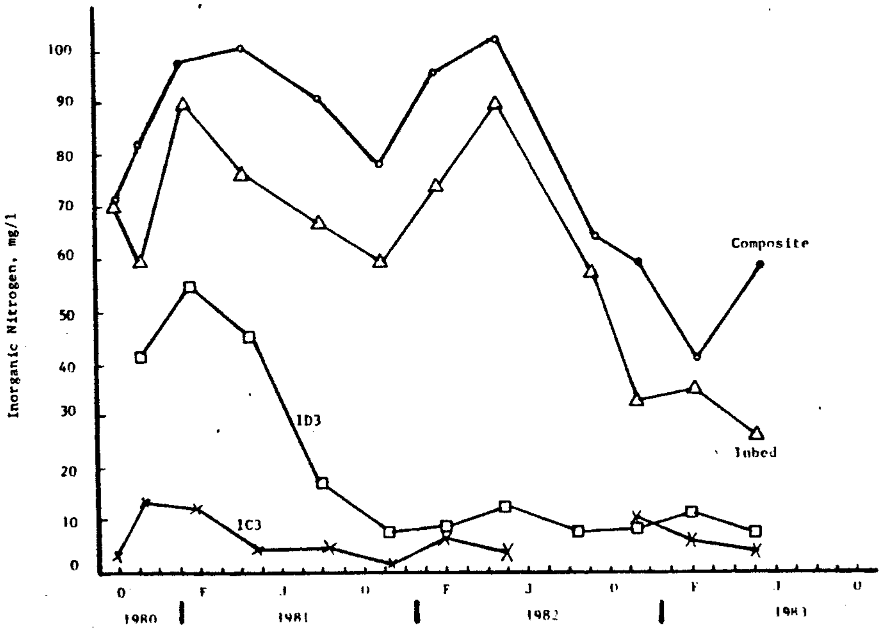

Figure 28. Inorganic nitrogen in the composite, inbed wells, and exbed wells 107 and 122 cm horizontally and 30 cm vertically from the seepage bed of the 01ST76 filter field bed.

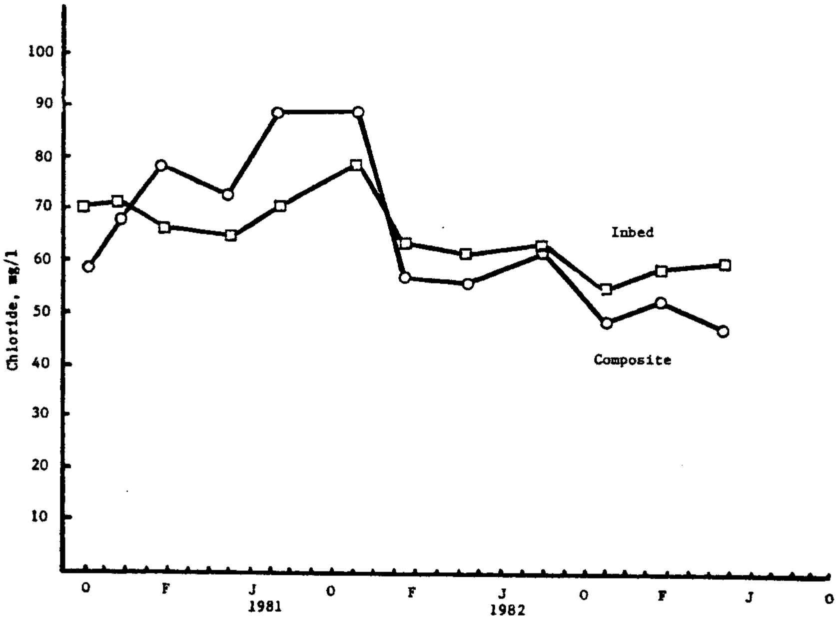

Figure 29. Chloride in the composite and the inbed wells of the 01ST76 filter field.

siderably during the period of experimentation as did the inbed and exbed depths of the 01ST76 filter field. Although comparison of inbed depths during the dry periods of each year seems to be a useful technique in evaluating filter field performance, especially with respect to crusting, it cannot be used for 02MG30 because effluent was not continuously ponded within the bed. Therefore, the periods during which one or more of the exbed wells was dry were used for identifying periods of minimum stress on the filter field.

During FY-81 exbed wells (Figure 30) were dry only during October, November and parts of December 1981. Effluent was ponded in the bed on December 8 of 1980 and on February 9 (although no effluent was delivered to the bed from December 19 through January 29), May 18, August 3 and 17, and September 14, 1981. The ponded effluent was greater than 25 cm below the soil surface on all dates except August 3, 1981 when it was 10 cm below the surface, the maximum inbed rise for FY-81.

Exbed wells were dry on only one date during FY-82, November 16, 1981. Although several months received low rainfall (Figure 30) during FY-82, they were during periods of relatively low ET. This climatic load with the effluent load usually provided sufficient moisture to cause exbed wells to contain water. Inbed wells show the seepage bed saturated on nine observations during FY-82 - one in October of 1981, three in February, one in March, and four in June of 1982. The inbed effluent was deeper than 25 cm on six of these dates and deeper than 18 cm on the other two dates. The maximum inbed rise was to 17 cm below the soil surface on June 16, 1982 (Appendix Table A-8 and Figure 30).

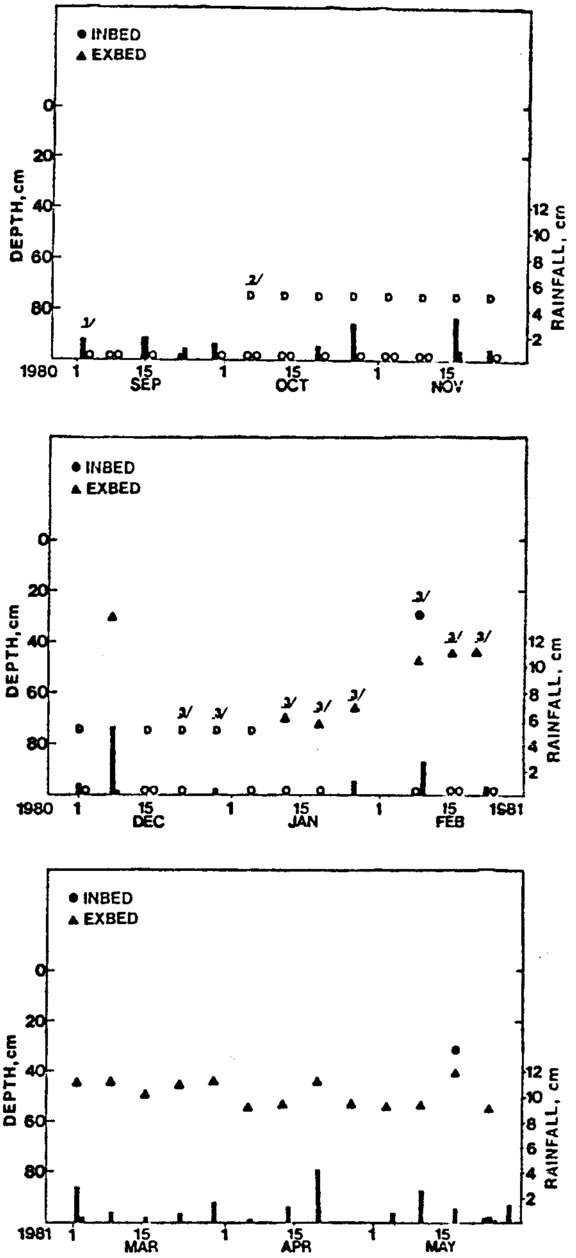

Figure 30. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 02MG30 filter field.

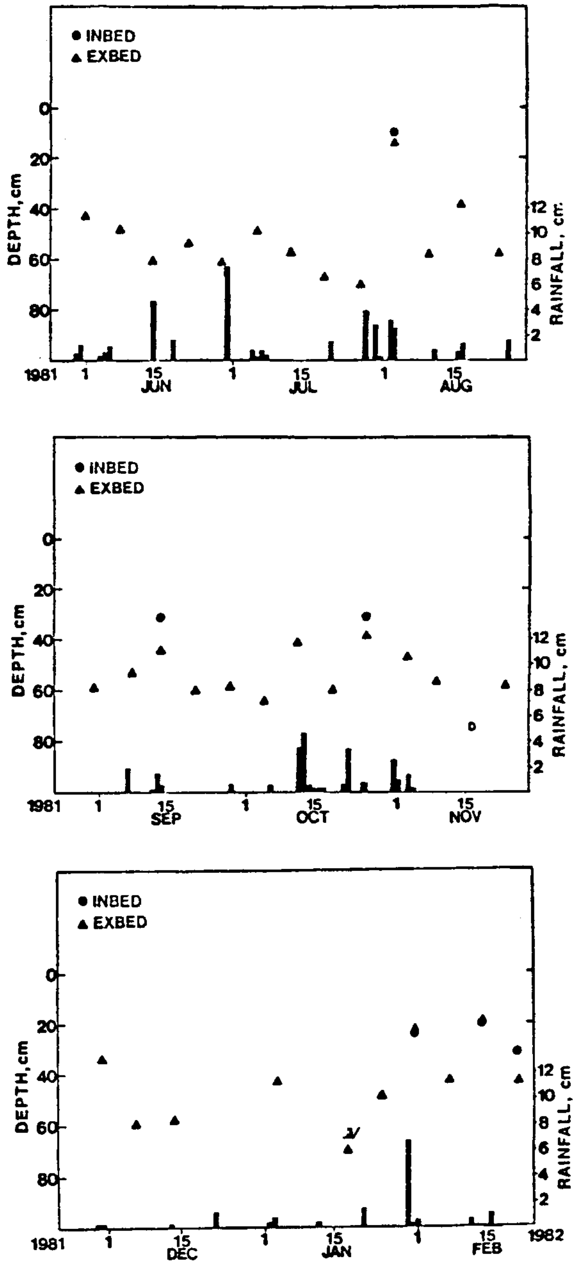

Figure 30. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 02MG30 filter field, continued.

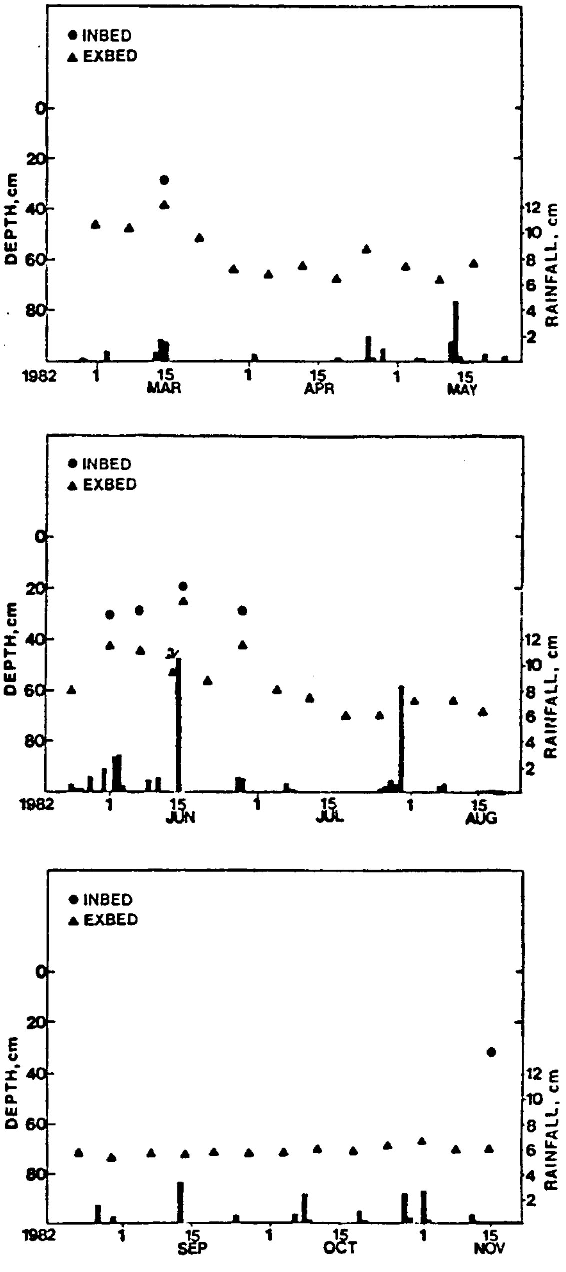

Figure 30. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 02MG30 filter field, continued.

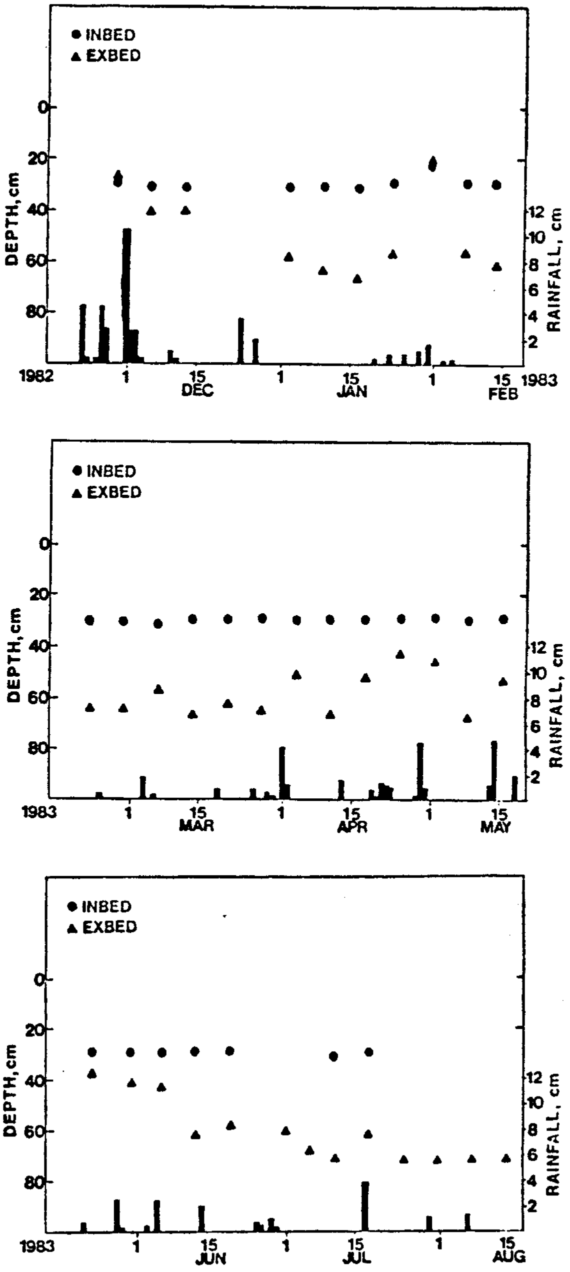

Figure 30. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 02MG30 filter field, continued.

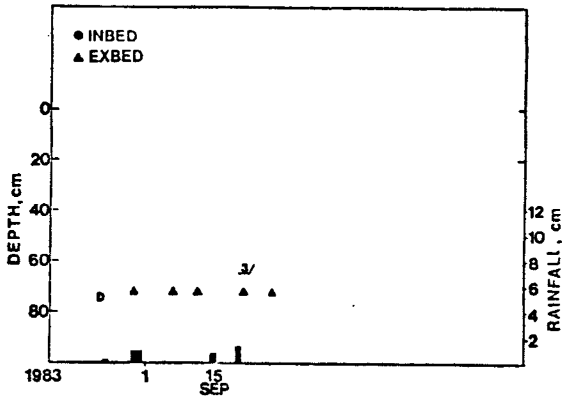

Figure 30. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 02MG30 filter field, continued.

[1] Rainfall values are cumulative since the previous observation through May 22, 1981 when an automatically recording raingauge was installed. Daily values are reported after May 22, 1981. An "o", used only during the period of cumulative raingauge use, denotes no rainfall since the previous observation.

[2] D indicates one or more of the exbed wells which were used to form the mean was dry.

[3] Data influenced by malfunction of the effluent delivery system. Details of effluent delivery are given in Appendix Table A-3.

As in FY-82, exbed wells were dry on only one date during FY-83, August 23, 1983. This year contained low rainfall during January, February, and March when the ET was low but it also contained a period of low rainfall during July, August, and September when ET was relatively high. The abundance of water in the exbed well during July, August, and September of 1983 is not understood.

The seepage bed frequently contained ponded effluent during FY-83. The inbed wells contained effluent except during October, early November of 1982, and during parts of July and all of August and September of 1983. All inbed depths were below 26 cm except on February 1, 1983. On that date the inbed depth was 20 cm below the surface which was the minimum inbed depth for FY-83.

During each of the three fiscal years the hydraulic load within the 02MG30 filter field varied considerably. During parts of each year the seepage bed was ponded with effluent, and during parts of each year no effluent was contained within the seepage bed. During periods of maximum hydraulic load the effluent rose within the bed. The maximum yearly rise came to between 10 and 20 cm of the soil surface.

2. Crusting

Crusting was evaluated in the 01ST76 seepage bed by evaluating and comparing the yearly maximum inbed depth. Since effluent was not continuously ponded in the 02MG30 seepage bed, this approach was not appropriate for this filter field. An earlier report (Rutledge et al., 1983) analyzed data from tensiometers placed on the seepage bed-soil interface and concluded that crusting increased between the summers of 1978 and 1979. The data for the summer of 1980 were not comparable to the earlier data because the location of the effluent entrance into the bed had changed due to blocking of the distribution pipe by growth of a gelatin-like substance. After the summer of 1979 the tensiometers had deteriorated to the point of giving unreliable data and were removed. During the period of this experiment, October 1, 1980 to September 30, 1983, the 02MG30 seepage bed did not contain tensiometers and evaluation of crusting must be less quantitative.

Between October of 1980 and December of 1982 effluent was not ponded in the bed when exbed free-water depths were greater than about 50 cm. However, between January and July of 1983 effluent was ponded in the bed when exbed depths were greater than 50 cm (between 50 and 75 cm); thus, some crusting was indicated. Although crusting had apparently occurred, effluent was not ponded in the bed during the hotter and dryer period from late July through September 1983.

3. Water Quality

Data were gathered from this modified gravity (02MG30) filter field by sampling 12 wells throughout the seepage bed and the adjacent natural soil. Location of these wells is given in Table 6 in the Methods and Materials section. The data describing the water quality of this filter field were presented in graphs of water quality variables for wells equidistant from the bed and of the inbed well data. Again, as in water quality of filter field 01ST76, the period of study is examined on a seasonal basis for clarity of presentation and interpretation of results.

A. Total Organic Carbon: As expected, passage of wastewater through soil improved the quality of the water with respect to organic carbon concentration. The reduction of TOC concentration upon infiltration through the bed was the major contribution to the treatment of organics in the septic tank effluent. As shown in Figure 31, the inbed treatment accounted for a reduction in TOC of approximately 56 percent from more than 100 mg/l in the composite to only about 50 to 60 mg/l in the seepage bed wells. Figures 32 through 36 demonstrate an improvement in water quality as the wastewater leaves the seepage bed and infiltrates into the soil. This improvement is marked in Figures 34 and 36 showing that samples from well 2A2 at 30 cm horizontally and 15 cm vertically from the bed contained water of virtually the same TOC quality as well 2B3 located 91 cm horizontally and 30 cm vertically from the bed. The results indicated that little improvement in TOC concentration was gained by passage of the water through the greater distance of the soil. However, when compared to the standard system, the wastewater of this gravity system had higher TOC concentrations in the soil, generally above 10 to 20 mg/l, and slightly higher treatment in the bed.

B. Ammonia: Figure 37, depicting the relationship of inbed ammonia concentration to the influent ammonia, shows that some reduction in ammonia occurred in the seepage bed but only about 15 percent and even less during the last year. However, further examination of the data, as shown in Figures 38 through 42, reveals that most ammonia conversion took place after the water moved from the bed into

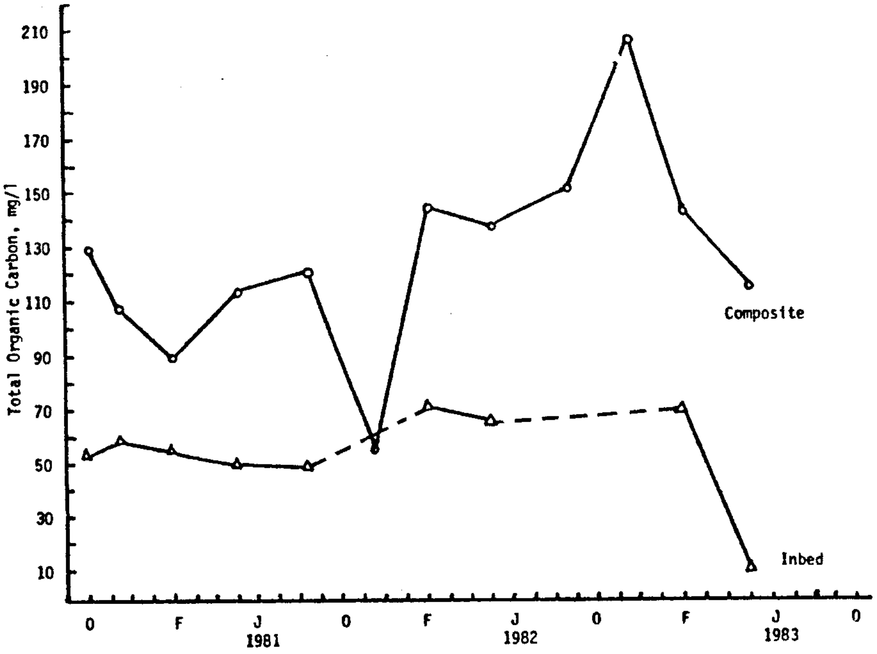

Figure 31. TOC of the composite and inbed wells of the 02MG30 filter field.

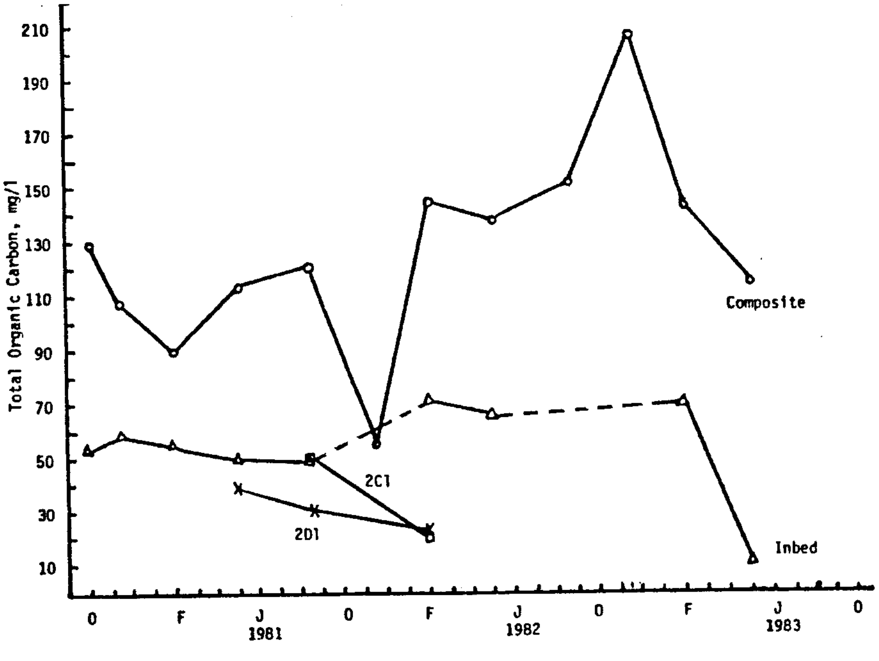

Figure 32. TOC of two exbed wells 61 cm from 02MG30 filter field bed.

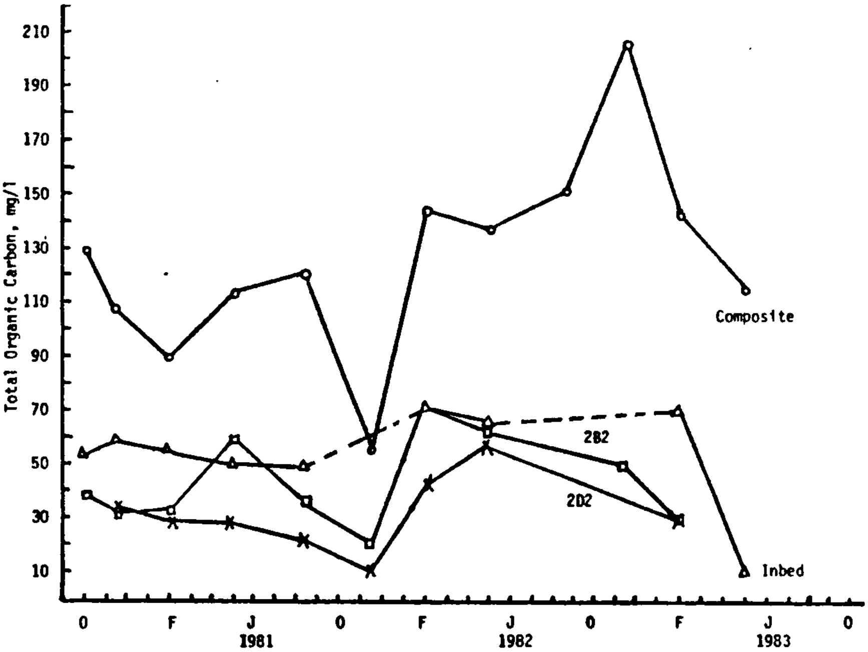

Figure 33. TOC of exbed wells 46 cm horizontally and 15 cm vertically from 02MG30 filter field bed.

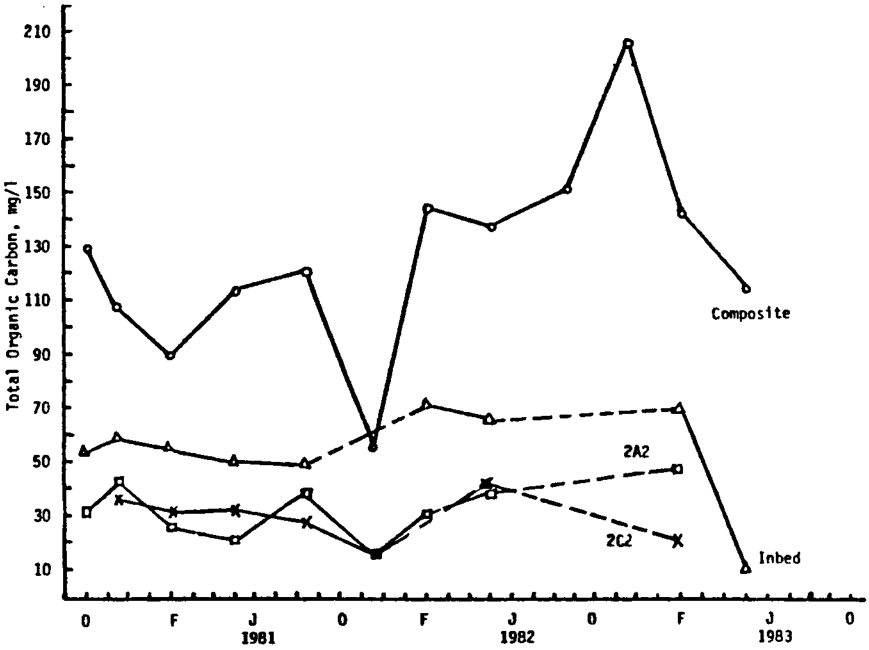

Figure 34. TOC of exbed wells 30 and 61 cm horizontally and 15 cm vertically from 02MG30 filter field bed.

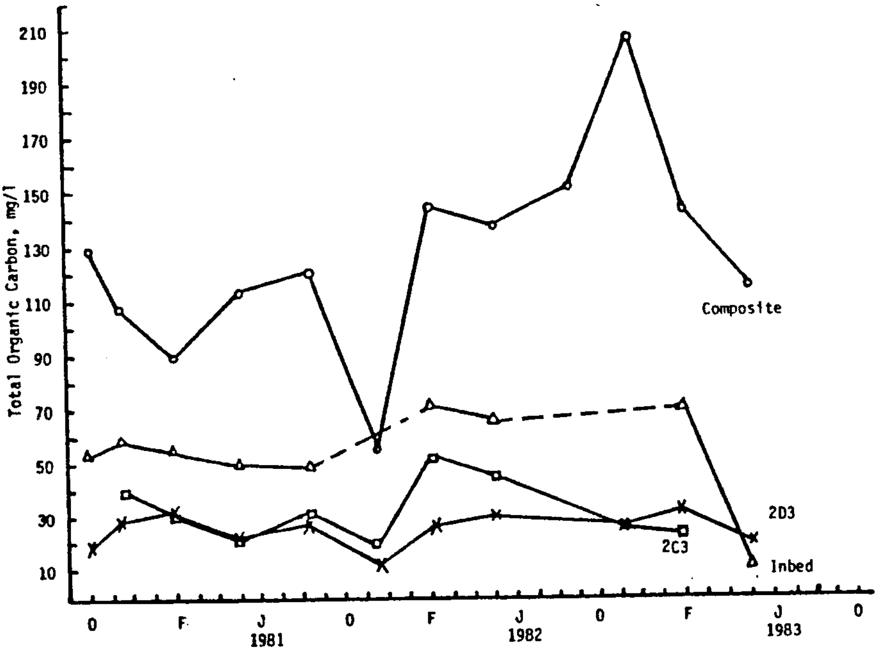

Figure 35. TOC of exbed wells 61 cm horizontally and 30 cm vertically from O2MG30 filter field bed.

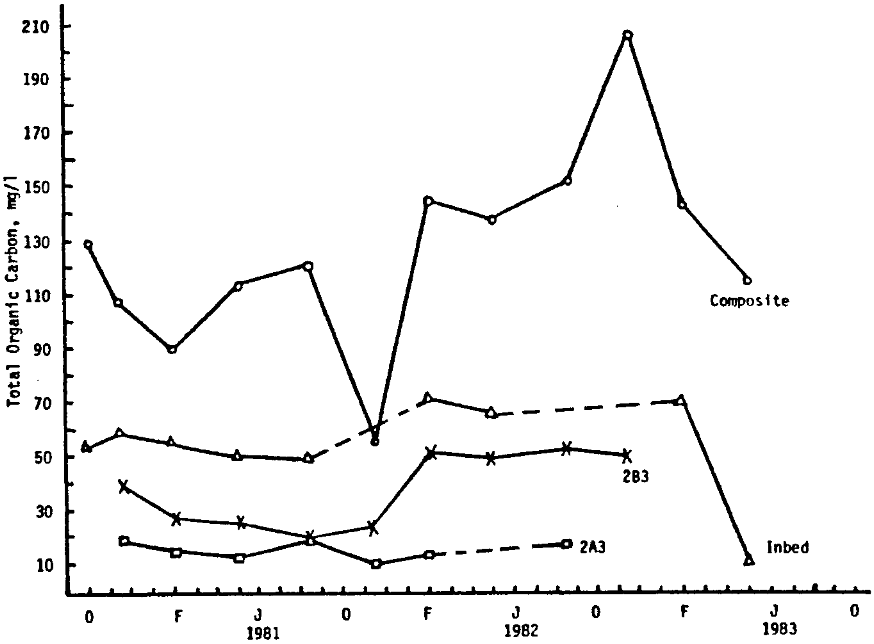

Figure 36. TOC of exbed wells 91 and 137 cm horizontally and 30 c vertically from O2MG30 filter field bed.

the soil. Usually better then 80 percent ammonia reduction was apparent.

Considering the ammonia parameter, this modified gravity filter field demonstrated less nitrification than the standard filter field, but both systems demonstrated considerable nitrification.

C. Nitrate: The generally low concentration of nitrate in the inbed wells, about 2 to 10 mg/l and only about 10 to 15 mg/l in the composite (Figure 43), indicates an absence of significant nitrification. However, in comparing the inbed ammonia, (Figure 37), and the inbed nitrate concentrations (Figure 43), apparently some denitrification was taking place in the bed because the inbed values of both ammonia, indicating nitrification, and nitrate, indicating denitrification , were always considerably less than the composite value.

Evidence that nitrification took place as the wastewater passed through the soil is shown in Figures 44 through 47. Virtually all the exbed wells had nitrate concentrations greater than that of the inbed wells. However, there was no apparent relationship with depth of soil percolation and nitrification as evidenced by the scattering of the data.

There was, however, considerable loss of inorganic nitrogen in the filter field as shown in Figure 48. The composite had between 80 and 95 mg/l combined inorganic nitrogen during the first 2 years of the study, while the inbed wells only had between 65 to 70 mg/l combined inorganic nitrogen during this same period, representing a loss of about 20 mg/l inorganic nitrogen. The two farthest exbeds, 2A3 and 2B3, had between 3 to 40 mg/l combined inorganic nitrogen.

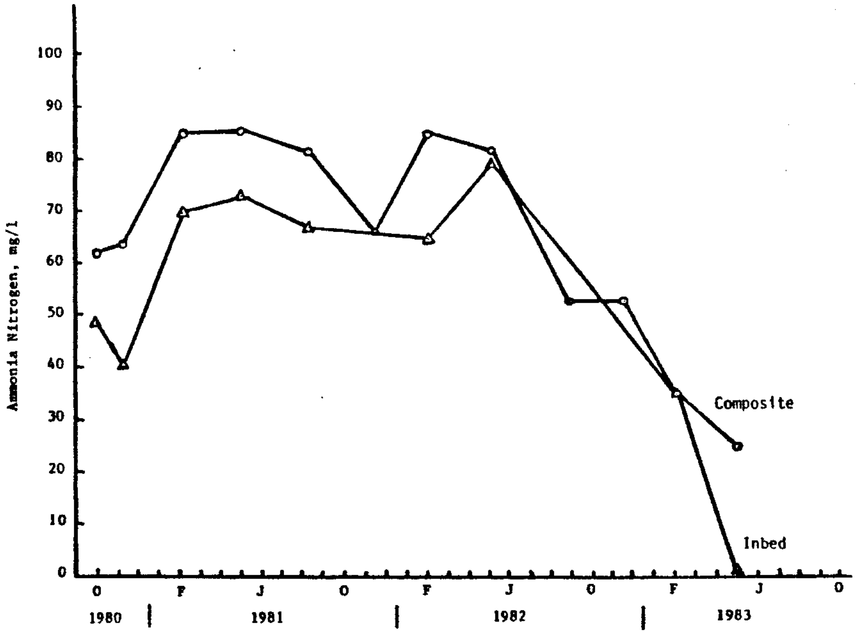

Figure 37. Ammonia in the composite and inbed wells of the 02MG30 filter field.

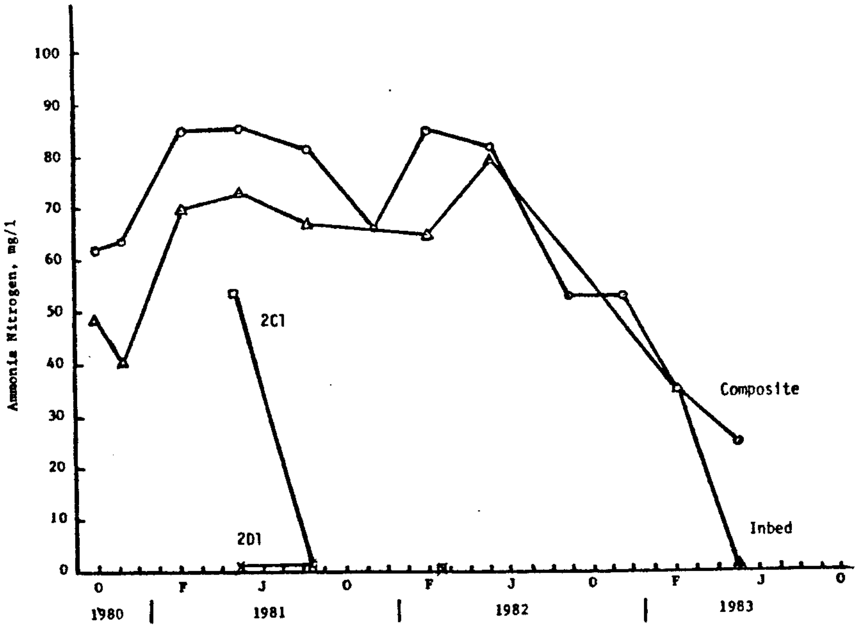

Figure 38. Ammonia in exbed wells 61 cm horizontally from 02MG30 filter field bed.

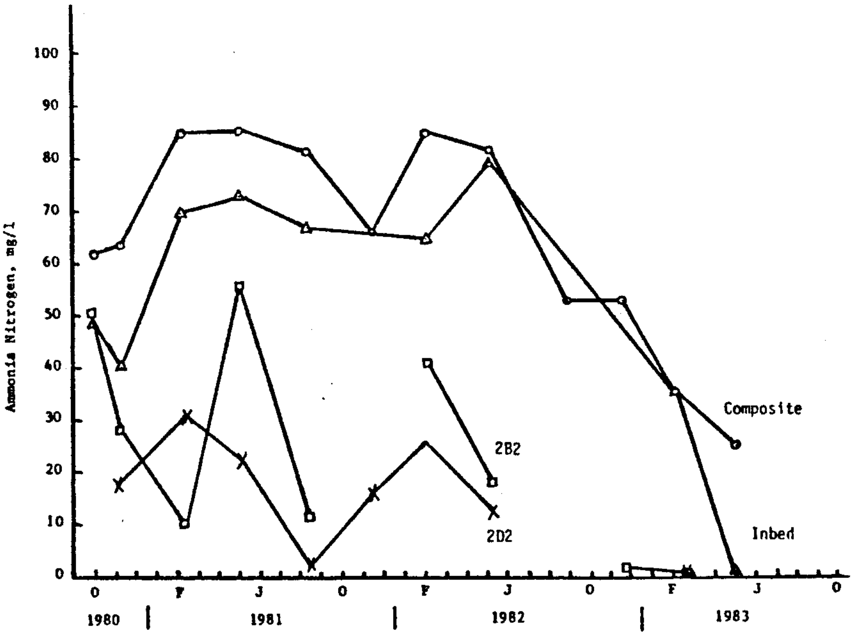

Figure 39. Ammonia in exbed wells 46 cm horizontally and 15 cm vertically from 02MG30 filter field bed.

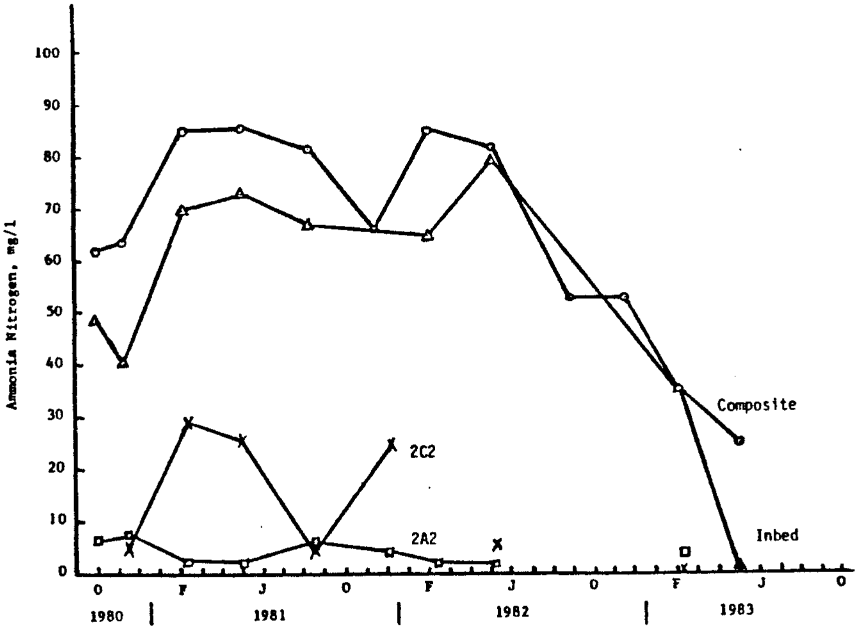

Figure 40. Ammonia in exbed wells 30 and 61 cm horizontally and 15 cm vertically from 02MG30 filter field bed.

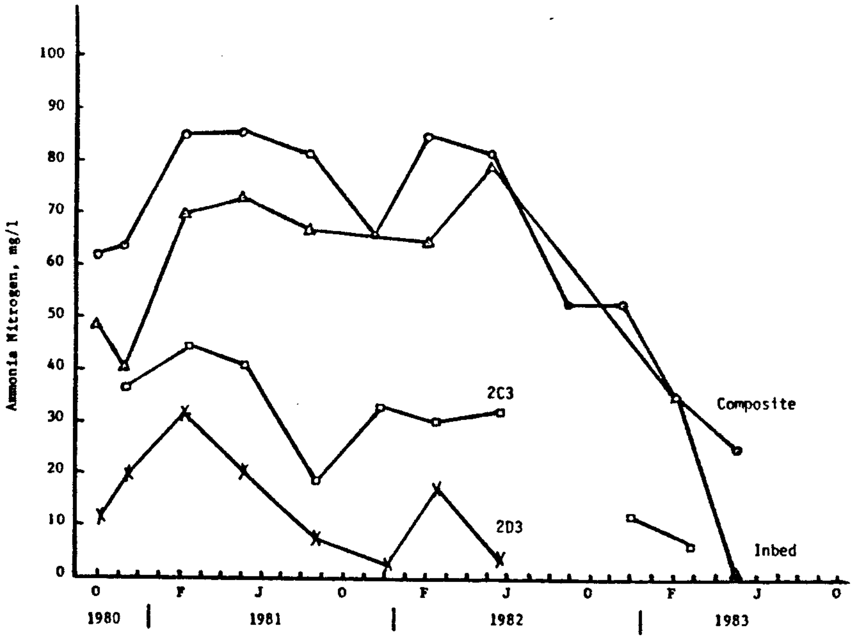

Figure 41. Ammonia in exbed wells 61 cm horizontally and 30 cm vertically from 02MG30 filter field bed.

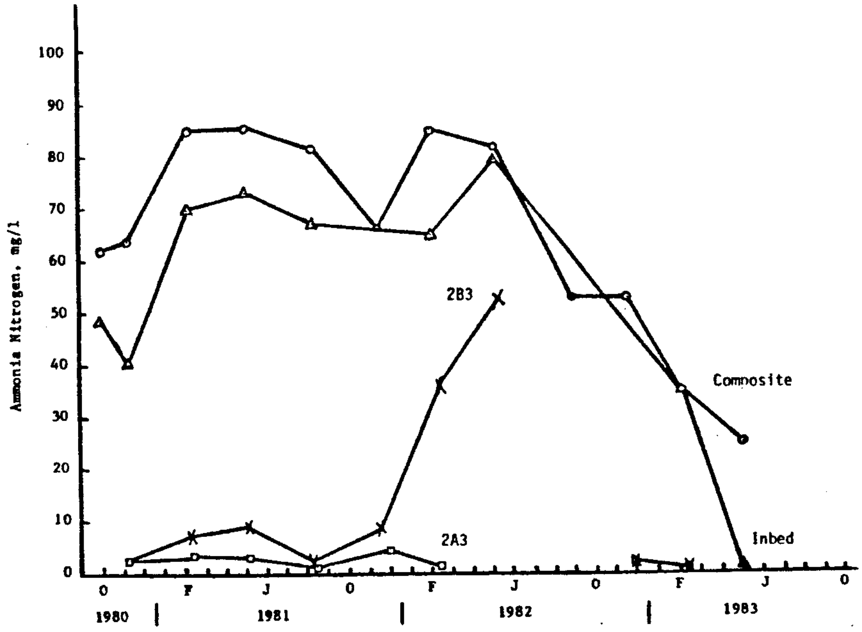

Figure 42. Ammonia in exbed wells 91 and 137 cm horizontally and 30 cm vertically from 02MG30 filter field bed.

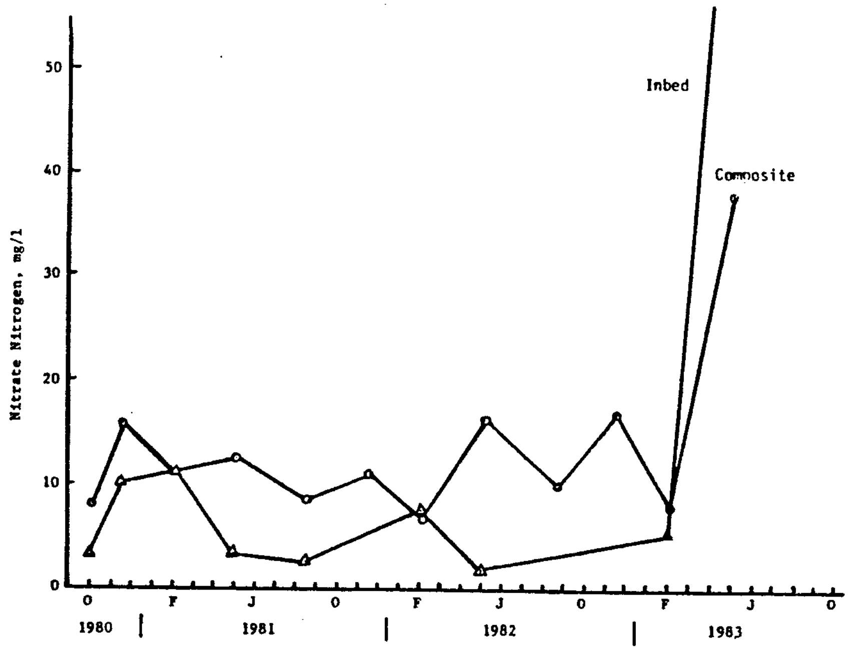

Figure 43. Nitrate in the composite and the inbed wells of the 02MG30 filter field.

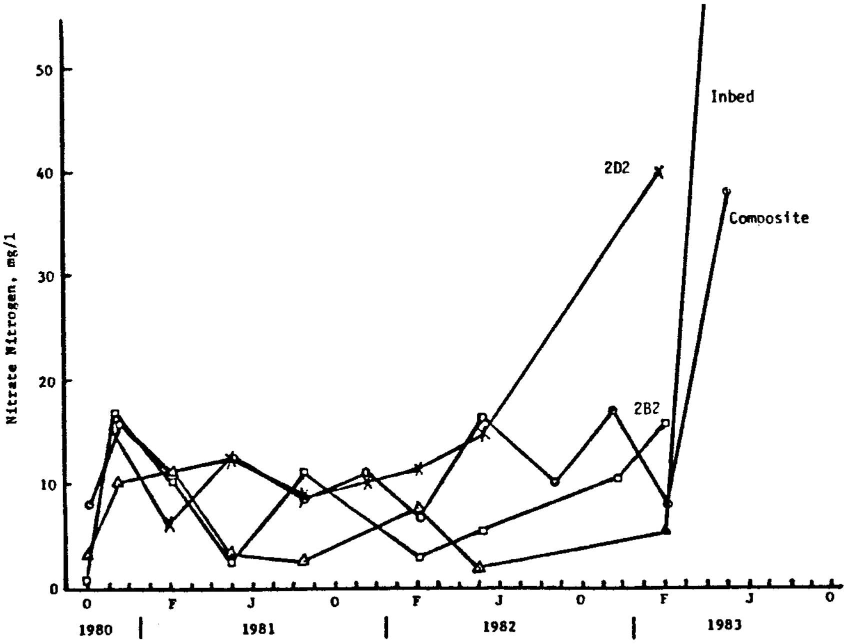

Figure 44. Nitrate in exbed wells 46 cm horizontally and 15 cm vertically from 02MG30 filter field bed.

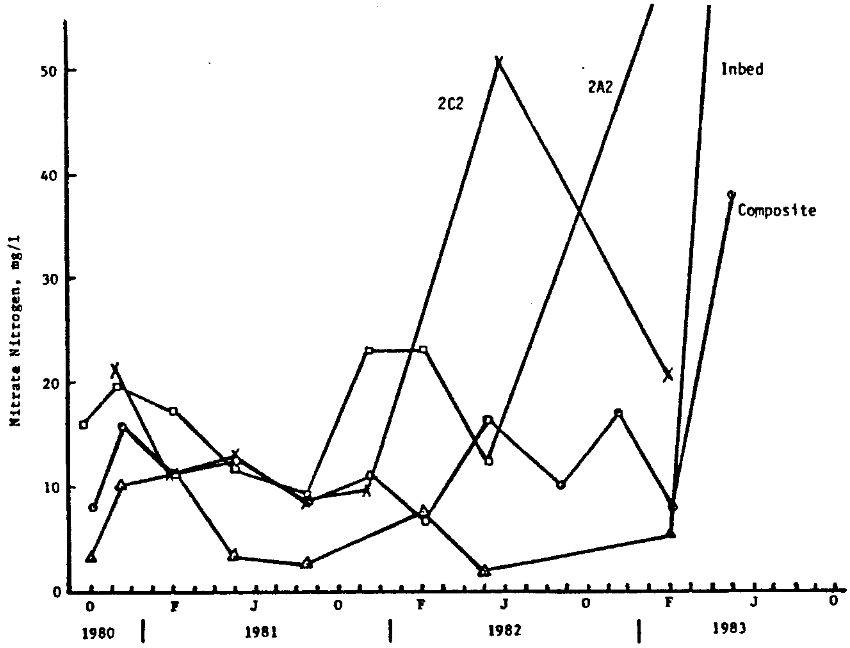

Figure 45. Nitrate in exbed wells 30 and 61 cm horizontally and 15 cm vertically from 02MG30 filter field bed.

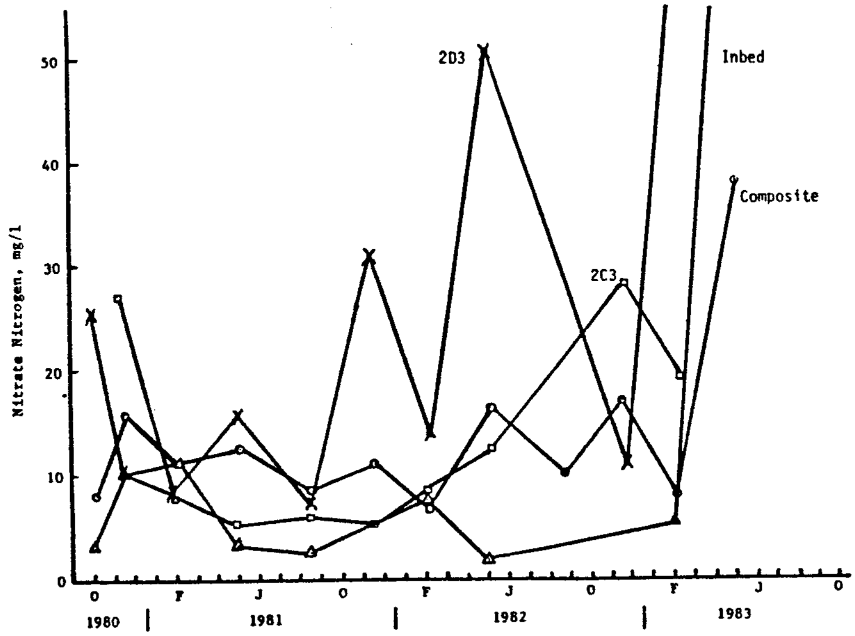

Figure 46. Nitrate in exbed wells 61 cm horizontally and 30 cm vertically from 02MG30 filter field bed.

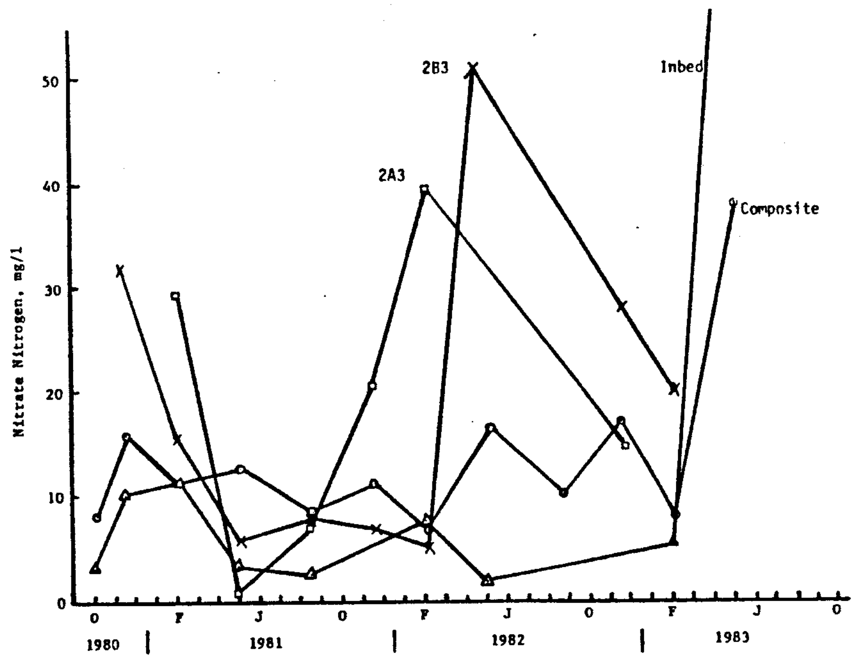

Figure 47. Nitrate in exbed wells 91 and 137 cm horizontally and 30 cm vertically from 02MG30 filter field bed.

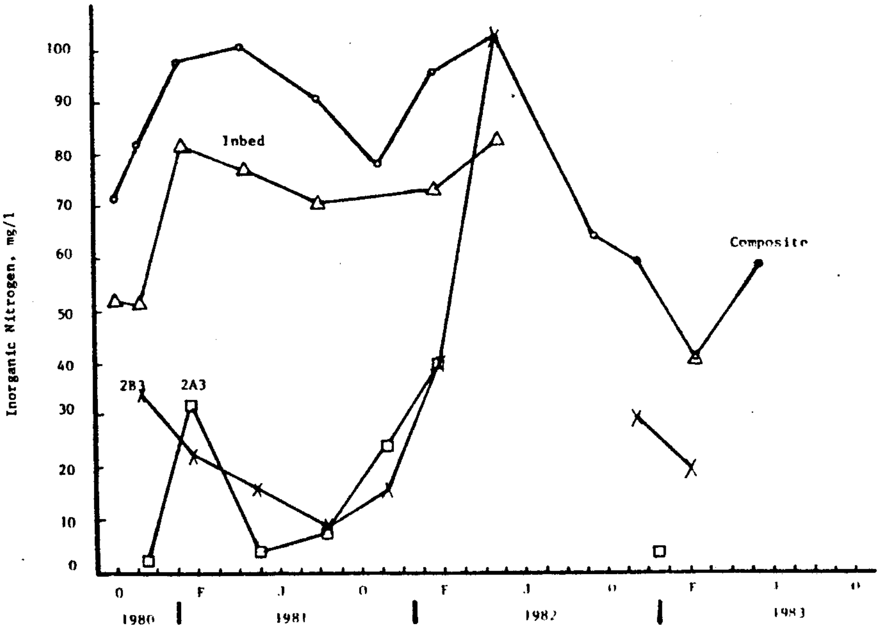

Figure 48. Inorganic nitrogen in the composite, inbed wells, and exbed wells 91 and 137 cm horizontally and 30 cm vertically from the seepage bed of the 02MG30 filter field.

D. Chloride: Dilution of the septic tank effluent during wet weather periods is not indicated by the data for chloride concentration presented in Figure 49. The inbed well samples had about the same chloride content as the septic tank effluent.

e. The 10MP40 Filter Field

This filter field was constructed with its seepage bed-soil interface 40 cm below the soil surface. It was loaded with approximately 1.5 cm of effluent per day. The effluent was dosed into the bed once per day through a pressure distribution system. Because this filter was constructed in a somewhat different soil than the other three filter fields (01ST76, 02MG30, and 11MP06) its performance is not directly comparable to the performance of the other filter fields.

1. Performance

Effluent was first added to this filter field on May 11, 1982. Installation of exbed wells was completed in July of 1982 and monitoring of them was started at that time (Appendix Table A-9). Figure 50 provides an approach to evaluating the performance of filter field 10MP40 by noting the height of effluent in the seepage bed before dosing and the height of effluent 30 minutes after dosing. The two filter fields which were previously discussed, 01ST76 and 02MG30, contained gravity effluent distribution. In evaluating the performance of those filter fields, considerable emphasis was placed on the amount and duration of effluent ponded within the bed. The ponded effluent status was related to environmental conditions (rainfall and ET) and interpreted into relative rates of water movement and the possible

Figure 49. Chloride in the composite and the inbed wells of the 02MG30 filter field.

occurrence of crusting. Thus, when a gravity distribution filter field does not continuously contain ponded effluent, the ability to make interpretations is limited. In filter fields with pressure distribution the rate of dissipation of the dose from the seepage bed can be measured and related to environmental conditions and possible crusting. Thus, dosed filter fields provide an additional parameter for evaluating their performance.

During the approximately 4 months (May through September) of FY-82 that the 10MP40 filter field was operated, one or both of the exbed wells were dry (Appendix Table A-9) except on one date, early August of 1982. However, the exbed wells were not installed until early July of that year.

Effluent was ponded within the seepage bed before dosing when the first observations were made in May 1982. For the period May through September 1982, effluent was ponded in the bed before dosing on all but five occasions. On all occasions during this period effluent was ponded in the bed for more than 30 minutes after dosing. The ponding of effluent in the bed during the initial use of the filter field demonstrates that the lower portion of the bed was constructed in or just above a soil horizon with a low hydraulic conductivity. Although effluent was ponded in the bed both before and 30 minutes after dosing from May through September of 1982, on most occasions it was ponded only to a height of 6 cm or less above the interface. The maximum rise of effluent above the interface (Figure 50) during this period was to 18 cm (before and 30 minutes after dosing) above the

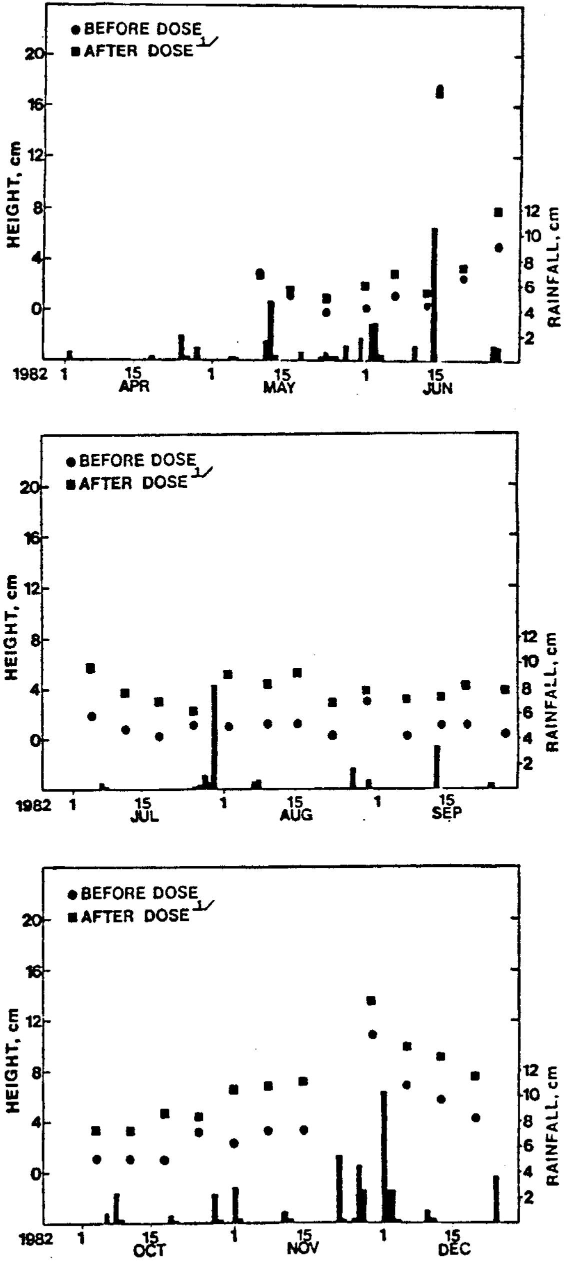

Figure 50. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 10MP40 filter field.

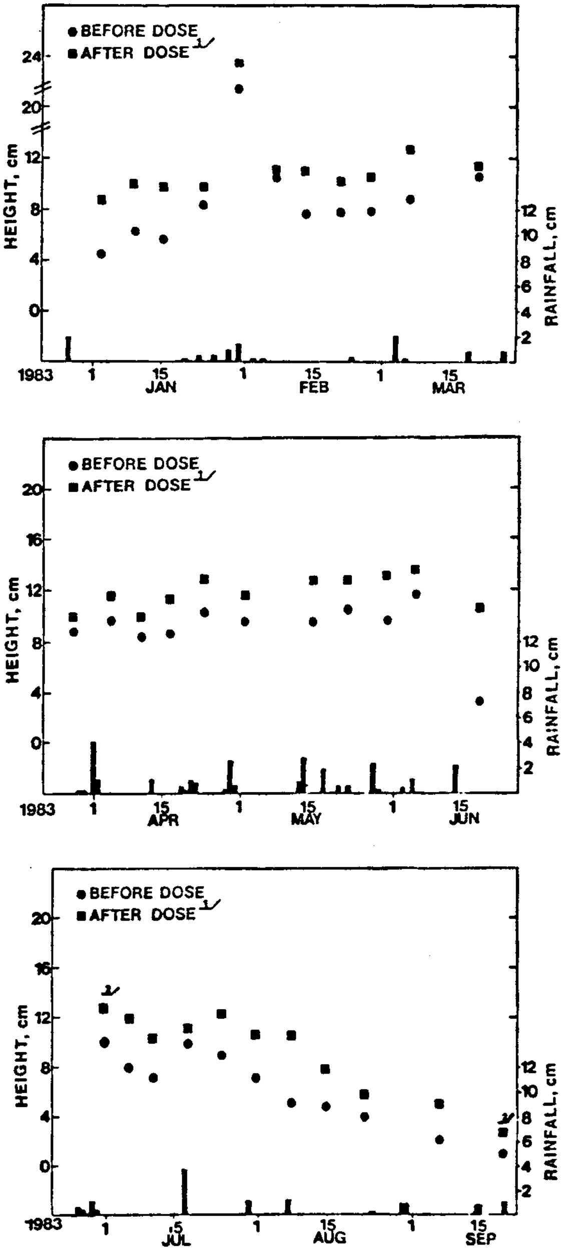

Figure 50. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 10MP40 filter field, continued.

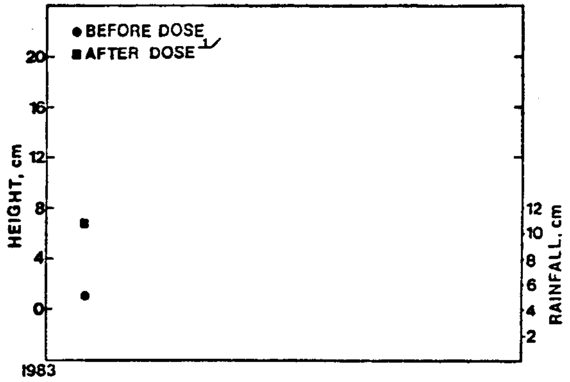

Figure 50. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 10MP40 filter field, continued.

---

[1] 30 minutes after dosing.

[2] Data influenced by malfunction of the effluent delivery system. Details of effluent delivery are given in Appendix Table A-4.

interface, or 22 cm below the soil surface, on June 16, 1982. The rise was in response to the 11-cm rainfall on June 15.

During FY-83 the exbed wells contained water continuously except during October of 1982 and July, August and September of 1983 as well as on one date in May of 1983 (Appendix Table A-9). Even during these dryer periods effluent was normally ponded within the bed before dosing; however, it was usually ponded to a height of 10 cm or less above the interface. During these as well as other periods, the effluent did not drain from the bed within 30 minutes after dosing.

Effluent was only 10 to 14 cm above the interface 30 minutes after dosing during most of 1983. The maximum rise 30 minutes after dosing occurred on February 1, 1983. Before dosing on that date the exbed depth (Appendix Table A-9) was 21 cm below the soil surface and the inbed depth was 20 cm above the interface and 20 cm below the soil surface. Thirty minutes after dosing on February 1, 1983, the inbed effluent was 24 cm above the interface and, thus, 16 cm below the soil surface.

In summary, the seepage bed of 10MP40 contained ponded effluent before most measured dosing events during the experiment. It also contained inbed effluent 30 minutes following all measured dosing events. This slow rate of drainage from the seepage bed, which was detected when the experiment was initiated, indicates the lower part of the bed was in or immediately above an horizon with a low hydraulic conductivity (Table 4). The maximum rise of effluent within the bed was on February 1, 1983, when the effluent was 20 cm above the interface before dosing and 24 cm above the interface (and 16 cm below the soil surface) 30 minutes after dosing.

2. Crusting

During August and September of 1982, shortly after introduction of effluent into 10MP40, the exbed wells were dry and the effluent was ponded 2 cm or less above the interface before dosing. During July of 1983, the exbed wells were dry, but the effluent was 7 to 10 cm or less above the interface before dosing. Thus, based on drainage rates, it appears some crusting did occur between August and September of 1982 and July of 1983. During August and September of 1983 the height of ponding before dosing decreased from about 5.5 cm in early August to about 1.2 cm in late September. It seems possible that the crust was aerating and deteriorating during this extended hot and dry period.

3. Water Quality

The water quality data taken from analyses of well samples are presented in tabular and graphical form for the 10MP40 filter field. Seasonal mean values are shown as data points of the graphs of equidistant wells. The tables give the maximum, minimum, and mean values as well as the standard deviation for each well. Data are from April of 1982 through June of 1983. There were 18 wells placed in the filter field, including two inbed wells (Table 6).

A. Total Organic Carbon: The TOC concentration in the wastewater was reduced greatly upon passage from the seepage bed into the soil. Examination of Table 11 shows that the wells farthest from the bed, NE3, NW3, SE3, and SW3 had average TOC concentrations higher than those of one of the closest wells, NE1, indicating the passage of the wastewater through the additional soil apparently did not always improve water quality with respect to TOC. Only one inbed well sample could be drawn during the year, and it contained a TOC concentration indicating the same approximately 50 percent reduction as seen in the other systems.

The TOC data are also presented in Figures 51 through 54. As shown in Figure 51 the two wells nearest the bed, XE1 and XW1, only about 10 cm directly under the seepage bed, had approximately 50 mg/l or about a 60 to 70 percent reduction in TOC. The greatest reduction apparently took place in the first few centimeters of percolation because as shown in Figure 53 and 54 wells at 60 and 80 cm horizontal from the bed and 20 cm below the bed did not indicate any further reduction or improvement in TOC.

One well, XE2 (Figure 52) had water values excessively high throughout most of this study. The TOC concentrations ranged from a high of 798 mg/l down to a low of 37 mg/l. The water from this well always had an earthy odor and dark amber color. There may have been an old decaying root near the well point, or the water, in traversing to the well, may have percolated through some organic decay. No other sampling wells in this system nor in the research site exhibited this characteristic. Therefore data from this well were rejected as invalid.

B. Ammonia: Table 12 and Figures 55 through 58 are used to evaluate ammonia analyses. These analyses indicate that the ammonia

Table 11. Total organic carbon contents within the composite, inbed wells, and exbed wells of the 10MP40 filter field.

Well I.D.	No. of samples	TOC (mg/l)			
		Min.	Max.	Mean	S.D.[1]
Composite	16	68	744	199	155
IE1	1	83	83	83	
IW1	0				
NE1	2	18	19	19	
NW1	1	40	40	40	
SE1	1	43	43	43	
SW1	1	50	50	50	
XE1	11	15	80	33	23
XW1					
EW1	14	23	124	56	38
NE2	4	9.0	23	16	5.8
NW2	5	40	73	56	11
SE2	7	31	150	61	44
SW2	2	37	61	49	
NE3	1	32	32	32	
NW3	3	22	54	42	17
SE3	2	30	42	36	
SW3	5	21	33	27	5.2
XE2	8	37	789	287	250
XW2	14	14	152	66	38

[1] Standard deviation.

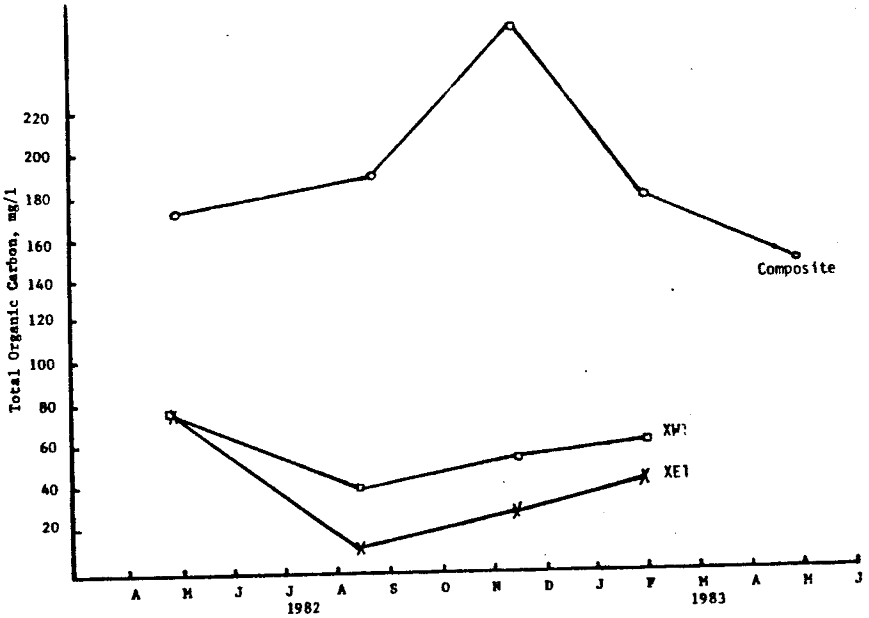

Figure 51: TOC of two exbed wells 10 and 11 cm vertically from 10MP40 filter field bed.

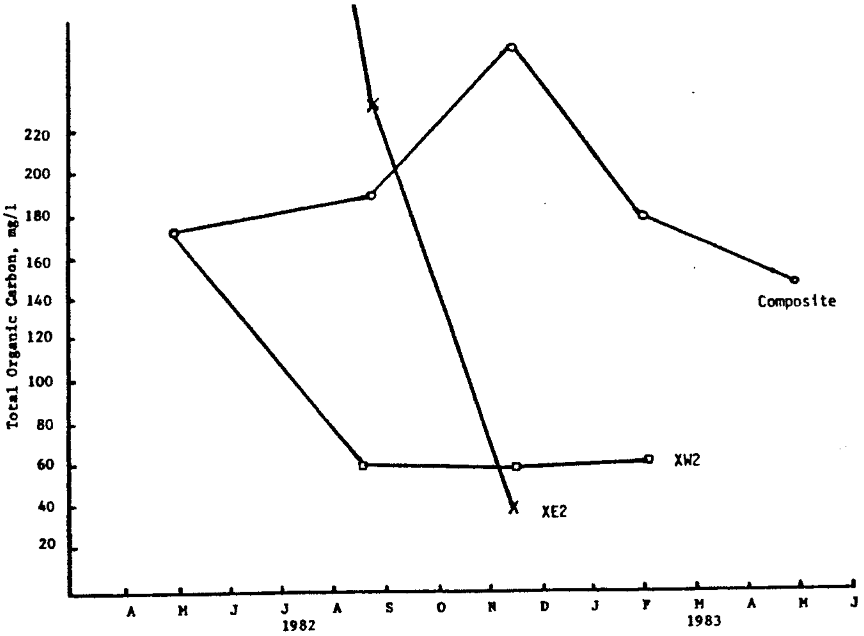

Figure 52. TOC of exbed wells 25 and 38 cm vertically from 10MP40 filter field bed.

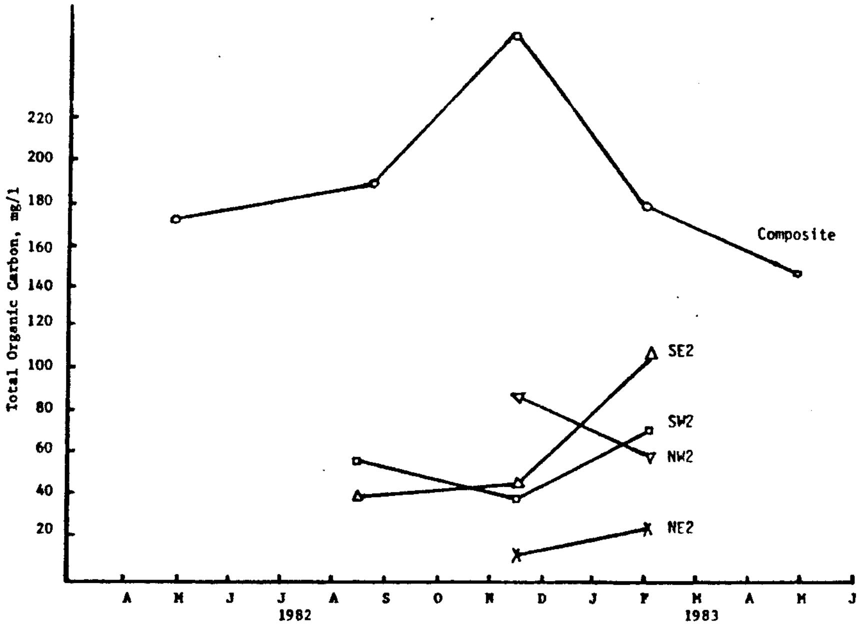

Figure 53. TOC of exbed wells 35 cm horizontally and 20 cm vertically from 10 MP40 filter field bed.

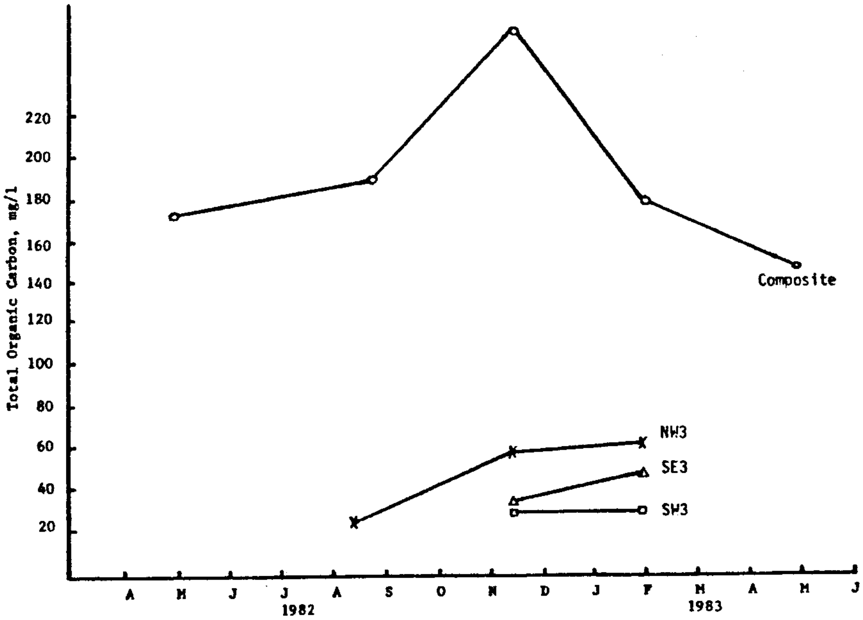

Figure 54. TOC of exbed wells 80 cm horizontally and 20 cm vertically from 10MP40 filter field bed.

Table 12. Ammonia contents within the composite, inbed wells, and exbed wells of the 10MP40.

Well I.D.	No. of samples	Ammonia (mg/l)			
		Min.	Max.	Mean	S.D.[1]
Composite	16	14	80	44	18
IE1	1	28	28	28	
IW1	0				
NE1	2	1.2	2.0	1.6	
NW1	1	7.0	7.0	7.0	
SE1	1	4.2	4.2	4.2	
SW1	2	8.0	24	16	
XE1	11	0.3	55	24	17
XW1	14	6.0	45	28	11
EW1					
NE2	4	0.7	2.0	1.4	0.7
NW2	5	2.0	6.0	3.6	1.8
SE2	7	0.5	6.0	2.0	2.0
SW2	3	8.0	12	9.3	2.3
NE3	2	0.8	2.0	1.8	
NW3	3	1.8	12	6.3	5.2
SE3	2	1.0	2.0	1.5	
SW3	5	0.0	3.0	2.0	1.2
XE2					
XW2	13	0.0	22	5.6	6.8

[1] Standard deviation.

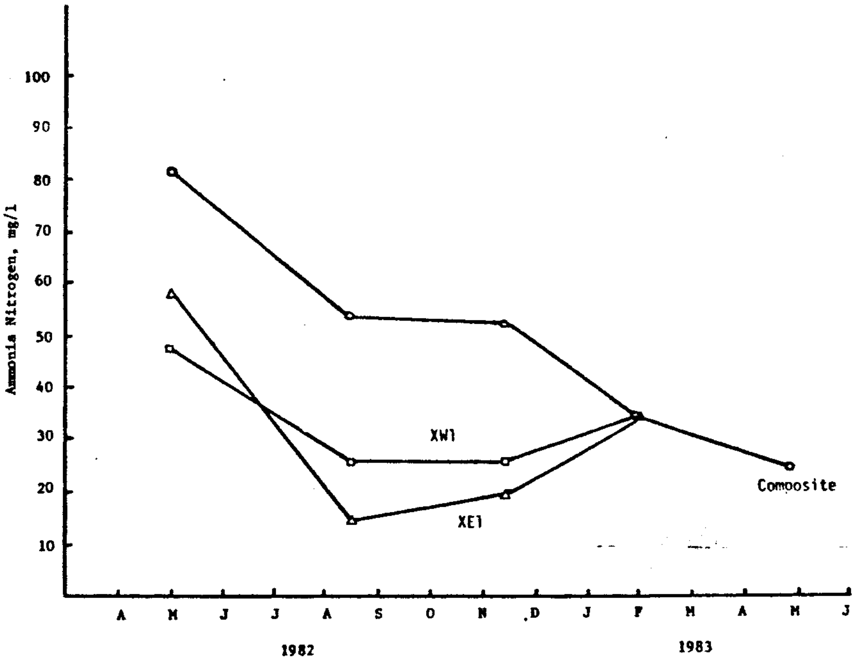

Figure 55. Ammonia in exbed wells 10 and 11 cm vertically from 10MP40 filter field bed.

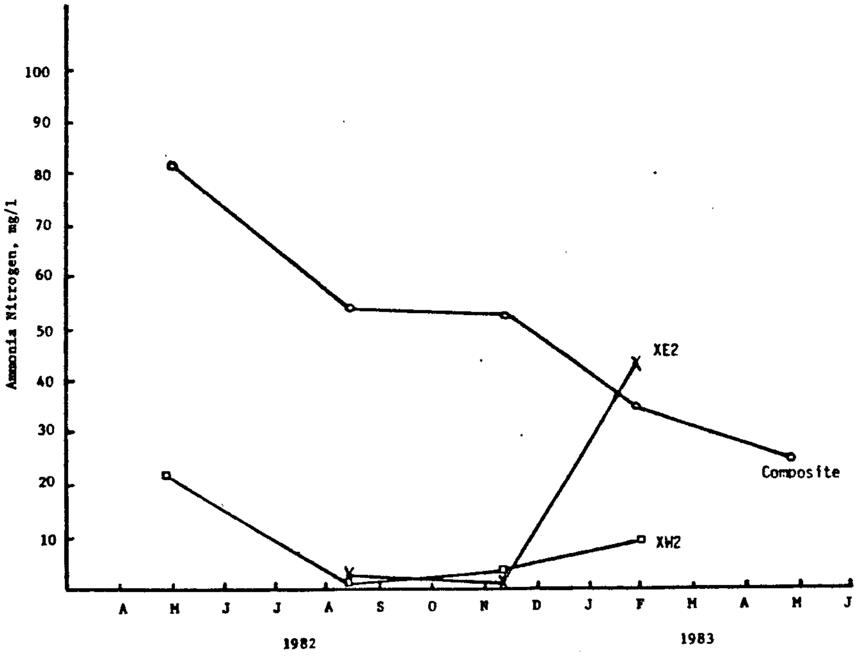

Figure 56. Ammonia in exbed wells 25 and 38 cm vertically from 10MP40 filter field bed.

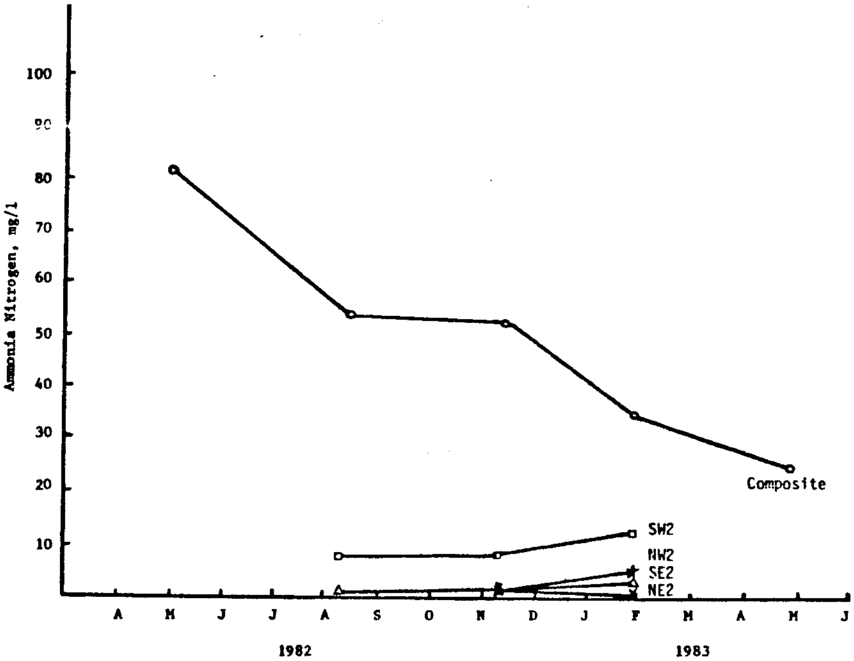

Figure 57. Ammonia in exbed wells 35 cm horizontally and 20 cm vertically from 10MP40 filter field bed.

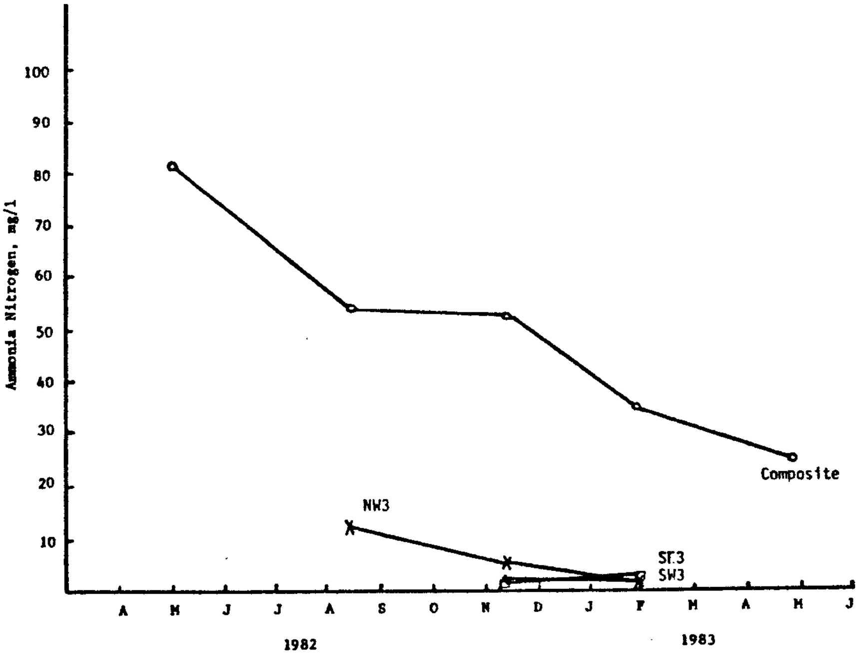

Figure 58. Ammonia in exbed wells 80 cm horizontally and 20 cm vertically from 10MP40 filter field bed.

concentration in the wastewater remained high until it reached wells NE2, NW2, SE2, and SW2. Passage of the water through more than 10 cm vertically of soil did not greatly reduce the ammonia concentration. Well NW3 had water in it, sufficient for sampling, only three times during the year. One of these, the 12 mg/l concentration appears to be inconsistent with the rest of the data. Rejecting this datum as an outrider will give an average value of only 3.4 mg/l for the remaining two samples from this well.

Even so, the nitrification was not as complete in this system as in the previous two systems. However, the depth below the bed at which sampling wells were located were greater in the previous systems. Had wells been placed at a greater depth below the bed, such as the 40 to 70 cm wells in systems 01ST76 and 02MG40, a more complete nitrification may have been demonstrated.

C. Nitrate: Table 13 and Figures 59 through 62 seem to indicate little change in nitrate levels as the wastewater moved through the seepage bed and the filter field. However, as discussed previously, the 20 cm depth may be insufficient for any conclusions regarding these data.

Evidence of denitrification in this system is demonstrated in Table 14. The combined inorganic nitrogen of the composite was from 44 to 64 mg/l in the observed samples while that of two wells farthest from the bed ranged from only 23 to 5 mg/l. Generally about an 80 percent reduction occurred in the combined inorganic nitrogen, a similar reduction to the other two filter fields previously discussed.

Table 13. Nitrate contents within composite, inbed wells, and exbed wells of the 10MP40 filter field.

Well I.D.	No. of samples	Nitrogen (mg/l-N)			
		Min.	Max.	Mean	S.D.[1]
Composite	15	5.0	19	11	4.4
IE1	1	11	11	11	
IW1	0				
NE1	2	17	25	21	
NW1	1	19	19	19	
SE1	1	7.4	7.4	7.4	
SW1	2	2.8	20	11	
XE1	11	1.2	27	7.1	7.6
XW1	13	1.2	25	6.1	7.7
EW1					
NE2	4	6.0	15	10	4.0
NW2	5	1.5	30	9.5	11.8
SE2	7	0.5	12	6.0	4.0
SW2	3	11	18	14	3.9
NE3	2	16	17	17	
NW3	3	3.5	11	6.7	3.9
SE3	2	18	20	19	
SW3	4	3.0	8.2	4.6	2.4
XE2					
XW2	14	1.8	180	18	47

[1] Standard deviation.

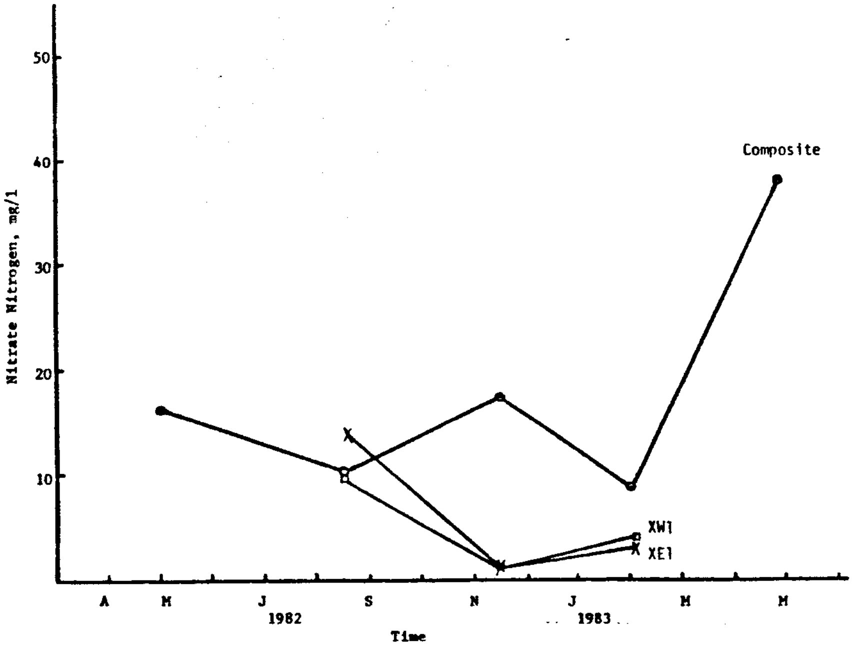

Figure 59. Nitrate in exbed wells 10 and 11 cm vertically from 10MP40 filter field bed.

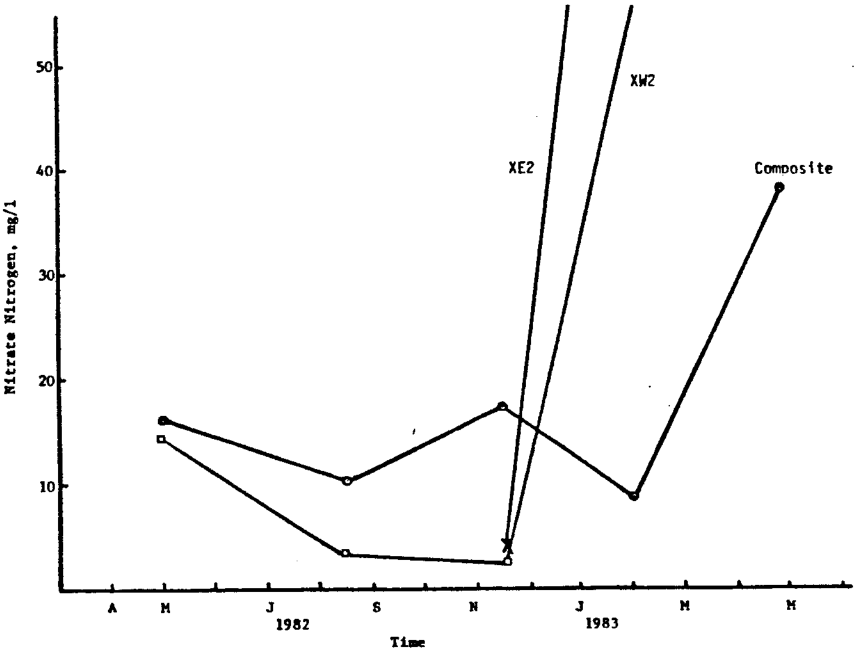

Figure 60. Nitrate in exbed wells 25 and 38 cm vertically from 10MP40 filter field bed.

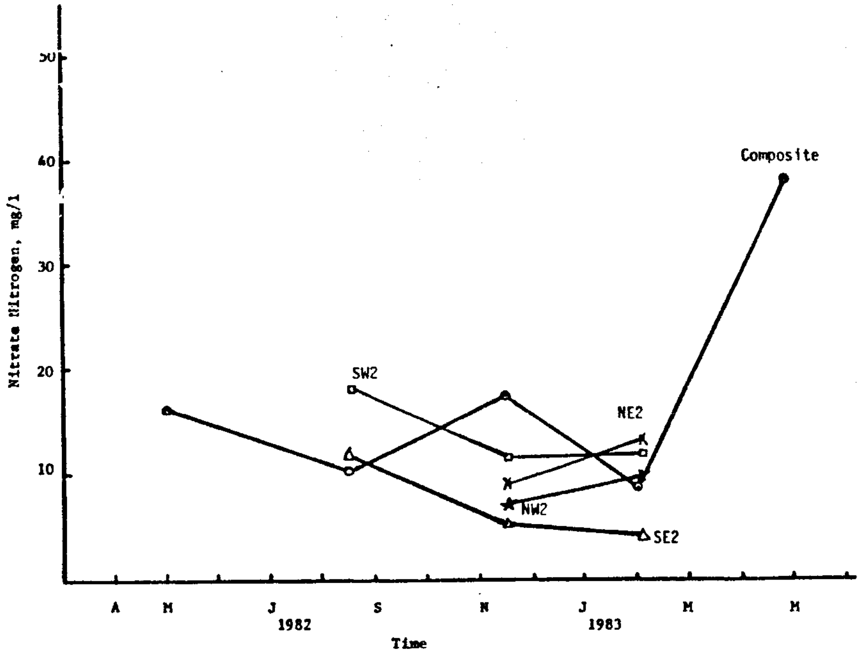

Figure 61. Nitrate in exbed wells 35 cm horizontally and 20 cm vertically from 10MP40 filter field bed.

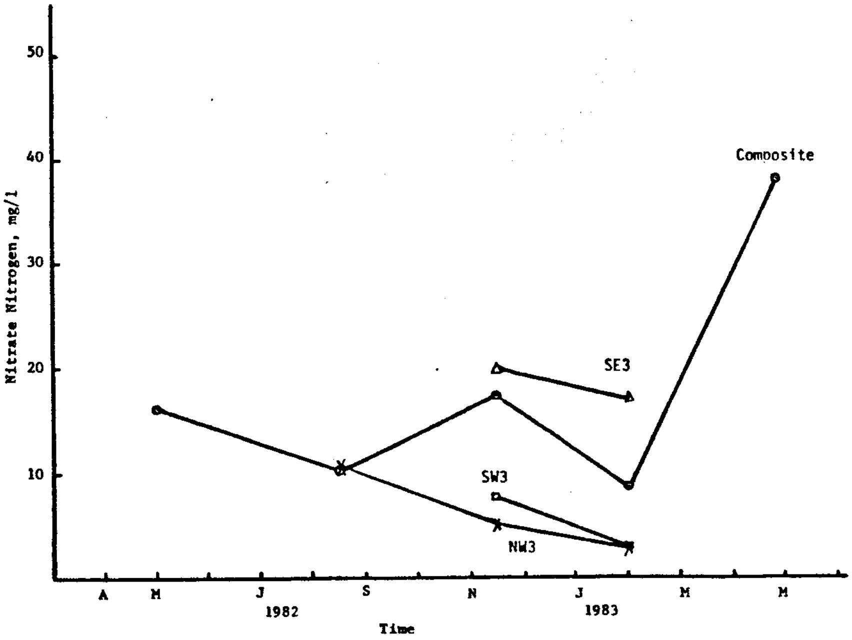

Figure 62. Nitrate in exbed wells 80 cm horizontally and 20 cm vertically from 10MP40 filter field bed.

Table 14. Inorganic nitrogen contents within the composite and exbed wells at greatest distance from the seepage bed of the 10MP40 filter field.

Date	Inorganic Nitrogen (mg/l-N)		
	Composite	Exbed wells	
		NW3	SW3
Jul-Oct 82	63	23	
Nov-Dec 82	56	10	10
Jan-Mar 83	44	5	6
Apr-Jun 83	64		

D. Chloride: Chloride analyses in this filter field (10MP40), as in 01ST76 and 02MG30 (Table 15), reveal little consistency in chloride concentration. Some wells had higher chloride concentrations than the septic tank effluent, supporting the suspicion of the chlorides washing through the soil. The single inbed well sample gave no indication of dilution during wet weather periods.

f. The 11MP06 Filter Field

The 11MP06 filter field was constructed with its lower seepage bed-soil interface 6 cm below the original soil surface. This was done by excavating 6 cm of the original soil; adding gravel, the distribution pipe, and additional gravel; covering that with building paper; and then covering the building paper with soil materials. Thus, the completed seepage bed rose above the original soil surface. However, the original surface was retained as the reference point in discussing performance of the filter field. The seepage bed was loaded with approximately 1.5 cm of effluent per day as were the other three beds. Effluent was dosed into the bed once per day by a pressure

Table 15. Chloride contents within the composite, inbed wells, and exbed wells within the 10MP40 filter field.

Well[1] I.D.	No. of samples	Chloride (mg/l)			
		Min.	Max.	Mean	S.E.[1]
		April-June, 1982			
Composite	5	40	60	56	4.0
XE1	1	55	55	55	
XE2	1	50	50	50	
XW1	1	60	60	60	
XW2	2	45	50	48	
		July-October, 1982			
Composite	8	50	80	63	3.8
NW3	1	60	60	60	
SE2	1	65	65	65	
SW2	1	44	44	44	
XE1	4	33	70	50	9.2
XE2	4	10	35	23	5.3
XW1	6	60	72	63	1.9
XW2	6	5.0	20	13	2.1
		November-December, 1982			
Composite	3	40	55	46	4.6
NE1	2	23	70	47	
NE2	3	15	50	37	11
NE3	2	15	30	23	
NW1	1	24	24	24	
NW2	1	32	32	32	
SE1	1	32	32	32	
SE2	3	62	180	109	36
SE3	1	63	63	63	
SW1	1	18	18	18	
SW2	1	18	18	18	
SW3	1	22	22	22	

Table 15. Chloride contents within the composite, inbed wells, and exbed wells within the 10MP40 filter field. (continued)

Well I.D.	No. of samples	Chloride (mg/l) Min.	Max.	Mean	S.E.[1]
XE1	3	25	35	29	3.1
XE2	1	5	5	5	
XW1	2	43	60	51	
XW2	3	20	27	24	2.1
		January-March, 1983			
Composite	6	30	82	53	7.4
IE1	1	60	60	60	
NE2	1	18	18	18	
NW2	4	25	55	45	4.1
NW3	1	15	15	15	
SE2	3	56	45	65	5.8
SE3	1	37	37	37	
SW1	1	22	22	22	
SW2	1	45	45	45	
SW3	3	35	75	53	12
XE1	3	45	52	48	2.1
XW1	4	35	65	48	7.5
XW2	2	20	33	27	
		April-June, 1983			
Composite	3	16	64	47	15

---

[1] Wells which did not yield samples were omitted.

[2] S. E. = Standard error

distribution system. This filter field was constructed in the Nixa soils and is, therefore, directly comparable to filter fields 01ST76 and 02MG30. The seepage bed was constructed in the upper part of the soils in order to make maximum utilization of higher hydraulic conductivities of the Ap and E horizons.

1. Performance

Discussion of the performance of the filter field 11MP06 is straightforward since there was little or no variability in the performance within the seepage bed. When effluent was first added to the bed (Figure 63), it drained from the bed in less than 30 minutes. Effluent continued to drain from the bed within 30 minutes or less throughout the experiment until it was terminated in September of 1983. At no time during the experiment was effluent ponded within the bed before dosing. The exbed wells (Appendix Table A-10) contained ground water before dosing on numerous occasions, but this water did not influence the inbed performance of the filter field. Depths to water in the exbed wells was mostly greater than 36 cm below the soil surface. On February 1, 1983, when the other three filter fields were under maximum stress, the exbed depth was 36 cm below the soil surface.

In summary, the inbed performance of filter field 11MP06 (Figure 63) did not change with respect to depth of effluent before dosing or 30 minutes after dosing during the experiment. Since the inbed performance did not change throughout the experiment and exbed depth did change (Appendix Table A-10) as a result of changes in climatic conditions (rainfall and ET), it is obvious that inbed performance of

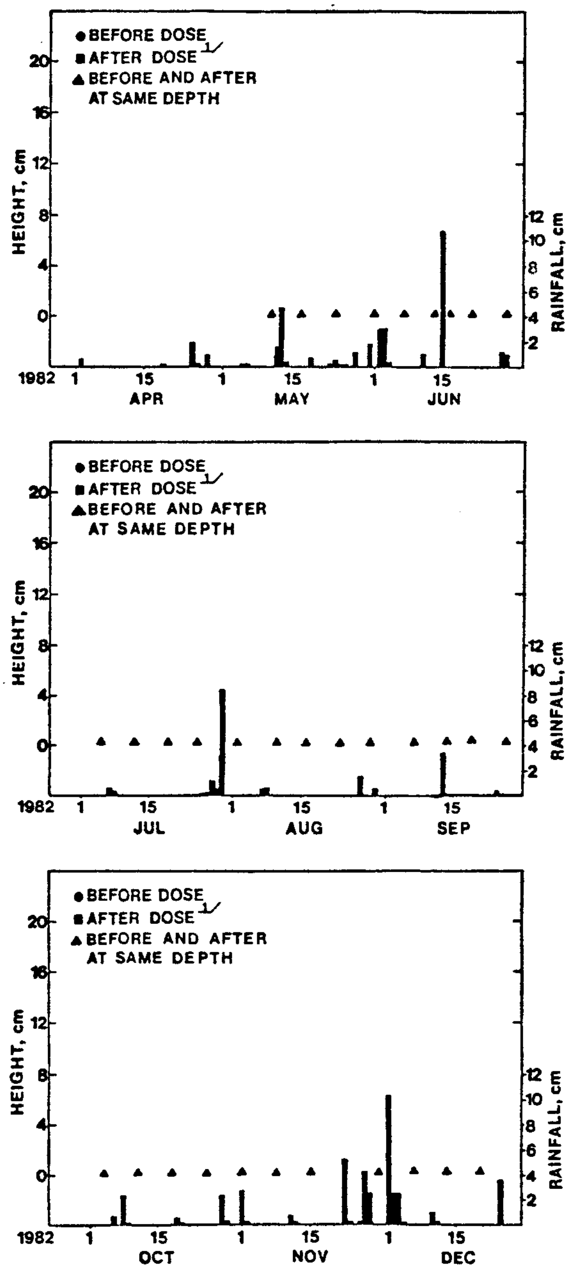

Figure 63. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 11MP06 filter field.

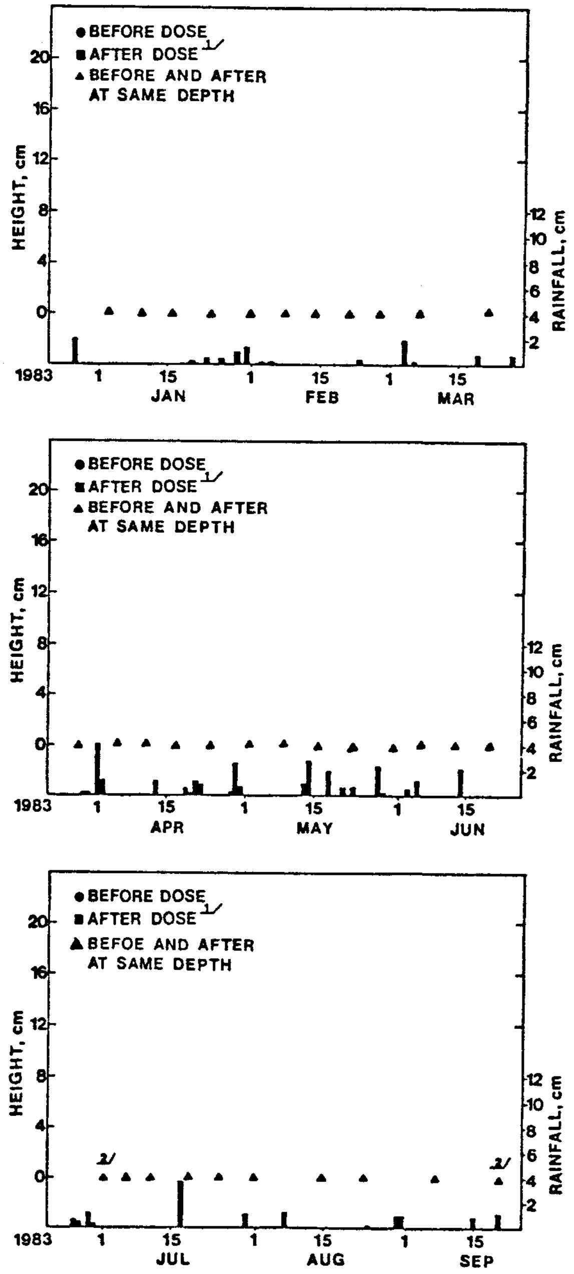

Figure 63. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 11MP06 filter field, continued.

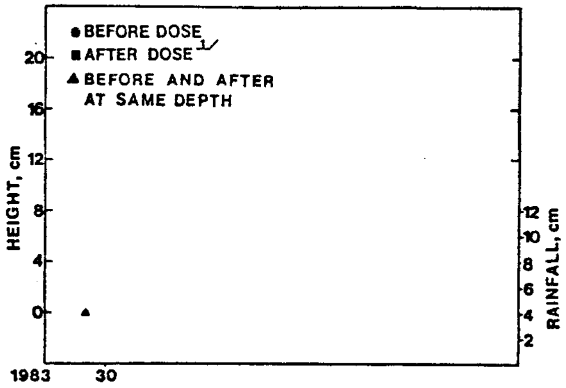

Figure 63. Relations among inbed effluent depths, exbed ground water depths, and rainfall within the 11MP06 filter field, continued.

---

[1] 30 minutes after dosing.

[2] Data influenced by malfunction of the effluent delivery system. Details of effluent delivery are given in Appendix Table A-4.

11MP06 was not detectably influenced by climatic conditions. This filter field was constructed high enough within the soil (interface 6 cm below the surface) that the seepage bed was able to operate without being detectably influenced by climatic conditions.

2. Crusting

Effluent doses were dissipated from the 11MP06 seepage bed 30 minutes after dosing for the duration of the experiment. Therefore, there was no detectable change in rate of effluent dissipation from the bed and, consequently, there was no measured or inferred crust formation during the experiment.

3. Water Quality

Data gathering for this filter field proceeded as usual, through sampling 22 monitoring wells in the seepage bed and the adjacent soil. Table 6 in the Methods and Materials section gives the location of these wells. The analyses of water quality are presented in both tabular and graphical form and are organized according to distance from the seepage bed centerline and depth of soil below the bed.

A. Total Organic Carbon: The total organic carbon data are summarized in Table 16. Neither of the inbed wells, IE1 nor IW1, ever retained sufficient water to provide a sample during the study period. Similarly, wells NE1, NW1, SE1, and SW1, never contained sufficient water for sampling.

Analyses from well XW1 samples (Figure 64) indicate that a 75 percent TOC reduction, from 199 mg/l down to 50 mg/l, was realized upon passage vertically through the seepage bed and through 21 cm

Table 16. Total organic carbon contents within the composite, inbed wells, and exbed wells of the 11MP06 filter field.

Well I.D.	No. of samples	TOC (mg/l) Min.	Max.	Mean	S.D.
Composite	16	68	744	199	154
NE1	0				
NW1	0				
SE1	0				
SW1	0				
IE1	0				
IW1	0				
NE3	1	40	40	40	
NW3	1	33	33	33	
SE3	2	28	38	33	
SW3	1	44	44	44	
NE2	1	31	31	31	
SE2	0				
XE2	4	24	39	31	7.0
XW2	1	98	98	98	
NW2	4	20	44	35	11
SW2	1	32	32	32	
NE4	7	9.0	24	16	5.0
NW4	3	11	28	21	15
SE4	9	11	28	15	6.5
SW4	5	24	44	34	8.7
XE1	0				
XW1	2	48	53	51	

[1] S.D. = Standard deviation

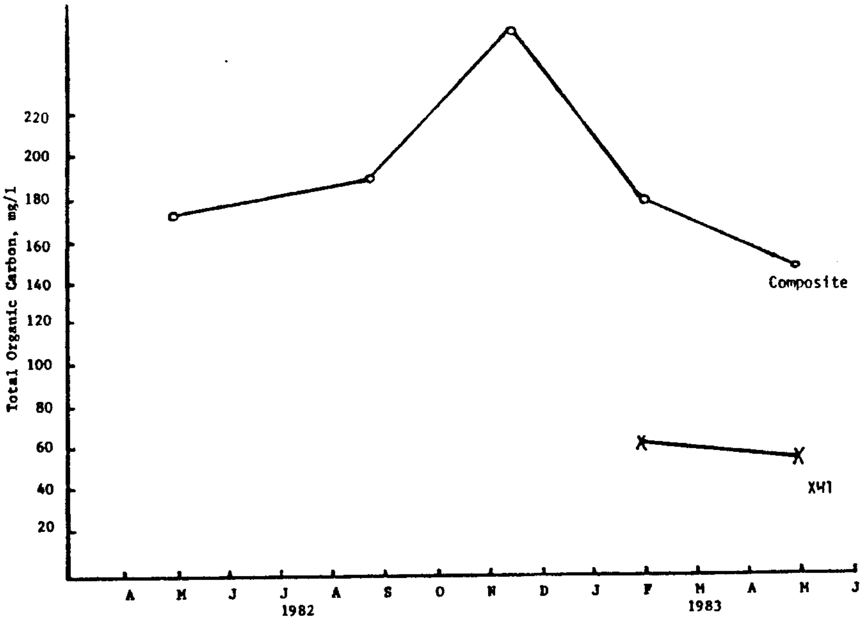

Figure 64. TOC of an exbed well 21 cm vertically from 11MP06 filter field bed.

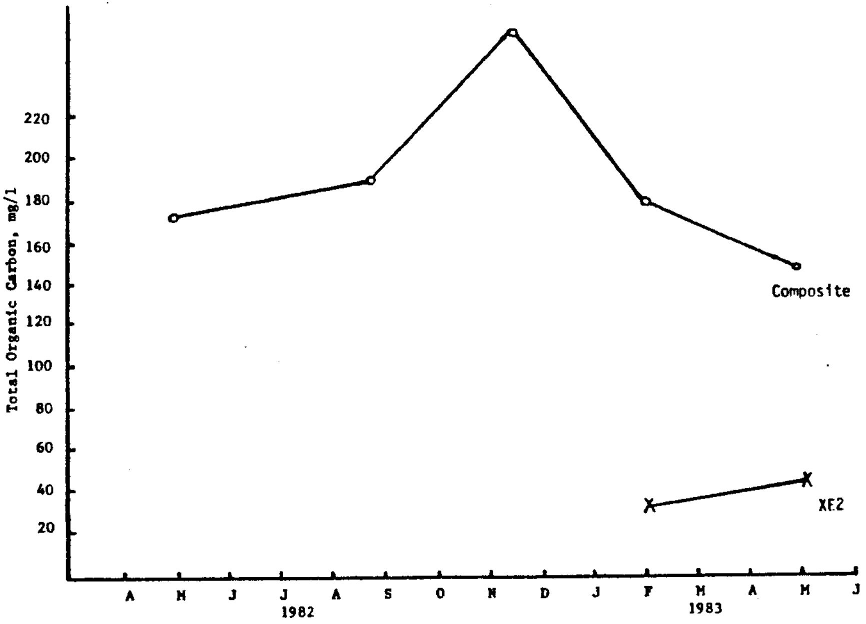

Figure 65. TOC of an exbed well 44 cm vertically from 11MP06 filter field bed.

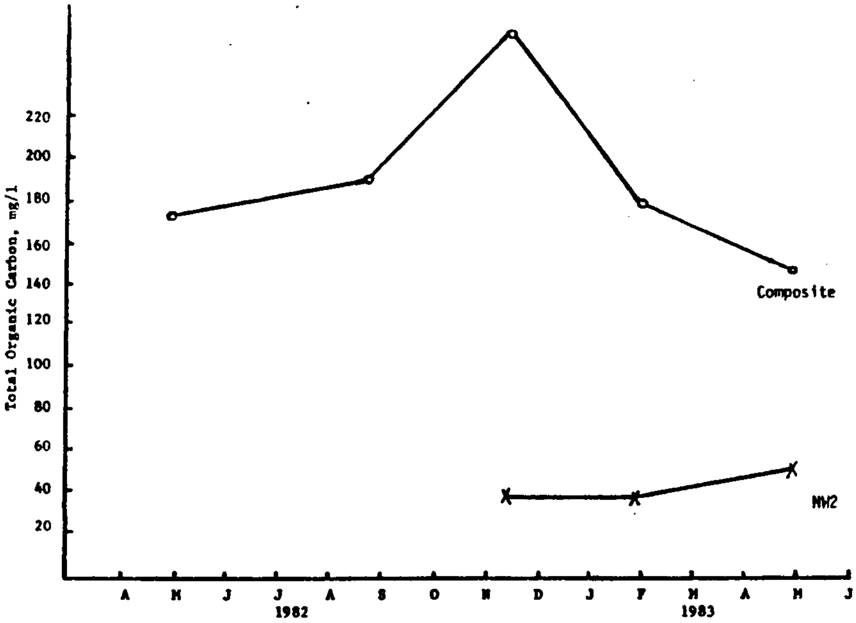

Figure 66. TOC of an exbed well 35 cm horizontally and 54 cm vertically from 11MP06 filter field bed.

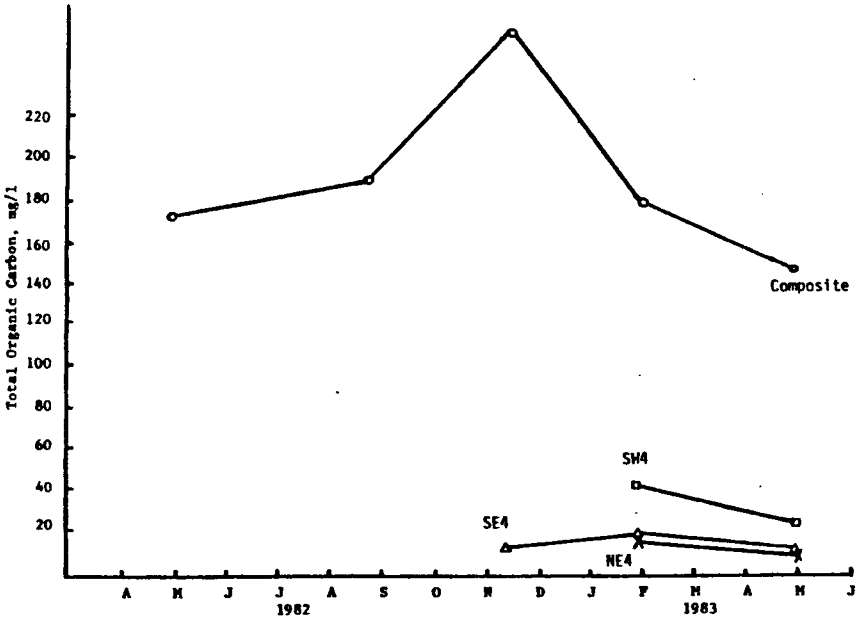

Figure 67. TOC of exbed wells 80 cm horizontally and 54 cm vertically from 11MP06 filter field bed.

of soil. Samples from well XE2, at 44 cm below the bed, had an average TOC concentration of 31 mg/l (Figure 65), indicating improved TOC reduction with passage through more soil in this system; a characteristic not indicated in any of the other three systems studied. This relationship is further indicated in Figure 67 as the TOC of samples from wells NE4, NW4, SE4, and SW4, located 80 cm horizontally and 54 cm vertically from the bottom of the seepage bed had values down to between 34 and 15 mg/l.

In general, the farthest wells from the bed in this pressure system produced samples of equivalent TOC concentrations as the farthest wells in the standard gravity filter field, but the standard system produced a superior water quality after passage through fewer centimeters of soil.

B. Ammonia: The ammonia data from 11MP06 are summarized in Table 17. The composite septic tank effluent mean concentration was 44 mg/l, and as percolation proceeded through the soil, the observed levels dropped to as low as 1 mg/l in the farthest wells.

Nitrogen appears to have occurred in the first 21 cm of soil as the samples from well XW1 had only about 13 to 20 mg/l ammonia (Figure 68). However, this well had water in it only twice during the study so that caution should be used in drawing conclusions from these data.

The ammonia concentrations observed in the farthest wells, NE4, NW4, SW4, and SE4 as shown in Figure 69, indicate much more complete nitrification, and these wells were analyzed three to nine times during the study.

Table 17. Ammonia contents within the composite, inbed wells, and exbed wells of the 11MP06 filter field.

Well I.D.	No. of samples	Ammonia (mg/l-N)			
		Min.	Max.	Mean	S.D.[1]
Composite	16	14	80	44	18
NE1	0				
NW1	0				
SE1	0				
SW1	0				
IE1	0				
IW1	0				
NE3	1	8.0	8.0	8.0	
NW3	1	8.0	8.0	8.0	
SE3	2	8.0	13	11	
SW3	1	12	12	12	
NE2	1	1.2	1.2	1.2	
SE2	0				
XE2	4	0.8	6.0	3.1	2.3
XW2	0				
NW2	4	0.9	8.0	3.5	3.3
SW2	2	1.8	2.0	1.9	
NE4	7	0.6	3.0	1.6	1.0
NW4	3	0.8	4.0	1.9	1.9
SE4	9	0.2	3.0	1.1	0.9
SW4	6	0.1	2.0	1.1	0.8
XE1	0				
XW1	2	13	20	17	

[1] S.D. = Standard deviation

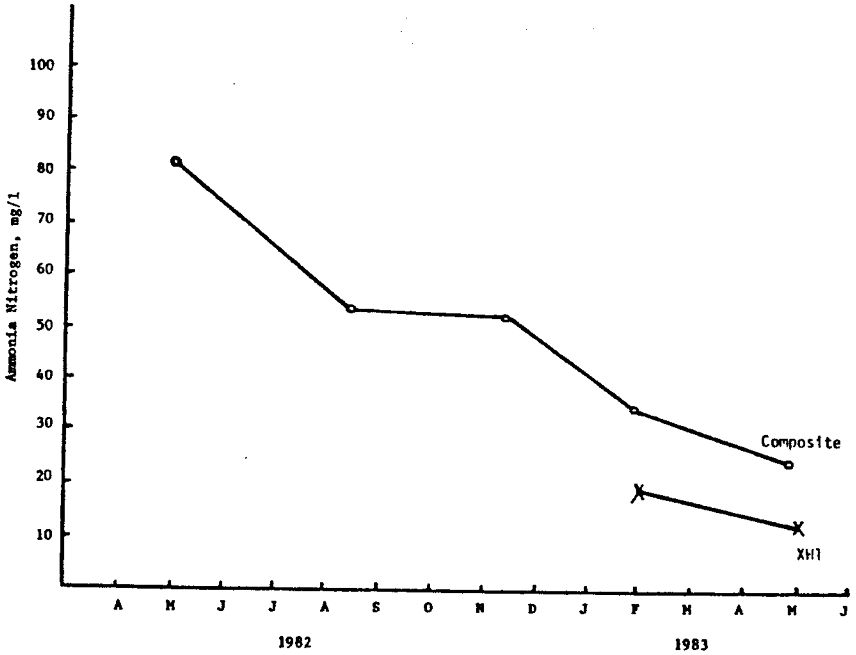

Figure 68. Ammonia in an exbed well 21 cm vertically from 11MP06 filter field bed.

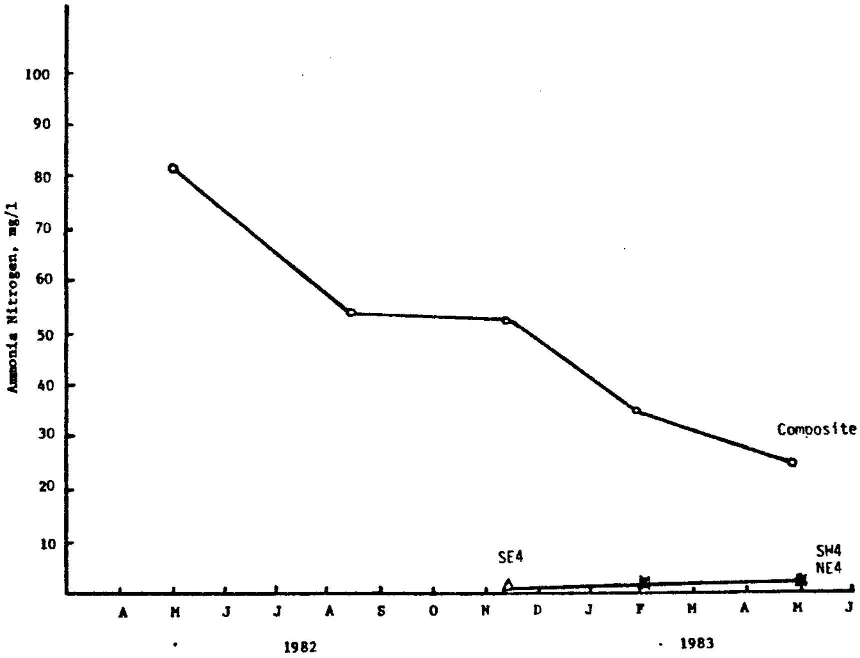

Figure 69. Ammonia in exbed wells 80 cm horizontally and 54 cm vertically from 11MP06 filter field bed.

C. Nitrate: The mean nitrate concentrations are summarized in Table 18 and graphically presented in Figures 70 and 71. The influent had a mean nitrate concentration of 11 mg/l, considerably less than the mean concentrations observed in all the wells but three, SW3, NE2, and SW2; however, these three wells were sampled only once each during the study period and are, therefore, at least suspect for comparisons.

The nitrate cencentrations of the farthest wells, NE4, NW4, SW4, and SE4 were usually considerably higher than the composite (Figure 71). The general trend, indicated by comparing the mean well concentrations with each other, is greater nitrification with increasing depth of soil percolation (Table 18). However, once again a paucity of observations indicates caution in making these generalizations.

Although the evidence of denitrification was not as apparent in 11MP06 as it was in the other leach fields, Table 19 does demonstrate considerable reduction of combined inorganic nitrogen between the composite to the farthest two wells. However, during the Jan-Mar 1983 season well SE4 actually showed an increase in the combined inorganic nitrogen from a composite concentration of 44 to 56 mg/l observed in the well. The last two seasons however show about 60 to 70 percent reduction in these two farthest wells.

Table 18. Nitrate contents within the composite, inbed wells, and exbed wells of the 11MP06 filter field.

Well I.D.	No. of samples	Nitrate (mg/l-N) Min.	Max.	Mean	S.D.[1]
Composite	15	5.0	19	11	4.4
NE1	0				
NW1	0				
SE1	0				
SW1	0				
IE1	0				
IW1	0				
NE3	1	16	16	16	
NW3	1	16	16	16	
SE3	2	20	20	20	
SW3	1	3.0	3.0	3.0	
NE2	1	5.5	5.5	5.5	
SE2	0				
XE2	4	13	20	17	3.1
XW2	1	14	14	14	
NW2	4	5.5	120	42	52
SW2	1	4.5	4.5	4.5	
NE4	7	0.5	60	15	21
NW4	3	14	63	39	25
SE4	9	17	118	43	34
SW4	6	7.8	30	13	8.5
XE1	0				
XW1	2	3.0	30	17	

[1] S.D. = Standard deviation

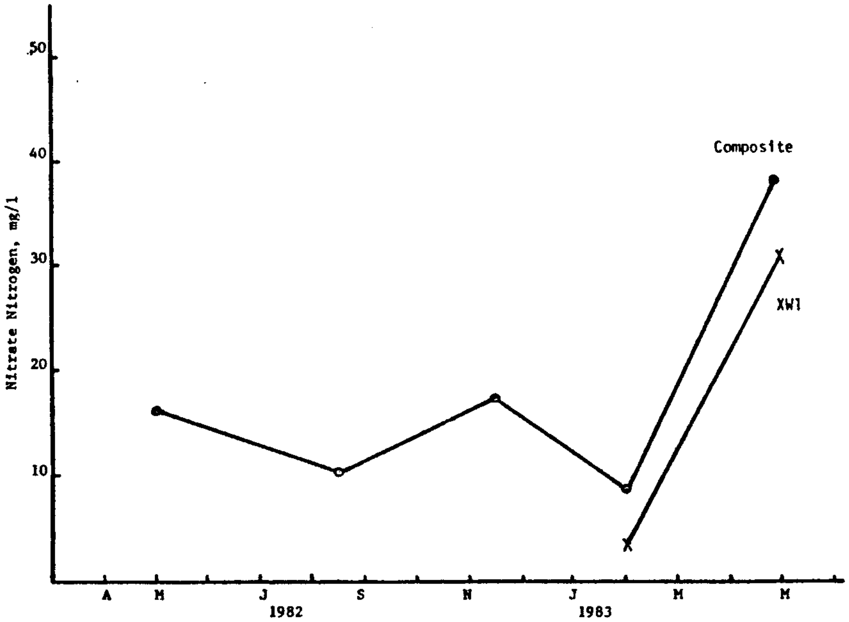

Figure 70. Nitrate in an exbed well 21 cm vertically from 11MP06 filter field bed.

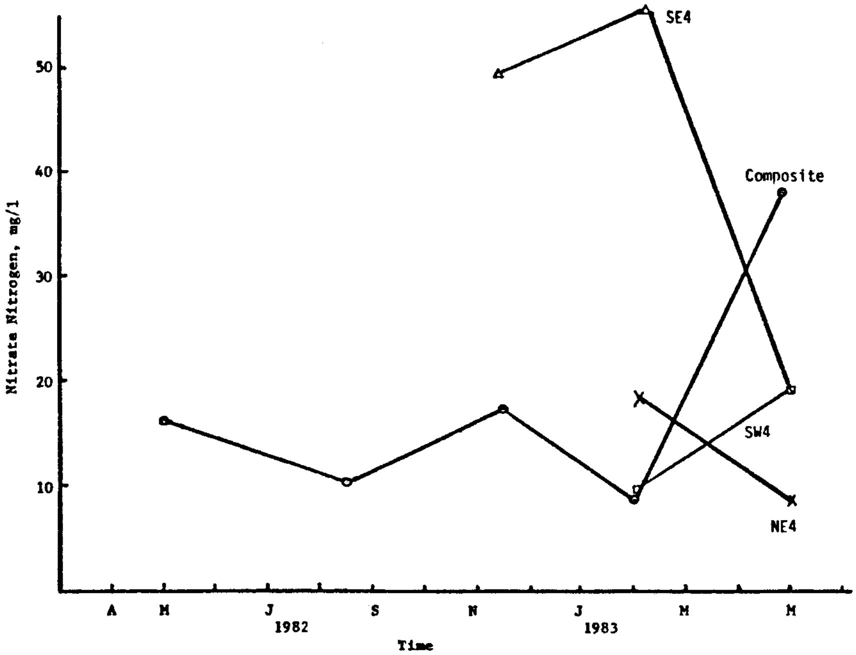

Figure 71. Nitrate in exbed wells 80 cm horizontally and 54 cm vertically from 11MP06 filter field bed.

Table 19. Inorganic nitrogen contents within the composite and exbed wells at greatest distance from the seepage bed of the 11MP06 filter field.

Date	Inorganic nitrogen (mg/l-N)		
	Composite	Exbed wells	
		NW3	SW3
Jul-Oct 82	63		
Nov-Dec 82	56	51	
Jan-Mar 83	44	56	20
Apr-Jun 83	64	22	11

D. Chloride: Table 20 shows that some of the monitoring wells had a higher chloride concentration than the septic tank effluent, again indicating chlorides had been deposited by evaportranspiration to be washed into the wells by later rains.

No inbed samples were available during the year, so no evidence exists in the form of chloride data to confirm or deny dilution of the wastewater in the seepage bed.

Table 20. Chloride contents within the composite, inbed wells and exbed wells within the 11MP06 filter field.

Well[1] I. D.	No. of samples	Chloride (mg/l) Min.	Max.	Mean	S.E.[2]
		April-June, 1982			
Composite	5	40	60	56	4.0
XW2	1	30	30	30	
		July-October, 1982			
Composite	8	50	80	63	3.8
		November-December, 1982			
Composite	3	40	55	46	4.6
NE2	1	40	40	40	
SE-4	2	35	40	38	
		January-March, 1983			
Composite	6	30	82	53	7.4
NE2	1	105	105	105	
NE3	1	15	15	15	
NE4	3	40	53	48	4.1
NW2	2	32	37	35	
NW3	1	22	22	22	
NW4	3	20	37	29	4.9
SE3	1	43	43	43	
SE4	3	45	70	57	7.2
SW3	1	73	73	73	
SW4	4	75	93	83	3.8
XE2	4	30	55	47	8.3
XW1	1	45	45	45	
		April-June, 1983			
Composite	3	16	64	47	15
NE4	3	41	85	70	15

[1] Wells which did not yield samples were omitted.

[2] S. E. = Standard error

V. CONCLUSIONS

This research sought to compare the performance of filter fields placed at various depths in Nixa soils and loaded by two types of effluent distribution, gravity and pressure. The results are complicated because one filter field, 10MP40, was inadvertently placed in a different soil from that used for the other three. Thus, performance of this filter field is not comparable to the performance of the other three. Interpretations are also limited because no filter field designs were replicated and because the two gravity filter fields (01ST76 and 02MG30) operated for more than 5 years and the two pressure fed filter fields (10MP40 and 11MP06) operated for less than 1½ years.

Our conclusions are:

1) Placing the seepage beds in the upper, more permeable portion of the Nixa soil improved the filter field performance.
    a. Maximum rise of effluent in the 3 fiscal years occurred on August 3, 1981, June 16, 1982 and February 1, 1983. On these dates the effluent rose to 0 to 4 cm from the soil surface in the seepage bed in 01ST76 and to 10 to 20 cm from the soil surface in seepage bed 02MG30. Thus, the filter field with the deeper seepage bed (01ST76 surfaced (although no effluent was identified on one date, August, 1981, and consistently rose nearer the surface than did the filter field with the more shallow seepage bed, 02MG30. No effluent was in the bed of 11MP06

before or 30 minutes after dosing on February 1, 1983, the only one of the three dates on which it was in operation. Thus, this filter field also performed better than 01ST76.

   b. The seepage bed of filter field 11MP06 was placed sufficiently high in the soil that its inbed performance, as evaluated by height of inbed effluent before and 30 minutes after dosing, did not change throughout the experiment. Thus, this seepage bed, with the bottom of its bed 6 cm below the original surface, was not measurably influenced by changes in climatic conditions which cause a variable hydraulic load on the soil.

2) We postulate that placing the seepage beds higher in the Nixa soil improved their performance because:
   a. The horizontal interface was in horizons of higher hydraulic conductivity, and hence, the effluent drained from the bed more rapidly, thus allowing more time for crust aeration.
   b. Seepage beds placed high in the soil are less influenced by seasonal water tables and are better aerated.
   c. Gaseous exchange is less efficient with depth in the soil. Thus, seepage beds nearer the surface are better aerated.

3) Because of the short period of operation of the pressure dosed filter fields, 10MP40 and 11MP06, and because filter field 10MP40 is not comparable to 02MG30 due to soil differ-

ences, we cannot reach conclusions regarding differences in performance of filter fields fed by pressure dosing and those fed by gravity distribution.

4) We have evaluated rates of water movement from the seepage bed and inferred that a crust had formed on some seepage bed interfaces and not on others. However, where crusts formed their rates of formation were relatively slow--so slow that the interpretation of their formation is tenuous.

5) We infer that the dominant factor controlling the day to day performance of the four filter fields was the variability of the hydraulic load caused by rainfall and ET--the climatic load. The filter field must transmit two hydraulic loads: the effluent load and the climatic load. The effluent load was essentially constant, and thus, it was the variable climatic load which caused fluctuations in the inbed depths of water. We strongly recognize the need to quantitatively relate filter field performance to climatic loads. Since crusting is not directly measurable, it is normally inferred from changes in seepage bed drainage rates and these rates are strongly influenced by the climatic load. Thus, better crust evaluation requires quantitative evaluation of climatic loads and filter field performance.

6) Our results indicate that the saturated hydraulic conductivity (Ksat) rates, not the stone or rock contents of the various soil horizons, are important in predicting filter

field performance. Soil horizons with low Ksats tended to pond water and those with high Ksats tended to transmit it. In some soils high Ksats may be related to high stone contents. However, this relationship is not universal; the low Ksats and high stone contents of the Nixa fragipan horizons are examples of exceptions.

7) The evaluation with respect to surfacing of effluent of the performance of filter fields within the Nixa soils is dependent upon society's goals. As discussed previously (Rutledge et al., 1983), the presently inferred goal of never surfacing seems excessive, and we have suggested that brief surfacing for 1 in 10 years may be acceptable. Designs outlined below are expected to meet the 1 in 10 year surfacing criterion.

8) Our results indicate that seepage beds in the upper soil horizons (Ap, E, and Bt1) which have higher saturated hydraulic conductivities and better aeration, are superior to those placed in the lower fragipan horizons which have considerably lower saturated hydraulic conductivities. Thus, we recommend placing the bottom of the seepage bed at or above 30 cm within the soil and 30 cm or more above the top of the fragipan within the Nixa soils. Because of the differences in length of operation of 02MG30 and 11MP06, we cannot say that a maximum seepage bed depth of 6 cm is superior to beds up to 30 cm deep or that pressure distribution is superior to gravity distribution. However, no

disadvantages were noted in placing the bottom of the seepage bed at 6 cm or with the use of pressure distribution. Since the results indicate that shallow beds are superior and since pressure distribution may retard crust formation, it seems prudent to use pressure distribution and construct the seepage bed 6 cm into the natural soil and more than 30 cm above the top of the fragipan.

9) Our results indicate that a reduction in TOC of about 50% occurred within the beds in 01ST76 and 02MG30. Further reductions occurred as the wastewater passed through the soil near the seepage beds. Total reductions amounted to 70% to 80% within a distance of about 60 cm.

10) Since inbed samples were seldom obtainable in 10MP40 and 11MP06, no conclusions can be drawn about reductions of TOC within the beds. Reductions in TOC did occur, however, in the soil next to the beds. Overall reductions amounted to about 70% to 80%.

11) Measurements of ammonia concentrations showed that only small reductions (10% to 15%) occurred in the seepage beds of 01ST76 and 02MG30. Again, it was not possible to observe such reductions in the beds of 10MP40 and 11MP06. In all four systems, reductions in ammonia concentrations occurred as the wastewater passed through the soil until the overall reductions were on the order of 80% to 90%.

12) Nitrate concentrations varied in a way that was consistent

with the simultaneous occurrence of both nitrification and denitrification reactions. The sum of the concentrations of ammonia and nitrate was observed to decrease with distance from the beds in every case. Overall reductions were about 87% in 01ST76, from 50% to 70% in 02MG30, from 67% to 88% in 10MP40, and from 50% to 75% in 11MP06. Although the amount of nitrogen contained within the filter field was not determined, it is assumed that the nitrogen losses were really due to the consistency of the data and the duration (more than 5 years) of operation of two of the filter fields.

VI. REFERENCES

1. Allison, L. E. 1947. Effect of microorganisms on permeability of soil under prolonged submergence. Soil Sci. 63:439-450.
2. Arkansas Department of Health. 1977. Rules and regulations pertaining to sewage disposal systems and installers. Division of Sanitarian Services, Arkansas Department of Health Little Rock, Arkansas.
3. Bouma, J., F. G. Baker, and P. L. M. Veneman. 1974. Measurement of water movement in soil pedons above the water table. Univ. of Wis. Ext. Geological and Natural History Survey.
4. Bouma, J., C. Belmans, L. W. Dekker, and W. H. M. Jeurissen. 1983. Assessing the suitability of soils with macropores for subsurface liquid waste disposal. J. Environ. Qual. 12:305-311.
5. Cooper, I. A. and J. W. Rezek. 1977. Septage treatment and disposal: In: Alternative for Small Scale Wastewater Treatment Systems. EPA-625/4-77-011. Environ. Prot. Agency Tech. Trans., Cincinatti, OH. pp.61-90.
6. Croneis, Carey. 1930. Geology of the Arkansas paleozoic area with special reference to oil and gas possibilities. Arkansas Geological Survey Bulletin No. 3. Little Rock, Arkansas.
7. Environmental Protection Agency. 1980. Design Manual for Onsite Wastewater Treatment and Disposal Systems. USEPA, Washington, D. C. 391 p.
8. Frezon, S. E., and E. E. Glick. 1959. Pre-atoka rocks of northern Arkansas. U.S. Geological Survey Prof. Paper 314-H.

9. Hagedorn, C., E. L. McCoy, and T. M. Rahe. 1982. The potential for ground water contamination from septic effluents. J. Environ. Qual. 10:1-8.

10. Harper, M. D., W. W. Phillips, and G. J. Haley. 1969. Soil Survey of Washington County, Arkansas. USDA Soil Conservation Service and Forest Service and Arkansas Agricultural Experiment Station, U. S. Govt. Printing Office, Washington, D. C. 20402.

11. Jones, J. H. and G. S. Taylor. 1965. Septic tank effluent percolation through sands under laboratory conditions. Soil Sci. 99:301-309.

12. Kropf, F. W., K. A. Healey, and R. Laak. 1975. Soil clogging in subsurface absorption systems for liquid domestic wastes. Progress in Water Technology. 7:767-774.

13. Laak, R. J. 1970. Influence of domestic wastewater pretreatment on soil clogging. Water Pollution and Control Federation. 8:1495.

14. McCalla, T. M. 1950. Studies on the effect of microorganisms on rate of percolation of water through soils. Soil Sci. Soc. Am. Proc. 15:182-186.

15. MacDonald, H. C., H. M. Jeffus, K. F. Steele, T. L. Coughlin, K. M. Kerr, and G. H. Wagner. 1975. Pollution susceptibility mapping for rural development and land use planning in carbonate terrain-Northwest Arkansas. Report obtained from Dep. of Agric. Econ. and Rural Soc., Ark. Agric. Exp. Stn., University of Arkansas, Fayetteville.

16. National Cooperative Soil Survey. 1977. Nixa Series, Rev LAQ, WER 1-79. USDA Soil Conservation Service, Fort Worth, Texas.

17. NOAA. 1980-1983. Climatological data, U. S. Department of Commerce, Washington, D. C.

18. Pettyjohn, W. 1983. Hydrologic considerations in waste disposal. In Microbial Health Considerations of Soil Disposal of Domestic Wastewater. USEPA, Norman, OK. pp.87-100.

19. Pound, C. E., and R. W. Crites. 1973. Wastewater Treatment and Revisement by Land Application. Vol I. USEPA, Cincinnati, OH.

20. Ransom, M. D. 1976. Three soil mapping units of Northwest Arkansas: Taxonomic composition and suitability for septic tank filter fields. M. S. Thesis, Univ. of Arkansas, Fayetteville.

21. Reneau, R. B., D. E. Pettry, M. I. Shanholtz, S. A. Graham, and C. W. Weston. 1977. Distribution of total and fecal coliform organisms from septic effluent in selected coastal plain soils. Public Health Reports. 92:251-259.

22. Rutledge, E. M., C. R. Mote, M. S. Hirsch, H. D. Scott, and D. T. Mitchell. 1983. Disposal of household wastewater in soils of high stone content (1977-1980). Publication 99. Arkansas Water Resources Research Center.

23. Sawhney, B. L. and J. L. Starr. 1977. Movement of phosphorus from a septic system drainfield. J. Water Poll. Cont. Fed. 49:2238-2242.
24. Simpson, T. W. and R. L. Cunningham. 1982. The occurrence of flow channels in soils. J. Environ. Qual. 11:29-30.
25. Soil Survey Staff. 1972. Soil survey laboratory methods and procedures for collecting soil samples. Soil Survey Investigations Report No. 1, USDA, SCS, U. S. Government Printing Office, Washington, D. C.
26. Stafford, P. S. 1979. An evaluation of a Nixa soil for septic tank filter fields. M. S. Thesis. University of Arkansas, Fayetteville.
27. Starr, J. L. and B. L. Sawhney. 1980. Movement of nitrogen and carbon from a septic system drainfield. Water, Air and Soil Pollution. 13:113-123.
28. Tare, V. and S. D. Bokel. 1982. Wastewater treatment by soils: role of particle-size distribution. J. Environ. Qual. 11:596-602.
29. Thomas, G. W. and R. E. Phillips. 1979. Consequences of water movement in macropores. J. Environ. Qual. 8:149-152.
30. Thornbury, W. D. 1965. Regional geomorphology of the United States. John Wiley and Sons, Inc., NY.
31. Winneberger, J. H., L. Francis, S. A. Klein and P. H. McGauhey. 1960. Biological aspects of failure of septic tank percolation systems. Final Report Sanitary Engineering Research Laboratory, University of California, Berkeley, CA.
32. Viraraghavan, T. 1978. Travel of microorganisms from a septic tile. Water, Air and Soil Pollution. 9:355-362.

VII. APPENDIX TABLES

Table A-1. Detailed pedon description of Nixa soil of filter field 01ST76 and 02MG30.

Location: University of Arkansas Agricultural Experiment Station: Beef Farm near Savoy. SE ¼, SW ¼, SW ¼, Section 20, T17N, R31W; 81 meters south of Sligar house, on the crest of a Nixa ridge about 80 meters wide (Washington County, Arkansas).

Physiography and elevation: Springfield plateau; 0.5-1.0 meters below maximum elevation of the area.

Parent material: Cherty limestone residuum

Slope: 1 to 3 percent

Soil drainage: Moderately well drained

Vegetation: Native grasses; sometimes used for garden.

Described and sampled by: P. S. Stafford and E. M. Rutledge, June 2, 1977.

Classification: Typic Fragiudult; loamy-skeletal, siliceous, mesic.

Pedon description:

Ap	0-13 cm	Yellowish brown (10YR 5/4) cherty silt loam; common coarse and medium dark brown (10YR 4/3) mottles; weak medium and fine subangular blocky structure; friable; many very fine, many fine and many medium imped pores; many very fine, many fine and many medium roots; 30-40% by volume coarse fragments ranging from 2 mm-12 cm in diameter but dominantly 2 mm-3 cm; abrupt smooth boundary. Sample No. 8555
E	13-31 cm	Yellowish brown (10YR5/4) cherty silt loam; weak medium subangular blocky structure; friable; few root channels filled with dark brown (10YR 4/3) material from Ap; many very

Table A-1. Detailed pedon description of Nixa soil of filter field 01ST76 and 02MG30. (continued)

		fine, many fine and many medium imped pores with many medium vesicular pores; many very fine and common fine roots; 35-40% by volume coarse fragments ranging from 2 mm-4 cm in diameter but dominantly 2 mm-2 cm; clear smooth boundary. Sample No. 8556
Bt1	31-44 cm	Strong brown (7.5YR 5/6) cherty heavy silt loam; common medium brownish yellow (10YR 6/6) mottles; weak to moderate medium subangular blocky structure; firm; occasional thin strong brown (7.5YR 5/6) clay film; few thin (.5 mm) white (10YR 8/2) dry silty skeletans that disappear upon wetting; many very fine, many fine and many medium imped pores; common very fine and few fine roots; 35-40% by volume coarse fragments ranging from 2 mm-6 cm in diameter but dominantly 2 mm-3 cm; clear smooth boundary. Sample No. 8557
Bt2	44-59 cm	Strong brown (7.5YR 5/6) light cherty silty clay loam; common medium yellowish red (5YR 4/6), few medium brownish yellow (10YR 6/6), few fine light gray (10YR 7/2) mottles; moderate medium and fine angular blocky structure; thin patchy clay film; common very fine, com-mon fine and few medium imped pores; common very fine roots; common fine and few medium black (10YR 2.5/1) charcoal root remnants; 30-35% by volume coarse fragments 2 mm-6 cm in diameter but dominantly 2 mm-2 cm; abrupt smooth boundary. Sample No. 8558
Btx1	59-76 cm	Yellowish red (5YR 4/6) cherty light silty clay loam; common medium yellowish brown (10YR 5/4) mottles; moderate fine angular blocky structure; firm and brittle in 85% of matrix; non-brittle portion consists of seams of light

Table A-1. Detailed pedon description of Nixa soil of filter field 01ST76 and 02MG30. (continued)

		brownish gray (10YR 6/2) silty clay loam forming a polygonal pattern; horizontal seams are about 5 mm wide and 2-10 cm apart, vertical seams are about 1 cm wide and spaced on an average of 20 cm apart but range from 5-50 cm apart; roots are excluded from red matrix and occur exclusively in gray seams; upper boundary of fragipan defined by gray seam throughout the pedon; thin patchy red (2.5YR 4/6) and light brownish gray (10YR 6/2) clay films; no skeletans observed; common very fine pores; few very fine roots in gray seams only; 40-50% by volume coarse fragments ranging from 2 mm-6 cm in diameter with occasional 20 cm fragment; clear smooth boundary. Sample No. 8559
Btx2	76-91 cm	Red (2.5YR 4/6) cherty silty clay loam; few fine light brownish gray (10YR 6/2) mottles; moderate fine angular blocky structure; very firm and brittle; thin discontinuous yellowish red (5YR 4/6) and thin patchy dark red (2.5YR 3/6) clay films with occasional light brownish gray (10Yr 6/2) clay film lining very fine pores and medium vesicular pores; light brownish gray (10YR 6/2) silty clay loam seams forming polygonal pattern; horizontal seams average 5 mm wide and are spaced on the average about 8 cm apart, vertical seams average 1 cm wide and are spaced on an average of 20 cm apart but range from 5-75 cm apart; strong brown coating 2 mm-1 cm thick on interface between red matrix and 20-40% of gray vertical seams; common very fine pores with occasional medium vesicular pore; few very fine roots limited to gray seams; 40-50% by volume coarse fragments that are 2 mm-6 cm in diameter; clear smooth boundary that is abrupt where terminated by gray horizontal seam. Sample No. 8560

Table A-1. Detailed pedon description of Nixa soil of filter field 01ST76 and 02MG30. (continued)

B'tl	91-93 cm	Dark red (2.5YR 3/6) silty clay; common coarse red (2.5YR 4/6) and few medium strong brown (7.5YR 5/8) mottles; moderate fine and medium angular blocky structure; firm; medium discontinuous dark red (10YR 3/6) clay films on ped faces and medium patchy gray (10YR 5/1) clay films in gray seams; gray seams of light brownish gray (10YR 6/2) light clay averaging 1 cm in width and form a polygonal pattern but pattern is less defined on horizontal and vertical planes than upper horizons; gray material occupies 25-30% by volume of horizon; common very fine pores; one root observed; 30-40% coarse fragments by volume ranging from 2 mm-10 cm in diameter; gradual, smooth boundary. 91-116 cm Sample No. 8561 116-142 cm Sample No. 8562 142-168 cm Sample No. 8563 168-193 cm Sample No. 8564
B't2	193-218+ cm	Dark red (2.5YR 3/6) light silty clay loam; other morphological features are as described for the B'tl above; boundary not observed. Sample No. 8565

Notes: This field was apparently plowed for the first time this year. Therefore, the color differences observed in Ap were due to mixing of the A and E horizons. In addition, larger coarse fragments had been removed from the surface. Some areas of the Btl horizon lacked clay films and the roots in the Bt2 appeared to terminate at the upper boundary of the pan with some evidence of root matting at this interface. Roots did penetrate gray areas, however, in the fragipan.

Textures have been changed, as needed, to agree with laboratory determinations. The B'tl horizon contains textures of silty clay, and clay loam.

Table A-1. Detailed pedon description of Nixa soil of filter field 01ST76 and 02MG30. (continued)

This soil is a taxadunct to the Nixa series. It is outside the range on the following properties: (1) the presence of an argillic horizon above the fragipan (2) the depth to unconsolidated bedded chert is greater than 218 cm (less than 120 cm is required). (3) the B't chert content (estimated) is lower than allowed. Chert contents (estimated) of other horizons are in the lower part of the range (4) the Btx horizons have redder hues than allowed.

Pedon No. 77WS02

Table A-2. Particle size and chemical data for Nixa soil of filter fields 01ST76 and 02MG30.

		Fine Earth Particle Size Distribution (%)										
		Sand (mm)						Silt (m)				Clay
Horizon	Depth cm	VCS 2-1	CS 1-0.5	MS 0.5-0.25	FS 0.25 -0.1	VFS 0.1 0.05	TS 2-0.05	CSI 50-20	MSI 20 -5	FSI 5-2	TSI 50 -2	TC <2 UM
Ap	0-13	5.8	3.4	1.3	2.4	1.9	14.8	36.6	30.1	11.0	77.7	7.5
E	13-31	5.2	2.5	1.2	2.2	1.8	12.9	29.0	34.1	11.9	75.0	12.1
Bt1	31-44	3.9	2.1	0.7	1.6	1.5	9.8	26.7	28.0	12.1	66.8	23.4
Bt2	44-59	3.2	2.2	0.7	1.7	1.5	9.3	27.5	25.1	10.1	62.7	28.0
Btx1	59-76	4.7	3.1	1.1	1.9	2.0	12.8	30.3	25.6	7.4	63.3	23.9
Btx2	76-91	4.8	2.9	1.2	2.9	2.6	14.4	29.3	21.4	8.3	59.0	26.6
B't1	91-116	2.9	1.7	0.7	2.0	2.2	9.5	25.5	15.9	7.0	48.4	42.1
B't1	116-142	1.6	1.5	0.8	2.7	3.1	9.7	20.6	16.2	6.5	43.3	47.0
B't1	142-168	2.1	2.0	1.5	3.8	4.0	13.4	18.7	14.7	6.3	39.7	46.9
B't1	168-193	2.1	3.1	2.5	6.5	6.5	20.7	18.3	23.8	5.9	41.3	38.0
B't2	193-218	4.3	3.2	1.9	4.9	5.4	19.7	26.8	18.1	7.7	52.6	27.7

Table A-2. Particle size and chemical data for Nixa soil of filter fields 01ST76 and 02MG30. (continued)

Horizon	Depth	pH	Tot. Car- bon	Extractable Bases				Ext. Acid- ity	Sum Base	Sum Cat- ions	Base Sat
				K	Ca	Mg	Na				
	cm		%	----------------meq/100 g Soil						----------------	%
Ap	0-13	5.1	1.97	0.4	3.5	0.8	0.1	11.7	4.8	16.5	29
E	13-31	5.1	0.59	0.3	2.0	0.6	0.0	7.7	2.9	10.6	27
Bt1	31-44	4.6	0.33	0.4	2.0	1.2	0.1	12.8	3.7	16.5	22
Bt2	44-59	4.4	0.32	0.5	1.9	1.2	0.0	15.1	3.6	18.7	19
Btx1	59-76	4.4	0.16	0.4	0.8	0.6	0.0	12.3	1.8	14.1	13
Btx2	76-91	4.4	0.11	0.3	0.4	0.5	0.1	14.0	1.3	15.3	9
B't1	91-116	4.1	0.12	0.3	0.3	0.6	0.0	18.3	1.2	19.5	6
B't1	116-142	4.1	0.16	0.2	0.3	0.7	0.0	21.1	1.2	22.3	5
B't1	142-168	3.8	0.17	0.2	0.3	0.7	0.0	22.3	1.2	23.5	5
B't1	168-193	3.7	0.13	0.1	0.3	1.1	0.1	21.5	1.6	23.1	7
B't2	193-218	3.9	0.12	0.1	0.5	0.7	0.2	15.6	1.5	17.1	9

Table A-3. Effluent loading rates for seepage beds 01ST76 and 02MG30[1]

Time period	01ST76 cm/day	02MG30 cm/day
1980		
30SEP-06OCT	1.41	1.39
07OCT-13OCT	1.37	1.44
14OCT-20OCT	1.40	1.48
21OCT-27OCT	1.41	1.55
28OCT-03NOV	1.24	1.37
04NOV-10NOV	1.04	1.11
11NOV-17NOV	1.43	1.39
18NOV-24NOV	1.85	1.69
25NOV-01DEC	1.92	1.74
02DEC-08DEC	1.96	1.76
09DEC-15DEC	2.05	1.69
16DEC-19DEC	2.11	1.76
Effluent delivery system down, no effluent delivered until 29 Jan 1981		
1981		
29JAN-30JAN	3.79	2.47
31JAN-02FEB	3.58	3.67
03FEB-04FEB	2.04	2.12
05FEB-09FEB	1.63	2.10
10FEB-16FEB	1.34	2.10
17FEB-23FEB	1.06	1.79
24FEB-02MAR	1.05	1.80
03MAR-09MAR	0.94	1.87
10MAR-16MAR	0.94	1.80
17MAR-23MAR	1.65	1.83
24MAR-30MAR	1.71	1.64
31MAR-06APR	1.27	1.36
07APR-13APR	1.81	2.50
14APR-20APR	1.61	2.47
20APR-27APR	1.50	1.35
28APR-04MAY	1.68	1.71
05MAY-11MAY	1.59	1.62
12MAY-18MAY	1.56	1.57
19MAY-25MAY	1.63	1.66
26MAY-01JUN	1.62	1.62
02JUN-08JUN	1.80	1.77
09JUN-15JUN	1.84	1.74
16JUN-22JUN	1.68	1.72
23JUN-06JUL	1.88	1.81
30JUN-06JUL	1.88	1.81
07JUL-13JUL	1.76	1.70
14JUL-20JUL	1.71	1.66
21JUL-27JUL	1.59	1.90
28JUL-03AUG	1.56	2.17
04AUG-10AUG	1.63	2.05
11AUG-17AUG	1.37	1.73
18AUG-24AUG	1.48	1.52
25AUG-31AUG	1.61	1.49
01SEP-08SEP	1.62	1.52
09SEP-14SEP	1.54	1.48
15SEP-21SEP	1.48	1.50
22SEP-28SEP	1.52	1.58
29SEP-05OCT	1.48	1.50
06OCT-12OCT	1.47	1.44
13OCT-19OCT	1.50	1.53
20OCT-26OCT	1.53	1.50
27OCT-03NOV	1.56	1.55
04NOV-09NOV	1.55	1.53
10NOV-16NOV	1.50	1.48
17NOV-23NOV	1.55	1.51
24NOV-30NOV	1.56	1.50
01DEC-07DEC	1.58	1.51
08DEC-14DEC	1.50	1.46
1982		
15DEC-04JAN	1.50	1.49
05JAN-08JAN	1.55	1.55
09JAN-15JAN[2]		0.51
16JAN-18JAN		0.34
19JAN-22JAN		1.37
23JAN-25JAN		1.86

Table A-3. Effluent loading rates for seepage beds 01ST76 and 02MG30[1] (continued)

Time period	01ST76	02MG30
26JAN-29JAN		1.86
30JAN-01FEB		1.81
02FEB-05FEB		1.60
06FEB-08FEB		1.49
09FEB-12FEB		1.51
13FEB-15FEB		1.50
1982		
16FEB-22FEB		1.60
23FEB-01MAR		1.56
02MAR-08MAR		1.50
09MAR-15MAR		1.50
16MAR-22MAR		1.57
23MAR-29MAR		1.48
30MAR-05APR		1.53
06APR-12APR		1.45
13APR-19APR		1.51
20APR-23APR	[3]	1.17
24APR-26APR	1.69	1.44
27APR-30APR	1.86	1.52
01MAY-03MAY	1.88	1.72
04MAY-07MAY	1.86	1.64
08MAY-10MAY	1.66	1.48
11MAY-17MAY	1.61	1.56
18MAY-24MAY	1.69	1.80
25MAY-01JUN	1.56	1.64
02JUN-07JUN	1.61	1.52
08JUN-11JUN	1.72	1.63
Effluent delivery system down, no effluent delivered until 14 Jun (started at same time as the 14 Jun monitoring)		
14JUN-21JUN	1.56	1.48
22JUN-28JUN	1.47	1.48
No effluent delivered for 3 hours on 23 Jun		
29JUN-05JUL	1.41	1.50
06JUL-12JUL	1.68	1.78
13JUL-19JUL	1.64	1.76
20JUL-26JUL	1.66	1.74
27JUL-02AUG	1.49	1.53
03AUG-09AUG	1.37	1.41
10AUG-16AUG	1.44	1.50
17AUG-23AUG	1.43	1.56
24AUG-30AUG	1.49	1.53
31AUG-07SEP	1.76	1.48
08SEP-14SEP	1.36[4]	1.28[4]
15SEP-20SEP	1.88[4]	1.75[4]
21SEP-27SEP	1.50	1.44
28SEP-04OCT	1.55	1.61
05OCT-11OCT	1.48	1.59
12OCT-18OCT	1.22	1.34
19OCT-25OCT	1.38	1.42
26OCT-01NOV	1.50	1.52
02NOV-08NOV	1.37	1.44
09NOV-15NOV	1.38	1.47
16NOV-29NOV	1.17	1.43
30NOV-06DEC	0.69	1.40
07DEC-13DEC	0.78	1.57
14DEC-23DEC	1.71	2.28
1983		
24DEC-03JAN	1.54	1.41
04JAN-10JAN	1.32	1.25
11JAN-17JAN	1.31	1.33
18JAN-24JAN	1.37	1.44
25JAN-01FEB	1.49	1.53
02FEB-07FEB	1.49	1.48
08FEB-14FEB	1.51	1.51
15FEB-21FEB	1.47	1.49
22FEB-28FEB	1.48	1.48
No effluent delivered for 3 hours on 22 Feb		
01MAR-07MAR	1.48	1.50
08MAR-14MAR	1.51	1.50
15MAR-21MAR	1.57	1.58

Table A-3. Effluent loading rates for seepage beds 01ST76 and 02MG30[1] (continued)

Time period	01ST76	02MG30
22MAR-28MAR	1.72	1.61
29MAR-04APR	1.38	1.48
05APR-11APR	1.44	1.44
12APR-18APR	1.58	1.59
19APR-25APR	1.48	1.48
26APR-02MAY	1.53	1.55
03MAY-09MAY	1.54	1.55
10MAY-16MAY	1.51	1.56
17MAY-23MAY	1.40	[5]
24MAY-31MAY	1.37	1.47
01JUN-06JUN	1.50	1.54
07JUN-13JUN	1.57	1.59
14JUN-20JUN	1.78	1.76
21JUN-24JUN	1.94	1.96
Effluent delivery system down, no effluent delivered until 27 Jun		
27JUN-01JUL	1.78	1.72
02JUL-06JUL	1.80	1.77
07JUL-11JUL	1.83	1.78
12JUL-18JUL	1.79	1.87
19JUL-25JUL	1.37	1.90
26JUL-01AUG	1.18	1.69
02AUG-08AUG	1.49	1.62
09AUG-15AUG	1.62	1.62
16AUG-23AUG	1.57	1.57
24AUG-30AUG	1.28[6]	1.43[6]
Effluent delivery down, no effluent delivered until 30 Aug		
31AUG-07SEP	1.45	1.46
08SEP-12SEP	1.13[6]	1.00[6]
Effluent delivery system down, no effluent delivered until 19 Sep		
19SEP-26SEP	1.50	1.50[7]

---

[1] No effluent was delivered to the seepage beds on several occasions due to equipment malfunctions or the need to adjust equipment. When the time interval was eight hours or less, the time was not included in calculating loading rates.

[2] Effluent delivery pipe to 01ST76 was damaged. It appears that the damage occurred between January 8 and January 15, but was not discovered until much later. There is no way to know how much effluent reached 01ST76 while the pipe was damaged.

[3] Effluent delivery pipe to the 01ST76 was repaired.

[4] Judging from all available data, it appears that a date was recorded incorrectly, causing the data for these two periods to be erroneous.

Table A-4. Effluent loading rates for seepage beds 10MP40 and 11MP06

Time period	10MP40 cm/day	11MP06 cm/day	Time period	10MP40 cm/day	11MP06 cm/day
1982			1983		
11MAY-16MAY	1.70	1.39	20DEC-02JAN	1.74	1.74
17MAY-23MAY	1.67	1.63	03JAN-09JAN	1.89	1.87
24MAY-31MAY	1.59	1.48	10JAN-16JAN	1.65	1.64
01JUN-06JUN	1.69	1.78	17JAN-23JAN	1.63	1.72
07JUN-11JUN	1.71	1.59	24JAN-31JAN	1.60	1.54
Effluent delivery system down,			01FEB-07FEB	1.58	1.59
no effluent delivered until 14JUN			08FEB-13FEB	1.60	1.61
14JUN-20JUN	1.70	1.71	14FEB-20FEB	1.65	1.66
21JUN-27JUN	1.71	1.71	21FEB-27FEB	1.64	1.63
28JUN-04JUL	1.72	1.71	28FEB-06MAR	1.65	1.67
05JUL-11JUL	1.72	1.70	07MAR-13MAR	1.65	1.65
12JUL-18JUL	1.75	1.70	14MAR-20MAR	1.84	1.87
19JUL-25JUL	1.72	1.72	21MAR-27MAR	1.63	1.68
26JUL-01AUG	1.72	1.70	28MAR-03APR	2.21	2.13
02AUG-09AUG	1.74	1.70	04APR-10APR	1.11	1.19
10AUG-15AUG	1.74	1.86	11APR-17APR	1.61	1.67
16AUG-22AUG	1.74	1.64	18APR-24APR	1.57	1.64
23AUG-29AUG	1.75	1.71	25APR-01MAY	1.64	1.67
30AUG-06SEP	1.74	1.74	02MAY-08MAY	1.64	1.69
07SEP-13SEP	1.48	1.56	09MAY-15MAY	1.64	1.66
14SEP-19SEP	1.99	1.87	16MAY-22MAY	1.66	1.70
20SEP-26SEP	1.71	1.69	23MAY-30MAY	1.63	1.68
27SEP-03OCT	1.69	1.68	31MAY-05JUN	1.65	1.71
04OCT-10OCT	1.72	1.69	06JUN-12JUN	1.76	1.70
11OCT-17OCT	1.69	1.10	13JUN-19JUN	1.56	1.74
18OCT-24OCT	1.71	1.70	20JUN-24JUN	1.72	1.79
25OCT-31OCT	1.68	1.69	Effluent delivery system down,		
01NOV-07OCT	1.67	1.69	no effluent delivered until 27		
08OCT-14NOV	1.68	1.67	Jun		
15NOV-28NOV	1.68	1.67	27JUN-30JUN	2.16	2.22
29NOV-05DEC	1.65	1.65	01JUL-05JUL	1.71	1.78
06DEC-12DEC	1.72	1.68	06JUL-10JUL	1.70	1.76
13DEC-19DEC	1.39	1.38	11JUL-17JUL	1.73	1.79
18JUL-24JUL	1.70	1.91	07SEP-12SEP	1.72	1.64
25JUL-31JUL	1.99	1.72	Effluent delivery system down,		
01AUG-07AUG	1.69	1.79	no effluent delivered until 27		
08AUG-14AUG	1.72	1.83	Jun		
15AUG-22AUG	1.67	1.80	19SEP	1.74	1.79
23AUG-06SEP	1.70	1.80	20SEP-26SEP	1.89	2.01

Table A-5. Detailed rainfall at the experimental site and at Fayetteville, Arkansas.

Date	Savoy[1] cm	Fay[2] cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1980			1980			1980		
01OCT			05NOV			10DEC		
02OCT			06NOV			11DEC		
03OCT			07NOV			12DEC		
04OCT			08NOV			13DEC		
05OCT			09NOV			14DEC		
06OCT	0.0		10NOV	0.0		15DEC	0.0	
07OCT	0.0		11NOV	0.0		16DEC	0.0	
08OCT			12NOV			17DEC		
09OCT			13NOV			18DEC		
10OCT			14NOV			19DEC		
11OCT			15NOV		1.4	20DEC		
12OCT			16NOV			21DEC		
13OCT	0.0		17NOV	3.7	1.7	22DEC	0.0	
14OCT	0.0		18NOV	0.9	0.8	23DEC		
15OCT			19NOV			24DEC		
16OCT			20NOV			25DEC		
17OCT		3.8	21NOV			26DEC		0.1
18OCT			22NOV			27DEC		
19OCT			23NOV		0.4	28DEC		
20OCT	1.4		24NOV	1.1		29DEC	0.4	
21OCT	0.0		25NOV			30DEC		
22OCT			26NOV			31DEC		0.2
23OCT			27NOV		0.1	DEC T	6.8	4.8
24OCT		0.7	28NOV		0.5			
25OCT			29NOV			1981		
26OCT			30NOV			01JAN		
27OCT	3.2	2.1	NOV T	5.7	4.9	02JAN		
28OCT	0.0					03JAN		
29OCT			01DEC			04JAN		
30OCT			02DEC			05JAN		
31OCT			03DEC			06JAN		
OCT T	4.6	6.6	04DEC			07JAN		
			05DEC			08JAN		
01NOV			06DEC			09JAN		
02NOV			07DEC			10JAN		
03NOV	0.0		08DEC	5.5	3.8	11JAN		
04NOV	0.0		09DEC	0.1	0.7	12JAN	0.0	

Table A-5. Detailed rainfall at the experimental site and at Fayetteville, Arkansas (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1981			1981			1981		
13JAN			16FEB	0.0		22MAR		7.9
14JAN			17FEB	0.0		23MAR	0.6	0.1
15JAN			18FEB			24MAR	0.0	
16JAN			19FEB			25MAR		
17JAN			20FEB			26MAR		
18JAN			21FEB			27MAR		
19JAN	0.0		22FEB			28MAR		3.1
20JAN		0.2	23FEB	0.8	1.1	29MAR		
21JAN		1.1	24FEB	0.0		30MAR	1.8	
22JAN			25FEB			31MAR	0.0	
23JAN			26FEB			MAR T	6.6	17.0
24JAN			27FEB					
25JAN			28FEB			01APR		
26JAN	1.4		FEB T	3.5	4.2	02APR		
27JAN						03APR		
28JAN			01MAR			04APR		0.2
29JAN			02MAR	2.7	3.6	05APR		
30JAN		0.4	03MAR	0.3		06APR	0.1	
31JAN			04MAR		1.4	07APR		
JAN T	1.4	1.7	05MAR			08APR		
			06MAR			09APR		0.1
01FEB		0.7	07MAR			10APR		0.1
02FEB		0.7	08MAR			11APR		0.1
03FEB			09MAR	0.8		12APR		
04FEB			10MAR	0.0		13APR	0.0	
05FEB			11MAR			14APR	1.2	1.9
06FEB			12MAR			15APR		
07FEB			13MAR			16APR		
08FEB			14MAR			17APR		
09FEB	0.0		15MAR		0.3	18APR		0.1
10FEB	2.7	2.2	16MAR	0.4		19APR		1.8
11FEB		0.2	17MAR	0.0		20APR	4.1	1.9
12FEB			18MAR		0.6	21APR	0.0	0.1
13FEB			19MAR			22APR		
14FEB			20MAR			23APR		2.8
15FEB			21MAR			24APR		

Table A-5. Detailed rainfall at the experimental site and at Fayetteville, Arkansas (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1981			1981			1981		
25APR			30MAY	0.3	1.6	01JUL		3.1
26APR			31MAY	1.4	1.1	02JUL		
27APR	0.0		MAY T	8.6	13.5	03JUL		
28APR	0.0					04JUL		
29APR		0.8	01JUN		0.1	05JUL	0.7	
30APR		0.2	02JUN		0.2	06JUL	0.1	0.1
APR T	5.4	10.1	03JUN			07JUL	0.8	1.2
			04JUN	0.1		08JUL	0.2	0.4
01MAY			05JUN	0.5	0.5	09JUL		
02MAY			06JUN	1.1	0.8	10JUL		
03MAY			07JUN		5.1	11JUL		
04MAY	0.0		08JUN			12JUL		
05MAY	0.6	1.1	09JUN			13JUL		
06MAY		0.3	10JUN			14JUL		
07MAY			11JUN			15JUL		
08MAY		0.2	12JUN			16JUL		0.3
09MAY			13JUN			17JUL		0.1
10MAY		2.8	14JUN		0.2	18JUL		
11MAY	2.7		15JUN	4.7		19JUL		
12MAY	0.0		16JUN		4.1	20JUL		0.4
13MAY		2.5	17JUN			21JUL	1.6	0.3
14MAY		0.4	18JUN			22JUL		0.4
15MAY			19JUN	1.7	1.7	23JUL		
16MAY		0.2	20JUN		0.4	24JUL		
17MAY			21JUN			25JUL		
18MAY	1.4	1.5	22JUN			26JUL		
19MAY	0.0		23JUN			27JUL		
20MAY			24JUN			28JUL	4.0	4.7
21MAY			25JUN			29JUL		
22MAY			26JUN			30JUL	2.9	0.1
23MAY		0.2	27JUN			31JUL	0.1	4.0
24MAY	0.2	0.5	28JUN			JUL T	10.4	15.1
25MAY	0.3		29JUN					
26MAY	0.1	0.6	30JUN	7.7	7.2	01AUG		
27MAY			JUN T	15.8	20.3	02AUG	3.3	0.4
28MAY						03AUG	2.8	4.0
29MAY	1.6	0.5				04AUG		0.7

Table A-5. Detailed rainfall at the experimental site and at Fayetteville, Arkansas (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1981			1981			1981		
05AUG			09SEP			14OCT	0.5	
06AUG			10SEP			15OCT	0.2	0.1
07AUG		1.7	11SEP			16OCT	0.2	0.1
08AUG			12SEP	0.1	0.5	17OCT	0.2	0.4
09AUG			13SEP	1.7	0.1	18OCT		
10AUG			14SEP	0.6	2.5	19OCT		
11AUG	0.8	0.2	15SEP			20OCT		
12AUG			16SEP			21OCT	0.5	4.8
13AUG			17SEP			22OCT	3.5	0.2
14AUG			18SEP			23OCT		
15AUG			19SEP			24OCT		
16AUG	0.7	0.3	20SEP			25OCT	0.8	1.0
17AUG	1.3	1.4	21SEP			26OCT		
18AUG		0.4	22SEP			27OCT		
19AUG			23SEP			28OCT		
20AUG			24SEP			29OCT		
21AUG			25SEP			30OCT		2.9
22AUG			26SEP			31OCT	2.5	
23AUG			27SEP	0.6	0.3	OCT T	17.5	15.3
24AUG			28SEP					
25AUG			29SEP			01NOV	1.0	1.6
26AUG	1.7	0.6	30SEP			02NOV		
27AUG		1.2	SEP T	5.0	5.6	03NOV	1.4	
28AUG		2.1				04NOV	0.2	1.3
29AUG			01OCT			05NOV		0.3
30AUG			02OCT			06NOV		
31AUG			03OCT			07NOV		
AUG T	10.6	13.0	04OCT			08NOV		
			05OCT			09NOV		
01SEP			06OCT	0.6	0.5	10NOV		
02SEP			07OCT		0.1	11NOV		
03SEP			08OCT			12NOV		
04SEP			09OCT		0.1	13NOV		
05SEP			10OCT			14NOV		
06SEP			11OCT		1.8	15NOV		
07SEP	2.0		12OCT	3.8	0.2	16NOV		
08SEP		2.2	13OCT	4.7	3.1	17NOV		

Table A-5. Detailed rainfall at the experimental site and at Fayetteville, Arkansas (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1981			1981			1982		
18NOV			23DEC			26JAN		
19NOV			24DEC			27JAN		
20NOV			25DEC			28JAN		
21NOV			26DEC			29JAN		
22NOV			27DEC			30JAN	7.4	3.8
23NOV			28DEC			31JAN	0.1	2.4
24NOV			29DEC			JAN T	10.6	6.6
25NOV			30DEC					
26NOV			31DEC			01FEB	0.6	
27NOV			DEC T	1.5	1.6	02FEB		
28NOV		0.2				03FEB		0.2
29NOV	0.1	0.1	1982			04FEB		
30NOV	0.1	1.8	01JAN			05FEB		
NOV T	2.8	3.2	02JAN	0.2		06FEB		
			03JAN	0.8		07FEB		
01DEC		0.1	04JAN			08FEB		
02DEC			05JAN			09FEB		0.2
03DEC			06JAN			10FEB		
04DEC			07JAN		0.1	11FEB		
05DEC			08JAN			12FEB	0.7	0.7
06DEC			09JAN			13FEB		
07DEC			10JAN			14FEB		
08DEC			11JAN			15FEB		
09DEC			12JAN	0.3		16FEB	1.2	1.1
10DEC			13JAN		0.3	17FEB		
11DEC			14JAN			18FEB		
12DEC			15JAN			19FEB		
13DEC	0.1		16JAN			20FEB		
14DEC		0.2	17JAN			21FEB		
15DEC			18JAN			22FEB		
16DEC			19JAN			23FEB		
17DEC			20JAN			24FEB		
18DEC			21JAN	0.3		25FEB		
19DEC			22JAN			26FEB	0.1	
20DEC			23JAN			27FEB		
21DEC			24JAN			28FEB		
22DEC	1.4	1.3	25JAN			FEB T	2.6	2.3

Table A-5. Detailed rainfall at the experimental site and at Fayetteville, Arkansas (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1982			1982			1982		
01MAR			05APR			10MAY		
02MAR			06APR			11MAY		
03MAR	0.8	0.1	07APR		1.3	12MAY	1.7	
04MAR		1.2	08APR			13MAY	4.8	4.0
05MAR			09APR		0.1	14MAY	0.3	5.5
06MAR			10APR			15MAY		0.3
07MAR			11APR			16MAY		
08MAR			12APR			17MAY		
09MAR			13APR			18MAY		
10MAR			14APR			19MAY	0.7	1.5
11MAR			15APR			20MAY		0.1
12MAR			16APR			21MAY		0.1
13MAR	0.7		17APR			22MAY		
14MAR	1.8	2.3	18APR			23MAY	0.2	
15MAR	1.6		19APR	0.2	0.1	24MAY	0.5	
16MAR		1.3	20APR			25MAY	0.1	0.5
17MAR			21APR			26MAY	0.1	
18MAR			22APR			27MAY		0.8
19MAR			23APR			28MAY	1.3	0.7
20MAR			24APR			29MAY		0.4
21MAR			25APR	2.0		30MAY		
22MAR			26APR	0.1	1.9	31MAY	1.9	2.0
23MAR			27APR			MAY T	11.8	17.3
24MAR			28APR	1.0				
25APR			29APR		1.3	01JUN		
26APR			30APR			02JUN	2.9	
27APR			APR T	3.8	6.6	03JUN	3.0	3.3
28APR						04JUN	0.3	3.3
29APR			01MAY			05JUN		
30APR		0.1	02MAY			06JUN		
31APR			03MAY			07JUN		
MAR T	4.9	5.0	04MAY			08JUN		
			05MAY	0.1		09JUN		
01APR			06MAY	0.1	0.3	10JUN		0.7
02APR	0.5		07MAY		1.8	11JUN	1.1	
03APR		1.8	08MAY			12JUN		2.2
04APR			09MAY			13JUN		

Table A-5. Detailed rainfall at the experimental site and at Fayetteville, Arkansas (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1982			1982			1982		
14JUN			19JUL			23AUG		
15JUN	10.9	19.8	20JUL			24AUG		
16JUN			21JUL			25AUG		0.1
17JUN			22JUL			26AUG		0.1
18JUN			23JUL			27AUG	1.7	0.6
19JUN			24JUL			28AUG		2.3
20JUN		0.3	25JUL			29AUG		
21JUN			26JUL	0.1		30AUG	0.5	
22JUN			27JUL	0.2		31AUG		1.0
23JUN			28JUL	1.2	0.3	AUG T	3.2	4.1
24JUN			29JUL	0.5	0.1			
25JUN			30JUL	8.5	8.3	01SEP		
26JUN		1.9	31JUL		0.1	02SEP		0.1
27JUN	1.3		JUL T	11.3	9.4	03SEP		
28JUN	1.2	3.1				04SEP		
29JUN			01AUG			05SEP		
30JUN			02AUG			06SEP		
JUN T	20.7	34.6	03AUG			07SEP		
			04AUG			08SEP		
01JUL			05AUG			09SEP		
02JUL			06AUG			10SEP		
03JUL			07AUG	0.4		11SEP		
04JUL			08AUG	0.5	3.6	12SEP		
05JUL			09AUG			13SEP	3.5	
06JUL			10AUG			14SEP		2.1
07JUL	0.7	0.4	11AUG			15SEP		
08JUL	0.1	0.2	12AUG		0.3	16SEP		
09JUL			13AUG			17SEP		
10JUL			14AUG		0.3	18SEP		0.1
11JUL			15AUG			19SEP		
12JUL			16AUG			20SEP		
13JUL			17AUG			21SEP		
14JUL			18AUG			22SEP		
15JUL			19AUG			23SEP		
16JUL			20AUG			24SEP	0.3	0.6
17JUL			21AUG			25SEP		
18JUL			22AUG			26SEP		

Table A-5. Detailed rainfall at the experimental site and at Fayetteville, Arkansas (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1982			1982			1982		
27SEP			OCT T	6.1	7.9	04DEC	0.2	1.7
28SEP						05DEC		0.3
29SEP			01NOV	2.6		06DEC		
30SEP			02NOV	0.1	1.6	07DEC		
SEP T	3.8	2.9	03NOV			08DEC		
			04NOV			09DEC		
01OCT			05NOV			10DEC	1.0	0.9
02OCT			06NOV			11DEC	0.2	1.2
03OCT			07NOV			12DEC		
04OCT			08NOV			13DEC		
05OCT			09NOV			14DEC		
06OCT	0.6		10NOV			15DEC		
07OCT		1.2	11NOV	0.8	0.2	16DEC		
08OCT	2.3		12NOV	0.1	1.1	17DEC		
09OCT	0.1	3.4	13NOV			18DEC		
10OCT			14NOV			19DEC		
11OCT			15NOV			20DEC		
12OCT		0.1	16NOV			21DEC		
13OCT			17NOV			22DEC		
14OCT			18NOV			23DEC		
15OCT			19NOV			24DEC	3.8	1.7
16OCT			20NOV			25DEC		1.7
17OCT			21NOV			26DEC		
18OCT			22NOV	5.4		27DEC	2.0	1.6
19OCT	0.5		23NOV	0.2	7.3	28DEC		2.2
20OCT	0.1	0.6	24NOV			29DEC		
21OCT			25NOV	0.2		30DEC		
22OCT			26NOV	4.3	3.8	31DEC		
23OCT			27NOV	2.5		DEC T	22.8	23.7
24OCT			28NOV		4.7			
25OCT			29NOV		0.1	1983		
26OCT			30NOV			01JAN		
27OCT			NOV T	16.2	18.8	02JAN		
28OCT	2.3	2.6				03JAN		
29OCT	0.2		01DEC	10.6		04JAN		
30OCT			02DEC	2.5	0.2	05JAN		
31OCT			03DEC	2.5	12.2	06JAN		

Table A-5. Detailed rainfall at the experimental site and at Fayetteville, Arkansas (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1983			1983			1983		
07JAN			11FEB			18MAR		
08JAN			12FEB			19MAR	0.7	
09JAN			13FEB			20MAR		0.8
10JAN			14FEB			21MAR		
11JAN			15FEB			22MAR		
12JAN			16FEB			23MAR		
13JAN			17FEB			24MAR		
14JAN			18FEB			25MAR		
15JAN			19FEB			26MAR	0.7	0.5
16JAN			20FEB			27MAR		0.5
17JAN			21FEB			28MAR		
18JAN			22FEB			29MAR	0.2	
19JAN			23FEB	0.3		30MAR	0.1	0.3
20JAN	0.2	0.3	24FEB		0.4	31MAR		
21JAN		0.1	25FEB			MAR T	3.8	4.8
22JAN			26FEB					
23JAN	0.4	0.9	27FEB			01APR	4.1	0.1
24JAN			28FEB			02APR	1.4	4.0
25JAN		0.1	FEB T	1.1	3.1	03APR		1.3
26JAN	0.4	0.2				04APR		
27JAN		0.3	01MAR			05APR		0.2
28JAN		1.7	02MAR			06APR		0.1
29JAN	1.0		03MAR			07APR		
30JAN			04MAR	1.9	0.5	08APR		0.3
31JAN	1.7		05MAR		1.8	09APR		0.1
JAN T	3.7	2.6	06MAR	0.2	0.2	10APR		
			07MAR		0.2	11APR		
01FEB	0.6	2.3	08MAR			12APR		
02FEB		0.2	09MAR			13APR	1.7	0.5
03FEB	0.1	0.1	10MAR			14APR		1.0
04FEB			11MAR			15APR		
05FEB	0.2	0.1	12MAR			16APR		
06FEB			13MAR			17APR		
07FEB			14MAR			18APR		0.2
08FEB			15MAR			19APR	0.6	
09FEB			16MAR			20APR	0.1	0.9
10FEB			17MAR			21APR	1.4	

Table A-5. Detailed rainfall at the experimental site and at Fayetteville, Arkansas (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1983			1983			1983		
22APR	1.2	1.7	26MAY			29JUN	0.3	1.5
23APR	0.9	2.4	27MAY			30JUN		0.1
24APR			28MAY	2.3	1.3	JUN T	6.2	11.5
25APR			29MAY	0.2	0.2			
26APR			30MAY			01JUL		
27APR			31MAY		0.5	02JUL		
28APR	0.1		MAY T	11.4	12.0	03JUL		
29APR	2.6					04JUL		
30APR	0.7	1.5	01JUN			05JUL		0.1
APR T	14.8	14.3	02JUN		0.1	06JUL		
			03JUN	0.4		07JUL		
01MAY			04JUN		0.2	08JUL		
02MAY		0.2	05JUN	1.4		09JUL		
03MAY			06JUN		1.7	10JUL		
04MAY			07JUN			11JUL		
05MAY			08JUN			12JUL		
06MAY			09JUN			13JUL		
07MAY		0.1	10JUN			14JUL		
08MAY			11JUN			15JUL		
09MAY			12JUN			16JUL		
10MAY			13JUN			17JUL	3.9	
11MAY			14JUN	2.1	2.5	18JUL		0.9
12MAY		0.3	15JUN		0.1	19JUL		
13MAY	1.1	0.1	16JUN			20JUL		
14MAY	2.8	3.4	17JUN			21JUL		
15MAY		1.3	18JUN			22JUL		
16MAY			19JUN			23JUL		
17MAY			20JUN			24JUL		
18MAY	2.0	1.5	21JUN			25JUL		
19MAY		0.5	22JUN			26JUL		0.4
20MAY			23JUN			27JUL		
21MAY	0.6	0.7	24JUN			28JUL		
22MAY		0.4	25JUN	0.5	0.9	29JUL		
23MAY	0.6	1.5	26JUN	0.4	1.8	30JUL	1.2	
24MAY			27JUN		1.1	31JUL		0.6
25MAY			28JUN	1.1	1.5	JUL T	5.1	2.0

Table A-5. Detailed rainfall at the experimental site and at Fayetteville, Arkansas (continued)

Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm	Date	Savoy cm	Fay cm
1983			1983			1983		
01AUG			29AUG		2.6	24SEP		
02AUG			30AUG	1.0		25SEP		
03AUG			31AUG	1.0	0.3	26SEP		
04AUG			AUG T	3.5	4.3	27SEP		
05AUG						28SEP		
06AUG			01SEP		0.4	29SEP		
07AUG	1.4	1.3	02SEP			30SEP		
08AUG			03SEP			SEP T	2.2	2.7
09AUG			04SEP					
10AUG			05SEP					
11AUG			06SEP					
12AUG			07SEP					
13AUG			08SEP					
14AUG			09SEP					
15AUG			10SEP					
16AUG			11SEP					
17AUG			12SEP					
18AUG			13SEP					
19AUG			14SEP					
20AUG			15SEP	0.8				
21AUG			16SEP		0.9			
22AUG			17SEP					
23AUG			18SEP					
24AUG	0.1		19SEP					
25AUG			20SEP	1.4				
26AUG		0.1	21SEP		1.4			
27AUG			22SEP					
28AUG			23SEP					

---

[1] Savoy rainfall values are cumulative since the previous observation for the period October 1, 1980 to May 22, 1981. They are daily values after May 22, 1981 when an automatic recording rain gauge was installed.

[2] Fay is an abbreviation for Fayetteville. Fayetteville data are from NOAA 1980-1983.

Table A-6. Inbed effluent depths and selected exbed ground water depths in the 01ST76 filter field.

Date	Water Depths, cm from the Soil Surface						
	Inbed wells			Exbed wells			
	C1	D1	Mean	A1	B1	B2	Mean
06OCT80	42.1	49.4	45.8	D[1]	92.6	75.7	
13OCT80	32.0	50.1	41.1	D	D	72.3	
20OCT80	49.4	45.5	47.5	D	D	74.7	
27OCT80	42.1	38.6	40.4	D	81.1	58.0	
03NOV80	45.7	52.3	49.0	83.8	D	72.9	
10NOV80	43.7	43.0	43.4	D	D	72.6	
17NOV80	46.1	50.9	48.5	99.2	87.5	62.6	83.1
24NOV80	37.0	36.4	36.7	49.8	57.3	51.5	52.9
01DEC80	36.3	37.0	36.7	50.7	41.5	45.0	45.7
08DEC80	19.0	20.2	19.6	27.5	25.9	20.8	24.7
15DEC80	36.1	36.2	36.2	51.9	55.9	54.3	54.0
22DEC80[2]	45.2	47.6	46.4	62.5	38.4	28.1	43.0
29DEC80[2]	51.4	49.5	50.5	82.8	77.8	72.3	77.6
05JAN81[2]	52.8	49.8	51.3	82.4	79.4	72.5	78.1
12JAN81[2]	59.7	58.9	59.3	84.8	78.9	91.9	85.2
19JAN81[2]	68.6	67.2	67.9	86.1	80.6	92.6	86.4
26JAN81[2]	74.1	73.3	73.7	84.1	84.8	91.7	86.9
09FEB81[2]	71.5	71.2	71.4	91.5	83.2	95.0	89.9
16FEB81[2]	48.1	50.7	49.4	70.1	61.6	55.8	62.5
23FEB81[2]	44.7	47.9	46.3	77.2	67.3	53.0	65.8
02MAR81	38.4	38.6	38.5	52.5	43.6	38.8	45.0
09MAR81	42.7	41.3	42.0	52.8	50.0	46.5	49.8
16MAR81	46.3	45.3	45.8	71.6	85.4	74.2	77.1
23MAR81	46.4	47.9	47.2	103.6	85.9	68.8	86.1
30MAR81	43.6	44.9	44.3	60.9	73.4	50.2	61.5
06APR81	50.0	49.9	50.0	84.5	96.0	83.4	88.0
13APR81	52.1	55.6	53.9	D	D	D	
20APR81	47.2	47.1	47.2	D	80.2	43.4	
27APR81	45.6	48.6	47.1	63.4	55.9	57.2	58.8
04MAY81	49.5	51.9	50.7	D	77.7	77.4	

Table A-6. Inbed effluent depths and selected exbed ground water depths in the 01ST76 filter field (continued)

Date	Water Depths, cm from the Soil Surface						
	Inbed wells			Exbed wells			
	C1	D1	Mean	A1	B1	B2	Mean
11MAY81	47.4	51.3	49.4	106.8	88.0	59.4	84.7
18MAY81	39.0	38.7	38.9	46.9	45.5	32.7	41.7
25MAY81	50.5	49.6	50.1	74.6	76.8	58.3	69.9
01JUN81	42.1	39.4	40.8	51.2	55.7	43.5	50.1
08JUN81	44.8	48.0	46.4	55.7	58.9	48.2	54.3
15JUN81	50.4	55.3	52.9	83.7	97.4	81.0	87.4
22JUN81	48.4	50.0	49.2	62.5	53.8	57.6	58.0
29JUN81	53.3	54.0	53.7	99.9	D	91.7	
06JUL81	47.1	48.3	47.7	65.8	57.7	54.8	59.4
13JUL81	49.7	51.3	50.5	74.9	77.0	70.0	74.0
20JUL81	52.8	53.9	53.4	107.7	D	95.1	
27JUL81	55.7	62.1	58.9	D	D	D	
03AUG81	1.2	-0.2	0.5	16.2	11.7	7.1	11.7
10AUG81	47.7	48.8	48.3	72.8	58.4	59.1	63.4
17AUG81	47.0	46.4	46.7	107.4	98.2	77.4	94.3
24AUG81	50.0	53.2	51.6	81.9	84.8	74.0	80.2
31AUG81	48.5	47.3	47.9	80.9	98.5	63.2	80.9
08SEP81	47.1	46.8	47.0	106.0	91.3	54.5	83.9
14SEP81	44.1	42.6	43.4	58.8	64.7	39.7	54.4
21SEP81	47.4	48.9	48.2	74.6	92.7	59.2	75.5
28SEP81	50.1	49.0	49.6	D	100.3	85.6	
05OCT81	48.2	50.9	49.6	D	100.8	108.3	
12OCT81	41.6	40.8	41.2	48.7	63.8	42.3	51.6
19OCT81	46.0	45.8	45.9	58.9	49.7	54.8	54.5
26OCT81	35.3	36.2	35.8	43.3	36.9	33.4	37.9
03NOV81	34.5	35.3	34.9	50.9	39.4	37.4	42.6
09NOV81	43.7	43.4	43.6	55.9	47.7	50.8	51.5
16NOV81	48.0	47.7	47.9	72.6	99.8	60.3	77.6
23NOV81	52.4	51.6	52.0	D	102.0	79.0	
30NOV81	45.0	44.6	44.8	105.9	75.6	64.0	81.8

Table A-6. Inbed effluent depths and selected exbed ground water depths in the 01ST76 filter field (continued)

Date	Water Depths, cm from the soil surface						
	Inbed wells			Exbed wells			
	C1	D1	Mean	A1	B1	B2	Mean
07DEC81	50.0	49.9	50.0	69.6	72.1	56.9	66.2
14DEC81	52.0	53.0	52.5	96.8	100.7	75.1	90.9
04JAN82	47.3	47.3	47.3	68.0	65.7	56.1	63.3
18JAN82[2]	52.3	51.7	52.0	89.2	77.4	83.8	83.5
25JAN82[2]	45.1	44.7	44.9	51.6	40.4	48.4	46.8
01FEB82[2]	12.2	9.7	11.0	23.8	17.5	12.6	18.0
08FEB82[2]	44.3	45.3	44.8	58.5	48.6	47.1	51.4
15FEB82[2]	14.9	14.2	14.6	20.9	15.4	5.0	13.8
22FEB82[2]	40.4	40.1	40.3	53.2	45.2	42.1	46.8
01MAR82[2]	48.7	48.6	48.7	78.2	76.0	56.2	70.1
08MAR82[2]	49.0	48.9	49.0	104.5	100.5	59.5	88.2
15MAR82[2]	36.2	36.6	36.4	46.1	45.5	35.0	42.2
22MAR82[2]	47.9	47.4	47.7	51.5	51.7	56.0	53.1
29MAR82[2]	50.1	50.8	50.5	103.2	99.3	70.5	91.0
05APR82[2]	53.1	53.2	53.2	103.7	101.1	89.2	98.0
12APR82[2]	53.8	54.3	54.1	D	101.8	92.5	
19APR82[2]	55.5	54.9	55.2	D	D	93.2	
26APR82[2]	48.8	48.4	48.6	D	D	93.1	
03MAY82[2]	39.1	38.8	39.0	103.2	D	D	
10MAY82[2]	37.5	37.2	37.4	95.8	102.1	81.9	93.3
17MAY82	38.1	37.0	37.6	53.5	45.6	51.4	50.2
24MAY82	36.3	35.9	36.1	58.6	54.6	56.9	56.7
01JUN82	33.0	33.6	33.3	45.7	47.8	39.0	44.2
07JUN82	29.1	28.8	29.0	41.4	38.4	31.6	37.1
14JUN82[2]	37.6	37.8	37.7	52.1	49.1	54.4	51.9
16JUN82	3.2	3.0	3.1	16.4	11.2	5.7	11.1
21JUN82	37.0	37.4	37.2	52.9	46.4	46.3	48.5
28JUN82	31.6	31.6	31.6	47.7	61.7	41.5	50.3
05JUL82	34.0	34.1	34.1	64.5	63.3	57.7	61.8
12JUL82	34.8	34.8	34.8	75.4	75.1	61.6	70.7

Table A-6. Inbed effluent depths and selected exbed ground water depths in the 01ST76 filter field

Date	Water Depths, cm from the soil surface						
	Inbed wells			Exbed wells			
	C1	D1	Mean	A1	B1	B2	Mean
19JUL82	37.9	37.6	37.8	84.5	77.5	76.8	79.6
26JUL82	40.8	39.8	40.3	89.4	79.4	87.9	85.6
02AUG82	40.3	38.8	39.6	60.4	47.6	54.2	54.1
10AUG82	38.4	38.3	38.4	70.4	55.6	57.5	61.2
16AUG82	37.8	37.9	37.9	77.7	67.3	61.9	69.0
23AUG82	40.1	39.8	40.0	85.9	77.4	78.1	80.5
30AUG82	38.0	38.1	38.1	89.6	84.4	85.9	86.6
07SEP82	37.5	37.7	37.6	89.2	82.2	74.0	81.8
14SEP82	37.9	37.8	37.9	89.5	84.1	85.4	86.3
20SEP82	37.0	36.7	36.9	68.8	63.9	60.2	64.3
27SEP82	38.2	36.3	37.3	74.2	86.6	69.5	76.8
04OCT82	36.9	37.9	37.4	76.7	77.8	70.8	75.1
11OCT82	37.2	38.1	37.7	60.5	61.4	56.7	59.5
18OCT82	37.7	36.6	37.2	67.7	77.2	62.0	69.0
25OCT82	35.4	35.8	35.6	68.5	76.1	66.6	70.4
01NOV82	34.8	34.1	34.5	54.7	55.5	54.4	54.9
08NOV82	35.8	34.7	35.3	57.3	55.4	55.3	56.0
15NOV82	35.2	34.7	35.0	56.2	58.3	55.7	56.7
29NOV82	9.2	8.1	8.7	23.6	18.6	15.3	19.2
06DEC82	18.5	18.5	18.5	29.6	24.3	19.0	24.3
13DEC82	33.4	32.7	33.1	45.4	42.2	38.2	41.9
03JAN83	35.4	36.1	35.8	49.1	46.6	50.3	48.7
10JAN83	36.0	35.0	35.5	58.6	65.6	55.5	59.9
17JAN83	34.0	34.1	34.1	65.3	76.5	58.0	66.6
24JAN83	32.0	32.2	32.1	49.4	65.3	48.0	54.2
01FEB83	6.2	1.8	4.0	20.9	13.3	10.4	14.9
08FEB83	28.6	29.2	28.9	43.8	40.1	36.3	40.1
14FEB83	32.4	32.3	32.4	48.8	55.6	53.0	52.5
21FEB83	32.0	31.8	31.9	54.0	62.8	55.7	57.5
28FEB83	31.2	30.8	31.0	53.6	69.3	55.7	59.5

Table A-6. Inbed effluent depths and selected exbed ground water depths in the 01ST76 filter field (continued)

Date	Water Depths, cm from the soil surface						
	Inbed wells			Exbed wells			
	C1	D1	Mean	A1	B1	B2	Mean
07MAR83	30.4	30.8	30.6	44.9	45.8	45.5	45.4
14MAR83	31.2	31.2	31.2	56.4	57.8	52.0	55.4
21MAR83	30.6	30.9	30.8	50.8	61.8	49.2	53.9
28MAR83	29.9	30.0	30.0	52.3	58.5	50.7	53.8
04APR83	22.1	22.6	22.4	33.6	29.6	22.6	28.6
11APR83	30.0	29.9	30.0	51.0	52.6	53.2	52.3
18APR83	27.8	29.3	28.6	51.4	53.2	51.8	52.1
25APR83	24.6	24.7	24.7	37.2	33.4	29.1	33.2
02MAY83	25.0	24.4	24.7	37.6	34.2	29.1	33.6
09MAY83	31.5	31.6	31.6	60.9	58.2	56.9	58.7
16MAY83	28.4	28.7	28.6	42.9	39.9	36.8	39.9
23MAY83	24.7	25.0	24.9	40.0	39.1	31.2	36.8
31MAY83	28.0	27.8	27.9	42.9	44.2	40.2	42.4
06JUN83	27.3	27.8	27.6	40.4	38.2	44.0	40.9
13JUN83	30.3	30.8	30.6	62.3	58.4	56.1	58.9
20JUN83	28.7	29.2	29.0	57.5	56.4	55.7	56.5
01JUL83[2]	28.3	29.1	28.7	50.5	57.4	53.1	53.7
06JUL83	32.8	33.1	33.0	62.7	61.7	58.4	60.9
11JUL83	33.7	33.5	33.6	77.4	70.4	60.3	69.4
18JUL83	32.2	32.4	32.3	51.7	47.9	52.4	50.7
25JUL83	39.7	39.7	39.7	77.5	63.3	62.0	67.6
01AUG83	36.8	36.7	36.8	99.8	80.0	85.1	88.3
08AUG83	35.7	35.7	35.7	101.5	83.6	90.9	92.0
15AUG83	36.2	36.5	36.4	102.6	85.6	87.7	92.0
23AUG83	39.5	39.8	39.7	D	119.4	93.4	
30AUG83	44.0	42.8	43.4	D	93.6	93.8	
07SEP83	41.3	41.9	41.6	D	97.4	94.0	
12SEP83	43.2	44.6	43.9	D	98.0	94.6	
20SEP83[2]	52.4	51.8	52.1	D	102.9	95.0	
26SEP83	47.1	47.1	47.1	D	102.9	94.6	

---

[1] D indicates the well was dry

[2] Data significantly influenced by malfunction(s) of the effluent delivery system. Details of malfunctions given in Appendix Table A-3.

Table A-7. Background water depths at the experimental site.

Date	Water depths, cm from the soil surface												
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F12	F14	F16
06OCT80	D	D	D	D	D	D	D	D	D	D	D	D	D
13OCT80	D	D	D	D	D	D	D	D	D	D	D	D	D
20OCT80	D	D	D	D	D	D	D	D	D	D	D	D	D
27OCT80	D	D	D	D	D	D	D	D	D	D	D	D	D
03NOV80	D	D	D	D	D	D	D	D	D	D	D	D	D
10NOV80	D	D	D	D	D	D	D	D	D	D	D	D	D
17NOV80	D	D	D	D	D	D	D	D	D	D	D	D	D
24NOV80	D	D	D	D	D	D	D	D	D	D	D	D	D
01DEC80	D	D	D	D	D	D	D	D	D	D	D	D	D
08DEC80	D	D	D	D	D	D	D	D	D	D	D	D	D
15DEC80	D	D	D	D	D	D	D	D	D	D	D	D	D
22DEC80	D	D	D	D	D	D	D	D	D	D	D	D	D
28DEC80	D	D	D	D	D	D	D	D	D	D	D	D	D
05JAN81	D	D	D	D	D	D	D	D	D	D	D	D	D
12JAN81	D	D	D	D	D	D	D	D	D	D	D	D	D
19JAN81	D	D	D	D	D	D	D	D	D	D	D	D	D
26JAN81	D	D	D	D	D	D	D	D	D	D	D	D	D
09FEB81	D	D	D	D	D	D	D	D	D	D	D	D	D

Table A-7. Background water depths at the experimental site. (continued)

Date	Water depths, cm from the soil surface												
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F12	F14	F16
16FEB81	D	D	D	D	D	D	D	D	D	D	D	D	D
23FEB81	D	D	D	D	D	D	D	D	D	D	D	D	D
02MAR81	D	D	D	D	D	D	D	D	D	D	D	D	D
09MAR81	D	D	D	D	D	D	D	D	D	D	D	D	D
16MAR81	D	D	D	D	D	D	D	D	D	D	D	D	D
23MAR81	D	D	D	D	D	D	D	D	D	D	D	D	D
30MAR81	D	D	D	D	D	D	D	D	D	D	D	D	D
06APR81	D	D	D	D	D	D	D	D	D	D	D	D	D
13APR81	D	D	D	D	D	D	D	D	D	D	D	D	D
20APR81	D	D	D	D	D	D	D	D	D	D	D	D	D
27APR81	D	D	D	D	D	D	D	D	D	D	D	D	D
04MAY81	D	D	D	D	D	D	D	D	D	D	D	D	D
11MAY81	D	D	D	D	D	D	D	D	D	D	D	D	D
18MAY81	D	D	D	D	D	D	D	D	D	57.0	80.8	D	D
25MAY81	D	D	D	D	D	D	D	D	D	D	D	D	D
01JUN81	D	D	D	D	D	D	D	D	D	65.2	76.3	107.2	D
08JUN81	D	D	D	D	D	D	D	D	D	D	76.4	111.9	D
15JUN81	D	D	D	D	D	D	D	D	D	D	D	D	D

Table A-7. Background water depths at the experimental site. (continued)

Date	Water depths, cm from the soil surface												
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F12	F14	F16
22JUN81	D	D	D	D	D	D	D	D	D	D	D	105.3	D
29JUN81	D	D	D	D	D	D	D	D	D	D	D	D	D
06JUL81	D	D	D	D	D	D	D	D	D	D	D	D	97.6
13JUL81	D	D	D	D	D	D	D	D	D	D	D	D	D
20JUL81	D	D	D	D	D	D	D	D	D	D	D	D	D
27JUL81	D	D	D	D	D	D	D	D	D	D	D	D	D
03AUG81	D	D	D	D	D	24.4	D	20.9	D	21.8	51.8	91.8	D
10AUG81	D	D	D	D	D	D	D	D	D	D	D	D	D
17AUG81	D	D	D	D	D	D	D	D	D	D	D	D	D
24AUG81	D	D	D	D	D	D	D	D	D	D	D	D	D
08SEP81	D	D	D	D	D	D	D	D	D	D	D	D	D
14SEP81	D	D	D	D	D	D	D	D	D	D	D	D	D
21SEP81	D	D	D	D	D	D	D	D	D	D	D	D	D
28SEP81	D	D	D	D	D	D	D	D	D	D	D	D	D
05OCT81	D	D	D	D	D	D	D	D	D	D	D	D	D
12OCT81	D	D	D	D	D	D	D	D	D	D	D	D	D
19OCT81	D	D	D	D	D	D	D	54.7	D	D	D	88.1	D
26OCT81	D	D	D	D	D	D	D	45.8	D	D	73.8	80.6	D

Table A-7. Background water depths at the experimental site. (continued)

Date	Water depths, cm from the soil surface												
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F12	F14	F16
03NOV81	D	D	D	D	D	D	D	40.8	D	61.3	66.8	71.7	D
09NOV81	D	D	D	D	D	D	D	D	D	D	D	82.4	D
16NOV81	D	D	D	D	D	D	D	D	D	D	D	D	D
23NOV81	D	D	D	D	D	D	D	D	D	D	D	D	D
07DEC81	D	D	D	D	D	D	D	D	D	D	D	D	D
14DEC81	D	D	D	D	D	D	D	D	D	D	D	D	D
18JAN82	D	D	D	D	D	D	D	D	D	D	D	D	D
25JAN82	D	D	D	D	D	D	D	D	D	D	D	D	D
01FEB82	D	D	D	D	43.2	D	42.9	42.8	47.9	56.6	51.8	63.3	D
08FEB82	D	D	D	D	D	D	D	49.6	D	61.8	72.1	96.5	D
15FEB82	D	D	D	D	D	D	D	D	D	D	67.3	98.3	D
22FEB82	D	D	D	D	D	D	D	53.7	D	64.8	73.0	91.1	D
01MAR82	D	D	D	D	D	D	D	D	D	D	87.7	108.4	D
08MAR82	D	D	D	D	D	D	55.8	D	D	D	91.0	122.5	D
15MAR82	D	D	D	D	D	D	D	D	D	D	77.9	101.2	D
22MAR82	D	D	D	D	D	D	D	D	D	D	78.9	93.3	D
28MAR82	D	D	57.4	D	D	D	D	D	D	D	D	122.4	D
05APR82	D	D	D	D	D	D	D	D	D	D	D	D	D

Table A-7. Background water depths at the experimental site. (continued)

Date	Water depths, cm from the soil surface												
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F12	F14	F16
12APR82	D	D	D	D	D	D	D	D	D	D	D	D	D
19APR82	D	D	D	D	D	D	D	D	D	D	D	D	D
26APR82	D	D	D	D	D	D	D	D	D	D	D	D	D
03MAY82	D	D	D	D	D	D	D	D	D	D	D	D	D
10MAY82	D	D	D	D	D	D	D	D	D	D	D	D	D
17MAY82	D	D	D	D	D	D	D	D	D	D	D	D	D
24MAY82	D	D	D	D	D	D	D	D	D	D	D	D	D
01JUN82	D	D	D	D	D	D	D	D	D	D	D	D	D
07JUN82	D	D	D	D	D	D	D	D	D	D	66.8	94.2	D
14JUN82	D	D	D	D	D	D	D	D	D	D	69.3	98.8	D
16JUN82	D	D	32.5	38.0	52.5	D	D	40.7	38.9	41.8	30.6	48.4	D
21JUN82	D	D	D	D	D	D	D	D	D	D	78.0	90.0	D
28JUN82	D	D	D	D	D	D	D	D	D	D	D	116.4	D
05JUL82	D	D	D	D	D	D	D	D	D	D	D	D	D
12JUL82	D	D	D	D	D	D	D	D	D	D	D	D	D
19JUL82	D	D	D	D	D	D	D	D	D	D	D	D	D
26JUL82	D	D	D	D	D	D	D	D	D	D	D	D	D
02AUG82	D	D	D	D	D	D	D	D	D	D	D	D	D

Table A-7. Background water depths at the experimental site. (continued)

Date	Water depths, cm from the soil surface												
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F12	F14	F16
10AUG82	D	D	D	D	D	D	D	D	D	D	D	D	D
16AUG82	D	D	D	D	D	D	D	D	D	D	D	D	D
23AUG82	D	D	D	D	D	D	D	D	D	D	D	D	D
30AUG82	D	D	D	D	D	D	D	D	D	D	D	D	D
07SEP82	D	D	D	D	D	D	D	D	D	D	D	D	D
14SEP82	D	D	D	D	D	D	D	D	D	D	D	D	D
20SEP82	D	D	D	D	D	D	D	D	D	D	D	D	D
27SEP82	D	D	D	D	D	D	D	D	D	D	D	D	D
04OCT82	D	D	D	D	D	D	D	D	D	D	D	D	D
11OCT82	D	D	D	D	D	D	D	D	D	D	D	D	D
18OCT82	D	D	D	D	D	D	D	D	D	D	D	D	D
25OCT82	D	D	D	D	D	D	D	D	D	D	D	D	D
01NOV82	D	D	D	D	D	D	D	D	D	D	D	D	D
08NOV82	D	D	D	D	D	D	D	D	D	D	D	D	D
15NOV82	D	D	D	D	D	D	D	D	D	D	D	D	D
29NOV82	50.9	D	46.7	D	43.1	D	D	47.0	D	62.8	56.6	49.1	D
06DEC82	45.6	D	49.5	D	D	D	D	48.2	D	60.7	38.7	53.4	D
13DEC82	D	D	D	D	D	D	D	49.4	45.0	62.8	61.1	60.8	D

Table A-7. Background water depths at the experimental site. (continued)

Date	Water depths, cm from the soil surface												
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F12	F14	F16
03JAN83	D	D	D	D	D	D	D	55.1	46.4	D	72.0	71.7	D
10JAN83	D	D	D	D	D	D	D	56.5	D	D	83.1	85.5	D
17JAN83	D	D	D	D	D	D	D	D	D	D	D	99.4	D
24JAN83	D	D	D	D	D	D	D	D	D	D	D	118.9	D
01FEB83	D	D	D	D	34.0	D	D	33.6	D	43.7	78.1	58.5	D
08FEB83	D	D	D	D	D	D	24.9	D	51.5	D	73.3	88.4	D
14FEB83	D	D	D	D	D	D	D	D	D	D	78.7	99.5	D
21FEB83	D	D	D	D	D	D	D	D	D	D	85.4	109.2	D
28FEB83	D	D	D	D	D	D	D	D	D	D	D	117.2	D
07MAR83	D	D	D	D	D	D	D	D	D	D	D	114.9	D
14MAR83	D	D	D	D	D	D	D	D	D	D	D	121.4	D
21MAR83	D	D	D	D	D	D	D	D	D	D	D	D	D
28MAR83	D	D	D	D	D	D	D	D	D	D	D	D	D
04APR83	D	D	D	D	D	D	D	D	D	D	59.2	81.5	D
11APR83	D	D	D	D	D	D	D	D	D	D	74.0	92.6	D
18APR83	D	D	D	D	D	D	D	D	D	D	80.9	104.0	D
25APR83	D	D	D	D	D	D	D	D	50.9	D	62.4	66.7	D
02MAY83	D	D	D	D	D	D	D	D	D	D	68.5	67.2	D

Table A-7. Background water depths at the experimental site. (continued)

Date	Water depths, cm from the soil surface												
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F12	F14	F16
09MAY83	D	D	D	D	D	D	D	D	D	D	80.4	86.3	D
16MAY83	D	D	D	D	D	D	D	D	D	D	89.9	96.5	D
23MAY83	D	D	D	D	D	D	D	D	D	D	86.1	81.4	D
31MAY83	D	D	D	D	D	D	D	D	D	D	85.6	88.9	D
06JUN83	D	D	D	D	D	D	D	D	D	D	D	108.5	D
13JUN83	D	D	D	D	D	D	D	D	D	D	91.2	122.4	D
20JUN83	D	D	D	D	D	D	D	D	D	D	D	D	D
01JUL83	D	D	D	D	D	D	D	D	D	D	D	D	D
06JUL83	D	D	D	D	D	D	D	D	D	D	D	D	D
11JUL83	D	D	D	D	D	D	D	D	D	D	D	D	D
18JUL83	D	D	D	D	D	D	D	D	D	D	D	D	D
25JUL83	D	D	D	D	D	D	D	D	D	D	D	D	D
01AUG83	D	D	D	D	D	D	D	D	D	D	D	D	D
08AUG83	D	D	D	D	D	D	D	D	D	D	D	D	D
15AUG83	D	D	D	D	D	D	D	D	D	D	D	D	D
23AUG83	D	D	D	D	D	D	D	D	D	D	D	D	D
30AUG83	D	D	D	D	D	D	D	D	D	D	D	D	D
07SEP83	D	D	D	D	D	D	D	D	D	D	D	D	D
12SEP83	D	D	D	D	D	D	D	D	D	D	D	D	D
21SEP83	D	D	D	D	D	D	D	D	D	D	D	D	D
26SEP83	D	D	D	D	D	D	D	D	D	D	D	D	D

Table A-8. Inbed effluent depths and selected exbed ground water depths in the 02MG30 filter field.

Date	Well depths, cm from the soil surface					
	Inbed wells			Exbed wells		
	A1	B1	Mean	C3	D3	Mean
06OCT80	D	D[1]		D	D	
13OCT80	D	D		D	D	
20OCT80	D	D		D	D	
27OCT80	D	D		D	46.7	
03NOV80	D	D		D	76.5	
10NOV80	D	D		D	D	
17NOV80	D	D		D	71.5	
24NOV80	D	D		D	43.9	
01DEC80	D	D		D	50.9	
08DEC80	30.0	28.2	29.1	30.1	26.9	28.5
15DEC80	28.2	D		D	49.0	
22DEC80[2]	D	D		D	40.7	
29DEC80[2]	D	D		D	74.3	
05JAN81[2]	D	D		D	D	
12JAN81[2]	D	D		65.2	71.9	68.6
19JAN81[2]	D	D		66.4	76.8	71.6
26JAN81[2]	D	D		58.4	71.6	65.0
09FEB81[2]	30.0	24.8	27.4	50.3	41.6	46.0
16FEB81[2]	D	D		48.0	38.1	43.1
23FEB81[2]	24.8	D		44.2	40.7	42.5
02MAR81	D	D		44.7	42.4	43.6
09MAR81	D	D		42.1	44.9	43.5
16MAR81	D	D		46.7	49.6	48.2
23MAR81	D	D		45.3	43.1	44.2
30MAR81	D	D		42.9	43.4	43.2
06APR81	D	D		56.8	49.7	53.3
13APR81	D	D		54.9	49.0	52.0

Table A-8. Inbed effluent depths and selected exbed ground water depths in the 02MG30 filter field. (continued)

Date	Well depths, cm from the soil surface					
	Inbed wells			Exbed wells		
	A1	B1	Mean	C3	D3	Mean
20APR81	29.0	D		42.0	42.8	42.4
27APR81	D	D		54.7	49.0	51.9
04MAY81	D	D		55.2	50.8	53.0
11MAY81	D	D		55.5	49.1	52.3
18MAY81	27.5	28.3	27.9	39.0	40.2	39.6
25MAY81	D	D		55.7	52.1	53.9
01JUN81	D	D		43.0	40.3	41.7
08JUN81	D	D		50.0	43.2	46.6
15JUN81	D	D		60.2	58.6	59.4
22JUN81	D	D		59.3	46.4	52.9
29JUN81	D	D		57.1	63.7	60.4
06JUL81	D	D		54.0	41.8	47.9
13JUL81	D	D		57.2	55.2	56.2
20JUL81	D	D		59.7	73.3	66.5
27JUL81	D	D		65.3	73.3	69.3
03AUG81	12.0	7.1	9.6	9.9	12.7	11.3
10AUG81	D	D		57.3	56.6	57.0
17AUG81	27.4	26.9	27.2	41.4	32.4	36.9
24AUG81	D	D		54.8	57.7	56.3
31AUG81	D	D		56.9	56.6	56.8
08SEP81	D	30.0		53.9	49.9	51.9
14SEP81	28.8	28.7	28.8	41.8	43.0	42.4
21SEP81	D	D		54.8	62.1	58.5
28SEP81	D	D		54.1	59.9	57.0
05OCT81	D	D		57.8	67.2	62.5
12OCT81	D	D		39.7	39.6	39.7
19OCT81	D	D		58.3	59.1	58.7

Table A-8. Inbed effluent depths and selected exbed ground water depths in the 02MG30 filter field. (continued)

Date	Well depths, cm from the soil surface					
	Inbed wells			Exbed wells		
	A1	B1	Mean	C3	D3	Mean
26OCT81	29.4	29.9	29.7	40.1	33.9	37.0
03NOV81	D	D		50.4	41.0	45.7
09NOV81	D	D		54.8	56.9	55.9
16NOV81	D	D		D	D	
23NOV81	D	D		53.9	60.2	57.1
30NOV81	28.9	D		33.9	31.4	32.7
07DEC81	D	D		53.2	63.3	58.3
14DEC81	D	D		50.8	62.8	56.8
04JAN82	D	D		42.8	40.5	41.7
18JAN82[2]	D	D		65.8	71.9	68.9
25JAN82	29.7	D		55.6	38.4	47.0
01FEB82	20.5	21.3	20.9	22.8	19.6	21.2
08FEB82	D	D		42.7	39.9	41.3
15FEB82	17.8	18.2	18.0	20.3	13.7	17.0
22FEB82	29.1	28.3	28.7	42.6	40.3	41.5
01MAR82	D	17.2		51.1	39.4	45.3
08MAR82	D	D		46.3	46.7	46.5
15MAR82	25.9	27.0	26.5	37.7	36.7	37.2
22MAR82	D	D		48.0	52.9	50.5
29MAR82	D	D		56.7	69.6	63.2
05APR82	D	D		60.6	70.4	65.5
12APR82	D	D		58.6	65.3	62.0
19APR82	D	D		62.0	72.0	67.0
26APR82	D	D		56.7	52.5	54.6
03MAY82	D	D		57.9	66.3	62.1
10MAY82	D	D		60.2	73.6	66.9
17MAY82	D	D		58.6	62.5	60.6

Table A-8. Inbed effluent depths and selected exbed ground water depths in the 02MG30 filter field. (continued)

Date	Well depths, cm from the soil surface					
	Inbed wells			Exbed wells		
	A1	B1	Mean	C3	D3	Mean
24MAY82	D	D		56.9	61.1	59.0
01JUN82	27.8	29.0	28.4	42.3	39.6	41.0
07JUN82	25.9	27.5	26.7	43.4	41.6	42.5
14JUN82[2]	D	D		53.6	49.8	51.7
16JUN82	16.7	17.5	17.1	20.0	26.9	23.5
21JUN82	29.6	D		55.3	53.5	54.4
28JUN82	25.7	27.0	26.4	40.6	40.1	40.4
05JUL82	D	D		53.9	63.3	58.6
12JUL82	D	D		55.5	67.7	61.6
19JUL82	D	D		65.7	72.7	69.2
26JUL82	D	D		66.4	72.6	69.5
02AUG82	D	D		59.7	65.8	62.8
10AUG82	D	D		59.9	66.0	63.0
16AUG82	D	D		61.5	73.2	67.4
23AUG82	D	D		67.3	72.8	70.1
30AUG82	D	D		68.6	75.5	72.1
07SEP82	D	D		68.8	74.5	71.7
14SEP82	D	D		68.8	74.9	71.9
20SEP82	D	D		65.9	74.8	70.4
27SEP82	D	D		67.3	74.9	71.1
04OCT82	D	D		67.4	74.6	71.0
11OCT82	D	D		66.4	72.5	69.5
18OCT82	D	D		66.8	72.8	69.8
25OCT82	D	D		67.0	68.0	67.5
01NOV82	D	D		66.7	64.1	65.4
08NOV82	D	D		66.5	71.7	69.1
15NOV82	29.7	29.9	29.8	66.3	72.3	69.3

Table A-8. Inbed effluent depths and selected exbed ground water depths in the 02MG30 filter field. (continued)

Date	Well depths, cm from the soil surface					
	Inbed wells			Exbed wells		
	A1	B1	Mean	C3	D3	Mean
29NOV82	26.6	26.9	26.8	27.7	23.8	25.8
06DEC82	28.5	28.4	28.5	43.5	34.6	39.1
13DEC82	28.6	29.0	28.8	42.8	34.8	38.8
03JAN83	28.6	29.3	29.0	57.2	56.0	56.6
10JAN83	28.5	28.4	28.5	57.6	66.5	62.1
17JAN83	27.9	29.1	28.5	62.7	68.4	65.6
24JAN83	27.4	28.1	27.8	56.3	55.7	56.0
01FEB83	19.8	20.1	20.0	18.8	17.3	18.1
08FEB83	27.6	27.8	27.7	58.3	52.6	55.5
14FEB83	27.2	28.0	27.6	60.7	59.9	60.3
21FEB83	27.9	28.3	28.1	60.3	65.0	62.7
28FEB83	27.8	28.5	28.2	64.6	62.6	63.6
07MAR83	27.6	29.4	28.5	60.8	49.1	55.0
14MAR83	27.4	28.2	27.8	63.1	67.9	65.5
21MAR83	27.5	28.2	27.9	62.3	59.3	60.8
28MAR83	26.5	27.5	27.0	62.3	64.6	63.5
04APR83	27.8	28.0	27.9	50.2	49.1	49.7
11APR83	27.5	27.5	27.5	62.3	68.5	65.4
18APR83	27.1	27.8	27.5	61.3	69.4	50.4
25APR83	26.6	27.1	26.9	42.2	40.1	41.2
02MAY83	25.7	27.1	26.4	44.7	44.0	44.4
09MAY83	26.8	27.8	27.3	60.6	72.6	66.6
16MAY83	26.4	27.3	26.9	56.6	47.3	52.0
23MAY83	25.9	27.1	26.5	38.1	33.5	35.8
31MAY83	26.2	27.8	27.0	39.3	39.0	39.2
06JUN83	26.1	27.2	26.7	40.3	41.7	41.0
13JUN83	25.6	27.5	26.6	56.1	64.7	60.4

Table A-8. Inbed effluent depths and selected exbed ground water depths in the 02MG30 filter field. (continued)

Date	Well depths, cm from the soil surface					
	Inbed wells			Exbed wells		
	A1	B1	Mean	C3	D3	Mean
20JUN83	25.7	26.8	26.3	50.1	62.9	56.5
01JUL83	29.2	D		59.3	59.8	59.6
06JUL83	29.1	D		65.3	70.1	67.7
11JUL83	28.1	29.1	28.6	67.4	72.7	70.1
18JUL83	26.9	28.1	27.5	59.7	62.3	61.0
25JUL83	D	D		68.1	73.3	70.7
01AUG83	D	D		68.2	73.5	70.9
08AUG83	D	D		68.5	73.1	70.8
15AUG83	D	D		68.1	73.3	70.7
23AUG83	D	D		D	D	
30AUG83	D	D		69.1	74.1	71.6
07SEP83	D	D		69.6	73.2	71.4
12SEP83	D	26.4		69.7	73.2	71.5
20SEP83	D	D		69.4	73.9	71.7
26SEP83	D	D		69.5	74.5	72.0

---

[1] D indicates the well was dry

[2] Data significantly influenced by malfunction of the effluent delivery system. Details of malfunctions given in Appendix Table A-3.

Table A-9. Selected exbed ground water depths before dosing in the 10MP40 filter field.

Date	Well depths, cm from soil surface		
	Exbed wells		
	NE2	SE2	Mean
12JUL82	59.7	D[1]	
19JUL82	D	D	
26JUL82	D	D	
02AUG82	48.0	45.2	45.1
10AUG82	D	51.3	
16AUG82	D	D	
23AUG82	D	D	
30AUG82	D	D	
07SEP82	D	D	
14SEP82	D	D	
20SEP82	D	D	
27SEP82	D	D	
04OCT82	D	D	
11OCT82	D	D	
18OCT82	D	D	
25OCT82	D	D	
01NOV82	58.1	56.2	57.2
08NOV82	56.3	56.9	56.6
15NOV82	55.6	54.1	54.9
29NOV82	13.0	20.5	16.8
06DEC82	34.3	22.8	28.6
13DEC82	39.5	33.7	36.6
20DEC82	59.4	47.2	53.3
03JAN83	53.7	32.5	43.1
10JAN83	55.0	43.5	49.3
17JAN83	55.9	46.5	51.2
24JAN83	44.2	32.0	38.1

Table A-9. Selected exbed ground water depths before dosing in the 10MP40 filter field. (continued)

	Well depths, cm from soil surface		
	Exbed wells		
Date	NE2	SE2	Mean
01FEB83	21.5	19.5	20.5
08FEB83	50.2	33.1	41.7
14FEB83	52.6	42.7	47.7
21FEB83	56.8	50.8	53.8
28FEB83	56.1	50.1	53.1
07MAR83	43.2	39.3	41.3
14MAR83	50.9	51.5	51.2
21MAR83	46.3	39.3	42.8
28MAR83	45.8	41.8	43.8
04APR83	26.3	32.6	29.5
11APR83	51.6	52.6	51.9
18APR83	51.2	47.0	49.1
25APR83	30.0	29.8	29.9
02MAY83	34.8	30.3	32.6
09MAY83	50.6	D	
16MAY83	42.2	32.5	37.4
23MAY83	41.2	40.2	40.7
31MAY83	45.9	46.9	46.4
06JUN83	47.8	44.0	45.9
13JUN83	51.5	D	
20JUN83	52.2	59.4	55.8
01JUL83[2]	56.4	D	
06JUL83	59.2	D	
11JUL83	D	D	
18JUL83	D	59.3	
25JUL83	D	D	
01AUG83	D	D	

Table A-9. Selected exbed ground water depths before dosing in the 10MP40 filter field. (continued)

	Well depths, cm from soil surface		
	Exbed wells		
Date	NE2	SE2	Mean
08AUG83	D	D	
15AUG83	D	D	
23AUG83	D	D	
07SEP83	D	D	
20SEP83[2]	D	D	
26SEP83	D	D	

---

[1] D indicates the well was dry.

[2] Data significantly influenced by malfunction of the effluent delivery system. Details of malfunctions given in Appendix Table A-4.

Table A-10. Selected exbed ground water depths before dosing in the 11MP40 filter field.

	Water depths, cm from the soil surface		
Date	NE2	SW2	Mean
19JUL82	47.6	44.2	45.9
26JUL82	51.7	D[1]	
02AUG82	41.0	D	
10AUG82	46.8	D	
16AUG82	48.7	D	
23AUG82	D	D	
30AUG82	D	D	
07SEP82	D	D	
14SEP82	D	D	
20SEP82	D	D	
27SEP82	D	D	
04OCT82	D	D	
11OCT82	D	D	
18OCT82	D	D	
25OCT82	D	D	
01NOV82	D	53.8	
08NOV82	44.7	50.5	47.6
15NOV82	42.8	50.8	46.8
29NOV82	27.0	44.8	35.9
06DEC82	23.5	43.1	33.3
13DEC82	41.9	40.8	41.4
20DEC82	39.7	49.2	44.5
03JAN83	33.6	39.0	36.3
10JAN83	36.0	38.8	37.4
17JAN83	37.1	38.4	37.8
24JAN83	38.0	49.4	43.7
01FEB83	30.0	41.0	35.5

Table A-10. Selected exbed ground water depths before dosing in the 11MP40 filter field. (continued)

	Water depths, cm from the soil surface		
Date	NE2	SW2	Mean
08FEB83	34.2	45.3	39.7
14FEB83	35.1	42.0	38.6
21FEB83	36.5	43.9	40.2
28FEB83	35.9	43.0	39.5
07MAR83	30.2	43.0	36.6
14MAR83	35.9	42.7	39.3
21MAR83	35.2	43.3	39.3
28MAR83	D	42.7	
04APR83	21.8	42.5	32.2
11APR83	29.9	42.7	36.3
18APR83	31.8	42.3	37.1
25APR83	21.2	54.3	37.7
02MAY83	23.2	52.8	28.0
09MAY83	35.0	52.8	43.9
16MAY83	26.7	52.7	39.7
23MAY83	28.5	D	
31MAY83	38.0	52.3	45.2
06JUN83	35.5	52.5	44.0
13JUN83	41.4	52.2	46.8
20JUN83	43.8	52.6	48.2
01JUL83[2]	42.8	52.7	47.8
06JUL83	45.6	53.0	49.3
11JUL83	50.1	53.5	51.8
18JUL83	50.0	D	
25JUL83	D	D	
01AUG83	D	D	
08AUG83	D	D	

Table A-10. Selected exbed ground water depths before dosing in the 11MP40 filter field. (continued)

	Water depths, cm from the soil surface		
Date	NE2	SW2	Mean
15AUG83	D	D	
23AUG83	D	D	
07SEP83	D	D	
20SEP83[2]	D	D	
26SEP83	D	D	

[1] D indicates the well was dry.

[2] Data significantly influenced by malfunction of the effluent delivery system. Details of malfunctions given in Appendix Table A-4.