A FIELD COLUMN STUDY TO DETERMINE THE EFFECTIVENESS OF DIFFERENT COVER MATERIALS IN REDUCING INFILTRATION INTO A COPPER MILL TAILINGS WASTE PILE

By

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Hydrology Report No. H89-2

(Formerly Open File Report No. 89-2)

NEW MEXICO TECH HYDROLOGY REPORT SERIES

HYDROLOGY PROGRAM
SOCORRO, NEW MEXICO 87801

May, 1989

This report was also submitted by Lori J. Williamson as an Independent Study in partial fulfillment of the requirements of the M.S. Degree in Hydrology

Research sponsored by:
U.S.B.M. Generic Research Center Waste Treatment and Recovery Division
Reno, Nevada
Grant No. G1175132

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An Independent Study Submitted in Partial Fulfillment
of the Requirement for the Degree
Master of Science in Hydrology

New Mexico Institute of Mining and Technology
Socorro, New Mexico

May 1, 1989

ABSTRACT

The purpose of this study was to determine the effectiveness of applying low permeable cover materials to copper mill tailings waste piles in order to reduce infiltration into, and subsequent leachate generation from, these piles. Leachate from these piles may contaminate underlying aquifers unless some type of remedial effort is taken.

Four field columns were packed with copper mill tailings and capped with different cover materials. The cover materials included a 50–50 mixture of copper mill tailings and bentonite clay, a fine-textured soil underlain by a gravel, a 95–5 mixture of tailings and bentonite, and a 100% tailings cover, which served as a control for the experiment. Initially bromide, and later four fluorinated organic tracers, were applied to the base of the cap materials. The columns were left outside at a field site adjacent to the New Mexico Tech campus in Socorro, NM for a period of 3.6 years. Precipitation averaged 9.8cm per year while lake evaporation averaged 36.3cm per year over the course of the experiment. Effluent was periodically sampled from the bottom of each column and analyzed. In addition, the columns were monitored with tensiometers, and precipitation and evaporation records were kept. The columns were later removed from the field and sectioned in order to determine the tracer concentration distribution and the moisture content distribution in each column. *In-situ* and repacked rings samples of the cap materials were obtained to undergo hydraulic characterization. Cap material effectiveness was gauged by evolution of the effluent records, tensiometric data, and the tracer concentration and moisture content distributions of the columns.

The experiment revealed that a cap material composed of 5% bentonite was nearly as effective in reducing infiltration as one composed of 50% bentonite. This may have been due to severe cracking in the 50% bentonite clay cap which was virtually nonexistent in the 5% cap. The 5% and 50% bentonite materials reduced infiltration by 13.5% and 19.8% relative to the 100% tailings material. The cap material composed of a fine-textured soil underlain by a gravel was ineffective in reducing infiltration which was directly related to the consolidation of the upper soil due to settling of the gravel beneath. This cover material was 17.1% *less* effective in reducing infiltration than the 100% tailings cover. All of the columns revealed a significant downward migration of tracers and moisture. Bromide proved to be a fairly effective soil-water tracer while the fluorinated organic tracers did not perform well, primarily due to the low pH of the copper mill tailings medium.

ACKNOWLEDGEMENTS

Funds for this research were provided by the U.S. Bureau of Mines Generic Research Center Waste Treatment and Recovery Division at Reno, Nevada.

The following individuals contributed to this research: Deborah McElroy, Gregory Lewis, Alva Parsons–Mattson, Robert Mace, Robert Liddle, Joseph Gibbens, David Grabka and Patrick (Rick) Dotson.

ACKNOWLEDGEMENTS

I gratefully acknowledge the support and suggestions provided by Dr. Daniel B. Stephens and Dr. Robert S. Bowman during the course of this research. In addition, I acknowledge the U.S.B.M. Generic Research Center Waste Treatment and Recovery Division at Reno, Nevada which supplied the funds necessary to purchase equipment and supplies for this research.

I owe a great deal of thanks to Deborah McElroy and Gregory Lewis for their efforts in constructing the original experiment and for monitoring the columns during the early stages of the experiment. I am also indebted to Alva Parsons–Mattson and Robert Mace for continuing to monitor the experiment after Deb and Greg had completed their work on the project.

I gratefully acknowledge the assistance provided by Robert Liddle, Joseph Gibbens, and David Grabka in the HPLC lab. Thanks is also extended to the Physical Plant for transporting the columns to the field site and then back to the laboratory.

Finally, special thanks goes to Patrick (Rick) Dotson for his assistance in monitoring the experiment, his suggestions, and his overall support.

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1.0. INTRODUCTION

1.1. BACKGROUND

Copper mill tailing waste piles found throughout the Southwest pose a potential threat to the groundwater. Mill tailings are the fines that have been collected after the crushing and processing of ore. Infiltration of precipitation through these waste piles may release undesirable metal ions into the subsurface environment and may eventually contaminate groundwater supplies. The leachate typically contains a significant amount of iron, copper, manganese, and zinc, and lesser amounts of cobalt, nickel, and lead. Iron and manganese are regulated in drinking water primarily due to aesthetic reasons. Although copper and zinc are relatively non–toxic to animals, these metals are quite toxic to plants. Cobalt, nickel, and lead may cause serious sickness or death if present in the drinking water. Many people in the Southwest use domestic wells as their sole supply of drinking water, and their water supplies may be threatened by these waste piles.

Until recent years, the study of groundwater contamination due to mill tailings focused primarily on uranium tailings due to the insidious nature of radioactive contamination. The realization that copper mill tailings were a serious threat, also, has driven many people, including myself, to search for solutions to this problem.

In order to reduce infiltration, low permeable cap materials may be applied to the tailings, but the long term effectiveness of these materials is unknown (Stephens, 1985). This study was meant to quantify the effectiveness of different cap materials in reducing the downward percolation of precipitation. In order to approximate field conditions, the experiment was conducted outside in the semi–arid climate of Socorro, New Mexico. The source of the tailings was a copper mill tailings impoundment in Tyrone, New Mexico. Although a copper mill tailings medium was used in this study, the results may be applied to other tailings piles with similar hydraulic characteristics which are found in similar climatic settings.

Synthetic and natural liners have long been used in hazardous waste and sanitary landfill design, but mill tailings waste piles have been created over the years with no such foresight. Since many of these waste piles are located in semi–arid regions with thick vadose zones and deep water tables, it was generally assumed that seepage through the mill tailings would be insignificant compared to the storage available in the vadose zone. Unfortunately, this has been shown to be an erroneous assumption. Now, as a remedial action, the idea of covering these vast waste piles with some type of low permeability material has been proposed (Stephens, 1985).

In order to evaluate the effectiveness of different cover materials in retarding infiltration, four field–scale columns were set up adjacent to the New Mexico Tech campus in Socorro, NM. Each column was capped with a different cover material, and tracers were applied to the base of the cap materials. The columns were monitored with tensiometers and thermistors, and effluent was periodically extracted from the bottom of each column. In addition, precipitation and evaporation records were kept.

The only source of water to these columns was natural precipitation, with the exception of the tracers which were applied in the liquid form and tensiometer fluid which occasionally leaked into the columns. Over the course of the experiment, evaporation greatly exceeded precipitation, and in such instances, it is often assumed that deep infiltration, or recharge, is negligible. This may be an erroneous assumption for New Mexico where severe thundershowers often produce a significant amount of rainfall over a very short time period. At a sandy, sparsely vegetated site about 20 miles north of Socorro, New Mexico, Stephens and Knowlton (1986) used tensiometers and a neutron probe access tube to monitor soil water movement and concluded that approximately 20% of the 17.9cm of annual precipitation may contribute to recharge. Phillips (1984) also found a net downward movement of water in his research near Socorro, New Mexico.

1.2. PREVIOUS WORK

This particular copper mill tailings sand from Tyrone, New Mexico has been the focus of more recent investigations at New Mexico Tech (Larson, 1984; Larson and Stephens, 1985; Lewis, 1986; McElroy, 1987). Larson (1984) and Larson and Stephens (1985) used various techniques to establish the saturated and unsaturated hydraulic characteristics of this medium. The results of their analyses have served as a foundation for further investigations.

Lewis (1986) studied infiltration and solute transport phenomena in the beach sand fraction of the copper mill tailings. These experiments revealed that under relatively dry conditions, there was a net downward migration of bromide tracer. Furthermore, it was shown that significant downward movement may occur simply due to diffusion in the unsaturated media.

McElroy (1987) studied dispersion phenomena in columns of unsaturated copper mill tailings sand and arrived at a mean dispersivity of 2.8cm for a column similar in dimensions to those in the current study.

A similar material from a mill tailings impoundment in Arizona was the focus of an experimental–numerical unsaturated flow study (Terauds, 1985). This study utilized two of the tracers which were used in the current study, namely pentafluorobenzoic acid (PFBA) and meta–(trifluoromethyl) benzoic acid (m–

TFMBA). Terauds (1985) found channeling to be the major mechanism of leachate flow through a copper mill tailings sand waste heap, and she found the tracers PFBA and m–TFMBA to be an effective means by which to monitor this flow.

Other investigators believe that some type of preferential flow is responsible for the deep transport of water and solutes that cannot be explained based on a region's water balance. Bowman and Rice (1984), for example, found that the deep percolation rates in a large–scale field study involving a sandy–loam material were up to five times faster than predicted by a simple water balance study.

1.3. RESEARCH OBJECTIVES

In summary, the three main objectives of this experiment were:

> (1.) quantify the effectiveness of different cap materials in reducing infiltration into a copper mill tailings waste pile.
>
> (2.) characterize the hydraulic properties of the different cap materials.
>
> (3.) evaluate the effectiveness of four relatively new fluoro–organic tracers for use in soil–water studies involving copper mill tailings.

The first and most important objective was to determine the relative effectiveness of three different cover materials in reducing infiltration through a copper mill tailings waste pile. The cover materials included a volumetric mixture of 50% tailings and 50% bentonite and one of 95% tailings and 5% bentonite. Another cover material, consisting of a fine–textured soil underlain by a gravel, was used in an attempt to create a hydraulic flow barrier. A fourth column, consisting of 100% copper mill tailings, was used as a standard, or control, for the experiment.

The second objective was to characterize the hydraulic properties of the different cap materials and the tailings medium itself. This was necessary in order to accomplish the main objective of determining the effectiveness of the different cover materials.

The final objective was to determine the effectiveness of the fluoro–organic tracers. These tracers had never been used in a medium of this type for the period of time that was necessary in this study.

2.0. SOIL MOISTURE FLOW CONCEPTS

2.1. INTRODUCTION

This chapter will address basic soil moisture flow concepts, such as infiltration, evaporation, redistribution, and flow due to temperature gradients, as well as the phenomena associated with moisture flow into, out of, and through a profile exhibiting an upper fine-textured layer (i.e., a cap material) underlain by a coarse-textured material. The cap materials employed in this study included a volumetric mixture of 50% tailings and 50% Wyoming bentonite clay, a gravel overlain by a fine-textured soil, and a mixture of 95% tailings and 5% bentonite. In addition, a column consisting of 100% tailings was used as a control for the experiment.

2.2. BASIC MATHEMATICAL MODEL

The basic mathematical expression for one-dimensional, unsteady vertical water flow through a soil column is:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left(K\frac{\partial \psi}{\partial z}\right) + \frac{\partial K}{\partial z} \qquad (2.1)$$

where: θ = volumetric moisture content (L^3/L^3)
t = time (T)
z = vertical distance (L); by definition it is positive upward
K = hydraulic conductivity (L/T)
ψ = matric suction (L)

The term, $\frac{\partial K}{\partial z}$, represents the downward force due to gravity. This is one form of the Richard's equation.

The hydraulic diffusivity (D) is defined as:

$$D = K\left(\frac{\partial \psi}{\partial \theta}\right) \tag{2.2}$$

where: D = hydraulic diffusivity (L^2/T).

When substituted into equation (2.1), it yields the θ–based form of the flow equation:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} D\left(\frac{\partial \theta}{\partial z}\right) + \frac{\partial K}{\partial z} \tag{2.3}$$

The specific moisture capacity (C) is defined as:

$$C(\psi) = \frac{\partial \theta}{\partial \psi} \tag{2.4}$$

where: C(ψ) = specific moisture capacity (1/L)

When substituted into equation (2.1), it yields the ψ–based form of the flow equation:

$$C(\psi)\frac{\partial \psi}{\partial t} = \frac{\partial}{\partial z}\left(K\frac{\partial \psi}{\partial z}\right) + \frac{\partial K}{\partial z} \tag{2.5}$$

2.3. INFILTRATION

Infiltration is controlled by a number of factors. The duration of the rainfall event is important because the infiltration rate decreases with time, approaching a final relatively constant value. Infiltration rate is usually higher for a soil with a higher saturated hydraulic conductivity. The type of soil is important, also; clay soils, for example, tend to swell and clog the pore spaces thereby reducing infiltration. Other factors include the pressure head gradient between the wetting front (at depth) and the infiltrating water at the top, capillary phenomena, and entrapped air (Hillel, 1980b).

Bodman and Colman (1943) performed series infiltration experiments into a Yolo sandy loam and a Yolo silt loam with ponded water at the surface. They concluded that the infiltration rate will approach a final constant value which is determined by the potential gradient and the soil permeability (i.e., hydraulic conductivity). The infiltration profiles that they discovered have become the classical model of the moisture content distribution during infiltration; a typical profile is shown in figure 2.1. The profile is characterized by a saturated zone immediately below the ponded water at the surface, a transmission zone of relatively uniform moisture content, and a wetting zone that decreases in moisture content down to the wetting front. Hillel (1980b) believes that this type of moisture content distribution profile probably does not exist in finer-textured soils.

When the rainfall rate exceeds the saturated hydraulic conductivity (K_s) of the soil, water will pond at the soil surface, and the moisture content versus time relationship will resemble that of figure 2.2. From the figure, it is apparent that the infiltration rate (i) is initially very high; then it decreases and finally, i approaches the K_s of the material as the hydraulic gradient goes to one, assuming

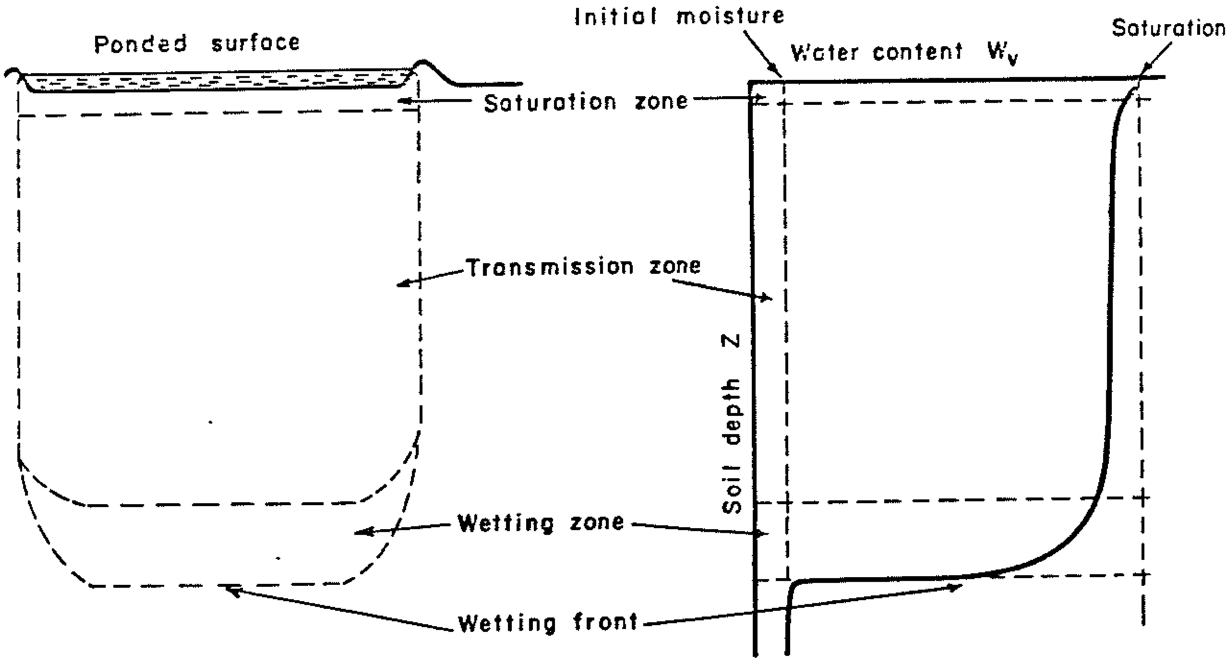


Figure 2.1. The classical infiltration moisture content profile of Bodman and Colman (1943) with ponded water at the surface (Hillel, 1980b).

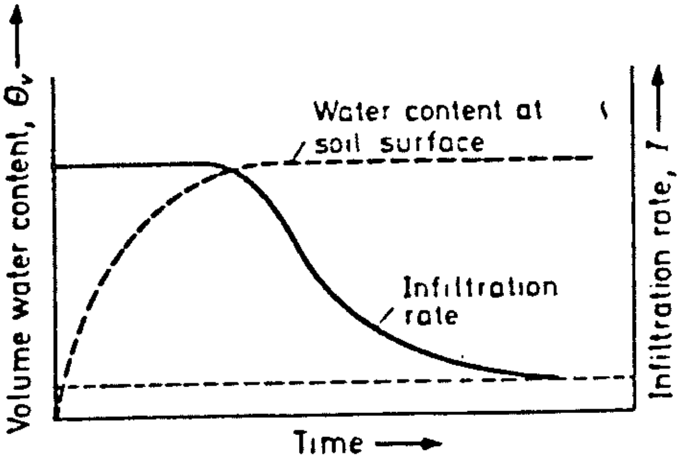


Figure 2.2. Infiltration rate as a function of time when the rainfall rate exceeds the saturated hydraulic conductivity of the soil, allowing ponding to take place at the soil surface (Hanks and Ashcroft, 1980).

the soil is sufficiently thick (Hanks and Ashcroft, 1980).

Philip (1957) developed a numerical solution for vertical infiltration into a homogeneous soil with a thin film of water ponded at the surface such that the pressure head was essentially zero at the upper boundary of the soil. For Philip's equations to apply, the upper soil surface must remain saturated. This condition is satisfied when the rainfall rate exceeds the saturated hydraulic conductivity of the soil surface.

Philip (1957) solved equation (2.1) subject to the conditions: $\theta=\theta_i$ for $t=0$ and $z<0$, and $\theta=\theta_o$ for $t>0$ and $z=0$. The solution is a power series in t^2. A complete formulation of the infiltration equations derived by Philip is not necessary for the purposes of this study. It should suffice to say that the power series converges rapidly for the range of values commonly encountered in soil-water studies. As an approximation, the equations for cumulative infiltration and infiltration rate may be expressed in truncated form as:

$$I(t) = St^{1/2} + Kt \qquad (2.6)$$

and

$$i(t) = \frac{1}{2}St^{-1/2} + K \qquad (2.7)$$

where: I = cumulative evaporation (L)
i = infiltration rate (L/T)
S = coefficient known as the sorptivity ($L/T^{1/2}$)
K = hydraulic conductivity of the transmission zone (L/T); equivalent to K_s under ponding conditions
t = time (T)

When the rainfall rate is less than the saturated hydraulic conductivity of the soil surface, water will never pond at the surface, and Philip's solutions will not apply. In this situation, which is shown in figure 2.3, the infiltration rate will be equal to the rainfall rate. Furthermore, the hydraulic gradient will approach one, and the hydraulic conductivity at the soil surface will approach a value corresponding to the moisture content at the soil surface (Hanks and Ashcroft, 1980).

2.3.1. INFILTRATION IN THE PRESENCE OF A SURFACE CRUST

Raindrop impacts may partially compact a soil, especially clay soils, causing a dense surface crust to form. This phenomena will reduce the permeability of the soil at the surface which will reduce the initial infiltration rate as well as reducing the cumulative infiltration as shown in figure 2.4.

Hillel and Gardner (1970) quantified transient infiltration into soils with a surface crust. The model assumed that the soil was initially dry and that the crust was thin enough to saturate immediately. The following equation was developed for cumulative infiltration (I) into a crust–topped soil:

$$I = (K_u^2 R_c^2 (\Delta\theta)^2 + 2K_u H_f \Delta\theta t)^{\frac{1}{2}} - K_u R_c = S t^{\frac{1}{2}} \qquad (2.8)$$

where: $S = (2K_u H_f \Delta\theta)^{\frac{1}{2}}$

Hillel and Gardner (1970).

where: I = cumulative infiltration (L)
K_u = hydraulic conductivity of the sub–crust (L/T)
R_c = hydraulic crust resistance (T)
$\Delta\theta$ = moisture content increment = $\theta_i - \theta_o$

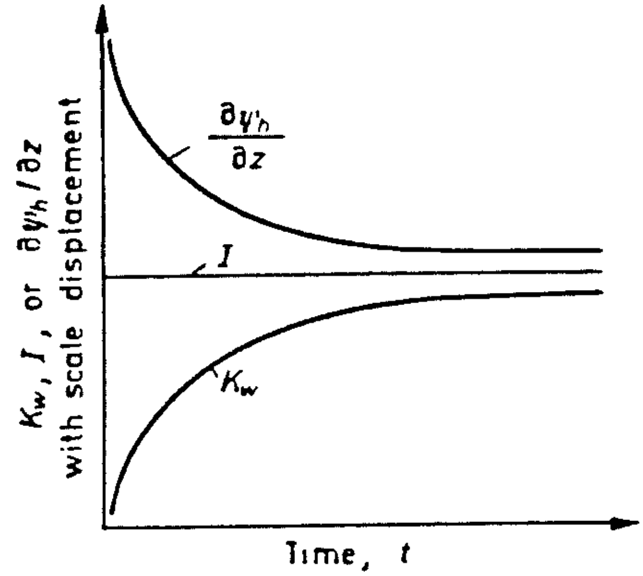


Figure 2.3. Infiltration rate as a function of time when the rainfall rate is less than the saturated hydraulic conductivity of the soil (Hanks and Ashcroft, 1980).

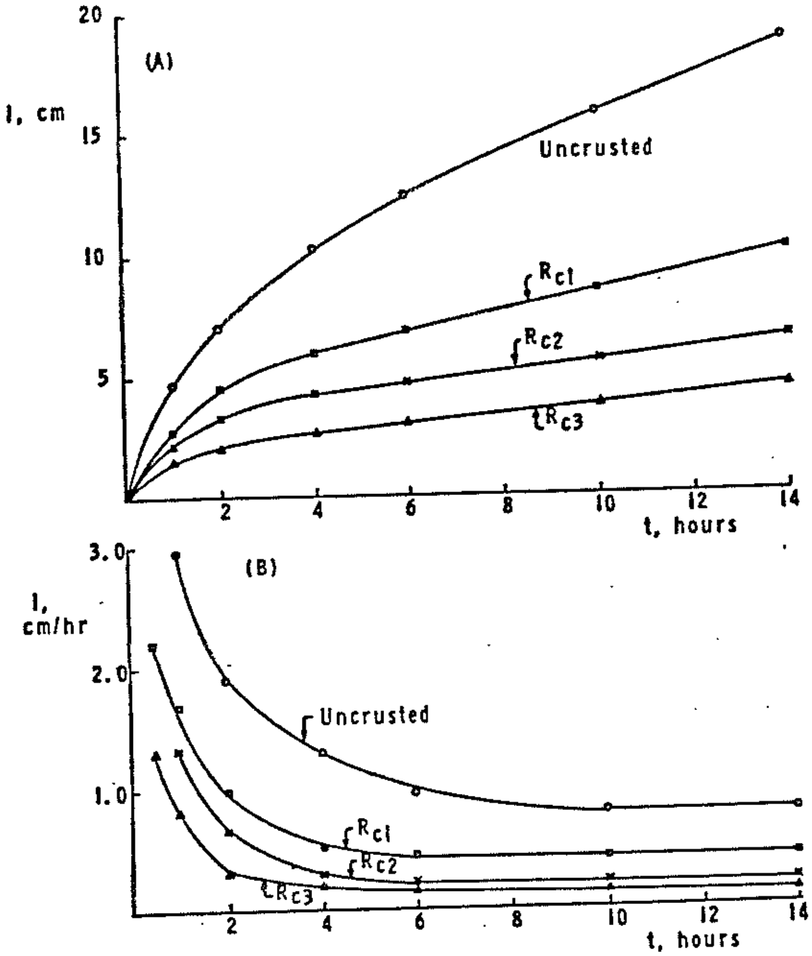


Figure 2.4. Effect of a surface crust on infiltration rate (top figure) and on cumulative infiltration (bottom figure). The crusted soils (R_{c3}, R_{c2}, R_{c1}) vary in their resistance to flow, with R_{c3} being the most resistant and R_{c1} being the least resistant (Hillel and Garnder, 1970).

θ_i = transmission zone moisture content during infiltration
θ_o = original moisture content
H_f = pressure head at the wetting front (L)
t = time (T)
S = coefficient known as the sorptivity ($L/T^{1/2}$)

In addition, Hillel and Gardner (1970) identified three stages of infiltration into crust-topped soils:

(1.) an initial stage where the infiltration rate is finite and depends on the resistance of the crust and on the suction in the soil column.

(2.) a second stage where cumulative infiltration increases approximately as the square root of time.

(3.) and a final stage where the cumulative infiltration equals the sum of the steady and the transient terms.

If unstable flow phenomena exists, which will be discussed in the following section, the stages described above will not apply (Hillel, 1980b).

2.3.2. INFILTRATION INTO STRATIFIED SOILS

Neglecting the formation of a surface crust, the addition of a cap material creates a two-layer soil profile which behaves differently than a single homogeneous soil profile. The equation for saturated, steady-state flow through a two-layer soil profile is given by:

$$q = \frac{H + D_1 + D_2}{\frac{D_1}{K_1} + \frac{D_2}{K_2}} \tag{2.9}$$

(Bear and Zaslavsky, 1968).

where: q = flux through the profile (L/T)
H = head at the soil surface; i.e., ponding depth (L)
K_n = hydraulic conductivity through layer n (L/T)
D_n = saturated thickness of layer n (L)
1 = upper layer
2 = lower layer

Unsaturated conditions persist in the lower layer as long as the ponding depth (H) satisfies the condition (Bear and Zaslavsky, 1968):

$$H < D_1\left(\frac{K_2}{K_1} - 1\right) \qquad (2.10)$$

From equation 2.10, it is evident that when a fine-textured soil overlies a coarser-textured soil, it would require either a large head of water or a very thin upper layer in order to maintain saturated conditions in the subsoil. The pressure head distribution in a profile with a fine-textured soil overlying a coarser-textured soil with ponded water at the soil surface is depicted in figure 2.5.

In layered soils the moisture content and the hydraulic conductivity may change abruptly at the interface (Miller and Gardner, 1962). Figure 2.6 illustrates the discontinuity in moisture content which may occur at the boundary between layers.

In addition to the phenomena just described, unstable flow conditions may exist in a two-layered profile with a fine-textured soil overlying a coarse-textured soil when water is ponded at the surface. This unstable flow leads to finger-like protrusions in the lower coarse-textured layer as shown in figure 2.7 (Hillel, 1980b, after Hill and Parlange, 1972; Raats, 1973; Philip, 1975). This phenomena may be important in column #1 (50% bentonite cover) because ponding was sometimes observed on top of this column. This phenomena would not have occurred

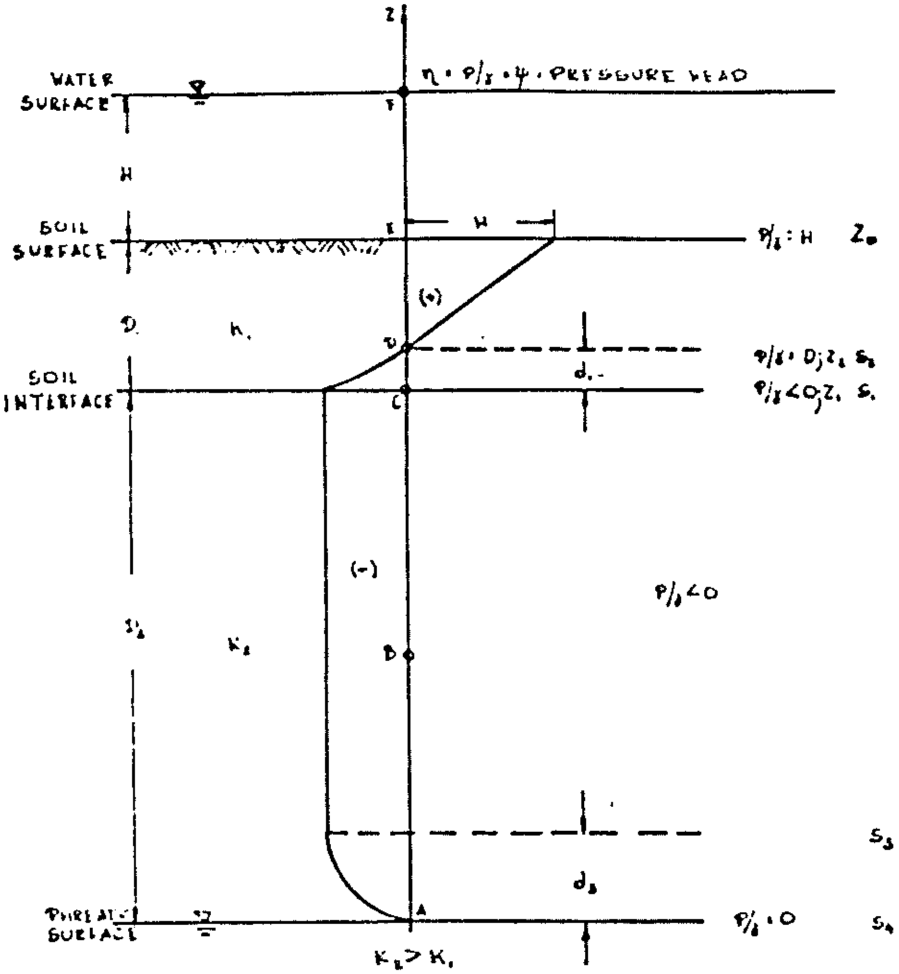


Figure 2.5. Pressure head distribution during unsaturated steady-state flow through a two-layer profile with a fine-textured layer overlying a coarser-textured layer and ponded water at the surface (Bear and Zaslavsky, 1968).

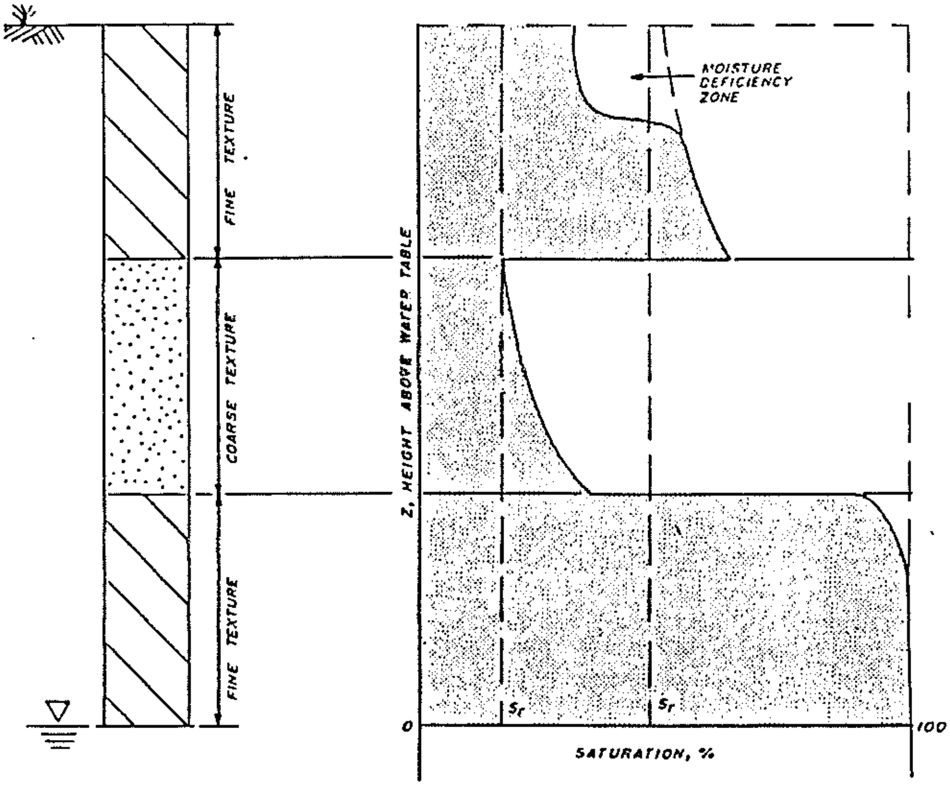


Figure 2.6. A field moisture content profile illustrating the abrupt discontinuities in moisture content that may take place at the interface between layers of different soil texture (Martin and Koerner, 1983).

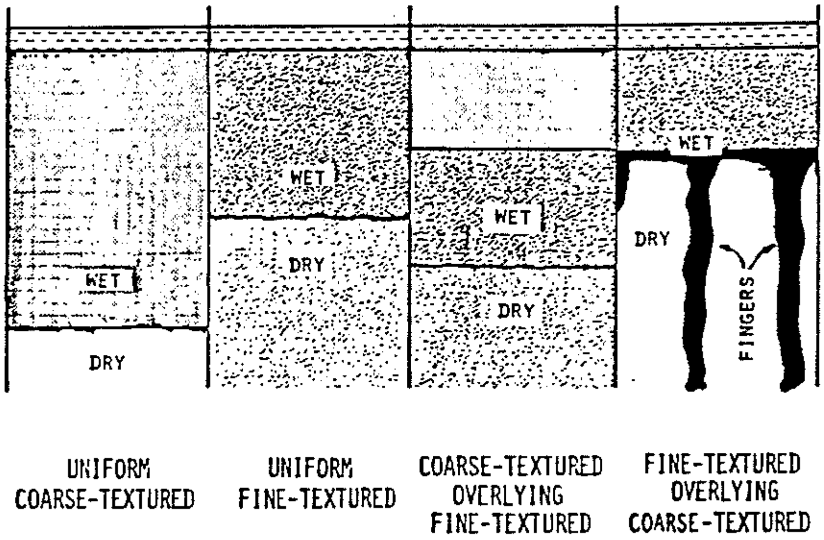


Figure 2.7. Unstable flow phenomena that may exist when a fine-textured soil overlies a coarse-textured soil as shown in figure 2.6 (Hillel, 1980b).

in column #4 (100% tailings cover), of course, because it was a homogeneous soil profile.

2.3.3. INFILTRATION INTO SOILS EXHIBITING SHRINKAGE CRACKS

Several researchers have examined the influence of shrinkage cracks upon infiltration (Bouma and Dekker, 1978; Hoogmoed and Bouma, 1980; among others). Bouma and Dekker (1978) examined preferential flow through the cracks in an unsaturated clay soil and coined the term "short-circuiting" to describe this flow. Water was ponded at the surface of a cracked clay soil, and a dilute methylene blue solution was used to trace the water movement. When the experiment was completed, the soil was sectioned and the pattern of blue dye was observed. The results lead Bouma and Dekker (1978) to conclude that water moved through these cracks, and as precipitation continued, the water created new pathways through which to flow. The absorption of water into the unsaturated soil clods between these cracks was insignificant in comparison.

Hoogmoed and Bouma (1980) studied infiltration into a heavy clay soil exhibiting shrinkage cracks, and they developed a model to simulate this phenomena. The model considered the following: vertical infiltration into the upper surface of the peds, downward flow into the cracks, and horizontal absorption from the cracks into the peds. All of the experiments conducted for the model were carried out for a short enough time period that swelling of the soil was not a factor. In the simulation, flow of water into the cracks was assumed to begin after a threshold ponding depth was achieved. Water was applied to an initially dry and an initially moist sample at rates of 20cm/d and 75cm/d for a period of five hours. As predicted, short-circuiting began once the threshold ponding depth was achieved, and it was greatest for the initially moist sample. In addition, horizontal absorption into the peds was negligible. The vertical infiltration rate and the horizontal absorption rate were found to be independent of the depth of ponding (Hoogmoed and Bouma, 1980).

In summary, it appears that under ponded conditions, the dominant mode of downward water transport in a cracked clay soil is through the cracks rather than through the soil itself. This is an extremely important finding since the hydraulic conductivity of a clay is usually very low, and gross underestimates of infiltration may occur if the cracks are not taken into consideration.

2.4. EVAPORATION

Evaporation is controlled by atmospheric conditions and soil surface conditions. Atmospheric conditions include air temperature, humidity, wind velocity, and radiation, while soil surface conditions include soil color, surface roughness, soil texture (grain-size), soil wetness, and depth to the wetting front (Hillel, 1980a). The effect of soil texture on evaporation, for example, is shown in figure 2.8.

The evaporation rate (E) from the soil surface is some value less than the potential evaporation rate (E_p), and this may be expressed in terms of a relative evaporation rate (E_r), defined as E/E_p. The actual rate is controlled by the atmospheric demand and the soil's ability to transmit or supply water to the surface. Under unsaturated conditions, evaporation is limited by the K–ψ relationship of the soil, a topic which will be addressed in the following chapter.

Initially, when the soil is saturated and the supply of water is not limited, the evaporation rate is equal to the potential rate, but as time increases, E and E_r

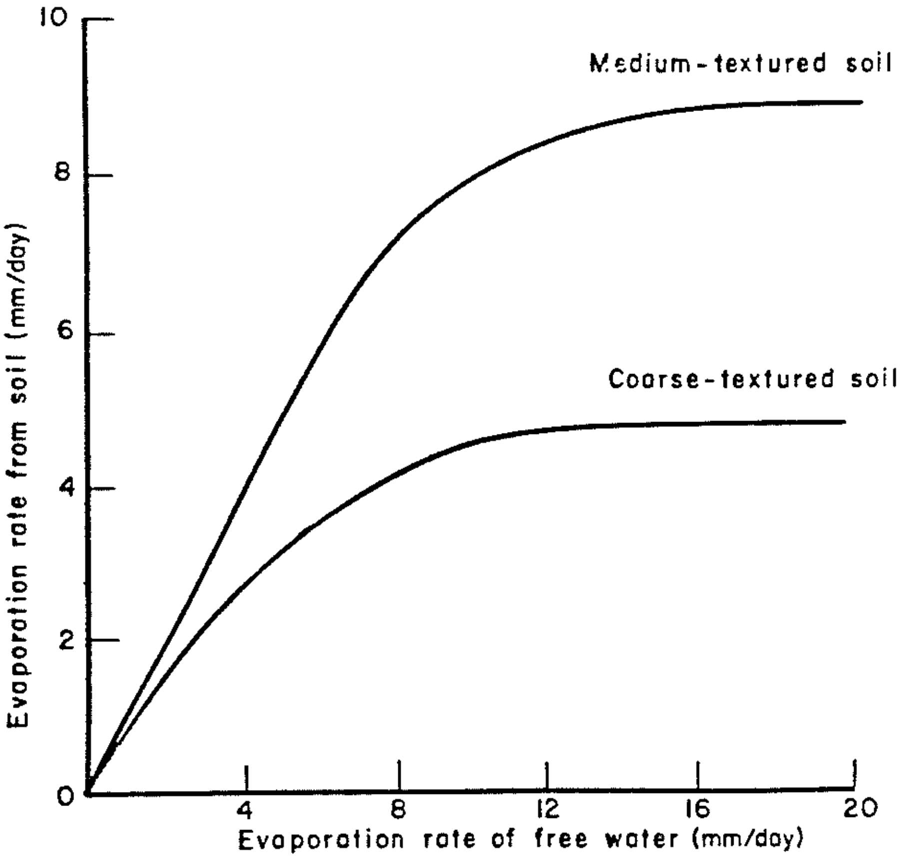


Figure 2.8. Effect of soil texture on evaporation rate (Hillel, 1980b).

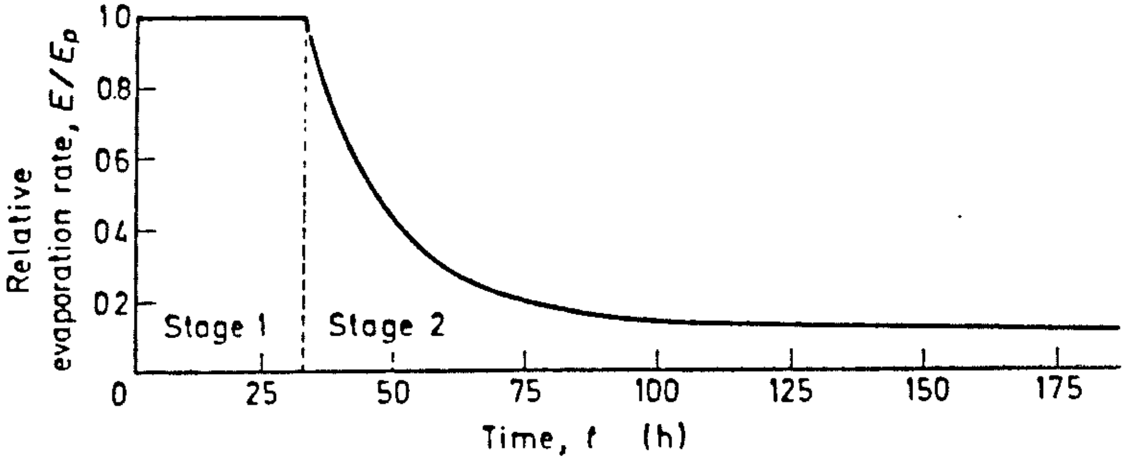


Figure 2.9. Stages of evaporation from a profile initially saturated at the soil surface (Hanks and Ashcroft, 1980).

decrease due to the increased resistance to flow as the pores desaturate (see figure 2.9). During the final stage, the soil is so desiccated that evaporation occurs only through slow vapor diffusion (Hanks and Ashcroft, 1980).

Black et al. (1969) found that under natural rainfall conditions, cumulative evaporation was approximately proportional to the square root of time, regardless of the stage of evaporation. Furthermore, the more rapid the wetting rate, the lower the cumulative evaporation will be. This is an important point since rainfall events in New Mexico are typically severe showers, and therefore, cumulative evaporation should be much lower than the potential.

2.4.1. EVAPORATION FROM SOILS EXHIBITING SHRINKAGE CRACKS

Shrinkage cracks may significantly enhance evaporation, and the effects may become even more significant with time. This phenomena has been examined by many researchers including Adams and Hanks, 1964; Selim and Kirkham, 1970; Ritchie and Adams, 1974; among others. Just as a shrinkage crack allows water to infiltrate deeper into the profile as discussed in section 2.3.3, it also allows evaporation to extend deeper into the profile. Figure 2.10 illustrates the moisture content distribution around an extensive shrinkage crack. The moisture contents were determined gravimetrically in the laboratory. At depth the moisture contents decrease around the crack as the moisture is drawn out of the surrounding soil. Adams and Hanks (1964) believe that such cracks may increase evaporation substantially.

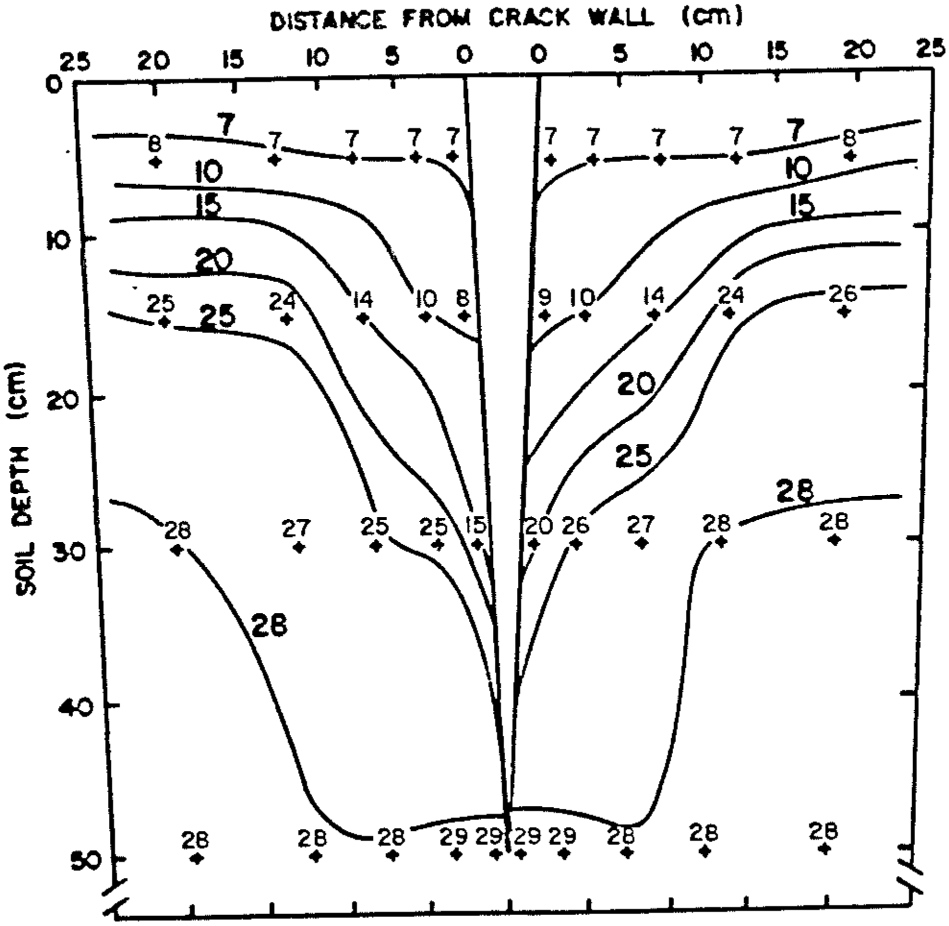


Figure 2.10. Moisture content distribution around an extensive shrinkage crack (Hillel, 1980b, after Ritchie and Adams, 1974).

2.5. REDISTRIBUTION:

Redistribution, or internal drainage, is the post–infiltration movement of water in a partially saturated soil profile. Following infiltration, the water at the surface moves downward under the force of gravity and suction gradients. The rate of redistribution is influenced by the hydraulic properties of the soil, the initial wetting depth, and the moisture content of the soil layers at depth. Redistribution proceeds rapidly when the initial depth of wetting is small and the soil below is dry (i.e., when the suction gradients are the greatest), and it decreases with time because the soil's ability to transmit water and the suction gradient decrease as the soil saturates (Hillel, 1980b). Figure 2.11 illustrates a typical moisture content profile in a soil during various stages in the redistribution process.

The processes of redistribution, infiltration, and evaporation rarely occur independently in the field. Following a precipitation event, evaporation usually begins at the surface while redistribution of infiltrated water is occurring at the wetting front at depth. With these two processes occurring simultaneously, producing fluxes in opposite directions, a "plane of zero flux" develops (Gardner et al., 1970) as illustrated in figure 2.12. This zero flux plane moves downward with time, and the concept has been used to the calculate percolation rates (Dreiss and Anderson, 1985).

Gardner et al (1970) found that redistribution tends to reduce evaporation by as much as 75% but that evaporation had little effect, less than 10% change, on redistribution. Initially, redistribution decreases the moisture content at the surface, but after several days, evaporation becomes dominant. The study conducted by Gardner et al (1970) did not consider the effects of vapor transport, thermal gradients, or hysteresis.

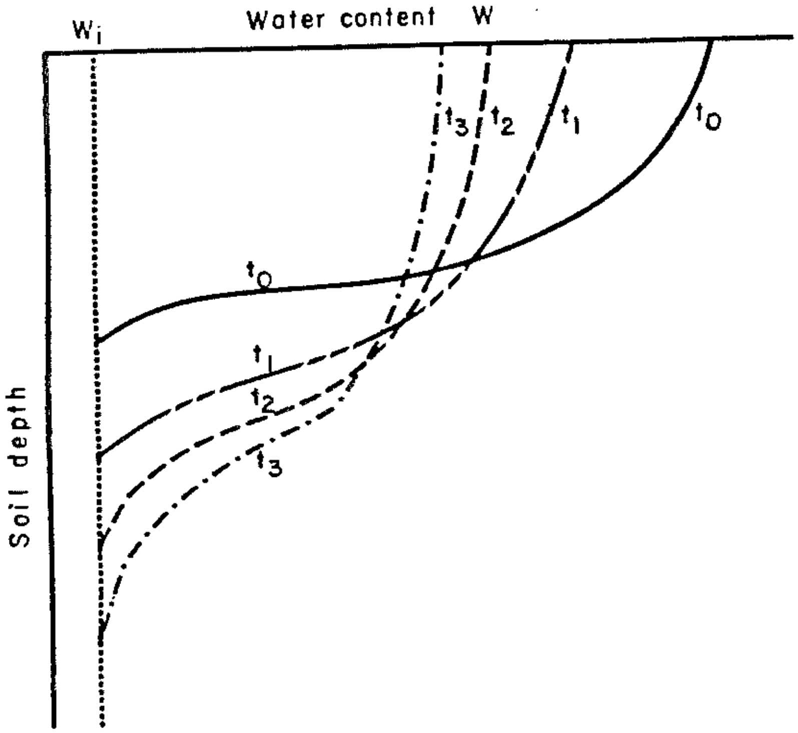


Figure 2.11. Redistribution neglecting the effects of hysteresis; t_0, t_1, t_2, and t_3 represent times of 0, 1, 4, and 14 days following irrigation, respectively (Hillel, 1980b).

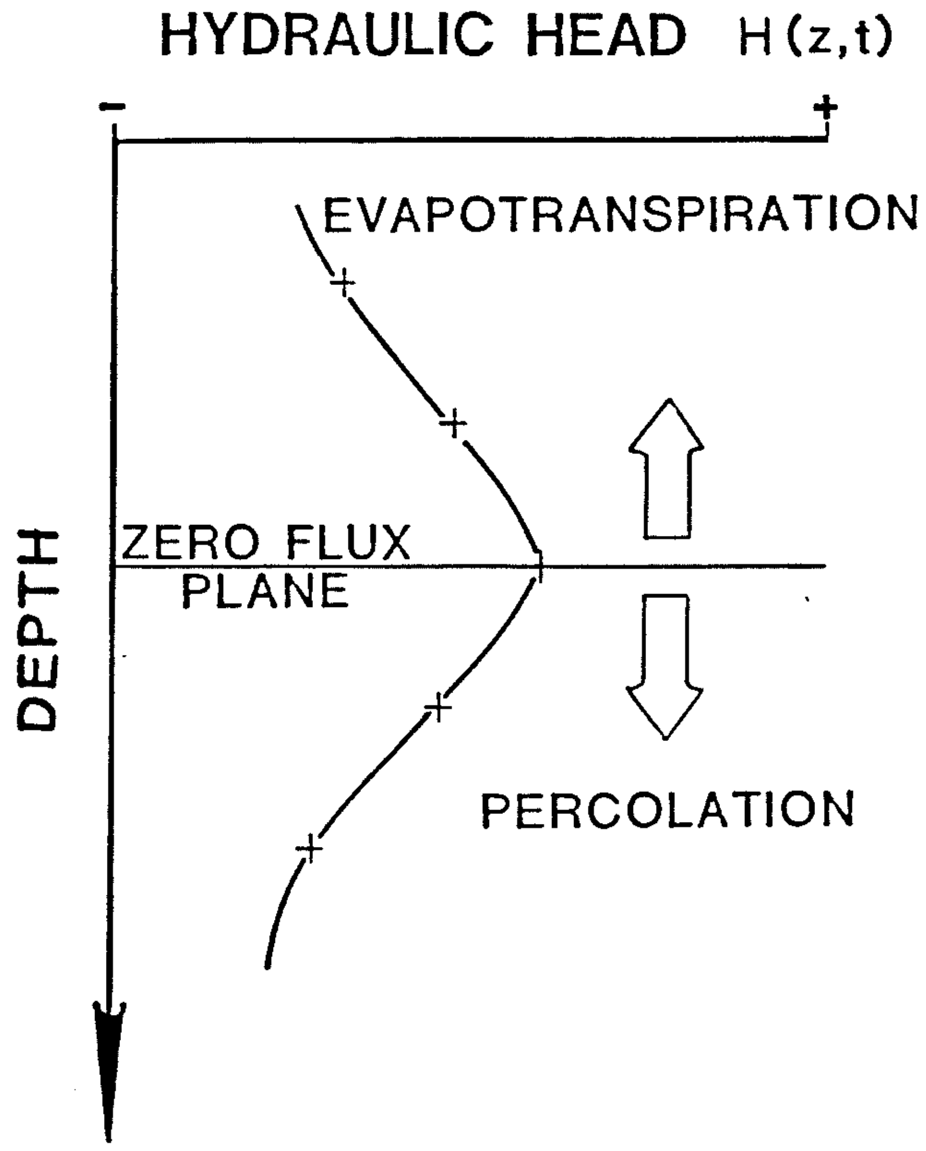


Figure 2.12. The "zero flux" plane concept (Dreiss and Anderson, 1985).

Hysteresis has been shown to retard the redistribution process (Hillel, 1980b, after Youngs, 1960; Rubin, 1967; Hanks et al., 1969). Since hysteresis will cause water to be retained in the upper portion of the profile for a longer period of time, higher evaporation is possible (Bresler et al., 1969) as shown in figure 2.13.

2.6. FLOW INDUCED BY TEMPERATURE GRADIENTS

Flow takes place from regions of high total soil–water potential to regions of low soil–water potential. Temperature is an important component of this potential. Moisture movement under the influence of a temperature gradient was first observed by Bouyoucos (1915). This was later confirmed by many investigators, and subsequent research was directed toward determining if this flow took place mainly in the vapor or the liquid phases.

Gurr et al. (1952) conducted experiments to determine whether the dominant mode of flow induced by a temperature gradient was in the liquid or the vapor phases. A soluble salt was used, and movement of the salt indicated movement in the liquid phase; this was found to be in the direction of cold to hot. Moisture movement in the opposite direction (i.e., from hot to cold) was due to vapor flow. As the vapor condensed, the soil–water pressure increased and water flowed opposite to the vapor flow. Because the flow of vapor was from high to low temperature, flow induced by a temperature gradient took place mainly in the vapor phase.

Gurr et al. (1952) also examined the influence that moisture content had on temperature gradients. When a temperature gradient was applied to several different columns of varying initial moisture contents as shown in figure 2.14, the wettest and driest columns exhibited no moisture transfer at all, indicating that

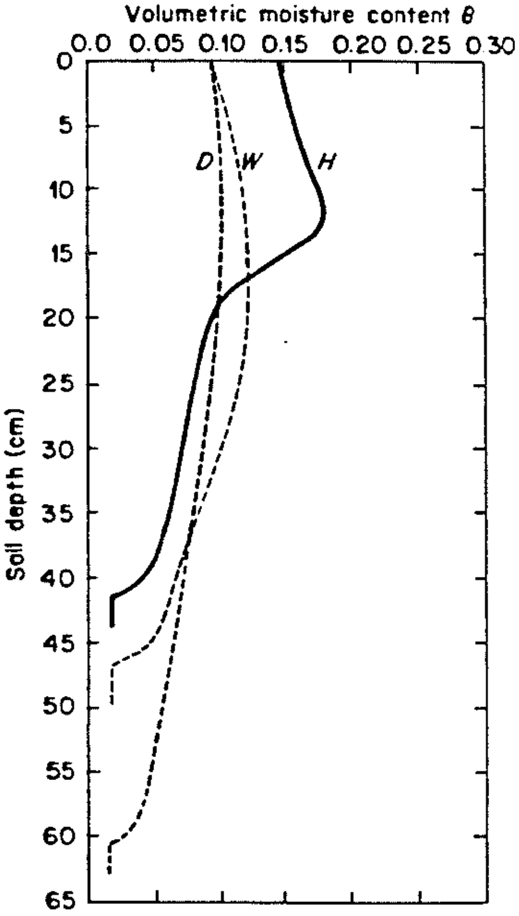


Figure 2.13. Effect of hysteresis on redistribution in a sandy soil; D represents drying curve without hysteresis, W represents wetting curve without hysteresis, and H illustrates redistribution considering the hysteresis effect (Hillel, 1980b).

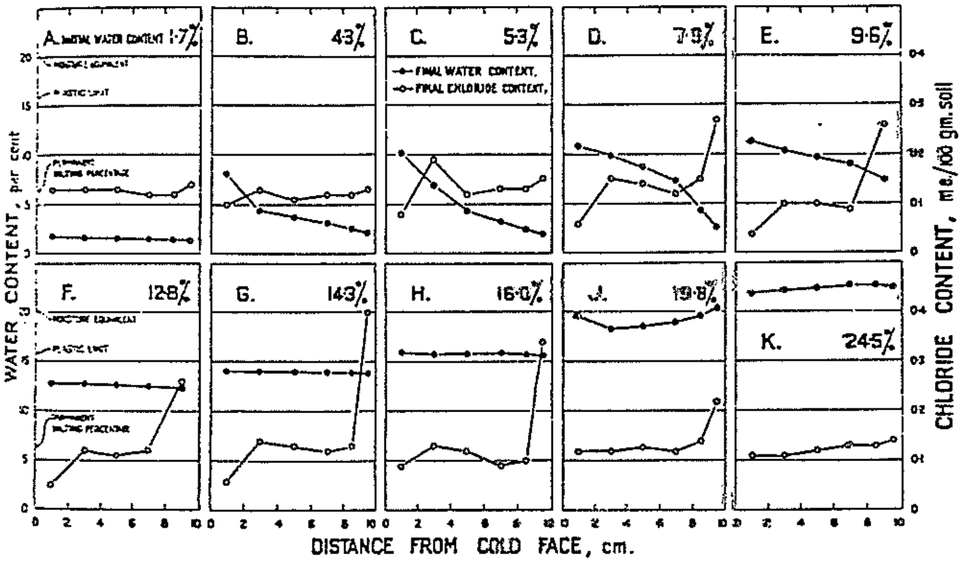


Figure 2.14. Moisture content distributions and chloride distributions in columns of loam soil, of varying intial water contents, subjected to a temperature gradient for five days (Gurr et al., 1952).

flow induced by a temperature gradient probably occurs only within some specified range of moisture contents.

2.6.1. FLOW IN FROZEN SOILS

Hoekstra (1966) presented the first conclusive evidence of moisture movement in a frozen soil. The study involved an unsaturated silty material, and moisture movement was found to occur in the unfrozen films of water within the frozen soil, induced by a temperature gradient. Hoekstra (1966) noted that the moisture movement diminished when the temperatures dropped too far below freezing because these films of unfrozen water would begin to disappear at that point. Moisture flow in frozen soil appears to be as significant as in unfrozen soil (Hoekstra, 1966). According to Dirksen and Miller (1966) moisture movement in unfrozen soil toward frozen soil is due to a difference in moisture contents which creates a pressure gradient between the frozen and unfrozen soil.

3.0. PROCEDURES

3.1. INTRODUCTION

The study began in the Fall of 1984 under the supervision of Dr. Dan Stephens and with the assistance of graduate student Deborah McElroy who originally set-up the experiment. The columns were prepared in the laboratory and then transported to the field site by forklift. Approximately two and a half years into the study, the experiment was modified slightly. The experiment came to a conclusion late in the Summer of 1988.

3.2. LABORATORY PREPARATION

The experiment consisted of four Plexiglas columns which were 180cm in length and 16.2cm in width as shown in figure 3.1. Each column consisted of three sections of Plexiglas bolted together with neoprene gaskets for seals. A blind flange was attached at the bottom into which a 1.3cm–diameter hole was drilled. A reducer was placed in the hole and tygon tubing was attached to the reducer. It was through this outlet that the effluent was sampled as shown in figure 3.2. The columns were supported by a metal frame attached to a large wooden platform with the bottom of each column positioned approximately 45cm above this platform as shown in the photographs in figure 3.3.

The columns were packed in the laboratory using a flat circular disk attached to a long pole which served as the handle. The lower 150cm of each column was uniformly packed with copper mill tailings beach sand fraction in five–centimeter increments to a dry bulk density of 1.44g/cc which is an optimum bulk density for this material (D. McElroy, personal communication, 1987). Lar

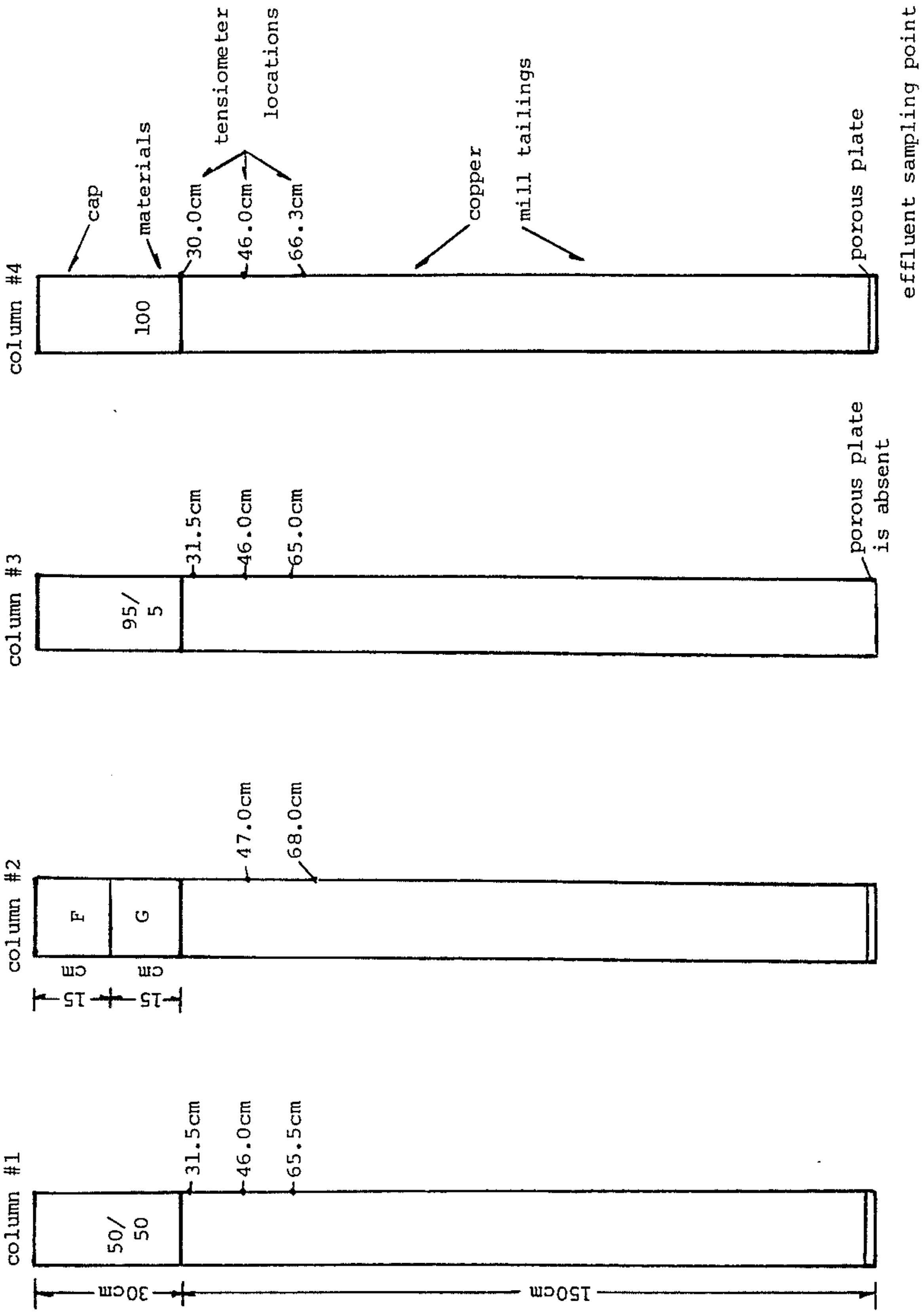


Figure 3.1. Schematic diagram of columns and associated apparatus (the thermistors were located just below the interface between the cap material and the rest of the column).

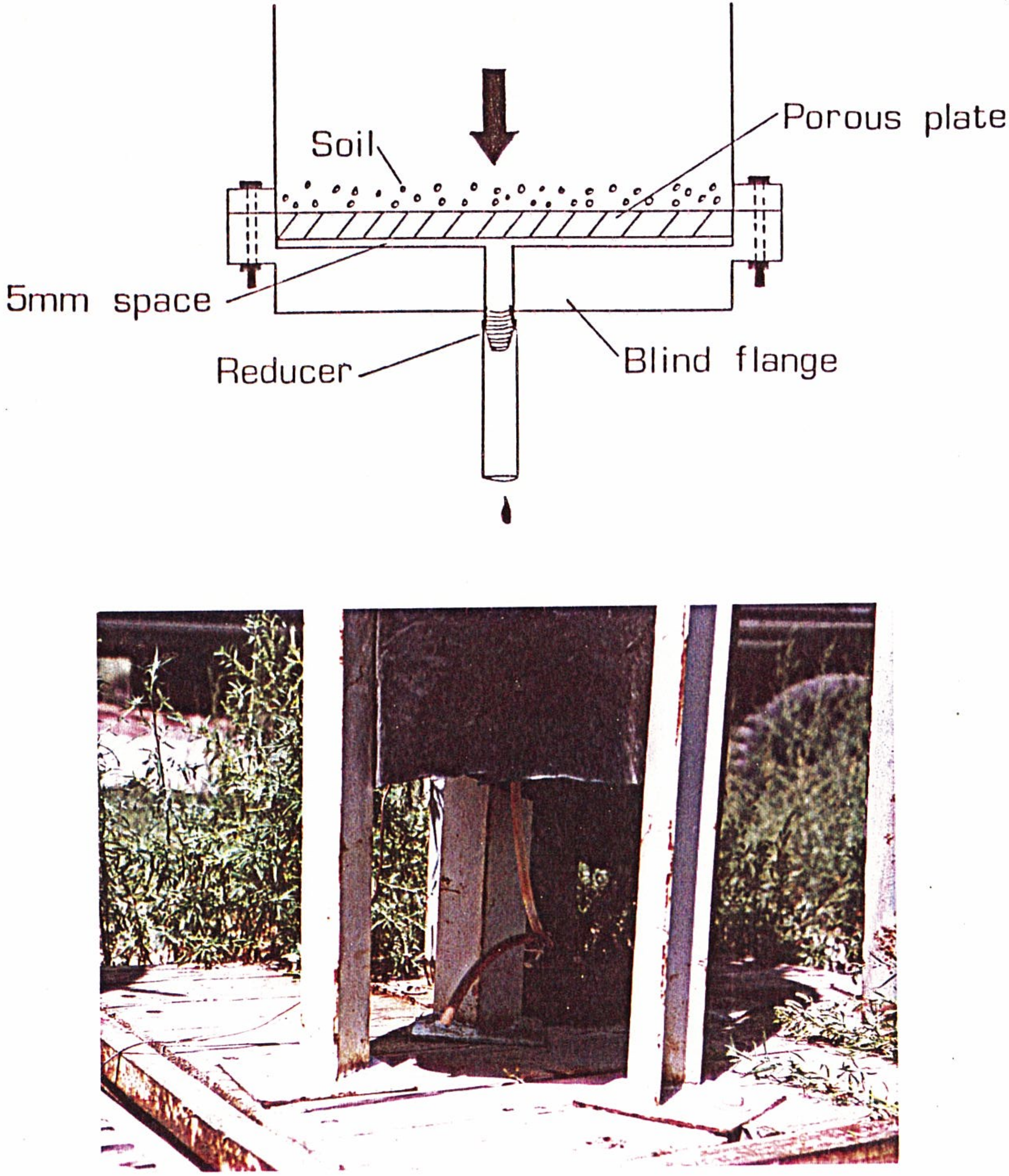


Figure 3.2. Flange and porous ceramic plate at the bottom of each column (McElroy, 1986), and a picture of the same taken in the field on August 9, 1988. (Note: as indicated in figure 3.1, the porous ceramic plate was absent from column #3).

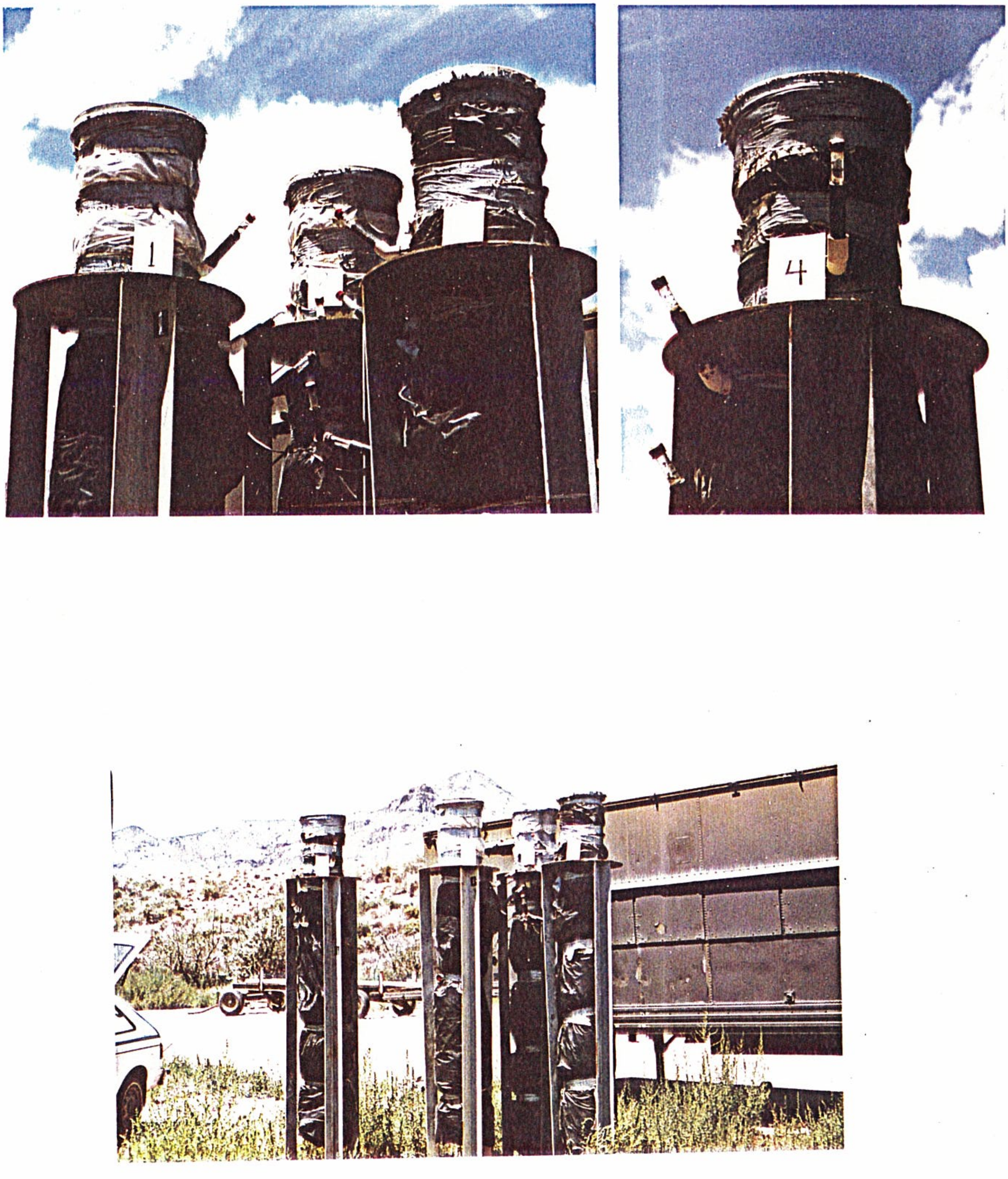
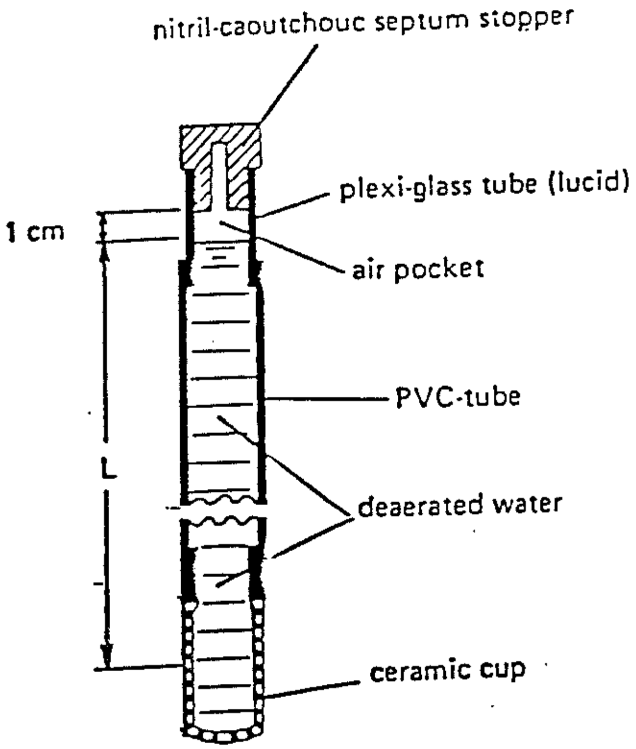
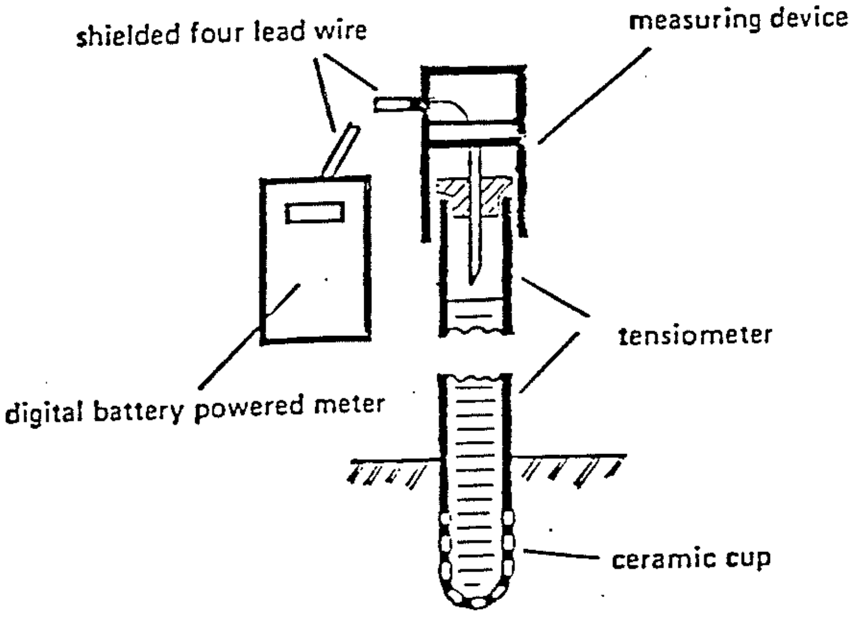


Figure 3.3. Pictures of the columns in the field (taken on August 9, 1988).



TENSIOMETER SETUP



MONITORING SETUP

Figure 3.4. Tensiometer–tensimeter apparatus (Knowlton, 1984).

son (1984) found the bulk density of undisturbed cores to range from 1.34g/cc to 1.51g/cc. McElroy (1987) found a bulk density of 1.44g/cc to be the easiest to work with, and it was within the range of field values.

Before the cap materials were emplaced, a solution consisting of 5g of calcium bromide ($CaBr_2$) dissolved in 5ml of distilled water was uniformly applied to the top of each column. Next, the upper 30cm of each column was packed with one of four different cap materials; these included a volumetric mixture of 50% tailings and 50% Wyoming bentonite clay for column #1, a combination of 15cm of gravel overlain by 15cm of a fine-textured soil for column #2, a mixture of 95% tailings and 5% bentonite for column #3, and a 100% tailings cover for column #4. The cap materials in columns #1, #2, #3, and #4 were packed in five-centimeter increments to bulk densities of 1.25, 1.19, 1.42, and 1.44g/cc, respectively (D. McElroy, personal communication, 1987).

Tensiometers were placed in succession directly below the base of the cap materials. Each tensiometer consisted of a large one-bar porous ceramic cup attached to PVC pipe connected to Plexiglas pipe, each having an inner diameter of 1.3cm. The vertical distance between the top of the tensiometer cup and the top of the tensiometer neck was approximately 10.5cm. A rubber stopper was placed on top of the tensiometer neck. The soil suction was measured by inserting a syringe attached to a portable pressure transducer, or "tensimeter," through the rubber stopper (Tensimeter, Soil Measurement Systems, Inc., Las Cruces, NM). Figure 3.4 illustrates the tensiometer-tensimeter apparatus used in this experiment.

Three tensiometers were placed in columns #1, #3, and #4 while column #2 had only two tensiometers due to problems related to consolidation of the cap material. In column #1 the tensiometers were placed at depths of 31.5, 46.0, and

65.5cm (distance measured from the top of the column to the top of the tensiometer cup). The two tensiometers in column #2 were placed at depths of 47.0 and 68.0cm, and the tensiometers in columns #3 and #4 were placed at depths of 31.5, 46.0, 65.0cm and 30.0, 46.0, and 66.3cm, respectively. In addition, the soil temperature inside of each column was monitored to $\pm 0.5^{0}$ C using a thermistor (Soiltest, Inc., Model MC-312, Evanston, IL).

The tensiometers were filled with a mixture consisting of 60% distilled water and 40% reagent-grade ethylene glycol. The mixture was de-aired by bubbling helium gas though it. This mixture was used in order to prevented freezing of the tensiometer fluid during the Winter months. Knowlton (1984) conducted experiments which showed that the addition of 40% ethylene glycol does not have a significant effect on the observed soil suction readings as shown in figure 3.5.

3.3. FIELD PREPARATION

The columns were transported by forklift to the field site on January 21, 1985 where they remained for the next 3.6 years. The monitoring began on February 18, 1985. The columns were wrapped with insulation to prevent freezing in the Winter months and to more closely approximate the more constant soil temperatures found below the ground surface. In addition, a class 'A' evaporation pan and a tipping bucket rain gage were installed in order to closely monitor the weather conditions at the field site.

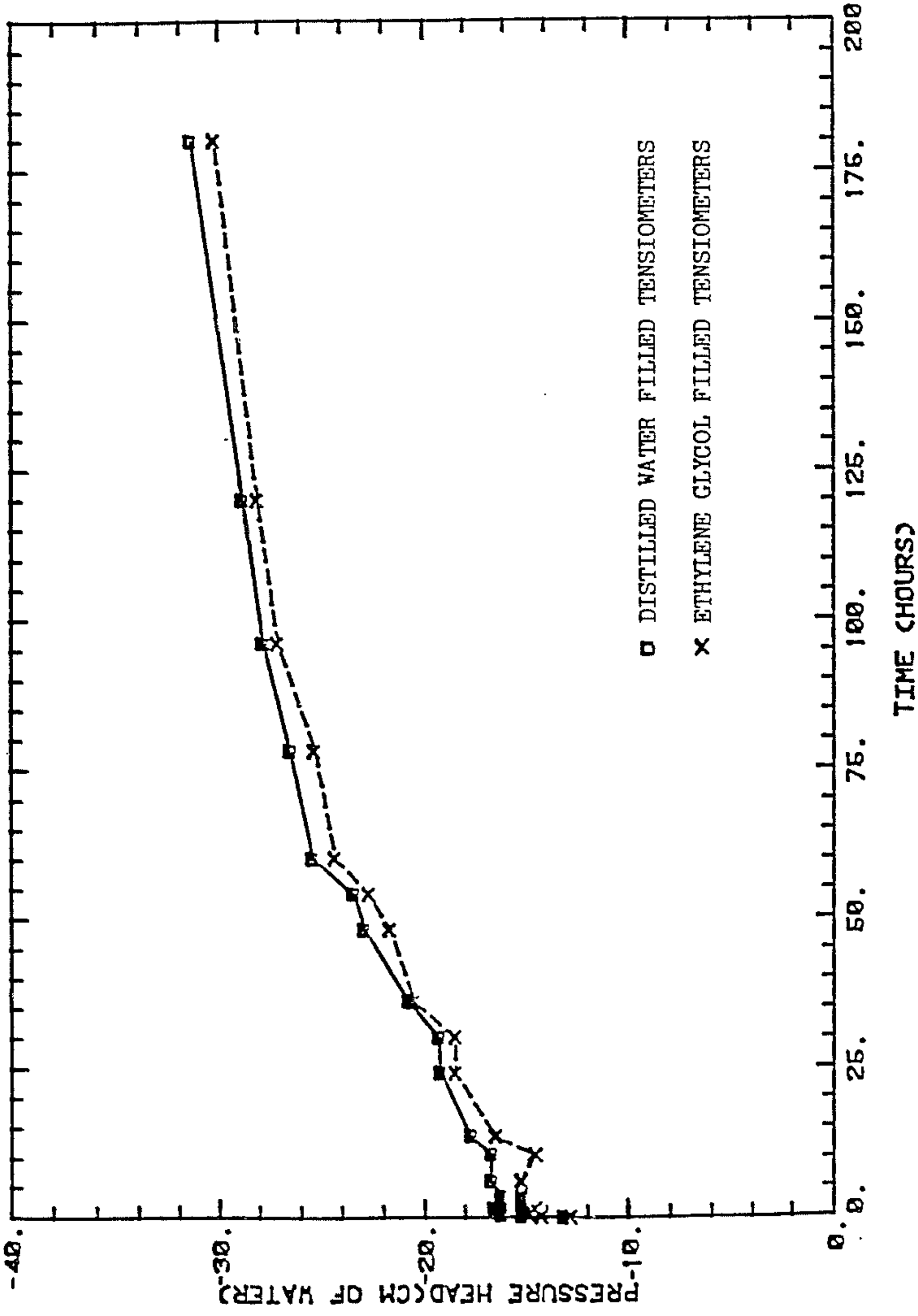


Figure 3.5. Effect of ethylene glycol mixture on observed soil suction measurements (Knowlton, 1984).

3.4. MONITORING

Tensiometric and evaporation data were collected one to two times per week, while the precipitation data was collected on a continual basis by a recorder. Effluent was sampled from the bottom of the columns approximately every two weeks or whenever it was necessary. The effluent samples were taken through the tube at the bottom of each column by applying a suction with a vacuum. The samples were stored in tightly sealed glass jars and transported to the laboratory for analysis.

3.5. EFFLUENT ANALYSIS

The effluent samples were analyzed with the Orion ion analyzer, an ion specific electrode, which detects the concentration of bromide ions in solution. Two percent (by volume) of an ionic strength adjuster, consisting of 5M $NaNO_3$, was added to the effluent before it underwent analysis to account for the interference created by the metal ions derived from the tailings. The electrode was first calibrated to a 10M solution of $CaBr_2$. Then it was rinsed in distilled water and placed in the effluent sample.

3.6. FLUORO-ORGANIC TRACER APPLICATION

On October 11, 1987 the upper 30cm of each column (i.e., the cap material) was removed for the purpose of applying several experimental fluoro-organic tracers. Several soil samples were taken, also, to determine the gravimetric moisture contents of the cap materials.

Four organic tracers (fluorobenzoates) were applied to the columns; these included meta-(trifluoromethyl) benzoic acid (m-TFMBA), ortho-(trifluoromethyl) benzoic acid (o-TFMBA), pentafluorobenzoic acid (PFBA), and 2,6-difluorobenzoic acid (2,6-DFBA). The tracers were applied in the proportions outlined in Bowman and Rice (1986). The total amount of tracers applied to each column was 0.030g of o-TFMBA, 0.030g of m-TFMBA, 0.060g of PFBA, and 0.047g of 2,6-DFBA. This information is included in table 3.1.

The tracers were prepared separately by mixing each with an equivalent molar amount of potassium hydroxide (KOH) in order to dissolve the crystals in 5ml of distilled water. The solutions were mixed for approximately 30 to 40 minutes until all of the crystals had dissolved. The four solutions were then combined to yield one 20ml solution containing each of the four fluoro-organic tracers. Four of these 20ml solutions were prepared in this manner and were then uniformly applied to the soil surface of each column using a calibrated pipette. The initial tracer concentrations were 1500mg/l of m-TFMBA, 1500mg/l of o-TFMBA, 3000mg/l of PFBA, and 2350mg/l of 2,6-DFBA. This information is included in table 3.1, also.

Next, the cap materials were repacked at their air-dry moisture contents. First, the cap materials were allowed to air-dry for several days, and then a small subsample of each soil was placed in the oven for 24 hours to determine the air-dry moisture contents. The weight of material required to repack each cap material at its air-dry moisture content to the appropriate dry bulk density was calculated using the equation:

$$M - MW_g = A\rho_b \qquad (3.1)$$

where: M = mass (g) of air-dry soil required per centimeter in order to pack at the desired dry bulk density (ρ_b).

W_g = air-dry gravimetric moisture content, expressed as a decimal.
A = surface area of the soil column (cm^2).
ρ_b = dry bulk density of the cap material (g/cc).

Equation 3.1 was solved for M to obtain the mass of soil required per one-centimeter increment. The value obtained was then multiplied by five to determine the amount required for each five-centimeter lift. The cap materials were packed using a flat circular disk until a total of six lifts or 30cm of material was placed into each column. Column #2 was the exception; first 15cm of a well-sorted gravel was placed into the column, and then three lifts, or 15cm, of a fine-textured soil was packed on top of the gravel. Table 3.2 summarizes the data for repacking the cap materials.

TRACER NAME	PROPORTION APPLIED * (g/m^2)	MASS APPLIED (g)	INITIAL CONCENTRATION OF TRACER (mg/l)
2,6-DFBA	2.34	0.047	2350
PFBA	2.99	0.060	3000
o-TFMBA	1.49	0.030	1500
m-TFMBA	1.49	0.030	1500

* Bowman and Rice (1986).

Table 3.1. Quantities of fluoro-organic tracers applied to each column.

COLUMN NUMBER	CAP MATERIAL	AIR-DRY Wg%	BULK DENSITY (g/cc)	MASS REQUIRED PER 5-cm LIFT (g)
1	50% tailings 50% bentonite	4.66	1.25	1318
2	fine-textured soil	4.93	1.19	1239
3	95% tailings 5% bentonite	1.55	1.42	1451
4	100% tailings	1.73	1.44	1473

Table 3.2. Data necessary for repacking cap materials.

This process was completed by the first week in December, and the monitoring routine resumed at that time. The columns were monitored one to five days per week depending upon the amount of precipitation received during that week. Effluent was sampled every one to two weeks in the manner described previously. The effluent samples collected between December 1987 and August 1988 were analyzed using the ion specific electrode described previously and by High Performance Liquid Chromatography (HPLC) which will be discussed in section 3.8. In addition, each effluent sample was filtered through a 0.45μm nylon filter at least twice to remove any solids which may have been detrimental to the HPLC system.

3.7. SOIL COLUMN SECTIONING and SOIL EXTRACT PREPARATION

On August 10, 1988 the columns were removed from their field site and transported by forklift to the laboratory for analysis. Using a hand auger, three 100cc ring samples were taken from the cap material of column #4 to undergo hydraulic characterization which is discussed in more detail in the following chapter. In addition, separate subsamples of the cap materials were taken from each of the four columns, in five-centimeter increments, in order to determine the gravimetric moisture contents.

After the cap materials had been removed, the lower 150cm of each column was carefully sectioned into one-, five-, ten-, and twenty-centimeter increments, beginning at the top, until all of the soil had been removed and placed into plastic bags. To facilitate the sampling, the column was cut horizontally into several pieces.

Once the soil was removed from the columns, the soil extracts could be prepared. For each depth increment, between one and six random soil samples of known mass were added to known volumes of distilled water and placed in separate centrifuge tubes. This amount was usually 10g of soil per 10ml of water, although some samples required more or less distilled water. In addition, a separate subsample from each depth interval was taken for the purpose of determining the gravimetric moisture contents which would be needed in later calculations. Appendix F contains the data for the soil extract preparation.

The centrifuge tubes containing the soil and water mixtures were then placed in a mechanical shaker for 30 minutes to insure that the ions were released from the soil. This was followed by 30 minutes in a centrifuge at 1500rpm. The eluent was then removed from the centrifuge tubes with a pipette and filtered through 0.45μm filter paper. The final sample was then ready to be analyzed by the HPLC.

3.8. EFFLUENT and SOIL EXTRACT ANALYSES via HPLC

The effluent collected between December 1987 and August 1988, and the soil extracts prepared in August 1988, were analyzed for the fluoro–organic and bromide tracers via High–Performance, or High–Pressure, Liquid Chromatography (HPLC). The HPLC chromatigraphically separates the ionic components of the sample which may then be identified based on their retention times. The separation of the ionic species is achieved through the competition between the ions in the mobile phase and those in the sample for ion exchange sites on the stationary phase in the column (Lindsay, 1987). By simply varying the chemistry of the mobile phase, the separation of the ionic species in the sample may be adjusted to obtain better resolution on the chromatograph. The analysis of soil extracts by High–Performance Liquid Chromatography is described by Bowman (1984).

The HPLC system is shown in the schematic diagram in figure 3.6 and in the photograph in figure 3.7. The mobile phase enters a filter and is delivered to the pump where it is sucked in by a vacuum. It leaves the pump under high pressure and then moves through the inline filter before going to the sample injection valve. The sample itself enters the system through this valve. Next, the sample and the mobile phase enter a pre–column filter and a guard column which is the final filter before entering the column. When the sample enters the column its components are separated and then flow back to the detector. The back pressure regulator prevents bubble formation by keeping minimum pressure on the

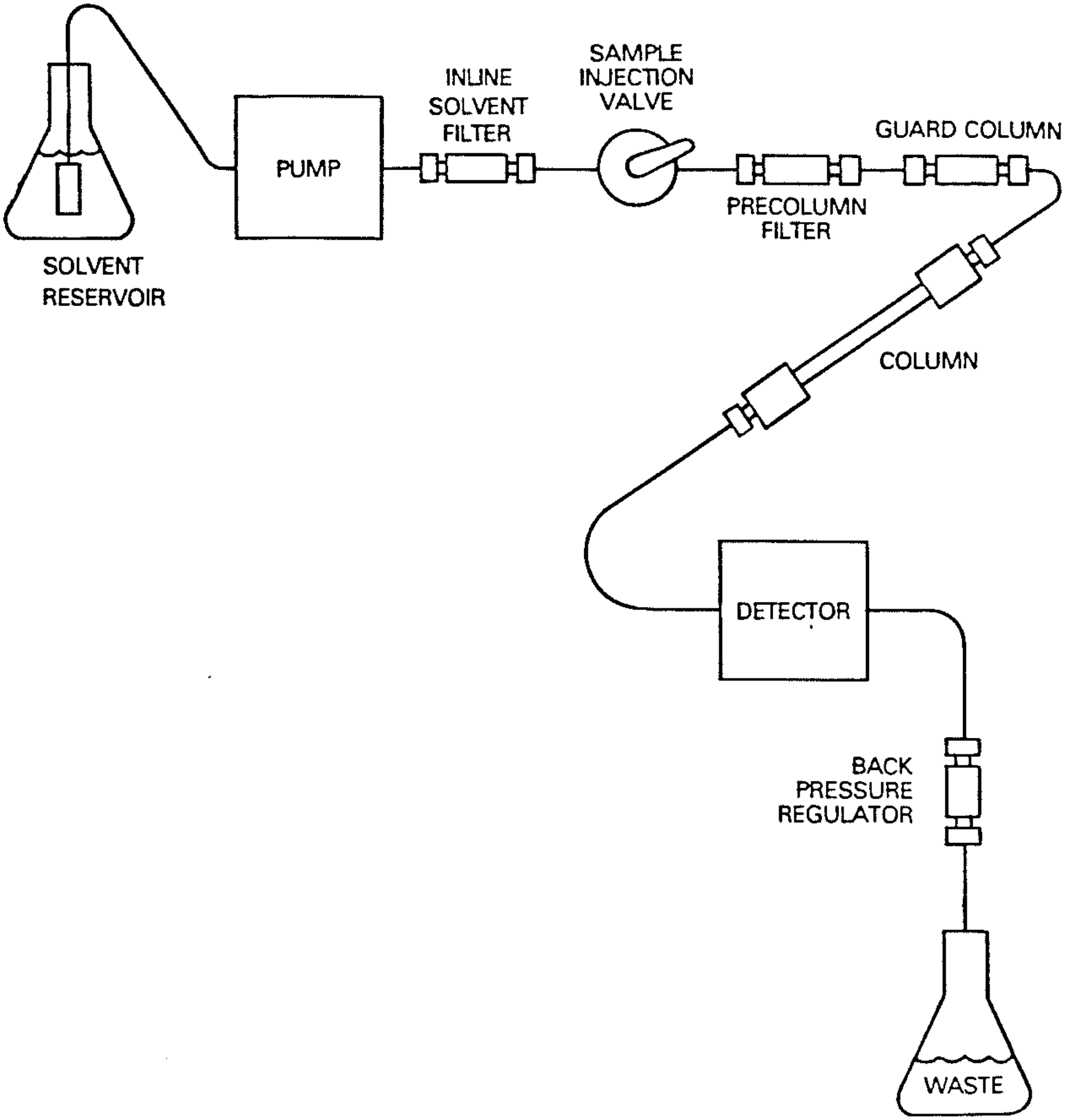


Figure 3.6. Schematic diagram of the HPLC system (Upchurch, 1988).

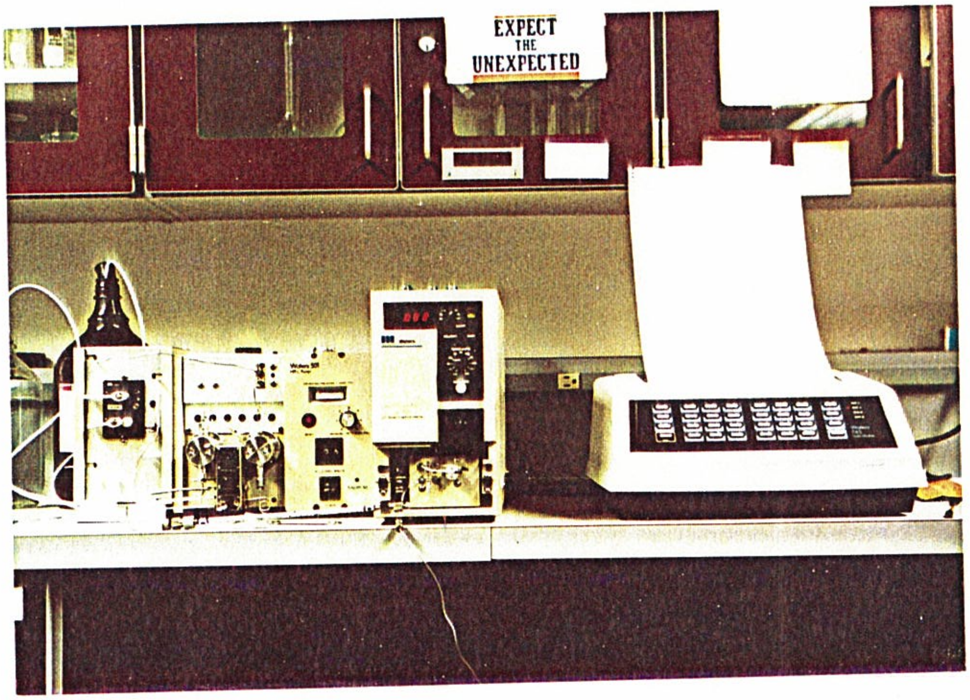


Figure 3.7. Photograph of the HPLC used in the analyses.

detector flow cell. From here, the sample goes to the waste bottle (Upchurch, 1988).

The mobile phase was prepared by dissolving 13.608g of potassium dihydrogen phosphate (KH_2PO_3) in two liters of Type I water (i.e., distilled, deionized water). The solution was mixed on a magnetic stir plate for approximately 30 to 60 minutes until all of the crystals had dissolved. The pH of the solution was then lowered to 2.60 by gradually adding drops of phosphoric acid (H_3PO_4). Next, 18% (by volume) reagent-grade acetonitrile (CH_3CN) was added to the solution; the mobile phase was later adjusted to 15% CH_3CN to achieve better resolution. Finally, the mixture was passed through a 0.45μm nylon filter and degassed by applying a vacuum. The equipment and analytical conditions for the HPLC analyses are given in table 3.3.

3.9. BATCH ISOTHERM ANALYSIS FOR FLUORO-ORGANICS

In order to determine the significance of adsorption of the fluoro-organic tracers onto the tailings medium, a batch isotherm analysis was performed. Solutions of the fluoro-organic tracers were prepared in concentrations of 0.4, 2, 10, 50, 100, 500, and 1000ppm in the manner described previously. Ten grams of dry tailings were then combined with 10ml of each of these solutions in centrifuge tubes. These tubes were then placed on a mechanical shaker for approximately 30 minutes followed by 30 minutes in a centrifuge at 1500rpm. The eluent was removed from each centrifuge tube with a pipette and filtered through 0.45μm filter paper. The concentrations of fluoro-organic tracers in the eluent samples were determined by the HPLC. This analysis allowed batch isotherms to be identified for each of the four fluoro-organic tracers. Lewis (1986) performed a batch study for $CaBr_2$ in the tailings medium. The results of both are shown in appendix H.

(1.) EQUIPMENT:

- A. WATERS 745 Data Module (Integrator)
- B. WATERS Lambda-Max Model 481 LC Spectrophotometer
- C. WATERS 501 HPLC pump
- D. WATERS Injector
- E. BECKMAN Model ϕ45 pH meter

(2.) COLUMN:

- A. REGIS Hi Chrom Reversible Strong Anion Exchange Column Code No. 731030, Serial No. 290094
- B. Packing: spherisorb, S5 SAX
- C. Particle Diameter: 5μm
- D. Length: 250mm
- E. Internal Diameter: 4.6mm

(3.) MOBILE PHASE:

- A. 0.005M Potassium Dihydrogen Phosphate (KH_2PO_3)
- B. pH 2.60
- C. 15–18% Acetonitrile (CH_3CN)

(4.) CONDITIONS:

- A. Flow Rate: varied from 1.5 to 2.0 ml/min depending on resolution
- B. Detection: UV/190nm
- C. Sample Injection: valve loop
- D. Injection Volume: 25μl
- E. Chart Speed: 0.5 cm/min.

Table 3.3. Summary of HPLC equipment and test conditions.

3.10. SOIL EXTRACT pH ANALYSIS

Since the fluoro-organic tracers will convert to their neutral (uncharged) form and be retained in the soil below a pH of approximately 3.0 (R. Bowman, personal communication, 1987), it is important to determine the pH of the soil extracts.

A Beckman model ϕ45 pH meter was used for the analyses, and it was calibrated using a pH 4.0 standard buffer. The electrode was rinsed with distilled water and placed in the extract sample. The results are shown in appendix H.

4.0. LABORATORY HYDRAULIC CHARACTERIZATION OF TAILINGS AND CAP MATERIALS

4.1. INTRODUCTION

In order to better assess the soil–water processes occurring in the field columns, the hydraulic properties of each soil were determined. The soils in question included 100% copper mill tailings beach sand (column #4), a volumetric mixture of 95% tailings and 5% bentonite clay (column #3), a volumetric mixture of 50% tailings and 50% bentonite clay (column #1), and a fine–textured soil (column #2). The analyses included particle size distribution, saturated hydraulic conductivity, and moisture retention characteristics (theta–psi curves). In addition, the unsaturated hydraulic conductivities were estimated using the model of Mualem (1976) which was later encoded by van Genuchten (1978, 1980).

Seven samples underwent analyses; three of these were *in–situ* ring samples (i.e., cores taken directly from the top of column #4) and four were repacked ring samples which included one sample from each of the four different cap materials.

Copper mill tailings from the same location have been described by Larson (1984) and Lewis (1986). In addition, NL Baroid/ NL Industries (1987) performed laboratory analyses on the Wyoming bentonite clay used in the cap materials of columns #1 and #3, and this data is included in appendix A.

4.2. SAMPLE PREPARATION

Using a hand auger, ring samples were obtained from the cap material of column #4, in depth increments of 0–5, 5–10, and 10–15cm, upon the conclusion of the experiment and prior to the dismantling of the column. Attempts to obtain *in-situ* ring samples from columns #1 and #3 failed due to the hard crust created by the bentonite clay, and the cap material of column #2 consolidated too much to obtain a good sample.

The repacked samples were packed in five one-centimeter lifts to the original bulk densities used when the experiment began. The mass of dry soil to be packed into each ring was determined using the equation:

$$M_d = V\rho_b \tag{4.1}$$

where: M_d = mass of dry soil to be packed in ring (g)
V = volume of ring (cc)
ρ_b = dry bulk density desired (g/cc)

4.3. DRY BULK DENSITY AND POROSITY

For each *in-situ* ring sample, a separate sample obtained from the adjacent soil was used to determine the gravimetric moisture content (W_g). With a knowledge of W_g, the dry bulk densities of the ring samples were then calculated using the equation:

$$\rho_b = \frac{M_d}{V} = \frac{M_i}{V(1 + W_g)} \tag{4.2}$$

where: ρ_b = dry bulk density (g/cc)
M_i = original mass of soil in the ring (g)

M_d = mass of soil in ring when oven dry (g)
W_g = gravimetric moisture content expressed as a decimal
V = volume of the ring sample (cc)

The dry bulk densities of the *in-situ* ring samples were determined in this manner in order to avoid putting the ring samples in the oven which could alter the soil structure and affect the results of the laboratory tests.

The porosities for all of the ring samples were determined using the equation:

$$n = 1 - \frac{\rho_b}{\rho_s} \qquad (4.3)$$

where: n = porosity (cc/cc), and ρ_s = particle density (g/cc)

The values for dry bulk density, porosity, and particle density for the *in-situ* and the repacked ring samples are given in tables 4.1 and 4.2 on the following page. The bulk densities of the *in-situ* ring samples were not the same as when the column was originally packed. The top sample (i.e., 0-5cm depth increment) had a considerably higher bulk density which may have been due to consolidation of the cap material over time and impact by raindrops. Other explanations for the discrepancies include sampling errors and variations in the initial packing of the columns.

4.4. PARTICLE SIZE ANALYSIS

The particle size distribution is important due to its influence upon the hydraulic conductivity, porosity, and tortuosity of the flow path. Attempts have been made to correlate particle size distribution with saturated and unsaturated

COLUMN NUMBER	MEDIUM	DRY BULK DENSITY (g/cc)	POROSITY $(1-\rho_b/\rho_s)$	PARTICLE DENSITY (g/cc)
1	50% tailings 50% bentonite	1.25	0.528	2.65*
2	fine-textured soil	1.19	0.551	2.65**
3	95% tailings 5% bentonite	1.42	0.490	2.79*
4	100% tailings	1.44	0.486	2.80***

* estimated using data from Lewis (1986) and NL Baroid/ NL Industries (1987).
** estimated.
*** from Lewis (1986).

Table 4.1. Dry bulk density and porosity values for repacked ring samples from the cap materials.

DEPTH (cm)	DRY BULK DENSITY (g/cc)	POROSITY $(1-\rho_b/\rho_s)$	PARTICLE DENSITY (g/cc)
0–5	1.50	0.464	2.80 *
5–10	1.43	0.489	2.80
10–15	1.46	0.479	2.80

* from Lewis (1986).

Table 4.2. Dry bulk density and porosity values for 100% tailings (column #4); *in-situ* ring samples.

hydraulic conductivity (Hillel, 1980b, after Child and Collis–George, 1950; Marshall, 1958; Millington and Quirk, 1959). These approaches use the pore size distribution as inferred from the particle size distributions.

Generally, the coarser the particle size and the higher the degree of sorting (poorly graded), the higher the saturated hydraulic conductivity. This may be due to the fact that the flow paths generally become longer or more tortuous as the degree of sorting decreases. Conversely, the finer the particle size and the poorer the sorting (well graded), the lower the saturated hydraulic conductivity. Porosity is highest for a well–sorted, or uniform, soil and it decreases as the degree of sorting decreases.

The particle size distributions were determined through mechanical sieve analysis for the coarse fraction and hydrometer analysis for the fine fraction. A representative soil sample from each of the cap materials was selected and allowed to oven–dry for twenty–four hours. Each sample was then gently disaggregated using a pastel and mortar and weighed prior to the analysis. A complete description of the sieve and the hydrometer procedures is given by Gee and Bauder (1982). The results are included in appendix B, and the particle size distributions are shown in figure 4.1.

The particle size distribution for the cap material of column #1 (50% bentonite) was estimated, based on values obtained from NL Baroid/NL Industries (1987), below a particle diameter of 0.045mm due to extreme difficulties in determining the particle size distribution of bentonite below this value. The significant amount of bentonite in the material caused a great deal of flocculation, and using additional dispersant did not alleviate the problem.

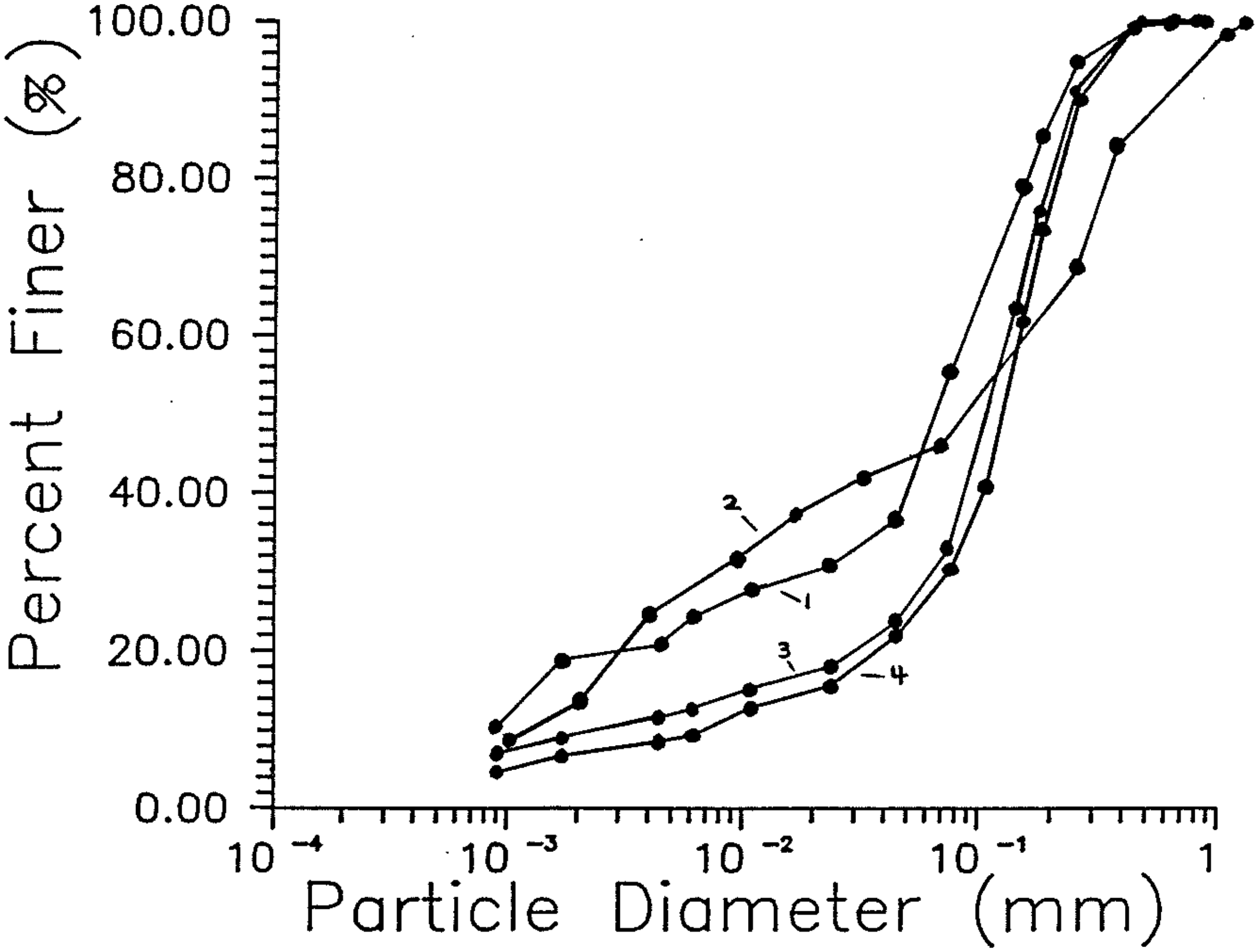


Figure 4.1. Particle size distributions for the cap materials of column #1 (50% tailings/ 50% bentonite), column #2 (fine-textured soil), column #3 (95% tailings/ 5% bentonite), and column #4 (100% tailings). Note: the gravel underlying the fine-textured soil of column #2 consisted of uniform pebbles, approximately 2cm in diameter.

The uniformity coefficient (C_u) and coefficient of curvature (C_c) were determined using the equations:

$$C_u = \frac{d_{60}}{d_{10}} \qquad (4.4)$$

$$C_c = \frac{[d_{30}]^2}{d_{60} d_{10}} \qquad (4.5)$$

where: d_{10}, d_{15}, d_{30}, d_{50}, and d_{60} represent the particle size diameters below which 10, 15, 30, 50, and 60% of the sample is found.

The uniformity coefficient is equal to one for a truly uniform soil, and its value increases as the degree of sorting decreases. Both the coefficient of curvature and the uniformity coefficient are indicators used in the Unified Soil Classification System (USCS) which is widely used among civil engineers. The median particle diameter (d_{50}) indicates whether a soil is generally fine– or coarse–textured.

Each soil was then classified according to the United States Department of Agriculture (USDA) soil textural triangle shown in figure 4.2. The soil classifications as well as some of the important particle size parameters are listed in table 4.3.

The 100% tailings soil classified as a loamy sand which is in agreement with Lewis (1986) who analyzed several samples of the same material and found it to vary in character between a loamy sand and a sandy loam and with Larson (1984) whose particle size distributions indicate that the tailings are a loamy sand.

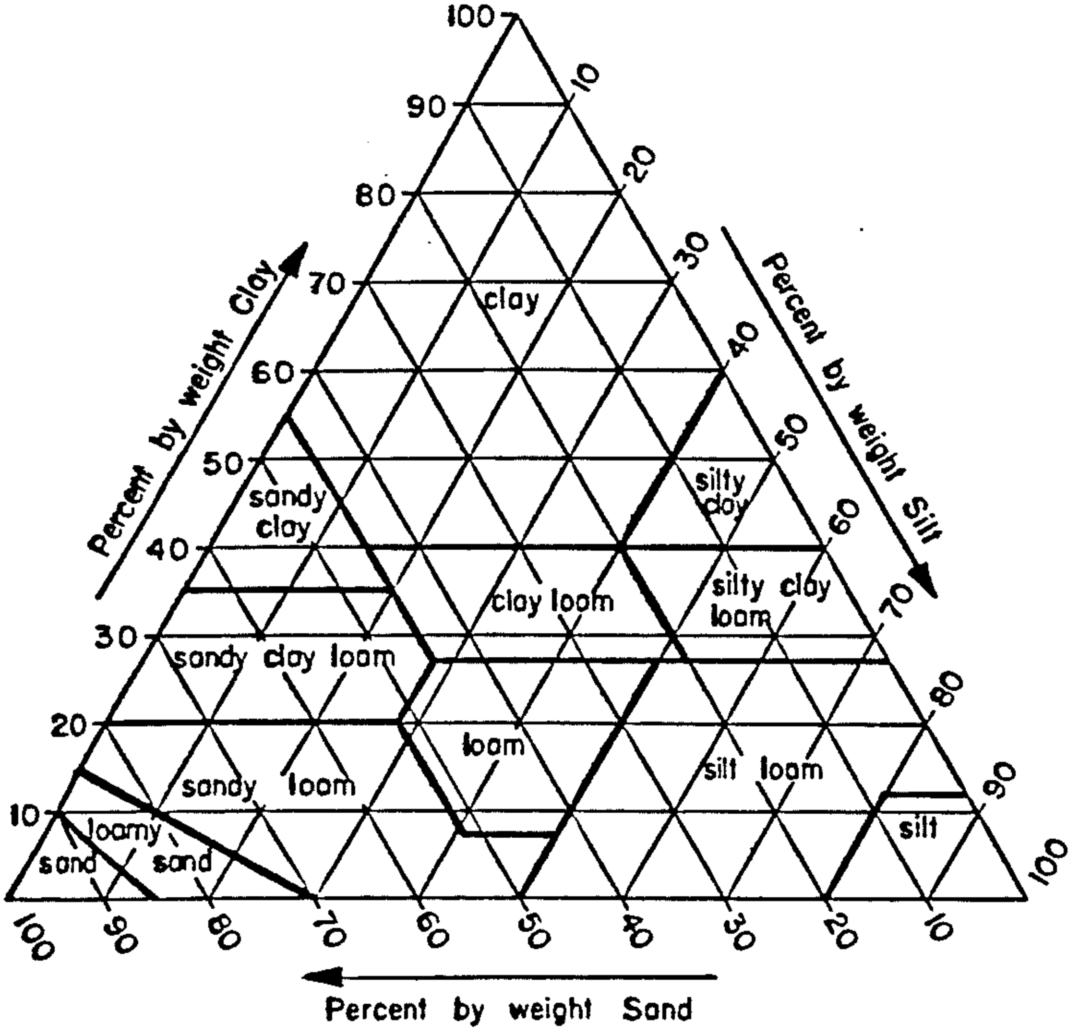


Figure 4.2. United States Department of Agriculture (USDA) soil textural triangle based on the following: clay: <0.002mm; silt: 0.002 - 0.05mm; sand: > 0.05mm (Hillel, 1980a).

PARAMETERS	COLUMN #1 (50/50)*	COLUMN #2 (fine soil)	COLUMN #3 (95/5)	COLUMN #4 (100%)
d_{10}	0.0009	0.0010	0.0044	0.0070
d_{30}	0.0235	0.0080	0.0065	0.0075
d_{50}	0.6500	0.0800	0.1050	0.1150
d_{60}	0.0850	0.1050	0.1480	0.1500
C_u	94.44	105.0	33.64	21.43
C_c	7.22	0.610	0.065	0.054
% SAND	63.20	57.10	76.61	78.1
% SILT	18.20	29.00	14.79	15.3
% CLAY	18.60	13.90	8.60	6.60
USDA CLASSIF.	sandy-loam	sandy-loam	sandy-loam	loamy-sand

* Estimated based on NL Baroid/ NL Industries (1987).

Table 4.3. Parameters and classifications derived from the particle size analyses.

The other three materials were classified as sandy loams, although the 50/50 material was very close to being a sandy clay loam.

4.5. SOIL-MOISTURE CHARACTERISTIC CURVES

The soil-moisture characteristic curve, or theta (θ) – psi (ψ) curve, is vital to any unsaturated flow study. It describes the hysteretic relationship between the volumetric moisture content (θ) and the matric pressure head (ψ). Used in combination with the saturated hydraulic conductivity, it allows the unsaturated hydraulic properties of a soil to be predicted.

The matric pressure head (ψ), often referred to as the suction or tension, is always negative for an unsaturated soil, and it is expressed in units of length. Theta (θ) is the volumetric moisture content of the soil, and it is usually expressed as a decimal or as a percent. At 100% saturation θ is numerically equal to the porosity (n) of the soil, but total saturation is rarely achieved under laboratory conditions due to such problems as entrapped air.

Water retention characteristics are highly dependent upon the texture and structure of a soil. Fine-textured soils are able to retain water at much higher suction values than coarser-textured soils. Figure 4.3 shows some typical θ–ψ drainage curves for coarse- and fine-textured soils. Coarse-textured soils usually have a well-defined air-entry suction value (i.e., ψ at which the first pores begin to drain), while this value is often indistinguishable in finer grained soils. Structure, or particle arrangement, is important, also; a soil that has undergone compaction will usually have less of the larger size pores and more of the intermediate size pores which will tend to "flatten out" the θ–ψ curve as shown in figure 4.4 (Hillel, 1980a).

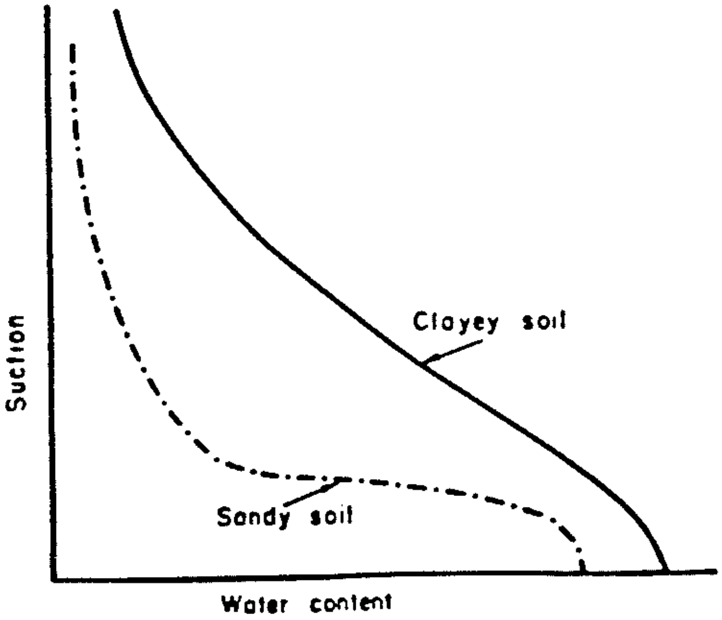


Figure 4.3. Typical θ–ψ drainage curves for a coarse (sandy) versus a fine (clayey) soil, illustrating the effect of soil texture on moisture retention (Hillel, 1980a).

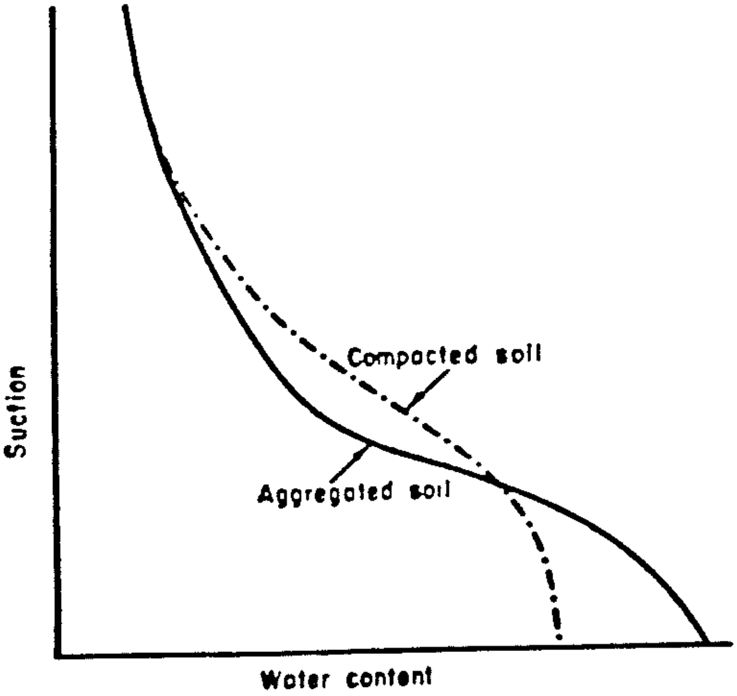


Figure 4.4. Hypothetical θ–ψ drainage curves for an aggregated versus a compacted soil, illustrating the effect of soil structure on moisture retention (Hillel, 1980a).

The θ–ψ relationship is hysteretic; it is not the same for wetting (sorption) as it is for drying (desorption) as illustrated in figure 4.5; the intermediate (scanning) curves result from different wetting and drying cycles. A draining soil will have a higher θ at a given ψ than will a wetting soil. A common cause for this is the "inkbottle effect," whereby the amount of moisture which may enter a soil during wetting is limited by the presence of larger pores which hinder capillary rise; hence, a lower θ may exist for a given ψ during wetting than during drying as shown in figure 4.6. Moreover, the contact angle is greater in an advancing (wetting) than in a receding (draining) meniscus, which means that during drainage ψ will be greater at a given θ than during wetting, as illustrated in figure 4.7. Other explanations for hysteresis include entrapped air, swelling and shrinking phenomena, and differences in the wetting and drying histories of a soil. Hysteresis is generally more pronounced in coarse-textured soils because the larger pores hinder capillary rise; in other words, the "inkbottle" effect is more pronounced (Hillel, 1980a).

The soil–moisture characteristic curves were determined using the hanging water column and the pressure plate extraction apparatuses shown in figures 4.8 and 4.9. The hanging column method is limited to suction values less than approximately 200cm of water which defines the air–entry value of the porous ceramic plate used in the analysis. The pressure plate apparatus can place up to 15 bars of suction on the sample, and the moisture retained at 15 bars is generally assumed to represent the residual moisture content of the soil.

First, the ring samples were placed in a shallow water–filled pan for twenty–four hours which allowed them to "wet–up" through capillarity. The next day, several Buchner funnels were inverted and filled with water. The burettes and associated tubing were also filled with water. Water was flushed through the

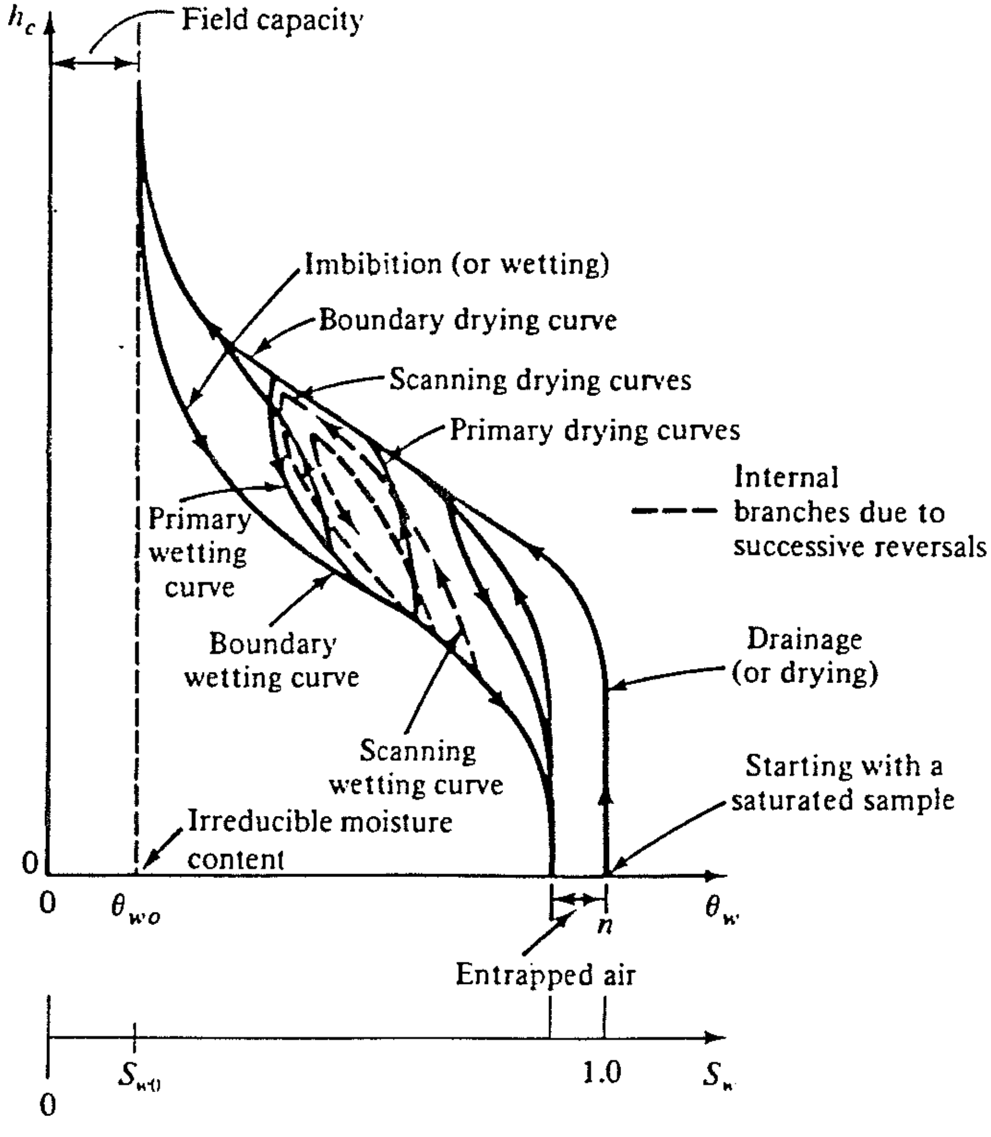


Figure 4.5. Soil-moisture characteristic curves showing wetting and drying curves and intermediate (scanning) curves for a coarse-textured soil (Bear, 1987).

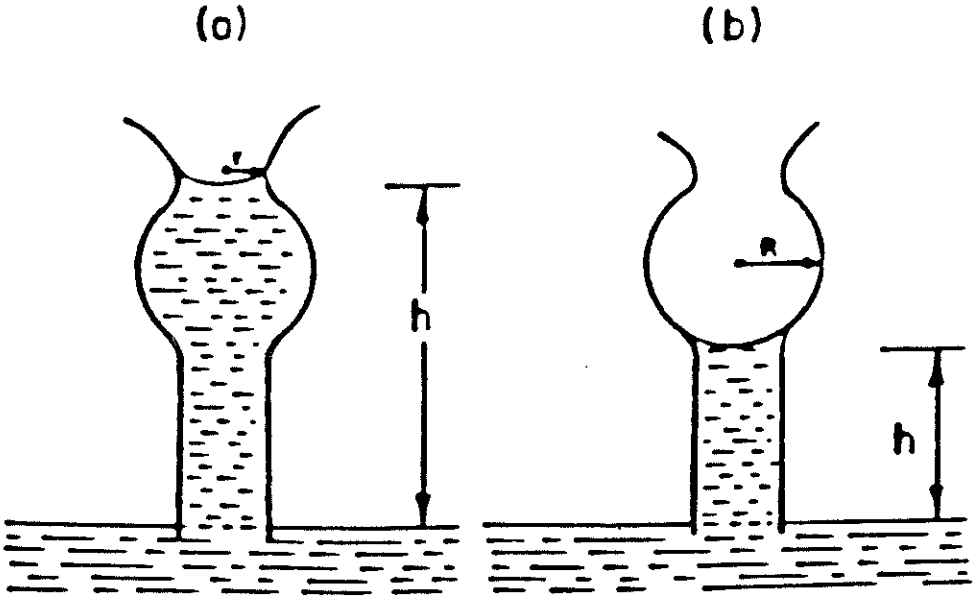


Figure 4.6. The "inkbottle" effect: (a.) drainage (b.) capillary rise (Hillel, 1980a).

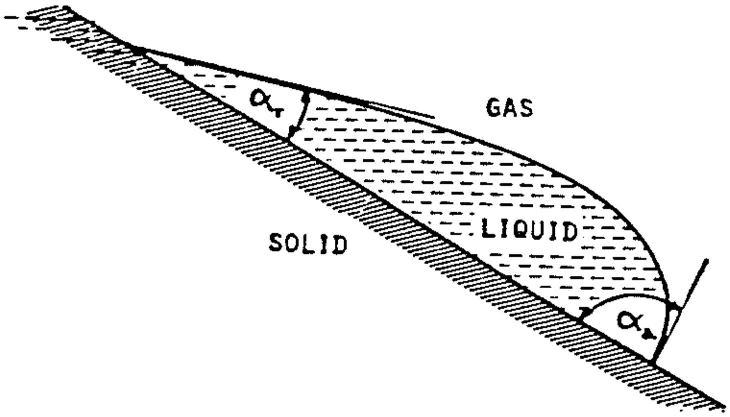


Figure 4.7. A drop of liquid on an inclined surface where α_r is the contact angle of the receding meniscus and α_a is the contact angle of the advancinging meniscus (Hillel, 1980a).

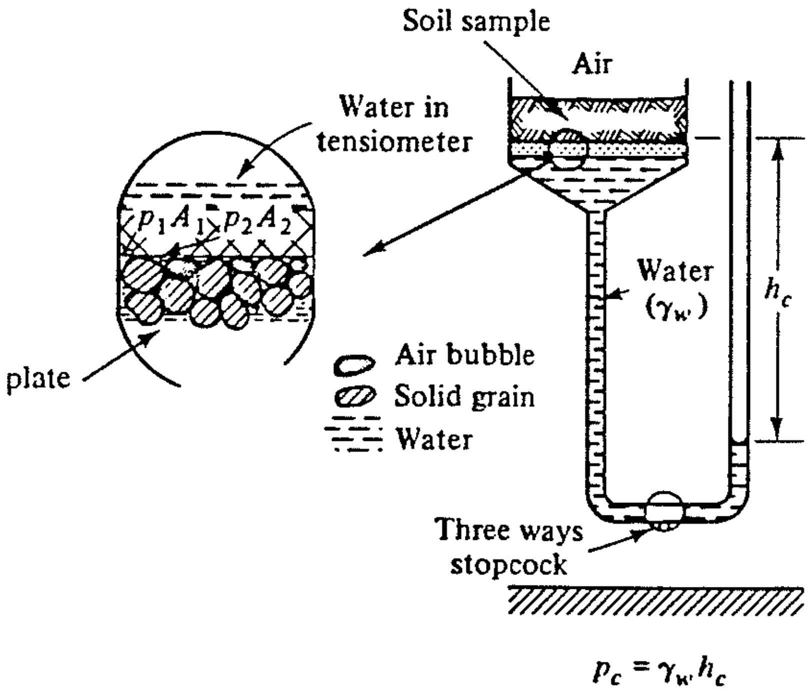


Figure 4.8. Hanging water column apparatus (Bear, 1987).

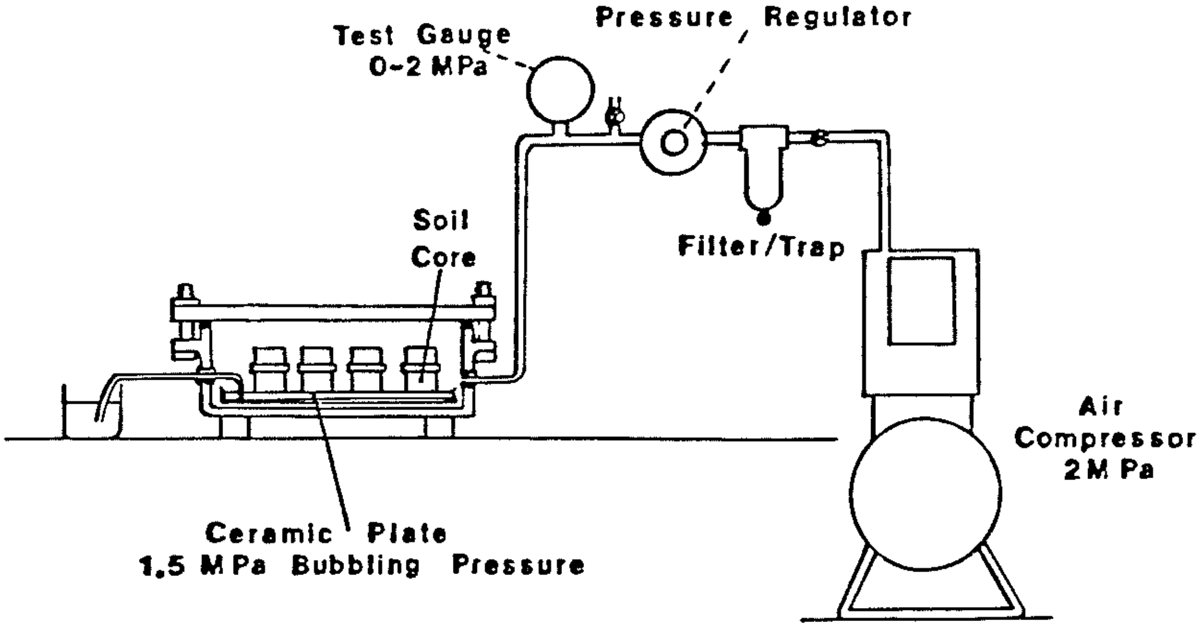


Figure 4.9. Pressure plate extraction apparatus (Klute, 1986).

system until all of the air bubbles were removed. Each ring sample was then removed from the wetting pan, weighed, and then firmly attached to the porous ceramic plate of the Buchner funnel. The initial water level in the burette was recorded with the stopcock closed. Each burette was then lowered approximately 20–25 centimeters and the stopcock was reopened. Twenty–four hours later, the stopcock was closed again and the water level in the burette was recorded. The distance between the lower meniscus of the water level and the middle of the sample was recorded, also. This measurement represented the suction, or tension, placed on the sample.

This process was repeated for several different suction values in order to establish the theta–psi drainage curve. When this was completed, the suction was successively decreased to define the wetting curve. The soil–moisture characteristic curves obtained from this procedure are shown in figures 4.10 through 4.13.

The pressure plate extraction method was used to determine the moisture content at 15 bars of pressure which is assumed to be the residual moisture content (θ_r) of the soil. The θ_r values for each sample are shown in table 4.4.

The cap material of column #1 (50% bentonite) did not undergo any of the analyses performed beyond the particle size analysis because of difficulties encountered in this medium. It would not saturate using the conventional "wetting up" procedure, and when an appreciable head of water was placed on top of the sample, the change in head over a period of several days was negligible.

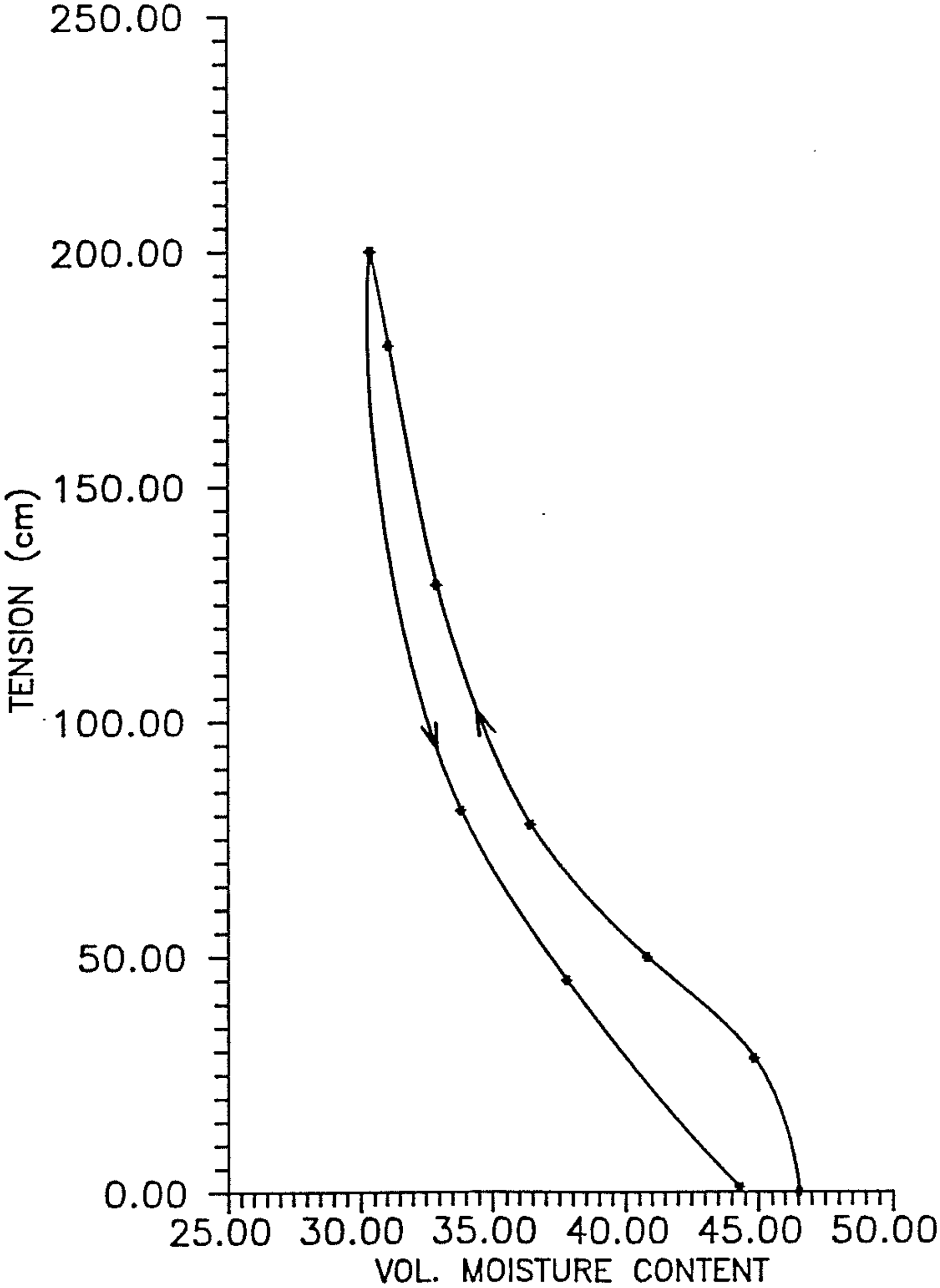


Figure 4.10. Soil moisture characteristic curves for column #2 (fine-textured soil); repacked ring sample.

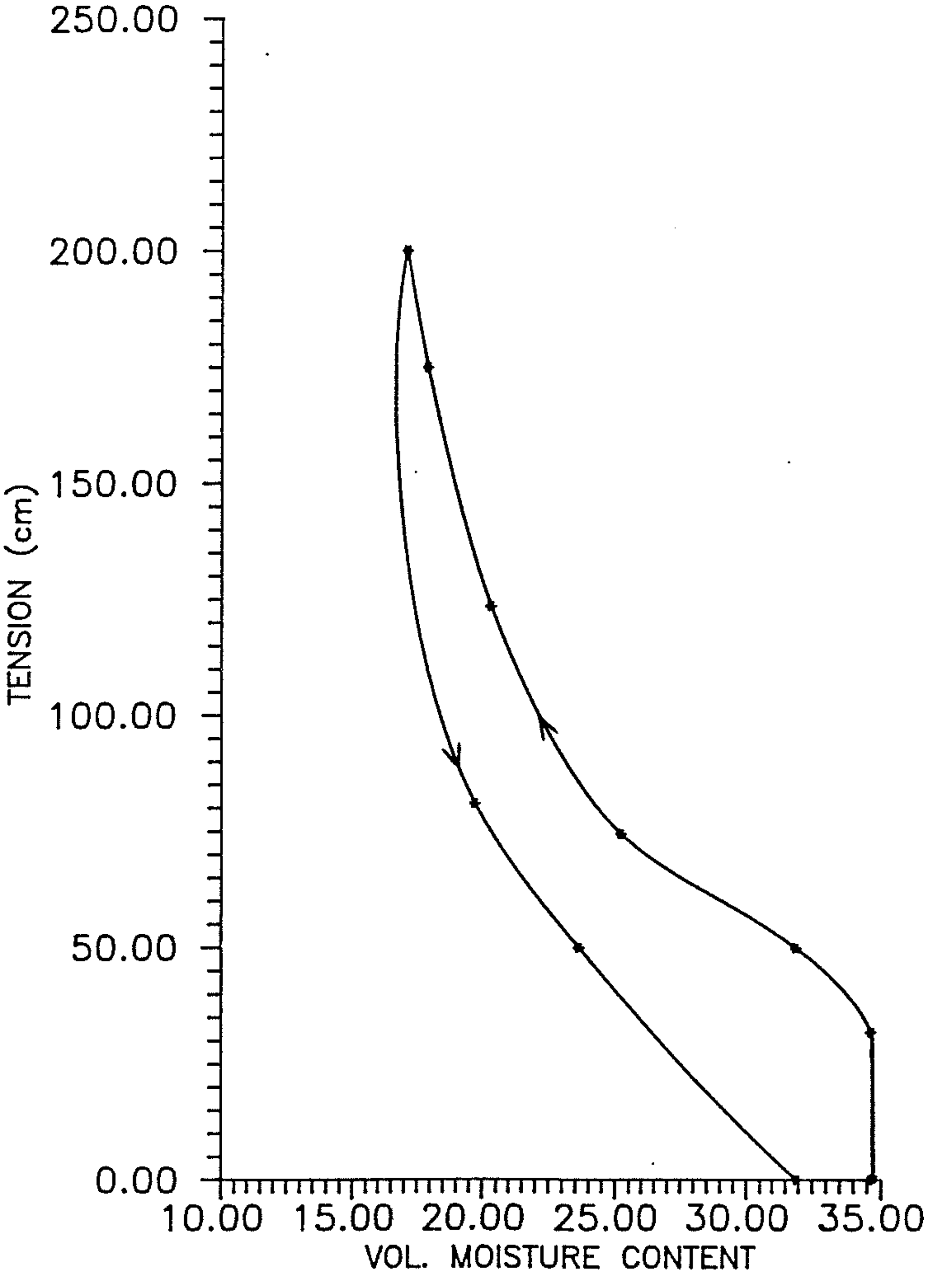


Figure 4.11. Soil moisture characteristic curves for column #3 (95% tailings/ 5% bentonite); repacked ring sample.

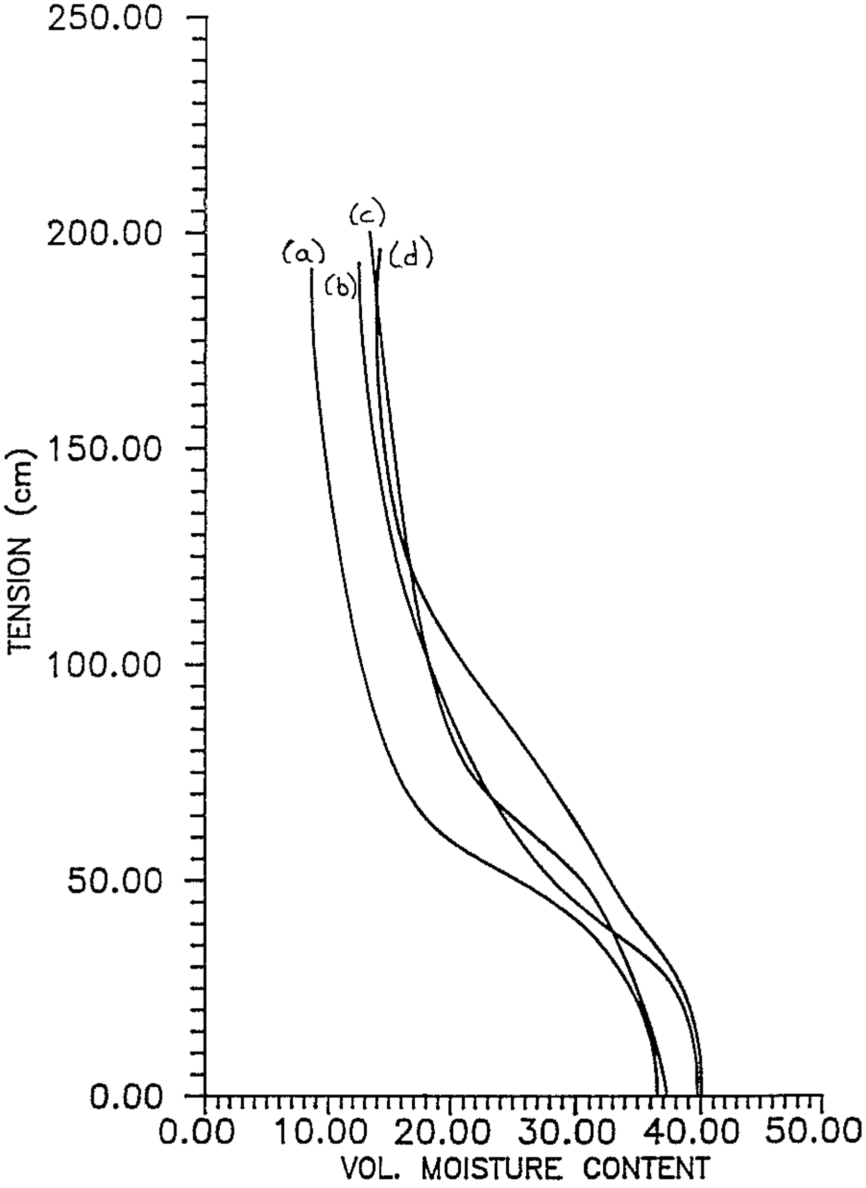


Figure 4.12. Soil moisture drying curves for column #4 (100% tailings): (a.) *in-situ* ring sample (0-5cm depth), (b.) *in-situ* ring sample (5-10cm depth), (c.) repacked ring sample, and (d.) *in-situ* ring sample (10-15cm depth).

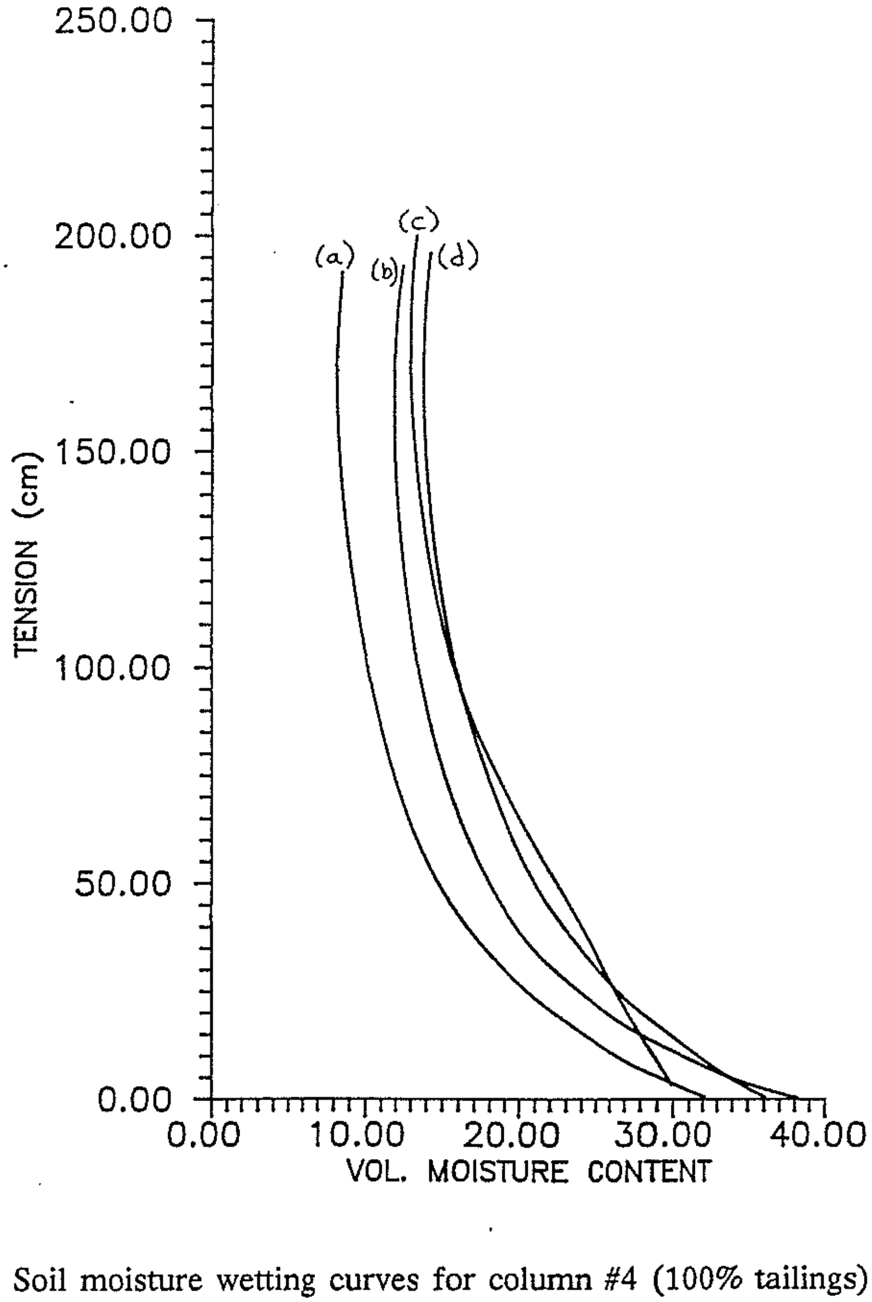


Figure 4.13. Soil moisture wetting curves for column #4 (100% tailings): (a.) *in–situ* ring sample (0–5cm depth), (b.) *in–situ* ring sample (5–10cm depth), (c.) repacked ring sample, and (d.) *in–situ* ring sample (10–15cm depth).

COLUMN NUMBER	SAMPLE IDENTIFICATION	θ_r	d_{10}	ρ_b	n
2	REPACKED	0.199	0.0010	1.19	0.551
3	REPACKED	0.118	0.0044	1.42	0.490
4	REPACKED	0.051	0.0070	1.44	0.486
4	IN-SITU (0-5cm)	0.045	0.0070	1.50	0.464
4	IN-SITU (5-10cm)	0.047	0.0070	1.43	0.489
4	IN-SITU(10-15cm)	0.054	0.0070	1.46	0.479

Table 4.4. Residual moisture contents (moisture retained at 15 bars of pressure) from pressure plate extraction test, and several other important parameters.

The effect of soil texture on the θ–ψ relationship was evident. Hysteresis, which may be gauged by the degree of separation between the wetting and drying curves, was the most pronounced in the 100% tailings medium (figures 4.12 and 4.13) and fairly well pronounced in the 95% tailings/ 5% bentonite medium (figure 4.11). In contrast, the fine-textured sample of column #2 (figure 4.10) had a very narrow θ–ψ relationship, indicating that hysteresis was not as pronounced.

The wide range of soil moisture characteristic curves obtained for column #4 (figures 4.12 and 4.13) may be due to the wide range of bulk densities or to variations in packing or particle arrangements of the samples. As you will recall from section 4.3 of this chapter, the bulk densities of the *in-situ* ring samples were 1.50g/cc for the 0-5cm depth, 1.43g/cc for the 5-10cm depth, and 1.46g/cc for the 10-15cm depth. The repacked sample had a bulk density of 1.44g/cc.

Although the volumetric moisture content should equal the porosity at saturation, this was not true for any of the samples tested. This was probably due to a combination of entrapped air in the sample during the "wetting up" process and an incorrect estimate of the porosity related to an error in the value used for the particle density (ρ_s). Volpe (1975) found the ρ_s of the sand fraction of copper mill tailings to range between 2.60g/cc and 2.80g/cc, and the value obtained by Lewis (1986) was 2.80g/cc which is on the high side of this range. Since Lewis (1986) worked with the same tailings used in this study, his value of ρ_s was used. The particle density of Wyoming bentonite (2.50g/cc) was obtained from NL Baroid/ NL Industries (1985) laboratory reports, and the fine-textured soil used in column #2 was estimated to have a ρ_s of 2.65g/cc.

4.6. SATURATED HYDRAULIC CONDUCTIVITY

The saturated hydraulic conductivity (K_s) is extremely important since it indicates a soil's ability to transmit fluid. It is affected by the geometry of the pores which is dependent upon the texture and structure of the soil. Under conditions of ponding and a deep water table, the infiltration rate will approach the saturated hydraulic conductivity as steady-state is approached.

Saturated hydraulic conductivity is a fluid transport coefficient in Darcy's Law:

$$q = -K_S \frac{\delta H}{\delta z} \qquad (4.6)$$

$$H = \psi + z \qquad (4.7)$$

where: q = specific discharge or fluid flux (cm/s)
θ = volumetric moisture content (cc/cc)
K_s = hydraulic conductivity (cm/s)
H = hydraulic head (cm)
ψ = pressure head (cm)
z = elevation (cm)

The saturated hydraulic conductivities were determined using a constant head permeameter. Each ring sample was placed in a ring holder and put into a permeameter apparatus similar to the one shown in figure 4.14. The external source reservoir was positioned so that the head inside of the tank was several centimeters above the top of the sample, and a siphon was used to drain water from the top of the sample. A complete description of this procedure is outlined in Klute and Dirksen (1982).

Periodic measurements of the volume of outflow, elapsed time, sample and reservoir heads, and temperature were recorded. The saturated hydraulic conductivities were then determined by the equation:

$$K_S = \frac{CVL}{At(H_2 - H_1)} \tag{4.8}$$

where: C = a correction factor equal to the viscosity of water at the experimental temperature divided by that at 25° Celsius.
V = volume of outflow (cc/s)
t = elapsed time (s)
A = cross-sectional area of the sample (cm^2)
H_2 = reservoir head (cm)
H_1 = sample head (cm)
L = length of the sample (cm)

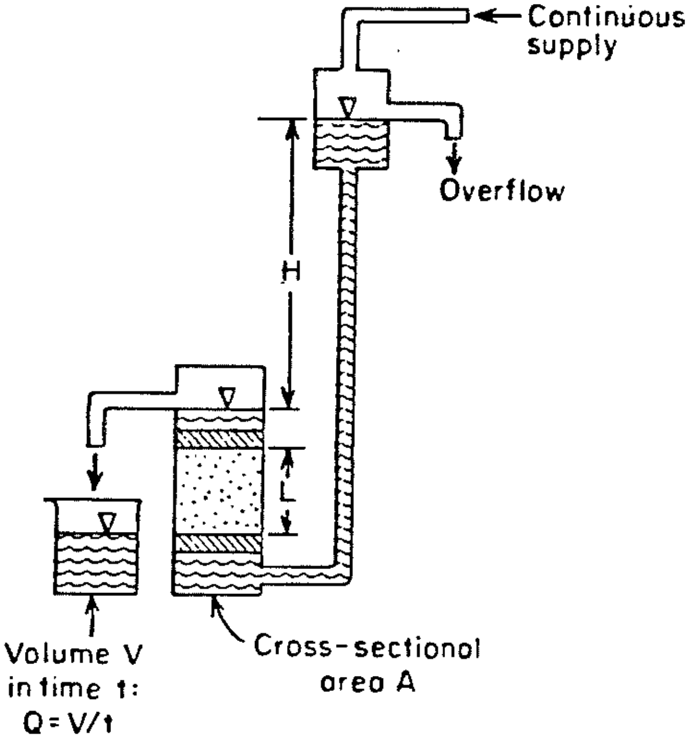


Figure 4.14. Constant head permeameter apparatus similar in function to the one used in this experiment (Freeze and Cherry, 1979).

The saturated hydraulic conductivity (K_s) values obtained for the repacked ring samples are given in appendix B, and the average of these values is shown in table 4.5. Larson (1984) and Lewis (1986) obtained average K_s values of 5.2×10^{-3} and 1.83×10^{-3} cm/s, respectively, for repacked ring samples of the tailings. Both of these values are slightly higher than the 1.65×10^{-3} cm/s obtained in this study. The 50/50 tailings/ bentonite material of column #1 did not undergo analysis for reasons discussed earlier.

4.7. UNSATURATED HYDRAULIC CONDUCTIVITY

The unsaturated hydraulic conductivity [$K(\theta)$ or $K(\psi)$] is important to any study of unsaturated flow. It may be estimated experimentally by performing the one–step outflow experiment described by Passioura (1976), or by choosing an appropriate model. The model developed by Mualem (1976) and encoded by van Genuchten (1978, 1980) has proven to be an adequate method for determining the unsaturated flow character of the copper mill tailings medium (Larson, 1984), and therefore, it was the method chosen for this study. Unfortunately, the validity of this model in making predictions for finer–textured mediums is questionable.

Mualem's analytical model was encoded by Van Genuchten (1978, 1980) who developed a closed–form analytical solution based on a two– and three–parameter fit. In this study, the best results were obtained using the two–parameter fit (α and n) and holding the residual moisture content (θ_r) constant.

The Mualem (1976) model is based on the equation:

$$K = K_s S_e^l \frac{f(S_e)}{f(l)^2} \tag{4.9}$$

Column Number	Medium	Type of Test	Number of Trials	Mean Ksat	Range		Variance	Standard Deviation
					High	Low		
1	50/50	N/A	N/A	BMC	N/A	N/A	N/A	N/A
2	Fine-Textured	FH	9	6.97E-06	4.67E-06	9.50E-06	1.40E-11	3.80E-06
3	95/5	CH	33	1.24E-03	6.80E-04	2.20E-03	1.76E-06	1.33E-03
4	100% Tails	CH	18	1.65E-03	1.16E-03	2.00E-03	2.70E-07	5.20E-04

FH = Falling Head permeameter
CH = Constant Head permeameter
BMC = Below Measurement Capabilities
N/A = Not Applicable

Table 4.5. Saturated hydraulic conductivity laboratory results for repacked ring samples.

where: K = unsaturated hydraulic conductivity (cm/s)
K_s = saturated hydraulic conductivity (cm/s)
l = parameter estimated to be 0.5 by Mualem (1976)
Se = reduced moisture content $= \frac{\theta - \theta_r}{\theta_s - \theta_r}$

θ = volumetric moisture content (cc/cc)
θ_r = residual moisture content (cc/cc)
θ_s = saturated moisture content (cc/cc)

and

$$f(S_e) = \int_0^{S_e} \frac{1}{h(S'_e)} dS'_e \qquad (4.10)$$

The closed-form analytical solution of equation 4.10 (van Genuchten, 1978, 1980) is:

$$K_r(\psi) = \frac{[[1-(a\psi)^{n-1}][1+(a\psi)^n]^{-m}]^2}{[1+(a\psi)^n]^{m/2}} \qquad (4.11)$$

where: $K_r(\psi)$ = relative hydraulic conductivity $=K(\psi)/K_s$ (dimensionless)
K_s = hydraulic conductivity at saturation (cm/s)
α = parameter of fit (cm^{-1})
n = parameter of fit (dimensionless)
ψ = soil suction; taken to be positive (cm)
$m = 1 - 1/n$ $(0 < m < 1;\ n > 1)$

This equation was modified by van Genuchten (1978, 1980) to yield the following equation:

$$K_r = \frac{[m[1 + (\alpha\psi)^n]^{-1}]^2}{1 + (\alpha\psi)^n]^{m/2}} \qquad (4.12)$$

The input data included the initial estimates of α and n, the complete θ–ψ database, the average saturated hydraulic conductivity (K_s) value, and the residual (θ_r) and the saturated (θ_s) moisture contents which were both held constant in the two-parameter fit model. The program then optimized the values of α and n by solving the following equation by successive iterations:

$$\theta = \theta_r + \frac{\theta_s - \theta_r}{[1 + (\alpha\psi)^n]^m} \qquad (4.13)$$

Only the data from the θ–ψ drainage curves of the three repacked ring samples were used in the van Genuchten code. There were too few data points on the θ–ψ wetting curves to obtain accurate predictions based on the model. The θ–ψ drainage curves generated by the code are shown in figure 4.15a, 4.16a, and 4.17a. Overall, the θ–ψ curves generated by the model were in close agreement with the experimental curves shown in figures 4.10 through 4.13, with only a few minor discrepancies in the low suction range.

The K(θ) and K(ψ) relationships generated by the van Genuchten code are shown in figures 4.15b and 4.15c, 4.16b and 4.16c, and 4.17b and 4.17c. These relationships are important because of their control over soil moisture flow processes, such as infiltration, evaporation, and redistribution, which were discussed in chapter 2.

The K–θ relationship is nearly linear when plotted on semi–log paper, but as it approaches the residual moisture content of the soil, the hydraulic conductivity drops off sharply. The K–ψ relationship is nearly linear, also, until it approaches very high suction values.

The input, output, and the complete computer code used to determine the unsaturated hydraulic conductivities are given in appendix B.

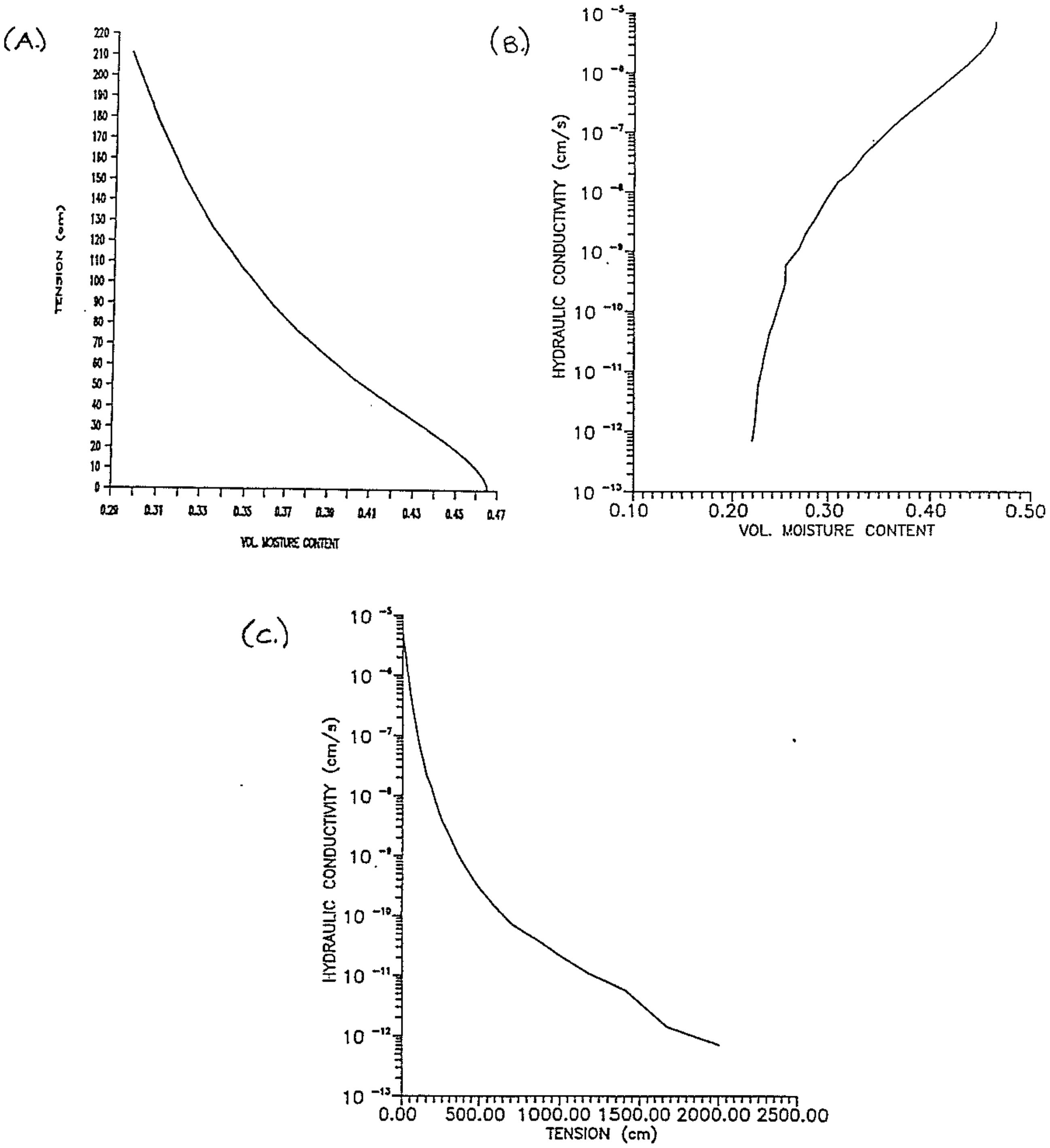


Figure 4.15. Curves generated by the van Genuchten code for column #2 (fine-textured soil): (a.) θ–ψ drainage curve, (b.) hydraulic conductivity as a function of moisture content, and (c.) hydraulic conductivity as a function of pressure head.

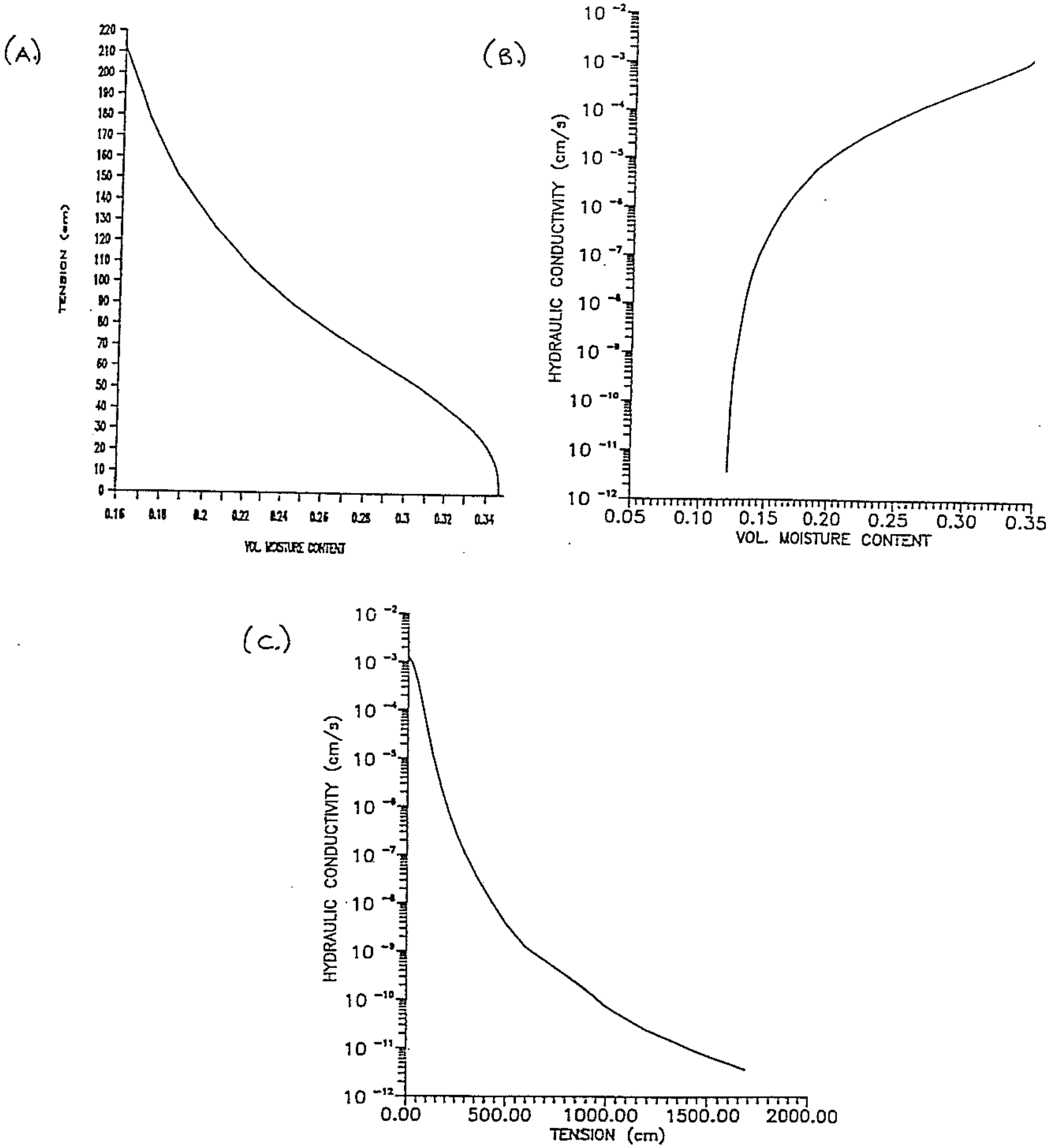


Figure 4.16. Curves generated by the van Genuchten code for column #3 (95/5 material): (a.) θ–ψ drainage curve, (b.) hydraulic conductivity as a function of moisture content, and (c.) hydraulic conductivity as a function of pressure head.

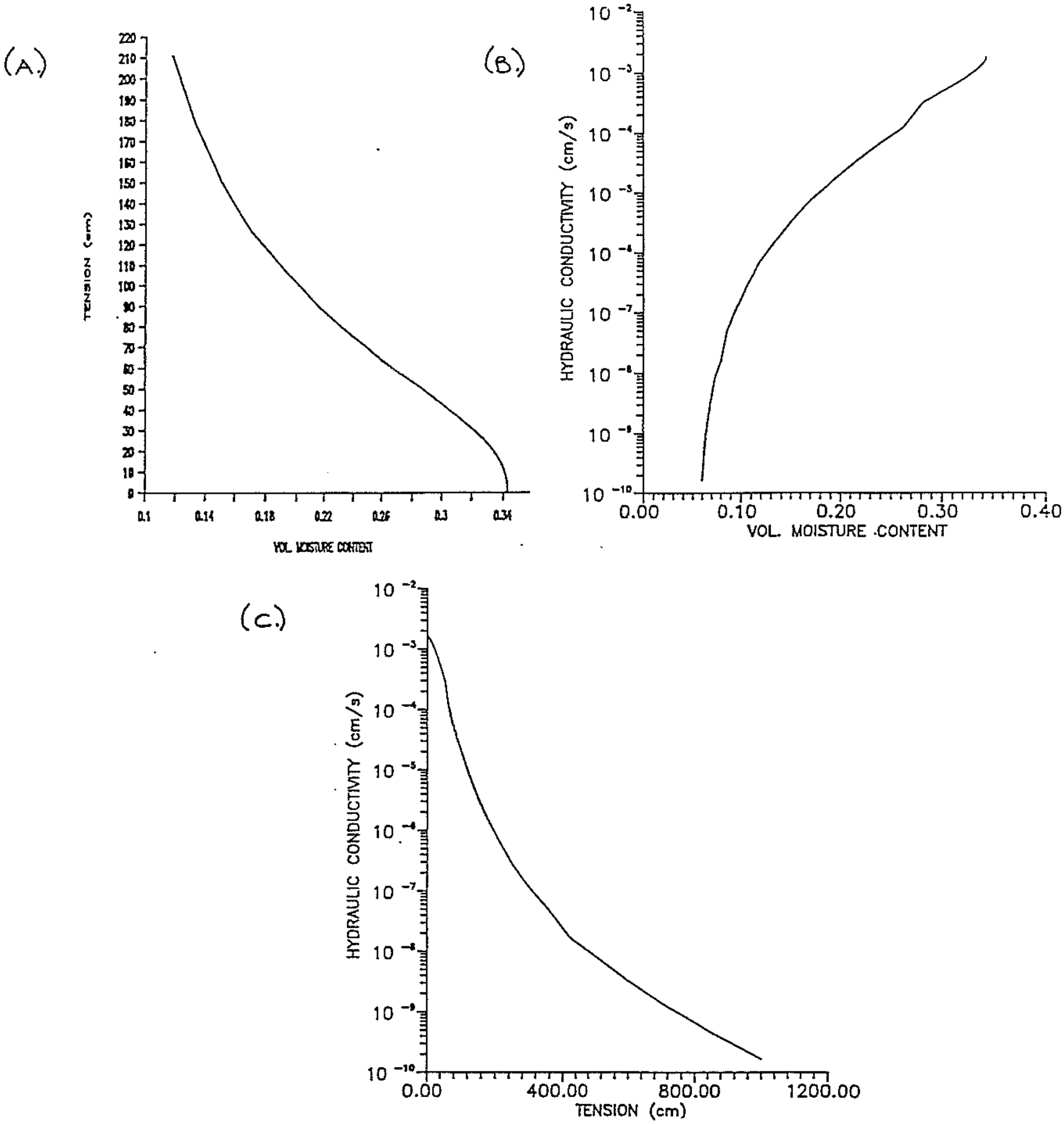


Figure 4.17. Curves generated by the van Genuchten code for column #4 (100% tailings): (a.) θ–ψ drainage curve, (b.) hydraulic conductivity as a function of moisture content, and (c.) hydraulic conductivity as a function of pressure head.

5.0. TENSIOMETRIC DATA

5.1. SOIL MOISTURE POTENTIAL

The soil–moisture potential, which is composed of a pressure, osmotic (solute), and matric potential, describes the energy status of the soil–water. The pressure potential applies mostly to saturated conditions, and the osmotic potential is often neglected in the absence of a semi–pemeable membrane and high salinity soil.

The matric potential is related to the capillary and adsorptive forces in the soil. Because the matric potential is negative in unsaturated soils, it is usually referred to as the matric "suction," or simply "suction." Theoretically, the matric potential is zero in saturated soil although it may have a small negative value at the air–entry pressure.

In general, capillary forces predominate in sandy soils and in the low suction range (i.e., moist conditions) while adsorptive forces predominate in clayey soils and in the very high suction range (i.e., relatively dry conditions). In unsaturated soils the adsorptive forces are very strong, and water may be held in thin films or exist only between the grains as shown in figure 5.1. Clay soils, in particular, are able to retain moisture at high suctions due to the adsorption of water onto the surface of the clay particles (Hillel, 1980a).

The gravitational potential, which is completely independent of soil properties, is taken to be the difference in elevation between the point in question and some reference point. By definition, the gravitational potential is negative in the downward direction. The soil–moisture potential, combined with the gravitational potential, yields the total hydraulic potential, or hydraulic head.

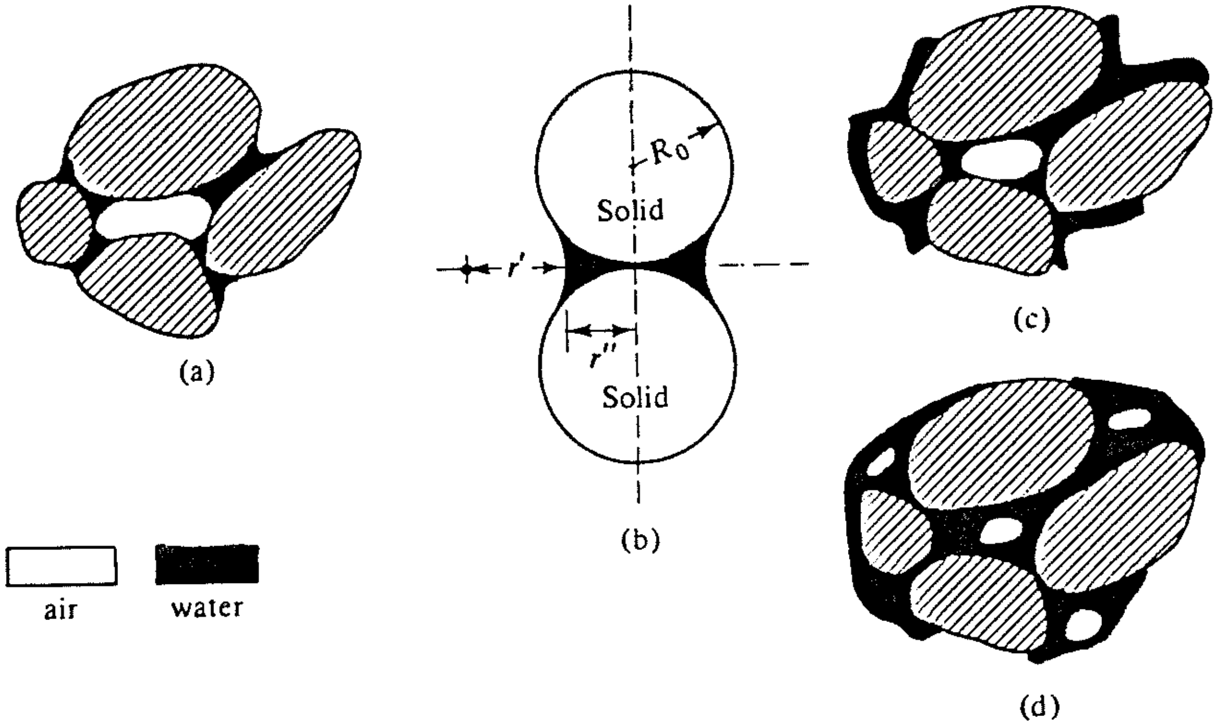


Figure 5.1. Varying degrees of saturation which may exist in an unsaturated soil: (a.) pendular saturation (b.) pendular ring between two spheres (c.) funicular saturation (d.) insular air saturation (Bear, 1987).

5.2. TENSIOMETRY

Matric potential can be measured with an instrument known as a tensiometer. Gardner et al. (1922) first suggested the use of porous ceramic equipment to measure the matric potential, and later, Richards (1928) proposed that porous ceramic cups connected to vacuum gages or manometers be used.

The porous ceramic cup of the tensiometer is placed in contact with the soil where it equilibrates with the soil-water. As the water content of the surrounding soil changes, the pressure in the water in the tensiometer cup changes. A decrease in soil moisture content will cause water to pass through the pores of the tensiometer cup and into the soil, thereby reducing the pressure in the tensiometer cup. Conversely, an increase in soil moisture content will increase the water pressure in the tensiometer cup. Assuming that the tensiometer water is in equilibrium with the soil-water, the pressure (or suction) of the soil-water may be measured (Cassel and Klute, 1985).

There are a few disadvantages to the use of tensiometry. First of all, there is a lag in the response time due to the hydraulic resistance between the ceramic cup and the soil. Second, it is often times difficult to obtain good hydraulic contact between the ceramic cup and the soil (Hillel, 1980a). Finally, one of the greatest problems lies in the reliability of the tensiometers after prolonged use in the field.

5.3. METHODS OF ANALYSIS

Soil suction measurements reveal the relative amount of moisture in a soil-water system. In general, high suction values indicate dry soil conditions while low suction values indicate moist soil conditions. Since suction is a potential, two or more of these measurements separated by some distance enables the flow direction to be determined.

In order to evaluate the effectiveness of the different cap materials in reducing infiltration, the following data sets were examined: 1. The suction values were compared among columns. These values revealed which cap material was releasing the most amount of moisture to the underlying tailings. 2. The hydraulic gradients were compared among columns. The magnitude, direction, and persistence of these gradients revealed which of the columns were first affected, most strongly affected, and continued to be affected by precipitation events of varying magnitude and duration.

The pressure head (Ψ) was determined by the equation:

$$\psi = \left(\frac{0.976cm\ of\ water}{1\ mb}\right)RC + \left(\frac{\varrho_{mix}}{\varrho_{water}}\right)W \qquad (5.1)$$

where: Ψ = pressure head (cm); suction equals $-\Psi$.
R = pressure reading on tensimeter gage (mb)
C = calibration factor for the tensimeter (0.9404 or 0.9177, depending on tensimeter used).
ρ_{mix} = density of 40% ethylene glycol–60% water mixture (1.045 g/cc).
ρ_{water} = density of water (1.00 g/cc).
W = vertical distance between the water level in the tensiometer and the top of the tensiometer cup (cm).
0.976 = conversion factor from centimeters of 40/60 mixture to millibars, assuming ρ_{mix} = 1.045g/cc.

The magnitude and the direction of the hydraulic gradient between any two tensiometers was determined by the following equation:

$$G_{12} = \frac{H_2 - H_1}{D_2 - D_1} \qquad (5.2)$$

where: G_{12} = gradient between tensiometers #1 and #2 (positive and negative values indicate upward and downward fluxes, respectively) (L/L)
H_2 = total hydraulic head at tensiometer #2 (L)
H_1 = total hydraulic head at tensiometer #1 (L)
D_2 = depth of tensiometer #2 (L)
D_1 = depth of tensiometer #1 (L)

5.4. PROBLEMS ASSOCIATED WITH DATA COLLECTION

Field equipment often has problems associated with it, and this experiment was no exception. The tensiometers in this experiment would often leak fluid into the columns, and the extra moisture in the soil surrounding the tensiometer cup may have affected the suction readings. In addition, the suction readings were found to vary throughout the day which may be attributed to changes in the ambient outdoor temperature.

5.4.1. TENSIOMETER FLUID ADDITIONS

Often times fluid would need to be added to the tensiometers because they had lost all or part of the fluid contained in them. Records were kept of the amount of fluid added to each column, and these amounts are recorded in appendix E and table 5.1. The tensiometers in columns #1 and #3 tended to lose more water than those in columns #2 and #4. The cumulative addition of tensiometer fluid to column #2 was less than that of the other three columns because column #2 had only two rather than three tensiometers.

Column Number	Tensiometer Number	Tensiometer Fluid Added (ml) -1985	Tensiometer Fluid Added (ml) -1986	Tensiometer Fluid Added (ml) -1987	Tensiometer Fluid Added (ml) -1988	CUMULATIVE FLUID ADDITIONS (ml)
1	1	49.4	203.7	83.5	196.9	533.5
	2	42.0	100.0	8.5	125.0	275.5
	3	16.2	78.0	7.0	52.5	153.7
	total	107.6	381.7	99.0	374.4	962.7
2	1	13.0	109.8	76.0	63.0	261.8
	2	58.4	98.1	13.0	157.0	326.5
	total	71.4	207.9	89.0	220.0	588.3
3	1	44.3	123.4	98.5	275.0	541.2
	2	109.0	114.1	36.0	86.0	345.1
	3	11.4	90.9	22.5	0.0	124.8
	total	164.7	328.4	157.0	361.0	1011.1
4	1	12.0	106.6	81.5	126.3	326.4
	2	46.3	78.3	69.2	54.3	248.1
	3	74.6	66.4	41.0	87.5	269.5
	total	132.9	251.3	191.7	268.1	844.0

Table 5.1. Tensiometer fluid added to each tensiometer of each column over the course of the experiment.

After fluid had been added to a tensiometer, the suction would not be monitored for approximately three to seven days. This gave the tensiometer time to re-equilibrate with the soil-water. Because small quantities of fluid were added to the tensiometers on a regular basis, there was no clear relationship between tensiometer fluid additions and erratic suction readings. However, the suction data was screened for such inconsistencies and readings thought to be invalid were eliminated from the database.

The loss of tensiometer fluid to the columns may have been related to the septum rubber stoppers used in the tensiometers. The stoppers may have lost their seals with the tensiometers due to changes in the outdoor temperature or other atmospheric conditions. The stoppers were replaced periodically, but this did not seem to alleviate the problem.

5.4.2. TEMPERATURE EFFECT ON SUCTION MEASUREMENTS

There has been much speculation in recent months concerning the reliability of suction values determined by the tensiometer-tensimeter apparatus used in this and other experiments. In order to address this concern, field tests were performed to determine the effect of daily temperature variations on resulting suction measurements.

On a cool Winter day in the middle of January 1988 and on a warm Summer day in August 1988, tensiometer readings were recorded at different times during the day. The results, which are shown in appendix C.2 and table 5.2, revealed that the ambient temperature *does* affect tensiometer readings, although a quantifiable relationship between temperature and suction could not be established based on this study. The effects varied between tensiometers in the same column and from one column to another. Therefore, the hydraulic gradient would be in–

Column Number	Time	Suction Values (% difference relative to initial reading)		
		Tensiometer #1	Tensiometer #2	Tensiometer #3
1	11:00	505.6	218.7	236.7
	14:00	496.1 (-2.1%)	213.1 (-2.6%)	232.0 (-2.0%)
	17:00	500.7 (-1.2%)	221.4 (+1.3%)	241.3 (+2.0%)
2	11:00	N/A	141.5	119.6
	14:00	N/A	132.1 (-6.6%)	114.0 (-4.7%)
	17:00	N/A	139.6 (-1.3%)	119.6 (0%)
3	11:00	434.6	294.1	62.3
	14:00	423.3 (-2.6%)	287.6 (-2.2%)	57.7 (-7.5%)
	17:00	426.1 (-1.9%)	294.1 (0%)	64.2 (+3.0%)
4	11:00	290.5	204.2	152.9
	14:00	(added water to	195.8 (-4.1%)	148.2 (-3.1%)
	17:00	tensiometer)	204.2 (0%)	153.8 (+0.6%)

Above: Results from January 19, 1988; Below: Results from August 9, 1988

1	07:15	412.3	16.0	261.8
	11:45	369.1 (-10.5%)	16.0 (0%)	280.4 (+7.1%)
	16:15	356.9 (-13.4%)	16.0 (0%)	227.1 (-13.3%)
2	07:15	N/A	118.3	74.3
	11:45	N/A	94.9 (-19.8%)	36.8 (-50.4%)
	16:15	N/A	116.4 (-1.6%)	53.7 (-27.7%)
3	07:15	Not	168.2	Not
	11:45		128.9 (-23.4%)	
	16:15	Operational	128.9 (-23.4%)	Operational
4	07:15	208.2	176.7	123.2
	11:45	151.0 (-27.5%)	138.3 (-21.7%)	110.8 (-10.0%)
	16:15	152.0 (-27.0%)	151.4 (-14.3%)	124.9 (+1.4%)

Table 5.2. Effect of temperature variation on suction measurements using the tensiometer–tensimeter apparatus used in this experiment.

fluenced, but in an unpredictable manner. In general, the suction readings were lowest during the warmest part of the day and highest during the coolest part of the day. Similar findings have been discovered by T. Stein and E. Hicks (Graduate Research Assistants, New Mexico Tech Geoscience Department, 1988, personal communication) at their field site just north of Socorro, NM. It is not certain what mechanism is responsible for this effect. One hypothesis is that it is somehow related to the decreasing surface tension of the tensiometer fluid with increasing temperature.

The tensiometers in this study were monitored at approximately the same time every day (i.e., in the early morning). Therefore, the temperature effect should not have been a major factor in this experiment. Temperature variations from Winter to Summer months would have been too gradual for one to detect an impact on the suction measurements. Furthermore, suction readings during the Summer months versus the Winter months did not differ significantly.

5.5. RESULTS AND DISCUSSION

The experimental and monitoring procedures for this chapter are given in chapter 3, sections 3.1 through 3.4. The tensiometric data is included in appendix C and the precipitation and evaporation data are included in appendix D. The terms "effective" and "effectiveness" will be used loosely throughout this paper in reference to the effectiveness of a cap material in reducing infiltration.

5.5.1. SUCTION MEASUREMENTS

Table 5.3 shows the high, low, and mean suction values for each tensiometer of each column for every year in which the experiment was monitored. The complete set of data is included in appendix C.

Column Number	Tensiometer Number	Suction (cm) -1985			Suction (cm) -1986			Suction (cm) -1987			Suction (cm) -1988		
		H	L	M	H	L	M	H	L	M	H	L	M
1	1	221.9	2.7	131.4	279.4	67.0	208.3	229.9	99.9	166.0	505.9	271.8	368.1
	2	182.7	36.6	101.0	193.0	46.9	141.0	187.9	86.8	143.8	239.3	77.7	188.1
	3	117.5	41.8	86.2	168.4	37.1	116.9	164.7	103.3	133.8	216.2	111.3	166.4
2	1	125.2	28.7	92.1	154.4	19.4	104.2	114.2	67.2	94.7	125.5	61.2	95.8
	2	41.7	112.3	110.9	113.3	36.1	111.3	98.5	41.5	80.2	154.4	34.0	72.7
3	1	322.8	64.2	194.9	247.7	25.1	130.0	328.7	54.0	148.2	401.4	68.4	218.1
	2	216.0	39.2	138.9	181.3	27.1	110.6	219.4	57.3	124.2	303.5	85.4	173.1
	3	133.7	31.4	98.1	134.9	29.5	86.9	154.0	9.9	84.0	106.4	0.1	39.5
4	1	252.8	0.4	141.2	273.7	4.6	135.8	380.0	73.2	172.2	341.7	67.2	172.0
	2	188.1	28.8	107.8	175.6	32.5	109.9	216.6	39.6	121.4	176.8	74.3	138.5
	3	120.1	27.2	77.0	158.2	37.3	96.4	124.9	71.3	98.5	159.6	46.7	100.2

H = High suction value (cm)
L = Low Suction value (cm)
M = Mean (weighted) suction value (cm)

Table 5.3. High, low, and mean suction values for each tensiometer of each column over the course of the experiment.

In the first few months of the experiment (experimental days 1 through ~100), the suction measurements in column #1 (50% bentonite cap) were relatively low (i.e., less than 100cm of suction). The suction data exhibited large temporal variations which probably indicates that this cap material was not very effective in retarding the effects of precipitation and evaporation, or possibly that the tensiometers were working improperly. The general trend in the data from column #1 was for the suction values to increase, or for the soil to become drier, with time. After the column was repacked in the Fall of 1987, the suctions were slightly higher at the lowermost tensiometer and significantly higher at the top two tensiometers as shown in table 5.3. One explanation for this is that when the dry cap material was packed on top of the relatively moist tailings, moisture moved from the tailings up into the cap material, or this may have been due simply to evaporation. Prior to repacking the cap material, the suction values at tensiometers #1, #2, and #3 averaged 172.1, 129.7, and 112.7cm of suction, respectively. Afterward, the suctions averaged 368.1, 188.1, and 166.4cm of suction.

The suction values directly below the loam/ gravel cap material of column #2 were always relatively low, and this situation did not change significantly after the cap material was repacked. The suction measurements at tensiometer #2 ranged from 19.4cm to 154.4cm while the range at tensiometer #3 was 34.0cm to 154.4cm. The lowest suction value at tensiometer #2 occurred on June 25, 1986 (experimental day 493), a few days following a major precipitation event, and the low at tensiometer #3 occurred on April 15, 1988 (experimental day 1150), following several small precipitation episodes. This was a good indication that this cap material was not very effective in reducing infiltration.

The three tensiometer locations below the 5% bentonite cap of column #3 had relatively high suctions throughout the first five months of the experiment (experimental days 1 through ~150). In general, these suctions decreased with time, but still remained higher than those recorded in column #2. The suctions in the top two tensiometers increased after the cap was repacked in the Fall of 1988 as shown in table 5.3. There was considerable variation in the suction measurements which may have been related to faulty tensiometers; the tensiometers would either lose water or lose hydraulic connection with the surrounding soil. Tensiometer #3, in particular, had to be removed and replaced several times.

The "average" suction measurements of column #4 (100% tailings) remained relatively constant through time although there was considerable variation in the overall data which was probably related to either infiltration and evaporation episodes or to improperly working tensiometers. On the average, the suctions did not increase much after the cap material was repacked.

The suction data revealed that the 5% and the 50% bentonite clay caps were both very effective in retarding seepage. Initially, column #3 appeared to be the most effective, releasing the least amount of moisture to the underlying tailings, as documented by the relatively high suction values measured in the tailings. Later in the experiment, column #1 appeared to be the most effective for the same reason. Column #2 never seemed to be very effective, being even less so than column #4. Table 5.4 shows the "average" hydraulic conductivities at the base of the cap materials based on the "average" suction readings at those locations; repacking was shown to reduce the "average" hydraulic conductivities, and therefore, seepage through the cap materials was probably reduced.

McElroy (1985) performed a series of geostatistical analyses on the precipitation, evaporation, and suction data from the first seven months of the experi–

Column Number	Mean Suction (cm) / Mean Unsaturated K (cm/s)	
	Before repacking	After repacking
1	138.2 / 1.2E-5	240.9 / 4.6E-7
2	99.8 / 4.2E-5	84.3 / 7.8E-5
3	122.6 / 2.0E-5	195.6 / 2.4E-6
4	117.5 / 2.5E-5	136.9 / 1.2E-5

Table 5.4. Mean unsaturated hydraulic conductivities K(ψ) below cap materials of columns before and after repacking. The values are based on the overall mean suction values.

ment. The only valid conclusion drawn from the analyses was that evaporation correlated well with high suctions while precipitation correlated well with low suctions, which one would generally expect. Although low evaporation rates should correlate with high precipitation rates and vice–versa, no correlation was found between the two. In the analyses, the suction values from a specified depth in one column were compared to those in another column. The results in table 5.5 show the cross–covariances for the strongest peaks and their lag times. McElroy (1985) hypothesized that since the column #1 series were in advance of the other columns, column #1 must have felt the effects of climatic change at depth in the column before the other columns were affected. In other words, the cap material of column #1 was the least effective in delaying infiltration. It is very important to note that these analyses considered only the data from the first seven months of the experiment. A simple observation of the hydraulic gradients during this time period supports the conclusions drawn by this analysis.

5.5.2. HYDRAULIC GRADIENTS

By definition, the hydraulic gradient is negative in the downward direction and positive in the upward direction. Therefore, in the upper part of the column, negative gradients generally correspond to infiltration episodes while positive gradients generally correspond to evaporation episodes. A zero gradient indicates no net flow between the two points. The terms "hydraulic gradient" and "gradient" will be used interchangeably in this section with no difference in meaning.

Figures 5.2 and 5.3 illustrate the hydraulic gradients at the base of the cap material of column #1 over the course of the experiment and the precipitation which accompanied those measurements. In the first few months of the experi–

Tensiometer Number	Column to Column	Cross-Covariance	Lag	Valid? (yes/no)
1	1 - 4	0.01900	+9	no
1	1 - 3	0.01300	+9	no
1	3 - 4	0.00946	0	yes
2	1 - 4	0.00476	0	no
2	1 - 3	0.00517	+15	no
2	1 - 2	0.00372	+9	yes
2	2 - 4	0.00365	-18	no
2	2 - 3	0.00425	0	yes
2	3 - 4	0.00789	0	yes
3	1 - 4	0.01067	+9	yes
3	1 - 3	0.00260	0	marginal
3	1 - 2	0.00283	+18	yes
3	2 - 4	0.00658	-6	no
3	2 - 3	0.00200	-18	no
3	3 - 4	0.00524	+15	marginal

SOURCE: McElroy (1985); *utilizing data from 2/85 to 9/85.*

Table 5.5. Geostatistical analysis performed by McElroy (1985); comparison of suction values at the same depths in different columns (only the "valid" results were used in the interpretation).

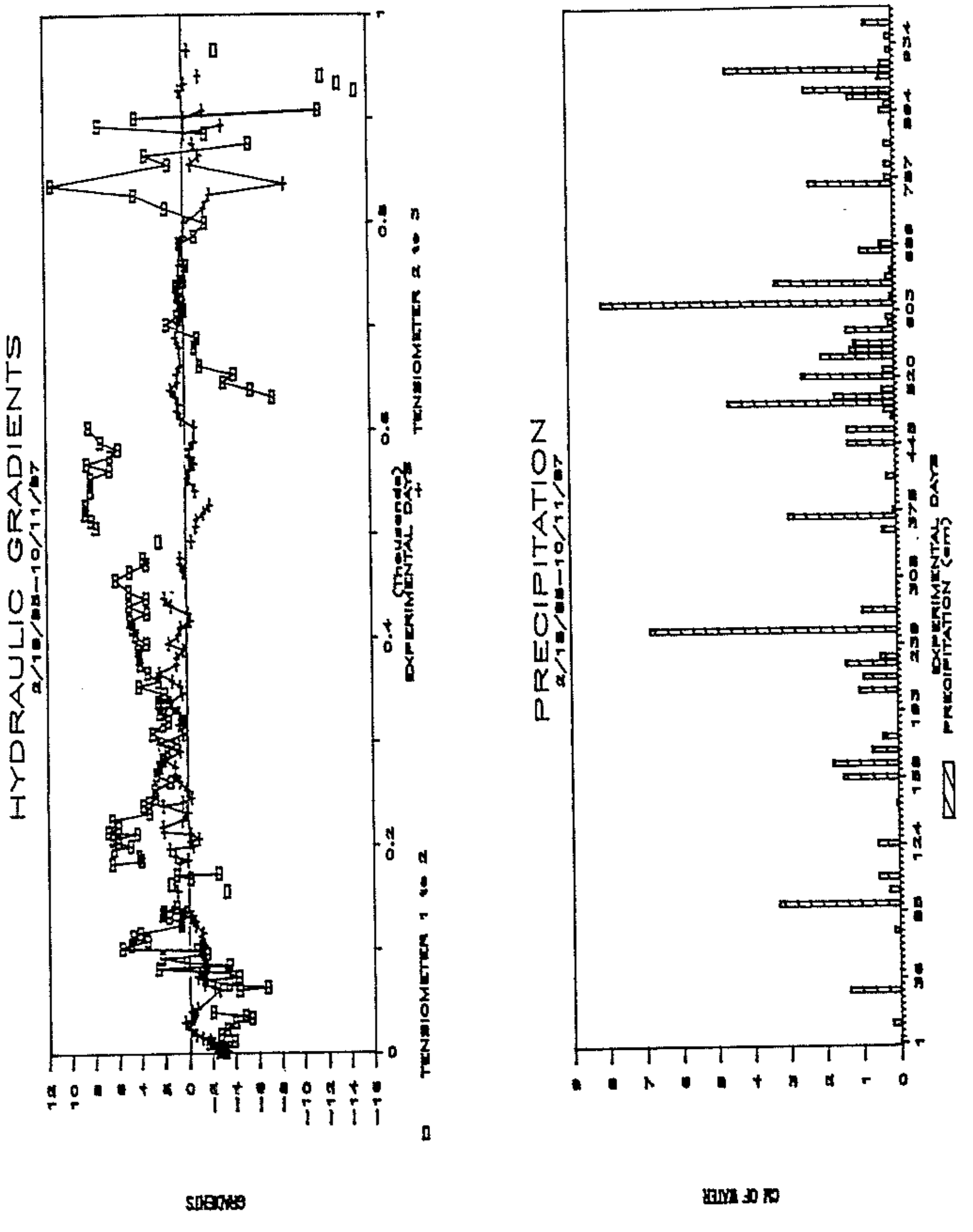


Figure 5.2. Top figure: hydraulic gradients at the base of the cap material of column #1 (50% bentonite) for the years prior to repacking the cap material (1985–1987); "1–2" and "2–3" refer to the gradients between tensiometers #1 and #2 and between #2 and #3, respectively. Bottom figure: precipitation during the same time period.

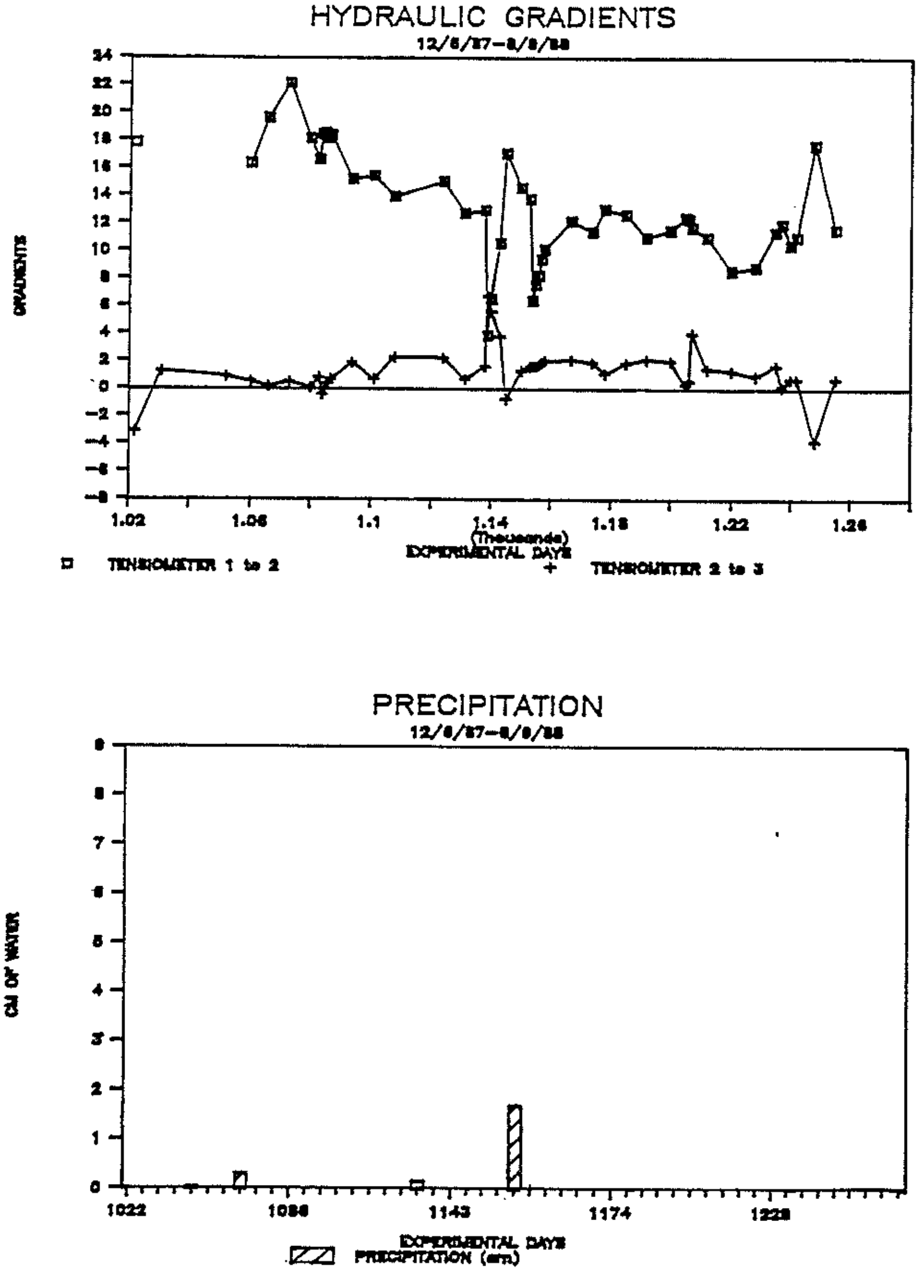


Figure 5.3. Top figure: hydraulic gradients at the base of the cap material of column #1 (50% bentonite) for the year after the cap material was repacked (1988); "1-2" and "2-3" refer to the gradients between tensiometers #1 and #2 and between #2 and #3, respectively. Bottom figure: precipitation during the same time period.

ment (experimental days 1 through 180), the gradients were predominantly downward. In the months that followed, the gradients were mostly upward with only a few instances of downward gradients as shown in figure 5.2. Table 5.6 summarizes the portion of the time that the gradients were upward and downward, and table 5.7 shows the mean values for the gradient when it was upward and downward.

Column #1 exhibited upward gradients during most of 1986. One exception occurred in the middle of October of that year (experimental day 605), when a precipitation event exceeding 8 cm of water resulted in a significant downward gradient between tensiometers #1 and #2 as shown in figure 5.2. Similar findings were recorded throughout 1987, although many inconsistencies were also recorded during that year. The upward gradients were generally more significant between tensiometers #1 and #2 than #2 and #3. Often times the gradients between tensiometers #2 and #3 were downward. One hypothesis is that a "zero flux plane," as described by Dreiss and Anderson (1985), existed in this column such that the top portion exhibited evaporation while infiltration, or redistribution, was occurring below that.

The cap material of each column was removed and repacked in the Fall of 1987 for the purpose of applying several new fluoro-organic tracers and to insure that the cap materials were in reasonably good condition. The columns were closely monitored in 1988 to determine the gradients during successive days following moderate to heavy rainfall events.

The 50-50 cap material of column #1 seemed to be very effective throughout 1988 after being repacked (figure 5.3). In contrast to the behavior prior to repacking, the fluxes recorded between tensiometers #1 and #2 were al–

Column Number	Tensiometer to Tensiometer	Year	Hydraulic Gradients * % Up	% Down
1	1 - 2	1985	70	30
	2 - 3		51	49
	1 - 2	1986	85	15
	2 - 3		71	29
	1 - 2	1987	58	42
	2 - 3		44	56
	1 - 2	1988	100	0
	2 - 3		92	8
2	2 - 3	1985	36	64
	2 - 3	1986	30	70
	2 - 3	1987	17	83
	2 - 3	1988	97	3
3	1 - 2	1985	82	18
	2 - 3		80	20
	1 - 2	1986	50	50
	2 - 3		42	58
	1 - 2	1987	65	35
	2 - 3		74	26
	1 - 2	1988	65	35
	2 - 3		100	0
4	1 - 2	1985	77	23
	2 - 3		59	41
	1 - 2	1986	65	35
	2 - 3		39	61
	1 - 2	1987	78	22
	2 - 3		40	60
	1 - 2	1988	75	25
	2 - 3		86	14

* Weighted Mean Percentages

Table 5.6. Mean weighted percentages of hydraulic gradients that were upward and downward for each year of the experiment.

Column Number	Tensiometer to Tensiometer	Average Hydraulic Gradients							
		1985		1986		1987		1988	
		up	down	up	down	up	down	up	down
1	1 - 2	3.1	-2.9	4.6	-3.7	2.4	-5.2	11.5	N/A
	2 - 3	0.7	-1.5	0.8	-0.7	0.4	-1.3	1.5	-1.5
2	2 - 3	0.3	-0.5	1.1	-0.4	1.9	-0.8	1.2	-0.8
3	1 - 2	3.3	-1.5	1.8	-1.5	2.8	-2.0	4.9	-2.6
	2 - 3	1.9	-0.8	1.3	-0.9	1.7	-1.1	8.0	N/A
4	1 - 2	2.0	-1.6	1.7	-1.3	3.7	-1.1	2.5	-2.3
	2 - 3	1.6	-0.8	0.8	-0.8	1.7	-0.8	1.2	-1.2

N/A = Not Applicable

Table 5.7. Average hydraulic gradients in the upward and downward directions (i.e., average value for the gradient when it was upward and average value when it was downward).

ways upward, regardless of rainfall intensity or duration. The upward gradients were steepest following rainfall events of low intensity but were also quite significant following events of higher intensity. The gradient between tensiometers #2 and #3 were occasionally downward but were insignificant in comparison to the upward gradients (see also: tables 5.6 and 5.7). One explanation for this improvement is that the cap material of column #1 was disturbed during its transport to the field site at the onset of the experiment and that repacking the cap at the field site improved its effectiveness. Another explanation, which was stated earlier in section 5.5.1, is that when the dry cap material was packed on top of the relatively moist tailings, moisture moved from the tailings up into the cap material, creating the upward gradients observed.

The two tensiometers in column #2 (loam/ gravel cap material) yielded fairly consistent results during the first three years of the experiment. The gradients between the two tensiometers at the base of the cap material showed negative, or downward gradients, which correlated very well with precipitation events (figure 5.4), indicating that this type of cover was not effective in reducing infiltration. The intensity of the downward gradients increased as the duration and the intensity of the precipitation events increased. In between the rainfall events, there were brief periods of evaporation (i.e., upward gradients). As time progressed, column #2 continued to show downward gradients with only occasional upward gradients as shown in table 5.6.

There was a noticeable change in the behavior of column #2 following the repacking of the cap material in the Fall of 1987 as shown in figure 5.5. In 1988 this column was exhibiting upward gradients while previously, they were mostly downward. It may be that in the original cap the upper finer textured soil

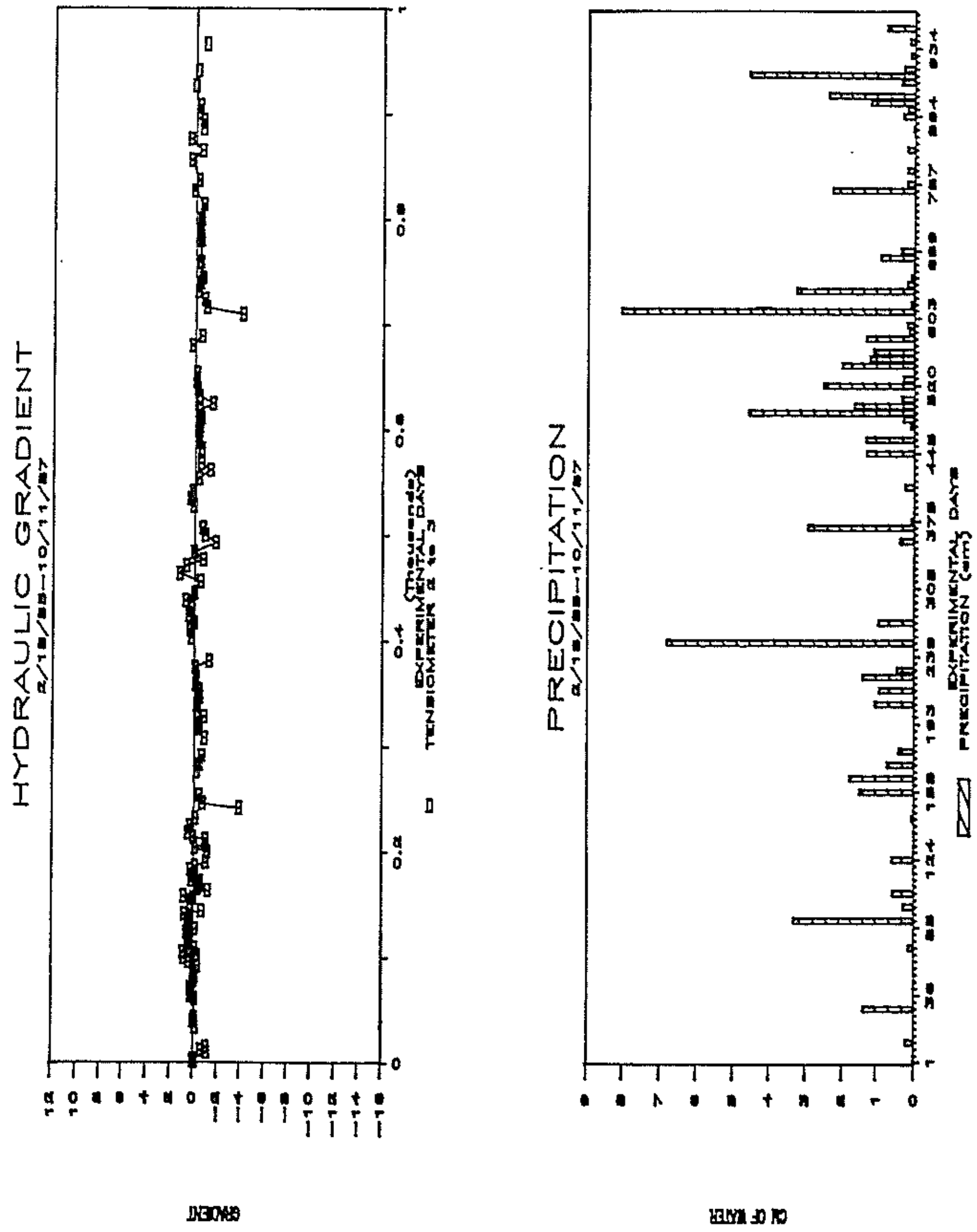


Figure 5.4. Top figure: hydraulic gradients at the base of the cap material of column #2 (loam/ gravel) for the years prior to repacking the cap material (1985–1987); "1–2" and "2–3" refer to the gradients between tensiometers #1 and #2 and between #2 and #3, respectively. Bottom figure: precipitation during the same time period.

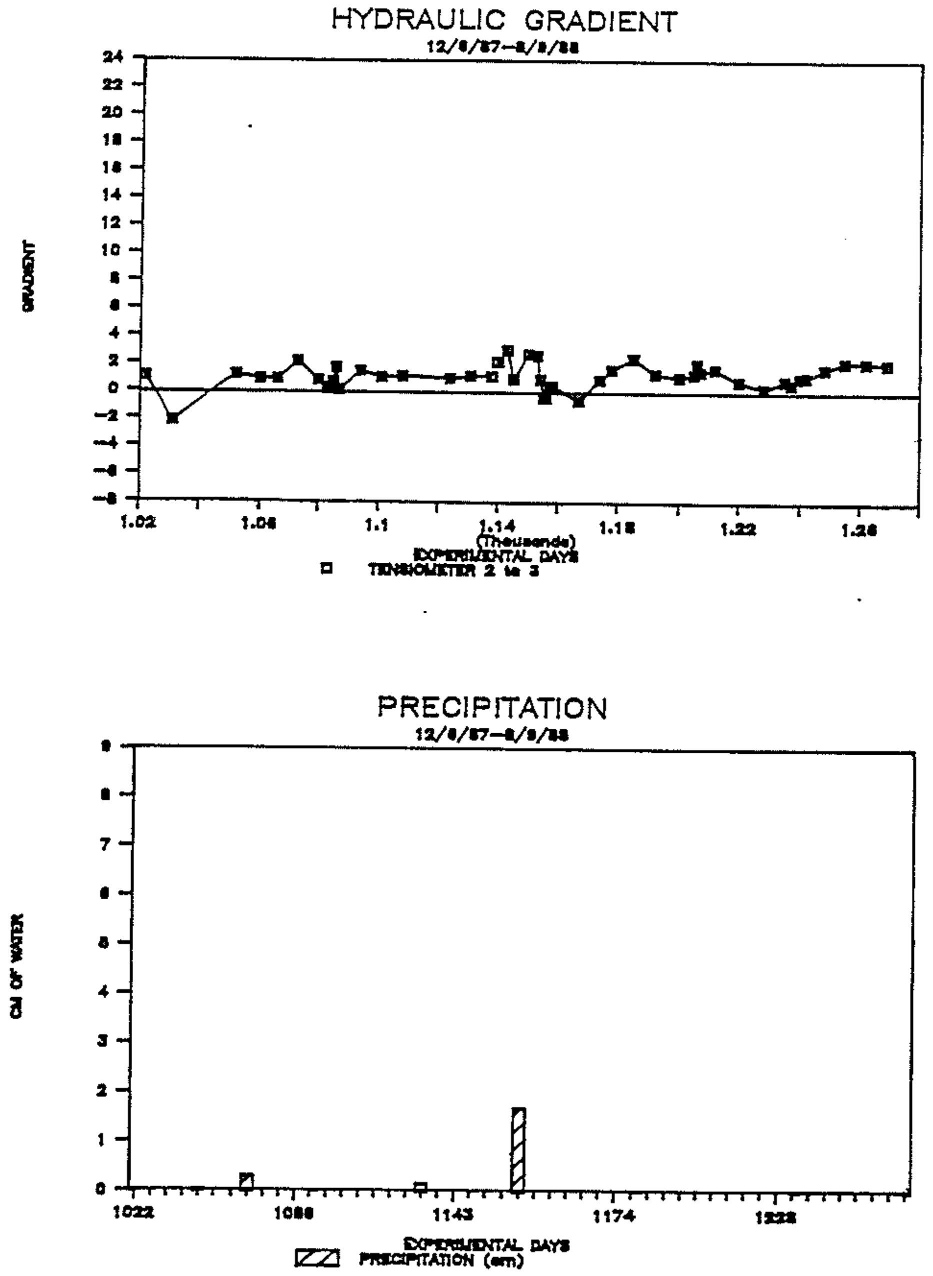


Figure 5.5. Top figure: hydraulic gradients at the base of the cap material of column #2 (loam/ gravel) for the year after the cap material was repacked (1988); "1–2" and "2–3" refer to the gradients between tensiometers #1 and #2 and between #2 and #3, respectively. Bottom figure: precipitation during the same time period.

settled into the voids in the underlying gravel, thereby destroying the hydraulic barrier effect. Another explanation is that the tensiometers simply were not working well after the prolonged time out in the field; the tensimeter sometimes revealed inconsistent readings and the tensiometers often lost water to the columns. In either case, the tensiometric data showed that infiltration penetrated the cap material of column #2 only a few times during 1988, following a moderate intensity precipitation event in the middle of April (experimental day -1150).

Early in the experiment (experimental days 1 through 150), the gradients in column #3 (5% bentonite cap material) were predominantly upward as depicted in figure 5.6. Initially, the gradients in column #3 suggested that the 95–5 cap material may the most effective in reducing infiltration. Data from the latter half of 1985 suggested that its effectiveness was intermediate between that of columns #4 (100% tailings cover) and #1 (50% tailings–50% bentonite cover). In the years that followed, the tensiometric data has supported the latter conclusion. Although column #3 exhibited periods of very strong upward gradients, it showed more instances of downward gradients than did column #1 (refer to table 5.6). These downward gradients typically occurred following significant precipitation episodes as shown in figures 5.6 and 5.7.

The gradients in column #4 were predominantly upward during the early part of the experiment (experimental days 1 through 400) as illustrated in figure 5.8. The geostatistical analyses performed by McElroy (1985) also revealed similarities between these two columns. After 1985 the behavior of column #4 changed drastically as shown in figure 5.9. Significant variations between upward and downward gradients occurred, indicating that the tensiometers were very much affected by the processes (i.e., precipitiation and evaporation) occurring at the soil surface.

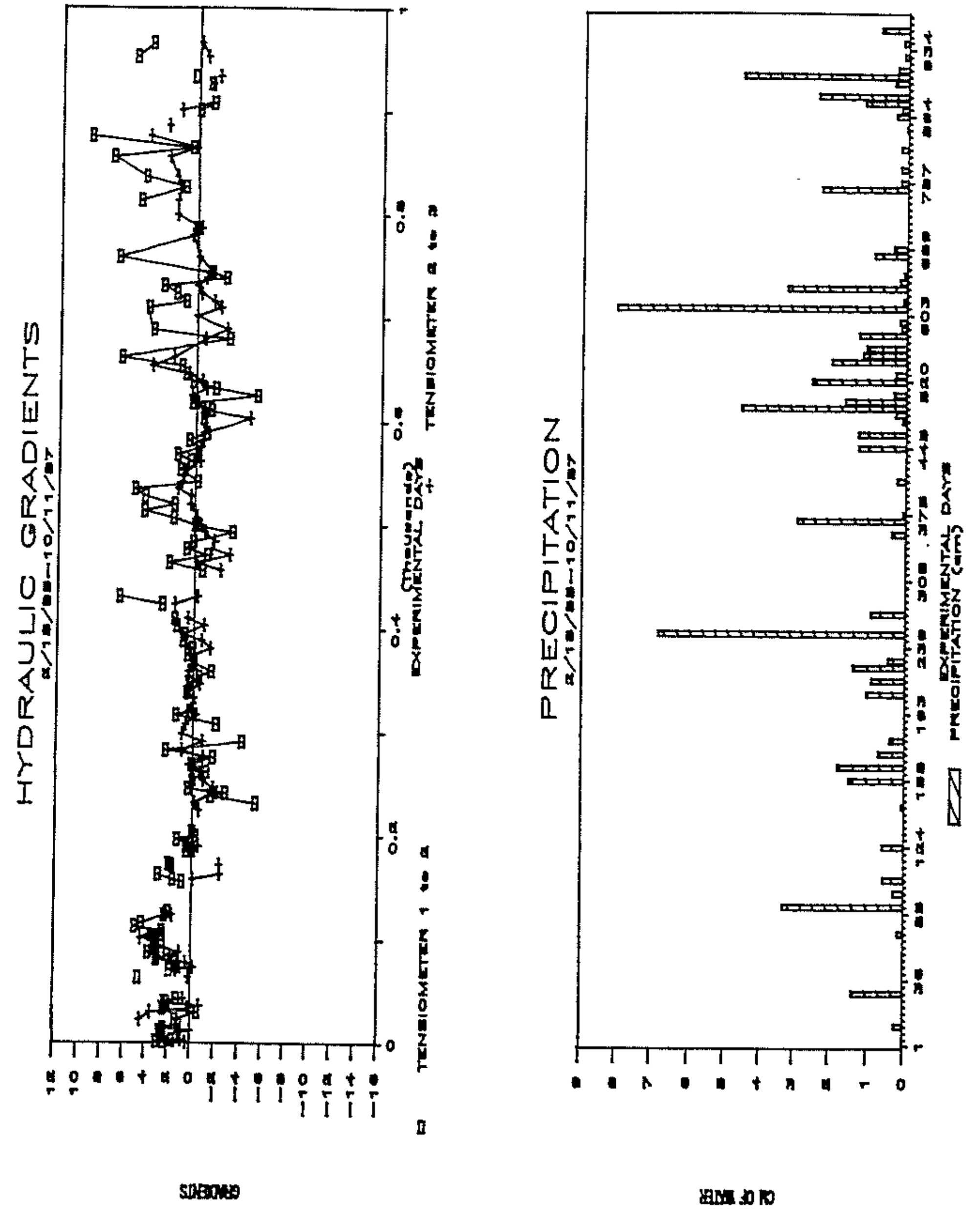


Figure 5.6. Top figure: hydraulic gradients at the base of the cap material of column #3 (5% bentonite) for the years prior to repacking the cap material (1985–1987); "1–2" and "2–3" refer to the gradients between tensiometers #1 and #2 and between #2 and #3, respectively. Bottom figure: precipitation during the same time period.

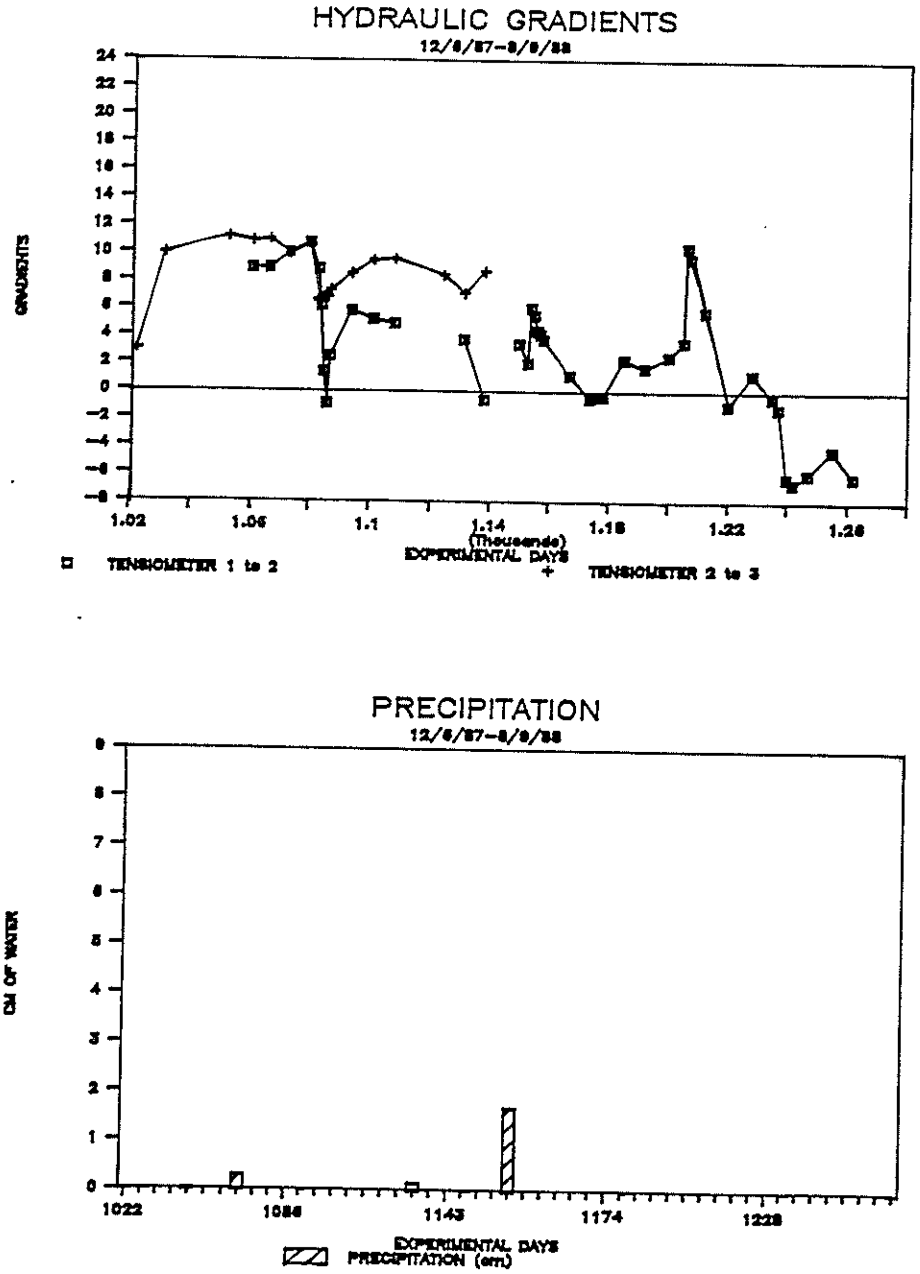


Figure 5.7. Top figure: hydraulic gradients at the base of the cap material of column #3 (5% bentonite) for the year after the cap material was repacked (1988); "1-2" and "2-3" refer to the gradients between tensiometers #1 and #2 and between #2 and #3, respectively. Bottom figure: precipitation during the same time period.

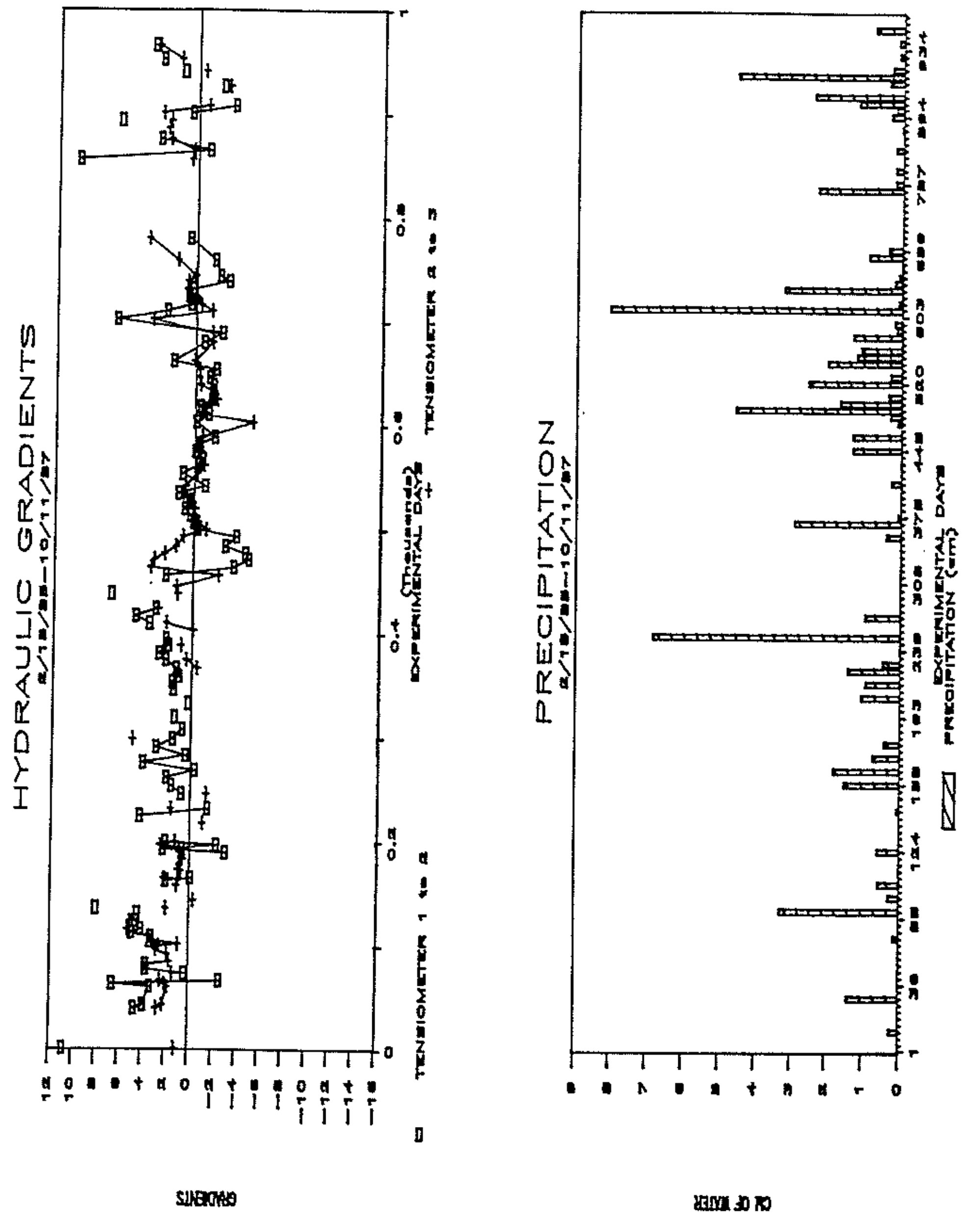


Figure 5.8. Top figure: hydraulic gradients at the base of the cap material of column #4 (100% tails) for the years prior to repacking the cap material (1985–1987); "1-2" and "2-3" refer to the gradients between tensiometers #1 and #2 and between #2 and #3, respectively. Bottom figure: precipitation during the same time period.

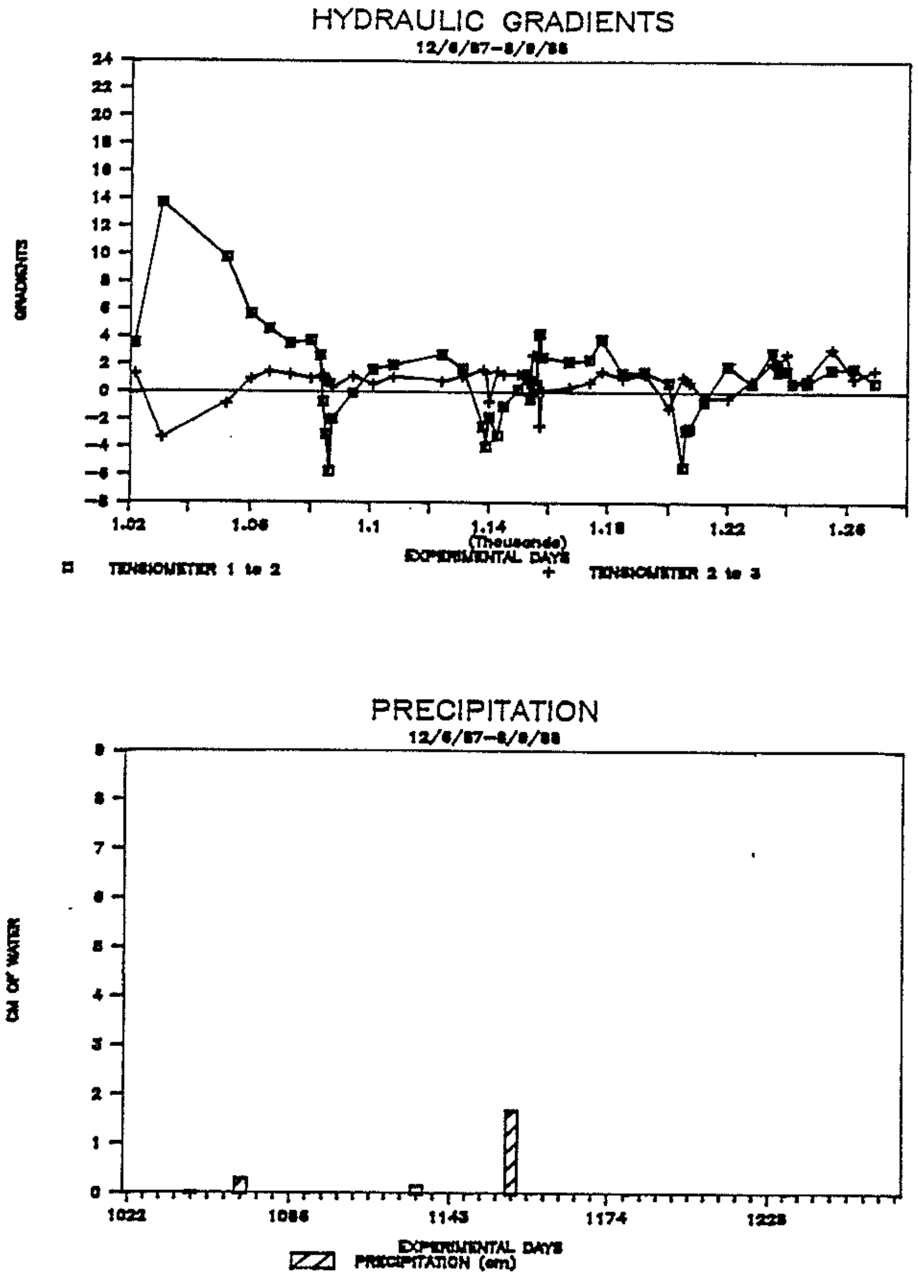


Figure 5.9. Top figure: hydraulic gradients at the base of the cap material of column #4 (100% tails) for the year after the cap material was repacked (1988); "1–2" and "2–3" refer to the gradients between tensiometers #1 and #2 and between #2 and #3, respectively. Bottom figure: precipitation during the same time period.

The hydraulic gradients from the last three years of the experiment seemed to indicate that the 50% bentonite cover was the most effective in reducing infiltration into the underlying tailings. The 5% bentonite cover was also very effective, and it appeared to be a significant improvement over a material consisting of 100% tailings. The loam–gravel combination, while ideal in theory, did not perform well under field conditions. The use of a finer textured gravel in this column may have reduced the settlement problem. Some type of clay cover material should probably be used in order to retard infiltration because the 100% tailings material appeared to offer little resistance to flow as indicated by the scatter in the data.

5.6. SUMMARY

The tensiometric data revealed that either 5% or 50% bentonite clay was the best type of cover material for inhibiting the downward penetration of precipitation. Although the 5% material of column #3 was the most effective during the first year of the experiment, the 50% material of column #1 was the most effective in the years that followed. The loam–gravel cover material of column #2 proved to be very ineffective although it did show signs of improvement after the caps were repacked in the Fall of 1987. The effectiveness of all of the cap materials improved after they were repacked.

Variations in temperature may have a significant effect on soil suction measurements obtained with the present instrumentation. It is uncertain just how these temperature variations affect the suction, but one idea is that it is related to the temperature dependence of the surface tension of the tensiometer fluid. The problem needs to be studied more closely and would be a good topic for future research.

6.0. MOISTURE DISTRIBUTION IN THE COLUMNS

6.1. INTRODUCTION

The moisture content distribution in each column was determined upon the conclusion of the experiment when the columns were dissected. For more information on this procedure, please refer to chapter 3. The moisture content data is given in appendix E, and as stated previously, the precipitation and evaporation records are included in appendix D.

The moisture content data was used to determine the percentages of precipitation that became "infiltration" and "deep percolation" as defined below, as well as the fluxes at the inlet and outlet boundaries of the columns. In addition, the distribution of moisture in each column was examined.

6.2. CORRECTIONS TO THE MOISTURE CONTENT DATA

Before any calculations could be performed, a few corrections to the moisture content data were required. The "unnatural" addition of moisture to the columns, referring to the addition of tensiometer and tracer fluids, needed to be taken into account.

As discussed in chapter 5, the tensiometers would lose their suction for reasons unknown, and the tensiometers would leak fluid into the columns. Records were kept of the amount of fluid added to each column through the tensiometers over the course of the experiment. Figure 6.1 shows these additions as a function of time, and table 6.1 summarizes the total amount of fluid added. The figure and table reveal that each column received relatively the same amount of tensiometer fluid.

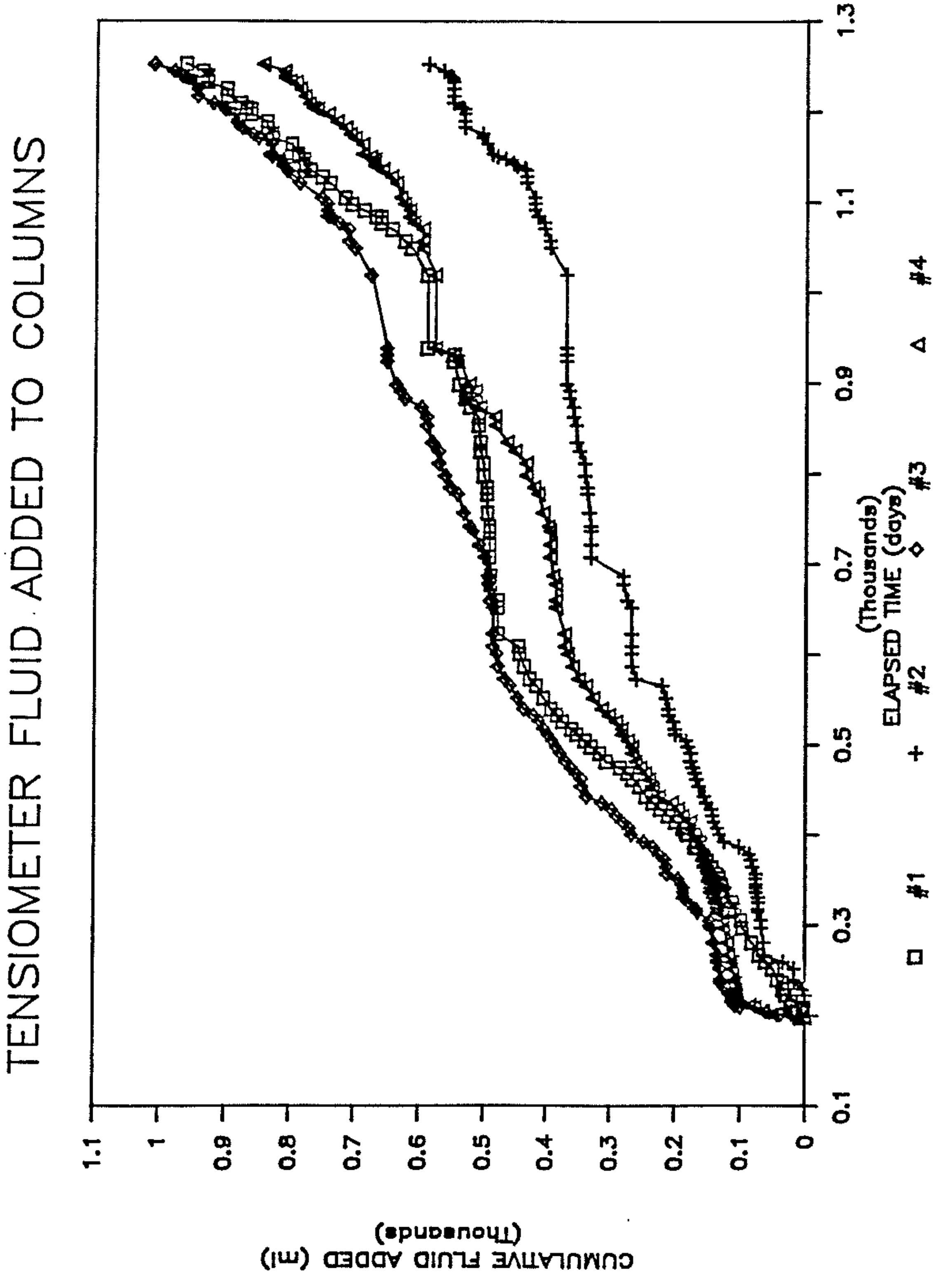


Figure 6.1. Addition of tensiometer fluid to each column as a function of time.

COLUMN NUMBER	TENSIOMETER FLUID ADDED (ml)	TRACER FLUID ADDED (ml)	MOISTURE LOST UPON REPACKING (ml)
1	962.7	25	331.75
2	588.3	25	341.70
3	1011.1	25	369.75
4	844.0	25	356.48

Table 6.1. Moisture added to each column from tensiometer and tracer fluids and moisture lost upon repacking the cap materials.

Another source of fluid to the columns was the tracers which were all applied in the liquid form. Each tracer, bromide and the four fluoro-organic tracers, were applied in a 5ml solution. Therefore, a total of 25ml of fluid was added to each column due to the tracers, and this is presented in table 6.1, also.

Recall from chapter 3 that the cap material of each column was removed for the purpose of applying several experimental fluoro-organic tracers approximately nine months prior to the conclusion of the experiment. At that time, several soil samples were taken to determine the moisture contents of the cap materials. The cap materials were then repacked at the air-dry moisture contents of each material which were less than the moisture contents at the time of removal. Therefore, there was a net loss of moisture from each column as shown in table 6.1.

This loss of moisture was neglected in the calculations which follow since: 1. it was only lost from the cap materials, 2. each column lost relatively the same amount of moisture, and 3. it was difficult to take these values into account because evaporation may have eventually drawn this moisture out of the cap materials anyway.

6.3. INFILTRATION ESTIMATES

The classical definition of infiltration is the downward flow of water from the ground surface through the unsaturated zone (Freeze and Cherry, 1979). This definition does not mention anything about the water reaching the water table; as long as the water is moving downward it is considered infiltration. In this study, "infiltration" was defined as the percentage of the total precipitation which passed *completely* through the cap materials. Moisture retained in the cap materials was not included in this percentage since it may have eventually moved upward and out of the column through evaporation.

The infiltration percentage was arrived at by first calculating the change in moisture content in the tailings below the cap material. Because the columns were originally packed at the air-dry moisture content of the tailings, moisture was present in each column at the onset of the experiment. The moisture content in each column at the conclusion of the experiment was greater than the initial value due to a change in storage in the unsaturated tailings. This change in moisture, together with the amount of effluent extracted from each column, represented the net gain in moisture below the cap material of each column. The change in moisture came from three different sources, two of which are known and one of which is unknown: 1. tensiometer fluid (known), 2. tracer fluid (known), and 3. infiltrated precipitation (unknown). The quantities of tensiometer and tracer fluids added to each column were subtracted from the total moisture to find the total amount of precipitation which infiltrated each column. This figure was divided by the total precipitation, as determined by the rain gage, to determine the percentage which passed completely through each cap material, or "infiltrated" each column. This may be summed up in the following two equations:

$$I_i = \frac{M_c}{P_t} \tag{6.1}$$

where: $$M_c = E_o + [(\theta_f - \theta_i)V_t - M_{t+t}] \tag{6.2}$$

where: I_i = percentage of precipitation which infiltrated column
M_c = corrected moisture in tailings (ml); equivalent to the amount of infiltrated precipitation
E_o = measured effluent value (ml)
θ_f = final moisture content in column (weighted average)
θ_i = initial moisture content in column (weighted average)
V = total volume below the cap material (cc) = (ml)
M_{t+t} = sum of tensiometer and tracer fluid additions (ml)
P_t = total amount of precipitation (ml)

Equation 6.1 assumes that all of the moisture which passed through the cap material would have continued moving downward. This may not be a good assumption, especially since the tensiometric data from the previous chapter showed evidence of upward gradients below the base of the cap materials.

Knowing the corrected value of moisture in the tailings (M_c), the cross-sectional area of the column, and the duration of the experiment, the "average" flux across the interface between the cap material and the tailings was calculated according to the equation:

$$q_{in} = \frac{M_c}{At} \qquad (6.3)$$

where: q_{in} = average flux across interface (L/T)
A = cross-sectional area of column (L^2)
t = duration of the experiment (T)

Equation 6.3 yields only an "average" flux into the tailings, while in reality the flux is a function of time and is highly dependent upon the precipitation rate and the antecedent moisture conditions.

6.4. DEEP PERCOLATION ESTIMATES

Internal drainage *beyond the root zone* has been referred to as "deep percolation" (Hillel, 1980a). The percentage of total precipitation which appeared as effluent may be thought of as representing deep percolation. This value may be a more valid indicator of cap material effectiveness than our previous estimate of "infiltration" because it represents only fluid which has traveled completely through the 180cm-long column while the infiltration estimate includes all water which has extended more than 30cm into the column.

Since the amount of effluent extracted from the bottom of each column represented not only infiltrated precipitation, but also water from the tensiometer and tracer fluids, these two sources needed to be taken into account. First, the percentage of tensiometer and tracer fluids relative to the net gain in moisture was calculated. This percentage was multiplied by the total effluent and then subtracted from the total effluent to obtain a corrected value of effluent, representing that due only to precipitation. Division of this value by the total precipitation yielded the percentage of precipitation that became "deep percolation" as defined above. These calculations are presented below for clarity:

$$I_d = \frac{E_c}{P_t} \tag{6.4}$$

where: $$E_c = E_o - E_o\left(\frac{M_{t+t}}{M_c}\right) \tag{6.5}$$

where: I_d = "deep percolation" (ml)
E_c = corrected effluent value (ml)

The flux at the outlet boundary (i.e., where the effluent was sampled) may be calculated according to the equation:

$$q_{out} = \frac{E_c}{At} \tag{6.6}$$

The percentage of precipitation that passed through the cap material and the percentage that appeared as effluent, were not necessarily the same due to a change in storage in the unsaturated zone. In simple terms this may be expressed as:

$$q_{out} = q_{in} \pm \Delta S \tag{6.7}$$

where: q_{out} = moisture which appeared as effluent
q_{in} = precipitation which infiltrated column (i.e., passed through the cap material)
ΔS = storage in the unsaturated zone

6.5. RESULTS AND DISCUSSION

There was 85.05cm of precipitation over the course of the experiment (i.e., February 1985 to August 1988) and the cross–sectional area of each column was 201.06cm^2. Therefore, 17,101cc (or 17,101ml) of water may have potentially infiltrated each column. This value was needed in the calculations which follow.

The data in table 6.2 and appendix E were used in equations 6.1 and 6.2 to calculate the percentages of precipitation that passed through the cap material of each column. The infiltration percentages for columns #1, 2, 3, and 4 were calculated to be 24.44, 35.70, 26.38, and 30.48%, respectively. Column #1 (50% bentonite cap) was the most effective in reducing infiltration into the tailings; it was 19.8% more effective than the control column (i.e., column #4: 100% tailings). Column #3 (5% bentonite cap) was 13.5% more effective than the control column. Column #2 (loam/ gravel cap) was very ineffective, allowing over a third of the precipitation to infiltrate its cap material; it was 17.1% *less* effective than the control column in reducing infiltration. These results are summarized in table 6.3.

Another method used to determine the effectiveness of different cap materials in reducing infiltration was to look at the percentage of the precipitation which was discharged from each column. Using the data in table 6.2 and appendix E and solving equations 6.4 and 6.5, the percentages of precipitation that became effluent were calculated to be 5.21, 0.80, 0.32, and 1.02% for columns #1, 2, 3, and 4, respectively. These values may or may not be valid because the sampling technique was poor. It was interesting, though, that column #1 produced the largest quantity of effluent which was unexpected based on other findings.

COLUMN NUMBER	EFFLUENT FROM COLUMN (ml) E.	MOISTURE LEFT IN COLUMN (ml) $(\theta f - \theta i)V$	SUM OF TENSIOMETER AND TRACER FLUID (ml) M_{t+t}
1	1172.8	4744.8	987.7
2	150.9	7318.9	613.3
3	66.6	6230.9	1036.1
4	202.6	6630.3	869.0

Table 6.2. Data used in the calculation of the infiltration percentage and the deep percolation percentage.

COLUMN NUMBER	PERCENTAGE THROUGH CAP MATERIAL (i.e., infiltration)	PERCENT REDUCTION IN INFILTRATION RELATIVE TO COL. #4	PERCENTAGE AS EFFLUENT (deep percol.)
1	24.44	+19.8	5.21
2	35.70	−17.1	0.80
3	26.38	+13.5	0.32
4	30.48	N/A	1.02

Table 6.3. Percentages of precipitation that passed through the cap materials (i.e., infiltration) and the percent reduction in infiltration relative to the control column (#4), and the percentages that appeared as effluent (i.e., deep percolation).

Figure 6.2 shows the cumulative effluent from each column as a function of time. Columns # 2, 3, and 4 had a linear relationship between effluent and time, and similar volumes of effluent were discharged from each. These systems were probably near steady–state since the slope of the effluent curve was constant through time. The rate of discharge from column #1 was virtually zero after approximately 750 days.

The high volume of effluent from column #1 seemed to be somewhat of an anomaly. Since this curve resembled a drainage curve, the effluent may have been due to internal drainage in the column. This was supported by the fact that the percentage of precipitation which infiltrated column #1 was small, and the amount of moisture retained in the column, shown in table 6.4, was also small. The suction values increased over time, also, indicating that at least the upper portion of this column was becoming drier.

Another explanation for the large volume of discharge from column #1 was that macropores or channeling along the column walls took place. Ponding was exhibited on the surface of this column which would have allowed channeling to occur. Most of the effluent obtained from column #1 was during the initial stages of the experiment, and the tensiometric data also indicated downward gradients below the base of the cap material during this time period. The column may have been disrupted during its transport from the laboratory to the field site, creating channels through which the precipitation could easily flow. These channels may have eventually sealed, causing the observed reduction in effluent over time. This was supported by the fact that the suction values increased over time, indicating that the upper portion of the column was becoming drier and less moisture was probably getting through the cap material. Both explanations presented for the

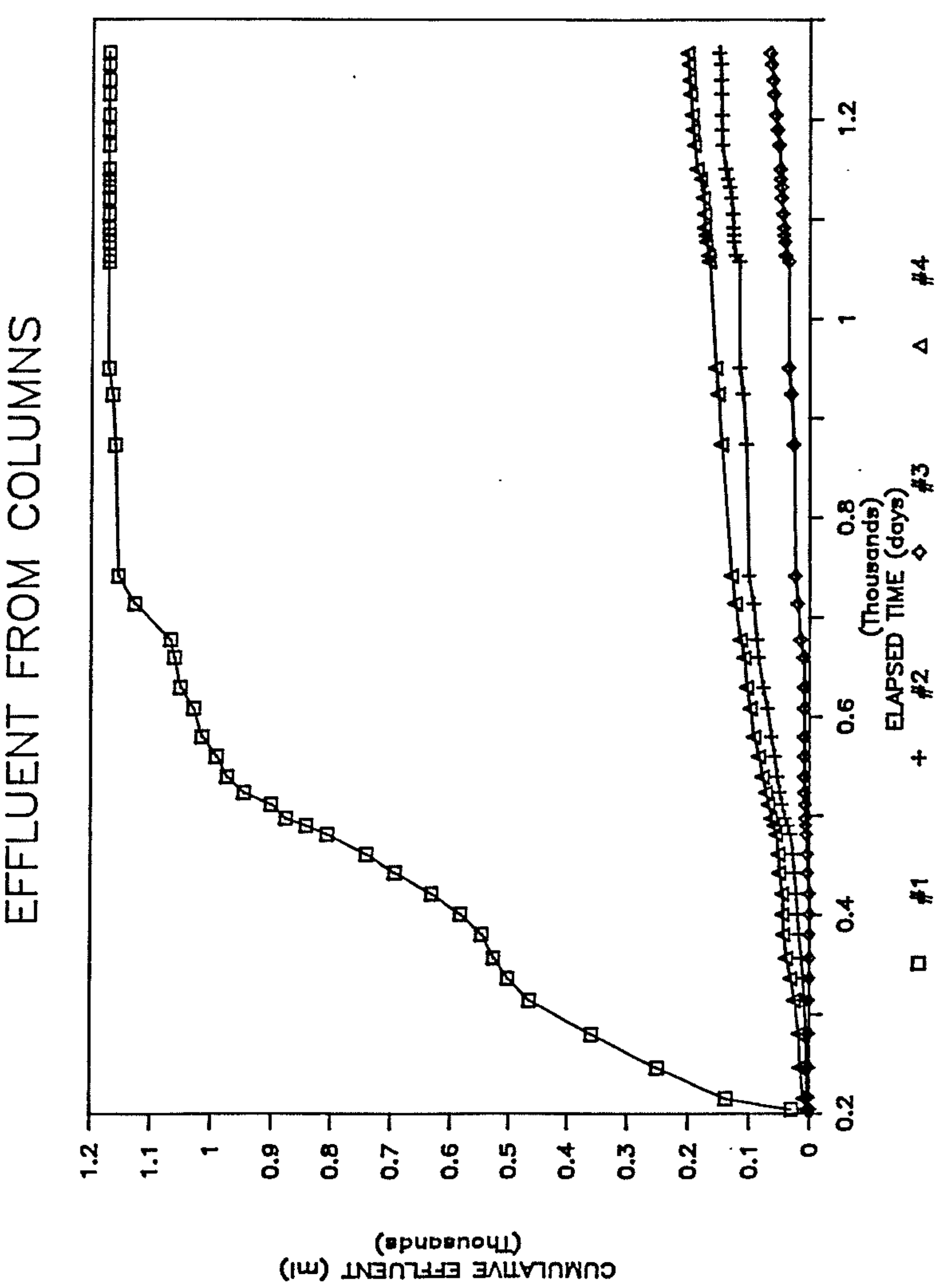


Figure 6.2. Cumulative effluent from each column as a function of time.

large volume of effluent obtained from column #1 (internal drainage and channeling) were supported by the fact that the volume of effluent released from column #1 decreased over time and eventually ceased. Furthermore, when column #1 was dissected at the conclusion of the experiment, it was found to have retained the least amount of moisture.

An attempt was made to determine the actual outflow from each column. The slopes of the curves in figures 6.1 (tensiometer fluid curves) and 6.2 (effluent curves) were calculated using the least squares linear regression method. Unfortunately, the slopes of the curves in figure 6.1 were greater than those in figure 6.2 which meant that if the addition of tensiometer fluid was taken into account, the outflow from each column would be either zero or a negative number. When the columns were dissected at the conclusion of the experiment, a substantial increase in moisture was found in each column. It is possible that more of this moisture would have appeared as effluent had the sampling technique been better.

Table 6.4 depicts the amount of moisture originally present in each column and the amount which was present at the conclusion of the experiment. The amount of moisture originally present in the tailings was determined prior to packing the columns by oven-drying a representative sample in the laboratory and determining its air-dry moisture content (D. McElroy, personal communication, 1987). The moisture present in each column at the conclusion of the experiment was determined by sampling at different depth intervals and then oven-drying each sample. The gravimetric moisture contents were multiplied by the bulk density and by the volume of soil that they represented and then summed to arrive at a volume of moisture present in each column as a whole (see also; appendix E).

Because the moisture retained in each column was a function of the moisture retention characteristics of the tailings, all of the columns should have retained relatively the same quantity of moisture below the cap material, but this was not the case. Perhaps the cap materials influenced the retention of moisture in the tailings below them, or perhaps channeling existed in some columns and not others, creating a direct route to the bottom, or perhaps the sampling technique somehow influenced moisture retention in the columns. It is difficult to prove or disprove any of these ideas. The results shown in table 6.4 indicate that column #2 retained the greatest quantity of moisture while column #1 retained the least amount. It is interesting to note that the cap material which allowed the most moisture to pass through it also retained the most moisture in the tailings. The irony in this is that the cap material which was the most effective in reducing infiltration was not the most effective in reducing deep percolation because it did not hold as much water in storage. Again, this may be unrelated to the type of cap material used; it is difficult to determine what is responsible for this phenomenon.

COLUMN NUMBER	INITIAL MOISTURE IN TAILINGS (30-180cm); (ml)	MOISTURE RETAINED IN TAILINGS (30-180cm); (ml)
1	750.96	4744.76
2	750.96	7318.94
3	750.96	6230.94
4	750.96	6630.33

Table 6.4. Quantity of moisture (in ml) present in the tailings below the cap material in each column at the onset and conclusion of the experiment.

Using equations 6.3 and 6.6, the fluxes at the inlet and outlet boundaries were calculated from the moisture content and effluent data given in table 6.2 and appendix E. The fluxes into and out of the tailings, shown in table 6.5, differed by between one and two orders of magnitude. This difference may be directly attributed to a change in storage in the unsaturated tailings. The quantity of moisture which became effluent was less than the quantity that initially infiltrated each column because the release of moisture at the bottom was a function of the moisture retention characteristics of the tailings.

When steady-state is achieved, q_{in} should equal q_{out}, and the quantity of effluent extracted from the bottom of the column should represent the flux through the system as the change in storage (ΔS) would be zero. Although the curves in figures 6.2 suggest a near steady-state condition for columns #2, 3, and 4, the results in table 6.5, do not support this.

COLUMN NUMBER	FLUX THROUGH CAP MATERIAL q_{in} (cm/s)	FLUX AT OUTLET BOUNDARY q_{out} (cm/s)
1	1.90×10^{-7}	4.05×10^{-8}
2	2.78×10^{-7}	6.22×10^{-9}
3	2.05×10^{-7}	2.49×10^{-9}
4	2.37×10^{-7}	7.93×10^{-9}

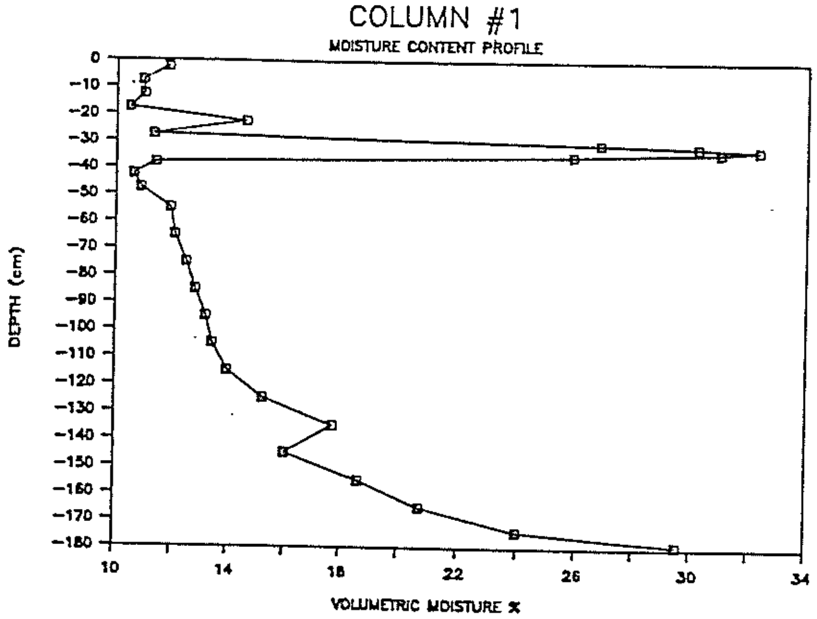
Table 6.5. Average fluxes through the cap material (q_{in}) and at the outlet boundary (q_{out}) based on moisture content and effluent data.

6.6. GENERAL OBSERVATIONS

The moisture content profiles for columns #1 through #4 are shown in figures 6.3 through 6.6. Each profile reveals the same general trend of increasing moisture content with depth. These profiles resemble drainage curves, and therefore, an attempt was made to correlate them with the moisture retention, or θ–ψ, relationship of the copper mill tailings. Smiles et al. (1971) and Vachaud et al. (1972) have shown that the θ–ψ relationship determined in the laboratory, particularly the desorption curve, may not accurately predict the relationship in the field due to the transient nature of the field situation.

In order to make the comparison, the distance above the plate at the bottom of the column (ψ) and its corresponding moisture content (θ) were compared to the θ–ψ values obtained from the curve shown in figure 4.17a. In general, the field columns were drier at a given depth than predicted by the θ–ψ relationship. The field columns would not be expected to be in total agreement with the laboratory curve because the bottom of each column did not represent a true water table. Column #1 was at least 35% drier than the laboratory θ–ψ curve at most depth increments except at the very bottom of the column. The moisture content profiles of columns #2, 3, and 4, on the other hand, correlated fairly well with the θ–ψ curve of the copper mill tailings which suggests that these systems may have been close to a static condition.

In column #1 (50% bentonite cap) and column #3 (5% bentonite cap) there is a spike of higher moisture content at a depth of approximately 30cm as shown in figures 6.3 and 6.5. This is probably a remnant of the fluoro–organic (F.O.) tracer solution which was applied in the Fall of 1987, but this is pure speculation since the initial moisture content at this depth before the tracers were ap–



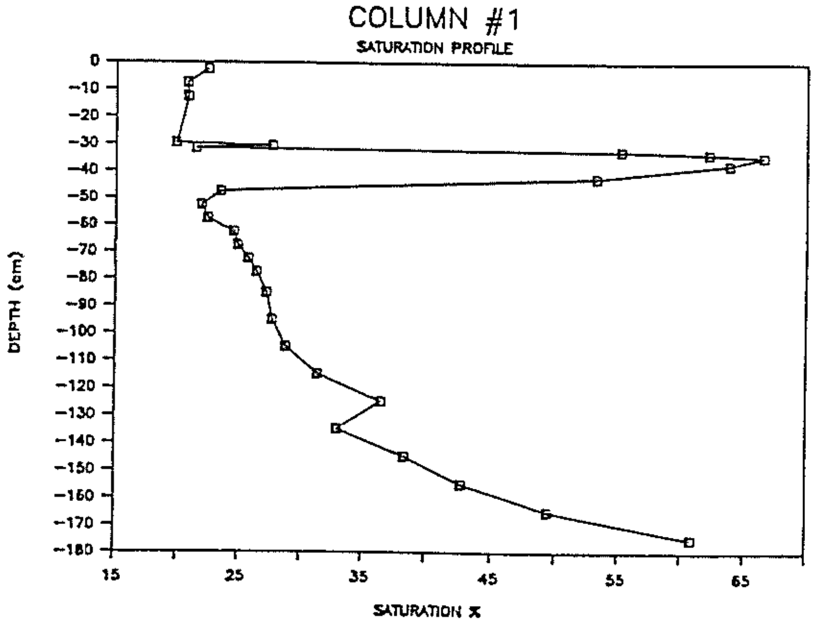


Figure 6.3. Moisture content profile for column #1 (50% bentonite cap) upon dissection of the column at the conclusion of the experiment.

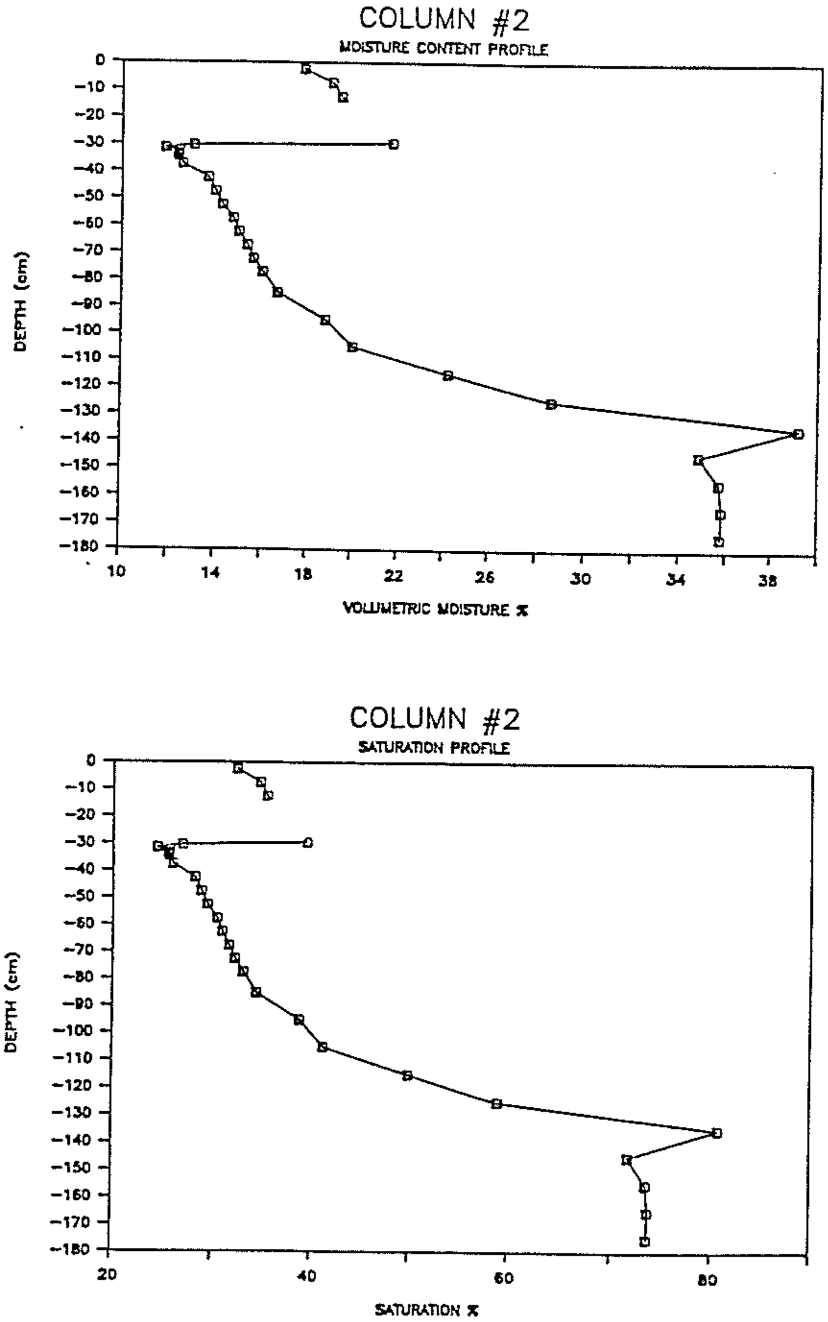
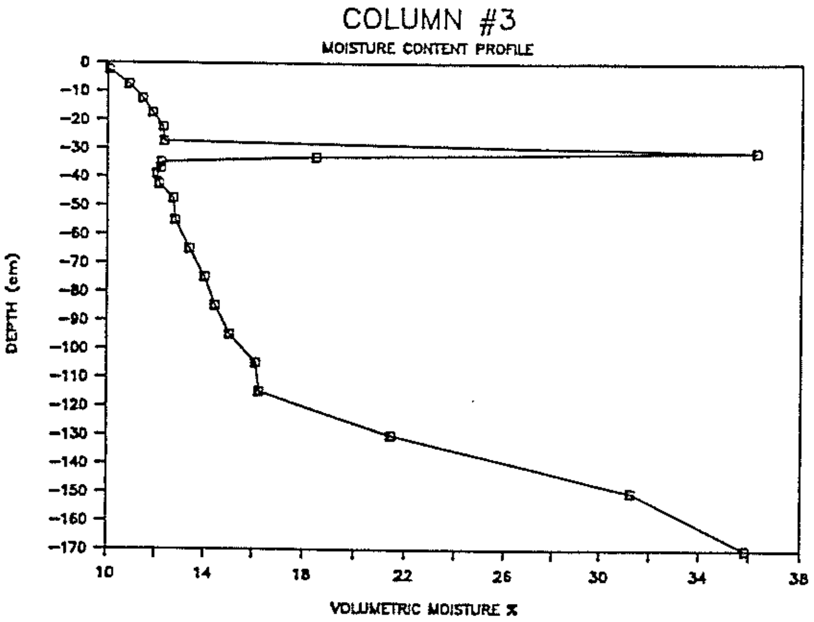


Figure 6.4. Moisture content profile for column #2 (loam/ gravel cap) upon dissection of the column at the conclusion of the experiment.



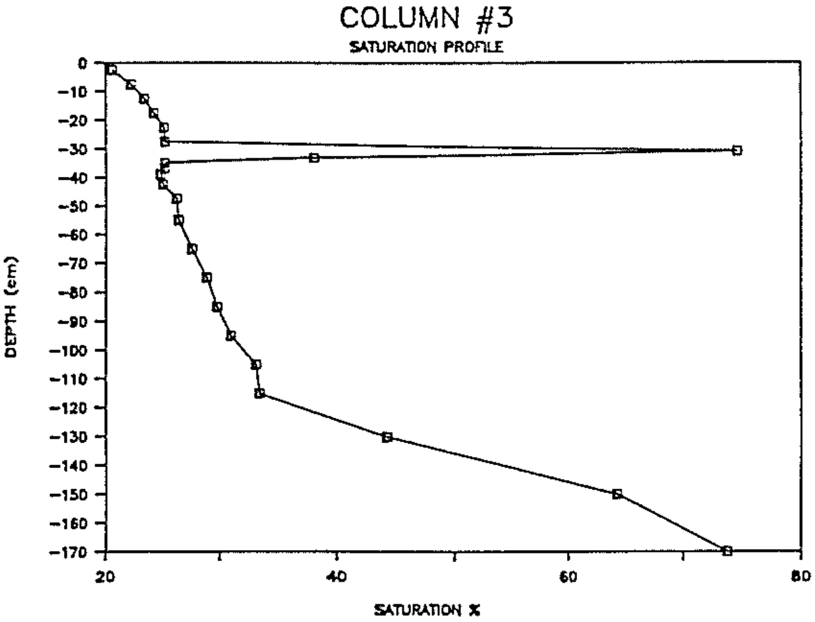


Figure 6.5. Moisture content profile for column #3 (5% bentonite cap) upon dissection of the column at the conclusion of the experiment.

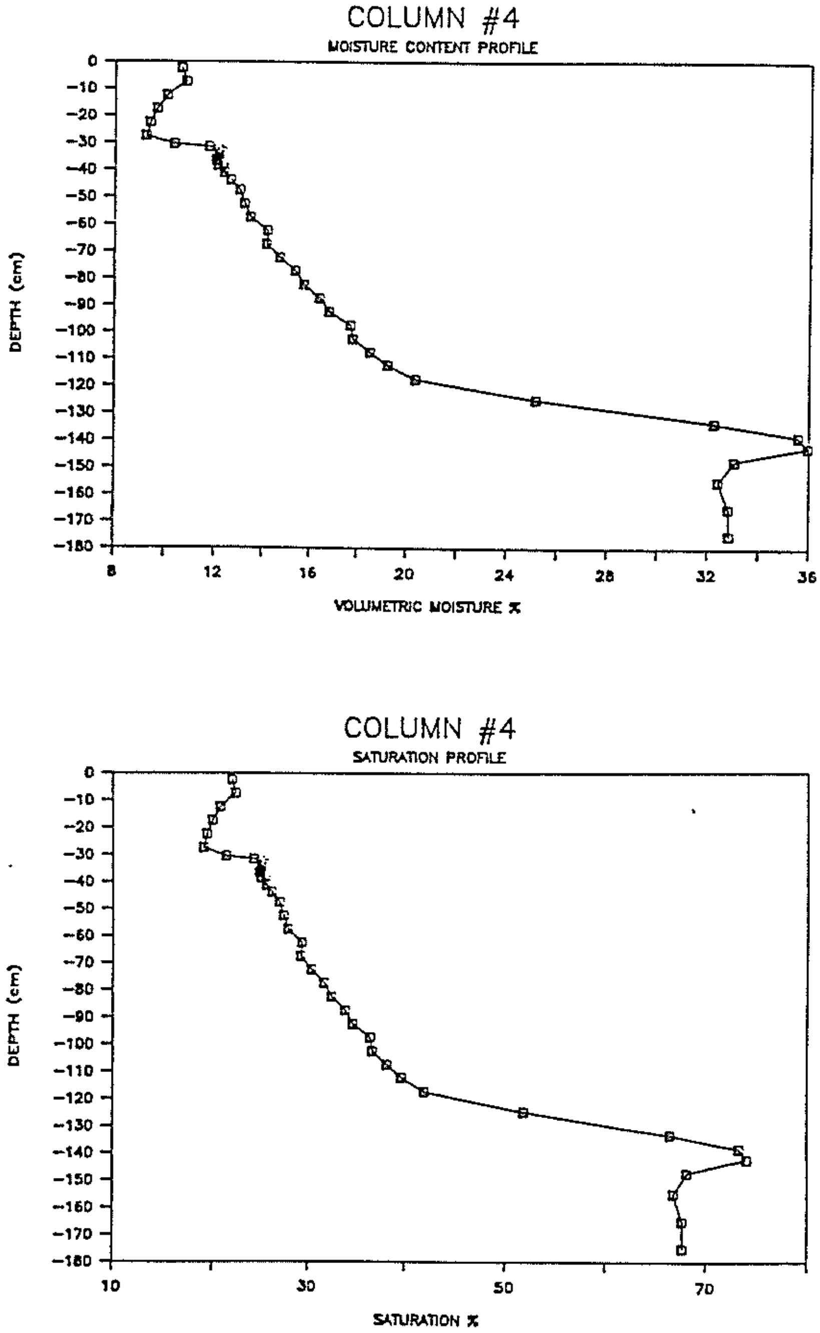


Figure 6.6. Moisture content profile for column #4 (100% tailings) upon dissection of the column at the conclusion of the experiment.

plied is unknown. The peak is very sharp in column #3 and more diffuse in column #1. These observations seem to suggest that after the F.O. tracers were applied and the cap materials were repacked, the column #3 cap (5% bentonite) was as effective as the column #1 cap (50% bentonite) in reducing infiltration.

In columns #2 and #4 there is a peak of higher moisture content located at depths of 134cm and 140cm, respectively, as shown in figures 6.4 and 6.6. It is reasonable to assume that the fluid associated with fluoro-organic tracer peaks was displaced downward by infiltrating precipitation (Nixon and Lawless, 1960), especially since the peak that was observed in columns #1 and #3 at the 30cm depth was absent from columns #2 and #4. Indeed, the fluoro-organic tracers were detected at these lower depths in columns #2 and #4 but in such trace concentrations that it was difficult to distinguish between the tracers and background noise (this topic will be addressed in the next chapter). Because the peak in column #4 was at a slightly greater depth than that of column #2, it is reasonable to assume that the flux was greater through column #4 for the time period following the repacking of the cap materials. These results support other results which indicate the relative ineffectiveness of the cap materials of columns #2 and #4 to reduce infiltration.

6.7. SUMMARY

In this experiment, a cover material consisting of 5% bentonite (column #3) was found to be almost as effective in reducing infiltration as one consisting of 50% bentonite (column #1). The 5% bentonite cover reduced infiltration by 13.5% over a cover consisting of 100% tailings (column #4) while the 50% bentonite cover reduced infiltration by 19.8%. The combination gravel overlain by loam (or fine-textured soil) which was used in column #2 was 17.1% *less* effective in reducing infiltration than the 100% tailings column. It was not possible to determine which type of cover material was the most effective in reducing deep percolation because problems associated with the sampling technique have lead to questionable results.

Because most of the effluent which was discharged from column #1 (50% bentonite cap) was during the early stages of the experiment, it is possible that channeling took place in this column during this time period. This could easily be explained by the fact that the columns were originally transported out to the field site by forklift which may have disrupted the column and created the channeling, or cracking.

Another explanation for the improved effectiveness of the 50% bentonite cover is that as it moistened from precipitation, it settled into a denser, more compact state, which was more effective in reducing infiltration. If this theory is correct, then it would seem that some optimum moisture content is required for the 50% cap to be the most effective. The 50% bentonite clay material should probably have been packed at this optimum moisture content, as determined in the laboratory, rather than at the air-dry moisture content as it had been in this experiment. If this had been done, the 50% bentonite cap may have been shown to be much more effective in reducing infiltration, especially since clays have much lower saturated hydraulic conductivities than sands.

The effectiveness of all of the cap materials used in this experiment may have been significantly higher had the caps been packed at some optimum moisture content (which will vary from soil to soil) rather than at their air-dry moisture contents. This optimum moisture content could be found by performing a Proctor test (American Society for Testing and Materials (ASTM) Standards, 1988) which is commonly performed on clay soils used in construction. For a given clay soil, the hydraulic conductivity will be lower for a soil in its densest, most compact, state. This is the theory behind the use of clay in liners used in landfill construction.

The moisture content of a thick tailings pile found in the field would be nearly uniform throughout. In this experiment there was an accumulation of moisture in each column, probably due to an impedence to drainage at the bottom. Because the columns exhibited similiar saturation profiles, a column-to-column comparision of cap material effectiveness is valid.

Under the conditions of this experiment, a 5% cover material seemed to be almost as effective as a 50% cover material in reducing infiltration through a copper mill tailings waste pile. A gravel overlain by a clay seemed to be ineffective because the finer-textured soil would fall through the voids left in the gravel. If a fine mesh screen had been placed between the two layers, this type of cap material would probably have been much more effective. It may be appropriate to examine this same problem using different initial conditions (i.e., varying the initial moisture contents or varying the packing densities of the cover materials) in order to obtain the optimum achievable conditions for each material.

7.0. BROMIDE AND FLUORO-ORGANIC TRACERS

7.1. SOLUTE TRANSPORT PROCESSES

Advection is the movement of the solute with the bulk flow of water where the flow is equal to the average linear velocity (Freeze and Cherry, 1979):

$$v = \frac{q}{n_e} = \frac{Ki}{n_e} \qquad (7.1)$$

where: q = specific discharge, or Darcy velocity (L/T)
n_e = effective porosity, expressed as a decimal
K = hydraulic conductivity (L/T)
i = hydraulic gradient, dH/dl
H = total hydraulic head (L)
l = path length (L))

In theory, the effective porosity (n_e) is equivalent to the moisture content (θ), but in reality, a portion of the soil solution may be immobile, or stagnant. It will not participate in the flow process, and hence, the effective water content will be less than the total water content. Gaudet et al. (1977) found that a large portion of the water may be stagnant during flow in an unsaturated sand and that the amount of stagnant water increased with decreasing water content (θ) and flux (q).

Hydrodynamic dispersion is the result of mechanical mixing and molecular diffusion. The coefficient of hydrodynamic dispersion (D') may be expressed as (Freeze and Cherry, 1979):

$$D' = \alpha V + D^{*} \qquad (7.2)$$

where: D' = hydrodynamic dispersion coefficient (L^2/T)
α = dispersivity (L)
V = seepage velocity (L/T)
D^* = coefficient of molecular diffusion (M/L^2)

Molecular diffusion is a process whereby the molecules move in response to a concentration gradient; this process is described by Fick's first law (Freeze and Cherry, 1979):

$$F = -D\frac{\partial c}{\partial x} \tag{7.3}$$

where: F = mass flux of solute (M/L^2T)
D = diffusion coefficient (L^2/T)
C = concentration (M/L^3)
$\partial c/\partial x$ = concentration gradient (negative in the direction of diffusion).

The processes of mechanical dispersion and molecular diffusion tend to spread out the solute front. The solute molecules move at varying rates; some faster, some slower, and some equal to the seepage velocity (v). At low velocities, molecular diffusion is the dominant spreading mechanism while at high velocities mechanical dispersion is the dominant mechanism. In the absence of these processes, the solute front should appear as a uniform "plug" as shown in figure 7.1.

Hydrodynamic dispersion may be the result of external forces acting on the liquid, the geometry of the pore system, molecular diffusion caused by concentration gradients, variations in liquid density and/or viscosity, variations in concentrations due to chemical and physical processes within the liquid phases, and in–

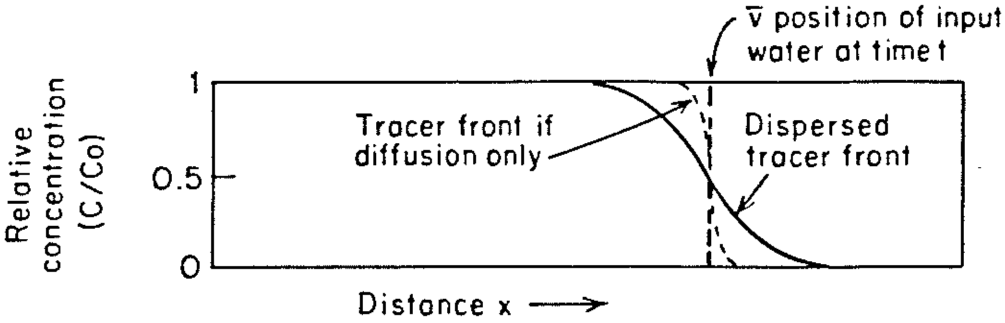


Figure 7.1. Solute front from a step-function input; actual (solid line) and theoretical (dashed lines) in the absence of molecular diffusion and mechanical dispersion (Freeze and Cherry, 1979).

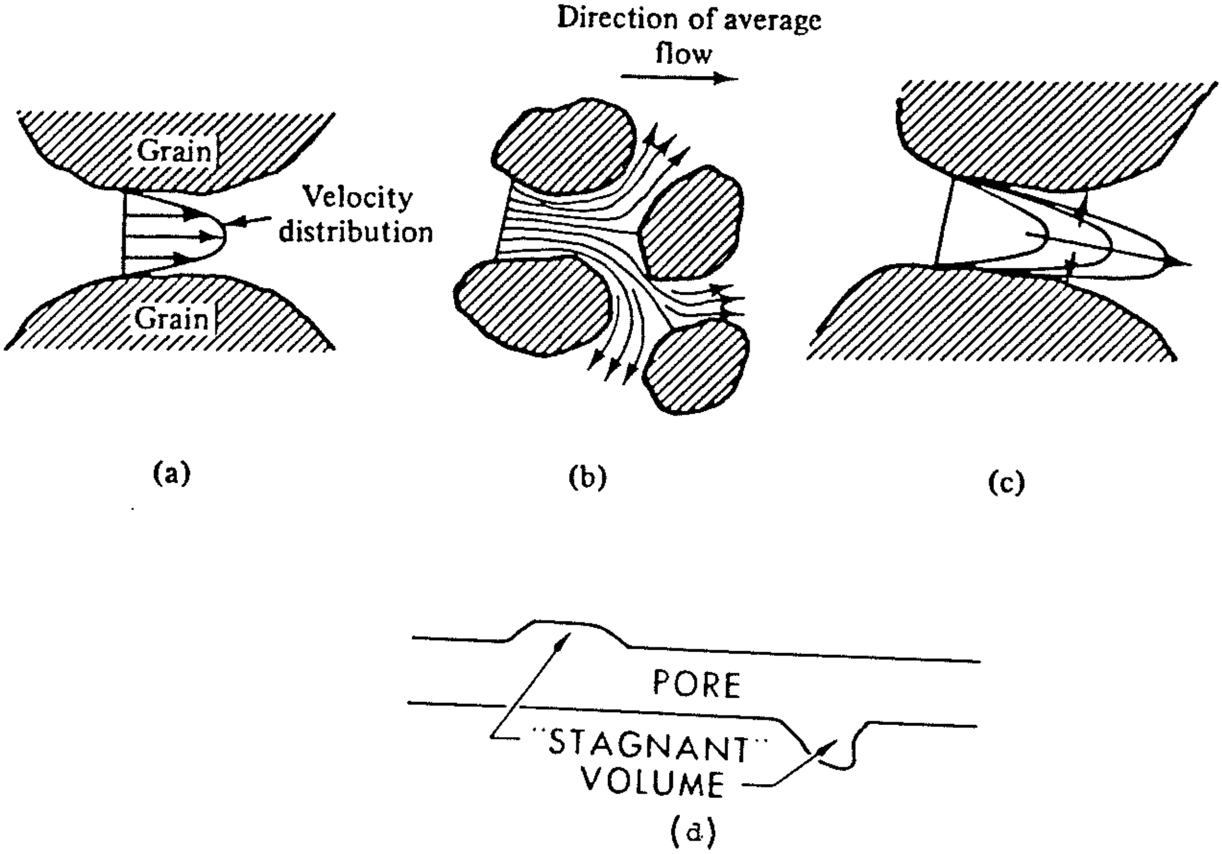


Figure 7.2. Common causes of mechanical dispersion (a,b) and molecular diffusion (c,d). [a.,b.,c.– (Bear, 1987); d.– (Coats et al, 1964)].

teractions between liquid and gas phases (Bear, 1973). Some of the common causes of dispersion and diffusion are illustrated in figure 7.2.

Dispersion is a scale-dependent phenomena. Dispersivity values in the field are generally larger than those determined in the laboratory. This is usually attributed to heterogeneities encountered on the field scale. McElroy (1986) found the average dispersivities of a small and a large soil column, packed with unsaturated copper mill tailings, to differ by approximately an order of magnitude; the average dispersivity for a column similar in dimensions to those used in the current study was 2.8cm. James and Rubin (1972) also found that in laboratory columns, particularly short columns or in unsaturated media, the column itself induced additional dispersion.

7.2. STEADY-STATE MODELS

The general formulation of the one-dimensional advection-dispersion equation for a single reactive solute species during steady-state flow is:

$$R\left(\frac{\partial C}{\partial t}\right) = D'\left(\frac{\partial^2 C}{\partial X^2}\right) - V\left(\frac{\partial C}{\partial x}\right) \qquad (7.4)$$

where: R = retardation factor (dimensionless)

C = solute concentration (M/L^3)
t = time (T)

D' = dispersion coefficient (L^2/T)
X = distance (L)
V = seepage Velocity (L/T) = q/θ
q = Darcy velocity (L/T)
θ = volumetric moisture content

The retardation factor (R) accounts for adsorption of the solute onto the solid phase and may be expressed as:

$$R = 1 + \frac{\varrho_b K_d}{\theta} \qquad (7.5)$$

where: ρ_b = dry bulk density of the soil (M/L^3)
K_d = distribution coefficient (L^3/M)
θ = volumetric moisture content (L^3/L^3)

For a nonadsorbed solute species, the distribution coefficient (K_d) is zero and the retardation factor (R) is equal to one.

7.3. TRANSIENT MODELS

Steady-state models are often used to describe transient flow problems since the steady-state models are simpler, often require less input data, and use considerably less computer time. Unfortunately, the assumptions and simplifications underlying these models may not be justified. Transient models may be required to satisfactorily describe and/ or predict solute behavior, but the solutions to transient problems often require large computers and a great deal of computer time which is cost prohibitive.

Wierenga (1977) compared the solutions to a transient, unsaturated flow problem using a steady-state and a transient model. The steady-state model held the moisture content and the flux constant during irrigation as in equation 7.4. In the transient model the moisture content and the flux varied with time and distance as shown below:

$$\frac{\partial \theta C}{\partial t} = \frac{\partial}{\partial x}\left(\theta D' \frac{\partial C}{\partial x}\right) - \frac{\partial q C}{\partial x} \qquad (7.6)$$

Although an analytical solution to equation 7.6 is not available since θ and q are transient terms, Wierenga (1977) obtained a numerical solution by solving the following two equations simultaneously:

$$\frac{\partial \theta}{\partial t} = - \frac{\partial q}{\partial x} \qquad (7.7)$$

where:

$$q = - K(\theta) \frac{\partial H}{\partial x} \qquad (7.8)$$

Wierenga (1977) found comparable results using both a transient and a steady-state model, indicating that the use of the latter was justified in this case. In the analysis, the relative effluent concentrations were plotted versus cumulative drainage rather than versus time in order to obtain smooth concentration profiles.

Other researchers have found that some transient problems may be accurately described using steady-state models. De Smedt and Wierenga (1977), for example, found that the moisture content distribution throughout a column did not influence the resulting effluent concentration distribution. Uniform and non-uniform moisture content distributions yielded identical effluent concentration distributions.

Warrick et al. (1971) studied simultaneous solute and water transport in an unsaturated soil. Although the advance of the solute front was found to be independent of the initial moisture content of the soil, it was found to be strongly influenced by the moisture content at the soil surface during irrigation. In other words, it was influenced indirectly by the infiltration rate. In a homogeneous soil profile the solute front was found to advance with:

$$\frac{K(\theta_{ss})}{\theta_{ss}} \qquad (7.9)$$

where: θ_{ss} = the moisture content maintained at soil surface
$K(\theta_{ss})$ = hydraulic conductivity at $\theta=\theta_{ss}$ (L/T)

The advance of the moisture front, on the other hand, was highly dependent upon the initial moisture content. In general, the higher the initial moisture content (θ_i), the greater the advance of the moisture front. Warrick et al. (1971) found that the moisture front would advance with:

$$\frac{K(\theta_{ss})}{\theta_{ss}-\theta_i} \qquad (7.10)$$

where: θ_i = initial moisture content of the soil

Although many transient problems may be adequately described using steady-state models, some of these problems are too complicated to be explained in such a simplistic manner. The existence of upward gradients, as in the case of evaporation, complicates the problem to such a degree that a steady-state solution is no longer valid.

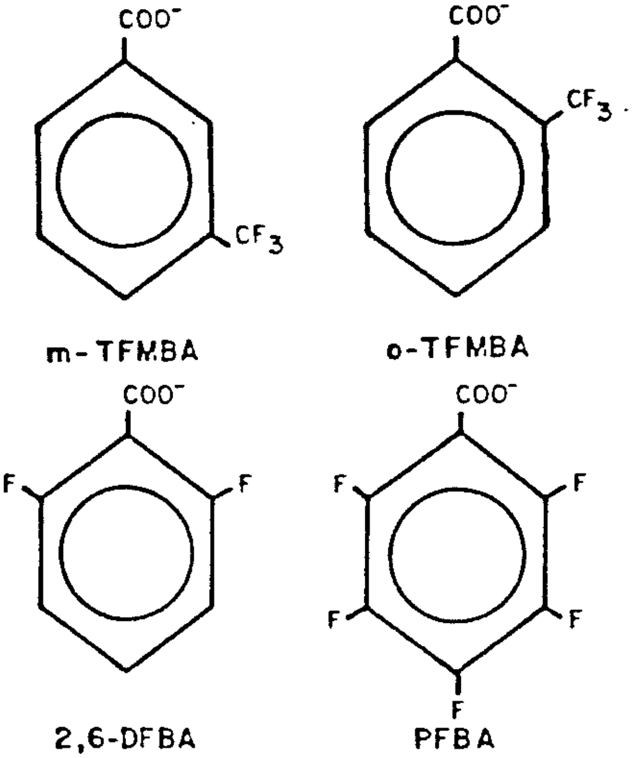
7.4. TRACER SELECTION

A good tracer is one that moves with the bulk flow of the groundwater. It should not degrade or otherwise lose mass, and it should not adsorb, or transform in a manner that would cause it to be retained in the soil or undetected in the soil-water. Another important characteristic is its ability to be detected, especially at low concentrations, in the soil-water. An ideal tracer should be exotic to the environment in which it is being used, or its concentrations in the background soil-water should be sufficiently low so as not to interfere with the analyses.

A number of tracers were used in order to follow the movement of soil-water in this field column study. A calcium bromide salt ($CaBr_2$) was applied in the Winter of 1985, and four experimental fluorinated benzoic acid derivatives, or fluoro-organic (F.O.) tracers, were applied to the columns in the Fall of 1987. The F.O. tracers included meta-(trifluoromethyl) benzoic acid (m-TFMBA), ortho-(trifluoromethyl) benzoic acid (o-TFMBA), pentafluorobenzoic acid (PFBA), and 2,3-difluorobenzoic acid (2,3-DFBA). Figure 7.3 show the chemical structures of the F.O. tracers used in this experiment.

Bromide is a conservative tracer; it does not degrade or adsorb. Furthermore, it is usually present in the background environment in trace concentrations. Lewis (1986) discovered a loss of bromide mass in a solution in equilibrium with the copper mill tailings medium which became even more significant at lower concentrations; on the average, the concentration of bromide in a solution in equilibrium with the tailings was half an order of magnitude lower than that of a standard reference solution (appendix H.1). Furthermore, problems with the detection of bromide may arise if it is analyzed by High Performance Liquid Chromatography (HPLC). Nitrate, which is ubiquitous in the environment due to its use in fertilizers, has a retention time similar to that of bromide which can obscure or distort the bromide peak on the chromatograph. For this reason, an ion specific electrode should probably be used instead of the HPLC when nitrate is present in the soil in significant background concentrations. Fortunately, this was not a problem with this experiment.

The fluoro-organic tracers are exotic to most natural soil-water systems, and should not be detected in the background leachate of the copper mill tailings. Furthermore, these tracers have been shown to be conservative (i.e., do not degrade) under field conditions. Bowman (1984) experimented with the F.O. tracers



m-TFMBA

o-TFMBA

2,6-DFBA

PFBA

Figure 7.3. Chemical structures of the four fluoro-organic tracers. The molecular weights of each are: m- and o-TFMBA =190.12 g/mole, 2,6-DFBA =158.10 g/mole, and PFBA =212.08 g/mole.

in a neutral pH, loamy sand, medium and found the tracers to be conservative, although it was discovered that m–TFMBA may not be conservative under aerobic field conditions. Terauds (1985) used PFBA and m–TFMBA as soil–water tracers in an unsaturated copper mill tailings experiment and found that m–TFMBA appeared to exhibit retardation. The "retardation" that was observed may have been related to aerobic conditions, as discussed by Bowman (1984).

One drawback with the fluoro–organic (F.O.) tracers is that they may revert to their neutral (uncharged) form and be retained in the soil below a pH of approximately 3.0 (R. Bowman, 1987, personal communication).

7.5. RESULTS AND DISCUSSION

The tracer data, which is included in appendix G and H, was examined from both a qualitative and quantitative perspective, although the latter may not be justified in this case due to the transient nature of the flow fields in the columns in this study.

7.5.1. EFFLUENT CONCENTRATION DISTRIBUTIONS

Although the effluent samples revealed trace concentrations of the fluoro–organic (F.O.) tracers, the abundance of background ions in the soil–water made it impossible to confirm that the F.O. tracers were actually present in the samples. Therefore, this section will focus only on bromide recovery in the effluent.

The distribution of bromide in the effluent is shown in figure 7.4. The detection limit for bromide was 10^{-6}M (0.80 mg/l). Columns #1 (capped by the 50% tailings/ 50% bentonite mixture) and #2 (capped by the loam–gravel combination) produced

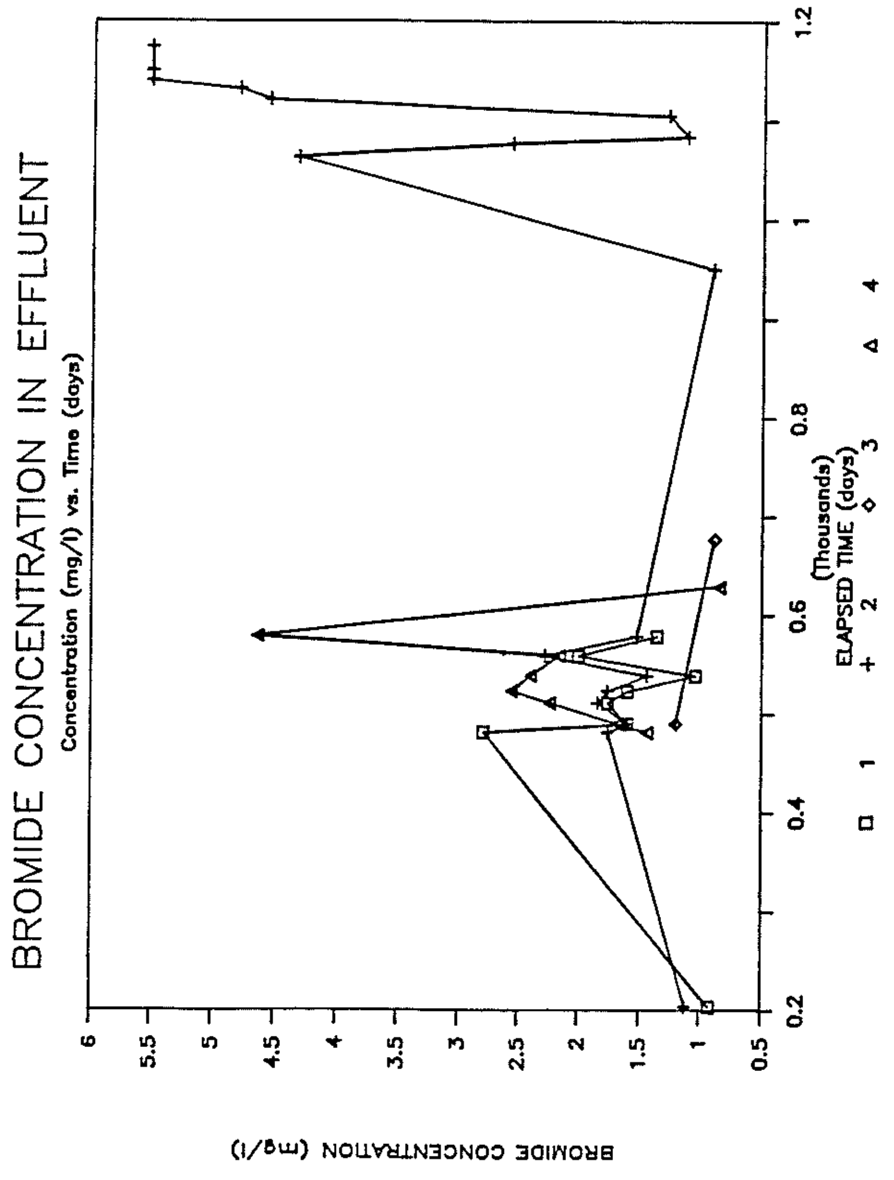


Figure 7.4. Bromide concentrations (mg/l) in the effluent as a function of time (note that the horizontal scale is in [number of days] x 1000, and "1," "2," "3," and "4" refer to columns #1, 2, 3, and 4, respectively).

the first bromide-laden effluent close to 7 months following the onset of the experiment. Bromide was detected in column #3 (95% tailings/ 5% bentonite mixture) and column #4 (100% tailings) approximately 16 months after the experiment had begun. The travel times based on the first detection of bromide in the effluent and the *number* of times bromide was detected in the effluent are shown in table 7.1.

Bromide was detected in the effluent of columns #1, 3, and 4 a total of 8, 2, and 8 times, respectively. In column #2, on the other hand, bromide was present in the effluent on 18 different occasions which should prove beyond reasonable doubt that bromide had traveled completely through the column. The effluent concentrations increased through time, becoming more significant in 1988 as shown in figure 7.4.

COLUMN NUMBER *	VELOCITY BASED ON FIRST Br DETECTION IN EFFLUENT (cm/s)	NUMBER OF TIMES Br DETECTED IN EFFLUENT
1	8.5×10^{-3}	8
2	8.5×10^{-3}	18
3	3.5×10^{-3}	2
4	3.3×10^{-3}	8

* 1 = 50/50, 2 = loam/ gravel, 3 = 95/5, 4 = 100% tails

Table 7.1. Solute travel times based on first detection of bromide in the effluent, and the number of times that bromide was detected in the effluent.

The large degree of scatter in the effluent concentrations was probably the result of poor sampling design. The effluent extraction method allowed considerable back–mixing of the effluent to occur before the sample was taken, a topic which will be addressed in a later section of this paper.

Table 7.2 shows the peak bromide concentrations in the effluent of each column, as well as the total mass of bromide recovered in the effluent and the percentage this was of the total amount applied (assuming that 5g of bromide was initially applied). The greatest concentrations of bromide were found in the effluent of columns #2 and #4. Column #1, on the other hand, discharged the greatest total mass of bromide in its effluent, although it did not have the greatest bromide concentration in any one sample. The large mass of bromide discharged from column #1 was related to the large volumes of effluent discharged from this column as discussed in the previous chapter.

Based on the effluent results alone (smallest tracer mass and smallest peak concentration), the cap material of column #3 (5% bentonite) appeared to be the most effective in reducing infiltration. A cap material consisting of gravel overlain by a fine–textured soil (loam) appeared to be the least effective; it did not even seem to be as effective as the control column which was composed of 100% tailings. The results of column #1 are confusing and difficult to interpret. A large volume of effluent and a large mass of bromide were discharged from column #1 during the first year and a half of the experiment. After this period, the column produced very little effluent, and bromide was undetected in the samples. Again, this seems to suggest that preferential flow, most likely in the form of channeling along the column walls, was responsible for the behavior of column #1 during the early stages of the experiment.

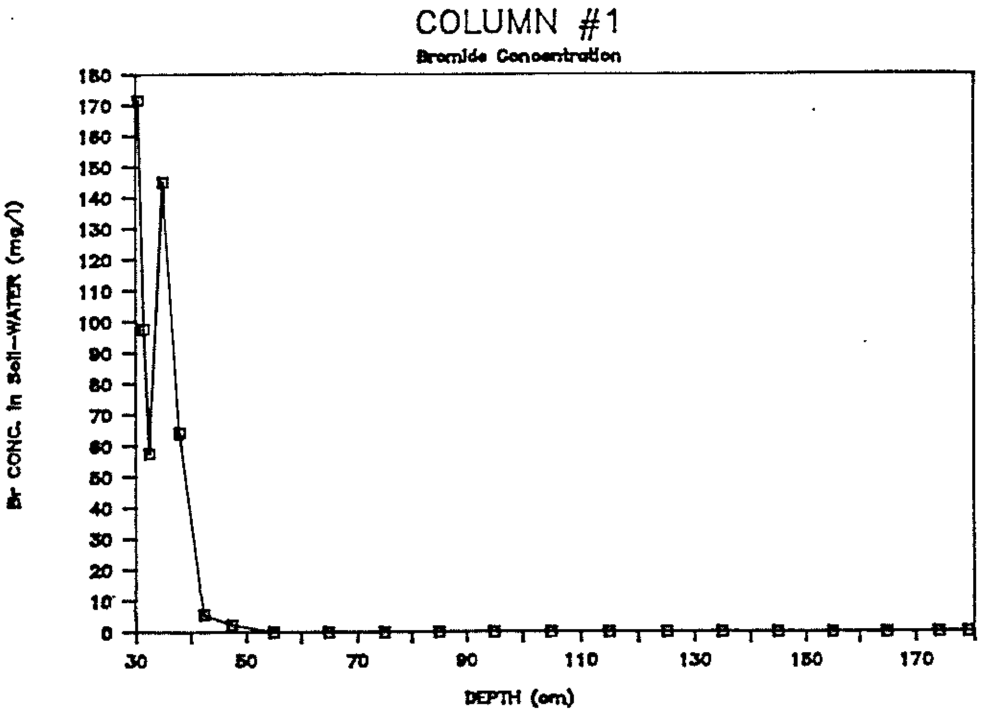
COLUMN NUMBER *	PEAK CONCENTRATION (mg/l)	TOTAL MASS RECOVERED (mg)	PERCENTAGE OF TOTAL APPLIED (%)
1	2.80	0.479	0.00958
2	5.51	0.101	0.00202
3	1.20	0.003	0.00012
4	4.33	0.100	0.00200

* 1 = 50/50, 2 = loam/ gravel, 3 = 95/5, 4 = 100% tails

Table 7.2. Bromide data from effluent samples; peak concentration in effluent, total mass which appeared in effluent, and percentage of the total mass applied.

7.5.2. BROMIDE CONCENTRATION PROFILES

The bromide concentration profiles are shown in figures 7.5 through 7.8. The upper graph in each figure depicts the concentration of each tracer in the soil-water while the lower graph depicts the mass of each tracer per equivalent mass of soil. It is important to keep in mind that the tracer was applied at the base of the cap materials (i.e., at a depth of 30cm below the surface of the columns). The soil extract analyses from each column revealed a high concentration of bromide near the point of application, and bromide was even detected *above* the point of application (i.e., in the cap material) in a few samples. One possible explanation for this is that the upward flux due to evaporation forced the solute to move upward through the cap material; this idea is supported by the tensiometric data. If this hypothesis is true it could explain the poor bromide recovery in the soil



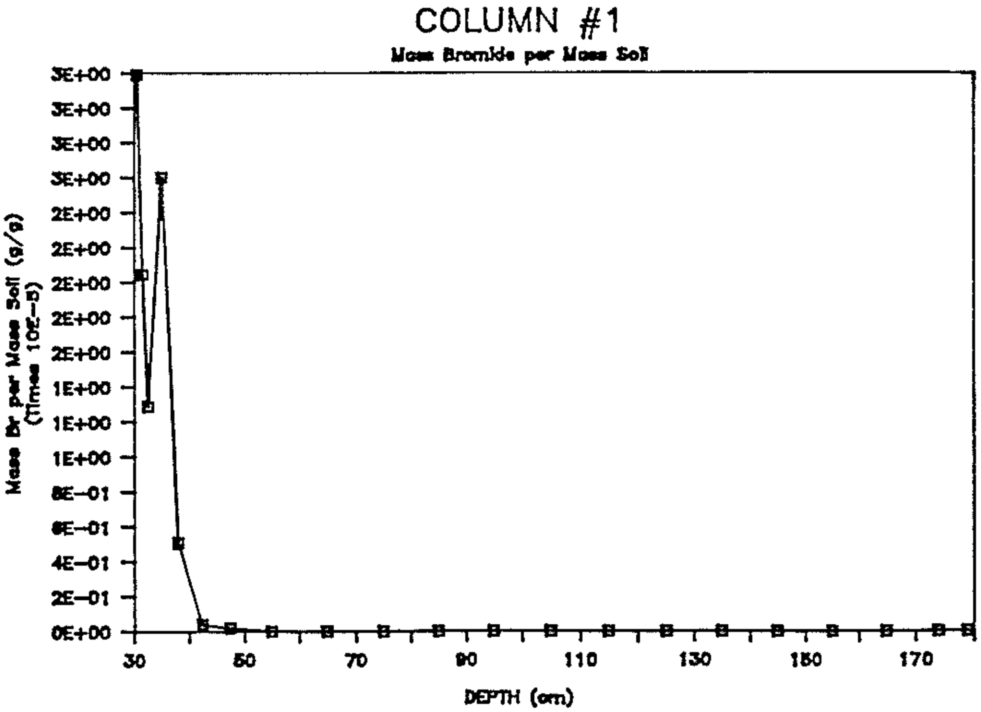


Figure 7.5. Bromide concentration profile for column #1 (50% bentonite cap); the upper figure depicts the concentration profile in terms of its concentration in the soil-water, while the lower figure depicts the concentration on a mass basis.

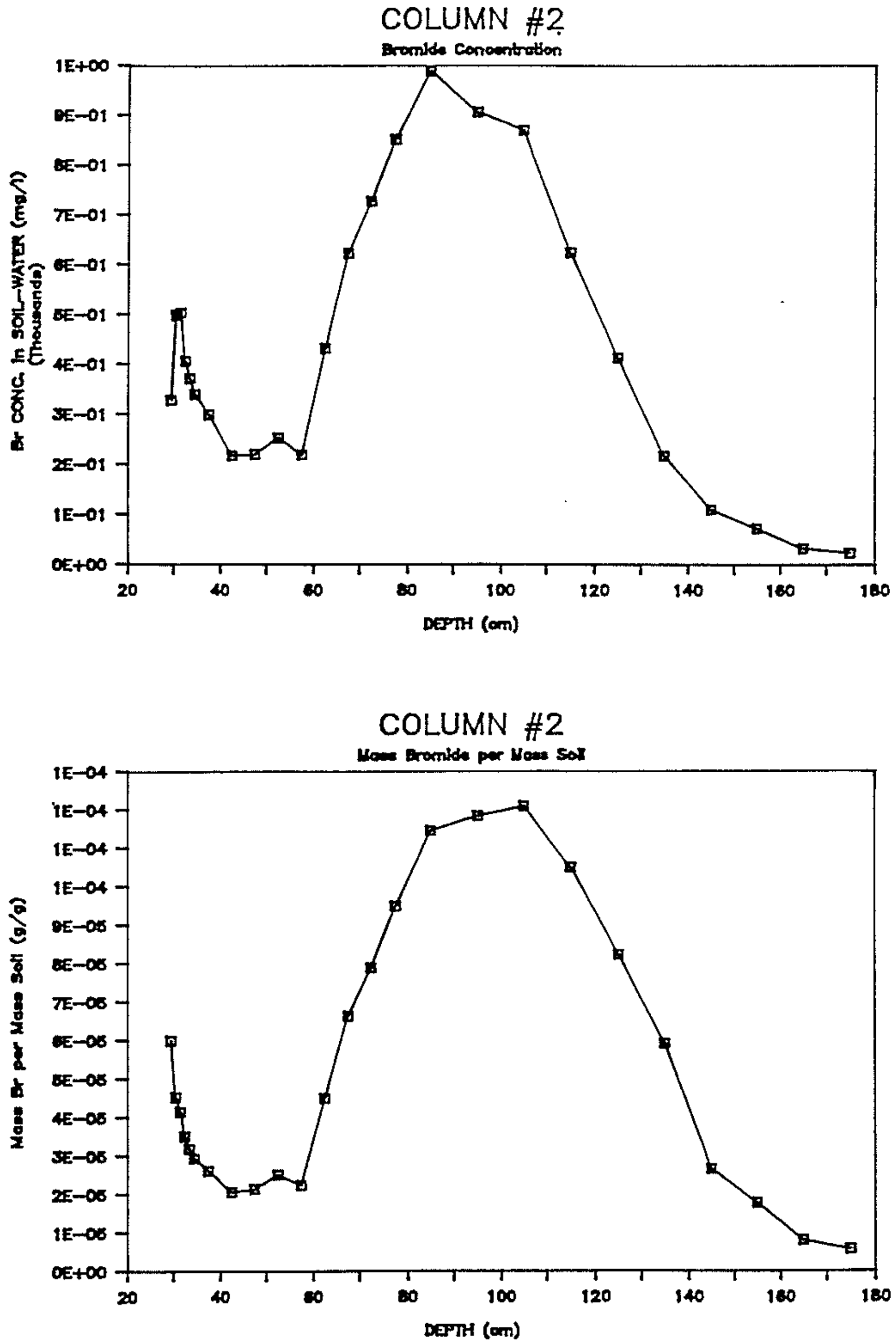


Figure 7.6. Bromide concentration profile for column #2 (loam/ gravel cap); the upper figure depicts the concentration profile in terms of its concentration in the soil-water, while the lower figure depicts the concentration on a mass basis.

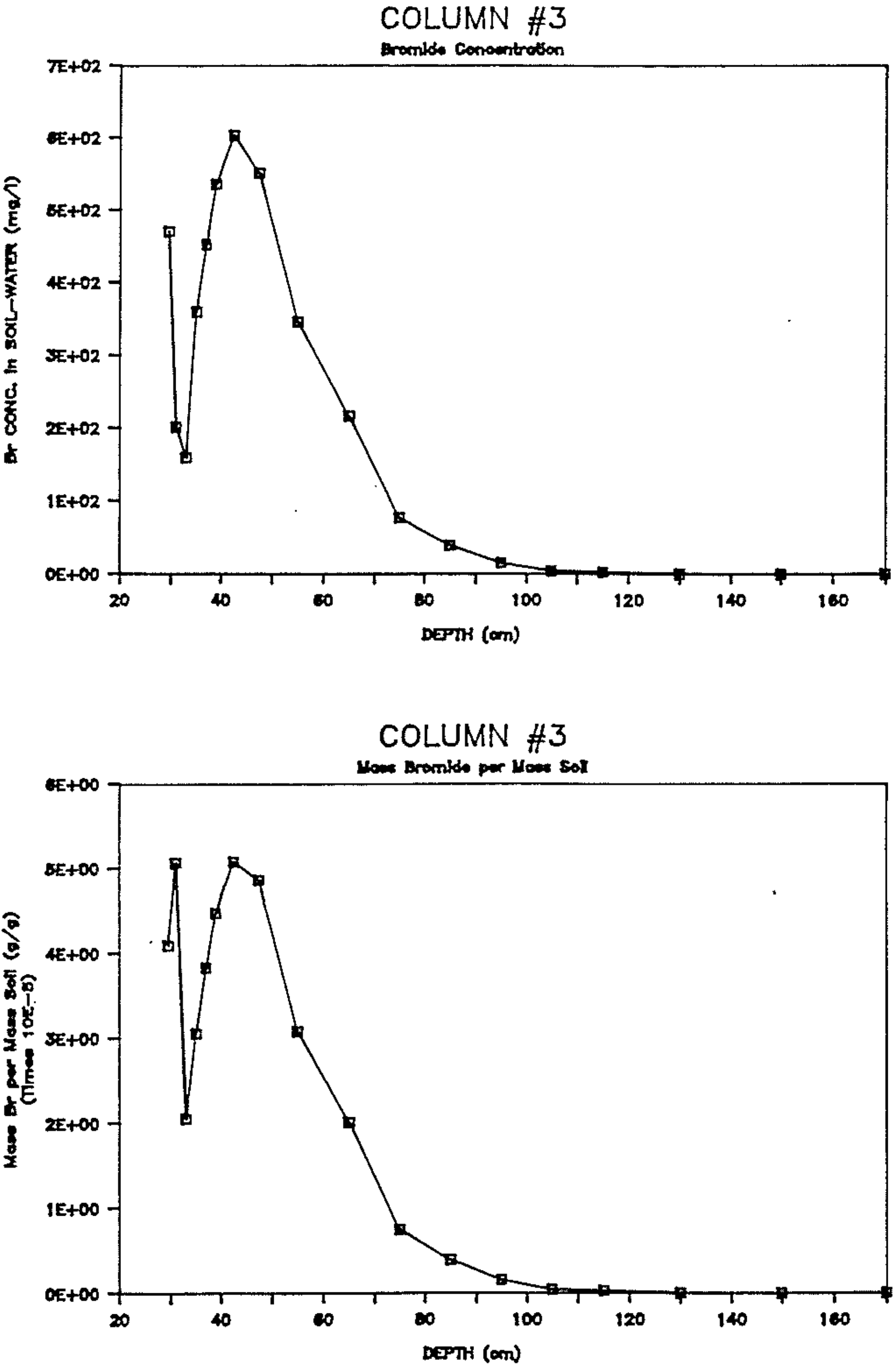


Figure 7.7. Bromide concentration profile for column #3 (5% bentonite cap); the upper figure depicts the concentration profile in terms of its concentration in the soil-water, while the lower figure depicts the concentration on a mass basis.

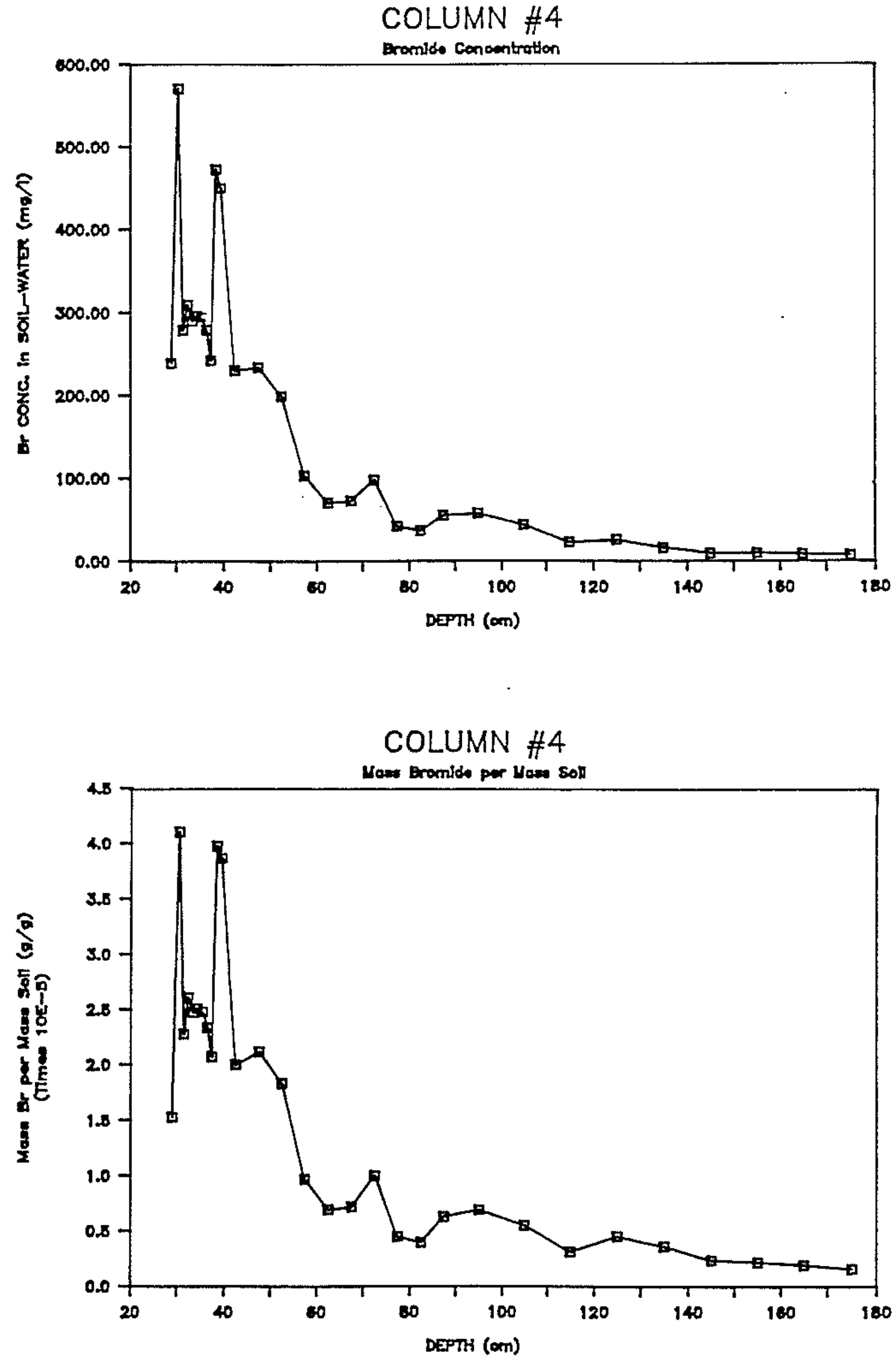


Figure 7.8. Bromide concentration profile for column #4 (100% tailings); the upper figure depicts the concentration profile in terms of its concentration in the soil-water, while the lower figure depicts the concentration on a mass basis.

extract analyses. Because the cap materials were removed and replaced two years after the bromide was applied, a considerable amount of the tracer may have been lost if it had migrated upward through the cap materials.

Table 7.3 summarizes the results of the soil extract analyses. In column #1, the bromide peak was found in the depth increment from 34 to 36cm, or 4 to 6cm from the point of application. In addition, the greatest depth at which bromide was detected in the column was in the depth increment from 36 to 40cm (6 to 10cm from point of application). These two findings support the hypothesis that the early detection of bromide in the effluent was derived from preferential flow along the column walls. Because bromide was not detected at depth in this column, it is doubtful that it had traveled completely through the soil matrix.

COLUMN NUMBER *	DEPTH OF PEAK Br CONCENTRATION IN SOIL-WATER (cm)	GREATEST DEPTH OF Br DETECTION IN SOIL EXTRACT (cm)
1	35.0	38.0
2	85.0	180.0
3	42.5	115.0
4	39.5	180.0

* 1 = 50/50, 2 = loam/ gravel, 3 = 95/5, 4 = 100% tails

Table 7.3. Depth of peak bromide concentration in soil–water, and greatest depth of bromide detection in columns (subtract 30cm from each value to obtain the distance from the point of bromide application).

In column #2, the peak bromide concentration in the soil–water was found in the depth increment from 80 to 90cm (i.e., 50 to 60cm from the source). Furthermore, the soil extract analyses revealed that bromide was present at all depths in the column in significant concentrations. These two factors should prove that the bromide had traveled completely through the column.

The bromide profile for column #3 follows the same general pattern as that of column #1 except that it is more dispersed. The peak bromide concentration is at a greater depth than it is column #1, but it still has not migrated far from its source. The peak bromide concentration was found in the depth increment from 40 to 45cm, or 10 to 15cm below its point of application, and the greatest depth increment in which bromide was detected in the soil extract analyses was 110 to 120cm, or 80 to 90cm from its source. These results support the conclusions drawn from the effluent data that a 5% bentonite cap is, indeed, an effective deterrent to infiltration.

The bromide concentration profile for column #4 does not resemble those of the other three columns; a single well–defined bromide peak is absent, and the profile is not as "smooth." Figure 7.8 more closely resembles the bromide distributions that Lewis (1986) discovered when he performed his controlled infiltration experiments. It is difficult to quantify much from the profile of column #4, but it does reveal a significant downward migration of bromide tracer. Because this was the first column to be analyzed, as many as five or six samples were analyzed from each depth increment; bromide was detected in every sample without exception. The small "bumps" near the bottom of the the profile have been observed in column experiments in which preferential flow, in the form of channeling along the column walls, was a significant contributor to downward flow (R.

Bowman, 1988, personal communication). The exact nature of the "bumps" in the profile of column #4 can only be speculated.

Because bromide is an ideal tracer, being nondegradeable and nonadsorbable, the depth of the bromide peak divided by the time elapsed for the experiment should yield the seepage velocity (v) of the soil–water. Unfortunately, the transient nature of the flow fields in these columns, make it impossible to quantify a true "seepage velocity." In effect, the seepage velocity was different at every point in the column, with no *one* true "seepage velocity" (R. Bowman, 1988, personal communication). The travel times based on the peak bromide concentration in the profiles were calculated for use in a qualitative comparison and are shown in table 7.4. The flux out of each column (q_{out}) could not be calculated as discussed in chapter 6.

COLUMN NUMBER	"AVERAGE" VELOCITY FROM Br_2 PEAK (cm/s)	ESTIMATED TIME FOR MAXIMUM Br CONC. APPEAR IN EFFLUENT (years)
1	4.3 X 10^{-8}	103.4
2	5.0 X 10^{-7}	9.5
3	1.1 X 10^{-7}	43.2
4	N/A	N/A

* 1 = 50/50, 2 = loam/ gravel, 3 = 95/5, 4 = 100% tails

Table 7.4. Average velocities based on bromide concentration profiles and predicted time (in years) for maximum bromide concentration to reach the bottom of each column (i.e., to appear in the effluent).

7.5.3. FLUORO–ORGANIC CONCENTRATION PROFILES

The fluoro–organic (F.O.) tracer concentration profiles are shown in figures 7.9 through 7.12. It was difficult to determine the greatest depth of F.O. penetration in the columns due to interference from other ions in solution; the lower the F.O. concentrations became, the more difficult it became to separate these background ions from the F.O. ions.

From the climate data (chapter 5 and appendix D), you can see that precipitation was the heaviest during a few times of the year when New Mexico had it "monsoons." Infiltration would be highest during these periods and absent during periods of drought.

The validity of the fluoro–organic (F.O.) tracer results is highly questionable because the F.O. tracers may convert to their neutral (uncharged) form and be retained in the soil at a pH below 3.0 (R. Bowman, 1987, personal communication). Although a sample of effluent obtained in the Fall of 1987 had a pH of 3.1, later analyses of other samples revealed much lower pH values. The pH of the soil extracts ranged from 1.97 to 6.65 (appendix H.3), with the majority of the samples being close to a pH of 3 or less (see section 7.6.2).

Although there were considerable problems associated with the fluoro–organic tracers, the tracers did show a downward movement in each profile. Column #4 (100% tailings) revealed the greatest downward movement, as expected, followed by column #3, column #2, and finally, by column #1. From a qualitative perspective, these results show that column #1 was the most effective. In addition, these results confirm the earlier findings which suggested that the cap material of column #2 had improved upon repacking.

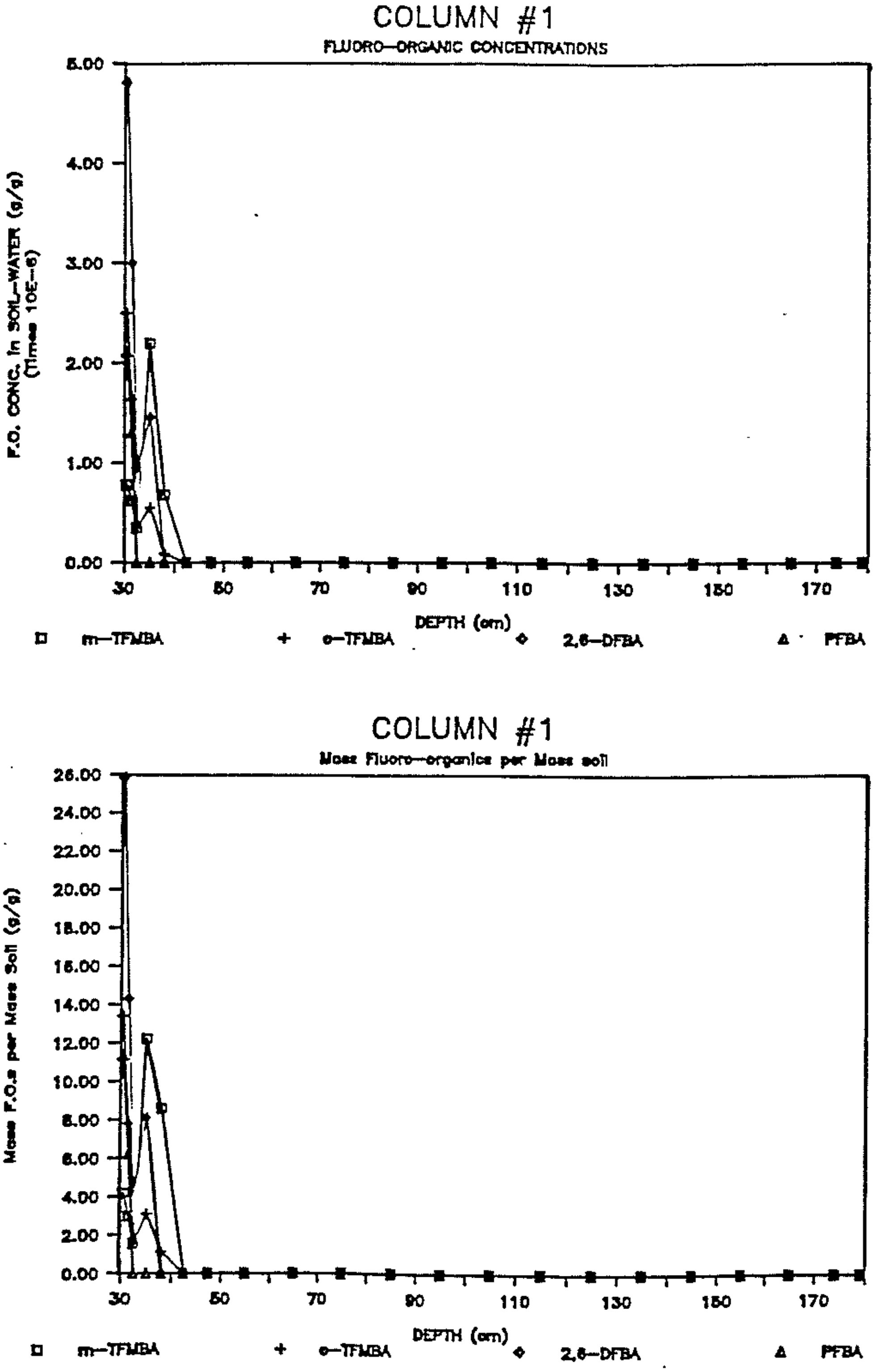


Figure 7.9. Fluoro-organic concentration profiles for column #1 (50% bentonite cap); the upper figure depicts the concentration profiles in terms of their concentrations in the soil-water, while the lower figure depicts the concentrations on a mass basis.

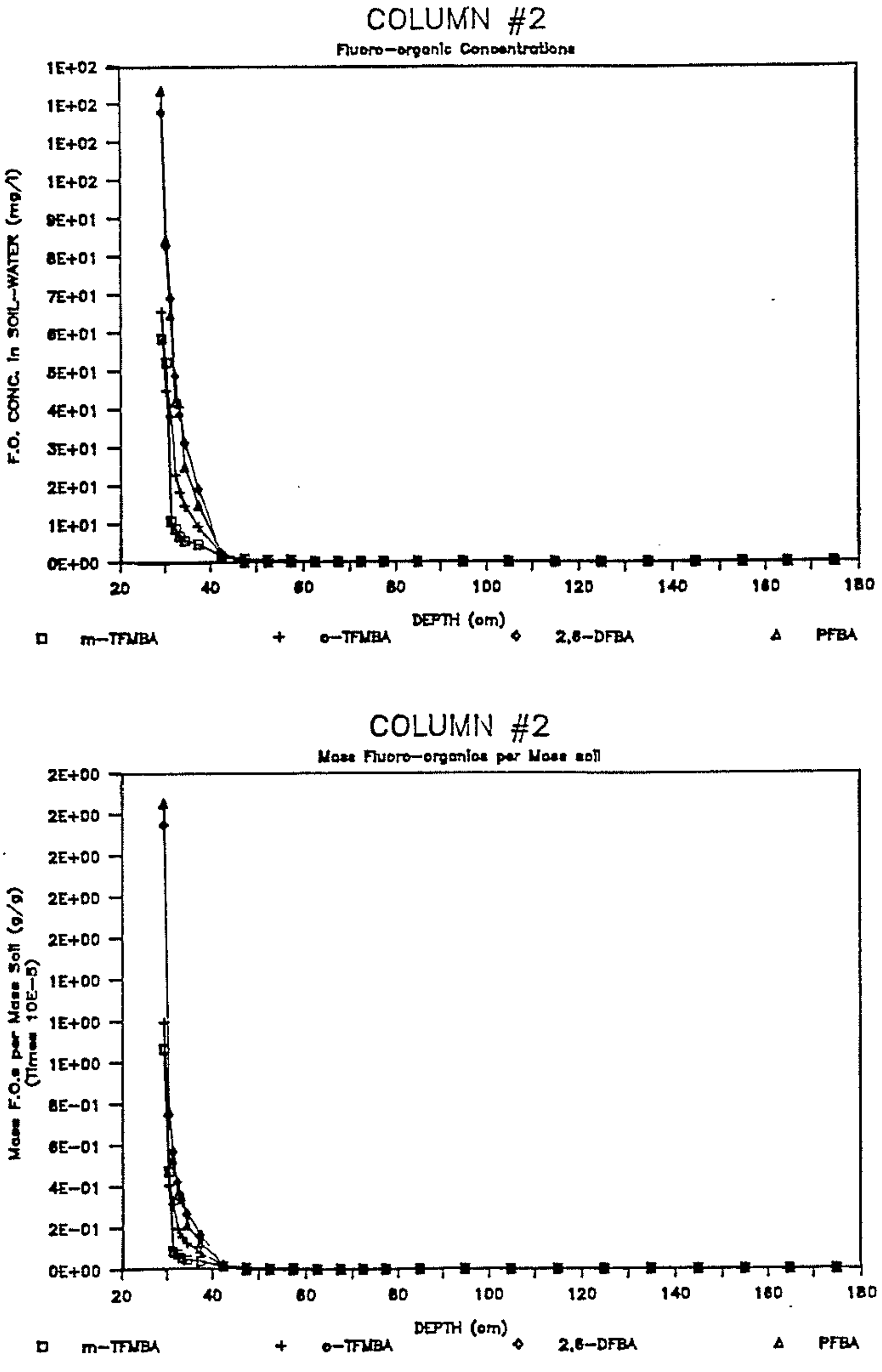
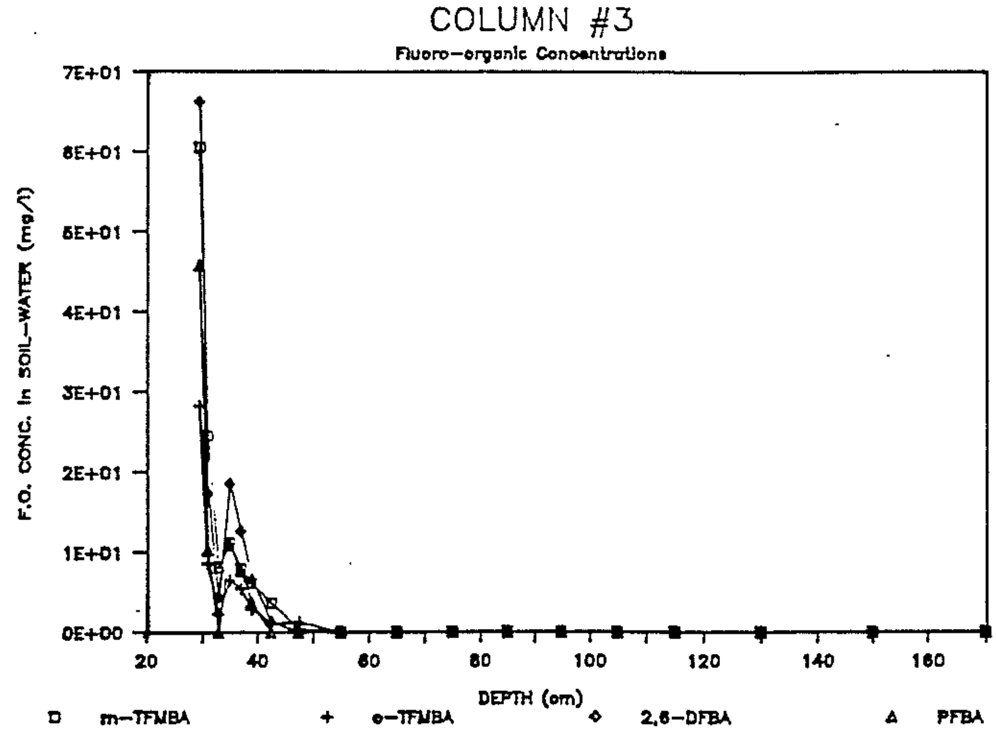


Figure 7.10. Fluoro-organic concentration profiles for column #2 (loam/ gravel cap); the upper figure depicts the concentration profiles in terms of their concentrations in the soil-water, while the lower figure depicts the concentrations on a mass basis.



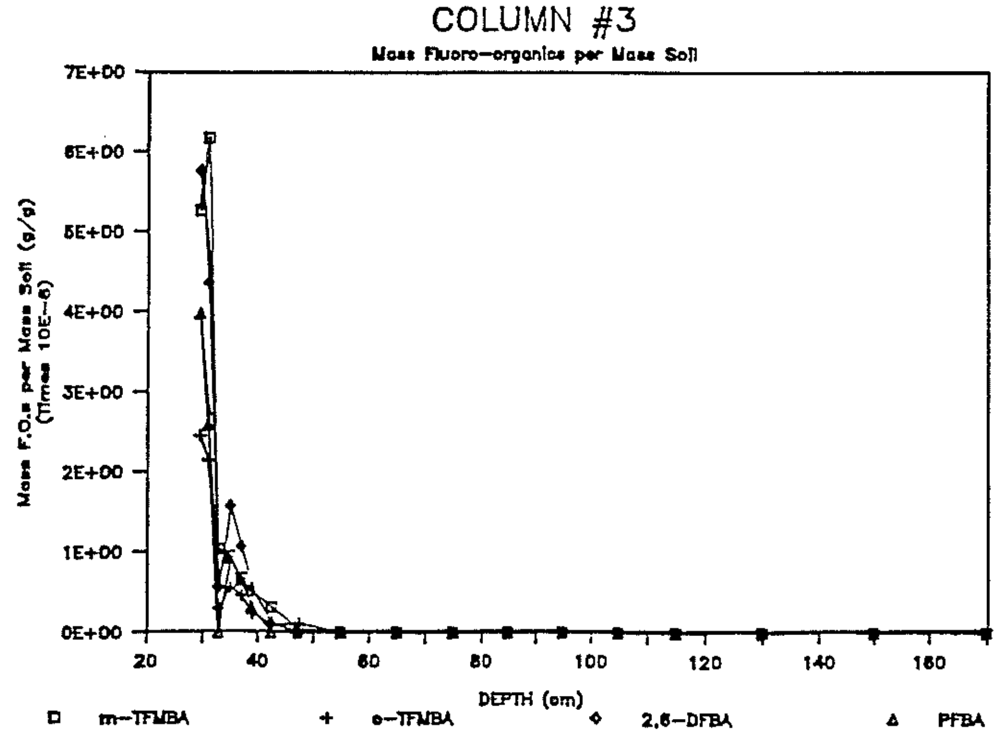


Figure 7.11. Fluoro-organic concentration profiles for column #3 (5% bentonite cap); the upper figure depicts the concentration profiles in terms of their concentrations in the soil-water, while the lower figure depicts the concentrations on a mass basis.

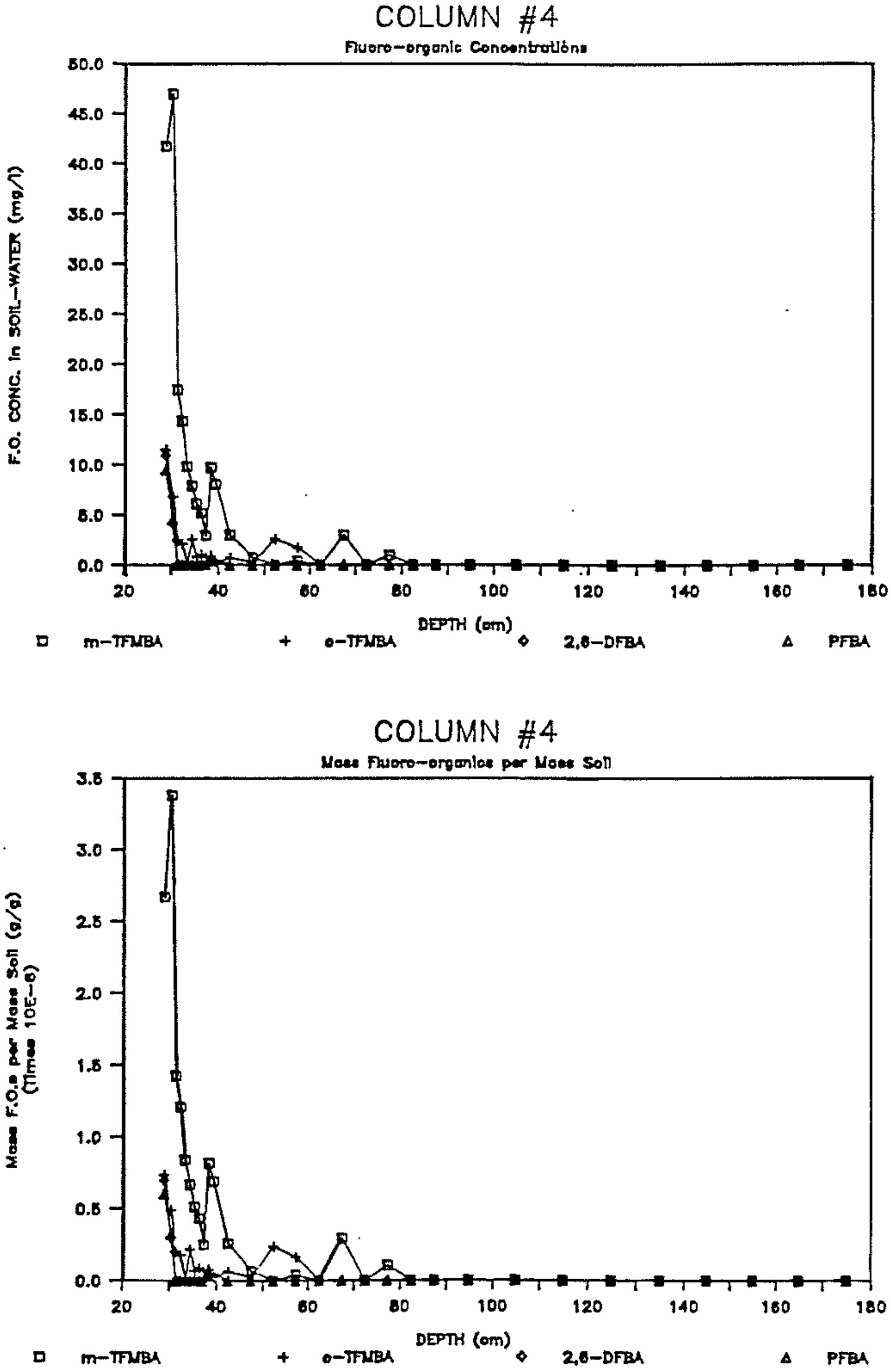


Figure 7.12. Fluoro-organic concentration profiles for column #4 (100% tails); the upper figure depicts the concentration profiles in terms of their concentrations in the soil-water, while the lower figure depicts the concentrations on a mass basis.

7.6. PROBLEMS ASSOCIATED WITH THE TRACERS

The conditions of this experiment were complicated by the effects of evaporation, which caused upward gradients, allowing tracer to move up into the cap material, and by back-mixing at the outlet boundary which occurred due to poor sampling design. Back-mixing was not a problem with the fluoro-organic tracers because they did not travel that far through the column. Unfortunately, the back-mixing at the outlet boundary and the significant evaporation effects make it impossible to realistically model the solute transport processes in these columns.

It was not possible to hold a negative pressure, or suction, at the outlet boundary with the present equipment and experimental design. Consequently, the columns were not allowed to drain freely out of the bottom, and a build-up of moisture began in each column which was quite evident in the moisture content profiles shown in the previous chapter. The validity of the effluent data is questionable for this reason.

7.6.1. PROBLEMS SPECIFIC TO BROMIDE

There were no major problems with the use of bromide in the copper mill tailings medium, with the exception of the loss of bromide mass in each system. Lewis (1986) performed batch experiments with bromide in the copper mill tailings medium, and his results are shown in appendix H.1; the major trend in the results was for bromide to lose greater mass at lower concentrations. The correction equation derived by Lewis (appendix H.1) did not sufficiently account for all of the bromide that was lost in this experiment. This could be related to the difference in residence times of bromide in the copper mill tailings medium. In the current study, bromide was in contact with the mill tailings for over three and a half years which may have significantly altered the behavior of bromide. Lewis

(1986) attributed the loss of bromide mass in his experiment to complexation with metal ions in solution.

The problems associated with the HPLC, which were mentioned earlier, were not a factor in this experiment because nitrate was not present in the samples.

7.6.2. PROBLEMS SPECIFIC TO FLUORINATED ORGANICS

The results of the batch analyses performed on the fluoro–organics (F.O.s) in the copper mill tailings medium are shown in figure 7.13. Most of the F.O.s appear to be conservative with the exception of m–TFMBA which exhibited a loss corresponding to a linear isotherm. This behavior may have been related to aerobic conditions as suggested by Bowman (1986).

The pH of the soil extracts varied from 1.97 to 6.65 with an average pH of approximately 3.0 (appendix H.3). A sample extracted from the loam material of column #2 had a pH of 6.65, although the pH of samples extracted from the underlying tailings were much lower. The pH values in column #1 (50/50) and column #3 (95/5) were as high as 6.63 and 5.03, respectively. These high pH values were found at the base of the cap materials where the bentonite probably had a buffering effect. The lower portion of these columns exhibited much lower pH values. Column #4 (100% tailings) had low pH values throughout. The pH of the soil extracts decreased with depth in each column.

The pH of the actual soil–water would be expected to be even lower than that of the extracts because the extracts have been diluted with neutral pH water. Below a pH of approximately 3.0, the fluoro–organic (F.O.) tracers will convert to the uncharged (neutral) form and be retained in the soil (R. Bowman, 1987, per–

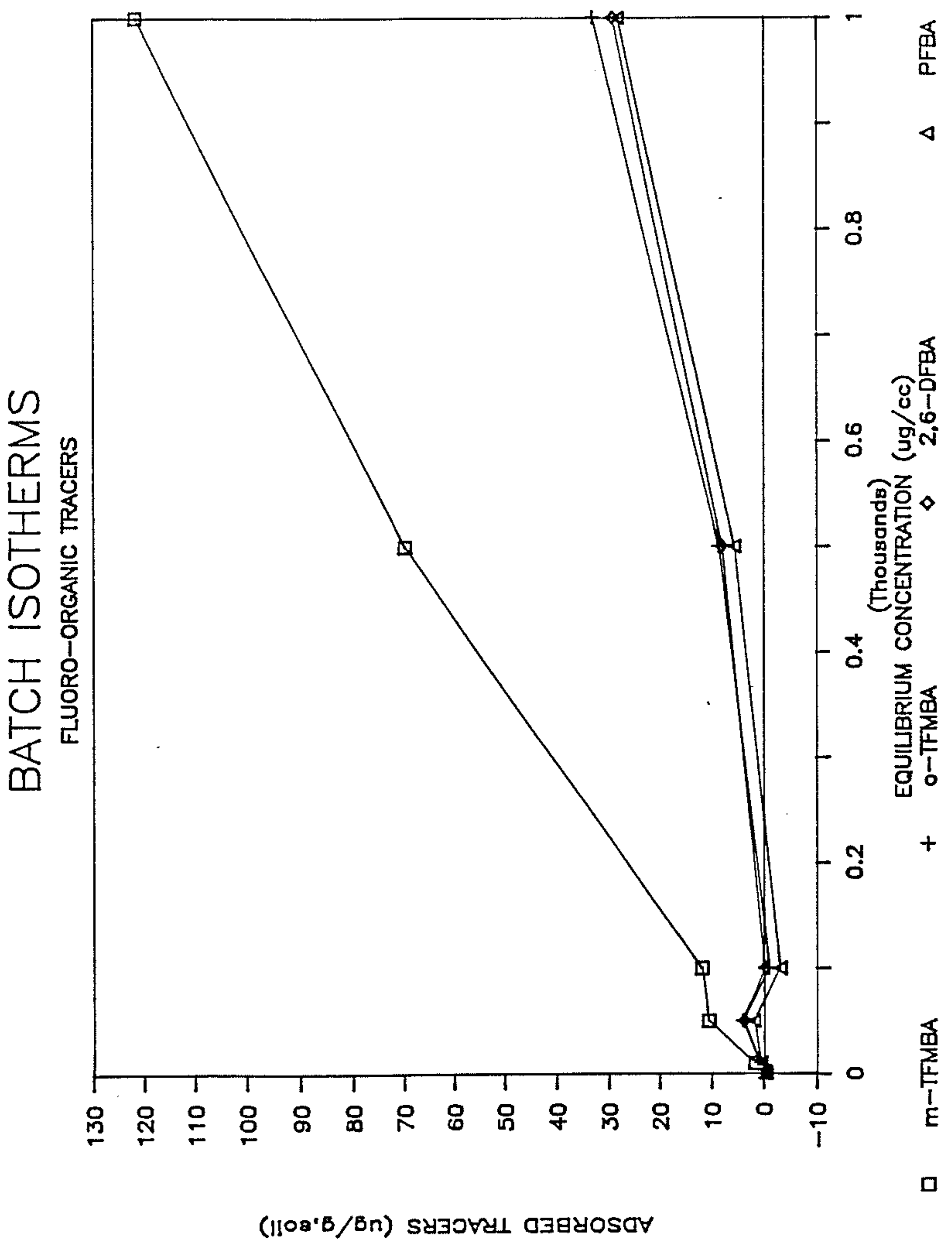


Figure 7.13. Batch isotherms for fluorinated organic tracers in the copper mill tailings medium.

sonal communication). Therefore, the F.O. tracers do not seem to be well–suited for this type of medium.

Under different circumstances the F.O. tracers may be suitable in a copper tailings medium. For example, in a saturated experiment where water is continuously being flushed through the medium, the soil–water would not have as long to equilibrate with the tailings and therefore, it would not become as acidic.

The tailings contain such a variety of ions that the background noise alone makes it difficult to detect the presence of the F.O. tracers. Many of these "background ions" elute (i.e., appear on the HPLC chromatograph) at the same time as the F.O. tracers and obscure the results. The research of Jenke and Pagenkopf (1983) confirm that metal cations may elute at the same times as other ions and overlap their peaks on the chromatograph. It is virtually impossible to separate the peaks without using different analytical techniques such as atomic absorption which determines the concentrations of metal cations in a solution. Reducing the flow rate and adjusting the mobile phase used in the HPLC analyses does not affect the results. Furthermore, if the F.O. tracers convert to the uncharged form as suggested earlier, they will not be detected by the HPLC.

The fine particles of bentonite clay present in the cap materials of columns #1 and #3 migrated downward several centimeters in these two columns. The effect was more pronounced in column #1, of course, because more bentonite was used. Because of bentonite's ability to absorb a large quantity of water, it was difficult to obtain a soil extract from the soil directly below the base of the cap material. In some cases, the soil extract was just a scant amount of liquid, and in severe cases more water was added to the soil in order to obtain an extract. This significantly reduced the concentration of tracers in the extract and reduced the chances of detecting these tracers.

Another problem was that the negatively charged fluoro-organic (F.O.) tracers may have possibly adsorbed onto the outer layer of the bentonite clay. Fortunately, this problem was probably not significant because the F.O. tracers are monovalent anions, and adsorption is more pronounced with divalent anions. If adsorption did take place, the F.O. tracers would be retained in the upper portion of the soil in columns #1 and #3 where the bentonite was present.

The fluoro-organic tracers are relatively new and still in the experimental stages. Previous studies involving these tracers have lasted no more than a few months. This experiment ran for almost ten months using these tracers. Although the F.O. tracers have been shown to be conservative in short duration experiments, the situation may be totally different for longer term experiments, and this aspect needs to be addressed in the future. It should also be noted that previous research involving the F.O. tracers was conducted mostly in neutral pH media. The research conducted by Terauds (1985) is one notable exception.

Given the problems just discussed, it is no wonder that the recovery of F.O. tracers was poor. The recoveries ranged from less than 2% in column #1 to approximately 30% in column #2, and the recovery was better for column #4 than column #3 (appendix H). The low recoveries for columns #1 and #3 may be attributed to the presence of the bentonite clay as stated previously.

The overall recovery of F.O. tracers in Terauds' (1984) study was probably higher than that of the current study because the solutes did not have as long a residence time in the copper mill tailings medium, and therefore the pH probably did not get as low as it did in the current study. Terauds (1984) did not quantify the recovery of F.O. tracers but did make reference to it.

7.7. SUMMARY

The results furnished by the tracers revealed that the cap material of column #2 (loam–gravel) was very ineffective in retarding infiltration, a conclusion that has been reached in most of the analyses. The results of the F.O. tracers, on the other hand, suggested that the effectiveness of column #2 had improved after it was repacked. This conclusion has also been supported by earlier findings.

Although the effluent data indicated that a 5% bentonite cap was more effective in reducing deep percolation, the results of the soil extract analyses indicated that a 50% cap was more effective in retarding downward flow. It should be noted, though, that the concentration of bromide in the effluent samples was negligible in comparison to the concentrations detected in the soil extracts. As suggested previously, the cap material of column #1 may have been disrupted early in the experiment during its transport out to the field site which would account for the downward gradients, the large volume of effluent, and the early detection of bromide in the effluent of this column. Whatever the explanation may be, it is clear that the 5% bentonite cap was a significant improvement over a 100% tailings cap, and it is very close in effectiveness to the 50% bentonite cap.

8.0. PHYSICAL OBSERVATIONS OF THE FIELD COLUMNS

8.1. INTRODUCTION

The conclusions drawn from the previous chapters can be partially explained through the physical observations made of the field columns and their cover materials over the course of the experiment. The processes discussed in chapter 2 should aid in understanding some of these observations and theories.

Chapter 4 described the hydraulic properties of the cap materials and the tailings. Unfortunately, it is not always appropriate to assume that a laboratory–determined value will be representative of a field–type situation. Factors are involved in the field that may have a significant impact upon the behavior of a material. Some of these factors include the alternating wetting and drying cycles created by periods of rainfall and drought and the addition of rainwater which may have a significantly different chemistry than the tap water used in the laboratory analyses. Some of these problems were evident upon physical observation of the columns.

8.2. COLUMN #1 (50% TAILINGS/ 50% BENTONITE CAP)

It was assumed that the presence of the bentonite in the cap material of column #1 would significantly retard infiltration. The saturated hydraulic conductivity (K_s) of the 50/50 material was below measurement capability as stated in chapter 4. Difficulties were encountered in attempting to define a $K(\theta)$ relationship, also, which was related to the low permeability of the material.

Although the bentonite comprised only 50% of this cap material, it seemed to control its overall behavior. The complete laboratory report of the

Wyoming bentonite was obtained by the supplier of the material, NL Baroid/NL Industries, and it is included in appendix A. This bentonite comes from the Wyoming–South Dakota area of the Black Hills. It is composed of 85–90% montmorillonite [$H_2O.(Al_2O_3,Fe_2O_3,3MgO).4SiO_2–nH_2O$], and the other 10–15% includes fragments of feldpar, gypsum, calcium, and quartz. The pH of the material in suspension is between 8.6 and 9.2. Some of the other important properties of this material are its ability to absorb close to five times its weight of water and to swell to up to fifteen times its original (dry) volume. Upon drying it will shrink to its original volume. This swelling process is rather slow, and it proceeds even slower when the water is cold (NL Baroid/NL Industries, 1987).

The copper mill tailings which comprised the other 50% of this cap material had significantly different properties from the bentonite clay. First of all, the pH of the tailings in suspension was between 2.0 and 4.0, depending upon the tailings–to–water ratio and the time allowed for equilibration. Furthermore, the particle size distribution of the tailings was that of a loamy sand with only a small fraction of clay (see also: chapter 4).

Since swelling is greatly reduced in a low pH solution due to the Al^{+3} ion (Hillel, 1980a), the presence of the tailings in the 50/50 material should limit the bentonite's ability to swell. The swelling is time–dependent, as shown in figure 8.1, which is related to the low hydraulic conductivity of the material (Hillel, 1980a). The clay may require several days to swell significantly, and in the field situation there may only be a fraction of a day in which it is in contact with water and swelling may take place. Therefore, it usually requires several days of continuous rainfall for the bentonite to swell, and this is not common in New Mexico. Furthermore, swelling of the 50/50 material may be reduced by the presence of the tailings which may act as a physical barrier to expansion (Hillel, 1980a).

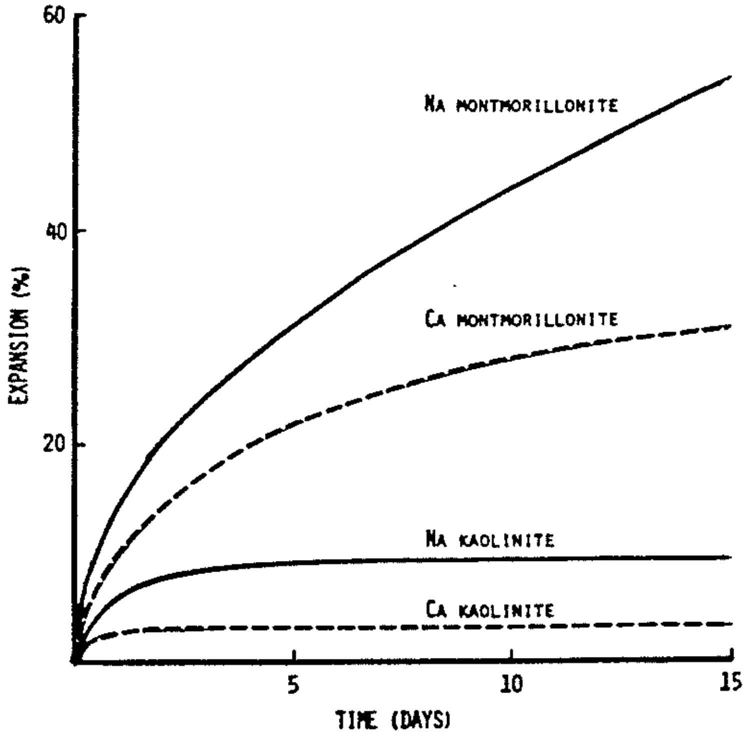


Figure 8.1. Time-dependence of swelling in an expandable clay soil (Hillel, 1980a).

Alternating wetting and drying cycles cause heavy clay soils to heave and settle, forming cracks and shear planes which may extend very deep into the profile (Hillel, 1980a). The surface of the 50/50 cap material, which is shown in figure 8.2, was usually severely desiccated and hummocky with material apparently "flaking off" in spots. It was characterized by several large polygonal-shaped aggregates of material, or peds, separated by very large cracks, and within the peds there were several hairline fractures. The larger cracks were between 0.5 and 2.0cm wide. A wire was used to determine their depths which ranged from a few millimeters to about a centimeter. Hairline cracks, within individual peds, were a few millimeters in width and extended to depths of at least 2.5cm. It was difficult to determine exactly how deep the hairline cracks extended because they became even narrower with depth. The existence of these cracks, especially the wider ones, undoubtedly had a significant impact on the infiltration and evaporation mechanisms occurring in this column.

From the field observations, it seemed that there were three modes of vertical water transport through the cap material: movement in the larger cracks between the aggregates, or peds, of the cap material, movement directly through these peds, and channeling along the column walls. Based on the laboratory analysis of the 50/50 cap material, movement through the peds was probably not significant. The third possible mechanism was channeling along the sides of the column, and a hairline fracture *was* evident near the column wall.

Following a precipitation event of a significant intensity and duration, the cracks would seal and the material at the surface would become extremely soft. Water would then begin to pond at the surface. These ponding depths were never found to be greater than 1.0cm, and this was the only column which exhibited ponding. The cracks did not seal immediately; it usually required a few days of

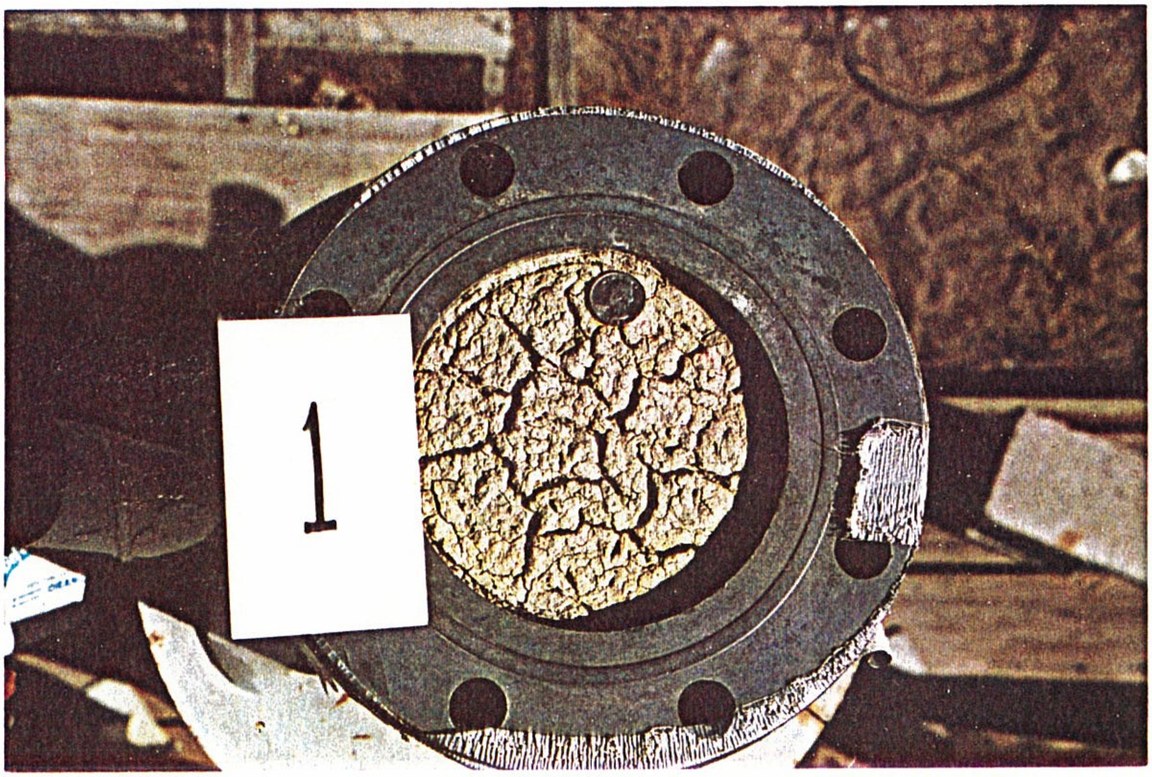


Figure 8.2. Photograph showing the surface of column #1 as it usually appeared following a period of drought (taken on October 11, 1988).

rain to seal them. Water would remain ponded at the surface for about two days following an intense storm, followed by another couple of days of dampness at the soil surface. Upon drying the cap material would become severely desiccated, forming the same pattern of cracks described previously.

Since the ponding depths were never greater than 1.0cm, it is reasonable to assume that unsaturated conditions prevailed in the tailings below the cap material. A quick calculation using equation 2.10 confirms this.

Following a lower intensity rainfall event or a brief shower, the cracks would not seal and the surface would only appear damp. The surface would retain its rigid form throughout the rainfall event, allowing precipitation to enter the column directly through the relatively large shrinkage cracks. Because it required a significant precipitation event to seal the cracks, it was not as common for that to happen.

Another important feature that was observed in this column, as well as in the other three columns, was a freezing of the upper portion of the soil column during the Winter months. If the top portion of the column had froze, there could possibly be an upward temperature gradient (from high to low temperature). During the brief time period in which the columns appeared to freeze, the tensiometers in each column revealed upward gradients. In addition, the top tensiometer in each column revealed a very high suction value which was probably related to the frozen soil water and hence, the lower moisture content, at that location. The other three columns showed even more conclusive evidence of a temperature gradient.

8.3. COLUMN #2 (GRAVEL OVERLAIN BY FINE-TEXTURED SOIL CAP)

The purpose of this cap material was to create a "hydraulic barrier" to flow. When the wetting front reached the loam-gravel interface, the relatively high suctions should have prevented water from passing into the large pores of the gravel (Hillel, 1980a). Under unsaturated conditions, the water would become trapped in the upper loam layer and eventually move upward due to evaporation. Unfortunately, this cap material was not very effective in restricting infiltration.

The upper fine-textured portion of the cap material had an extremely low saturated hydraulic conductivity (6.97×10^{-6} cm/s; chapter 4) and therefore, it should have been fairly effective in reducing infiltration even if the "hydraulic barrier" concept did not work. Hence, some other factors must have been at work in this column.

Short-circuiting, or preferential flow through the shrinkage cracks of the soil, may have been a major factor in this cap material. The cap material of column #2 often appeared loose and crumbly. It was characterized by hair-line cracks which were less than a few millimeters in width and which extended to at least a few centimeters in depth and probably much more. It was difficult to determine the exact depth to which the cracks extended because of their narrow width. Figure 8.3 shows the surface of column #2 as it usually appeared.

A peculiarity with this column was that small plants began to grow out of its top, but these were removed immediately because it would destroy the consistency between columns. The growth of these plants seemed to reinforce the observations that the cap material consisted of very loose soil.

The upper, finer-textured portion of the cap material underwent some settlement or consolidation which may have been induced by settlement of the

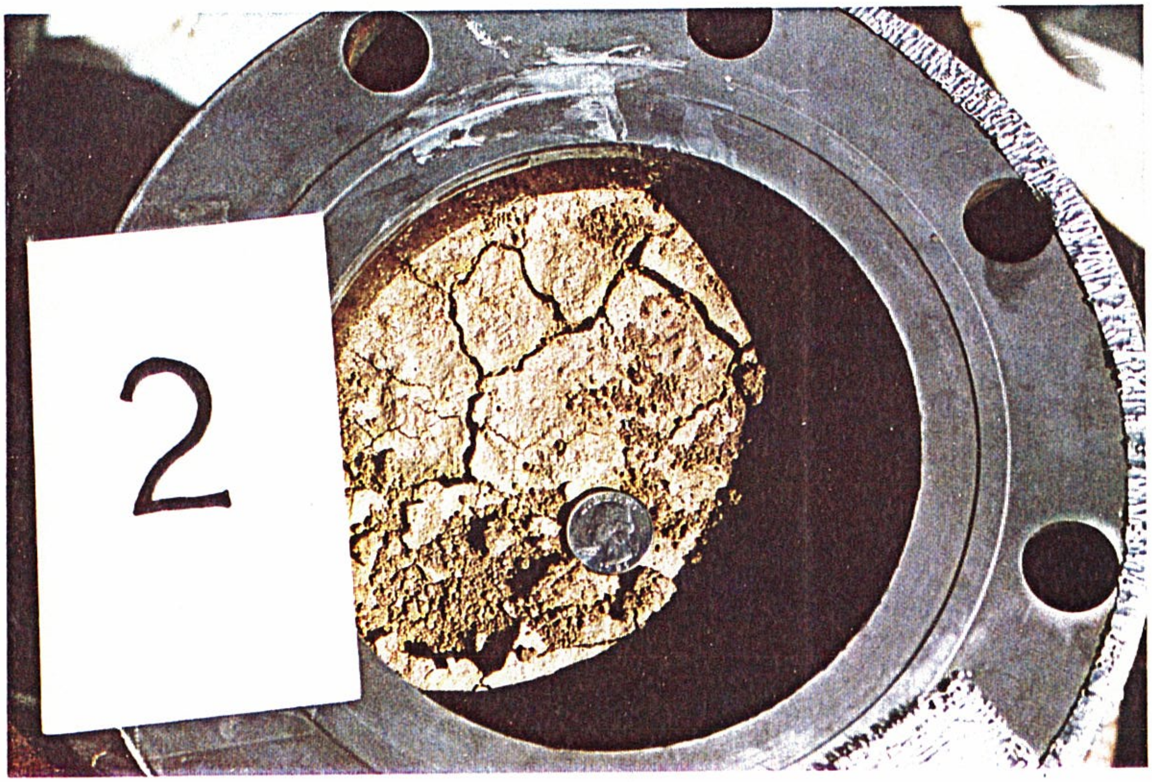


Figure 8.3. Photograph showing the surface of column #2 as it usually appeared following a period of drought (taken on October 11, 1988).

underlying gravel. Recall that the top tensiometer in this column had been removed earlier in the experiment due to problems related to consolidation of the cap material. The alternating cycles of wetting and drying may have induced some settling, also.

Another idea is that this "settling" may have actually been "heaving" due to temperature gradients, especially since it was observed during the Winter months. The lower portion of the columns which were wrapped with insulation would be warmer than the soil exposed at the surface. This would induce an upward gradient toward the lower temperature (i.e., lower potential) at the soil surface. According to Dirksen and Miller (1966) "experiments confirm that heaving sometimes occurs in moist closed soil columns, initially at uniform temperature and water content, when the temperature at one end is lowered below the ice point and kept at that temperature while the other end is held at the original temperature." It is plausible that the upper portions of the columns froze while the lower portion remained at a relatively constant temperature because of the insulation. If the heaving of the cap materials is explained in this manner, then a temperature gradient must have existed, and this gradient would have induced flow toward the frozen soil (i.e., upward flow). The tensiometric data confirms that upward gradients were dominant during this period.

8.4. COLUMN #3 (95% TAILINGS/ 5% BENTONITE CAP)

The cap material of column #3 consisted of 95% tailings and 5% bentonite clay. Using less clay reduced the number and the severity of the shrinkage cracks. The same hydraulic barrier phenomena should have taken place in this column, also, because the cap was composed of a fine-textured medium. In theory, water should not be released from the cap material until it is close to saturation. The saturated hydraulic conductivity (K_s) of the 95/5 material was found to be 1.24×10^{-3} cm/s, while the K_s of the tailings below was 1.65×10^{-3} cm/s.

Figure 8.4 shows the surface of column #3 as it usually appeared. The surface appeared to be compacted by the rain; it was marked by raindrop imprints and a surface crust was observed. This surface crust should have further reduced infiltration into the column. The only cracks observed in the surface of this cap material were very small hair-line fractures near the column walls. Again, this indicates that the boundaries of the column may have induced the cracking. There were no cracks observed in the interior of this cap material, indicating that this material had the potential be very effective in reducing infiltration.

Some heaving of the cap material was observed in column #3, suggesting that temperature gradients may have been a factor in this column. Unfortunately, there was no data to verify this theory for any of the columns because only one thermistor was placed in each column.

8.5. COLUMN #4 (100% TAILINGS COLUMN)

Column #4 was the control for the experiment. The physical observations of the surface of column #4 were virtually identical to that of column #3. The only real difference between the two was that column #3 was much more effective in reducing infiltration than column #4.

A surface crust was observed in column #4 which was very similar to that which formed in column #3 as shown in figure 8.5. The only cracks evident in this column were near the column walls. Because column #4 did not contain any bentonite, this further supported the idea that the small cracks observed near the column walls may have been induced by the column itself.

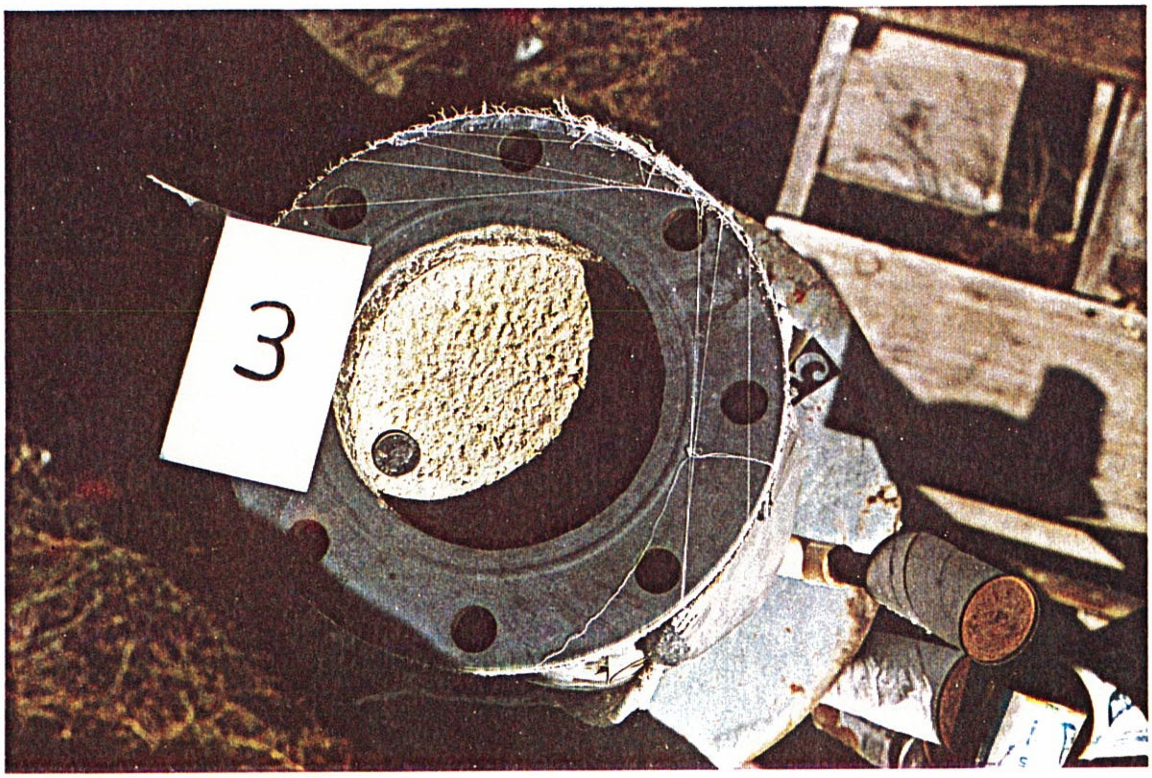


Figure 8.4. Photograph showing the surface of column #3 as it usually appeared following a period of drought (taken on October 11, 1988).

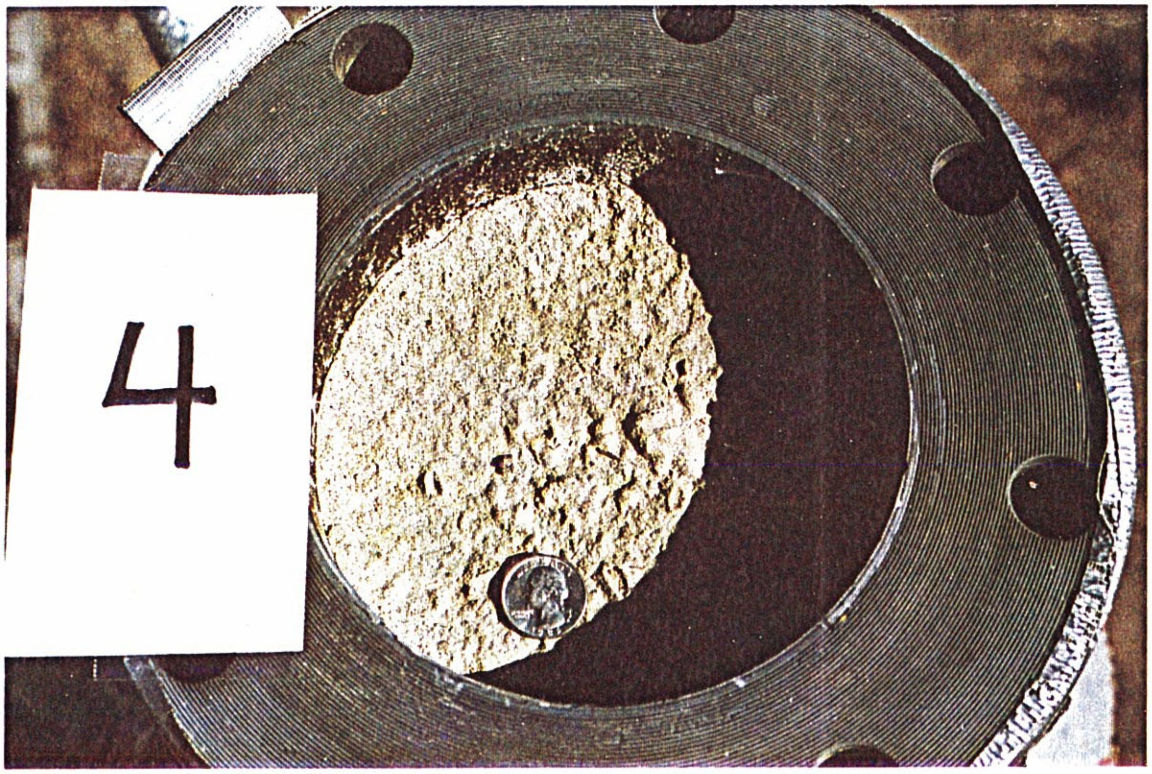


Figure 8.5. Photograph showing the surface of column #4 as it usually appeared following a period of drought (taken on October 11, 1988).

8.6. SUMMARY

Based on physical observations, the cap material of column #3 (5% bentonite cap) should have been more effective in reducing infiltration than column #1 (50% bentonite cap). On the other hand, the evidence presented in the previous chapters supports the opposite conclusion. One explanation is that the cracks in column #1 did not extend the entire length of the cap material, and precipitation cannot penetrate any deeper than these cracks do. Although the 50% bentonite cap material was more effective than the 5% bentonite cap, the cost benefit relationship may support the latter as an appropriate cover material (i.e., bentonite is a relatively expensive material, and it would be much cheaper to use 5% as opposed to 50%).

Column #2 appeared to have the least effective cap material which may be attributed to settlement of the gravel in the cap material. Although the theory behind the use of a gravel overlain by a fine-textured soil (column #2) is a sound idea, it may be difficult to put this theory to work in the field. If a fabric was used to separate the loam from the gravel, the cover material may have been much more effective.

9.0 SUMMARY AND CONCLUSIONS

In order to refresh the memory of the reader, the cap materials consisted of a 50% tailings/ 50% bentonite mixture for column #1, a fine–textured (clay or loam) soil underlain by a gravel for column #2, a 95% tailings/ 5% bentonite mixture for column #3, and 100% tailings for column #4. The major finding of this experiment was that the cap material of column #1 was the most effective, followed very closely by column #3. The cap material of column #2 was found to be less effective than that of column #4 (the control column). In addition, the fluorinated organic tracers were found to be a poor choice of tracers under these experimental conditions, primarily due to the low pH of the media. A basic summary of the major findings will be presented in the next several paragraphs.

During the first few months of the experiment, the cap material of column #1 was very ineffective in reducing infiltration into the copper mill tailings. This statement is substantiated by the fact that during this time period, a large volume of effluent was discharged from the column, and the tensiometers indicated predominantly downward gradients. In addition, bromide was detected in the effluent within seven months of the onset of the experiment which was rather early. The behavior of column #1 improved significantly over time; the tensiometers began to indicate predominantly upward gradients and the column ceased to produce effluent. After the cap material of column #1 was repacked at the field site in the Fall of 1987, the column continued to behave in an *effective* manner; the gradients continued to be upward and little or no effluent was released from the column.

The early behavior of column #1 was probably related to a disturbance during its transport to the field site. Because the columns were originally prepared (i.e., packed) in the laboratory and then transported to the field site by forklift, some cracking or settling of the material in the column may have occurred. It seems reasonable to assume that a 50% bentonite cap would have been the most effective cover material had the early disturbance to the column not occurred. It would be difficult to predict how much cracking or settling would have occurred in each column under normal circumstances.

Although the data from the earlier portion of the experiment indicated that the 5% bentonite cap material of column #3, was more effective than the 50% bentonite cap, data collected afterward indicated that it was less effective than the 50% bentonite cover. In the first few months of the experiment, column #3 revealed mostly upward gradients, and the volume of effluent discharged from the column was insignificant in comparison to that of column #1. In addition, bromide was detected in the effluent nearly 9 months after it had been detected in that of column #1. These facts suggest that the 5% bentonite cap material was more effective than the 50% bentonite cap. On the other hand, column #3 continued to produce effluent long after column #1 had stopped, and column #3 showed weak upward gradients and often indicated downward gradients while column #1 indicated strong upward gradients. In addition, the soil extracts revealed that bromide had penetrated deeper in column #3 than in column #1. Furthermore, relative to the 100% tailings cover material, the 5% bentonite material was 13.5% more effective while the 50% bentonite material was 19.8% more effective in reducing infiltration.

A cap material consisting of just 5% bentonite *does* significantly retard infiltration, but it *does not* seem to be more effective than a 50% cover material. The cost–benefit relationship between using a 5% versus a 50% bentonite clay cap is the real question which needs to be addressed here. It is this author's belief that the use of a 50% bentonite cap material to reduce infiltration into a copper mill tailings waste pile is not worth the additional cost. Bentonite is a fairly expensive material, and the results of this experiment indicate that the use of ten times as much bentonite does not translate into a ten–fold reduction in seepage.

In general, the cover material used in column #2 was not effective in reducing infiltration. The theory behind the use of the loam-gravel cover material was that moisture would not be released from the upper loam layer until it was completely saturated because of the lower suction (i.e., higher potential) present in the gravel layer beneath. This would allow moisture to become trapped in the upper layer and possibly be lost to evaporation over time. Unfortunately, it was difficult to apply this theory to the field situation. Column #2 was disturbed during its transport to the field site; the uppermost tensiometer had to be removed from this column due to problems related to the consolidation of the cap material which occurred during its transport to the field site. The effectiveness of this cover material showed some improvement after the column was repacked. After this time, the tensiometers indicated some upward gradients, whereas previously, they were predominantly downward. On the other hand, the column continued to discharge effluent on a regular basis, and bromide was detected in almost every sample. Furthermore, the soil extract analyses revealed that bromide was present throughout the soil column. This cover material was 17.1% less effective in reducing infiltration than the 100% tailings cover material. If a fabric had been used to separate the fine-textured layer from the underlying gravel, this cover material would probably have been much more effective.

Column #4 (100% tailings) produced about as much effluent as that of columns #2 and #3. Bromide had a rather strange distribution in this column which was probably related to the transient nature of the flow field, and it was difficult to interpret the data. For the most part, upward gradients (i.e., evaporation) appeared to correlate with periods of dryness while downward gradients (i.e., infiltration) appeared to correlate with periods following precipitation events, indicating that the 100% tailings cover was ineffective in reducing infiltration.

The water and solute transport phenomena for each column could not be modeled using a steady–state solution due to the transient nature of the flow fields. One of the major problems encountered in modeling the transport phenomena was the existence of upward gradients in the columns. Furthermore, the fluxes into and out of the column would not be the same due to a change in storage in the column. The different degrees of saturation from one column to another suggest that the lower boundary conditions may have been different. Therefore, it was not possible to legitimately quantify a flux through the system (or a flux out of the system).

The results of this experiment strongly indicate that some type of cover material is necessary to reduce the downward migration of precipitation through a copper mill tailings waste pile. The copper mill tailings leachate, which contains harmful metals, will continue to seep to underlying aquifers for years to come unless some type of remedial action is taken.

10.0 RECOMMENDATIONS FOR FUTURE RESEARCH

This experiment represented the first step toward quantifying the effectiveness of different cap materials in reducing infiltration through a copper mill tailings impoundment or waste pile. The study has created a tremendous database (included in the appendices) which may serve as a foundation for future research. Several suggestions for future work have evolved over the course of this research, and these are categorically listed below.

10.1. CHEMISTRY

(1.) The behavior of the fluoro-organic tracers in low pH media, such as copper mill tailings, needs to be examined more closely. These tracers should transform below some threshold pH, but little work has been done to quantify this.

(2.) Research into the use of fluoro-organic tracers in the field for extended periods of time needs to be examined, also. This experiment represented the longest period of time that these tracers had been used in the field (10 months), and it is not known if these tracers will degrade significantly.

(3.) The analysis of copper mill tailings leachate by High Performance Liquid Chromatography (HPLC) needs to be examined more closely. There were many problems associated with the detection of the tracers, especially the fluoro-organic tracers, which was related to interference from other ions in the tailings. The research of Jenke and Pagenkopf (1983) has begun to examine this problem.

10.2. MODELING

(1.) A one–dimensional simulation of water and solute transport through any one of the columns could be attempted, although the transient nature of the flow fields may severely curtail any modeling efforts.

(2.) A geostatistical analysis (i.e., time series or spectral analysis) could be performed using the tensiometric and precipitation data to see exactly how the precipitation affects the gradients through time. McElroy (1985) has already performed a geostatistical analysis using data from the first few months of the experiment. A long–term time series analysis may be more revealing.

10.3. EXPERIMENTAL CHANGES

If the experiment were to be recreated, several modifications should be made:

(1.) More tensiometers should be used (recall that this experiment had only three tensiometers per column, and they were placed directly below the cap material). A few could be placed directly in the cap material and others could be placed throughout the columns.

(2.) More than one thermistor could be placed in each column in order to check for possible thermal gradients. Recall that there was physical evidence for thermal gradient effects in this experiment (i.e., heaving) but no quantifiable evidence.

(3.) A more efficient technique for sampling the effluent needs to be devised. The vacuum gage used in this experiment just could not pull enough suction to sufficiently sample the effluent at the bottom. Also, this method allows back-mixing of the effluent samples to occur. One alternative may be to obtain a better vacuum pump. Another idea is to use porous cup samplers near the bottom of the column to prevent the build-up of moisture at that location.

(4.) Neutron access probes could be used to determine the moisture contents in the columns, but this may require wider columns due to the zone of influence of the neutron probe.

(5.) The cap materials could be packed at different bulk densities or at different initial moisture contents to try to optimize their effectiveness.

(6.) The columns could be packed *at* the field site rather than in the laboratory in order to minimize transport-induced cracking and settling of the material in the columns.

10.3. TOPICS FOR FUTURE EXPERIMENTS

More research needs to be done in several areas (many of these experiments may serve to either verify or disprove the conclusions drawn from this experiment).

(1.) The effects of variations in temperature on the performance of the tensimeter-tensiometer apparatus needs to be examined more closely.

(2.) More experiments need to be conducted which examine preferential flow through the shrinkage cracks in a clay soil. It would be interesting to look at the effect of increasing bentonite clay content on increasing number and severity of the shrinkage cracks.

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A FIELD COLUMN STUDY TO DETERMINE THE EFFECTIVENESS OF DIFFERENT COVER MATERIALS IN REDUCING INFILTRATION INTO A COPPER MILL TAILINGS WASTE PILE

BY

LORI J. WILLIAMSON

An Independent Study Submitted in Partial Fulfillment
of the Requirement for the Degree
Master of Science in Hydrology

New Mexico Institute of Mining and Technology
Socorro, New Mexico

May 1, 1989

APPENDICES

APPENDIX A

NL Baroid
Specialty Products

NATIONAL® Standard Western Bentonite

Slurry Trench and Soil Sealing Grade - 200 Mesh

Typical Physical and Chemical Properties

X-RAY ANALYSIS

85%	Montmorillonite
5%	Quartz
5%	Feldspars
2%	Cristobalite
2%	Illite
1%	Calcium and Gypsum

CHEMICAL ANALYSIS

SiO_2	55.44%
Al_2O_3	20.14%
Fe_2O_3	3.67%
CaO	0.49%
MgO	2.49%
Na_2O	2.67%
K_2O	0.60%
Bound Water	5.50%
Moisture at 220°F	8.00%
TOTAL	99.09%

SCREEN ANALYSIS	TYPICAL	SPECIFICATION
Dry Screen, percent minus 200 mesh	85	70 min
Wet Screen, percent plus 200 mesh	2	4 max
Wet Screen, percent plus 325 mesh	3	5 max

SLURRY PROPERTIES (6% SUSPENSION)

Viscosity-Fann 600 RPM	20	------
Apparent Viscosity, cps	10	------
Plastic Viscosity (PV)	7.5	------
Yield Point, lb/100 ft²	5.5	------
Filtrate, 30 minutes @ 100 psi	16	
Yield - 42 gal bbl of 15 cps slurry/ton	84	
Filter Cake	3/32	

OTHER PROPERTIES

Moisture - percent	8	10 max
Free Swell (ml)	28	
Specific Gravity	2.5	
pH - 6% Suspension	9.0	
Bulk Density (lbs. per ft³) compacted	72	

NOTE: The typical chemical and physical values listed are not to be construed as rigid specifications. Metals listed in the chemical analysis are complexed in the mineral. They do not necessarily exist as free oxides.

NL Baroid P.O. Box 1675, Houston, Texas 77251

NL BAROID ENVIRONMENTAL, SAFETY AND TRANSPORTATION DATA SHEET

BEST Sheet

GENERAL INFORMATION

1507

I PRODUCT IDENTIFICATION

SUPPLIER NL BAROID/NL INDUSTRIES, INC.	REGULAR TELEPHONE NO. EMERGENCY TELEPHONE NO. 713/527-1447
ADDRESS P.O. BOX 1675 HOUSTON, TEXAS 77001	
TRADE NAME NATIONAL® Standard Bentonite	
GENERIC DESCRIPTION WYOMING BENTONITE, SODIUM MONTMORILLONITE	

II HAZARDOUS INGREDIENTS

MATERIAL OR COMPONENT	%	HAZARD DATA
NONE		

III PHYSICAL DATA

BOILING POINT (°F) NA	MELTING POINT ND	FREEZING POINT ND
SPECIFIC GRAVITY (H_2O = 1) 2.5	VAPOR PRESSURE (mm Hg) NA	
VAPOR DENSITY (AIR = 1) NA	SOLUBILITY IN H_2O, % BY WT. NA	
% VOLATILES BY VOL. NA	EVAPORATION RATE (BUTYL ACETATE = 1) NA	
APPEARANCE AND ODOR LIGHT TAN TO GRAY POWDER, NO ODOR	Density @ 20° C: 47 lbs/cubic foot	
pH NA		

N/A = Not Applicable N/D = Not Determined

0 HEALTH HAZARD

0 FLAMMABILITY

0 REACTIVITY

All information recommendations and suggestions appearing herein concerning our product are based upon tests and data believed to be reliable however it is the user's responsibility to determine the safety, toxicity, and suitability for his own use of the product described herein. Since the actual use by others is beyond our control no guarantee expressed or implied is made by NL Baroid/NL Industries Inc. as to the effects of such use, the results to be obtained or the safety and toxicity of the product nor does NL Baroid/NL Industries Inc. assume any liability arising out of use by others of the product referred to herein. Nor is the information herein to be construed as absolutely complete since additional information may be necessary or desirable when particular or exceptional conditions or circumstances exist or because of applicable laws or government regulations.

IV FIRE AND EXPLOSION DATA

NATIONAL® Standard Bentonite is not flammable and not explosive. Does not support combustion. Extinguishing media: Water.

V HEALTH HAZARD INFORMATION

ACUTE ORAL LD_{50}	ACUTE DERMAL LD_{50}	AQUATIC TOXICITY (LC_{50})
		10,000 mg/l

ROUTES OF EXPOSURE AND EFFECTS

NON TOXIC NUISANCE DUST TLV 2 mg/m³

IRRITANT; EYES, NOSE, THROAT, LUNGS

BENTONITE CONTAINS SMALL AMOUNTS OF FREE SILICA.

PROLONGED INHALATION MAY CAUSE LUNG INJURY, OR DISEASE.

TYPICAL ANALYSIS OF HEAVY METALS

As	1.5 ppm
Cd	0.25 ppm
Cr	1.0 ppm
Co	1.8 ppm
Pb	21 ppm
Hg	0.04 ppm
Ni	< 1.0 ppm

EMERGENCY AND FIRST AID PROCEDURES

NORMAL HYGIENE

APPENDIX B

APPENDIX B.1

RESULTS OF PARTICLE SIZE ANALYSES

COL. 1 50/50% TAILS/ BENTONITE

DIAM (mm)	% FINER
0.8500	100.00
0.6000	99.95
0.4250	99.65
0.2500	95.00
0.1800	85.75
0.1500	78.80
0.0750	55.40
0.0450	36.80
0.0235	30.50
0.0107	27.80
0.0062	24.30
0.0044	20.50
0.0017	18.60
0.0009	10.00

COL. 2 FINE-GRAINED SOIL

DIAM (mm)	% FINER
3	100.00
1.5	99.50
1.1800	98.83
0.4250	84.18
0.2500	68.74
0.0640	45.90
0.0330	41.90
0.0170	37.50
0.0087	31.50
0.0044	24.20
0.002	13.90
0.001	8.00
0.0001	5.00

COL. 3 95/5% TAILS/ BENTONITE

DIAM (mm)	% FINER
0.8500	100.00
0.6000	99.91
0.4250	99.34
0.2500	90.50
0.1800	74.73
0.1500	63.50
0.0750	32.72
0.0450	23.39
0.0235	17.50
0.0107	14.80
0.0062	11.30
0.0044	10.50
0.0017	8.60
0.0009	6.50

COL. 4 100% TAILS

DIAM (mm)	% FINER
0.8500	100.00
0.6000	99.90
0.4250	99.30
0.2500	90.00
0.1800	73.50
0.1500	61.80
0.1060	40.90
0.0750	30.20
0.0450	21.90
0.0235	15.50
0.0107	12.80
0.0062	9.30
0.0044	8.50
0.0017	6.60
0.0009	4.50

APPENDIX B.2

HANGING COLUMN RESULTS

SAMPLE #	I. D.	TENS.	VOL. CHG.	THETA
H12	#1,0-5	0.0	0.00	36.53
		22.5	1.70	34.83
		44.1	6.20	28.63
		63.0	10.20	18.43
		119.5	7.20	11.23
		191.5	2.70	8.53
		83.5	-2.7	11.23
		40	-5.3	16.53
		0.5	-15.6	32.13
B1	#1,5-10	0.0	0.00	39.705
		28.0	2.60	37.105
		41.5	5.70	31.405
		64.5	7.15	24.255
		120.0	8.30	15.955
		193.0	3.50	12.455
		85.7	-1.9	14.355
		38	-5.8	20.155
		0.3	-18	38.155
H2	#1,10-15	0.0	0.00	40.05
		27.5	2.00	38.05
		41.5	3.40	34.65
		70.0	6.10	28.55
		120.0	11.50	17.05
		196.0	2.80	14.25
		94	-2	16.25
		39.8	-6.6	22.85
		0.5	-13.2	36.05

SAMPLE #	I. D.	TENS.	VOL. CHG.	THETA
2C	#2-rpk	0	0	46.53
		28.5	1.69	44.84
		50	4.01	40.83
		78	4.4	36.43
		129	3.5	32.93
		180	1.8	31.13
		200	0.7	30.43
		81	-3.4	33.83
		45	-3.95	37.78
		1	-8.05	45.83
14D	#3-rpk	0	0	34.6
		32	0	34.6
		50	2.75	31.85
		74.5	6.65	25.2
		123.5	4.9	20.3
		175	2.4	17.9
		200	0.8	17.1
		81	-2.6	19.7
		50	-3.9	23.6
		0.1	-8.3	31.9
6B	#4-rpk	0	0	34.27
		29.8	0	34.27
		51.5	4.3	29.97
		73.5	8	21.97
		119.5	5.1	16.87
		176	2.6	14.27
		200	0.9	13.37
		87	-3.6	16.97
		51.5	-5.2	22.17
		3.5	-7.7	29.87

APPENDIX B.3

SATURATED HYDRAULIC CONDUCTIVITY RESULTS (cm/s)

COLUMN #2 REPACKED SAMPLE
(fine-textured soil)

TRIAL #	K sat (corrected)
1	5.91E-06
2	7.65E-06
3	8.41E-06
4	4.67E-06
5	9.50E-06
6	5.46E-06
7	6.65E-06
8	7.66E-06
9	6.86E-06
ave:	6.97E-06

*NOTE: apparatus began to leak and distort results beyond trial #9

COLUMN #4 REPACKED SAMPLE
(100% tailings)

TRIAL #	K sat (corrected)
1	2.00E-03
2	1.77E-03
3	1.93E-03
4	1.67E-03
5	1.75E-03
6	1.54E-03
7	1.66E-03
8	1.67E-03
9	1.65E-03
10	1.60E-03
11	1.64E-03
12	1.70E-03
13	1.73E-03
14	1.68E-03
15	1.55E-03
16	1.57E-03
17	1.49E-03
18	1.16E-03
ave:	1.65E-03

COLUMN #3 REPACKED SAMPLE
(5% clay/ 95% tailings)

TRIAL #	K sat (corrected)
1	1.37E-03
2	1.35E-03
3	1.26E-03
4	1.29E-03
5	1.34E-03
6	1.27E-03
7	1.26E-03
8	1.08E-03
9	1.19E-03
10	1.06E-03
11	1.04E-03
12	1.65E-03
13	1.28E-03
14	1.64E-03
15	2.20E-03
16	1.32E-03
17	1.56E-03
18	1.66E-03
19	1.19E-03
20	1.84E-03
21	1.32E-03
22	1.26E-03
23	6.80E-04
24	9.20E-04
25	7.35E-04
26	1.02E-03
27	1.01E-03
28	1.05E-03
29	1.04E-03
30	1.07E-03
31	1.05E-03
32	9.89E-04
33	1.00E-03
ave:	1.24E-03

APPENDIX B.4

INPUT FILES FOR VAN GENUCHTEN CODE:

```
COLUMN #2
FINE-TEXTURED SOIL
REPACKED SAMPLE
2,2,20,.001,.20,.4653,.000007
.017,2.0
ALPHA,WCR,N
0,.4653
28.5,.4484
50,.4083
78,.3643
129,.3293
180,.3113
200,.3043
```

```
COLUMN #3
95/5 TAILS/BENTONITE
REPACKED SAMPLE
2,2,20,.001,.12,.346,.00124
.013,2.5
ALPHA,WCR,N
0,.346
32,.346
50,.3185
74.5,.252
123.5,.203
175,.179
200,.171
```

```
COLUMN #4
100% TAILS
REPACKED SAMPLE
2,2,20,.001,.05,.3427,.00165
.014,2.0
ALPHA,WCR,N
0,.3427
29.8,.3427
51.5,.2997
73.5,.2197
119.5,.1687
176,.1427
200,.1337
```

```
1          ********************************************************************************
           *                                                                                *
           *         NON-LINEAR LEAST SQUARES ANALYSIS                                      *
           *                                                                                *
           *COLUMN #2                                                                       *
           *FINE-TEXTURED SOIL                                                              *
           *REPACKED SAMPLE                                                                 *
           *                                                                                *
           **********************************************************************************


           INPUT PARAMETERS
           ================
           MODEL NUMBER.....................................  2
           NUMBER OF COEFFICIENTS...........................  2
           MAXIMUM NUMBER OF ITERATIONS..................... 20
           RATIO OF COEFFICIENTS CRITERION...............    0.0010
           RESIDUAL MOISTURE CONTENT (FOR MODEL 2).......    0.2000
           SATURATED MOISTURE CONTENT....................    0.4653
           SATURATED HYDRAULIC CONDUCTIVITY..............    0.0000


           OBSERVED DATA
           =============
           OBS. NO.    PRESSURE HEAD  MOISTURE CONTENT
               1             0.00          0.4653
               2            28.50          0.4484
               3            50.00          0.4083
               4            78.00          0.3643
               5           129.00          0.3293
               6           180.00          0.3113
               7           200.00          0.3043
1          ITERATION NO        WCR        ALPHA          N             SSQ        MODEL
                0            0.2000     0.017000      2.0000        0.0022229      2
                1            0.2000     0.017169      1.7202        0.0002936      2
                2            0.2000     0.017382      1.7430        0.0002442      2
                3            0.2000     0.017353      1.7449        0.0002442      2
                4            0.2000     0.017355      1.7448        0.0002442      2


           CORRELATION MATRIX
           ==================
                   1          2
             1   1.0000
             2  -0.9083     1.0000


           NON-LINEAR LEAST-SQUARES ANALYSIS: FINAL RESULTS
           ================================================
                                                                95% CONFIDENCE LIMITS
           VARIABLE        VALUE       S.E.COEFF.   T-VALUE      LOWER          UPPER
             ALPHA,       0.01736        0.0017     10.07       0.0129         0.0218
             N            1.74476        0.0775     22.50       1.5454         1.9441


          --------ORDERED BY COMPUTER INPUT--------       ----------ORDERED BY RESIDUALS----------
                          MOISTURE CONTENT   RESI-                           MOISTURE CONTENT   RESI-
          NO   PRESSURE     OBS    FITTED    DUAL         NO   PRESSURE     OBS    FITTED    DUAL
           1       0.00   0.4653   0.4653   0.0000         2     28.50    0.4484   0.4378   0.0107
           2      28.50   0.4484   0.4378   0.0107         7    200.00    0.3043   0.3003   0.0040
           3      50.00   0.4083   0.4074   0.0009         6    180.00    0.3113   0.3075   0.0038
           4      78.00   0.3643   0.3737  -0.0094         3     50.00    0.4083   0.4074   0.0009
           5     129.00   0.3293   0.3326  -0.0033         1      0.00    0.4653   0.4653   0.0000
           6     180.00   0.3113   0.3075   0.0038         5    129.00    0.3293   0.3326  -0.0033
           7     200.00   0.3043   0.3003   0.0040         4     78.00    0.3643   0.3737  -0.0094
1          PRESSURE    LOG P      WC       REL K     LOG RK      ABS K    LOG KA     DIFFUS     LOG D     SWC
           0.000e+00            0.4653    0.100e+01            0.700e-05
           0.141e+01   0.150    0.4651    0.877e+00  -0.057    0.614e-05  -5.212    0.284e-01  -1.546 0.216e-03
           0.168e+01   0.225    0.4651    0.861e+00  -0.065    0.603e-05  -5.220    0.245e-01  -1.610 0.246e-03
           0.200e+01   0.300    0.4650    0.843e+00  -0.074    0.590e-05  -5.229    0.211e-01  -1.675 0.279e-03
           0.237e+01   0.375    0.4649    0.822e+00  -0.085    0.576e-05  -5.240    0.182e-01  -1.741 0.317e-03
           0.282e+01   0.450    0.4647    0.799e+00  -0.097    0.560e-05  -5.252    0.156e-01  -1.808 0.360e-03
           0.335e+01   0.525    0.4645    0.774e+00  -0.111    0.542e-05  -5.266    0.133e-01  -1.877 0.408e-03
           0.398e+01   0.600    0.4642    0.745e+00  -0.128    0.521e-05  -5.283    0.113e-01  -1.948 0.462e-03
           0.473e+01   0.675    0.4639    0.713e+00  -0.147    0.499e-05  -5.302    0.953e-02  -2.021 0.523e-03
           0.562e+01   0.750    0.4634    0.677e+00  -0.169    0.474e-05  -5.324    0.802e-02  -2.096 0.591e-03
```

0.668e+01	0.825	0.4627	0.638e+00	-0.195	0.447e-05	-5.350	0.670e-		
0.794e+01	0.900	0.4618	0.596e+00	-0.225	0.417e-05	-5.380	0.556e-02	-2.255	0.750e-03
0.944e+01	0.975	0.4606	0.550e+00	-0.260	0.385e-05	-5.415	0.458e-02	-2.339	0.840e-03
0.112e+02	1.050	0.4590	0.500e+00	-0.301	0.350e-05	-5.456	0.374e-02	-2.427	0.936e-03
0.133e+02	1.125	0.4569	0.448e+00	-0.349	0.313e-05	-5.504	0.302e-02	-2.519	0.104e-02
0.158e+02	1.200	0.4542	0.393e+00	-0.406	0.275e-05	-5.561	0.242e-02	-2.616	0.114e-02
0.188e+02	1.275	0.4507	0.337e+00	-0.472	0.236e-05	-5.627	0.191e-02	-2.718	0.123e-02
0.224e+02	1.350	0.4461	0.282e+00	-0.550	0.197e-05	-5.704	0.150e-02	-2.825	0.132e-02
0.266e+02	1.425	0.4404	0.229e+00	-0.640	0.160e-05	-5.795	0.115e-02	-2.937	0.139e-02
0.316e+02	1.500	0.4333	0.179e+00	-0.746	0.126e-05	-5.901	0.880e-03	-3.056	0.143e-02
0.376e+02	1.575	0.4248	0.136e+00	-0.868	0.949e-06	-6.023	0.662e-03	-3.179	0.143e-02
0.447e+02	1.650	0.4147	0.982e-01	-1.008	0.688e-06	-6.163	0.492e-03	-3.308	0.140e-02
0.531e+02	1.725	0.4032	0.683e-01	-1.166	0.478e-06	-6.321	0.361e-03	-3.443	0.132e-02
0.631e+02	1.800	0.3905	0.454e-01	-1.342	0.318e-06	-6.497	0.262e-03	-3.581	0.121e-02
0.750e+02	1.875	0.3769	0.290e-01	-1.537	0.203e-06	-6.692	0.189e-03	-3.724	0.108e-02
0.891e+02	1.950	0.3628	0.179e-01	-1.748	0.125e-06	-6.903	0.135e-03	-3.870	0.927e-03
0.106e+03	2.025	0.3485	0.106e-01	-1.975	0.742e-07	-7.130	0.956e-04	-4.019	0.776e-03
0.126e+03	2.100	0.3345	0.611e-02	-2.214	0.428e-07	-7.369	0.675e-04	-4.171	0.634e-03
0.150e+03	2.175	0.3211	0.343e-02	-2.464	0.240e-07	-7.619	0.474e-04	-4.324	0.507e-03
0.178e+03	2.250	0.3084	0.189e-02	-2.723	0.132e-07	-7.878	0.332e-04	-4.478	0.398e-03
0.211e+03	2.325	0.2966	0.102e-02	-2.990	0.717e-08	-8.145	0.232e-04	-4.634	0.309e-03
0.251e+03	2.400	0.2859	0.548e-03	-3.262	0.383e-08	-8.416	0.162e-04	-4.790	0.236e-03
0.299e+03	2.475	0.2761	0.290e-03	-3.538	0.203e-08	-8.693	0.113e-04	-4.947	0.180e-03
0.355e+03	2.550	0.2673	0.152e-03	-3.817	0.107e-08	-8.972	0.786e-05	-5.105	0.136e-03
0.422e+03	2.625	0.2595	0.795e-04	-4.099	0.557e-09	-9.254	0.546e-05	-5.262	0.102e-03
0.501e+03	2.700	0.2525	0.414e-04	-4.383	0.289e-09	-9.538	0.380e-05	-5.420	0.762e-04
0.596e+03	2.775	0.2463	0.214e-04	-4.669	0.150e-09	-9.824	0.264e-05	-5.579	0.569e-04
0.708e+03	2.850	0.2407	0.111e-04	-4.955	0.776e-10	-10.110	0.183e-05	-5.737	0.423e-04
0.841e+03	2.925	0.2359	0.572e-05	-5.243	0.400e-10	-10.398	0.127e-05	-5.896	0.315e-04
0.100e+04	3.000	0.2316	0.295e-05	-5.531	0.206e-10	-10.686	0.883e-06	-6.054	0.234e-04
0.119e+04	3.075	0.2278	0.152e-05	-5.819	0.106e-10	-10.974	0.613e-06	-6.213	0.173e-04
0.141e+04	3.150	0.2244	0.780e-06	-6.108	0.546e-11	-11.263	0.425e-06	-6.371	0.128e-04
0.168e+04	3.225	0.2215	0.401e-06	-6.397	0.281e-11	-11.552	0.295e-06	-6.530	0.952e-05
0.200e+04	3.300	0.2189	0.206e-06	-6.686	0.144e-11	-11.841	0.205e-06	-6.689	0.705e-05
0.237e+04	3.375	0.2166	0.106e-06	-6.975	0.741e-12	-12.130	0.142e-06	-6.847	0.522e-05
0.282e+04	3.450	0.2146	0.544e-07	-7.265	0.380e-12	-12.420	0.985e-07	-7.007	0.386e-05
0.335e+04	3.525	0.2129	0.279e-07	-7.554	0.195e-12	-12.709	0.683e-07	-7.165	0.286e-05
0.398e+04	3.600	0.2113	0.143e-07	-7.844	0.100e-12	-12.998	0.474e-07	-7.324	0.212e-05
0.473e+04	3.675	0.2100	0.736e-08	-8.133	0.515e-13	-13.288	0.329e-07	-7.483	0.157e-05
0.562e+04	3.750	0.2088	0.378e-08	-8.423	0.265e-13	-13.577	0.228e-07	-7.641	0.116e-05
0.668e+04	3.825	0.2077	0.194e-08	-8.712	0.136e-13	-13.867	0.158e-07	-7.800	0.857e-06
0.794e+04	3.900	0.2068	0.996e-09	-9.002	0.697e-14	-14.157	0.110e-07	-7.959	0.634e-06
0.944e+04	3.975	0.2060	0.511e-09	-9.291	0.358e-14	-14.446	0.763e-08	-8.118	0.469e-06
0.112e+05	4.050	0.2052	0.262e-09	-9.581	0.184e-14	-14.736	0.529e-08	-8.277	0.347e-06
0.133e+05	4.125	0.2046	0.135e-09	-9.871	0.943e-15	-15.025	0.367e-08	-8.435	0.257e-06
0.158e+05	4.200	0.2040	0.692e-10	-10.160	0.484e-15	-15.315	0.255e-08	-8.594	0.190e-06
0.188e+05	4.275	0.2036	0.355e-10	-10.450	0.248e-15	-15.605	0.177e-08	-8.753	0.141e-06
0.224e+05	4.350	0.2031	0.182e-10	-10.739	0.128e-15	-15.894	0.123e-08	-8.912	0.104e-06
0.266e+05	4.425	0.2028	0.935e-11	-11.029	0.655e-16	-16.184	0.850e-09	-9.070	0.770e-07
0.316e+05	4.500	0.2024	0.480e-11	-11.319	0.336e-16	-16.474	0.590e-09	-9.229	0.570e-07
0.376e+05	4.575	0.2021	0.246e-11	-11.608	0.172e-16	-16.763	0.409e-09	-9.388	0.421e-07
0.447e+05	4.650	0.2019	0.126e-11	-11.898	0.885e-17	-17.053	0.284e-09	-9.547	0.312e-07
0.531e+05	4.725	0.2016	0.649e-12	-12.188	0.454e-17	-17.342	0.197e-09	-9.706	0.231e-07
0.631e+05	4.800	0.2014	0.333e-12	-12.477	0.233e-17	-17.632	0.137e-09	-9.864	0.171e-07
0.750e+05	4.875	0.2013	0.171e-12	-12.767	0.120e-17	-17.922	0.948e-10	-10.023	0.126e-07
0.891e+05	4.950	0.2011	0.878e-13	-13.057	0.615e-18	-18.211	0.658e-10	-10.182	0.934e-08
0.106e+06	5.025	0.2010	0.451e-13	-13.346	0.315e-18	-18.501	0.456e-10	-10.341	0.691e-08
0.126e+06	5.100	0.2009	0.231e-13	-13.636	0.162e-18	-18.791	0.317e-10	-10.499	0.511e-08
0.150e+06	5.175	0.2008	0.119e-13	-13.925	0.831e-19	-19.080	0.220e-10	-10.658	0.378e-08
0.178e+06	5.250	0.2007	0.609e-14	-14.215	0.427e-19	-19.370	0.152e-10	-10.817	0.280e-08
0.211e+06	5.325	0.2006	0.313e-14	-14.505	0.219e-19	-19.660	0.106e-10	-10.976	0.207e-08
0.251e+06	5.400	0.2005	0.161e-14	-14.794	0.112e-19	-19.949	0.734e-11	-11.135	0.153e-08
0.298e+06	5.475	0.2005	0.824e-15	-15.084	0.577e-20	-20.239	0.509e-11	-11.293	0.113e-08
0.355e+06	5.550	0.2004	0.423e-15	-15.374	0.296e-20	-20.529	0.353e-11	-11.452	0.839e-09
0.422e+06	5.625	0.2004	0.217e-15	-15.663	0.152e-20	-20.818	0.245e-11	-11.611	0.621e-09
0.501e+06	5.700	0.2003	0.111e-15	-15.953	0.780e-21	-21.108	0.170e-11	-11.770	0.459e-09

```
1          ********************************************************************************
           *                                                                                *
           *         NON-LINEAR LEAST SQUARES ANALYSIS                                      *
           *                                                                                *
           *COLUMN #3                                                                       *
           *95/5 TAILS/BENTONITE                                                            *
           *REPACKED SAMPLE                                                                 *
           *                                                                                *
           **********************************************************************************


           INPUT PARAMETERS
           ================
           MODEL NUMBER....................................  2
           NUMBER OF COEFFICIENTS..........................  2
           MAXIMUM NUMBER OF ITERATIONS.................... 20
           RATIO OF COEFFICIENTS CRITERION...............   0.0010
           RESIDUAL MOISTURE CONTENT (FOR MODEL 2).......   0.1200
           SATURATED MOISTURE CONTENT....................   0.3460
           SATURATED HYDRAULIC CONDUCTIVITY..............   0.0012


           OBSERVED DATA
           =============
           OBS. NO.    PRESSURE HEAD  MOISTURE CONTENT
               1            0.00          0.3460
               2           32.00          0.3460
               3           50.00          0.3185
               4           74.50          0.2520
               5          123.50          0.2030
               6          175.00          0.1790
               7          200.00          0.1710
1          ITERATION NO        WCR       ALPHA          N           SSQ          MODEL
                0            0.1200    0.013000     2.5000      0.0008407        2
                1            0.1200    0.013455     2.5901      0.0006464        2
                2            0.1200    0.013405     2.6124      0.0006451        2
                3            0.1200    0.013418     2.6111      0.0006450        2


           CORRELATION MATRIX
           ==================
                  1          2
             1   1.0000
             2  -0.7510     1.0000


           NON-LINEAR LEAST-SQUARES ANALYSIS: FINAL RESULTS
           ================================================
                                                                95% CONFIDENCE LIMITS
           VARIABLE        VALUE        S.E.COEFF.   T-VALUE     LOWER          UPPER
             ALPHA,       0.01342         0.0011      12.14      0.0106         0.0163
             N            2.61106         0.2310      11.30      2.0172         3.2049


          --------ORDERED BY COMPUTER INPUT--------      ----------ORDERED BY RESIDUALS----------
                          MOISTURE CONTENT   RESI-                            MOISTURE CONTENT   RESI-
          NO    PRESSURE    OBS     FITTED    DUAL           NO   PRESSURE     OBS     FITTED    DUAL
           1      0.00    0.3460   0.3460   0.0000           2      32.00    0.3460   0.3319   0.0141
           2     32.00    0.3460   0.3319   0.0141           3      50.00    0.3185   0.3076   0.0109
           3     50.00    0.3185   0.3076   0.0109           7     200.00    0.1710   0.1640   0.0070
           4     74.50    0.2520   0.2674  -0.0154           6     175.00    0.1790   0.1736   0.0054
           5    123.50    0.2030   0.2065  -0.0035           1       0.00    0.3460   0.3460   0.0000
           6    175.00    0.1790   0.1736   0.0054           5     123.50    0.2030   0.2065  -0.0035
           7    200.00    0.1710   0.1640   0.0070           4      74.50    0.2520   0.2674  -0.0154
1          PRESSURE     LOG P       WC        REL K      LOG RK      ABS K     LOG KA     DIFFUS      LOG D      SWC
           0.000e+00             0.3460    0.100e+01             0.124e-02
           0.141e+01    0.150    0.3460    0.997e+00   -0.001    0.124e-02   -2.908    0.151e+03   2.178 0.821e-05
           0.168e+01    0.225    0.3460    0.996e+00   -0.002    0.123e-02   -2.909    0.114e+03   2.057 0.108e-04
           0.200e+01    0.300    0.3460    0.994e+00   -0.003    0.123e-02   -2.909    0.861e+02   1.935 0.143e-04
           0.237e+01    0.375    0.3460    0.992e+00   -0.003    0.123e-02   -2.910    0.651e+02   1.814 0.189e-04
           0.282e+01    0.450    0.3460    0.990e+00   -0.004    0.123e-02   -2.911    0.492e+02   1.692 0.250e-04
           0.335e+01    0.525    0.3460    0.986e+00   -0.006    0.122e-02   -2.913    0.371e+02   1.569 0.330e-04
           0.398e+01    0.600    0.3459    0.982e+00   -0.008    0.122e-02   -2.914    0.280e+02   1.447 0.435e-04
           0.473e+01    0.675    0.3459    0.976e+00   -0.010    0.121e-02   -2.917    0.211e+02   1.324 0.575e-04
           0.562e+01    0.750    0.3458    0.969e+00   -0.014    0.120e-02   -2.920    0.158e+02   1.200 0.758e-04
           0.668e+01    0.825    0.3457    0.959e+00   -0.018    0.119e-02   -2.925    0.119e+02   1.075 0.100e-03
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0.794e+01    0.900    0.3456    0.946e+00  -0.024    0.117e-02  -2.931    0.889e+
0.944e+01    0.975    0.3454    0.929e+00  -0.032    0.115e-02  -2.939    0.662e+01    0.821 0.174e-03
0.112e+02    1.050    0.3450    0.906e+00  -0.043    0.112e-02  -2.949    0.491e+01    0.691 0.229e-03
0.133e+02    1.125    0.3445    0.877e+00  -0.057    0.109e-02  -2.964    0.362e+01    0.559 0.300e-03
0.158e+02    1.200    0.3436    0.839e+00  -0.076    0.104e-02  -2.983    0.265e+01    0.424 0.392e-03
0.188e+02    1.275    0.3422    0.790e+00  -0.102    0.980e-03  -3.009    0.192e+01    0.284 0.510e-03
0.224e+02    1.350    0.3402    0.729e+00  -0.137    0.905e-03  -3.044    0.138e+01    0.139 0.657e-03
0.266e+02    1.425    0.3370    0.655e+00  -0.184    0.812e-03  -3.091    0.971e+00   -0.013 0.836e-03
0.316e+02    1.500    0.3323    0.566e+00  -0.247    0.701e-03  -3.154    0.673e+00   -0.172 0.104e-02
0.376e+02    1.575    0.3254    0.465e+00  -0.333    0.577e-03  -3.239    0.457e+00   -0.340 0.126e-02
0.447e+02    1.650    0.3157    0.358e+00  -0.446    0.444e-03  -3.352    0.302e+00   -0.519 0.147e-02
0.531e+02    1.725    0.3026    0.255e+00  -0.594    0.316e-03  -3.501    0.195e+00   -0.710 0.162e-02
0.631e+02    1.800    0.2861    0.164e+00  -0.784    0.204e-03  -3.690    0.122e+00   -0.912 0.167e-02
0.750e+02    1.875    0.2666    0.957e-01  -1.019    0.119e-03  -3.925    0.748e-01   -1.126 0.159e-02
0.891e+02    1.950    0.2455    0.501e-01  -1.300    0.622e-04  -4.206    0.446e-01   -1.351 0.139e-02
0.106e+03    2.025    0.2243    0.238e-01  -1.623    0.295e-04  -4.530    0.261e-01   -1.584 0.113e-02
0.126e+03    2.100    0.2044    0.104e-01  -1.982    0.129e-04  -4.889    0.150e-01   -1.824 0.862e-03
0.150e+03    2.175    0.1870    0.427e-02  -2.370    0.529e-05  -5.276    0.852e-02   -2.070 0.621e-03
0.178e+03    2.250    0.1724    0.167e-02  -2.778    0.207e-05  -5.685    0.480e-02   -2.319 0.430e-03
0.211e+03    2.325    0.1605    0.629e-03  -3.201    0.780e-06  -6.108    0.269e-02   -2.570 0.290e-03
0.251e+03    2.400    0.1511    0.232e-03  -3.634    0.288e-06  -6.541    0.150e-02   -2.823 0.192e-03
0.299e+03    2.475    0.1438    0.843e-04  -4.074    0.105e-06  -6.981    0.837e-03   -3.077 0.125e-03
0.355e+03    2.550    0.1381    0.303e-04  -4.518    0.376e-07  -7.425    0.465e-03   -3.332 0.808e-04
0.422e+03    2.625    0.1338    0.108e-04  -4.965    0.134e-07  -7.872    0.258e-03   -3.588 0.520e-04
0.501e+03    2.700    0.1304    0.384e-05  -5.415    0.477e-08  -8.322    0.143e-03   -3.845 0.333e-04
0.596e+03    2.775    0.1279    0.137e-05  -5.865    0.169e-08  -8.771    0.794e-04   -4.100 0.213e-04
0.708e+03    2.850    0.1260    0.484e-06  -6.315    0.600e-09  -9.222    0.441e-04   -4.356 0.136e-04
0.841e+03    2.925    0.1245    0.171e-06  -6.766    0.212e-09  -9.673    0.244e-04   -4.612 0.869e-05
0.100e+04    3.000    0.1234    0.606e-07  -7.218    0.751e-10 -10.124    0.136e-04   -4.868 0.554e-05
0.119e+04    3.075    0.1226    0.214e-07  -7.669    0.266e-10 -10.576    0.751e-05   -5.124 0.353e-05
0.141e+04    3.150    0.1220    0.757e-08  -8.121    0.938e-11 -11.028    0.417e-05   -5.380 0.225e-05
0.168e+04    3.225    0.1215    0.267e-08  -8.573    0.331e-11 -11.480    0.231e-05   -5.636 0.143e-05
0.200e+04    3.300    0.1211    0.944e-09  -9.025    0.117e-11 -11.932    0.128e-05   -5.893 0.914e-06
0.237e+04    3.375    0.1209    0.333e-09  -9.477    0.413e-12 -12.384    0.710e-06   -6.149 0.583e-06
0.282e+04    3.450    0.1206    0.118e-09  -9.929    0.146e-12 -12.836    0.393e-06   -6.405 0.371e-06
0.335e+04    3.525    0.1205    0.416e-10 -10.381    0.516e-13 -13.288    0.218e-06   -6.661 0.236e-06
0.398e+04    3.600    0.1204    0.147e-10 -10.833    0.182e-13 -13.740    0.121e-06   -6.918 0.151e-06
0.473e+04    3.675    0.1203    0.519e-11 -11.285    0.643e-14 -14.192    0.670e-07   -7.174 0.960e-07
0.562e+04    3.750    0.1202    0.183e-11 -11.737    0.227e-14 -14.644    0.372e-07   -7.430 0.611e-07
0.668e+04    3.825    0.1202    0.647e-12 -12.189    0.802e-15 -15.096    0.206e-07   -7.686 0.389e-07
0.794e+04    3.900    0.1201    0.228e-12 -12.641    0.283e-15 -15.548    0.114e-07   -7.943 0.248e-07
0.944e+04    3.975    0.1201    0.806e-13 -13.093    0.100e-15 -16.000    0.633e-08   -8.199 0.158e-07
0.112e+05    4.050    0.1201    0.285e-13 -13.545    0.353e-16 -16.452    0.351e-08   -8.455 0.101e-07
0.133e+05    4.125    0.1201    0.101e-13 -13.998    0.125e-16 -16.904    0.194e-08   -8.711 0.641e-08
0.158e+05    4.200    0.1200    0.355e-14 -14.450    0.440e-17 -17.356    0.108e-08   -8.967 0.409e-08
0.188e+05    4.275    0.1200    0.125e-14 -14.902    0.156e-17 -17.808    0.597e-09   -9.224 0.260e-08
0.224e+05    4.350    0.1200    0.443e-15 -15.354    0.549e-18 -18.260    0.331e-09   -9.480 0.166e-08
0.266e+05    4.425    0.1200    0.156e-15 -15.806    0.194e-18 -18.712    0.184e-09   -9.736 0.106e-08
0.316e+05    4.500    0.1200    0.552e-16 -16.258    0.685e-19 -19.164    0.102e-09   -9.992 0.673e-09
```

```
1           ******************************************************************************
            *                                                                            *
            *         NON-LINEAR LEAST SQUARES ANALYSIS                                  *
            *                                                                            *
            *COLUMN #4                                                                   *
            *100% TAILS                                                                  *
            *REPACKED SAMPLE                                                             *
            *                                                                            *
            ******************************************************************************


            INPUT PARAMETERS
            ================
            MODEL NUMBER....................................  2
            NUMBER OF COEFFICIENTS..........................  2
            MAXIMUM NUMBER OF ITERATIONS.................... 20
            RATIO OF COEFFICIENTS CRITERION..............    0.0010
            RESIDUAL MOISTURE CONTENT (FOR MODEL 2).......   0.0500
            SATURATED MOISTURE CONTENT...................    0.3427
            SATURATED HYDRAULIC CONDUCTIVITY.............    0.0017


            OBSERVED DATA
            =============
            OBS. NO.    PRESSURE HEAD  MOISTURE CONTENT
                1           0.00           0.3427
                2          29.80           0.3427
                3          51.50           0.2997
                4          73.50           0.2197
                5         119.50           0.1687
                6         176.00           0.1427
                7         200.00           0.1337
1           ITERATION NO       WCR        ALPHA          N           SSQ        MODEL
                 0            0.0500    0.014000     2.0000      0.0033456       2
                 1            0.0500    0.014103     2.2491      0.0015196       2
                 2            0.0500    0.014183     2.2854      0.0014832       2
                 3            0.0500    0.014177     2.2890      0.0014831       2
                 4            0.0500    0.014179     2.2890      0.0014831       2


            CORRELATION MATRIX
            ==================
                    1          2
              1   1.0000
              2  -0.8114     1.0000


            NON-LINEAR LEAST-SQUARES ANALYSIS: FINAL RESULTS
            ================================================
                                                             95% CONFIDENCE LIMITS
            VARIABLE        VALUE      S.E.COEFF.   T-VALUE     LOWER         UPPER
              ALPHA,       0.01418       0.0017       8.37      0.0098        0.0185
              N            2.28899       0.2344       9.77      1.6864        2.8916


           --------ORDERED BY COMPUTER INPUT--------       ----------ORDERED BY RESIDUALS----------
                          MOISTURE CONTENT   RESI-                           MOISTURE CONTENT   RESI-
           NO   PRESSURE    OBS     FITTED    DUAL           NO   PRESSURE    OBS     FITTED    DUAL
            1      0.00   0.3427   0.3427   0.0000           2     29.80   0.3427   0.3220   0.0207
            2     29.80   0.3427   0.3220   0.0207           3     51.50   0.2997   0.2841   0.0156
            3     51.50   0.2997   0.2841   0.0156           7    200.00   0.1337   0.1227   0.0110
            4     73.50   0.2197   0.2428  -0.0231           6    176.00   0.1427   0.1343   0.0084
            5    119.50   0.1687   0.1780  -0.0093           1      0.00   0.3427   0.3427   0.0000
            6    176.00   0.1427   0.1343   0.0084           5    119.50   0.1687   0.1780  -0.0093
            7    200.00   0.1337   0.1227   0.0110           4     73.50   0.2197   0.2428  -0.0231
1           PRESSURE     LOG P       WC        REL K      LOG RK     ABS K     LOG KA     DIFFUS      LOG D     SWC
            0.000e+00              0.3427   0.100e+01              0.165e-02
            0.141e+01   0.150      0.3427   0.987e+00  -0.006     0.163e-02  -2.788    0.471e+02    1.673 0.346e-04
            0.168e+01   0.225      0.3427   0.984e+00  -0.007     0.162e-02  -2.790    0.376e+02    1.575 0.432e-04
            0.200e+01   0.300      0.3427   0.980e+00  -0.009     0.162e-02  -2.791    0.299e+02    1.476 0.540e-04
            0.237e+01   0.375      0.3426   0.975e+00  -0.011     0.161e-02  -2.794    0.239e+02    1.378 0.674e-04
            0.282e+01   0.450      0.3426   0.969e+00  -0.014     0.160e-02  -2.796    0.190e+02    1.278 0.842e-04
            0.335e+01   0.525      0.3425   0.961e+00  -0.017     0.159e-02  -2.800    0.151e+02    1.178 0.105e-03
            0.398e+01   0.600      0.3425   0.951e+00  -0.022     0.157e-02  -2.804    0.120e+02    1.077 0.131e-03
            0.473e+01   0.675      0.3424   0.939e+00  -0.027     0.155e-02  -2.810    0.946e+01    0.976 0.164e-03
            0.562e+01   0.750      0.3422   0.924e+00  -0.034     0.152e-02  -2.817    0.746e+01    0.873 0.204e-03
```

```
0.668e+01   0.825   0.3420   0.905e+00  -0.043    0.149e-02  -2.826    0.586e+
0.794e+01   0.900   0.3416   0.883e+00  -0.054    0.146e-02  -2.837    0.459e+01   0.662 0.317e-03
0.944e+01   0.975   0.3411   0.854e+00  -0.068    0.141e-02  -2.851    0.358e+01   0.553 0.394e-03
0.112e+02   1.050   0.3403   0.820e+00  -0.086    0.135e-02  -2.869    0.277e+01   0.442 0.489e-03
0.133e+02   1.125   0.3391   0.778e+00  -0.109    0.128e-02  -2.892    0.212e+01   0.327 0.604e-03
0.158e+02   1.200   0.3374   0.727e+00  -0.138    0.120e-02  -2.921    0.162e+01   0.209 0.742e-03
0.188e+02   1.275   0.3350   0.667e+00  -0.176    0.110e-02  -2.958    0.122e+01   0.085 0.906e-03
0.224e+02   1.350   0.3314   0.598e+00  -0.223    0.987e-03  -3.006    0.903e+00  -0.044 0.109e-02
0.266e+02   1.425   0.3264   0.520e+00  -0.284    0.857e-03  -3.067    0.660e+00  -0.180 0.130e-02
0.316e+02   1.500   0.3193   0.434e+00  -0.362    0.716e-03  -3.145    0.475e+00  -0.324 0.151e-02
0.376e+02   1.575   0.3097   0.346e+00  -0.461    0.570e-03  -3.244    0.335e+00  -0.475 0.170e-02
0.447e+02   1.650   0.2970   0.260e+00  -0.586    0.428e-03  -3.368    0.231e+00  -0.636 0.185e-02
0.531e+02   1.725   0.2811   0.182e+00  -0.740    0.300e-03  -3.522    0.156e+00  -0.806 0.192e-02
0.631e+02   1.800   0.2619   0.118e+00  -0.927    0.195e-03  -3.709    0.103e+00  -0.986 0.189e-02
0.750e+02   1.875   0.2402   0.710e-01  -1.148    0.117e-03  -3.931    0.670e-01  -1.174 0.175e-02
0.891e+02   1.950   0.2170   0.395e-01  -1.404    0.651e-04  -4.186    0.427e-01  -1.369 0.152e-02
0.106e+03   2.025   0.1937   0.204e-01  -1.690    0.337e-04  -4.473    0.268e-01  -1.571 0.125e-02
0.126e+03   2.100   0.1715   0.993e-02  -2.003    0.164e-04  -4.785    0.167e-01  -1.778 0.983e-03
0.150e+03   2.175   0.1512   0.460e-02  -2.337    0.759e-05  -5.119    0.103e-01  -1.989 0.740e-03
0.178e+03   2.250   0.1334   0.205e-02  -2.688    0.339e-05  -5.470    0.628e-02  -2.202 0.539e-03
0.211e+03   2.325   0.1181   0.890e-03  -3.050    0.147e-05  -5.833    0.382e-02  -2.417 0.384e-03
0.251e+03   2.400   0.1053   0.378e-03  -3.422    0.624e-06  -6.205    0.232e-02  -2.634 0.269e-03
0.299e+03   2.475   0.0947   0.158e-03  -3.800    0.261e-06  -6.583    0.141e-02  -2.852 0.186e-03
0.355e+03   2.550   0.0860   0.657e-04  -4.183    0.108e-06  -6.965    0.850e-03  -3.071 0.128e-03
0.422e+03   2.625   0.0789   0.270e-04  -4.568    0.446e-07  -7.350    0.513e-03  -3.290 0.870e-04
0.501e+03   2.700   0.0732   0.111e-04  -4.955    0.183e-07  -7.738    0.310e-03  -3.509 0.591e-04
0.596e+03   2.775   0.0686   0.453e-05  -5.344    0.747e-08  -8.127    0.187e-03  -3.729 0.400e-04
0.708e+03   2.850   0.0649   0.184e-05  -5.735    0.304e-08  -8.517    0.112e-03  -3.949 0.271e-04
0.841e+03   2.925   0.0620   0.750e-06  -6.125    0.124e-08  -8.907    0.678e-04  -4.169 0.183e-04
0.100e+04   3.000   0.0596   0.305e-06  -6.515    0.504e-09  -9.298    0.409e-04  -4.389 0.123e-04
0.119e+04   3.075   0.0577   0.124e-06  -6.906    0.205e-09  -9.689    0.246e-04  -4.608 0.831e-05
0.141e+04   3.150   0.0561   0.504e-07  -7.297    0.832e-10 -10.080    0.149e-04  -4.828 0.560e-05
0.168e+04   3.225   0.0549   0.205e-07  -7.689    0.338e-10 -10.471    0.895e-05  -5.048 0.377e-05
0.200e+04   3.300   0.0539   0.831e-08  -8.080    0.137e-10 -10.863    0.540e-05  -5.268 0.254e-05
0.237e+04   3.375   0.0532   0.338e-08  -8.472    0.557e-11 -11.254    0.325e-05  -5.488 0.171e-05
0.282e+04   3.450   0.0525   0.137e-08  -8.863    0.226e-11 -11.646    0.196e-05  -5.708 0.115e-05
0.335e+04   3.525   0.0520   0.556e-09  -9.255    0.917e-12 -12.037    0.118e-05  -5.928 0.777e-06
0.398e+04   3.600   0.0516   0.226e-09  -9.647    0.372e-12 -12.429    0.711e-06  -6.148 0.523e-06
0.473e+04   3.675   0.0513   0.916e-10 -10.038    0.151e-12 -12.821    0.429e-06  -6.368 0.353e-06
0.562e+04   3.750   0.0510   0.372e-10 -10.430    0.613e-13 -13.212    0.258e-06  -6.588 0.237e-06
0.668e+04   3.825   0.0508   0.151e-10 -10.822    0.249e-13 -13.604    0.156e-06  -6.808 0.160e-06
0.794e+04   3.900   0.0507   0.612e-11 -11.213    0.101e-13 -13.996    0.938e-07  -7.028 0.108e-06
0.944e+04   3.975   0.0505   0.248e-11 -11.605    0.410e-14 -14.387    0.565e-07  -7.248 0.725e-07
0.112e+05   4.050   0.0504   0.101e-11 -11.997    0.166e-14 -14.779    0.340e-07  -7.468 0.489e-07
0.133e+05   4.125   0.0503   0.409e-12 -12.388    0.675e-15 -15.171    0.205e-07  -7.688 0.329e-07
0.158e+05   4.200   0.0503   0.166e-12 -12.780    0.274e-15 -15.562    0.124e-07  -7.908 0.222e-07
0.188e+05   4.275   0.0502   0.674e-13 -13.172    0.111e-15 -15.954    0.745e-08  -8.128 0.149e-07
0.224e+05   4.350   0.0502   0.273e-13 -13.563    0.451e-16 -16.346    0.449e-08  -8.348 0.101e-07
0.266e+05   4.425   0.0501   0.111e-13 -13.955    0.183e-16 -16.737    0.270e-08  -8.568 0.677e-08
0.316e+05   4.500   0.0501   0.450e-14 -14.347    0.743e-17 -17.129    0.163e-08  -8.788 0.456e-08
0.376e+05   4.575   0.0501   0.183e-14 -14.738    0.301e-17 -17.521    0.982e-09  -9.008 0.307e-08
0.447e+05   4.650   0.0501   0.741e-15 -15.130    0.122e-17 -17.912    0.592e-09  -9.228 0.207e-08
0.531e+05   4.725   0.0501   0.301e-15 -15.522    0.496e-18 -18.304    0.356e-09  -9.448 0.139e-08
0.631e+05   4.800   0.0501   0.122e-15 -15.913    0.201e-18 -18.696    0.215e-09  -9.668 0.938e-09
0.750e+05   4.875   0.0500   0.495e-16 -16.305    0.817e-19 -19.088    0.129e-09  -9.888 0.632e-09
```

APPENDIX B.5

```
C
C
C     ******************************************************************
C     *                                                                *
C     *       SOIL HYDRAULIC PROPERTIES:                               *
C     *       NON-LINEAR LEAST-SQUARES ANALYSIS                        *
C     *                                                                *
C     *       --------------- INPUT INFORMATION ---------------        *
C     *       CARDS 1,2,3: THREE INFORMATION CARDS                     *
C     *       CARD 4: MODEL NUMBER (MODE), NUMBER OF COEFFICIENTS (NP),*
C     *               MAXIMUM NUMBER OF ITERATIONS (MIT), RATIO OF     *
C     *               COEFFICIENTS CRITERION (STOPCR), RESIDUAL MOISTU-*
C     *               RE CONTENT (IF MODE=2) (WCR), SATURATED MOISTURE *
C     *               CONTENT (WCS), CONDUCTIVITY AT SATURATION (SATK) *
C     *               (3I10,4F10.0)                                    *
C     *       CARD 5: INITIAL ESTIMATES OF THE COEFFICIENTS (3F10.0)   *
C     *       CARD 6: NAMES OF THE COEFFICIENTS; 3(A4,A2,4X)           *
C     *       CARD 7, ETC: EXPERIMENTAL DATA: MOISTURE CONTENT AND     *
C     *               PRESSURE HEAD, RESPECTIVELY; (2F10.0)            *
C     *       LAST CARD IS BLANK                                       *
C     *                                                                *
C     *       THIS SLIGHTLY MODIFIED VERSION WILL PROMPT THE USER      *
C     *       FOR NAMES OF THE "REL. K VS PRESSURE" AND                *
C     *       "ABS. K VS PRESSURE" AND                                 *
C     *       "PRESSURE VS THETA" FILES THAT THIS PROGRAM GENERATES    *
C     *       FOR EASY PLOTTING.  RICH R.                              *
C     ******************************************************************
C             THIS VERSION OF VAN GUNUCHTEN'S CODE HAS BEEN ALTERED
C             TO PRODUCE A FILE OF THETA-PSI VALUES AND THE CORRESPONDING
C             SPECIFIC WATER CONTENT.  THE OUTPUT FILE IS CALLED WATERCON.DAT
C             THE COMMAND TO PRINT THIS FILE CAN BE FOUND ON STATEMENT
C             LABEL 555. THE OPENED FILE IS UNIT 25.  JAMES A. BEACH
C
CC      DOUBLE PRECISION FLNI, FLNO, FLNM, flnf
CC
c      character*20   FLNI, FLNO, FLNM, flnf
      character*20   flnf
      DIMENSION X(300),Y(300),R(300),F(300),DELZ(300,4),LSORT(300),
     1B(3),BI(6),E(3),P(3),PHI(3),Q(3),TB(3),A(3,3),D(3,3),
     1TITLE(20),TH(3)
C
C     ----------
      write(6,13)
   13 FORMAT(1X,'INPUT FILE NAME: ',$)
      READ(5,9)flnf
      open (unit=1,STATUS='OLD',file=flnf)
cc      TYPE 5
C      write (6,5)
C    5 FORMAT(1X, 'REL. K VS PRESSURE FILE NAME:',$)
C      READ(5,9)FLNI
    9 FORMAT(A10)
      OPEN (UNIT=21,STATUS='unknown',FILE='RELK')
C      OPEN (UNIT=21, FILE=FLNI, ACCESS='SEQOUT')
      OPEN (UNIT=24, FILE='vang.out', STATUS='unknown')
C      write (6,11)
C   11 FORMAT(1X, 'ABS. K VS PRESSURE FILE NAME: ',$)
C      READ(5,9)FLNM
cc      OPEN (UNIT=23, DEVICE='DSK', FILE=FLNM, ACCESS='SEQOUT')
C      OPEN (UNIT=23, FILE=FLNM, ACCESS='SEQOUT')
cc      TYPE 7
```

```
C        write (6,7)
C     7 FORMAT(1X,'PRESSURE VS THETA FILE NAME:',$)
C       READ(5,9)FLNO
CC        OPEN (UNIT=22, DEVICE='DSK', FILE=FLNO, ACCESS='SEQOUT')
C       OPEN (UNIT=22, FILE=FLNO, ACCESS='SEQOUT')
C       OPEN (UNIT=25, FILE='WATER.D',STATUS='NEW',
C      1      CARRIAGECONTROL='LIST')
C       WRITE(25,1076)
      WRITE(24,1000)
      DO 2 I=1,3
      READ(1,1001) TITLE
    2 write(24,1002) TITLE
      write(24,1003)
C
C     ----- READ INPUT PARAMETERS -----
      read(1,*) MODE,NP,MIT,STOPCR,WCR,WCS,SATK
      write(24,1005) MODE,NP,MIT,STOPCR,WCR,WCS,SATK
C
C     ----- READ INITIAL ESTIMATES -----
C      READ(1,1006) (B(I),I=1,NP)
      READ(1,*) (B(I),I=1,NP)
C
C     ----- READ COEFFICIENTS NAMES -----
      NBI=2*NP
      READ(1,1007) (BI(I),I=1,NBI)
C
C     ----- READ AND WRITE EXPERIMENTAL DATA -----
      write(24,1008)
      write(6,*)' read the saturation or the pressure first'
      write(6,*)'    1 = saturation    2 = pressure'
      read(5,*)ifirst
      I=0
    4 I=I+1
      if(ifirst.eq.1)then
        read(1,*,end=6)y(i),x(i)
        write(24,1011) I,X(I),Y(I)
      elseif(ifirst.eq.2)then
        READ(1,*,END=6) x(i),y(i)
        write(24,1011) I,X(I),Y(I)
      endif
        GOTO 4
C      IF(X(I).EQ.0.) GO TO 6
C      GO TO 4
    6 NOB=I-1
C
C     ----------
      DO 8 I=1,NP
    8 TH(I)=B(I)
      IF((NP-2)*(NP-3)) 12,14,12
   12 write(24,1016)
      GO TO 142
   14 GA=0.02
      CALL MODEL(TH,F,NOB,X,WCS,MODE,NP,WCR)
      SSQ=0.
      DO 32 I=1,NOB
      R(I)=Y(I)-F(I)
   32 SSQ=SSQ+R(I)*R(I)
      NIT=0
      write(24,1030)
      IF(MODE.EQ.2) write(24,1026) NIT,WCR,B(1),B(2),SSQ,MODE
```

```
      IF(MODE.NE.2) write(24,1026) NIT,B(1),B(2),B(3),SSQ,MODE
C
C     ----- BEGIN OF ITERATION -----
   34 NIT=NIT+1
      GA=0.1*GA
      DO 38 J=1,NP
      TEMP=TH(J)
      TH(J)=1.01*TH(J)
      Q(J)=0
      CALL MODEL(TH,DELZ(1,J),NOB,X,WCS,MODE,NP,WCR)
      DO 36 I=1,NOB
      DELZ(I,J)=DELZ(I,J)-F(I)
   36 Q(J)=Q(J)+DELZ(I,J)*R(I)
      Q(J)=100.*Q(J)/TH(J)
C
C     ----- STEEPEST DESCENT -----
   38 TH(J)=TEMP
      DO 44 I=1,NP
      DO 42 J=1,I
      SUM=0
      DO 40 K=1,NOB
   40 SUM=SUM+DELZ(K,I)*DELZ(K,J)
      D(I,J)=10000.*SUM/(TH(I)*TH(J))
   42 D(J,I)=D(I,J)
C
C     ----- D = MOMENT MATRIX -----
   44 E(I)=SQRT(D(I,I))
   50 DO 52 I=1,NP
      DO 52 J=1,NP
   52 A(I,J)=D(I,J)/(E(I)*E(J))
C
C     ----- A IS THE SCALED MOMENT MATRIX -----
      DO 54 I=1,NP
      P(I)=Q(I)/E(I)
      PHI(I)=P(I)
   54 A(I,I)=A(I,I)+GA
      CALL MATINV(A,NP,P)
C
C     ----- P/E IS THE CORRECTION VECTOR -----
      STEP=1.0
   56 DO 58 I=1,NP
   58 TB(I)=P(I)*STEP/E(I)+TH(I)
      DO 62 I=1,NP
      IF(TH(I)*TB(I))66,66,62
   62 CONTINUE
      SUMB=0.0
      CALL MODEL(TB,F,NOB,X,WCS,MODE,NP,WCR)
      DO 64 I=1,NOB
      R(I)=Y(I)-F(I)
   64 SUMB=SUMB+R(I)*R(I)
   66 SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      DO 68 I=1,NP
      SUM1=SUM1+P(I)*PHI(I)
      SUM2=SUM2+P(I)*P(I)
   68 SUM3=SUM3+PHI(I)*PHI(I)
      ANGLE=57.29578*ACOS(SUM1/SQRT(SUM2*SUM3))
C
C     ----------
```

```
      DO 72 I=1,NP
      IF(TH(I)*TB(I))74,74,72
   72 CONTINUE
      IF(SUMB/SSQ-1.0)80,80,74
   74 IF(ANGLE-30.0)76,76,78
   76 STEP=STEP/2.0
      GO TO 56
   78 GA=10.*GA
      GO TO 50
C
C     ----- PRINT COEFFICIENTS AFTER EACH ITERATION -----
   80 CONTINUE
      DO 82 I=1,NP
   82 TH(I)=TB(I)
      IF(MODE.EQ.2) write(24,1026) NIT,WCR,TH(1),TH(2),SUMB,MODE
      IF(MODE.NE.2) write(24,1026) NIT,TH(1),TH(2),TH(3),SUMB,MODE
      DO 92 I=1,NP
      IF(ABS(P(I)*STEP/E(I))/(1.0E-20+ABS(TH(I)))-STOPCR) 92,92,94
   92 CONTINUE
      GO TO 96
   94 SSQ=SUMB
      IF(NIT-MIT)34,34,96
C
C     ----- END OF ITERATION LOOP -----
   96 IDF=NOB-NP
      CALL MATINV(D,NP,P)
C
C     ----- WRITE CORRELATION MATRIX -----
      DO 98 I=1,NP
   98 E(I)=SQRT(D(I,I))
      write(24,1044) (I,I=1,NP)
      DO 102 I=1,NP
      DO 100 J=1,I
  100 A(J,I)=D(J,I)/(E(I)*E(J))
  102 write(24,1048) I,(A(J,I),J=1,I)
C
C     ----- CALCULATE 95% CONFIDENCE INTERVAL -----
      RMS=SUMB/FLOAT(IDF)
      SDEV=SQRT(RMS)
      write(24,1052)
      TVAR=TTEST(IDF)
      DO 108 I=1,NP
      SECOEF= E(I)*SDEV
      TVALUE= TH(I)/SECOEF
      TSEC=TVAR*SECOEF
      TMCOE=TH(I)-TSEC
      TPCOE=TH(I)+TSEC
      K=2*I
      J=K-1
  108 write(24,1058) BI(J),BI(K),TH(I),SECOEF,TVALUE,TMCOE,TPCOE
C
C     ----- PREPARE FINAL OUTPUT -----
      LSORT(1)=1
      DO 116 J=2,NOB
      TEMP=R(J)
      K=J-1
      DO 111 L=1,K
      LL=LSORT(L)
      IF(TEMP-R(LL)) 112,112,111
  111 CONTINUE
```

```
      LSORT(J)=J
      GO TO 116
  112 KK=J
  113 KK=KK-1
      LSORT(KK+1)=LSORT(KK)
      IF(KK-L) 115,115,113
  115 LSORT(L)=J
  116 CONTINUE
      write(24,1066)
      DO 118 I=1,NOB
      J=LSORT(NOB+1-I)
  118 write(24,1068) I,X(I),Y(I),F(I),R(I),J,X(J),Y(J),F(J),R(J)
C
C     ----- WRITE SOIL HYDRAULIC PROPERTIES -----
      write(24,1069)
      PRESS=1.18850
      RN1=0.0
      RKLN=1.0
      write(24,1072) RN1,WCS,RKLN,SATK
      WRITE(21,1073)RN1, RKLN
      WRITE(22,1074)WCS, RN1
      WRITE(23,1073)RN1, SATK
      DO 140 I=1,75
      IF(RKLN.LT.(-16.)) GO TO 142
      PRESS=1.18850*PRESS
      IF(MODE-2) 120,122,120
  120 WCR=TH(1)
      ALPHA=TH(2)
      RN=TH(3)
      GO TO 124
  122 ALPHA=TH(1)
      RN=TH(2)
  124 RM=1.-1./RN
      IF(MODE.EQ.3) RM=1.-2./RN
      RN1=RM*RN
      RWC=1./(1.+(ALPHA*PRESS)**RN)**RM
      WC=WCR+(WCS-WCR)*RWC
      TERM=1.-RWC*(ALPHA*PRESS)**RN1
      IF(RWC.LT.0.06) TERM=RM*RWC**(1./RM)
      IF(MODE.EQ.3) RK=RWC*RWC*TERM
      IF(MODE.NE.3) RK=SQRT(RWC)*TERM*TERM
      TERM=ALPHA*RN1*(WCS-WCR)*RWC*RWC**(1./RM)*(ALPHA*PRESS)**(RN-1.)
      AK=SATK*RK
      DIFFUS=AK/TERM
      PRLN=ALOG10(PRESS)
      AKLN=ALOG10(AK)
      RKLN=ALOG10(RK)
      DIFLN=ALOG10(DIFFUS)
      WRITE(21,1073)PRESS, RK
      WRITE(22,1074)WC, PRESS
  555 WRITE(25,1075) PRESS, TERM
      WRITE(23,1073)PRESS, AK
  140 write(24,1070) PRESS,PRLN,WC,RK,RKLN,AK,AKLN,DIFFUS,DIFLN,TERM
  142 CONTINUE
C
C     ----- END OF PROBLEM -----
 1000 FORMAT(1H1,10X,82(1H*)/11X,1H*,80X,1H*/11X,1H*, 9X,'NON-LINEAR LEA
     1ST SQUARES ANALYSIS',38X,1H*/11X,1H*,80X,1H*)
 1001 FORMAT(20A4)
 1002 FORMAT(11X,1H*,20A4,1H*)
```

```
 1003 FORMAT(11X,1H*,80X,1H*/11X,82(1H*))
C1004 FORMAT(3I10,5F10.0)
 1005 FORMAT(//11X,'INPUT PARAMETERS'/11X,16(1H=)/
     211X,'MODEL NUMBER.....................................',I3/
     311X,'NUMBER OF COEFFICIENTS...........................',I3/
     411X,'MAXIMUM NUMBER OF ITERATIONS.....................',I3/
     511X,'RATIO OF COEFFICIENTS CRITERION...............',F10.4/
     611X,'RESIDUAL MOISTURE CONTENT (FOR MODEL 2).......',F10.4/
     711X,'SATURATED MOISTURE CONTENT....................',F10.4/
     811X,'SATURATED HYDRAULIC CONDUCTIVITY..............',F10.4)
 1006 FORMAT(4F10.0)
 1007 FORMAT(4(A4,A2,4X))
 1008 FORMAT(//11X,'OBSERVED DATA',/11X,13(1H=)/11X,'OBS. NO.',4X,'PRESS
     1URE HEAD',2X,'MOISTURE CONTENT')
 1011 FORMAT(11X,I5,5X,F12.2,4X,F12.4)
 1016 FORMAT(//5X,10(1H*),' ERROR: INCORRECT NUMBER OF COEFFICIENTS')
 1026 FORMAT(15X,I2,10X,F8.4,3X,F10.6,2X,F10.4,5X,F12.7,4X,I4)
 1030 FORMAT(1H1,10X,'ITERATION NO',8X,'WCR',8X,'ALPHA',10X,'N',13X,'SSQ
     1',8X,'MODEL')
 1044 FORMAT(//11X,'CORRELATION MATRIX'/11X,18(1H=)/14X,10(4X,I2,5X))
 1048 FORMAT(11X,I3,10(2X,F7.4,2X))
 1052 FORMAT(//11X,'NON-LINEAR LEAST-SQUARES ANALYSIS: FINAL RESULTS'/
     111X,48(1H=)/64X,'95% CONFIDENCE LIMITS'/11X,'VARIABLE',8X,'VALUE',
     27X,'S.E.COEFF.',3X,'T-VALUE',6X,'LOWER',10X,'UPPER')
 1058 FORMAT(13X,A4,A2,4X,F10.5,5X,F9.4,5X,F6.2,4X,F9.4,5X,F9.4)
 1066 FORMAT(//10X,8(1H-),'ORDERED BY COMPUTER INPUT', 8(1H-), 7X,10(1H-
     1),'ORDERED BY RESIDUALS',10(1H-)/26X,'MOISTURE CONTENT',3X,'RESI-'
     1,24X,'MOISTURE CONTENT',3X,'RESI-'/10X,'NO',3X,'PRESSURE',5X,'OBS'
     2,4X,'FITTED',4X,'DUAL', 9X,'NO',3X,'PRESSURE',5X,'OBS',4X,'FITTED'
     3,4X,'DUAL')
 1068 FORMAT(10X,I2,F10.2,1X,3F9.4,8X,I2,F10.2,1X,3F9.4)
 1069 FORMAT(1H1,10X,'PRESSURE',4X,'LOG P',6X,'WC',7X,'REL K',5X,'LOG RK
     1',6X,'ABS K',4X,'LOG KA',5X,'DIFFUS',5X,'LOG D',5X,'SWC')
 1070 FORMAT(10X,E10.3,F8.3,F10.4,3(E13.3,F8.3),E10.3)
 1072 FORMAT(10X,E10.3,8X,F10.4,E13.3,8X,E13.3)
 1073 FORMAT(F10.3,E10.3)
 1074 FORMAT(F10.4,E10.3)
 1075 FORMAT(F10.3,E10.3)
C 1076 FORMAT(3X,'THETA    PSI      SP. WATER CON.',/)
      write(6,*)' output file is vang.out'
      STOP
      END
      SUBROUTINE MODEL(B,FY,NOB,X,WCS,MODE,NP,WCR)
      DIMENSION B(3),FY(40),X(40)
C
C     MODE=1 : MUALEM THEORY WITH THREE COEFFICIENTS
C     MODE=2 : MUALEM THEORY WITH TWO COEFFICIENTS
C     MODE=3 : BURDINE THEORY WITH THREE COEFFICIENTS
C
      IF(MODE-2) 10,20,30
   10 CONTINUE
      DO 12 J=1,NOB
   12 FY(J)=B(1)+(WCS-B(1))/(1.+(B(2)*X(J))**B(3))**(1.-1./B(3))
      RETURN
   20 CONTINUE
      DO 22 J=1,NOB
   22 FY(J)=WCR+(WCS-WCR)/(1.+(B(1)*X(J))**B(2))**(1.-1./B(2))
      RETURN
   30 CONTINUE
      DO 32 J=1,NOB
```

```
   32 FY(J)=B(1)+(WCS-B(1))/(1.+(B(2)*X(J))**B(3))**(1.-2./B(3))
      RETURN
      END
      FUNCTION TTEST(IDF)
      DIMENSION TA(30)
      DATA TA/12.706,4.303,3.182,2.776,2.571,2.447,2.365,2.306,2.262,
     12.228,2.201,2.179,2.160,2.145,2.131,2.120,2.110,2.101,2.093,2.086,
     22.080,2.074,2.069,2.064,2.060,2.056,2.052,2.048,2.045,2.042/
      IF(IDF-30)10,10,11
   10 TTEST=TA(IDF)
      RETURN
   11 IF(IDF-120)12,12,13
   13 TTEST=1.96
      RETURN
   12 IF(IDF-40)14,14,15
   14 TTEST=2.042-0.021*FLOAT(IDF-30)/10.0
      RETURN
   15 IF(IDF-60)16,16,17
   16 TTEST=2.021-0.021*FLOAT(IDF-40)/20.0
      RETURN
   17 TTEST=2.000-0.002*FLOAT(IDF-60)/60.0
      RETURN
      END
      SUBROUTINE MATINV(A,NP,B)
      DIMENSION A(3,3),B(3),INDEX(3,2)
      DO 2 J=1,4
    2 INDEX(J,1)=0
      I=0
    4 AMAX=-1.0
      DO 10 J=1,NP
      IF(INDEX(J,1)) 10,6,10
    6 DO 10 K=1,NP
      IF(INDEX(K,1)) 10,8,10
    8 P=ABS(A(J,K))
      IF(P.LE.AMAX) GO TO 10
      IR=J
      IC=K
      AMAX=P
   10 CONTINUE
      IF(AMAX) 30,30,14
   14 INDEX(IC,1)=IR
      IF(IR.EQ.IC) GO TO 18
      DO 16 L=1,NP
      P=A(IR,L)
      A(IR,L)=A(IC,L)
   16 A(IC,L)=P
      P=B(IR)
      B(IR)=B(IC)
      B(IC)=P
      I=I+1
      INDEX(I,2)=IC
   18 P=1./A(IC,IC)
      A(IC,IC)=1.0
      DO 20 L=1,NP
   20 A(IC,L)=A(IC,L)*P
      B(IC)=B(IC)*P
      DO 24 K=1,NP
      IF(K.EQ.IC) GO TO 24
      P=A(K,IC)
      A(K,IC)=0.0
```

```
   DO 22 L=1,NP
22 A(K,L)=A(K,L)-A(IC,L)*P
   B(K)=B(K)-B(IC)*P
24 CONTINUE
   GO TO 4
26 IC=INDEX(I,2)
   IR=INDEX(IC,1)
   DO 28 K=1,NP
   P=A(K,IR)
   A(K,IR)=A(K,IC)
28 A(K,IC)=P
   I=I-1
30 IF(I) 26,32,26
32 RETURN
   END
```

APPENDIX C

APPENDIX C.1

APPENDIX C— TENSIOMETRIC DATA

COLUMN 1

TENSIOMETER 1 31.5 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
2/18/85	1	49	−24.0	9.5	−12.1	−43.6
2/19/85	2	50	−41.0	9.5	−27.7	−59.2
2/20/85	3	51	−20.0	9.6	−8.3	−39.8
2/27/85	10	58	−42.0	9.5	−28.6	−60.1
3/1/85	12	60	−24.0	9.5	−12.1	−43.6
3/4/85	15	63				
3/7/85	18	66	−80.0	9.5	−63.5	−95.0
3/12/85	23	71	−93.0	9.4	−75.5	−107.0
3/19/85	30	78	−83.0	9.3	−66.5	−98.0
3/23/85	34	82	−42.0	9.3	−28.8	−60.3
3/25/85	36	84	−50.0	9.3	−36.2	−67.7
3/29/85	40	88	−123.0	9.3	−103.2	−134.7
4/1/85	43	91				
4/19/85	61	109	−30.0	8.8	−18.4	−49.9
4/22/85	64	112	−13.0	8.8	−2.7	−34.2
4/25/85	67	115	−64.0	8.5	−49.9	−81.4
4/29/85	71	119	−101.0	8.5	−83.8	−115.3
5/2/85	74	122	−62.0	8.5	−48.0	−79.5
5/6/85	78	126	−65.0	7.3	−52.1	−83.6
5/10/85	82	130	−160.0	9.8	−136.6	−168.1
5/13/85	85	133	−66.0	9.8	−50.3	−81.8
5/16/85	88	136	−127.0	9.5	−106.6	−138.1
5/20/85	92	140	−161.0	9.5	−137.8	−169.3
5/24/85	96	144	−100.0	9.4	−82.0	−113.5
5/28/85	100	148	−105.0	9.0	−87.0	−118.5
5/30/85	102	150	−218.0	8.8	−190.9	−222.4
6/2/85	105	153	−193.0	8.5	−168.3	−199.8
6/6/85	109	157	−173.0	8.4	−150.0	−181.5
6/10/85	113	161	−197.0	8.0	−172.4	−203.9
6/13/85	116	164	−186.0	7.9	−162.5	−194.0
6/21/85	124	172	−148.0	9.6	−125.8	−157.3
6/24/85	127	175	−157.0	9.6	−134.1	−165.6
6/28/85	131	179	−189.0	9.5	−163.5	−195.0
7/1/85	134	182	−197.0	9.3	−171.1	−202.6
7/3/85	136	184	−201.0	9.2	−174.9	−206.4
7/8/85	141	189	−183.0	8.0	−159.6	−191.1
7/11/85	144	192	−140.0	7.5	−120.7	−152.2
7/15/85	148	196				
7/18/85	151	199				
7/23/85	156	204	−117.0	9.2	−97.8	−129.3
7/25/85	158	206				
7/30/85	163	211	−184.0	9.3	−159.2	−190.7
8/1/85	165	213				
8/5/85	169	217	−133.0	8.6	−113.1	−144.6
8/8/85	172	220	−156.0	8.2	−134.6	−166.1
8/9/85	173	221	−89.0	7.5	−73.8	−105.3
8/13/85	177	225	−135.0	8.8	−114.7	−146.2
8/19/85	183	231	−210.0	9.7	−182.6	−214.1
8/22/85	186	234	−189.0	9.7	−163.3	−194.8
8/26/85	190	238	−200.0	9.7	−173.4	−204.9
8/29/85	193	241	−172.0	9.6	−147.8	−179.3
9/2/85	197	245	−226.0	9.5	−197.5	−229.0

APPENDIX C- TENSIOMETRIC DATA

COLUMN 1

TENSIOMETER 1 31.5 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
9/5/85	200	248	-188.0	9.5	-162.6	-194.1
9/9/85	204	252	-225.0	9.5	-196.6	-228.1
9/12/85	207	255	-218.0	9.5	-190.2	-221.7
9/17/85	212	260	-212.0	9.4	-184.8	-216.3
9/19/85	214	262	-246.0	9.4	-216.0	-247.5
9/23/85	218	266	-238.0	9.3	-208.7	-240.2
9/30/85	225	273	-251.0	8.1	-221.9	-253.4
10/7/85	232	280	-211.0	8.3	-185.0	-216.5
10/14/85	239	287	-228.0	9.3	-199.5	-231.0
10/17/85	242	290	-215.0	9.3	-187.6	-219.1
10/21/85	246	294	-195.0	9.0	-169.6	-201.1
10/29/85	254	302	-208.0	9.0	-181.5	-213.0
11/6/85	262	310	-191.0	8.3	-166.6	-198.1
11/13/85	269	317	-223.0	8.0	-196.3	-227.8
11/20/85	276	324	-205.0	9.0	-178.7	-210.2
11/27/85	283	331	-210.0	8.3	-184.1	-215.6
12/5/85	291	339	-190.0	8.5	-165.5	-197.0
12/13/85	299	347	-238.0	8.5	-209.6	-241.1
12/22/85	308	356	-203.0	9.7	-176.2	-207.7
12/31/85	317	365	-215.0	8.5	-188.4	-219.9
1/3/86	320	3	-199.0	9.7	-172.5	-204.0
1/11/86	328	11	-198.0	9.7	-171.6	-203.1
1/16/86	333	16	-216.0	9.0	-188.8	-220.3
1/22/86	339	22	-224.0	10.0	-195.1	-226.6
1/30/86	347	30	-204.0	9.5	-177.3	-208.8
2/6/86	354	37	-248.0	8.7	-218.5	-250.0
2/11/86	359	42	-233.0	8.5	-205.0	-236.5
2/19/86	367	50	-244.0	10.0	-213.5	-245.0
2/27/86	375	58	-259.0	9.0	-228.3	-259.8
3/5/86	381	64	-243.0	9.0	-213.6	-245.1
3/13/86	389	72	-245.0	8.7	-215.8	-247.3
3/19/86	395	78	-240.0	9.7	-210.1	-241.6
3/27/86	403	86	-246.0	9.0	-216.4	-247.9
4/3/86	410	93	-275.0	9.3	-242.7	-274.2
4/10/86	417	100	-240.0	9.0	-210.9	-242.4
4/17/86	424	107	-236.0	8.7	-207.5	-239.0
4/24/86	431	114	-256.0	10.0	-224.5	-256.0
5/1/86	438	121	-239.0	8.5	-210.5	-242.0
5/8/86	445	128	-274.0	8.3	-242.8	-274.3
5/19/86	456	139	-234.0	8.7	-205.7	-237.2
5/27/86	464	147	-250.0	9.2	-219.8	-251.3
6/3/86	471	154	-215.0	9.6	-187.3	-218.8
6/9/86	477	160	-229.0	8.7	-201.1	-232.6
6/16/86	484	167	-224.0	8.4	-196.8	-228.3
6/25/86	493	176	-112.0	8.5	-93.9	-125.4
7/2/86	500	183	-261.0	8.4	-230.8	-262.3
7/9/86	507	190	-290.0	8.5	-257.3	-288.8
7/16/86	514	197	-288.0	8.0	-256.0	-287.5
7/22/86	520	203	-287.0	9.0	-254.0	-285.5
7/30/86	528	211	-265.0	8.5	-234.3	-265.8
8/6/86	535	218	-281.0	9.2	-248.3	-279.8
8/13/86	542	225	-292.0	9.5	-258.1	-289.6

APPENDIX C- TENSIOMETRIC DATA

COLUMN 1

TENSIOMETER 1 31.5 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
8/25/86	554	237	-300.0	7.5	-267.5	-299.0
9/2/86	562	245	-275.0	9.4	-242.6	-274.1
9/8/86	568	251	-296.0	8.4	-262.9	-294.4
9/15/86	575	258	-265.0	9.8	-233.0	-264.5
9/22/86	582	265	-262.0	9.7	-230.3	-261.8
9/29/86	589	272	-282.0	8.5	-249.9	-281.4
10/13/86	603	286	-313.0	7.5	-279.4	-310.9
10/21/86	611	294				
10/28/86	618	301				
11/4/86	625	308				
11/11/86	632	315	-84.0	9.7	-67.0	-98.5
11/18/86	639	322	-132.0	9.7	-111.0	-142.5
11/25/86	646	329	-158.0	9.6	-135.0	-166.5
12/3/86	654	337	-139.0	9.5	-117.6	-149.1
12/11/86	662	345	-216.0	9.4	-188.4	-219.9
12/29/86	680	363	-208.0	9.3	-181.2	-212.7
1/7/87	689	7	-214.0	9.8	-186.2	-217.7
1/20/87	702	20	-250.0	7.7	-221.4	-252.9
1/28/87	710	28	-191.0	9.6	-165.3	-196.8
2/3/87	716	34	-177.0	9.5	-152.5	-184.0
2/11/87	724	42	-173.0	9.6	-148.7	-180.2
2/18/87	731	49	-221.0	9.5	-192.9	-224.4
2/26/87	739	57	-211.0	9.5	-183.7	-215.2
3/3/87	744	62	-190.0	9.5	-164.5	-196.0
3/18/87	759	77	-181.0	8.7	-157.0	-188.5
4/8/87	780	98	-196.0	9.5	-170.0	-201.5
4/15/87	787	105	-164.0	8.7	-141.4	-172.9
4/28/87	800	118	-151.0	7.8	-130.4	-161.9
5/12/87	814	132	-170.0	8.0	-147.7	-179.2
5/25/87	827	145	-213.0	7.7	-187.4	-218.9
6/4/87	837	155	-202.0	9.0	-176.0	-207.5
6/23/87	856	174	-198.0	8.5	-172.8	-204.3
7/2/87	865	183	-185.0	8.5	-160.9	-192.4
7/13/87	876	194	-114.0	4.5	-99.9	-131.4
7/23/87	886	204	-153.0	6.5	-133.6	-165.1
7/31/87	894	212	-233.0	8.5	-205.0	-236.5
8/7/87	901	219	-259.0	7.5	-229.9	-261.4
8/14/87	908	226				
9/2/87	927	245				
9/9/87	934	252				
9/16/87	941	259				
9/28/87	953	271				
10/11/87	966	284	-147.0	10.3	-124.2	-155.7

APPENDIX C- TENSIOMETRIC DATA

COLUMN 1

TENSIOMETER 2 46.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
2/18/85	1	49	-57.0	9.5	-42.4	-88.4
2/19/85	2	50	-64.0	9.2	-49.1	-95.1
2/20/85	3	51	-49.0	8.0	-36.6	-82.6
2/27/85	10	58	-51.0	9.0	-37.4	-83.4
3/1/85	12	60	-67.0	8.9	-52.2	-98.2
3/4/85	15	63	-81.0	8.9	-65.0	-111.0
3/7/85	18	66	-105.0	8.7	-87.3	-133.3
3/12/85	23	71	-127.0	8.7	-107.5	-153.5
3/19/85	30	78	-128.0	8.7	-108.4	-154.4
3/23/85	34	82	-108.0	8.6	-90.1	-136.1
3/25/85	36	84	-107.0	8.5	-89.3	-135.3
3/29/85	40	88	-138.0	8.5	-117.8	-163.8
4/1/85	43	91	-107.0	8.5	-89.3	-135.3
4/19/85	61	109	-78.0	6.5	-64.8	-110.8
4/22/85	64	112	-100.0	9.0	-82.4	-128.4
4/25/85	67	115	-102.0	8.9	-84.3	-130.3
4/29/85	71	119	-107.0	9.0	-88.8	-134.8
5/2/85	74	122	-113.0	9.3	-93.9	-139.9
5/6/85	78	126	-101.0	8.8	-83.5	-129.5
5/10/85	82	130	-105.0	8.8	-87.2	-133.2
5/13/85	85	133	-103.0	8.8	-85.4	-131.4
5/16/85	88	136	-108.0	8.8	-90.0	-136.0
5/20/85	92	140	-111.0	8.8	-92.7	-138.7
5/24/85	96	144	-108.0	8.8	-90.0	-136.0
5/28/85	100	148	-99.0	8.7	-81.8	-127.8
5/30/85	102	150	-116.0	8.8	-97.3	-143.3
6/2/85	105	153	-103.0	8.5	-85.7	-131.7
6/6/85	109	157	-105.0	8.5	-87.5	-133.5
6/10/85	113	161	-110.0	8.5	-92.1	-138.1
6/13/85	116	164	-109.0	8.5	-91.2	-137.2
6/21/85	124	172	-121.0	8.0	-102.7	-148.7
6/24/85	127	175	-130.0	8.0	-111.0	-157.0
6/28/85	131	179	-146.0	8.0	-125.6	-171.6
7/1/85	134	182	-146.0	8.0	-125.6	-171.6
7/3/85	136	184	-151.0	7.4	-130.9	-176.9
7/8/85	141	189	-151.0	6.9	-131.4	-177.4
7/11/85	144	192				
7/15/85	148	196				
7/18/85	151	199				
7/23/85	156	204	-154.0	9.6	-131.3	-177.3
7/25/85	158	206	-139.0	9.6	-117.5	-163.5
7/30/85	163	211	-146.0	9.6	-124.0	-170.0
8/1/85	165	213	-131.0	9.6	-110.2	-156.2
8/5/85	169	217	-121.0	9.3	-101.3	-147.3
8/8/85	172	220	-126.0	9.1	-106.1	-152.1
8/9/85	173	221	-116.0	8.8	-97.3	-143.3
8/13/85	177	225				
8/19/85	183	231	-91.0	8.1	-75.1	-121.1
8/22/85	186	234	-109.0	7.0	-92.7	-138.7
8/26/85	190	238	-119.0	9.2	-99.6	-145.6
8/29/85	193	241				
9/2/85	197	245	-111.0	9.4	-92.1	-138.1

APPENDIX C- TENSIOMETRIC DATA

COLUMN 1

TENSIOMETER 2 46.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
9/5/85	200	248	-93.0	7.0	-78.0	-124.0
9/9/85	204	252	-114.0	7.7	-96.6	-142.6
9/12/85	207	255	-98.0	7.0	-82.6	-128.6
9/17/85	212	260	-127.0	7.4	-108.8	-154.8
9/19/85	214	262	-123.0	8.7	-103.8	-149.8
9/23/85	218	266	-129.0	8.6	-109.4	-155.4
9/30/85	225	273	-134.0	8.2	-114.4	-160.4
10/7/85	232	280	-145.0	8.3	-124.4	-170.4
10/14/85	239	287	-153.0	8.4	-131.6	-177.6
10/17/85	242	290	-147.0	8.3	-126.2	-172.2
10/21/85	246	294	-137.0	8.3	-117.1	-163.1
10/29/85	254	302	-149.0	8.3	-128.1	-174.1
11/6/85	262	310	-153.0	8.2	-131.9	-177.9
11/13/85	269	317	-167.0	8.1	-144.8	-190.8
11/20/85	276	324	-152.0	8.4	-130.7	-176.7
11/27/85	283	331	-162.0	8.2	-140.1	-186.1
12/5/85	291	339	-148.0	8.3	-127.2	-173.2
12/13/85	299	347	-207.0	7.0	-182.7	-228.7
12/22/85	308	356	-141.0	8.9	-120.1	-166.1
12/31/85	317	365	-168.0	8.8	-145.0	-191.0
1/3/86	320	3	-158.0	8.8	-135.8	-181.8
1/11/86	328	11	-145.0	8.0	-124.7	-170.7
1/16/86	333	16	-170.0	9.0	-146.6	-192.6
1/22/86	339	22	-170.0	9.0	-146.6	-192.6
1/30/86	347	30	-157.0	7.9	-135.8	-181.8
2/6/86	354	37	-169.0	8.8	-145.9	-191.9
2/11/86	359	42	-181.0	8.9	-156.8	-202.8
2/19/86	367	50	-174.0	7.5	-151.9	-197.9
2/27/86	375	58	-182.0	8.9	-157.7	-203.7
3/5/86	381	64	-165.0	8.8	-142.2	-188.2
3/13/86	389	72	-165.0	8.3	-142.8	-188.8
3/19/86	395	78	-171.0	9.1	-147.4	-193.4
3/27/86	403	86	-162.0	8.4	-139.9	-185.9
4/3/86	410	93	-187.0	9.0	-162.2	-208.2
4/10/86	417	100	-147.0	7.4	-127.2	-173.2
4/17/86	424	107	-168.0	8.4	-145.4	-191.4
4/24/86	431	114	-162.0	8.3	-140.0	-186.0
5/1/86	438	121	-171.0	8.9	-147.6	-193.6
5/8/86	445	128	-182.0	8.5	-158.2	-204.2
5/19/86	456	139	-123.0	8.0	-104.5	-150.5
5/27/86	464	147	-158.0	8.4	-136.2	-182.2
6/3/86	471	154	-146.0	8.9	-124.7	-170.7
6/9/86	477	160	-156.0	8.2	-134.6	-180.6
6/16/86	484	167				
6/25/86	493	176	-61.0	8.7	-46.9	-92.9
7/2/86	500	183				
7/9/86	507	190	-155.0	8.3	-133.6	-179.6
7/16/86	514	197	-148.0	8.5	-127.0	-173.0
7/22/86	520	203	-139.0	9.1	-118.1	-164.1
7/30/86	528	211	-119.0	9.5	-99.3	-145.3
8/6/86	535	218				
8/13/86	542	225	-150.0	8.9	-128.4	-174.4

APPENDIX C- TENSIOMETRIC DATA

COLUMN 1

TENSIOMETER 2 46.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
8/25/86	554	237	-161.0	9.4	-137.9	-183.9
9/2/86	562	245	-157.0	8.4	-135.3	-181.3
9/8/86	568	251	-150.0	8.4	-128.9	-174.9
9/15/86	575	258	-147.0	8.4	-126.1	-172.1
9/22/86	582	265	-156.0	8.9	-133.9	-179.9
9/29/86	589	272	-154.0	8.9	-132.0	-178.0
10/13/86	603	286	-171.0	9.0	-147.5	-193.5
10/21/86	611	294	-158.0	9.0	-135.6	-181.6
10/28/86	618	301	-168.0	9.5	-144.3	-190.3
11/4/86	625	308	-197.0	8.6	-171.8	-217.8
11/11/86	632	315	-185.0	8.6	-160.8	-206.8
11/18/86	639	322	-204.0	8.5	-178.4	-224.4
11/25/86	646	329	-194.0	8.5	-169.2	-215.2
12/3/86	654	337	-189.0	8.5	-164.6	-210.6
12/11/86	662	345	-220.0	8.5	-193.0	-239.0
12/29/86	680	363	-205.0	8.5	-179.3	-225.3
1/7/87	689	7	-215.0	9.0	-187.9	-233.9
1/20/87	702	20	-213.0	9.1	-186.0	-232.0
1/28/87	710	28	-166.0	9.2	-142.7	-188.7
2/3/87	716	34	-161.0	9.1	-138.3	-184.3
2/11/87	724	42	-155.0	9.0	-132.9	-178.9
2/18/87	731	49	-197.0	9.0	-171.4	-217.4
2/26/87	739	57	-185.0	9.0	-160.4	-206.4
3/3/87	744	62	-174.0	9.0	-150.3	-196.3
3/18/87	759	77	-169.0	8.9	-145.8	-191.8
4/8/87	780	98	-175.0	8.8	-151.4	-197.4
4/15/87	787	105	-163.0	8.7	-140.5	-186.5
4/28/87	800	118	-166.0	8.5	-143.5	-189.5
5/12/87	814	132	-131.0	8.5	-111.4	-157.4
5/25/87	827	145	-133.0	8.5	-113.2	-159.2
6/4/87	837	155				
6/23/87	856	174	-162.0	8.5	-139.8	-185.8
7/2/87	865	183	-119.0	8.3	-100.5	-146.5
7/13/87	876	194	-192.0	8.3	-167.5	-213.5
7/23/87	886	204	-170.0	8.2	-147.5	-193.5
7/31/87	894	212	-104.0	8.3	-86.8	-132.8
8/7/87	901	219	-181.0	8.0	-157.8	-203.8
8/14/87	908	226	-142.0	8.0	-122.0	-168.0
9/2/87	927	245	-191.0	8.0	-166.9	-212.9
9/9/87	934	252	-169.0	9.0	-145.7	-191.7
9/16/87	941	259	-147.0	9.0	-125.5	-171.5
9/28/87	953	271	-177.0	9.0	-153.0	-199.0
10/11/87	966	284	-174.0	8.3	-151.0	-197.0

APPENDIX C- TENSIOMETRIC DATA

COLUMN 1

TENSIOMETER 3 65.5 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
2/18/85	1	49	-83.0	8.3	-67.5	-133.0
2/19/85	2	50	-112.0	8.3	-94.1	-159.6
2/20/85	3	51	-82.0	8.2	-66.7	-132.2
2/27/85	10	58	-73.0	8.4	-58.2	-123.7
3/1/85	12	60	-81.0	8.4	-65.6	-131.1
3/4/85	15	63	-82.0	8.4	-66.5	-132.0
3/7/85	18	66	-95.0	8.4	-78.4	-143.9
3/12/85	23	71	-107.0	8.4	-89.4	-154.9
3/19/85	30	78	-99.0	8.5	-82.0	-147.5
3/23/85	34	82	-93.0	8.3	-76.7	-142.2
3/25/85	36	84	-94.0	7.9	-78.0	-143.5
3/29/85	40	88	-119.0	7.7	-101.2	-166.7
4/1/85	43	91	-99.0	7.6	-82.9	-148.4
4/19/85	61	109	-115.0	8.5	-96.7	-162.2
4/22/85	64	112	-123.0	8.5	-104.0	-169.5
4/25/85	67	115	-107.0	8.1	-89.7	-155.2
4/29/85	71	119	-113.0	8.2	-95.1	-160.6
5/2/85	74	122	-105.0	7.9	-88.1	-153.6
5/6/85	78	126	-98.0	7.5	-82.1	-147.6
5/10/85	82	130	-116.0	9.0	-97.1	-162.6
5/13/85	85	133	-111.0	9.0	-92.5	-158.0
5/16/85	88	136	-116.0	9.0	-97.1	-162.6
5/20/85	92	140	-116.0	8.9	-97.2	-162.7
5/24/85	96	144	-108.0	8.6	-90.1	-155.6
5/28/85	100	148	-101.0	8.3	-84.0	-149.5
5/30/85	102	150	-124.0	8.3	-105.1	-170.6
6/2/85	105	153	-109.0	8.3	-91.4	-156.9
6/6/85	109	157	-106.0	8.1	-88.8	-154.3
6/10/85	113	161	-110.0	7.9	-92.7	-158.2
6/13/85	116	164	-113.0	8.0	-95.4	-160.9
6/21/85	124	172	-111.0	7.8	-93.7	-159.2
6/24/85	127	175	-120.0	7.7	-102.1	-167.6
6/28/85	131	179	-130.0	7.9	-111.1	-176.6
7/1/85	134	182	-114.0	7.9	-96.4	-161.9
7/3/85	136	184	-126.0	8.7	-106.6	-172.1
7/8/85	141	189	-106.0	8.6	-88.3	-153.8
7/11/85	144	192	-105.0	8.5	-87.5	-153.0
7/15/85	148	196	-122.0	8.4	-103.2	-168.7
7/18/85	151	199	-108.0	8.3	-90.5	-156.0
7/23/85	156	204	-114.0	9.3	-94.9	-160.4
7/25/85	158	206				
7/30/85	163	211				
8/1/85	165	213				
8/5/85	169	217				
8/8/85	172	220				
8/9/85	173	221				
8/13/85	177	225	-69.0	18.7	-43.8	-109.3
8/19/85	183	231	-66.0	18.0	-41.8	-107.3
8/22/85	186	234	-100.0	18.6	-72.3	-137.8
8/26/85	190	238	-85.0	18.6	-58.6	-124.1
8/29/85	193	241	-98.0	18.5	-70.6	-136.1
9/2/85	197	245	-66.0	17.4	-42.4	-107.9

APPENDIX C- TENSIOMETRIC DATA

COLUMN 1

TENSIOMETER 3 65.5 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
9/5/85	200	248	-93.0	17.6	-67.0	-132.5
9/9/85	204	252	-107.0	17.6	-79.8	-145.3
9/12/85	207	255	-108.0	17.6	-80.7	-146.2
9/17/85	212	260	-122.0	17.6	-93.6	-159.1
9/19/85	214	262	-70.0	17.6	-45.9	-111.4
9/23/85	218	266	-74.0	17.7	-49.4	-114.9
9/30/85	225	273	-114.0	17.6	-86.2	-151.7
10/7/85	232	280	-134.0	17.5	-104.7	-170.2
10/14/85	239	287	-99.0	17.3	-72.8	-138.3
10/17/85	242	290	-128.0	17.3	-99.4	-164.9
10/21/85	246	294	-134.0	17.7	-104.5	-170.0
10/29/85	254	302	-137.0	17.6	-107.3	-172.8
11/6/85	262	310	-129.0	17.3	-100.3	-165.8
11/13/85	269	317	-134.0	17.5	-104.7	-170.2
11/20/85	276	324	-119.0	17.5	-90.9	-156.4
11/27/85	283	331	-112.0	17.1	-84.9	-150.4
12/5/85	291	339	-125.0	17.6	-96.3	-161.8
12/13/85	299	347	-148.0	17.5	-117.5	-183.0
12/22/85	308	356	-123.0	17.1	-95.0	-160.5
12/31/85	317	365	-141.0	17.4	-111.2	-176.7
1/3/86	320	3	-142.0	17.8	-111.7	-177.2
1/11/86	328	11	-120.0	17.7	-91.6	-157.1
1/16/86	333	16	-133.0	17.7	-103.6	-169.1
1/22/86	339	22	-129.0	17.5	-100.1	-165.6
1/30/86	347	30	-140.0	17.7	-110.0	-175.5
2/6/86	354	37	-146.0	17.7	-115.5	-181.0
2/11/86	359	42	-143.0	17.7	-112.8	-178.3
2/19/86	367	50	-115.0	17.3	-87.5	-153.0
2/27/86	375	58	-153.0	18.0	-121.6	-187.1
3/5/86	381	64	-136.0	17.5	-106.5	-172.0
3/13/86	389	72	-149.0	17.5	-118.5	-184.0
3/19/86	395	78	-128.0	18.0	-98.7	-164.2
3/27/86	403	86	-138.0	18.6	-107.2	-172.7
4/3/86	410	93	-166.0	17.7	-133.9	-199.4
4/10/86	417	100	-144.0	17.5	-113.9	-179.4
4/17/86	424	107	-159.0	17.5	-127.6	-193.1
4/24/86	431	114	-122.0	16.0	-95.3	-160.8
5/1/86	438	121	-120.0	17.5	-91.8	-157.3
5/8/86	445	128				
5/19/86	456	139				
5/27/86	464	147	-143.0	18.0	-112.4	-177.9
6/3/86	471	154	-125.0	18.0	-95.9	-161.4
6/9/86	477	160	-136.0	18.0	-106.0	-171.5
6/16/86	484	167	-133.0	18.6	-102.6	-168.1
6/25/86	493	176	-61.0	18.1	-37.1	-102.6
7/2/86	500	183	-151.0	17.7	-120.1	-185.6
7/9/86	507	190	-164.0	18.0	-131.7	-197.2
7/16/86	514	197	-157.0	17.8	-125.5	-191.0
7/22/86	520	203	-161.0	18.0	-129.0	-194.5
7/30/86	528	211	-152.0	18.0	-120.7	-186.2
8/6/86	535	218	-157.0	17.7	-125.6	-191.1
8/13/86	542	225	-156.0	17.7	-124.7	-190.2

APPENDIX C- TENSIOMETRIC DATA

COLUMN 1

TENSIOMETER 3 65.5 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
8/25/86	554	237	-153.0	17.7	-121.9	-187.4
9/2/86	562	245	-155.0	17.8	-123.7	-189.2
9/8/86	568	251	-156.0	17.3	-125.1	-190.6
9/15/86	575	258	-143.0	17.6	-112.9	-178.4
9/22/86	582	265	-154.0	18.0	-122.5	-188.0
9/29/86	589	272	-159.0	18.0	-127.1	-192.6
10/13/86	603	286	-177.0	18.0	-143.6	-209.1
10/21/86	611	294	-141.0	18.2	-110.4	-175.9
10/28/86	618	301	-143.0	18.2	-112.2	-177.7
11/4/86	625	308	-177.0	18.1	-143.5	-209.0
11/11/86	632	315	-159.0	18.0	-127.1	-192.6
11/18/86	639	322	-168.0	18.0	-135.4	-200.9
11/25/86	646	329	-172.0	18.0	-139.1	-204.6
12/3/86	654	337	-165.0	18.0	-132.6	-198.1
12/11/86	662	345	-204.0	18.0	-168.4	-233.9
12/29/86	680	363	-186.0	18.0	-151.9	-217.4
1/7/87	689	7	-189.0	18.3	-154.3	-219.8
1/20/87	702	20	-192.0	17.5	-157.9	-223.4
1/28/87	710	28	-154.0	17.3	-123.3	-188.8
2/3/87	716	34	-148.0	18.0	-117.0	-182.5
2/11/87	724	42	-133.0	18.0	-103.3	-168.8
2/18/87	731	49	-180.0	18.0	-146.4	-211.9
2/26/87	739	57	-164.0	18.0	-131.7	-197.2
3/3/87	744	62	-153.0	18.0	-121.6	-187.1
3/18/87	759	77	-151.0	18.0	-119.8	-185.3
4/8/87	780	98	-158.0	17.9	-126.3	-191.8
4/15/87	787	105	-153.0	17.7	-121.9	-187.4
4/28/87	800	118	-159.0	17.5	-127.6	-193.1
5/12/87	814	132	-158.0	17.5	-126.7	-192.2
5/25/87	827	145	-171.0	17.1	-139.1	-204.6
6/4/87	837	155	-181.0	17.0	-148.4	-213.9
6/23/87	856	174	-165.0	17.3	-133.4	-198.9
7/2/87	865	183	-138.0	17.3	-108.6	-174.1
7/13/87	876	194	-199.0	17.2	-164.7	-230.2
7/23/87	886	204	-163.0	17.3	-131.5	-197.0
7/31/87	894	212	-164.0	17.0	-132.8	-198.3
8/7/87	901	219	-173.0	16.5	-141.5	-207.0
8/14/87	908	226	-171.0	19.5	-136.6	-202.1
9/2/87	927	245	-176.0	18.5	-142.2	-207.7
9/9/87	934	252	-163.0	18.2	-130.6	-196.1
9/16/87	941	259	-166.0	18.2	-133.3	-198.8
9/28/87	953	271	-187.0	18.2	-152.6	
10/11/87	966	284	-174.0	18.2	-140.7	-206.2

APPENDIX C- TENSIOMETRIC DATA

COLUMN 1

			GRADIENTS		
DATE	XD	JD	G12	G13	G23
2/18/85	1	49	-3.1	-2.6	-2.3
2/19/85	2	50	-2.5	-3.0	-3.3
2/20/85	3	51	-3.0	-2.7	-2.5
2/27/85	10	58	-1.6	-1.9	-2.1
3/1/85	12	60	-3.8	-2.6	-1.7
3/4/85	15	63			-1.1
3/7/85	18	66	-2.6	-1.4	-0.5
3/12/85	23	71	-3.2	-1.4	-0.1
3/19/85	30	78	-3.9	-1.5	0.4
3/23/85	34	82	-5.2	-2.4	-0.3
3/25/85	36	84	-4.7	-2.2	-0.4
3/29/85	40	88	-2.0	-0.9	-0.2
4/1/85	43	91			-0.7
4/19/85	61	109	-4.2	-3.3	-2.6
4/22/85	64	112	-6.5	-4.0	-2.1
4/25/85	67	115	-3.4	-2.2	-1.3
4/29/85	71	119	-1.3	-1.3	-1.3
5/2/85	74	122	-4.2	-2.2	-0.7
5/6/85	78	126	-3.2	-1.9	-0.9
5/10/85	82	130	2.4	0.2	-1.5
5/13/85	85	133	-3.4	-2.2	-1.4
5/16/85	88	136	0.1	-0.7	-1.4
5/20/85	92	140	2.1	0.2	-1.2
5/24/85	96	144	-1.6	-1.2	-1.0
5/28/85	100	148	-0.6	-0.9	-1.1
5/30/85	102	150	5.5	1.5	-1.4
6/2/85	105	153	4.7	1.3	-1.3
6/6/85	109	157	3.3	0.8	-1.1
6/10/85	113	161	4.5	1.3	-1.0
6/13/85	116	164	3.9	1.0	-1.2
6/21/85	124	172	0.6	-0.1	-0.5
6/24/85	127	175	0.6	-0.1	-0.5
6/28/85	131	179	1.6	0.5	-0.3
7/1/85	134	182	2.1	1.2	0.5
7/3/85	136	184	2.0	1.0	0.2
7/8/85	141	189	0.9	1.1	1.2
7/11/85	144	192			
7/15/85	148	196			
7/18/85	151	199			
7/23/85	156	204	-3.3	-0.9	0.9
7/25/85	158	206			
7/30/85	163	211	1.4		
8/1/85	165	213			
8/5/85	169	217	-0.2		
8/8/85	172	220	1.0		
8/9/85	173	221	-2.6		
8/13/85	177	225			
8/19/85	183	231	6.4	3.1	0.7
8/22/85	186	234	3.9	1.7	0.0
8/26/85	190	238	4.1	2.4	1.1
8/29/85	193	241			
9/2/85	197	245	6.3	3.6	1.5

APPENDIX C- TENSIOMETRIC DATA

COLUMN 1

			GRADIENTS		
DATE	XD	JD	G12	G13	G23
9/5/85	200	248	4.8	1.8	-0.4
9/9/85	204	252	5.9	2.4	-0.1
9/12/85	207	255	6.4	2.2	-0.9
9/17/85	212	260	4.2	1.7	-0.2
9/19/85	214	262	6.7	4.0	2.0
9/23/85	218	266	5.8	3.7	2.1
9/30/85	225	273	6.4	3.0	0.4
10/7/85	232	280	3.2	1.4	0.0
10/14/85	239	287	3.7	2.7	2.0
10/17/85	242	290	3.2	1.6	0.4
10/21/85	246	294	2.6	0.9	-0.4
10/29/85	254	302	2.7	1.2	0.1
11/6/85	262	310	1.4	1.0	0.6
11/13/85	269	317	2.6	1.7	1.1
11/20/85	276	324	2.3	1.6	1.0
11/27/85	283	331	2.0	1.9	1.8
12/5/85	291	339	1.6	1.0	0.6
12/13/85	299	347	0.9	1.7	2.3
12/22/85	308	356	2.9	1.4	0.3
12/31/85	317	365	2.0	1.3	0.7
1/3/86	320	3	1.5	0.8	0.2
1/11/86	328	11	2.2	1.4	0.7
1/16/86	333	16	1.9	1.5	1.2
1/22/86	339	22	2.3	1.8	1.4
1/30/86	347	30	1.9	1.0	0.3
2/6/86	354	37	4.0	2.0	0.6
2/11/86	359	42	2.3	1.7	1.3
2/19/86	367	50	3.3	2.7	2.3
2/27/86	375	58	3.9	2.1	0.9
3/5/86	381	64	3.9	2.1	0.8
3/13/86	389	72	4.0	1.9	0.2
3/19/86	395	78	3.3	2.3	1.5
3/27/86	403	86	4.3	2.2	0.7
4/3/86	410	93	4.5	2.2	0.5
4/10/86	417	100	4.8	1.9	-0.3
4/17/86	424	107	3.3	1.3	-0.1
4/24/86	431	114	4.8	2.8	1.3
5/1/86	438	121	3.3	2.5	1.9
5/8/86	445	128	4.8		
5/19/86	456	139	6.0		
5/27/86	464	147	4.8	2.2	0.2
6/3/86	471	154	3.3	1.7	0.5
6/9/86	477	160	3.6	1.8	0.5
6/16/86	484	167			
6/25/86	493	176	2.2	0.7	-0.5
7/2/86	500	183			
7/9/86	507	190	7.5	2.7	-0.9
7/16/86	514	197	7.9	2.8	-0.9
7/22/86	520	203	8.4	2.7	-1.6
7/30/86	528	211	8.3	2.3	-2.1
8/6/86	535	218			
8/13/86	542	225	7.9	2.9	-0.8

APPENDIX C- TENSIOMETRIC DATA

COLUMN 1

			GRADIENTS		
DATE	XD	JD	G12	G13	G23
8/25/86	554	237	7.9	3.3	-0.2
9/2/86	562	245	6.4	2.5	-0.4
9/8/86	568	251	8.2	3.1	-0.8
9/15/86	575	258	6.4	2.5	-0.3
9/22/86	582	265	5.7	2.2	-0.4
9/29/86	589	272	7.1	2.6	-0.7
10/13/86	603	286	8.1	3.0	-0.8
10/21/86	611	294			0.3
10/28/86	618	301			0.6
11/4/86	625	308			0.5
11/11/86	632	315	-7.5	-2.8	0.7
11/18/86	639	322	-5.6	-1.7	1.2
11/25/86	646	329	-3.4	-1.1	0.5
12/3/86	654	337	-4.2	-1.4	0.6
12/11/86	662	345	-1.3	-0.4	0.3
12/29/86	680	363	-0.9	-0.1	0.4
1/7/87	689	7	-1.1	-0.1	0.7
1/20/87	702	20	1.4	0.9	0.4
1/28/87	710	28	0.6	0.2	-0.0
2/3/87	716	34	-0.0	0.0	0.1
2/11/87	724	42	0.1	0.3	0.5
2/18/87	731	49	0.5	0.4	0.3
2/26/87	739	57	0.6	0.5	0.5
3/3/87	744	62	-0.0	0.3	0.5
3/18/87	759	77	-0.2	0.1	0.3
4/8/87	780	98	0.3	0.3	0.3
4/15/87	787	105	-0.9	-0.4	-0.0
4/28/87	800	118	-1.9	-0.9	-0.2
5/12/87	814	132	1.5	-0.4	-1.8
5/25/87	827	145	4.1	0.4	-2.3
6/4/87	837	155	11.1	-0.2	-8.6
6/23/87	856	174	1.3	0.2	-0.7
7/2/87	865	183	3.2	0.5	-1.4
7/13/87	876	194	-5.7	-2.9	-0.9
7/23/87	886	204	-2.0	-0.9	-0.2
7/31/87	894	212	7.2	1.1	-3.4
8/7/87	901	219	4.0	1.6	-0.2
8/14/87	908	226	-11.6	-5.9	-1.7
9/2/87	927	245	-14.7	-6.1	0.3
9/9/87	934	252	-13.2	-5.8	-0.2
9/16/87	941	259	-11.8	-5.8	-1.4
9/28/87	953	271			
10/11/87	966	284	-2.9	-1.5	-0.5

APPENDIX C— TENSIOMETRIC DATA

COLUMN 2

47.0 CM DEEP; TENSIOMETER 2

DATE	XD	JD	READING	H2O	PSI	TH
2/18/85	1	49	-73.0	8.0	-58.6	-105.6
2/19/85	2	50	-94.0	8.3	-77.6	-124.6
2/20/85	3	51	-82.0	7.9	-67.0	-114.0
2/27/85	10	58	-70.0	8.9	-54.9	-101.9
3/1/85	12	60	-69.0	8.8	-54.1	-101.1
3/4/85	15	63	-67.0	8.8	-52.3	-99.3
3/7/85	18	66	-80.0	9.5	-63.5	-110.5
3/12/85	23	71	-82.0	9.5	-65.3	-112.3
3/23/85	34	82	-81.0	7.7	-66.3	-113.3
3/25/85	36	84	-67.0	7.0	-54.2	-101.2
3/29/85	40	88	-95.0	9.4	-77.4	-124.4
4/1/85	43	91	-92.0	9.3	-74.7	-121.7
4/19/85	61	109	-98.0	6.8	-82.8	-129.8
4/22/85	64	112	-107.0	8.2	-89.7	-136.7
4/25/85	67	115	-111.0	7.9	-93.6	-140.6
4/29/85	71	119	-106.0	8.0	-88.9	-135.9
5/2/85	74	122				
5/6/85	78	126	-108.0	8.0	-90.8	-137.8
5/10/85	82	130	-102.0	8.8	-84.4	-131.4
5/13/85	85	133	-114.0	8.5	-95.7	-142.7
5/16/85	88	136				
5/20/85	92	140	-108.0	9.3	-89.5	-136.5
5/24/85	96	144	-112.0	9.1	-93.3	-140.3
5/28/85	100	148	-107.0	8.4	-89.4	-136.4
5/30/85	102	150	-116.0	8.4	-97.7	-144.7
6/2/85	105	153	-110.0	8.1	-92.5	-139.5
6/6/85	109	157	-119.0	7.8	-101.1	-148.1
6/10/85	113	161	-114.0	8.5	-95.7	-142.7
6/13/85	116	164	-117.0	9.0	-98.0	-145.0
6/21/85	124	172	-120.0	8.7	-101.0	-148.0
6/24/85	127	175	-124.0	8.7	-104.7	-151.7
6/28/85	131	179	-134.0	8.6	-114.0	-161.0
7/1/85	134	182	-133.0	8.5	-113.2	-160.2
7/3/85	136	184	-137.0	8.5	-116.9	-163.9
7/8/85	141	189	-138.0	8.3	-118.0	-165.0
7/11/85	144	192	-117.0	7.9	-99.1	-146.1
7/15/85	148	196				
7/18/85	151	199	-138.0	9.2	-117.0	-164.0
7/23/85	156	204	-143.0	9.2	-121.6	-168.6
7/25/85	158	206	-147.0	9.3	-125.2	-172.2
7/30/85	163	211	-128.0	9.3	-107.8	-154.8
8/1/85	165	213	-124.0	9.2	-104.2	-151.2
8/5/85	169	217	-129.0	9.1	-108.9	-155.9
8/8/85	172	220	-134.0	9.1	-113.5	-160.5
8/9/85	173	221	-134.0	9.1	-113.5	-160.5
8/13/85	177	225	-141.0	8.5	-120.5	-167.5
8/19/85	183	231	-137.0	9.5	-115.8	-162.8
8/22/85	186	234	-131.0	8.6	-111.2	-158.2
8/26/85	190	238	-107.0	8.4	-89.4	-136.4
8/29/85	193	241				
9/2/85	197	245				
9/5/85	200	248	-112.0	9.6	-92.8	-139.8
9/9/85	204	252	-128.0	9.5	-107.6	-154.6
9/12/85	207	255	-122.0	9.5	-102.0	-149.0

APPENDIX C- TENSIOMETRIC DATA

COLUMN 2

47.0 CM DEEP; TENSIOMETER 2

DATE	XD	JD	READING	H2O	PSI	TH
9/17/85	212	260	-128.0	9.4	-107.7	-154.7
9/19/85	214	262	-139.0	9.4	-117.8	-164.8
9/23/85	218	266	-140.0	9.0	-119.1	-166.1
9/30/85	225	273	-149.0	9.0	-127.3	-174.3
10/7/85	232	280	-144.0	8.5	-123.3	-170.3
10/14/85	239	287	-147.0	9.4	-125.1	-172.1
10/17/85	242	290	-42.0	9.4	-28.7	-75.7
10/21/85	246	294	-66.0	9.4	-50.8	-97.8
10/29/85	254	302	-82.0	9.4	-65.4	-112.4
11/6/85	262	310	-86.0	9.4	-69.1	-116.1
11/13/85	269	317	-97.0	8.7	-79.9	-126.9
11/20/85	276	324	-95.0	9.5	-77.3	-124.3
11/27/85	283	331	-95.0	9.5	-77.3	-124.3
12/5/85	291	339	-95.0	9.5	-77.3	-124.3
12/13/85	299	347				
12/22/85	308	356	-93.0	9.0	-76.0	-123.0
12/31/85	317	365	-118.0	9.0	-98.9	-145.9
1/3/86	320	3	-109.0	9.5	-90.1	-137.1
1/11/86	328	11	-109.0	9.5	-90.1	-137.1
1/16/86	333	16	-124.0	9.4	-104.0	-151.0
1/22/86	339	22	-120.0	8.5	-101.3	-148.3
1/30/86	347	30	-115.0	9.1	-96.0	-143.0
2/6/86	354	37	-125.0	9.1	-105.2	-152.2
2/11/86	359	42	-136.0	9.3	-115.1	-162.1
2/19/86	367	50	-123.0	8.3	-104.2	-151.2
2/27/86	375	58	-136.0	9.3	-115.1	-162.1
3/5/86	381	64	-128.0	9.2	-107.9	-154.9
3/13/86	389	72	-129.0	9.0	-109.0	-156.0
3/19/86	395	78	-132.0	9.1	-111.6	-158.6
3/27/86	403	86	-123.0	8.5	-104.0	-151.0
4/3/86	410	93	-141.0	8.5	-120.5	-167.5
4/10/86	417	100	-130.0	8.5	-110.4	-157.4
4/17/86	424	107	-143.0	9.8	-121.0	-168.0
4/24/86	431	114	-141.0	9.7	-119.3	-166.3
5/1/86	438	121	-148.0	8.6	-126.8	-173.8
5/8/86	445	128	-149.0	9.4	-126.9	-173.9
5/19/86	456	139	-136.0	9.5	-114.9	-161.9
5/27/86	464	147	-179.0	9.5	-154.4	-201.4
6/3/86	471	154	-157.0	10.0	-133.6	-180.6
6/9/86	477	160	-123.0	9.1	-103.4	-150.4
6/16/86	484	167	-139.0	9.5	-117.6	-164.6
6/25/86	493	176	-32.0	9.5	-19.4	-66.4
7/2/86	500	183	-102.0	9.3	-83.9	-130.9
7/9/86	507	190	-111.0	9.5	-91.9	-138.9
7/16/86	514	197	-118.0	9.4	-98.5	-145.5
7/22/86	520	203	-113.0	9.3	-94.0	-141.0
7/30/86	528	211	-113.0	8.5	-94.8	-141.8
8/6/86	535	218	-123.0	9.0	-103.5	-150.5
8/13/86	542	225	-131.0	9.6	-110.2	-157.2
8/25/86	554	237	-139.0	9.6	-117.5	-164.5
9/2/86	562	245	-113.0	8.5	-94.8	-141.8
9/8/86	568	251	-120.0	8.5	-101.3	-148.3
9/15/86	575	258				

APPENDIX C- TENSIOMETRIC DATA

COLUMN 2

47.0 CM DEEP; TENSIOMETER 2

DATE	XD	JD	READING	H2O	PSI	TH
9/22/86	582	265	-101.0	9.3	-83.0	-130.0
9/29/86	589	272	-111.0	9.2	-92.3	-139.3
10/13/86	603	286	-69.0	9.4	-53.5	-100.5
10/21/86	611	294	-93.0	9.5	-75.4	-122.4
10/28/86	618	301	-104.0	9.3	-85.7	-132.7
11/4/86	625	308	-65.0	9.3	-49.9	-96.9
11/11/86	632	315	-95.0	9.3	-77.5	-124.5
11/18/86	639	322	-104.0	9.3	-85.7	-132.7
11/25/86	646	329	-111.0	9.3	-92.2	-139.2
12/3/86	654	337	-106.0	9.3	-87.6	-134.6
12/11/86	662	345	-338.0			
12/29/86	680	363	-108.0	8.8	-89.9	-136.9
1/7/87	689	7	-114.0	9.3	-94.9	-141.9
1/28/87	710	28				
2/3/87	716	34	-84.0	9.5	-67.2	-114.2
2/11/87	724	42	-88.0	9.4	-70.9	-117.9
2/18/87	731	49	-106.0	9.4	-87.5	-134.5
2/26/87	739	57	-103.0	9.4	-84.7	-131.7
3/3/87	744	62	-98.0	9.4	-80.1	-127.1
3/18/87	759	77	-103.0	9.3	-84.8	-131.8
4/8/87	780	98	-105.0	8.0	-88.0	-135.0
4/15/87	787	105	-112.0	10.0	-92.3	-139.3
4/28/87	800	118	-111.0	9.5	-91.9	-138.9
5/12/87	814	132	-118.0	8.2	-99.7	-146.7
5/25/87	827	145	-112.0	8.0	-94.4	-141.4
6/4/87	837	155	-117.0	7.3	-99.8	-146.8
6/23/87	856	174	-116.0	8.0	-98.1	-145.1
7/2/87	865	183	-112.0	7.0	-95.5	-142.5
7/13/87	876	194	-133.0	9.2	-112.5	-159.5
7/23/87	886	204	-108.0	6.0	-92.9	-139.9
7/31/87	894	212	-116.0	8.0	-98.1	-145.1
8/7/87	901	219	-118.0	6.0	-102.0	-149.0
8/14/87	908	226	-132.0	9.0	-111.7	-158.7
9/2/87	927	245	-127.0	9.3	-106.8	-153.8
9/9/87	934	252	-121.0	9.4	-101.2	-148.2
9/16/87	941	259	-118.0	9.2	-98.7	-145.7
9/28/87	953	271	-133.0	7.5	-114.2	-161.2
10/11/87	966	284	-120.0	9.5	-100.2	-147.2

APPENDIX C– TENSIOMETRIC DATA

COLUMN 2

TENSIOMETER 3 68.0 CM DEEP

DATE	XD	JD	READING	H20	PSI	TH
2/18/85	1	49	-56.0	9.2	-41.7	-112.1
2/19/85	2	50	-73.0	9.2	-57.2	-128.4
2/20/85	3	51	-63.0	9.2	-48.1	-118.8
2/27/85	10	58	-74.0	9.1	-58.3	-129.5
3/1/85	12	60	-63.0	9.0	-48.3	-119.0
3/4/85	15	63	-68.0	7.5	-54.6	-122.6
3/7/85	18	66				
3/12/85	23	71				
3/23/85	34	82	-63.0	7.3	-50.2	-118.2
3/25/85	36	84				
3/29/85	40	88	-74.0	9.5	-58.0	-126.0
4/1/85	43	91	-73.0	9.5	-57.1	-125.1
4/19/85	61	109	-82.0	9.1	-65.8	-133.8
4/22/85	64	112	-81.0	8.7	-65.3	-133.3
4/25/85	67	115	-88.0	8.9	-71.5	-139.5
4/29/85	71	119	-80.0	9.0	-64.0	-132.0
5/2/85	74	122	-93.0	8.8	-76.2	-144.2
5/6/85	78	126	-89.0	8.8	-72.4	-140.4
5/10/85	82	130	-83.0	8.0	-67.8	-135.8
5/13/85	85	133	-93.0	8.7	-76.3	-144.3
5/16/85	88	136	-96.0	8.6	-79.1	-147.1
5/20/85	92	140	-94.0	8.8	-77.1	-145.1
5/24/85	96	144	-81.0	8.8	-65.1	-133.1
5/28/85	100	148	-68.0	8.7	-53.3	-121.3
5/30/85	102	150	-102.0	8.7	-84.6	-152.6
6/2/85	105	153	-69.0	8.6	-54.3	-122.3
6/6/85	109	157	-101.0	8.5	-83.8	-151.8
6/10/85	113	161	-82.0	9.0	-65.9	-133.9
6/13/85	116	164	-87.0	8.5	-71.0	-139.0
6/21/85	124	172	-84.0	8.2	-68.5	-136.5
6/24/85	127	175	-104.0	8.1	-87.0	-155.0
6/28/85	131	179	-101.0	8.2	-84.1	-152.1
7/1/85	134	182	-101.0	8.2	-84.1	-152.1
7/3/85	136	184	-104.0	8.2	-86.9	-154.9
7/8/85	141	189	-98.0	8.0	-81.6	-149.6
7/11/85	144	192	-110.0	7.9	-92.7	-160.7
7/15/85	148	196	-122.0	7.9	-103.7	-171.7
7/18/85	151	199	-108.0	7.7	-91.1	-159.1
7/23/85	156	204	-119.0	7.6	-101.3	-169.3
7/25/85	158	206	-104.0	7.6	-87.5	-155.5
7/30/85	163	211	-131.0	7.6	-112.3	-180.3
8/1/85	165	213	-109.0	7.6	-92.1	-160.1
8/5/85	169	217	-116.0	7.4	-98.7	-166.7
8/8/85	172	220	-122.0	7.4	-104.2	-172.2
8/9/85	173	221	-106.0	7.5	-89.5	-157.5
8/13/85	177	225	-117.0	9.6	-97.4	-165.4
8/19/85	183	231	-109.0	9.7	-89.9	-157.9
8/22/85	186	234	-113.0	9.8	-93.5	-161.5
8/26/85	190	238	-109.0	9.7	-89.9	-157.9
8/29/85	193	241	-113.0	9.8	-93.5	-161.5
9/2/85	197	245	-99.0	9.5	-80.9	-148.9
9/5/85	200	248	-115.0	9.5	-95.6	-163.6
9/9/85	204	252	-108.0	9.5	-89.2	-157.2
9/12/85	207	255	-122.0	9.5	-102.0	-170.0
9/17/85	212	260	-128.0	9.4	-107.7	-175.7
9/19/85	214	262	-116.0	9.4	-96.6	-164.6
9/23/85	218	266	-107.0	9.5	-88.3	-156.3

APPENDIX C– TENSIOMETRIC DATA

COLUMN 2

68.0 CM DEEP; TENSIOMETER 3

DATE	XD	JD	READING	H2O	PSI	TH
9/30/85	225	273	-120.0	9.5	-100.2	-168.2
10/7/85	232	280	-126.0	9.5	-105.7	-173.7
10/14/85	239	287				
10/17/85	242	290	-107.0	9.3	-88.5	-156.5
10/21/85	246	294	-60.0	9.3	-45.4	-113.4
10/29/85	254	302	-70.0	9.2	-54.6	-122.6
11/6/85	262	310				
11/13/85	269	317				
11/20/85	276	324	-78.0	8.9	-62.3	-130.3
11/27/85	283	331	-83.0	8.9	-66.9	-134.9
12/5/85	291	339	-87.0	8.9	-70.5	-138.5
12/13/85	299	347	-97.0	8.9	-79.7	-147.7
12/22/85	308	356	-90.0	8.8	-73.4	-141.4
12/31/85	317	365	-104.0	8.8	-86.3	-154.3
1/3/86	320	3	-97.0	9.1	-79.5	-147.5
1/11/86	328	11	-105.0	8.9	-87.1	-155.1
1/16/86	333	16	-108.0	8.9	-89.8	-157.8
1/22/86	339	22	-103.0	8.9	-85.2	-153.2
1/30/86	347	30	-103.0	8.9	-85.2	-153.2
2/6/86	354	37	-112.0	8.9	-93.5	-161.5
2/11/86	359	42	-116.0	8.9	-97.2	-165.2
2/19/86	367	50	-105.0	8.7	-87.3	-155.3
2/27/86	375	58	-115.0	8.5	-96.7	-164.7
3/5/86	381	64	-133.0	8.4	-113.3	-181.3
3/13/86	389	72				
3/19/86	395	78				
3/27/86	403	86	-95.0	8.4	-78.4	-146.4
4/3/86	410	93	-111.0	9.4	-92.1	-160.1
4/10/86	417	100	-109.0	9.3	-90.3	-158.3
4/17/86	424	107	-110.0	9.8	-90.7	-158.7
4/24/86	431	114	-112.0	8.9	-93.5	-161.5
5/1/86	438	121	-109.0	9.0	-90.6	-158.6
5/8/86	445	128	-127.0	9.5	-106.6	-174.6
5/19/86	456	139	-125.0	9.4	-104.9	-172.9
5/27/86	464	147	-128.0	9.3	-107.8	-175.8
6/3/86	471	154	-118.0	9.3	-98.6	-166.6
6/9/86	477	160	-118.0	9.4	-98.5	-166.5
6/16/86	484	167	-115.0	8.5	-96.7	-164.7
6/25/86	493	176	-50.0	9.4	-36.1	-104.1
7/2/86	500	183	-100.0	9.6	-81.7	-149.7
7/9/86	507	190	-104.0	9.5	-85.5	-153.5
7/16/86	514	197				
7/22/86	520	203				
7/30/86	528	211	-90.0	9.6	-72.6	-140.6
8/6/86	535	218	-93.0	9.0	-76.0	-144.0
8/13/86	542	225	-105.0	9.5	-86.4	-154.4
8/25/86	554	237	-125.0	9.5	-104.8	-172.8
9/2/86	562	245	-121.0	9.2	-101.4	-169.4
9/8/86	568	251	-110.0	9.0	-91.6	-159.6
9/15/86	575	258	-95.0	9.9	-76.8	-144.8
9/22/86	582	265	-92.0	9.7	-74.3	-142.3
9/29/86	589	272	-96.0	8.5	-79.2	-147.2
10/13/86	603	286	-57.0	9.8	-42.1	-110.1

APPENDIX C- TENSIOMETRIC DATA .

COLUMN 2

68.0 CM DEEP; TENSIOMETER 3

DATE	XD	JD	READING	H2O	PSI	TH
10/21/86	611	294	-83.0	9.7	-66.0	-134.0
10/28/86	618	301	-91.0	9.7	-73.4	-141.4
11/4/86	625	308	-77.0	9.7	-60.5	-128.5
11/11/86	632	315	-82.0	9.7	-65.1	-133.1
11/18/86	639	322	-87.0	9.6	-69.8	-137.8
11/25/86	646	329	-91.0	9.5	-73.6	-141.6
12/3/86	654	337	-87.0	9.4	-70.0	-138.0
12/11/86	662	345	-99.0	9.4	-81.0	-149.0
12/29/86	680	363	-80.0	8.5	-64.5	-132.5
1/7/87	689	7	-105.0	9.5	-86.4	-154.4
1/28/87	710	28	-54.0	7.7	-41.5	-109.5
2/3/87	716	34	-83.0	9.3	-66.5	-134.5
2/11/87	724	42	-83.0	9.2	-66.6	-134.6
2/18/87	731	49	-89.0	9.3	-72.0	-140.0
2/26/87	739	57	-91.0	9.2	-73.9	-141.9
3/3/87	744	62	-89.0	9.1	-72.2	-140.2
3/18/87	759	77	-89.0	8.0	-73.3	-141.3
4/8/87	780	98	-95.0	9.2	-77.6	-145.6
4/15/87	787	105	-97.0	8.2	-80.5	-148.5
4/28/87	800	118	-97.0	7.1	-81.6	-149.6
5/12/87	814	132	-112.0	9.0	-93.4	-161.4
5/25/87	827	145	-87.0	8.0	-71.5	-139.5
6/4/87	837	155	-102.0	8.8	-84.4	-152.4
6/23/87	856	174	-85.0	8.0	-69.7	-137.7
7/2/87	865	183	-103.0	7.5	-86.7	-154.7
7/13/87	876	194	-99.0	8.0	-82.5	-150.5
7/23/87	886	204	-102.0	7.8	-85.5	-153.5
7/31/87	894	212	-107.0	7.5	-90.4	-158.4
8/7/87	901	219	-104.0	7.5	-87.6	-155.6
8/14/87	908	226	-117.0	8.5	-98.5	-166.5
9/2/87	927	245	-103.0	8.8	-85.3	-153.3
9/9/87	934	252	-101.0	8.6	-83.7	-151.7
9/16/87	941	259	-99.0	8.7	-81.8	-149.8
9/28/87	953	271	-111.0	8.5	-93.0	-161.0
10/11/87	966	284	-117.0	8.5	-98.5	-166.5

APPENDIX C- TENSIOMETRIC DATA

			COLUMN 2
			GRADIENT
DATE	XD	JD	623
2/18/85	1	49	-0.2
2/19/85	2	50	0.0
2/20/85	3	51	-0.1
2/27/85	10	58	-1.2
3/1/85	12	60	-0.7
3/4/85	15	63	-1.1
3/7/85	18	66	
3/12/85	23	71	
3/19/85	30	78	
3/23/85	34	82	-0.2
3/25/85	36	84	
3/29/85	40	88	-0.1
4/1/85	43	91	-0.2
4/19/85	61	109	-0.2
4/22/85	64	112	0.2
4/25/85	67	115	0.1
4/29/85	71	119	0.2
5/2/85	74	122	
5/6/85	78	126	-0.1
5/10/85	82	130	-0.2
5/13/85	85	133	-0.1
5/16/85	88	136	
5/20/85	92	140	-0.4
5/24/85	96	144	0.3
5/28/85	100	148	0.7
5/30/85	102	150	-0.4
6/2/85	105	153	0.8
6/6/85	109	157	-0.2
6/10/85	113	161	0.4
6/13/85	116	164	0.3
6/21/85	124	172	0.5
6/24/85	127	175	-0.2
6/28/85	131	179	0.4
7/1/85	134	182	0.4
7/3/85	136	184	0.4
7/8/85	141	189	0.7
7/11/85	144	192	-0.7
7/15/85	148	196	
7/18/85	151	199	0.2
7/23/85	156	204	-0.0
7/25/85	158	206	0.8
7/30/85	163	211	-1.2
8/1/85	165	213	-0.4
8/5/85	169	217	-0.5
8/8/85	172	220	-0.6
8/9/85	173	221	0.1
8/13/85	177	225	0.1
8/19/85	183	231	0.2
8/22/85	186	234	-0.2
8/26/85	190	238	-1.0
8/29/85	193	241	
9/2/85	197	245	
9/5/85	200	248	-1.1
9/9/85	204	252	-0.1
9/12/85	207	255	-1.0
9/17/85	212	260	-1.0
9/19/85	214	262	0.0
9/23/85	218	266	0.5

APPENDIX C- TENSIOMETRIC DATA

			COLUMN 2 GRADIENT
DATE	XD	JD	G23
9/30/85	225	273	0.3
10/7/85	232	280	-0.2
10/14/85	239	287	
10/17/85	242	290	-3.8
10/21/85	246	294	-0.7
10/29/85	254	302	-0.5
11/6/85	262	310	
11/13/85	269	317	
11/20/85	276	324	-0.3
11/27/85	283	331	-0.5
12/5/85	291	339	-0.7
12/13/85	299	347	
12/22/85	308	356	-0.9
12/31/85	317	365	-0.4
1/3/86	320	3	-0.5
1/11/86	328	11	-0.9
1/16/86	333	16	-0.3
1/22/86	339	22	-0.2
1/30/86	347	30	-0.5
2/6/86	354	37	-0.4
2/11/86	359	42	-0.1
2/19/96	367	50	-0.2
2/27/86	375	58	-0.1
3/5/86	381	64	-1.3
3/13/86	389	72	
3/19/86	395	78	
3/27/86	403	86	0.2
4/3/86	410	93	0.4
4/10/86	417	100	-0.0
4/17/86	424	107	0.4
4/24/86	431	114	0.2
5/1/86	438	121	0.7
5/8/86	445	128	-0.0
5/19/86	456	139	-0.5
5/27/86	464	147	1.2
6/3/86	471	154	0.7
6/9/86	477	160	-0.8
6/16/86	484	167	-0.0
6/25/86	493	176	-1.8
7/2/86	500	183	-0.9
7/9/86	507	190	-0.7
7/16/86	514	197	
7/22/86	520	203	
7/30/86	528	211	0.1
8/6/86	535	218	0.3
8/13/86	542	225	0.1
8/25/86	554	237	-0.4
9/2/86	562	245	-1.3
9/8/86	568	251	-0.5
9/15/86	575	258	
9/22/86	582	265	-0.6
9/29/86	589	272	-0.4
10/13/86	603	286	-0.5

APPENDIX C– TENSIOMETRIC DATA

COLUMN 2

GRADIENT

DATE	XD	JD	G23
10/21/86	611	294	-0.6
10/28/86	618	301	-0.4
11/4/86	625	308	-1.5
11/11/86	632	315	-0.4
11/18/86	639	322	-0.2
11/25/86	646	329	-0.1
12/3/86	654	337	-0.2
12/11/86	662	345	
12/29/86	680	363	0.2
1/7/87	689	7	-0.6
1/28/87	710	28	-5.2
2/3/87	716	34	-1.0
2/11/87	724	42	-0.8
2/18/87	731	49	-0.3
2/26/87	739	57	-0.5
3/3/87	744	62	-0.6
3/18/87	759	77	-0.5
4/8/87	780	98	-0.5
4/15/87	787	105	-0.4
4/28/87	800	118	-0.5
5/12/87	814	132	-0.7
5/25/87	827	145	0.1
6/4/87	837	155	-0.3
6/23/87	856	174	0.4
7/2/87	865	183	-0.6
7/13/87	876	194	0.4
7/23/87	886	204	-0.6
7/31/87	894	212	-0.6
8/7/87	901	219	-0.3
8/14/87	908	226	-0.4
9/2/87	927	245	0.0
9/9/87	934	252	-0.2
9/16/87	941	259	-0.2
9/28/87	953	271	0.0
10/11/87	966	284	-0.9

COLUMN 3

TENSIOMETER 1 31.5 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
2/18/85	1	49	−310.0	7.5	−276.1	−307.6
2/19/85	2	50	−361.0	7.5	−322.8	−354.3
2/20/85	3	51	−285.0	7.5	−253.2	−284.7
2/27/85	10	58	−145.0	6.5	−126.0	−157.5
3/1/85	12	60				
3/4/85	15	63				
3/7/85	18	66				
3/12/85	23	71				
3/19/85	30	78				
3/23/85	34	82	−192.0	8.8	−166.7	−198.2
3/29/85	40	88	−288.0	8.8	−255.2	−286.7
4/1/85	43	91	−241.0	8.8	−212.0	−243.5
4/19/85	61	109	−252.0	8.5	−222.4	−253.9
4/22/85	64	112	−290.0	8.2	−257.6	−289.1
4/25/85	67	115	−171.0	6.7	−149.9	−181.4
4/29/85	71	119	−264.0	8.9	−233.0	−264.5
5/2/85	74	122	−194.0	7.9	−169.8	−201.3
5/6/85	78	126	−224.0	7.5	−197.8	−229.3
5/10/85	82	130	−274.0	7.3	−243.9	−275.4
5/13/85	85	133				
5/16/85	88	136	−299.0	7.5	−266.6	−298.1
5/20/85	92	140				
5/24/85	96	144				
5/28/85	100	148				
5/30/85	102	150				
6/2/85	105	153	−265.0	8.7	−234.1	−265.6
6/6/85	109	157	−274.0	7.8	−243.3	−274.8
6/10/85	113	161	−322.0	8.6	−286.5	−318.0
6/13/85	116	164	−321.0	7.3	−286.9	−318.4
6/21/85	124	172	−325.0	8.6	−289.3	−320.8
6/24/85	127	175				
6/28/85	131	179	−306.0	6.9	−273.6	−305.1
7/1/85	134	182	−319.0	8.0	−284.4	−315.9
7/3/85	136	184	−324.0	7.0	−290.1	−321.6
7/8/85	141	189				
7/11/85	144	192				
7/15/85	148	196	−289.0	7.7	−257.2	−288.7
7/18/85	151	199				
7/23/85	156	204	−162.0	6.9	−141.5	−173.0
7/25/85	158	206				
7/30/85	163	211	−238.0	9.0	−209.0	−240.5
8/1/85	165	213	−189.0	8.4	−164.7	−196.2
8/5/85	169	217				
8/8/85	172	220				
8/9/85	173	221				
8/13/85	177	225				
8/19/85	183	231				
8/22/85	186	234				
8/26/85	190	238	−126.0	8.8	−106.4	−137.9
8/29/85	193	241	−219.0	8.7	−191.9	−223.4
9/2/85	197	245	−177.0	8.8	−153.3	−184.8
9/5/85	200	248	−247.0	8.4	−217.9	−249.4
9/9/85	204	252	−153.0	8.5	−131.5	−163.0
9/12/85	207	255	−177.0	8.4	−153.7	−185.2
9/17/85	212	260				
9/19/85	214	262				
9/23/85	218	266				
9/30/85	225	273	−148.0	9.3	−126.1	−157.6
10/7/85	232	280	−112.0	7.9	−94.5	−126.0
10/14/85	239	287				
10/17/85	242	290				
10/21/85	246	294	−80.0	8.8	−64.2	−95.7

APPENDIX C- TENSIOMETRIC DATA

COLUMN 3

31.5 CM DEEP; TENSIOMETER 1

DATE	XD	JD	READING	H2O	PSI	TH
10/29/85	254	302	-123.0	8.8	-103.7	-135.2
11/6/85	262	310	-135.0	8.7	-114.8	-146.3
11/13/85	269	317	-109.0	9.2	-90.4	-121.9
11/20/85	276	324	-173.0	8.9	-149.5	-181.0
11/27/85	283	331	-134.0	8.5	-114.1	-145.6
12/5/85	291	339	-189.0	8.8	-164.3	-195.8
12/13/85	299	347	-205.0	8.7	-179.1	-210.6
12/22/85	308	356	-174.0	8.6	-150.7	-182.2
12/31/85	317	365	-172.0	9.0	-148.5	-180.0
1/3/86	320	3	-180.0	9.0	-155.8	-187.3
1/11/86	328	11	-167.0	9.0	-143.9	-175.4
1/16/86	333	16	-151.0	9.0	-129.2	-160.7
1/22/86	339	22	-184.0	9.0	-159.5	-191.0
1/30/86	347	30	-193.0	8.7	-168.0	-199.5
2/6/86	354	37	-208.0	8.7	-181.8	-213.3
2/11/86	359	42	-209.0	8.7	-182.7	-214.2
2/19/86	367	50	-166.0	9.0	-143.0	-174.5
2/27/86	375	58	-192.0	9.0	-166.8	-198.3
3/5/86	381	64	-190.0	8.9	-165.1	-196.6
3/13/86	389	72	-219.0	9.0	-191.6	-223.1
3/19/86	395	78	-227.0	9.0	-198.9	-230.4
3/27/86	403	86				
4/3/86	410	93	-276.0	9.5	-243.4	-274.9
4/10/86	417	100	-255.0	9.0	-224.6	-256.1
4/17/86	424	107	-271.0	8.6	-239.7	-271.2
4/24/86	431	114	-280.0	8.9	-247.7	-279.2
5/1/86	438	121	-284.0	9.5	-250.7	-282.2
5/8/86	445	128				
5/19/86	456	139	-174.0	9.5	-149.8	-181.3
5/27/86	464	147	-155.0	9.5	-132.3	-163.8
6/3/86	471	154	-122.0	9.4	-102.1	-133.6
6/9/86	477	160	-125.0	8.9	-105.4	-136.9
6/16/86	484	167	-141.0	9.0	-120.0	-151.5
6/25/86	493	176	-38.0	9.4	-25.1	-56.6
7/2/86	500	183	-83.0	9.0	-66.8	-98.3
7/9/86	507	190	-106.0	9.0	-87.9	-119.4
7/16/86	514	197	-122.0	9.3	-102.3	-133.8
7/22/86	520	203	-142.0	9.3	-120.6	-152.1
7/30/86	528	211	-144.0	9.0	-122.8	-154.3
8/6/86	535	218	-177.0	9.0	-153.0	-184.5
8/13/86	542	225	-153.0	7.3	-132.8	-164.3
8/25/86	554	237	-175.0	8.8	-151.4	-182.9
9/2/86	562	245	-146.0	9.3	-124.3	-155.8
9/8/86	568	251	-139.0	9.3	-117.9	-149.4
9/15/86	575	258	-147.0	8.9	-125.6	-157.1
9/22/86	582	265	-144.0	9.3	-122.4	-153.9
9/29/86	589	272	-121.0	9.3	-101.3	-132.8
10/13/86	603	286	-53.0	9.0	-39.2	-70.7
10/21/86	611	294	-65.0	8.7	-50.6	-82.1
10/28/86	618	301	-88.0	8.9	-71.5	-103.0
11/4/86	625	308	-59.0	8.9	-44.9	-76.4
11/11/86	632	315	-58.0	8.9	-43.9	-75.4
11/18/86	639	322	-71.0	8.7	-56.1	-87.6

APPENDIX C- TENSIOMETRIC DATA

COLUMN 3

31.5 CM DEEP; TENSIOMETER 1

DATE	XD	JD	READING	H2O	PSI	TH
11/25/86	646	329	-85.0	8.7	-68.9	-100.4
12/3/86	654	337	-71.0	8.6	-56.2	-87.7
12/11/86	662	345	-150.0	7.1	-130.3	-161.8
12/29/86	680	363	-76.0	8.5	-60.9	-92.4
1/7/87	689	7	-69.0	8.9	-54.0	-85.5
1/20/87	702	20	-299.0	7.0	-267.1	-298.6
1/28/87	710	28	-124.0	7.0	-106.5	-138.0
2/3/87	716	34	-102.0	9.0	-84.2	-115.7
2/11/87	724	42	-113.0	9.0	-94.3	-125.8
2/18/87	731	49	-147.0	9.0	-125.5	-157.0
2/26/87	739	57	-86.0	9.0	-69.5	-101.0
3/3/87	744	62	-69.0	8.8	-54.1	-85.6
3/18/87	759	77	-95.0	7.0	-79.9	-111.4
4/8/87	780	98	-175.0	7.5	-152.8	-184.3
4/15/87	787	105	-138.0	9.3	-116.9	-148.4
4/28/87	800	118				
5/25/87	827	145				
6/4/87	837	155	-357.0	6.8	-320.6	-352.1
6/23/87	856	174	-365.0	6.0	-328.7	-360.2
7/2/87	865	183	-162.0	7.0	-141.4	-172.9
7/13/87	876	194	-308.0	7.0	-275.4	-306.9
7/23/87	886	204				
7/31/87	894	212	-346.0	7.0	-310.2	-341.7
8/7/87	901	219	-272.0	8.5	-240.8	-272.3
8/14/87	908	226	-122.0	8.5	-103.1	-134.6
9/2/87	927	245	-71.0	4.5	-60.5	-92.0
9/9/87	934	252	-102.0	9.1	-84.1	-115.6
9/16/87	941	259	-117.0	9.0	-98.0	-129.5
9/28/87	953	271	-206.0	7.8	-180.9	-212.4
10/11/87	966	284	-237.0	9.3	-207.8	-239.3

COLUMN 3

TENSIOMETER 2 46.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
2/18/85	1	49	-132.0	8.0	-112.5	-158.5
2/19/85	2	50				
2/20/85	3	51				
2/27/85	10	58				
3/1/85	12	60				
3/4/85	15	63				
3/7/85	18	66				
3/12/85	23	71				
3/19/85	30	78				
3/23/85	34	82				
3/25/85	36	84				
3/29/85	40	88	-204.0	9.8	-176.6	-222.6
4/1/85	43	91	-169.0	9.7	-145.0	-191.0
4/19/85	61	109	-187.0	8.1	-163.2	-209.2
4/22/85	64	112	-179.0	10.6	-153.2	-199.2
4/25/85	67	115	-198.0	8.8	-172.5	-218.5
4/29/85	71	119				
5/2/85	74	122	-175.0	8.8	-151.4	-197.4
5/6/85	78	126	-155.0	8.5	-133.4	-179.4
5/10/85	82	130	-205.0	8.5	-179.3	-225.3
5/13/85	85	133	-195.0	7.6	-171.0	-217.0
5/16/85	88	136				
5/20/85	92	140	-206.0	8.3	-180.4	-226.4
5/24/85	96	144	-206.0	7.2	-181.5	-227.5
5/28/85	100	148	-173.0	7.5	-150.9	-196.9
5/30/85	102	150	-191.0	6.6	-168.4	-214.4
6/2/85	105	153	-201.0	9.6	-174.4	-220.4
6/6/85	109	157	-212.0	9.4	-184.8	-230.8
6/10/85	113	161	-233.0	8.5	-205.0	-251.0
6/13/85	116	164	-245.0	8.5	-216.0	-262.0
6/21/85	124	172	-239.0	8.6	-210.4	-256.4
6/24/85	127	175	-222.0	7.4	-196.0	-242.0
6/28/85	131	179	-223.0	7.9	-196.4	-242.4
7/1/85	134	182				
7/3/85	136	184	-185.0	6.9	-162.6	-208.6
7/8/85	141	189				
7/11/85	144	192	-146.0	6.9	-126.8	-172.8
7/15/85	148	196				
7/18/85	151	199				
7/23/85	156	204				
7/25/85	158	206	-169.0	9.2	-145.5	-191.5
7/30/85	163	211	-192.0	9.1	-166.8	-212.8
8/1/85	165	213	-175.0	8.5	-151.7	-197.7
8/5/85	169	217	-158.0	10.6	-133.9	-179.9
8/8/85	172	220	-153.0	13.1	-126.7	-172.7
8/9/85	173	221	-147.0	9.1	-125.4	-171.4
8/13/85	177	225	-157.0	9.0	-134.7	-180.7
8/19/85	183	231	-159.0	9.0	-136.5	-182.5
8/22/85	186	234	-155.0	8.6	-133.3	-179.3
8/26/85	190	238	-157.0	8.4	-135.3	-181.3
8/29/85	193	241	-168.0	8.3	-145.5	-191.5
9/2/85	197	245	-196.0	8.3	-171.2	-217.2
9/5/85	200	248	-199.0	7.9	-174.4	-220.4
9/9/85	204	252				
9/12/85	207	255				
9/17/85	212	260				
9/19/85	214	262				
9/23/85	218	266	-106.0	7.2	-89.8	-135.8
9/30/85	225	273	-65.0	8.7	-50.6	-96.6
10/7/85	232	280	-121.0	9.4	-101.2	-147.2
10/14/85	239	287	-60.0	8.7	-46.0	-92.0
10/17/85	242	290	-72.0	9.4	-56.3	-102.3
10/21/85	246	294	-53.0	9.0	-39.2	-85.2

APPENDIX C- TENSIOMETRIC DATA

COLUMN 3

46.0 CM DEEP; TENSIOMETER 2

DATE	XD	JD	READING	H2O	PSI	TH
10/29/85	254	302	−83.0	9.0	−66.8	−112.8
11/6/85	262	310	−88.0	9.0	−71.4	−117.4
11/13/85	269	317	−99.0	9.4	−81.0	−127.0
11/20/85	276	324	−95.0	9.4	−77.4	−123.4
11/27/85	283	331	−112.0	8.7	−93.7	−139.7
12/5/85	291	339	−128.0	9.0	−108.1	−154.1
12/13/85	299	347	−166.0	8.7	−143.3	−189.3
12/22/85	308	356	−148.0	9.3	−126.1	−172.1
12/31/85	317	365				
1/3/86	320	3	−143.0	9.2	−121.6	−167.6
1/11/86	328	11				
1/16/86	333	16	−130.0	7.3	−111.7	−157.7
1/22/86	339	22				
1/30/86	347	30	−155.0	9.4	−132.4	−178.4
2/6/86	354	37	−168.0	9.3	−144.5	−190.5
2/11/86	359	42	−178.0	9.9	−153.0	−199.0
2/19/86	367	50	−131.0	9.4	−110.4	−156.4
2/27/86	375	58	−142.0	8.8	−121.1	−167.1
3/5/86	381	64	−132.0	9.6	−111.1	−157.1
3/13/86	389	72	−173.0	9.1	−149.3	−195.3
3/19/86	395	78	−177.0	8.8	−153.3	−199.3
3/27/86	403	86	−146.0	9.7	−123.9	−169.9
4/3/86	410	93	−204.0	9.7	−177.1	−223.1
4/10/86	417	100	−165.0	9.5	−141.5	−187.5
4/17/86	424	107	−208.0	9.2	−181.3	−227.3
4/24/86	431	114				
5/1/86	438	121	−159.0	8.0	−137.6	−183.6
5/8/86	445	128	−184.0	8.9	−159.6	−205.6
5/19/86	456	139	−122.0	8.8	−102.8	−148.8
5/27/86	464	147	−194.0	9.5	−168.1	−214.1
6/3/86	471	154	−181.0	9.4	−156.3	−202.3
6/9/86	477	160	−180.0	9.7	−155.1	−201.1
6/16/86	484	167	−168.0	8.8	−145.0	−191.0
6/25/86	493	176	−80.0	9.4	−63.6	−109.6
7/2/86	500	183	−74.0	10.0	−57.5	−103.5
7/9/86	507	190	−91.0	9.5	−73.6	−119.6
7/16/86	514	197	−102.0	9.2	−84.0	−130.0
7/22/86	520	203	−115.0	9.2	−95.9	−141.9
7/30/86	528	211	−125.0	9.5	−104.8	−150.8
8/6/86	535	218	−142.0	9.2	−120.7	−166.7
8/13/86	542	225	−154.0	9.1	−131.8	−177.8
8/25/86	554	237	−145.0	8.8	−123.9	−169.9
9/2/86	562	245	−136.0	9.5	−114.9	−160.9
9/8/86	568	251	−134.0	9.3	−113.3	−159.3
9/15/86	575	258	−134.0	9.7	−112.9	−158.9
9/22/86	582	265	−135.0	8.8	−114.7	−160.7
9/29/86	589	272	−132.0	8.9	−111.9	−157.9
10/13/86	603	286	−40.0	9.2	−27.1	−73.1
10/21/86	611	294	−67.0	8.0	−53.1	−99.1
10/28/86	618	301	−81.0	9.4	−64.5	−110.5
11/4/86	625	308	−65.0	9.0	−50.3	−96.3
11/11/86	632	315	−66.0	9.0	−51.2	−97.2
11/18/86	639	322	−80.0	9.0	−64.0	−110.0

APPENDIX C- TENSIOMETRIC DATA

COLUMN 3

46.0 CM DEEP; TENSIOMETER 2

DATE	XD	JD	READING	H2O	PSI	TH
11/25/86	646	329	-89.0	9.0	-72.3	-118.3
12/3/86	654	337	-84.0	8.9	-67.8	-113.8
12/11/86	662	345	-108.0	8.8	-89.9	-135.9
12/29/86	680	363	-73.0	9.3	-57.3	-103.3
1/7/87	689	7	-94.0	13.2	-72.5	-118.5
1/20/87	702	20	-186.0	13.1	-157.0	-203.0
1/28/87	710	28	-77.0	12.8	-57.3	-103.3
2/3/87	716	34	-84.0	12.5	-64.0	-110.0
2/11/87	724	42	-91.0	11.8	-71.2	-117.2
2/18/87	731	49	-133.0	14.2	-107.2	-153.2
2/26/87	739	57	-120.0	14.0	-95.5	-141.5
3/3/87	744	62	-91.0	14.0	-68.9	-114.9
3/18/87	759	77	-110.0	12.0	-88.4	-134.4
4/8/87	780	98	-156.0	12.0	-130.6	-176.6
4/15/87	787	105				
4/28/87	800	118				
5/25/87	827	145				
6/4/87	837	155				
6/23/87	856	174	-200.0	13.4	-169.6	-215.6
7/2/87	865	183	-169.0	13.2	-141.3	-187.3
7/13/87	876	194	-250.0	13.0	-215.9	-261.9
7/23/87	886	204	-239.0	11.1	-207.8	-253.8
7/31/87	894	212	-234.0	12.5	-201.7	-247.7
8/7/87	901	219	-251.0	10.5	-219.4	-265.4
8/14/87	908	226	-162.0	14.0	-134.1	-180.1
9/2/87	927	245	-98.0	12.5	-76.9	-122.9
9/9/87	934	252				
9/16/87	941	259	-87.0	13.0	-66.3	-112.3
9/28/87	953	271	-149.0	13.0	-123.2	-169.2
10/11/87	966	284	-163.0	9.3	-139.9	-185.9

COLUMN 3

TENSIOMETER 3 65.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
2/18/85	1	49	-100.0	16.5	-74.4	-139.4
2/19/85	2	50	-139.0	16.5	-110.1	-175.1
2/20/85	3	51	-102.0	16.0	-76.7	-141.7
2/27/85	10	58				
3/1/85	12	60				
3/4/85	15	63				
3/7/85	18	66				
3/12/85	23	71				
3/19/85	30	78				
3/23/85	34	82				
3/25/85	36	84				
3/29/85	40	88	-130.0	9.5	-109.4	-174.4
4/1/85	43	91	-106.0	9.5	-87.4	-152.4
4/19/85	61	109	-134.0	8.7	-113.9	-178.9
4/22/85	64	112	-118.0	8.8	-99.2	-164.2
4/25/85	67	115	-130.0	8.5	-110.4	-175.4
4/29/85	71	119	-131.0	8.6	-111.2	-176.2
5/2/85	74	122	-129.0	8.5	-109.5	-174.5
5/6/85	78	126				
5/10/85	82	130	-117.0	8.0	-99.0	-164.0
5/13/85	85	133	-145.0	9.0	-123.7	-188.7
5/16/85	88	136	-141.0	7.8	-121.3	-186.3
5/20/85	92	140	-152.0	9.5	-129.6	-194.6
5/24/85	96	144	-133.0	9.1	-112.6	-177.6
5/28/85	100	148	-106.0	9.0	-87.9	-152.9
5/30/85	102	150	-156.0	8.6	-134.2	-199.2
6/2/85	105	153	-121.0	8.3	-102.4	-167.4
6/6/85	109	157				
6/10/85	113	161	-113.0	7.6	-95.8	-160.8
6/13/85	116	164	-120.0	7.0	-102.8	-167.8
6/21/85	124	172	-117.0	8.3	-98.7	-163.7
6/24/85	127	175				
6/28/85	131	179				
7/1/85	134	182	-125.0	0.0	-114.7	-179.7
7/3/85	136	184	-126.0	7.8	-107.5	-172.5
7/8/85	141	189	-144.0	8.5	-123.3	-188.3
7/11/85	144	192	-134.0	7.6	-115.0	-180.0
7/15/85	148	196				
7/18/85	151	199	-121.0	7.3	-103.4	-168.4
7/23/85	156	204	-140.0	7.6	-120.6	-185.6
7/25/85	158	206	-127.0	9.0	-107.2	-172.2
7/30/85	163	211	-151.0	7.1	-131.2	-196.2
8/1/85	165	213	-110.0	7.0	-93.6	-158.6
8/5/85	169	217				
8/8/85	172	220	-113.0	7.7	-95.7	-160.7
8/9/85	173	221	-107.0	8.8	-89.0	-154.0
8/13/85	177	225	-118.0	7.0	-101.0	-166.0
8/19/85	183	231	-129.0	9.7	-108.3	-173.3
8/22/85	186	234	-124.0	9.5	-103.9	-168.9
8/26/85	190	238	-120.0	9.0	-100.7	-165.7
8/29/85	193	241	-140.0	8.3	-119.8	-184.8
9/2/85	197	245	-125.0	8.4	-105.9	-170.9
9/5/85	200	248	-155.0	8.2	-133.7	-198.7
9/9/85	204	252	-138.0	8.2	-118.1	-183.1
9/12/85	207	255	-128.0	8.4	-108.7	-173.7
9/17/85	212	260	-130.0	9.0	-109.9	-174.9
9/19/85	214	262	-122.0	9.0	-102.6	-167.6
9/23/85	218	266	-109.0	9.0	-90.6	-155.6
9/30/85	225	273				
10/7/85	232	280	-68.0	9.3	-52.7	-117.7
10/14/85	239	287				
10/17/85	242	290				
10/21/85	246	294	-61.0	9.3	-46.3	-111.3

APPENDIX C- TENSIOMETRIC DATA

COLUMN 3

65.0 CM DEEP; TENSIOMETER 3

DATE	XD	JD	READING	H2O	PSI	TH
10/29/85	254	302				
11/6/85	262	310				
11/13/85	269	317				
11/20/85	276	324				
11/27/85	283	331				
12/5/85	291	339				
12/13/85	299	347	-45.0	9.5	-31.4	-96.4
12/22/85	308	356				
12/31/85	317	365	-74.0	8.8	-58.7	-123.7
1/3/86	320	3				
1/11/86	328	11				
1/16/86	333	16				
1/22/86	339	22				
1/30/86	347	30				
2/6/86	354	37				
2/11/86	359	42				
2/19/86	367	50	-120.0	9.4	-100.3	-165.3
2/27/86	375	58	-113.0	9.4	-93.9	-158.9
3/5/86	381	64				
3/13/86	389	72	-134.0	9.6	-113.0	-178.0
3/19/86	395	78				
3/27/86	403	86	-126.0	8.7	-106.6	-171.6
4/3/86	410	93	-139.0	9.7	-117.4	-182.4
4/10/86	417	100				
4/17/86	424	107	-128.0	9.0	-108.1	-173.1
4/24/86	431	114	-158.0	9.7	-134.9	-199.9
5/1/86	438	121	-115.0	9.5	-95.6	-160.6
5/8/86	445	128	-137.0	10.1	-115.2	-180.2
5/19/86	456	139	-148.0	10.0	-125.4	-190.4
5/27/86	464	147	-100.0	9.5	-81.9	-146.9
6/3/86	471	154	-94.0	9.5	-76.3	-141.3
6/9/86	477	160	-110.0	9.5	-91.0	-156.0
6/16/86	484	167	-120.0	10.0	-99.7	-164.7
6/25/86	493	176	-43.0	9.5	-29.5	-94.5
7/2/86	500	183	-75.0	9.5	-58.9	-123.9
7/9/86	507	190	-79.0	9.5	-62.6	-127.6
7/16/86	514	197	-82.0	9.5	-65.3	-130.3
7/22/86	520	203	-97.0	9.6	-79.0	-144.0
7/30/86	528	211	-99.0	10.0	-80.4	-145.4
8/6/86	535	218	-103.0	9.5	-84.6	-149.6
8/13/86	542	225	-120.0	9.8	-99.9	-164.9
8/25/86	554	237	-131.0	9.6	-110.2	-175.2
9/2/86	562	245	-133.0	9.5	-112.1	-177.1
9/8/86	568	251	-124.0	9.5	-103.9	-168.9
9/15/86	575	258	-124.0	9.6	-103.8	-168.8
9/22/86	582	265	-123.0	9.5	-103.0	-168.0
9/29/86	589	272	-126.0	9.6	-105.6	-170.6
10/13/86	603	286	-123.0	9.5	-103.0	-168.0
10/21/86	611	294	-61.0	9.5	-46.1	-111.1
10/28/86	618	301	-73.0	9.5	-57.1	-122.1
11/4/86	625	308	-84.0	9.5	-67.2	-132.2
11/11/86	632	315	-79.0	9.5	-62.6	-127.6
11/18/86	639	322	-70.0	9.5	-54.3	-119.3

APPENDIX C- TENSIOMETRIC DATA

COLUMN 3

65.0 CM DEEP; TENSIOMETER 3

DATE	XD	JD	READING	H2O	PSI	TH
11/25/86	646	329	-76.0	9.5	-59.8	-124.8
12/3/86	654	337	-72.0	9.5	-56.2	-121.2
12/11/86	662	345	-87.0	9.5	-69.9	-134.9
12/29/86	680	363	-83.0	9.5	-66.3	-131.3
1/7/87	689	7	-98.0	9.5	-80.0	-145.0
1/20/87	702	20	-87.0	9.5	-69.9	-134.9
1/28/87	710	28	-81.0	9.5	-64.4	-129.4
2/3/87	716	34	-68.0	8.4	-53.6	-118.6
2/11/87	724	42	-65.0	7.1	-52.2	-117.2
2/18/87	731	49	-91.0	8.8	-74.3	-139.3
2/26/87	739	57	-76.0	5.0	-64.5	-129.5
3/3/87	744	62	-61.0	7.0	-48.7	-113.7
3/18/87	759	77	-50.0	5.0	-40.7	-105.7
4/8/87	780	98	-45.0	5.0	-36.1	-101.1
4/15/87	787	105	0.0	9.5	9.9	-55.1
4/28/87	800	118	-26.0	9.6	-13.8	-78.8
5/25/87	827	145	-151.0	9.1	-129.1	-194.1
6/4/87	837	155	-153.0	9.0	-131.0	-196.0
6/23/87	856	174	-165.0	9.3	-141.7	-206.7
7/2/87	865	183	-138.0	9.2	-117.0	-182.0
7/13/87	876	194	-178.0	9.0	-154.0	-219.0
7/23/87	886	204	-164.0	9.1	-141.0	-206.0
7/31/87	894	212	-163.0	9.0	-140.2	-205.2
8/7/87	901	219	-168.0	9.0	-144.8	-209.8
8/14/87	908	226	-154.0	9.0	-131.9	-196.9
9/2/87	927	245	-128.0	9.0	-108.1	-173.1
9/9/87	934	252	-82.0	9.6	-65.2	-130.2
9/16/87	941	259	-74.0	9.6	-57.9	-122.9
9/28/87	953	271	-95.0	9.6	-77.2	-142.2
10/11/87	966	284	-73.0	9.5	-57.1	-122.1

APPENDIX C- TENSIOMETRIC DATA

COLUMN 3 GRADIENTS

DATE	XD	JD	G12	G13	G23
2/18/85	1	49	10.3	5.0	1.0
2/19/85	2	50		5.4	
2/20/85	3	51		4.3	
2/27/85	10	58			
3/23/85	34	82			
3/29/85	40	88	4.4	3.4	2.6
4/1/85	43	91	3.6	2.7	2.0
4/19/85	61	109	3.1	2.2	1.6
4/22/85	64	112	6.2	3.7	1.8
4/25/85	67	115	-2.6	0.2	2.3
4/29/85	71	119		2.6	
5/2/85	74	122	0.3	0.8	1.2
5/6/85	78	126	3.4		
5/10/85	82	130	3.5	3.3	3.2
5/13/85	85	133			1.5
5/16/85	88	136		3.3	
5/20/85	92	140			1.7
5/24/85	96	144			2.6
5/28/85	100	148			2.3
5/30/85	102	150			0.8
6/2/85	105	153	3.1	2.9	2.8
6/6/85	109	157	3.0		
6/10/85	113	161	4.6	4.7	4.7
6/13/85	116	164	3.9	4.5	5.0
6/21/85	124	172	4.4	4.7	4.9
6/24/85	127	175			
6/28/85	131	179	4.3		
7/1/85	134	182		4.1	
7/3/85	136	184	7.8	4.4	1.9
7/8/85	141	189			
7/11/85	144	192			-0.4
7/15/85	148	196			
7/18/85	151	199			
7/23/85	156	204		-0.4	
7/25/85	158	206			1.0
7/30/85	163	211	1.9	1.3	0.9
8/1/85	165	213	-0.1	1.1	2.1
8/5/85	169	217			
8/8/85	172	220			0.6
8/9/85	173	221			0.9
8/13/85	177	225			0.8
8/19/85	183	231			0.5
8/22/85	186	234			0.5
8/26/85	190	238	-3.0	-0.8	0.8
8/29/85	193	241	2.2	1.2	0.4
9/2/85	197	245	-2.2	0.4	2.4
9/5/85	200	248	2.0	1.5	1.1
9/9/85	204	252		-0.6	
9/12/85	207	255		0.3	
9/17/85	212	260			
9/19/85	214	262			

APPENDIX C- TENSIOMETRIC DATA

COLUMN 3

			GRADIENTS		
DATE	XD	JD	G12	G13	G23
9/23/85	218	266			-1.0
9/30/85	225	273	4.2		
10/7/85	232	280	-1.5	0.2	1.6
10/14/85	239	287			
10/17/85	242	290			
10/21/85	246	294	0.7	-0.5	-1.4
10/29/85	254	302	1.5		
11/6/85	262	310	2.0		
11/13/85	269	317	-0.4		
11/20/85	276	324	4.0		
11/27/85	283	331	0.4		
12/5/85	291	339	2.9		
12/13/85	299	347	1.5	3.4	4.9
12/22/85	308	356	0.7		
12/31/85	317	365		1.7	
1/3/86	320	3	1.4		
1/11/86	328	11			
1/16/86	333	16	0.2		
1/22/86	339	22			
1/30/86	347	30	1.5		
2/6/86	354	37	1.6		
2/11/86	359	42	1.0		
2/19/86	367	50	1.2	0.3	-0.5
2/27/86	375	58	2.2	1.2	0.4
3/5/86	381	64	2.7		
3/13/86	389	72	1.9	1.3	0.9
3/19/86	395	78	2.2		
3/27/86	403	86			-0.1
4/3/86	410	93	3.6	2.8	2.1
4/10/86	417	100	4.7		
4/17/86	424	107	3.0	2.9	2.9
4/24/86	431	114		2.4	
5/1/86	438	121	6.8	3.6	1.2
5/8/86	445	128			1.3
5/19/86	456	139	2.2	-0.3	-2.2
5/27/86	464	147	-3.5	0.5	3.5
6/3/86	471	154	-4.7	-0.2	3.2
6/9/86	477	160	-4.4	-0.6	2.4
6/16/86	484	167	-2.7	-0.4	1.4
6/25/86	493	176	-3.7	-1.1	0.8
7/2/86	500	183	-0.4	-0.8	-1.1
7/9/86	507	190	-0.0	-0.2	-0.4
7/16/86	514	197	0.3	0.1	-0.0
7/22/86	520	203	0.7	0.2	-0.1
7/30/86	528	211	0.2	0.3	0.3
8/6/86	535	218	1.2	1.0	0.9
8/13/86	542	225	-0.9	-0.0	0.7
8/25/86	554	237	0.9	0.2	-0.3
9/2/86	562	245	-0.4	-0.6	-0.9
9/8/86	568	251	-0.7	-0.6	-0.5
9/15/86	575	258	-0.1	-0.3	-0.5
9/22/86	582	265	-0.5	-0.4	-0.4
9/29/86	589	272	-1.7	-1.1	-0.7

APPENDIX C- TENSIOMETRIC DATA

COLUMN 3

DATE	XD	JD	GRADIENTS G12	G13	G23
10/13/86	603	286	-0.2	-2.9	-5.0
10/21/86	611	294	-1.2	-0.9	-0.6
10/28/86	618	301	-0.5	-0.6	-0.6
11/4/86	625	308	-1.4	-1.7	-1.9
11/11/86	632	315	-1.5	-1.6	-1.6
11/18/86	639	322	-1.5	-0.9	-0.5
11/25/86	646	329	-1.2	-0.7	-0.3
12/3/86	654	337	-1.8	-1.0	-0.4
12/11/86	662	345	1.8	0.8	0.1
12/29/86	680	363	-0.8	-1.2	-1.5
1/7/87	689	7	-2.3	-1.8	-1.4
1/20/87	702	20	6.6	4.9	3.6
1/28/87	710	28	2.4	0.3	-1.4
2/3/87	716	34	0.4	-0.1	-0.5
2/11/87	724	42	0.6	0.3	-0.0
2/18/87	731	49	0.3	0.5	0.7
2/26/87	739	57	-2.8	-0.9	0.6
3/3/87	744	62	-2.0	-0.8	0.1
3/18/87	759	77	-1.6	0.2	1.5
4/8/87	780	98	0.5	2.5	4.0
4/15/87	787	105		2.8	
4/28/87	800	118			
5/25/87	827	145			
6/4/87	837	155		4.7	
6/23/87	856	174	10.0	4.6	0.5
7/2/87	865	183	-1.0	-0.3	0.3
7/13/87	876	194	3.1	2.6	2.3
7/23/87	886	204			2.5
7/31/87	894	212	6.5	4.1	2.2
8/7/87	901	219	0.5	1.9	2.9
8/14/87	908	226	-3.1	-1.9	-0.9
9/2/87	927	245	-2.1	-2.4	-2.6
9/9/87	934	252		-0.4	
9/16/87	941	259	1.2	0.2	-0.6
9/28/87	953	271	3.0	2.1	1.4
10/11/87	966	284	3.7	3.5	3.4

APPENDIX C– TENSIOMETRIC DATA

COLUMN 4

30.0 CM DEEP; TENSIOMETER 1

DATE	XD	JD	READING	H2O	PSI	TH
2/18/85	1	49	−172.0	8.0	−149.5	−179.5
2/19/85	2	50	−236.0	7.8	−208.5	−238.5
2/20/85	3	51	−166.0	7.8	−144.2	−174.2
2/27/85	10	58	−158.0	8.2	−136.4	−166.4
3/1/85	12	60	−154.0	8.2	−132.8	−162.8
3/4/85	15	63	−180.0	8.0	−156.8	−186.8
3/7/85	18	66	−166.0	8.0	−144.0	−174.0
3/12/85	23	71	−191.0	7.5	−167.5	−197.5
3/19/85	30	78	−162.0	7.2	−141.2	−171.2
3/23/85	34	82	−156.0	7.0	−135.9	−165.9
3/25/85	36	84	−141.0	6.5	−122.6	−152.6
3/29/85	40	88	−214.0	9.4	−186.6	−216.6
4/1/85	43	91	−180.0	9.3	−155.4	−185.4
4/19/85	61	109	−185.0	7.2	−162.3	−192.3
4/22/85	64	112	−211.0	9.5	−183.7	−213.7
4/25/85	67	115	−168.0	9.0	−144.8	−174.8
4/29/85	71	119	−191.0	8.8	−166.1	−196.1
5/2/85	74	122	−165.0	8.7	−142.3	−172.3
5/6/85	78	126	−168.0	8.2	−145.6	−175.6
5/10/85	82	130	−231.0	7.5	−204.2	−234.2
5/13/85	85	133	−234.0	8.7	−205.7	−235.7
5/16/85	88	136	−238.0	8.5	−209.6	−239.6
5/20/85	92	140	−252.0	8.0	−222.9	−252.9
5/24/85	96	144	−245.0	8.8	−215.7	−245.7
5/28/85	100	148	−232.0	8.2	−204.4	−234.4
5/30/85	102	150	−284.0	7.5	−252.8	−282.8
6/2/85	105	153	−245.0	9.5	−214.9	−244.9
6/6/85	109	157	−240.0	9.0	−210.9	−240.9
6/10/85	113	161	−270.0	8.3	−239.1	−269.1
6/13/85	116	164	−265.0	7.6	−235.3	−265.3
6/21/85	124	172	−223.0	8.5	−195.8	−225.8
6/24/85	127	175	−219.0	7.5	−193.2	−223.2
6/28/85	131	179	−205.0	7.6	−180.2	−210.2
7/1/85	134	182				
7/3/85	136	184	−183.0	7.3	−160.3	−190.3
7/15/85	148	196				
7/23/85	156	204	−155.0	8.2	−133.7	−163.7
7/25/85	158	206	−162.0	9.5	−138.8	−168.8
7/30/85	163	211	−174.0	9.2	−150.1	−180.1
8/1/85	165	213	−155.0	9.0	−132.9	−162.9
8/5/85	169	217	−138.0	8.7	−117.6	−147.6
8/8/85	172	220	−142.0	8.5	−121.4	−151.4
8/9/85	173	221	−137.0	8.5	−116.9	−146.9
8/13/85	177	225	−137.0	8.7	−116.6	−146.6
8/19/85	183	231	−150.0	8.7	−128.6	−158.6
8/22/85	186	234	−134.0	7.8	−114.8	−144.8
8/26/85	190	238	−133.0	9.0	−112.7	−142.7
8/29/85	193	241	−130.0	7.8	−111.2	−141.2
9/2/85	197	245	−146.0	9.5	−124.1	−154.1
9/5/85	200	248	−125.0	9.4	−104.9	−134.9
9/9/85	204	252	−122.0	9.3	−102.3	−132.3
9/12/85	207	255	−96.0	9.2	−78.5	−108.5
9/17/85	212	260	−97.0	9.0	−79.6	−109.6
9/19/85	214	262	−99.0	9.0	−81.5	−111.5

APPENDIX C- TENSIOMETRIC DATA

COLUMN 4

TENSIOMETER 1 30.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
9/23/85	218	266	-98.0	8.3	-81.3	-111.3
9/30/85	225	273				
10/7/85	232	280	-12.0	9.3	-1.3	-31.3
10/14/85	239	287	-35.0	9.3	-22.4	-52.4
10/17/85	242	290	-11.0	9.3	-0.4	-30.4
10/21/85	246	294	-81.0	9.0	-64.9	-94.9
10/29/85	254	302	-119.0	9.0	-99.8	-129.8
11/6/85	262	310	-107.0	8.7	-89.1	-119.1
11/13/85	269	317	-115.0	8.6	-96.6	-126.6
11/20/85	276	324	-118.0	9.2	-98.7	-128.7
11/27/85	283	331	-177.0	8.7	-153.4	-183.4
12/5/85	291	339	-90.0	9.3	-72.9	-102.9
12/13/85	299	347				
12/22/85	308	356	-130.0	9.0	-109.9	-139.9
12/31/85	317	365	-176.0	8.8	-152.3	-182.3
1/3/86	320	3	-168.0	9.0	-144.8	-174.8
1/11/86	328	11				
1/16/86	333	16				
1/22/86	339	22	-147.0	9.0	-125.5	-155.5
1/30/86	347	30	-158.0	9.0	-135.6	-165.6
2/6/86	354	37	-158.0	9.0	-135.6	-165.6
2/11/86	359	42	-136.0	9.5	-114.9	-144.9
2/19/86	367	50	-107.0	9.5	-88.3	-118.3
2/27/86	375	58	-146.0	9.5	-124.1	-154.1
3/5/86	381	64	-147.0	9.5	-125.0	-155.0
3/13/86	389	72	-183.0	9.3	-158.2	-188.2
3/19/86	395	78	-173.0	9.3	-149.1	-179.1
3/27/86	403	86	-181.0	8.2	-157.6	-187.6
4/3/86	410	93	-223.0	9.3	-195.0	-225.0
4/10/86	417	100	-195.0	9.4	-169.2	-199.2
4/17/86	424	107	-236.0	8.5	-207.7	-237.7
4/24/86	431	114	-258.0	8.8	-227.6	-257.6
5/1/86	438	121	-257.0	9.0	-226.5	-256.5
5/8/86	445	128	-154.0	9.1	-131.8	-161.8
5/19/86	456	139	-129.0	9.0	-109.0	-139.0
5/27/86	464	147	-193.0	7.9	-168.9	-198.9
6/3/86	471	154	-122.0	9.0	-102.6	-132.6
6/9/86	477	160	-142.0	9.0	-120.9	-150.9
6/16/86	484	167	-142.0	8.5	-121.4	-151.4
6/25/86	493	176	-15.0	8.8	-4.6	-34.6
7/2/86	500	183	-94.0	9.0	-76.9	-106.9
7/9/86	507	190	-148.0	9.3	-126.1	-156.1
7/16/86	514	197	-209.0	8.1	-183.4	-213.4
7/22/86	520	203	-177.0	9.2	-152.8	-182.8
7/30/86	528	211	-217.0	8.1	-190.7	-220.7
8/6/86	535	218	-268.0	7.9	-237.7	-267.7
8/13/86	542	225	-175.0	8.4	-151.8	-181.8
8/25/86	554	237	-214.0	8.3	-187.7	-217.7
9/2/86	562	245	-164.0	9.3	-140.8	-170.8
9/8/86	568	251	-182.0	8.7	-158.0	-188.0
9/15/86	575	258	-153.0	8.5	-131.5	-161.5
9/22/86	582	265	-156.0	8.6	-134.2	-164.2
9/29/86	589	272	-129.0	8.5	-109.5	-139.5
10/13/86	603	286	-51.0	9.2	-37.2	-67.2
10/21/86	611	294	-81.0	9.2	-64.7	-94.7

APPENDIX C- TENSIOMETRIC DATA

COLUMN 4

TENSIOMETER 1 30.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
10/28/86	618	301	-131.0	9.2	-110.6	-140.6
11/4/86	625	308	-58.0	9.2	-43.6	-73.6
11/11/86	632	315	-76.0	8.7	-60.7	-90.7
11/18/86	639	322	-114.0	8.5	-95.7	-125.7
11/25/86	646	329	-167.0	8.5	-144.4	-174.4
12/3/86	654	337	-230.0		-211.1	-241.1
12/11/86	662	345	-309.0	9.5	-273.7	-303.7
12/29/86	680	363	-69.0	9.0	-53.9	-83.9
1/7/87	689	7	-135.0	9.0	-114.5	-144.5
1/20/87	702	20	-375.0			
1/28/87	710	28	-153.0	7.0	-133.1	-163.1
2/3/87	716	34	-141.0	9.5	-119.5	-149.5
2/11/87	724	42	-171.0	9.2	-147.3	-177.3
2/18/87	731	49	-198.0	8.8	-172.5	-202.5
2/26/87	739	57	-94.0	9.0	-76.9	-106.9
3/3/87	744	62	-90.0	9.0	-73.2	-103.2
3/18/87	759	77	-256.0	5.0	-229.7	-259.7
4/8/87	780	98	-163.0	8.0	-141.2	-171.2
4/15/87	787	105	-151.0	9.5	-128.7	-158.7
4/28/87	800	118				
5/12/87	814	132	-299.0	7.7	-266.4	-296.4
5/25/87	827	145	-209.0	7.0	-184.5	-214.5
6/4/87	837	155	-262.0	7.0	-233.2	-263.2
6/23/87	856	174	-317.0	7.0	-283.6	-313.6
7/2/87	865	183	-186.0	8.5	-161.8	-191.8
7/13/87	876	194	-422.0	7.0	-380.0	-410.0
7/23/87	886	204				
7/31/87	894	212	-285.0	8.0	-253.2	-283.2
8/7/87	901	219	-210.0	7.5	-184.9	-214.9
8/14/87	908	226	-122.0	9.0	-102.6	-132.6
9/2/87	927	245	-105.0	9.0	-87.0	-117.0
9/9/87	934	252	-129.0	9.5	-108.5	-138.5
9/16/87	941	259	-154.0	8.5	-132.5	-162.5
9/28/87	953	271	-223.0	7.0	-197.4	-227.4
10/11/87	966	284	-250.0	7.3	-221.8	-251.8

APPENDIX C- TENSIOMETRIC DATA

COLUMN 4

TENSIOMETER 2 46.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
2/18/85	1	49	-116.0	7.6	-98.3	-144.3
2/19/85	2	50	-170.0	7.5	-147.9	-193.9
2/20/85	3	51	-123.0	7.5	-104.8	-150.8
2/27/85	10	58	-101.0	9.0	-83.1	-129.1
3/1/85	12	60	-94.0	8.9	-77.0	-123.0
3/4/85	15	63	-125.0	8.8	-105.5	-151.5
3/7/85	18	66	-134.0	8.5	-114.1	-160.1
3/12/85	23	71	-153.0	8.0	-132.1	-178.1
3/19/85	30	78	-156.0	7.8	-135.0	-181.0
3/23/85	34	82	-100.0	7.2	-84.3	-130.3
3/25/85	36	84	-92.0	6.8	-77.3	-123.3
3/29/85	40	88	-159.0	5.9	-139.8	-185.8
4/1/85	43	91	-144.0	9.5	-122.2	-168.2
4/19/85	61	109				
4/22/85	64	112	-115.0	7.1	-98.1	-144.1
4/25/85	67	115				
4/29/85	71	119	-144.0	9.4	-122.3	-168.3
5/2/85	74	122	-131.0	9.3	-110.6	-156.6
5/6/85	78	126	-130.0	9.2	-109.7	-155.7
5/10/85	82	130	-166.0	9.1	-142.8	-188.8
5/13/85	85	133	-168.0	8.2	-145.6	-191.6
5/16/85	88	136	-158.0	7.6	-137.1	-183.1
5/20/85	92	140	-186.0	9.3	-161.0	-207.0
5/24/85	96	144	-177.0	8.7	-153.4	-199.4
5/28/85	100	148	-164.0	8.4	-141.7	-187.7
5/30/85	102	150	-214.0	8.0	-188.1	-234.1
6/2/85	105	153	-184.0	7.8	-160.8	-206.8
6/6/85	109	157	-179.0	7.3	-156.7	-202.7
6/10/85	113	161	-169.0	7.0	-147.8	-193.8
6/13/85	116	164	-176.0	7.8	-153.4	-199.4
6/21/85	124	172	-166.0	8.7	-143.3	-189.3
6/24/85	127	175	-167.0	7.5	-145.4	-191.4
6/28/85	131	179				
7/1/85	134	182				
7/3/85	136	184				
7/15/85	148	196				
7/23/85	156	204	-124.0	8.4	-105.0	-151.0
7/25/85	158	206	-116.0	8.6	-97.5	-143.5
7/30/85	163	211	-105.0	7.4	-88.6	-134.6
8/1/85	165	213				
8/5/85	169	217				
8/8/85	172	220	-93.0	7.3	-77.7	-123.7
8/9/85	173	221	-86.0	9.0	-69.5	-115.5
8/13/85	177	225				
8/19/85	183	231				
8/22/85	186	234	-111.0	9.1	-92.4	-138.4
8/26/85	190	238	-107.0	8.5	-89.3	-135.3
8/29/85	193	241	-111.0	8.3	-93.2	-139.2
9/2/85	197	245	-106.0	8.4	-88.5	-134.5
9/5/85	200	248	-112.0	8.0	-94.4	-140.4
9/9/85	204	252	-104.0	8.0	-87.1	-133.1
9/12/85	207	255				
9/17/85	212	260				
9/19/85	214	262				

APPENDIX C- TENSIOMETRIC DATA

COLUMN 4

46.0 CM DEEP; TENSIOMETER 2

DATE	XD	JD	READING	H2O	PSI	TH
9/23/85	218	266				
9/30/85	225	273	-73.0	9.4	-57.2	-103.2
10/7/85	232	280	-87.0	9.3	-70.1	-116.1
10/14/85	239	287	-46.0	9.3	-32.5	-78.5
10/17/85	242	290	-42.0	9.3	-28.8	-74.8
10/21/85	246	294	-58.0	9.3	-43.5	-89.5
10/29/85	254	302	-102.0	8.9	-84.3	-130.3
11/6/85	262	310	-111.0	9.0	-92.5	-138.5
11/13/85	269	317	-99.0	9.0	-81.5	-127.5
11/20/85	276	324	-131.0	9.4	-110.4	-156.4
11/27/85	283	331	-120.0	9.1	-100.6	-146.6
12/5/85	291	339	-144.0	8.8	-123.0	-169.0
12/13/85	299	347	-175.0	8.6	-151.6	-197.6
12/22/85	308	356	-147.0	9.2	-125.3	-171.3
12/31/85	317	365	-134.0	9.0	-113.6	-159.6
1/3/86	320	3	-147.0	9.5	-125.0	-171.0
1/11/86	328	11	-167.0	9.3	-143.6	-189.6
1/16/86	333	16	-169.0	9.0	-145.7	-191.7
1/22/86	339	22	-122.0	9.8	-101.7	-147.7
1/30/86	347	30	-136.0	9.7	-114.7	-160.7
2/6/86	354	37	-150.0	9.3	-128.0	-174.0
2/11/86	359	42	-145.0	9.2	-123.5	-169.5
2/19/86	367	50	-90.0	9.1	-73.1	-119.1
2/27/86	375	58	-120.0	9.3	-100.4	-146.4
3/5/86	381	64	-128.0	9.1	-108.0	-154.0
3/13/86	389	72	-150.0	9.0	-128.3	-174.3
3/19/86	395	78	-143.0	9.5	-121.3	-167.3
3/27/86	403	86	-140.0	9.5	-118.6	-164.6
4/3/86	410	93	-177.0	9.2	-152.8	-198.8
4/10/86	417	100				
4/17/86	424	107	-173.0	10.0	-148.3	-194.3
4/24/86	431	114	-129.0	10.0	-107.9	-153.9
5/1/86	438	121				
5/8/86	445	128				
5/19/86	456	139	-124.0	9.3	-104.1	-150.1
5/27/86	464	147	-140.0	9.3	-118.8	-164.8
6/3/86	471	154	-124.0	9.3	-104.1	-150.1
6/9/86	477	160	-114.0	9.6	-94.6	-140.6
6/16/86	484	167	-124.0	9.0	-104.4	-150.4
6/25/86	493	176	-54.0	9.6	-39.5	-85.5
7/2/86	500	183	-78.0	9.5	-61.7	-107.7
7/9/86	507	190	-100.0	9.5	-81.9	-127.9
7/16/86	514	197	-118.0	9.5	-98.4	-144.4
7/22/86	520	203	-130.0	9.4	-109.5	-155.5
7/30/86	528	211	-127.0	9.3	-106.8	-152.8
8/6/86	535	218	-162.0	9.2	-139.1	-185.1
8/13/86	542	225	-162.0	9.2	-139.1	-185.1
8/25/86	554	237	-175.0	8.3	-151.9	-197.9
9/2/86	562	245	-139.0	8.7	-118.5	-164.5
9/8/86	568	251	-138.0	8.5	-117.8	-163.8
9/15/86	575	258	-140.0	8.4	-119.7	-165.7
9/22/86	582	265	-130.0	9.3	-109.6	-155.6
9/29/86	589	272	-129.0	9.0	-109.0	-155.0

APPENDIX C- TENSIOMETRIC DATA

COLUMN 4

46.0 CM DEEP; TENSIOMETER 2

DATE	XD	JD	READING	H2O	PSI	TH
10/13/86	603	286	-45.0	8.4	-32.5	-78.5
10/21/86	611	294	-86.0	8.2	-70.4	-116.4
10/28/86	618	301	-109.0	8.7	-90.9	-136.9
11/4/86	625	308	-130.0	9.0	-109.9	-155.9
11/11/86	632	315	-88.0	8.9	-71.5	-117.5
11/18/86	639	322	-93.0	8.8	-76.2	-122.2
11/25/86	646	329	-135.0	8.7	-114.8	-160.8
12/3/86	654	337	-201.0	8.5	-175.6	-221.6
12/11/86	662	345	-178.0	9.2	-153.8	-199.8
12/29/86	680	363	-100.0	9.2	-82.2	-128.2
1/7/87	689	7	-54.0	9.5	-39.6	-85.6
1/20/87	702	20	-135.0	9.6	-113.9	-159.9
1/28/87	710	28	-67.0	9.5	-51.6	-97.6
2/3/87	716	34	-108.0	9.4	-89.3	-135.3
2/11/87	724	42	-124.0	9.3	-104.1	-150.1
2/18/87	731	49	-132.0	9.5	-111.2	-157.2
2/26/87	739	57	-120.0	9.4	-100.3	-146.3
3/3/87	744	62	-95.0	9.4	-77.4	-123.4
3/18/87	759	77	-125.0	9.1	-105.2	-151.2
4/8/87	780	98	-143.0	9.0	-121.8	-167.8
4/15/87	787	105	-129.0	7.0	-111.1	-157.1
4/28/87	800	118	-180.0	8.8	-156.0	-202.0
5/12/87	814	132	-197.0	8.5	-171.9	-217.9
5/25/87	827	145	-176.0	8.5	-152.7	-198.7
6/4/87	837	155	-169.0	8.5	-146.2	-192.2
6/23/87	856	174	-172.0	7.0	-150.5	-196.5
7/2/87	865	183	-160.0	8.0	-138.5	-184.5
7/13/87	876	194	-244.0	7.0	-216.6	-262.6
7/23/87	886	204	-213.0	7.6	-187.6	-233.6
7/31/87	894	212				
8/7/87	901	219	-196.0	8.5	-171.0	-217.0
8/14/87	908	226	-126.0	7.7	-107.6	-153.6
9/2/87	927	245	-104.0	7.5	-87.6	-133.6
9/9/87	934	252	-104.0	7.4	-87.7	-133.7
9/16/87	941	259				
9/28/87	953	271	-114.0	9.5	-94.7	-140.7
10/11/87	966	284	-165.0	9.0	-142.0	-188.0

APPENDIX C- TENSIOMETRIC DATA

COLUMN 4

TENSIOMETER 3 66.3 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
2/18/85	1	49	-89.0	8.5	-72.6	-138.9
2/19/85	2	50	-120.0	8.5	-101.0	-167.3
2/20/85	3	51	-87.0	8.5	-70.8	-137.1
2/27/85	10	58	-58.0	9.2	-43.5	-109.8
3/1/85	12	60	-74.0	9.1	-58.4	-124.7
3/4/85	15	63	-58.0	9.2	-43.6	-109.9
3/7/85	18	66				
3/12/85	23	71	-40.0	9.1	-27.2	-93.5
3/19/85	30	78	-62.0	9.0	-47.5	-113.8
3/23/85	34	82	-77.0	8.6	-61.7	-128.0
3/25/85	36	84	-90.0	8.4	-73.8	-140.1
3/29/85	40	88	-89.0	8.0	-73.3	-139.6
4/1/85	43	91	-109.0	7.6	-92.1	-158.4
4/19/85	61	109	-96.0	7.5	-80.3	-146.6
4/22/85	64	112	-92.0	8.5	-75.6	-141.9
4/25/85	67	115	-98.0	7.1	-82.5	-148.8
4/29/85	71	119	-95.0	8.3	-78.6	-144.9
5/2/85	74	122	-113.0	7.5	-95.9	-162.2
5/6/85	78	126	-99.0	8.7	-81.8	-148.1
5/10/85	82	130	-81.0	7.8	-66.2	-132.5
5/13/85	85	133	-109.0	8.4	-91.2	-157.5
5/16/85	88	136	-116.0	7.7	-98.4	-164.7
5/20/85	92	140	-116.0	8.6	-97.5	-163.8
5/24/85	96	144	-92.0	7.5	-76.6	-142.9
5/28/85	100	148	-73.0	7.8	-58.8	-125.1
5/30/85	102	150	-99.0	7.0	-83.5	-149.8
6/2/85	105	153	-86.0	8.7	-69.9	-136.2
6/6/85	109	157				
6/10/85	113	161				
6/13/85	116	164				
6/21/85	124	172	-109.0	9.0	-90.6	-156.9
6/24/85	127	175				
6/28/85	131	179	-105.0	8.2	-87.8	-154.1
7/1/85	134	182	-85.0	7.2	-70.5	-136.8
7/3/85	136	184	-102.0	7.4	-85.9	-152.2
7/15/85	148	196	-109.0	8.0	-91.7	-158.0
7/23/85	156	204				
7/25/85	158	206	-98.0	9.2	-80.3	-146.6
7/30/85	163	211	-137.0	8.1	-117.3	-183.6
8/1/85	165	213	-114.0	7.6	-96.7	-163.0
8/5/85	169	217	-110.0	9.0	-91.6	-157.9
8/8/85	172	220	-124.0	8.4	-105.0	-171.3
8/9/85	173	221				
8/13/85	177	225	-117.0	8.2	-98.8	-165.1
8/19/85	183	231	-94.0	8.4	-77.5	-143.8
8/22/85	186	234	-93.0	7.7	-77.3	-143.6
8/26/85	190	238	-98.0	8.2	-81.4	-147.7
8/29/85	193	241				
9/2/85	197	245				
9/5/85	200	248				
9/9/85	204	252				
9/12/85	207	255	-74.0	7.4	-60.2	-126.5
9/17/85	212	260	-102.0	8.2	-85.0	-151.3
9/19/85	214	262	-65.0	9.3	-49.9	-116.2

APPENDIX C- TENSIOMETRIC DATA

COLUMN 4

66.3 CM DEEP; TENSIOMETER 3

DATE	XD	JD	READING	H2O	PSI	TH
9/23/85	218	266	-50.0	8.8	-36.7	-103.0
9/30/85	225	273	-63.0	8.5	-48.9	-115.2
10/7/85	232	280	-68.0	8.1	-53.9	-120.2
10/14/85	239	287	-53.0	8.5	-39.8	-106.1
10/17/85	242	290	-66.0	8.2	-52.0	-118.3
10/21/85	246	294	-75.0	9.0	-59.4	-125.7
10/29/85	254	302	-100.0	8.7	-82.7	-149.0
11/6/85	262	310	-104.0	8.8	-86.3	-152.6
11/13/85	269	317	-71.0	8.8	-56.0	-122.3
11/20/85	276	324	-129.0	9.2	-108.8	-175.1
11/27/85	283	331	-78.0	9.2	-62.0	-128.3
12/5/85	291	339	-141.0	8.9	-120.1	-186.4
12/13/85	299	347	-133.0	8.9	-112.8	-179.1
12/22/85	308	356	-112.0	8.8	-93.6	-159.9
12/31/85	317	365	-119.0	9.0	-99.8	-166.1
1/3/86	320	3	-116.0	9.3	-96.7	-163.0
1/11/86	328	11	-145.0	8.5	-124.2	-190.5
1/16/86	333	16	-149.0	9.0	-127.3	-193.6
1/22/86	339	22	-88.0	8.9	-71.5	-137.8
1/30/86	347	30	-126.0	8.9	-106.3	-172.6
2/6/86	354	37	-119.0	8.9	-99.9	-166.2
2/11/86	359	42	-114.0	8.9	-95.3	-161.6
2/19/86	367	50				
2/27/86	375	58	-100.0	8.8	-82.6	-148.9
3/5/86	381	64	-138.0	9.1	-117.1	-183.4
3/13/86	389	72	-143.0	8.8	-122.1	-188.4
3/19/86	395	78	-100.0	9.2	-82.2	-148.5
3/27/86	403	86	-137.0	8.9	-116.4	-182.7
4/3/86	410	93	-144.0	9.3	-122.4	-188.7
4/10/86	417	100	-183.0	9.3	-158.2	-224.5
4/17/86	424	107	-111.0	7.0	-94.6	-160.9
4/24/86	431	114	-113.0	9.0	-94.3	-160.6
5/1/86	438	121	-126.0	9.2	-106.0	-172.3
5/8/86	445	128	-114.0	7.3	-97.0	-163.3
5/19/86	456	139	-150.0	8.9	-128.4	-194.7
5/27/86	464	147	-123.0	9.5	-103.0	-169.3
6/3/86	471	154	-168.0	9.5	-144.3	-210.6
6/9/86	477	160	-124.0	9.5	-103.9	-170.2
6/16/86	484	167	-141.0	9.7	-119.3	-185.6
6/25/86	493	176	-51.0	9.1	-37.3	-103.6
7/2/86	500	183	-68.0	9.6	-52.4	-118.7
7/9/86	507	190	-82.0	9.7	-65.1	-131.4
7/16/86	514	197	-96.0	9.5	-78.2	-144.5
7/22/86	520	203	-100.0	10.0	-81.3	-147.6
7/30/86	528	211	-99.0	10.0	-80.4	-146.7
8/6/86	535	218	-107.0	9.0	-88.8	-155.1
8/13/86	542	225	-116.0	9.2	-96.9	-163.2
8/25/86	554	237	-139.0	8.7	-118.5	-184.8
9/2/86	562	245	-127.0	8.5	-107.7	-174.0
9/8/86	568	251	-121.0	8.5	-102.2	-168.5
9/15/86	575	258	-127.0	8.5	-107.7	-174.0
9/22/86	582	265	-123.0	9.0	-103.5	-169.8
9/29/86	589	272	-122.0	8.3	-103.3	-169.6

APPENDIX C– TENSIOMETRIC DATA

COLUMN 4

66.3 CM DEEP; TENSIOMETER 3

DATE	XD	JD	READING	H2O	PSI	TH
10/13/86	603	286	-124.0	9.0	-104.4	-170.7
10/21/86	611	294	-81.0	9.0	-64.9	-131.2
10/28/86	618	301	-91.0	8.9	-74.2	-140.5
11/4/86	625	308	-100.0	9.0	-82.4	-148.7
11/11/86	632	315	-86.0	8.8	-69.7	-136.0
11/18/86	639	322	-82.0	8.8	-66.1	-132.4
11/25/86	646	329	-99.0	8.5	-82.0	-148.3
12/3/86	654	337	-95.0	8.4	-78.4	-144.7
12/11/86	662	345	-114.0	9.4	-94.8	-161.1
12/29/86	680	363	-95.0	9.0	-77.8	-144.1
1/7/87	689	7	-86.0	7.3	-71.3	-137.6
1/20/87	702	20	-113.0	9.3	-94.0	-160.3
1/28/87	710	28	-89.0	9.3	-72.0	-138.3
2/3/87	716	34	-118.0	9.2	-98.7	-165.0
2/11/87	724	42	-110.0	9.0	-91.6	-157.9
2/18/87	731	49	-110.0	8.7	-91.9	-158.2
2/26/87	739	57	-115.0	8.7	-96.5	-162.8
3/3/87	744	62	-100.0	8.6	-82.8	-149.1
3/18/87	759	77	-106.0	9.3	-87.6	-153.9
4/8/87	780	98	-110.0	8.4	-92.2	-158.5
4/15/87	787	105	-116.0	8.5	-97.6	-163.9
4/28/87	800	118	-118.0	7.8	-100.2	-166.5
5/12/87	814	132	-136.0	8.0	-116.5	-182.8
5/25/87	827	145	-122.0	7.5	-104.1	-170.4
6/4/87	837	155	-107.0	8.0	-89.8	-156.1
6/23/87	856	174	-96.0	7.5	-80.3	-146.6
7/2/87	865	183	-136.0	8.8	-115.6	-181.9
7/13/87	876	194	-131.0	7.8	-112.1	-178.4
7/23/87	886	204	-135.0	8.3	-115.2	-181.5
7/31/87	894	212	-142.0	7.5	-122.5	-188.8
8/7/87	901	219	-140.0	6.5	-121.7	-188.0
8/14/87	908	226	-129.0	9.0	-109.0	-175.3
9/2/87	927	245	-107.0	8.0	-89.8	-156.1
9/9/87	934	252	-123.0	9.5	-103.0	-169.3
9/16/87	941	259	-110.0	9.5	-91.0	-157.3
9/28/87	953	271	-107.0	8.7	-89.1	-155.4
10/11/87	966	284	-145.0	7.8	-124.9	-191.2

APPENDIX C– TENSIOMETRIC DATA

COLUMN 4 GRADIENTS

DATE	XD	JD	G12	G13	G23
2/18/85	1	49	2.2	1.1	0.3
2/19/85	2	50	2.8	1.9	1.3
2/20/85	3	51	1.4	1.0	0.7
2/27/85	10	58	2.3	1.6	1.0
3/1/85	12	60	2.5	1.0	−0.1
3/4/85	15	63	2.2	2.1	2.0
3/7/85	18	66	0.9		
3/12/85	23	71	1.2	2.9	4.2
3/19/85	30	78	−0.6	1.6	3.3
3/23/85	34	82	2.2	1.0	0.1
3/25/85	36	84	1.8	0.3	−0.8
3/29/85	40	88	1.9	2.1	2.3
4/1/85	43	91	1.1	0.7	0.5
4/19/85	61	109		1.3	
4/22/85	64	112	4.4	2.0	0.1
4/25/85	67	115		0.7	
4/29/85	71	119	1.7	1.4	1.2
5/2/85	74	122	1.0	0.3	−0.3
5/6/85	78	126	1.2	0.8	0.4
5/10/85	82	130	2.8	2.8	2.8
5/13/85	85	133	2.8	2.2	1.7
5/16/85	88	136	3.5	2.1	0.9
5/20/85	92	140	2.9	2.5	2.1
5/24/85	96	144	2.9	2.8	2.8
5/28/85	100	148	2.9	3.0	3.1
5/30/85	102	150	3.0	3.7	4.1
6/2/85	105	153	2.4	3.0	3.5
6/6/85	109	157	2.4		
6/10/85	113	161	4.7		
6/13/85	116	164	4.1		
6/21/85	124	172	2.3	1.9	1.6
6/24/85	127	175	2.0		
6/28/85	131	179		1.5	
7/1/85	134	182			
7/3/85	136	184		1.1	
7/15/85	148	196			
7/23/85	156	204	0.8		
7/25/85	158	206	1.6	0.6	−0.2
7/30/85	163	211	2.8	−0.1	−2.4
8/1/85	165	213		−0.0	
8/5/85	169	217		−0.3	
8/8/85	172	220	1.7	−0.5	−2.3
8/9/85	173	221	2.0		
8/13/85	177	225		−0.5	
8/19/85	183	231		0.4	
8/22/85	186	234	0.4	0.0	−0.3
8/26/85	190	238	0.5	−0.1	−0.6
8/29/85	193	241	0.1		
9/2/85	197	245	1.2		
9/5/85	200	248	−0.3		
9/9/85	204	252	−0.1		
9/12/85	207	255		−0.5	
9/17/85	212	260		−1.1	
9/19/85	214	262		−0.1	
9/23/85	218	266		0.2	
9/30/85	225	273			−0.6
10/7/85	232	280	−5.3	−2.5	−0.2

APPENDIX C- TENSIOMETRIC DATA

COLUMN 4

DATE	XD	JD	GRADIENTS G12	G13	G23
10/14/85	239	287	-1.6	-1.5	-1.4
10/17/85	242	290	-2.8	-2.4	-2.1
10/21/85	246	294	0.3	-0.8	-1.8
10/29/85	254	302	-0.0	-0.5	-0.9
11/6/85	262	310	-1.2	-0.9	-0.7
11/13/85	269	317	-0.1	0.1	0.3
11/20/85	276	324	-1.7	-1.3	-0.9
11/27/85	283	331	2.3	1.5	0.9
12/5/85	291	339	-4.1	-2.3	-0.9
12/13/85	299	347			0.9
12/22/85	308	356	-2.0	-0.6	0.6
12/31/85	317	365	1.4	0.4	-0.3
1/3/86	320	3	0.2	0.3	0.4
1/11/86	328	11			-0.0
1/16/86	333	16			-0.1
1/22/86	339	22	0.5	0.5	0.5
1/30/86	347	30	0.3	-0.2	-0.6
2/6/86	354	37	-0.5	-0.0	0.4
2/11/86	359	42	-1.5	-0.5	0.4
2/19/86	367	50	-0.1		
2/27/86	375	58	0.5	0.1	-0.1
3/5/86	381	64	0.1	-0.8	-1.5
3/13/86	389	72	0.9	-0.0	-0.7
3/19/86	395	78	0.7	0.8	0.9
3/27/86	403	86	1.4	0.1	-0.9
4/3/86	410	93	1.6	1.0	0.5
4/10/86	417	100		-0.7	
4/17/86	424	107	2.7	2.1	1.6
4/24/86	431	114	6.5	2.7	-0.3
5/1/86	438	121		2.3	
5/8/86	445	128		-0.0	
5/19/86	456	139	-0.7	-1.5	-2.2
5/27/86	464	147	2.1	0.8	-0.2
6/3/86	471	154	-1.1	-2.1	-3.0
6/9/86	477	160	0.6	-0.5	-1.5
6/16/86	484	167	0.1	-0.9	-1.7
6/25/86	493	176	-3.2	-1.9	-0.9
7/2/86	500	183	-0.0	-0.3	-0.5
7/9/86	507	190	1.8	0.7	-0.2
7/16/86	514	197	4.3	1.9	-0.0
7/22/86	520	203	1.7	1.0	0.4
7/30/86	528	211	4.2	2.0	0.3
8/6/86	535	218	5.2	3.1	1.5
8/13/86	542	225	-0.2	0.5	1.1
8/25/86	554	237	1.2	0.9	0.6
9/2/86	562	245	0.4	-0.1	-0.5
9/8/86	568	251	1.5	0.5	-0.2
9/15/86	575	258	-0.3	-0.3	-0.4
9/22/86	582	265	0.5	-0.2	-0.7
9/29/86	589	272	-1.0	-0.8	-0.7
10/13/86	603	286	-0.7	-2.9	-4.5
10/21/86	611	294	-1.4	-1.0	-0.7
10/28/86	618	301	0.2	0.0	-0.2

APPENDIX C– TENSIOMETRIC DATA

COLUMN 4

DATE	XD	JD	GRADIENTS G12	G13	G23
11/4/86	625	308	-5.1	-2.1	0.4
11/11/86	632	315	-1.7	-1.2	-0.9
11/18/86	639	322	0.2	-0.2	-0.5
11/25/86	646	329	0.8	0.7	0.6
12/3/86	654	337	1.2	2.7	3.8
12/11/86	662	345	6.5	3.9	1.9
12/29/86	680	363	-2.8	-1.7	-0.8
1/7/87	689	7	3.7	0.2	-2.6
1/20/87	702	20	--	5.9	-0.0
1/28/87	710	28	4.1	0.7	-2.0
2/3/87	716	34	0.9	-0.4	-1.5
2/11/87	724	42	1.7	0.5	-0.4
2/18/87	731	49	2.8	1.2	-0.0
2/26/87	739	57	-2.5	-1.5	-0.8
3/3/87	744	62	-1.3	-1.3	-1.3
3/18/87	759	77	6.8	2.9	-0.1
4/8/87	780	98	0.2	0.4	0.5
4/15/87	787	105	0.1	-0.1	-0.3
4/28/87	800	118			1.8
5/12/87	814	132	4.9	3.1	1.7
5/25/87	827	145	1.0	1.2	1.4
6/4/87	837	155	4.4	2.9	1.8
6/23/87	856	174	7.3	4.6	2.5
7/2/87	865	183	0.5	0.3	0.1
7/13/87	876	194	9.2	6.4	4.2
7/23/87	886	204			2.6
7/31/87	894	212		2.6	
8/7/87	901	219	-0.1	0.7	1.4
8/14/87	908	226	-1.3	-1.2	-1.1
9/2/87	927	245	-1.0	-1.1	-1.1
9/9/87	934	252	0.3	-0.8	-1.8
9/16/87	941	259		0.1	
9/28/87	953	271	5.4	2.0	-0.7
10/11/87	966	284	4.0	1.7	-0.2

APPENDIX C- TENSIOMETRIC DATA

DATA FROM REPACKED COLUMNS

COLUMN 1

TENSIOMETER 1 31.5 CM DEEP

DATE	XD	JD	READING	H20	PSI	TH
12/6/87	1019	340	-375.0	10.3	-325.1	-356.6
12/15/87	1028	349				
1/5/88	1049	5				
1/13/88	1057	13	-468.0	7.0	-411.9	-443.4
1/19/88	1063	19	-531.0	9.2	-466.0	-497.5
1/26/88	1070	26	-573.0	7.0	-505.9	-537.4
2/2/88	1077	33	-477.0	8.0	-418.9	-450.4
2/5/88	1080	36	-440.0	8.2	-385.5	-417.0
2/6/88	1081	37	-453.0	8.0	-397.4	-428.9
2/7/88	1082	38	-450.0	8.0	-394.7	-426.2
2/8/88	1083	39	-456.0	7.8	-400.3	-431.8
2/9/88	1084	40	-441.0	7.5	-387.2	-418.7
2/16/88	1091	47	-453.0	7.8	-397.6	-429.1
2/23/88	1098	54	-440.0	7.0	-386.8	-418.3
3/1/88	1105	61	-452.0	8.3	-396.2	-427.7
3/17/88	1121	77	-503.0	7.0	-443.2	-474.7
3/24/88	1128	84	-405.0	6.5	-356.0	-387.5
3/31/88	1135	91	-451.0	8.2	-395.4	-426.9
4/1/88	1136	92	-338.0	9.4	-292.9	-324.4
4/2/88	1137	93	-354.0	9.1	-307.6	-339.1
4/5/88	1140	96	-411.0	8.7	-359.0	-390.5
4/7/88	1142	98	-424.0	8.5	-370.9	-402.4
4/12/88	1147	103	-461.0	8.3	-404.2	-435.7
4/15/88	1150	106	-457.0	7.2	-401.8	-433.3
4/16/88	1151	107	-361.0	9.4	-313.5	-345.0
4/17/88	1152	108	-384.0	9.4	-334.1	-365.6
4/18/88	1153	109	-380.0	8.9	-331.1	-362.6
4/19/88	1154	110	-379.0	8.8	-330.3	-361.8
4/20/88	1155	111	-391.0	8.8	-341.0	-372.5
4/29/88	1164	120	-432.0	7.0	-379.6	-411.1
5/6/88	1171	127	-415.0	7.4	-364.0	-395.5
5/10/88	1175	131	-418.0	9.3	-364.7	-396.2
5/17/88	1182	138	-423.0	7.6	-370.9	-402.4
5/24/88	1189	145	-431.0	9.4	-376.2	-407.7
6/1/88	1197	153	-453.0	7.3	-398.1	-429.6
6/6/88	1202	158	-429.0	9.2	-374.6	-406.1
6/7/88	1203	159	-414.0	8.8	-361.6	-393.1
6/8/88	1204	160	-409.0	8.6	-357.3	-388.8
6/13/88	1209	165	-376.0	7.9	-328.5	-360.0
6/21/88	1217	173	-311.0	6.5	-271.8	-303.3
6/29/88	1225	181	-348.0	8.6	-302.7	-334.2
7/6/88	1232	188	-459.0	7.7	-403.1	-434.6
7/8/88	1234	190	-356.0	9.6	-308.8	-340.3
7/11/88	1237	193	-385.0	17.7	-326.3	-357.8
7/13/88	1239	195	-373.0	9.4	-324.3	-355.8
7/19/88	1245	201	-421.0	8.5	-368.2	-399.7
7/26/88	1252	208	-410.0	7.7	-359.2	-390.7
8/2/88	1259	215	-379.0	9.5	-329.5	-361.0
8/9/88	1266	222	-430.0	9.4	-375.3	-406.8

APPENDIX C- TENSIOMETRIC DATA

****
DATA FROM REPACKED COLUMNS
****

COLUMN 1

TENSIOMETER 2 46.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
12/6/87	1019	340	-98.0	9.6	-77.7	-123.7
12/15/87	1028	349	-271.0	9.5	-232.8	-278.8
1/5/88	1049	5	-233.0	8.5	-199.8	-245.8
1/13/88	1057	13	-216.0	8.0	-185.1	-231.1
1/19/88	1063	19	-225.0	7.8	-193.4	-239.4
1/26/88	1070	26	-230.0	7.3	-198.4	-244.4
2/2/88	1077	33	-196.0	8.0	-167.2	-213.2
2/5/88	1080	36	-183.0	8.5	-155.0	-201.0
2/6/88	1081	37	-167.0	8.0	-141.2	-187.2
2/7/88	1082	38	-162.0	7.8	-136.9	-182.9
2/8/88	1083	39	-175.0	7.8	-148.6	-194.6
2/9/88	1084	40	-156.0	7.8	-131.6	-177.6
2/16/88	1091	47	-217.0	7.3	-186.7	-232.7
2/23/88	1098	54	-202.0	8.0	-172.6	-218.6
3/1/88	1105	61	-235.0	7.0	-203.2	-249.2
3/17/88	1121	77	-270.0	7.0	-234.5	-280.5
3/24/88	1128	84	-210.0	8.5	-179.2	-225.2
3/31/88	1135	91	-250.0	7.7	-215.9	-261.9
4/1/88	1136	92	-276.0	7.6	-239.3	-285.3
4/2/88	1137	93	-251.0	7.6	-216.9	-262.9
4/5/88	1140	96	-245.0	7.3	-211.8	-257.8
4/7/88	1142	98	-160.0	9.2	-133.7	-179.7
4/12/88	1147	103	-236.0	9.2	-201.8	-247.8
4/15/88	1150	106	-245.0	8.5	-210.6	-256.6
4/16/88	1151	107	-261.0	8.6	-224.8	-270.8
4/17/88	1152	108	-266.0	8.6	-229.3	-275.3
4/18/88	1153	109	-252.0	8.6	-216.7	-262.7
4/19/88	1154	110	-233.0	8.5	-199.8	-245.8
4/20/88	1155	111	-233.0	8.0	-200.3	-246.3
4/29/88	1164	120	-244.0	7.5	-210.7	-256.7
5/6/88	1171	127	-237.0	6.4	-205.6	-251.6
5/10/88	1175	131	-216.0	9.4	-183.6	-229.6
5/17/88	1182	138	-228.0	8.4	-195.4	-241.4
5/24/88	1189	145	-258.0	7.4	-223.4	-269.4
6/1/88	1197	153	-274.0	6.8	-238.3	-284.3
6/6/88	1202	158	-236.0	9.0	-202.0	-248.0
6/7/88	1203	159	-223.0	8.9	-190.4	-236.4
6/8/88	1204	160	-228.0	8.8	-195.0	-241.0
6/13/88	1209	165	-206.0	8.1	-176.0	-222.0
6/21/88	1217	173	-179.0	6.8	-153.2	-199.2
6/29/88	1225	181	-211.0	8.2	-180.4	-226.4
7/6/88	1232	188	-282.0	7.2	-245.1	-291.1
7/8/88	1234	190	-169.0	7.9	-143.1	-189.1
7/11/88	1237	193	-212.0	7.8	-181.7	-227.7
7/13/88	1239	195	-200.0	7.5	-171.3	-217.3
7/19/88	1245	201	-146.0	8.0	-122.4	-168.4
7/26/88	1252	208	-230.0	7.2	-198.5	-244.5
8/2/88	1259	215				
8/9/88	1266	222				

APPENDIX C- TENSIOMETRIC DATA

****
DATA FROM REPACKED COLUMNS
****

COLUMN 1

TENSIOMETER 3 65.5 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
12/6/87	1019	340	-173.0	18.1	-136.0	-201.5
12/15/87	1028	349	-254.0	18.1	-208.6	-274.1
1/5/88	1049	5	-225.0	17.8	-182.9	-248.4
1/13/88	1057	13	-216.0	17.8	-174.9	-240.4
1/19/88	1063	19	-233.0	17.9	-190.0	-255.5
1/26/88	1070	26	-231.0	17.6	-188.5	-254.0
2/2/88	1077	33	-205.0	17.6	-165.2	-230.7
2/5/88	1080	36	-175.0	16.5	-139.5	-205.0
2/6/88	1081	37	-185.0	16.5	-148.5	-214.0
2/7/88	1082	38	-172.0	16.5	-136.8	-202.3
2/8/88	1083	39	-176.0	16.5	-140.4	-205.9
2/9/88	1084	40	-151.0	16.5	-118.0	-183.5
2/16/88	1091	47	-187.0	16.1	-150.7	-216.2
2/23/88	1098	54	-195.0	15.0	-159.0	-224.5
3/1/88	1105	61	-199.0	17.9	-159.5	-225.0
3/17/88	1121	77	-235.0	17.5	-192.2	-257.7
3/24/88	1128	84	-203.0	15.8	-165.3	-230.8
3/31/88	1135	91	-225.0	16.1	-184.7	-250.2
4/1/88	1136	92	-146.0	17.8	-112.2	-177.7
4/2/88	1137	93	-145.0	17.8	-111.3	-176.8
4/5/88	1140	96	-178.0	17.6	-141.0	-206.5
4/7/88	1142	98	-185.0	17.5	-147.4	-212.9
4/12/88	1147	103	-218.0	17.5	-177.0	-242.5
4/15/88	1150	106	-221.0	17.3	-179.9	-245.4
4/16/88	1151	107	-236.0	17.3	-193.3	-258.8
4/17/88	1152	108	-241.0	17.3	-197.8	-263.3
4/18/88	1153	109	-225.0	17.3	-183.4	-248.9
4/19/88	1154	110	-203.0	17.3	-163.7	-229.2
4/20/88	1155	111	-200.0	17.1	-161.3	-226.8
4/29/88	1164	120	-210.0	16.5	-170.8	-236.3
5/6/88	1171	127	-208.0	16.1	-169.5	-235.0
5/10/88	1175	131	-202.0	17.8	-162.3	-227.8
5/17/88	1182	138	-199.0	17.5	-160.0	-225.5
5/24/88	1189	145	-224.0	17.1	-182.8	-248.3
6/1/88	1197	153	-243.0	16.6	-200.3	-265.8
6/6/88	1202	158	-238.0	16.6	-195.8	-261.3
6/7/88	1203	159	-220.0	16.5	-179.8	-245.3
6/8/88	1204	160	-154.0	18.0	-119.1	-184.6
6/13/88	1209	165	-187.0	17.9	-148.8	-214.3
6/21/88	1217	173	-164.0	17.5	-128.6	-194.1
6/29/88	1225	181	-201.0	16.7	-162.6	-228.1
7/6/88	1232	188	-257.0	16.5	-212.9	-278.4
7/8/88	1234	190	-177.0	17.8	-139.9	-205.4
7/11/88	1237	193	-208.0	17.7	-167.8	-233.3
7/13/88	1239	195	-197.0	17.6	-158.1	-223.6
7/19/88	1245	201	-236.0	17.6	-193.0	-258.5
7/26/88	1252	208	-226.0	17.4	-184.2	-249.7
8/2/88	1259	215	-236.0	16.9	-193.7	-259.2
8/9/88	1266	222	-261.0	16.8	-216.2	-281.7

APPENDIX C- TENSIOMETRIC DATA

****

DATA FROM REPACKED COLUMNS

****

COLUMN 1

			GRADIENTS		
DATE	XD	JD	G12	G13	G23
12/6/87	1019	340	16.1	4.6	−4.0
12/15/87	1028	349			0.2
1/5/88	1049	5			−0.1
1/13/88	1057	13	14.6	6.0	−0.5
1/19/88	1063	19	17.8	7.1	−0.8
1/26/88	1070	26	20.2	8.3	−0.5
2/2/88	1077	33	16.4	6.5	−0.9
2/5/88	1080	36	14.9	6.2	−0.2
2/6/88	1081	37	16.7	6.3	−1.4
2/7/88	1082	38	16.8	6.6	−1.0
2/8/88	1083	39	16.4	6.6	−0.6
2/9/88	1084	40	16.6	6.9	−0.3
2/16/88	1091	47	13.5	6.3	0.8
2/23/88	1098	54	13.8	5.7	−0.3
3/1/88	1105	61	12.3	6.0	1.2
3/17/88	1121	77	13.4	6.4	1.2
3/24/88	1128	84	11.2	4.6	−0.3
3/31/88	1135	91	11.4	5.2	0.6
4/1/88	1136	92	2.7	4.3	5.5
4/2/88	1137	93	5.3	4.8	4.4
4/5/88	1140	96	9.2	5.4	2.6
4/7/88	1142	98	15.4	5.6	−1.7
4/12/88	1147	103	13.0	5.7	0.3
4/15/88	1150	106	12.2	5.5	0.6
4/16/88	1151	107	5.1	2.5	0.6
4/17/88	1152	108	6.2	3.0	0.6
4/18/88	1153	109	6.9	3.3	0.7
4/19/88	1154	110	8.0	3.9	0.8
4/20/88	1155	111	8.7	4.3	1.0
4/29/88	1164	120	10.6	5.1	1.0
5/6/88	1171	127	9.9	4.7	0.9
5/10/88	1175	131	11.5	5.0	0.1
5/17/88	1182	138	11.1	5.2	0.8
5/24/88	1189	145	9.5	4.7	1.1
6/1/88	1197	153	10.0	4.8	0.9
6/6/88	1202	158	10.9	4.3	−0.7
6/7/88	1203	159	10.8	4.3	−0.5
6/8/88	1204	160	10.2	6.0	2.9
6/13/88	1209	165	9.5	4.3	0.4
6/21/88	1217	173	7.2	3.2	0.3
6/29/88	1225	181	7.4	3.1	−0.1
7/6/88	1232	188	9.9	4.6	0.6
7/8/88	1234	190	10.4	4.0	−0.8
7/11/88	1237	193	9.0	3.7	−0.3
7/13/88	1239	195	9.5	3.9	−0.3
7/19/88	1245	201	16.0	4.2	−4.6
7/26/88	1252	208	10.1	4.1	−0.3
8/2/88	1259	215		3.0	
8/9/88	1266	222		3.7	

APPENDIX C- TENSIOMETRIC DATA

****
DATA FROM REPACKED COLUMNS
****

COLUMN 2

TENSIOMETER 2 47.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
12/6/87	1019	340	-151.0	9.3	-125.5	-172.5
12/15/87	1028	349	-131.0	6.0	-111.1	-158.1
1/5/88	1049	5	-131.0	6.5	-110.5	-157.5
1/13/88	1057	13	-126.0	10.0	-102.4	-149.4
1/19/88	1063	19	-140.0	10.0	-114.9	-161.9
1/26/88	1070	26	-137.0	10.0	-112.3	-159.3
2/2/88	1077	33	-126.0	10.0	-102.4	-149.4
2/5/88	1080	36	-114.0	7.0	-94.8	-141.8
2/6/88	1081	37	-113.0	7.0	-93.9	-140.9
2/7/88	1082	38	-117.0	6.8	-97.7	-144.7
2/8/88	1083	39	-107.0	5.0	-90.6	-137.6
2/9/88	1084	40	-114.0	7.8	-94.0	-141.0
2/16/88	1091	47	-119.0	8.3	-97.9	-144.9
2/23/88	1098	54	-126.0	8.1	-104.4	-151.4
3/1/88	1105	61	-128.0	8.1	-106.2	-153.2
3/17/88	1121	77	-124.0	7.0	-103.7	-150.7
3/24/88	1128	84	-125.0	9.7	-101.8	-148.8
3/31/88	1135	91	-137.0	9.6	-112.7	-159.7
4/1/88	1136	92	-137.0	9.5	-112.8	-159.8
4/2/88	1137	93	-124.0	9.4	-101.2	-148.2
4/5/88	1140	96	-130.0	9.3	-106.7	-153.7
4/7/88	1142	98	-86.0	4.0	-72.8	-119.8
4/12/88	1147	103	-128.0	9.3	-104.9	-151.9
4/15/88	1150	106	-107.0	8.0	-87.5	-134.5
4/16/88	1151	107	-127.0	8.1	-105.3	-152.3
4/17/88	1152	108	-96.0	7.5	-78.1	-125.1
4/18/88	1153	109	-80.0	6.5	-64.9	-111.9
4/19/88	1154	110	-100.0	9.4	-79.7	-126.7
4/20/88	1155	111	-102.0	9.4	-81.5	-128.5
4/29/88	1164	120	-73.0	4.0	-61.2	-108.2
5/6/88	1171	127	-109.0	8.5	-88.7	-135.7
5/10/88	1175	131	-124.0	8.5	-102.2	-149.2
5/17/88	1182	138	-103.0	7.5	-84.4	-131.4
5/24/88	1189	145	-122.0	9.3	-99.6	-146.6
6/1/88	1197	153	-118.0	9.2	-96.1	-143.1
6/6/88	1202	158	-125.0	8.9	-102.7	-149.7
6/7/88	1203	159	-121.0	8.9	-99.1	-146.1
6/8/88	1204	160	-122.0	8.9	-100.0	-147.0
6/13/88	1209	165	-111.0	7.0	-92.1	-139.1
6/21/88	1217	173	-93.0	8.7	-74.2	-121.2
6/29/88	1225	181	-84.0	8.9	-65.9	-112.9
7/6/88	1232	188	-115.0	7.9	-94.7	-141.7
7/8/88	1234	190	-106.0	7.3	-87.3	-134.3
7/11/88	1237	193	-116.0	7.7	-95.9	-142.9
7/13/88	1239	195	-112.0	7.6	-92.4	-139.4
7/19/88	1245	201	-118.0	7.7	-97.6	-144.6
7/26/88	1252	208	-107.0	7.7	-87.8	-134.8
8/2/88	1259	215	-112.0	7.6	-92.4	-139.4
8/9/88	1266	222	-123.0	3.0	-107.0	-154.0

APPENDIX C- TENSIOMETRIC DATA

****

DATA FROM REPACKED COLUMNS

****

COLUMN 2

TENSIOMETER 3 68.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
12/6/87	1019	340	-126.0	8.8	-103.7	-171.7
12/15/87	1028	349	-181.0	7.4	-154.4	-222.4
1/5/88	1049	5	-103.0	6.0	-86.0	-154.0
1/13/88	1057	13	-104.0	8.8	-84.0	-152.0
1/19/88	1063	19	-118.0	8.8	-96.5	-164.5
1/26/88	1070	26	-84.0	7.0	-67.9	-135.9
2/2/88	1077	33	-105.0	8.3	-85.4	-153.4
2/5/88	1080	36	-109.0	7.0	-90.3	-158.3
2/6/88	1081	37	-106.0	7.0	-87.6	-155.6
2/7/88	1082	38	-101.0	6.8	-83.4	-151.4
2/8/88	1083	39	-68.0	5.0	-55.7	-123.7
2/9/88	1084	40	-110.0	7.0	-91.2	-159.2
2/16/88	1091	47	-82.0	6.0	-67.2	-135.2
2/23/88	1098	54	-101.0	7.5	-82.6	-150.6
3/1/88	1105	61	-101.0	7.2	-82.9	-150.9
3/17/88	1121	77	-102.0	7.0	-84.0	-152.0
3/24/88	1128	84	-97.0	8.1	-78.4	-146.4
3/31/88	1135	91	-110.0	8.0	-90.2	-158.2
4/1/88	1136	92				
4/2/88	1137	93	-73.0	7.8	-57.2	-125.2
4/5/88	1140	96	-58.0	6.5	-45.2	-113.2
4/7/88	1142	98	-69.0	7.4	-54.1	-122.1
4/12/88	1147	103	-61.0	5.0	-49.4	-117.4
4/15/88	1150	106	-45.0	6.0	-34.0	-102.0
4/16/88	1151	107	-107.0	8.7	-86.7	-154.7
4/17/88	1152	108	-106.0	8.6	-86.0	-154.0
4/18/88	1153	109	-92.0	8.6	-73.4	-141.4
4/19/88	1154	110	-91.0	8.5	-72.6	-140.6
4/20/88	1155	111	-91.0	8.5	-72.6	-140.6
4/29/88	1164	120	-91.0	7.5	-73.7	-141.7
5/6/88	1171	127	-87.0	7.0	-70.6	-138.6
5/10/88	1175	131	-87.0	8.6	-68.9	-136.9
5/17/88	1182	138	-41.0	2.0	-34.6	-102.6
5/24/88	1189	145	-90.0	7.7	-72.6	-140.6
6/1/88	1197	153	-91.0	7.4	-73.8	-141.8
6/6/88	1202	158	-94.0	7.4	-76.5	-144.5
6/7/88	1203	159	-71.0	6.8	-56.5	-124.5
6/8/88	1204	160	-88.0	8.8	-69.6	-137.6
6/13/88	1209	165	-72.0	6.8	-57.4	-125.4
6/21/88	1217	173	-75.0	8.5	-58.3	-126.3
6/29/88	1225	181	-76.0	7.9	-59.8	-127.8
7/6/88	1232	188	-95.0	7.8	-76.9	-144.9
7/8/88	1234	190	-93.0	7.5	-75.5	-143.5
7/11/88	1237	193	-91.0	7.5	-73.7	-141.7
7/13/88	1239	195	-85.0	6.9	-68.9	-136.9
7/19/88	1245	201	-78.0	7.4	-62.1	-130.1
7/26/88	1252	208	-56.0	7.0	-42.8	-110.8
8/2/88	1259	215	-61.0	6.5	-47.8	-115.8
8/9/88	1266	222	-76.0	3.0	-64.9	-132.9

APPENDIX C- TENSIOMETRIC DATA

****

DATA FROM REPACKED COLUMNS

****

COLUMN 2 GRADIENT

DATE	XD	JD	G23
12/6/87	1019	340	0.0
12/15/87	1028	349	-3.1
1/5/88	1049	5	0.2
1/13/88	1057	13	-0.1
1/19/88	1063	19	-0.1
1/26/88	1070	26	1.1
2/2/88	1077	33	-0.2
2/5/88	1080	36	-0.8
2/6/88	1081	37	-0.7
2/7/88	1082	38	-0.3
2/8/88	1083	39	0.7
2/9/88	1084	40	-0.9
2/16/88	1091	47	0.5
2/23/88	1098	54	0.0
3/1/88	1105	61	0.1
3/17/88	1121	77	-0.1
3/24/88	1128	84	0.1
3/31/88	1135	91	0.1
4/1/88	1136	92	
4/2/88	1137	93	1.1
4/5/88	1140	96	1.9
4/7/88	1142	98	-0.1
4/12/88	1147	103	1.6
4/15/88	1150	106	1.5
4/16/88	1151	107	-0.1
4/17/88	1152	108	-1.4
4/18/88	1153	109	-1.4
4/19/88	1154	110	-0.7
4/20/88	1155	111	-0.6
4/29/88	1164	120	-1.6
5/6/88	1171	127	-0.1
5/10/88	1175	131	0.6
5/17/88	1182	138	1.4
5/24/88	1189	145	0.3
6/1/88	1197	153	0.1
6/6/88	1202	158	0.2
6/7/88	1203	159	1.0
6/8/88	1204	160	0.4
6/13/88	1209	165	0.7
6/21/88	1217	173	-0.2
6/29/88	1225	181	-0.7
7/6/88	1232	188	-0.2
7/8/88	1234	190	-0.4
7/11/88	1237	193	0.1
7/13/88	1239	195	0.1
7/19/88	1245	201	0.7
7/26/88	1252	208	1.1
8/2/88	1259	215	1.1
8/9/88	1266	222	1.0

APPENDIX C- TENSIOMETRIC DATA

****
DATA FROM REPACKED COLUMNS
****

COLUMN 3

TENSIOMETER 1 31.5 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
12/6/87	1019	340				
12/15/87	1028	349				
1/5/88	1049	5				
1/13/88	1057	13	-452.0	5.0	-399.6	-431.1
1/19/88	1063	19	-454.0	9.3	-396.9	-428.4
1/26/88	1070	26	-457.0	7.6	-401.4	-432.9
2/2/88	1077	33	-439.0	7.5	-385.4	-416.9
2/5/88	1080	36	-355.0	6.0	-311.7	-343.2
2/6/88	1081	37	-324.0	6.0	-283.9	-315.4
2/7/88	1082	38	-246.0	6.0	-214.1	-245.6
2/8/88	1083	39	-208.0	6.0	-180.0	-211.5
2/9/88	1084	40	-248.0	6.8	-215.0	-246.5
2/16/88	1091	47	-329.0	8.3	-286.0	-317.5
2/23/88	1098	54	-321.0	7.4	-279.8	-311.3
3/1/88	1105	61	-314.0	6.8	-274.1	-305.6
3/17/88	1121	77				
3/24/88	1128	84	-241.0	6.5	-209.1	-240.6
3/31/88	1135	91	-205.0	6.0	-177.3	-208.8
4/1/88	1136	92	-202.0	8.8	-171.7	-203.2
4/2/88	1137	93	-202.0	8.3	-172.3	-203.8
4/5/88	1140	96	-216.0	6.9	-186.3	-217.8
4/7/88	1142	98	-219.0	8.8	-187.0	-218.5
4/12/88	1147	103	-267.0	8.1	-230.7	-262.2
4/15/88	1150	106	-226.0	7.0	-195.1	-226.6
4/16/88	1151	107	-237.0	8.2	-203.7	-235.2
4/17/88	1152	108	-244.0	7.7	-210.5	-242.0
4/18/88	1153	109	-221.0	7.7	-189.9	-221.4
4/19/88	1154	110	-217.0	7.6	-186.4	-217.9
4/20/88	1155	111	-227.0	7.5	-195.5	-227.0
4/29/88	1164	120	-240.0	7.2	-207.4	-238.9
5/6/88	1171	127	-257.0	5.5	-224.4	-255.9
5/10/88	1175	131	-218.0	6.0	-189.0	-220.5
5/17/88	1182	138	-245.0	7.0	-212.1	-243.6
5/24/88	1189	145	-254.0	7.0	-220.2	-251.7
6/1/88	1197	153	-287.0	7.0	-249.7	-281.2
6/6/88	1202	158	-314.0	8.4	-272.5	-304.0
6/7/88	1203	159	-283.0	7.9	-245.2	-276.7
6/8/88	1204	160	-276.0	7.5	-239.4	-270.9
6/13/88	1209	165	-234.0	4.0	-205.4	-236.9
6/21/88	1217	173	-156.0	4.0	-135.5	-167.0
6/29/88	1225	181	-202.0	7.9	-172.7	-204.2
7/6/88	1232	188	-258.0	7.9	-222.8	-254.3
7/8/88	1234	190	-198.0	6.8	-170.2	-201.7
7/11/88	1237	193	-119.0	6.3	-100.0	-131.5
7/13/88	1239	195	-101.0	5.5	-84.7	-116.2
7/19/88	1245	201	-137.0	7.4	-115.0	-146.5
7/26/88	1252	208	-141.0	6.0	-120.0	-151.5
8/2/88	1259	215	-84.0	6.5	-68.4	-99.9
8/9/88	1266	222				

APPENDIX C- TENSIOMETRIC DATA

****

DATA FROM REPACKED COLUMNS

****

COLUMN 3

TENSIOMETER 2 46.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
12/6/87	1019	340	-151.0	13.5	-121.1	-167.1
12/15/87	1028	349	-354.0	13.0	-303.5	-349.5
1/5/88	1049	5	-324.0	12.3	-277.3	-323.3
1/13/88	1057	13	-305.0	11.3	-261.4	-307.4
1/19/88	1063	19	-302.0	11.0	-259.0	-305.0
1/26/88	1070	26	-289.0	10.5	-247.9	-293.9
2/2/88	1077	33	-259.0	9.7	-221.8	-267.8
2/5/88	1080	36	-210.0	12.5	-175.0	-221.0
2/6/88	1081	37	-220.0	12.3	-184.2	-230.2
2/7/88	1082	38	-216.0	12.3	-180.6	-226.6
2/8/88	1083	39	-214.0	12.3	-178.8	-224.8
2/9/88	1084	40	-199.0	12.1	-165.6	-211.6
2/16/88	1091	47	-227.0	12.0	-190.8	-236.8
2/23/88	1098	54	-229.0	11.5	-193.1	-239.1
3/1/88	1105	61	-227.0	11.0	-191.8	-237.8
3/17/88	1121	77	-231.0	9.5	-197.0	-243.0
3/24/88	1128	84	-174.0	12.5	-142.8	-188.8
3/31/88	1135	91	-206.0	12.0	-172.0	-218.0
4/1/88	1136	92	-226.0	12.0	-189.9	-235.9
4/2/88	1137	93	-197.0	11.6	-164.3	-210.3
4/5/88	1140	96	-197.0	11.0	-165.0	-211.0
4/7/88	1142	98	-187.0	10.0	-157.0	-203.0
4/12/88	1147	103	-200.0	9.8	-168.9	-214.9
4/15/88	1150	106	-181.0	9.0	-152.7	-198.7
4/16/88	1151	107	-133.0	13.0	-105.5	-151.5
4/17/88	1152	108	-149.0	12.9	-120.0	-166.0
4/18/88	1153	109	-143.0	12.7	-114.8	-160.8
4/19/88	1154	110	-143.0	12.8	-114.7	-160.7
4/20/88	1155	111	-158.0	11.8	-129.2	-175.2
4/29/88	1164	120	-210.0	10.1	-177.5	-223.5
5/6/88	1171	127	-253.0	8.5	-217.7	-263.7
5/10/88	1175	131	-213.0	10.5	-179.8	-225.8
5/17/88	1182	138	-196.0	9.2	-165.9	-211.9
5/24/88	1189	145	-217.0	11.6	-182.2	-228.2
6/1/88	1197	153	-235.0	10.0	-200.0	-246.0
6/6/88	1202	158	-243.0	9.0	-208.2	-254.2
6/7/88	1203	159	-109.0	11.7	-85.4	-131.4
6/8/88	1204	160	-115.0	11.7	-90.8	-136.8
6/13/88	1209	165	-132.0	7.0	-110.9	-156.9
6/21/88	1217	173	-162.0	9.6	-135.1	-181.1
6/29/88	1225	181	-171.0	11.5	-141.1	-187.1
7/6/88	1232	188	-253.0	11.5	-214.6	-260.6
7/8/88	1234	190	-206.0	11.2	-172.8	-218.8
7/11/88	1237	193	-205.0	11.0	-172.1	-218.1
7/13/88	1239	195	-194.0	10.6	-162.7	-208.7
7/19/88	1245	201	-208.0	10.3	-175.5	-221.5
7/26/88	1252	208	-195.0	9.8	-164.4	-210.4
8/2/88	1259	215	-168.0	10.0	-140.0	-186.0
8/9/88	1266	222	-168.0	10.5	-139.5	-185.5

APPENDIX C- TENSIOMETRIC DATA

****

DATA FROM REPACKED COLUMNS

****

COLUMN 3

TENSIOMETER 3 65.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
12/6/87	1019	340	-64.0	9.5	-47.4	-112.4
12/15/87	1028	349	-127.0	9.5	-103.8	-168.8
1/5/88	1049	5	-73.0	9.5	-55.5	-120.5
1/13/88	1057	13	-61.0	9.5	-44.7	-109.7
1/19/88	1063	19	-56.0	9.5	-40.2	-105.2
1/26/88	1070	26	-65.0	9.5	-48.3	-113.3
2/2/88	1077	33	-22.0	9.5	-9.8	-74.8
2/5/88	1080	36	-53.0	9.5	-37.5	-102.5
2/6/88	1081	37	-59.0	9.5	-42.9	-107.9
2/7/88	1082	38	-53.0	9.5	-37.5	-102.5
2/8/88	1083	39	-52.0	9.5	-36.6	-101.6
2/9/88	1084	40	-26.0	9.5	-13.4	-78.4
2/16/88	1091	47	-30.0	9.5	-16.9	-81.9
2/23/88	1098	54	-13.0	9.5	-1.7	-66.7
3/1/88	1105	61	-9.0	9.5	1.9	-63.1
3/17/88	1121	77	-39.0	9.5	-25.0	-90.0
3/24/88	1128	84	-5.0	9.5	5.4	-59.6
3/31/88	1135	91	-6.0	9.5	4.6	-60.4
4/1/88	1136	92	-37.0	9.5	-23.2	-88.2
4/2/88	1137	93	-25.0	9.2	-12.8	-77.8
4/5/88	1140	96	-48.0	9.3	-33.3	-98.3
4/7/88	1142	98	-43.0	9.3	-28.8	-93.8
4/12/88	1147	103	-11.0	9.3	-0.1	-65.1
4/15/88	1150	106				
4/16/88	1151	107				
4/17/88	1152	108				
4/18/88	1153	109				
4/19/88	1154	110				
4/20/88	1155	111				
4/29/88	1164	120				
5/6/88	1171	127				
5/10/88	1175	131	-92.0	9.8	-72.2	-137.2
5/17/88	1182	138				
5/24/88	1189	145	-130.0	9.6	-106.4	-171.4
6/1/88	1197	153	-118.0	9.6	-95.7	-160.7
6/6/88	1202	158	-107.0	9.6	-85.8	-150.8
6/7/88	1203	159	-92.0	9.6	-72.4	-137.4
6/8/88	1204	160	-82.0	9.5	-63.5	-128.5
6/13/88	1209	165	-58.0	9.5	-42.0	-107.0
6/21/88	1217	173				
6/29/88	1225	181				
7/6/88	1232	188				
7/8/88	1234	190				
7/11/88	1237	193				
7/13/88	1239	195				
7/19/88	1245	201				
7/26/88	1252	208				
8/2/88	1259	215				
8/9/88	1266	222				

APPENDIX C- TENSIOMETRIC DATA

****

DATA FROM REPACKED COLUMNS

****

COLUMN 3

			GRADIENTS		
DATE	XD	JD	G12	G13	G23
12/6/87	1019	340			2.9
12/15/87	1028	349			9.5
1/5/88	1049	5			10.7
1/13/88	1057	13	8.5	9.6	10.4
1/19/88	1063	19	8.5	9.6	10.5
1/26/88	1070	26	9.6	9.5	9.5
2/2/88	1077	33	10.3	10.2	10.2
2/5/88	1080	36	8.4	7.2	6.2
2/6/88	1081	37	5.9	6.2	6.4
2/7/88	1082	38	1.3	4.3	6.5
2/8/88	1083	39	-0.9	3.3	6.5
2/9/88	1084	40	2.4	5.0	7.0
2/16/88	1091	47	5.6	7.0	8.1
2/23/88	1098	54	5.0	7.3	9.1
3/1/88	1105	61	4.7	7.2	9.2
3/17/88	1121	77			8.1
3/24/88	1128	84	3.6	5.4	6.8
3/31/88	1135	91	-0.6	4.4	8.3
4/1/88	1136	92			
4/2/88	1137	93			
4/5/88	1140	96			
4/7/88	1142	98			
4/12/88	1147	103	3.3		
4/15/88	1150	106	1.9		
4/16/88	1151	107	5.8		
4/17/88	1152	108	5.2		
4/18/88	1153	109	4.2		
4/19/88	1154	110	3.9		
4/20/88	1155	111	3.6		
4/29/88	1164	120	1.1		
5/6/88	1171	127	-0.5		
5/10/88	1175	131	-0.4		
5/17/88	1182	138	2.2		
5/24/88	1189	145	1.6		
6/1/88	1197	153	2.4		
6/6/88	1202	158	3.4		
6/7/88	1203	159	10.0		
6/8/88	1204	160	9.2		
6/13/88	1209	165	5.5		
6/21/88	1217	173	-1.0		
6/29/88	1225	181	1.2		
7/6/88	1232	188	-0.4		
7/8/88	1234	190	-1.2		
7/11/88	1237	193	-6.0		
7/13/88	1239	195	-6.4		
7/19/88	1245	201	-5.2		
7/26/88	1252	208	-4.1		
8/2/88	1259	215	-5.9		
8/9/88	1266	222			

APPENDIX C- TENSIOMETRIC DATA

****
DATA FROM REPACKED COLUMNS
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COLUMN 4

TENSIOMETER 1 30.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
12/6/87	1019	340	-251.0	9.8	-214.6	-244.6
12/15/87	1028	349	-392.0	9.0	-341.7	-371.7
1/5/88	1049	5	-312.0	8.3	-270.8	-300.8
1/13/88	1057	13	-288.0	8.0	-249.6	-279.6
1/19/88	1063	19	-302.0	7.5	-262.7	-292.7
1/26/88	1070	26	-250.0	8.4	-215.1	-245.1
2/2/88	1077	33	-258.0	7.6	-223.1	-253.1
2/5/88	1080	36	-255.0	8.5	-219.5	-249.5
2/6/88	1081	37	-200.0	8.0	-170.8	-200.8
2/7/88	1082	38	-141.0	7.3	-118.7	-148.7
2/8/88	1083	39	-83.0	6.8	-67.2	-97.2
2/9/88	1084	40	-148.0	9.0	-123.2	-153.2
2/16/88	1091	47	-186.0	7.3	-159.0	-189.0
2/23/88	1098	54	-214.0	6.4	-185.0	-215.0
3/1/88	1105	61	-233.0	8.6	-199.7	-229.7
3/17/88	1121	77	-245.0	8.0	-211.1	-241.1
3/24/88	1128	84	-212.0	6.8	-182.8	-212.8
3/31/88	1135	91	-153.0	6.8	-129.9	-159.9
4/1/88	1136	92	-144.0	8.9	-119.7	-149.7
4/2/88	1137	93	-128.0	8.6	-105.7	-135.7
4/5/88	1140	96	-130.0	6.9	-109.2	-139.2
4/7/88	1142	98	-158.0	8.0	-133.2	-163.2
4/12/88	1147	103	-199.0	7.5	-170.4	-200.4
4/15/88	1150	106	-201.0	7.0	-172.7	-202.7
4/16/88	1151	107	-202.0	9.3	-171.2	-201.2
4/17/88	1152	108	-214.0	9.3	-182.0	-212.0
4/18/88	1153	109	-191.0	9.3	-161.4	-191.4
4/19/88	1154	110	-184.0	9.2	-155.2	-185.2
4/20/88	1155	111	-201.0	9.2	-170.4	-200.4
4/29/88	1164	120	-204.0	8.5	-173.8	-203.8
5/6/88	1171	127	-211.0	7.5	-181.1	-211.1
5/10/88	1175	131	-259.0	7.3	-224.4	-254.4
5/17/88	1182	138	-199.0	7.2	-170.7	-200.7
5/24/88	1189	145	-216.0	6.5	-186.7	-216.7
6/1/88	1197	153	-151.0	6.9	-128.0	-158.0
6/6/88	1202	158	-80.0	2.5	-69.0	-99.0
6/7/88	1203	159	-123.0	9.2	-100.6	-130.6
6/8/88	1204	160	-128.0	8.5	-105.8	-135.8
6/13/88	1209	165	-145.0	6.0	-123.6	-153.6
6/21/88	1217	173	-170.0	6.5	-145.5	-175.5
6/29/88	1225	181	-180.0	6.5	-154.4	-184.4
7/6/88	1232	188	-263.0	8.6	-226.6	-256.6
7/8/88	1234	190	-213.0	8.5	-181.9	-211.9
7/11/88	1237	193	-226.0	8.2	-193.9	-223.9
7/13/88	1239	195	-188.0	7.6	-160.4	-190.4
7/19/88	1245	201	-207.0	7.5	-177.6	-207.6
7/26/88	1252	208	-200.0	7.3	-171.5	-201.5
8/2/88	1259	215	-206.0	8.8	-175.3	-205.3
8/9/88	1266	222	-213.0	8.5	-181.9	-211.9

APPENDIX C- TENSIOMETRIC DATA

****

DATA FROM REPACKED COLUMNS

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COLUMN 4

TENSIOMETER 2 46.0 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
12/6/87	1019	340	-172.0	9.5	-144.1	-190.1
12/15/87	1028	349	-136.0	6.0	-115.5	-161.5
1/5/88	1049	5	-125.0	6.0	-105.7	-151.7
1/13/88	1057	13	-175.0	9.0	-147.3	-193.3
1/19/88	1063	19	-208.0	9.1	-176.8	-222.8
1/26/88	1070	26	-173.0	9.0	-145.5	-191.5
2/2/88	1077	33	-177.0	8.3	-149.9	-195.9
2/5/88	1080	36	-193.0	9.2	-163.3	-209.3
2/6/88	1081	37	-196.0	9.2	-165.9	-211.9
2/7/88	1082	38	-178.0	9.2	-149.8	-195.8
2/8/88	1083	39	-166.0	9.0	-139.3	-185.3
2/9/88	1084	40	-164.0	9.1	-137.4	-183.4
2/16/88	1091	47	-171.0	9.0	-143.8	-189.8
2/23/88	1098	54	-170.0	8.2	-143.7	-189.7
3/1/88	1105	61	-181.0	8.2	-153.5	-199.5
3/17/88	1121	77	-180.0	7.5	-153.4	-199.4
3/24/88	1128	84	-167.0	8.7	-140.5	-186.5
3/31/88	1135	91	-180.0	8.5	-152.3	-198.3
4/1/88	1136	92	-193.0	8.5	-164.0	-210.0
4/2/88	1137	93	-141.0	8.4	-117.5	-163.5
4/5/88	1140	96	-167.0	7.9	-141.3	-187.3
4/7/88	1142	98	-159.0	9.6	-132.4	-178.4
4/12/88	1147	103	-180.0	9.5	-151.3	-197.3
4/15/88	1150	106	-162.0	8.8	-135.9	-181.9
4/16/88	1151	107	-192.0	8.8	-162.8	-208.8
4/17/88	1152	108	-185.0	8.7	-156.6	-202.6
4/18/88	1153	109	-163.0	8.7	-136.9	-182.9
4/19/88	1154	110	-92.0	7.8	-74.3	-120.3
4/20/88	1155	111	-138.0	7.8	-115.5	-161.5
4/29/88	1164	120	-147.0	7.5	-123.8	-169.8
5/6/88	1171	127	-152.0	7.0	-128.8	-174.8
5/10/88	1175	131	-177.0	9.0	-149.1	-195.1
5/17/88	1182	138	-158.0	7.9	-133.3	-179.3
5/24/88	1189	145	-173.0	6.8	-147.8	-193.8
6/1/88	1197	153	-122.0	7.5	-101.4	-147.4
6/6/88	1202	158	-163.0	9.6	-136.0	-182.0
6/7/88	1203	159	-152.0	9.6	-126.1	-172.1
6/8/88	1204	160	-156.0	9.5	-129.8	-175.8
6/13/88	1209	165	-142.0	9.3	-117.5	-163.5
6/21/88	1217	173	-121.0	8.2	-99.8	-145.8
6/29/88	1225	181	-153.0	8.1	-128.6	-174.6
7/6/88	1232	188	-193.0	7.0	-165.6	-211.6
7/8/88	1234	190	-170.0	9.4	-142.4	-188.4
7/11/88	1237	193	-182.0	9.4	-153.2	-199.2
7/13/88	1239	195	-160.0	9.1	-133.8	-179.8
7/19/88	1245	201	-161.0	8.5	-135.3	-181.3
7/26/88	1252	208	-154.0	8.2	-129.4	-175.4
8/2/88	1259	215	-156.0	7.8	-131.6	-177.6
8/9/88	1266	222	-181.0	7.0	-154.8	-200.8

APPENDIX C- TENSIOMETRIC DATA

****

DATA FROM REPACKED COLUMNS

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COLUMN 4

TENSIOMETER 3 66.3 CM DEEP

DATE	XD	JD	READING	H2O	PSI	TH
12/6/87	1019	340	-120.0	9.3	-97.8	-164.1
12/15/87	1028	349	-189.0	9.3	-159.6	-225.9
1/5/88	1049	5	-120.0	6.0	-101.2	-167.5
1/13/88	1057	13	-132.0	9.3	-108.5	-174.8
1/19/88	1063	19	-153.0	9.3	-127.3	-193.6
1/26/88	1070	26	-122.0	8.6	-100.3	-166.6
2/2/88	1077	33	-132.0	8.0	-109.9	-176.2
2/5/88	1080	36	-145.0	8.5	-121.0	-187.3
2/6/88	1081	37	-145.0	8.5	-121.0	-187.3
2/7/88	1082	38	-138.0	8.5	-114.7	-181.0
2/8/88	1083	39	-125.0	8.5	-103.1	-169.4
2/9/88	1084	40	-133.0	8.5	-110.2	-176.5
2/16/88	1091	47	-122.0	8.0	-100.9	-167.2
2/23/88	1098	54	-134.0	7.7	-112.0	-178.3
3/1/88	1105	61	-133.0	7.2	-111.6	-177.9
3/17/88	1121	77	-141.0	8.5	-117.4	-183.7
3/24/88	1128	84	-118.0	8.0	-97.3	-163.6
3/31/88	1135	91	-119.0	6.6	-99.7	-166.0
4/1/88	1136	92	-140.0	9.0	-116.0	-182.3
4/2/88	1137	93	-134.0	8.9	-110.7	-177.0
4/5/88	1140	96	-110.0	7.5	-90.7	-157.0
4/7/88	1142	98	-105.0	7.5	-86.2	-152.5
4/12/88	1147	103	-127.0	8.5	-104.9	-171.2
4/15/88	1150	106	-122.0	7.3	-101.6	-167.9
4/16/88	1151	107	-144.0	7.2	-121.5	-187.8
4/17/88	1152	108	-101.0	7.0	-83.1	-149.4
4/18/88	1153	109	-79.0	6.0	-64.5	-130.8
4/19/88	1154	110	-124.0	9.1	-101.6	-167.9
4/20/88	1155	111	-113.0	8.8	-92.0	-158.3
4/29/88	1164	120	-116.0	7.4	-96.2	-162.5
5/6/88	1171	127	-113.0	7.0	-93.9	-160.2
5/10/88	1175	131	-121.0	9.3	-98.7	-165.0
5/17/88	1182	138	-114.0	8.5	-93.2	-159.5
5/24/88	1189	145	-122.0	8.0	-100.9	-167.2
6/1/88	1197	153	-124.0	7.8	-102.9	-169.2
6/6/88	1202	158	-113.0	7.4	-93.5	-159.8
6/7/88	1203	159	-106.0	7.4	-87.2	-153.5
6/8/88	1204	160	-115.0	7.1	-95.6	-161.9
6/13/88	1209	165	-126.0	8.5	-104.0	-170.3
6/21/88	1217	173	-106.0	7.7	-86.9	-153.2
6/29/88	1225	181	-110.0	7.2	-91.0	-157.3
7/6/88	1232	188	-125.0	8.6	-103.0	-169.3
7/8/88	1234	190	-96.0	5.5	-80.2	-146.5
7/11/88	1237	193	-92.0	4.5	-77.7	-144.0
7/13/88	1239	195	-123.0	9.0	-100.8	-167.1
7/19/88	1245	201	-100.0	8.5	-80.7	-147.0
7/26/88	1252	208	-58.0	5.0	-46.7	-113.0
8/2/88	1259	215	-111.0	8.2	-90.9	-157.2
8/9/88	1266	222	-123.0	7.7	-102.1	-168.4

APPENDIX C- TENSIOMETRIC DATA

****

DATA FROM REPACKED COLUMNS

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COLUMN 4

			GRADIENTS		
DATE	XD	JD	G12	G13	G23
12/6/87	1019	340	3.4	2.2	1.3
12/15/87	1028	349	13.1	4.0	-3.2
1/5/88	1049	5	9.3	3.7	-0.8
1/13/88	1057	13	5.4	2.9	0.9
1/19/88	1063	19	4.4	2.7	1.4
1/26/88	1070	26	3.3	2.2	1.2
2/2/88	1077	33	3.6	2.1	1.0
2/5/88	1080	36	2.5	1.7	1.1
2/6/88	1081	37	-0.7	0.4	1.2
2/7/88	1082	38	-2.9	-0.9	0.7
2/8/88	1083	39	-5.5	-2.0	0.8
2/9/88	1084	40	-1.9	-0.6	0.3
2/16/88	1091	47	-0.0	0.6	1.1
2/23/88	1098	54	1.6	1.0	0.6
3/1/88	1105	61	1.9	1.4	1.1
3/17/88	1121	77	2.6	1.6	0.8
3/24/88	1128	84	1.6	1.4	1.1
3/31/88	1135	91	-2.4	-0.2	1.6
4/1/88	1136	92	-3.8	-0.9	1.4
4/2/88	1137	93	-1.7	-1.1	-0.7
4/5/88	1140	96	-3.0	-0.5	1.5
4/7/88	1142	98	-1.0	0.3	1.3
4/12/88	1147	103	0.2	0.8	1.3
4/15/88	1150	106	1.3	1.0	0.7
4/16/88	1151	107	-0.5	0.4	1.0
4/17/88	1152	108	0.6	1.7	2.6
4/18/88	1153	109	0.5	1.7	2.6
4/19/88	1154	110	4.1	0.5	-2.3
4/20/88	1155	111	2.4	1.2	0.2
4/29/88	1164	120	2.1	1.1	0.4
5/6/88	1171	127	2.3	1.4	0.7
5/10/88	1175	131	3.7	2.5	1.5
5/17/88	1182	138	1.3	1.1	1.0
5/24/88	1189	145	1.4	1.4	1.3
6/1/88	1197	153	0.7	-0.3	-1.1
6/6/88	1202	158	-5.2	-1.7	1.1
6/7/88	1203	159	-2.6	-0.6	0.9
6/8/88	1204	160	-2.5	-0.7	0.7
6/13/88	1209	165	-0.6	-0.5	-0.3
6/21/88	1217	173	1.9	0.6	-0.4
6/29/88	1225	181	0.6	0.7	0.9
7/6/88	1232	188	2.8	2.4	2.1
7/8/88	1234	190	1.5	1.8	2.1
7/11/88	1237	193	1.5	2.2	2.7
7/13/88	1239	195	0.7	0.6	0.6
7/19/88	1245	201	1.6	1.7	1.7
7/26/88	1252	208	1.6	2.4	3.1
8/2/88	1259	215	1.7	1.3	1.0
8/9/88	1266	222	0.7	1.2	1.6

APPENDIX C.2

COLUMN #1

DATE	TENS. #	TIME	READING	W. L.	PSI	% DIFF.
1/19/88	1	11.00	-531	9.20	-506.56	0.00
		14.00	-520	9.00	-496.06	-2.07
		17.00	-525	9.00	-500.74	-1.15
	2	11.00	-225	7.75	-218.67	0.00
		14.00	-219	7.75	-213.05	-2.57
		17.00	-228	7.70	-221.42	1.26
	3	11.00	-233	17.85	-236.71	0.00
		14.00	-228	17.80	-231.98	-2.00
		17.00	-238	17.80	-241.34	1.95
8/9/88	1	7.25	-430	9.40	-412.25	0.00
		11.75	-384	9.30	-369.09	-10.47
		16.25	-371	9.30	-356.93	-13.42
	2	7.25	-7	9.00	-15.96	0.00
		11.75	-7	9.00	-15.96	0.00
		16.25	-7	9.00	-15.96	0.00
	3	7.25	-261	16.80	-261.82	0.00
		11.75	-281	16.70	-280.43	7.11
		4.25	-224	16.70	-227.09	-13.27

COLUMN #2

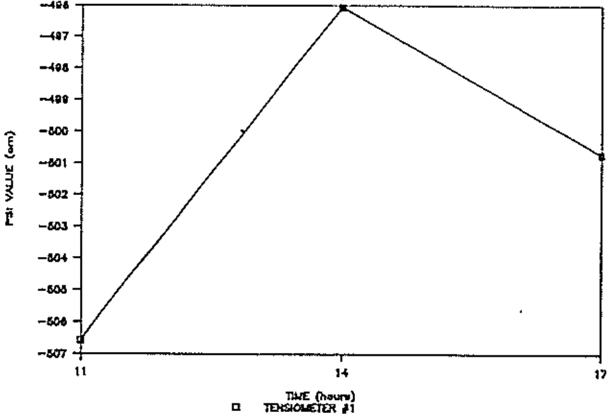
DATE	TENS. #	TIME	READING	W. L.	PSI	% DIFF.
1/19/88	2	11.00	-140	10.00	-141.47	0.00
		14.00	-130	10.00	-132.11	-6.62
		17.00	-138	10.00	-139.60	-1.32
	3	11.00	-118	8.75	-119.58	0.00
		14.00	-112	8.75	-113.96	-4.70
		17.00	-118	8.75	-119.58	0.00
8/9/88	2	7.25	-123	3.00	-118.25	0.00
		11.75	-98	3.00	-94.85	-19.79
		16.25	-121	3.00	-116.38	-1.58
	3	7.25	-76	3.00	-74.26	0.00
		11.75	-36	3.00	-36.83	-50.41
		16.25	-54	3.00	-53.67	-27.73

COLUMN #3

DATE	TENS. #	TIME	READING	W. L.	PSI	% DIFF.
1/19/88	1	11.00	-454	9.25	-434.55	0.00
		14.00	-442	9.25	-423.32	-2.58
		17.00	-445	9.25	-426.13	-1.94
	2	11.00	-302	11.00	-294.13	0.00
		14.00	-295	11.00	-287.58	-2.23
		17.00	-302	11.00	-294.13	0.00
	3	11.00	-56	9.50	-62.34	0.00
		14.00	-51	9.50	-57.66	-7.51
		17.00	-58	9.50	-64.21	3.00
8/9/88	2	7.25	-168	10.50	-168.20	0.00
		11.75	-126	10.50	-128.89	-23.37
		16.25	-126	10.50	-128.89	-23.37

COLUMN #4

DATE	TENS. #	TIME	READING	W. L.	PSI	% DIFF.
1/19/88	1	11.00	-302	7.50	-290.47	0
		14.00	ADDED WATER TO TENSIOMETER			
		17.00	HAS NOT EQUILIBRATED YET			
	2	11.00	-208	9.10	-204.17	0.00
		14.00	-199	9.10	-195.75	-4.13
		17.00	-208	9.10	-204.17	0.00
	3	11.00	-153	9.25	-152.85	0.00
		14.00	-148	9.25	-148.18	-3.06
		17.00	-154	9.25	-153.79	0.61
8/9/88	1	7.25	-213	8.50	-208.22	0.00
		11.75	-152	8.40	-151.03	-27.47
		16.25	-153	8.40	-151.97	-27.02
	2	7.25	-181	7.00	-176.71	0.00
		11.75	-140	7.00	-138.34	-21.71
		16.25	-154	7.00	-151.44	-14.30
	3	7.25	-123	7.70	-123.16	0.00
		11.75	-110	7.55	-110.84	-10.01
		16.25	-125	7.55	-124.87	1.39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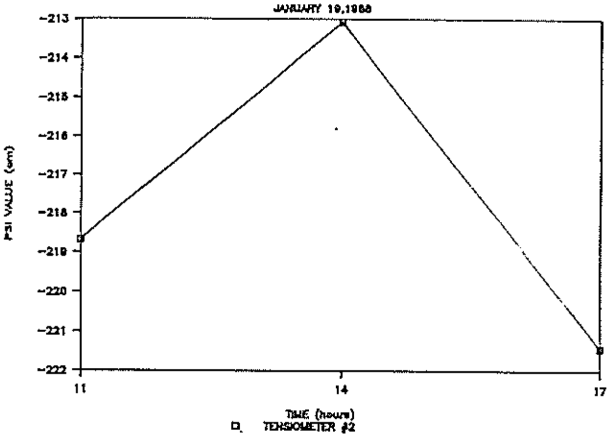
JANUARY 19,1988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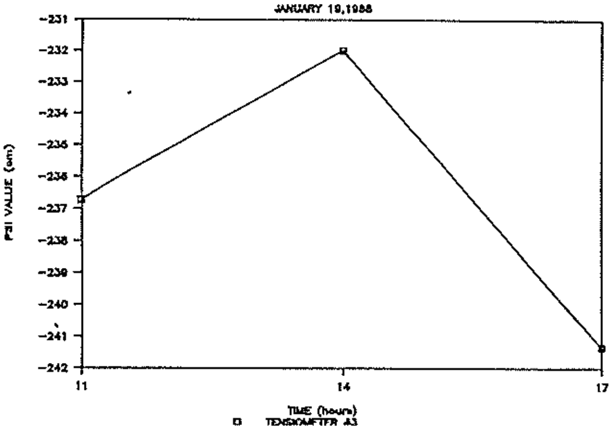
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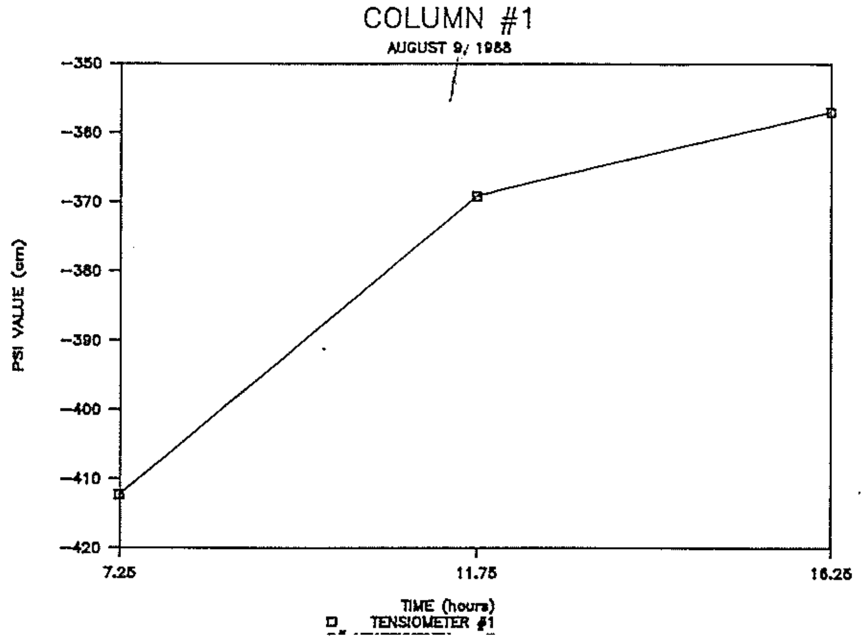
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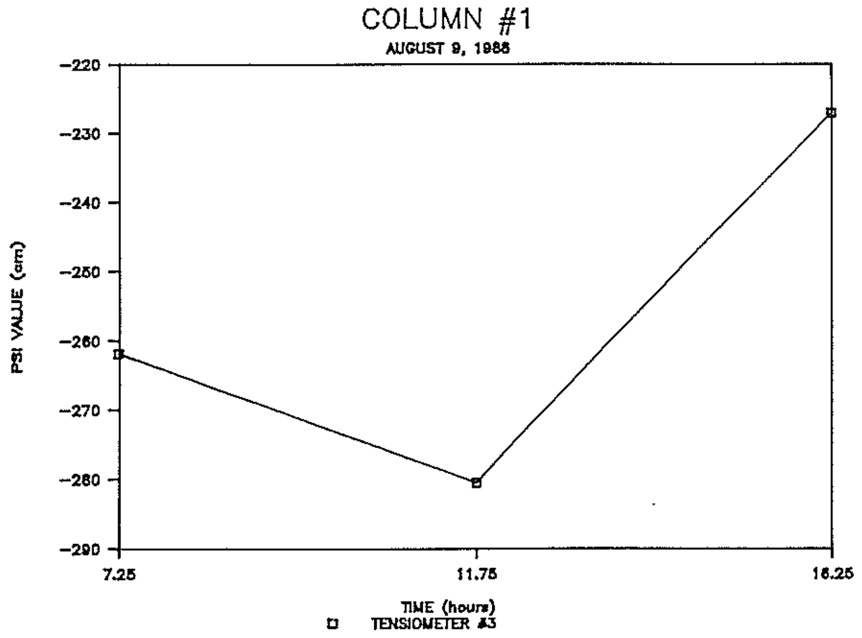
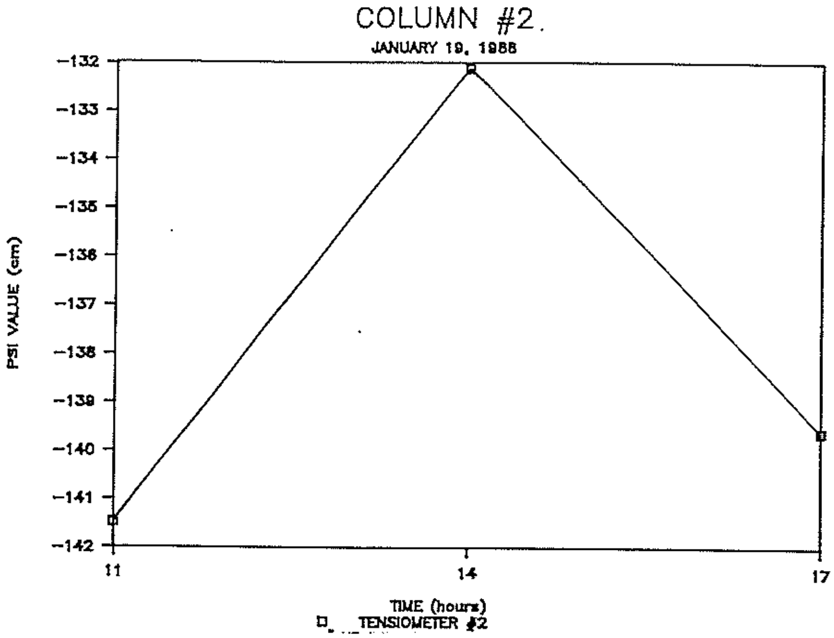
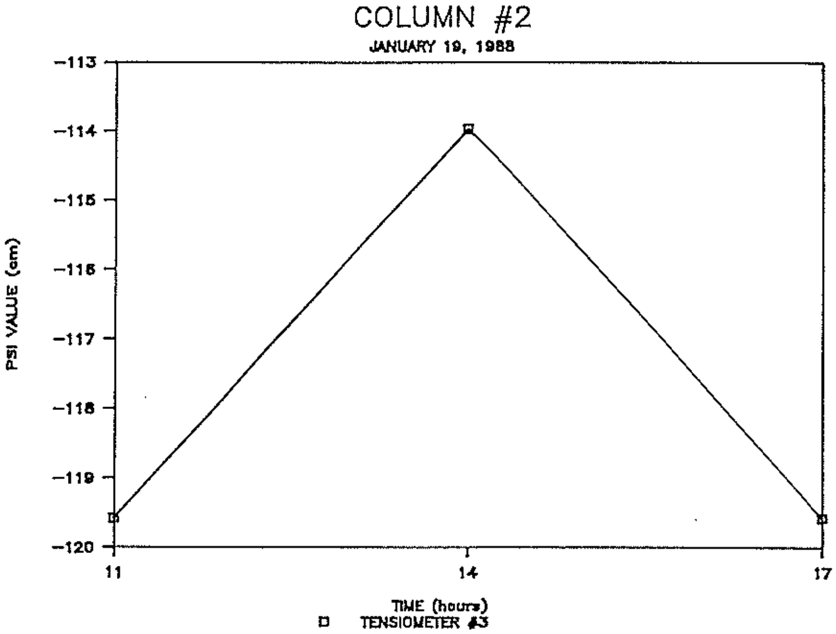
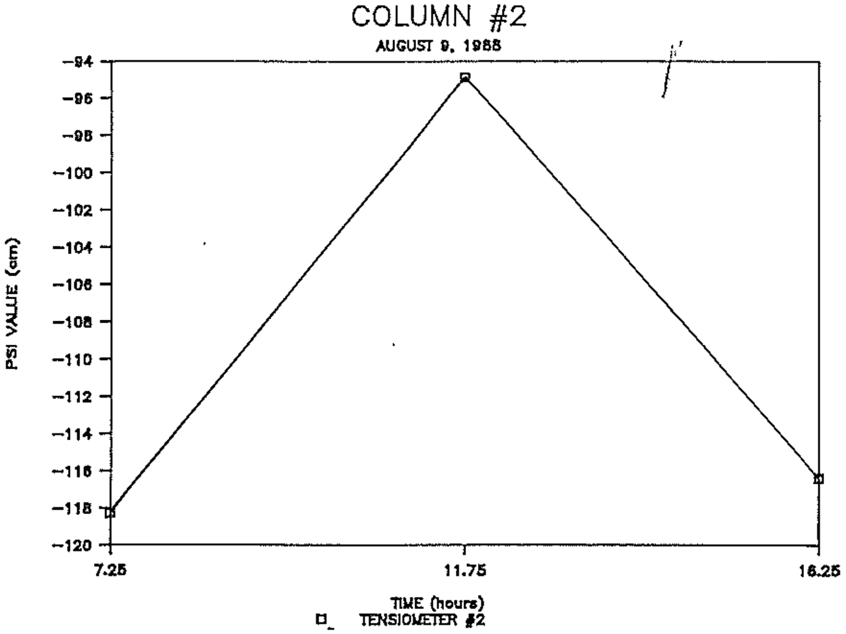
AUGUST 9, 1988
PSI VALUE (cm)
-350
-360
-370
-380
-390
-400
-410
-420
7.25
11.75
16.25
TIME (hours)
□ TENSIOMETER #1


COLUMN #1
AUGUST 9, 1988
PSI VALUE (cm)
-220
-230
-240
-250
-260
-270
-280
-290
7.25
11.75
16.25
TIME (hours)
□ TENSIOMETER #3

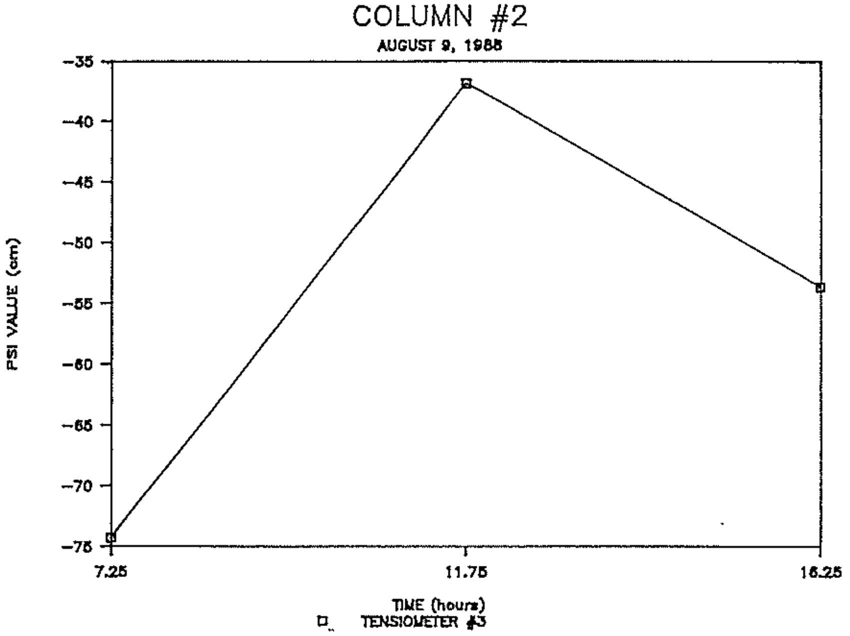

COLUMN #2.
JANUARY 19, 1988
PSI VALUE (cm)
-132
-133
-134
-135
-136
-137
-138
-139
-140
-141
-142
11
14
17
TIME (hours)
□ TENSIOMETER #2


COLUMN #2
JANUARY 19, 1988
PSI VALUE (cm)
-113
-114
-115
-116
-117
-118
-119
-120
11
14
17
TIME (hours)
□ TENSIOMETER #3



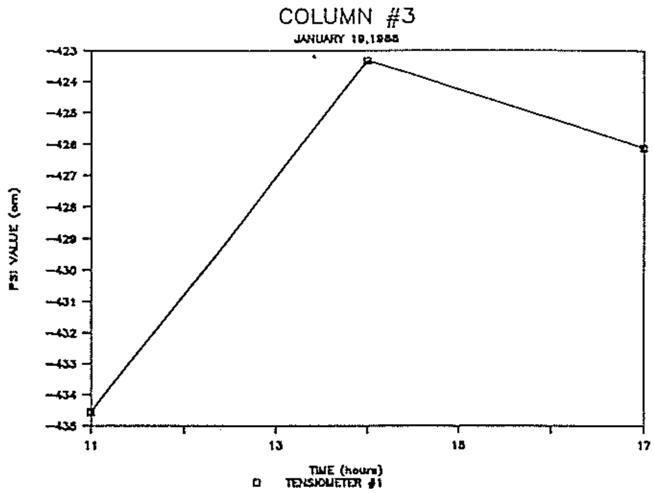
COLUMN #2

AUGUST 9, 1988



COLUMN #2

AUGUST 9, 1988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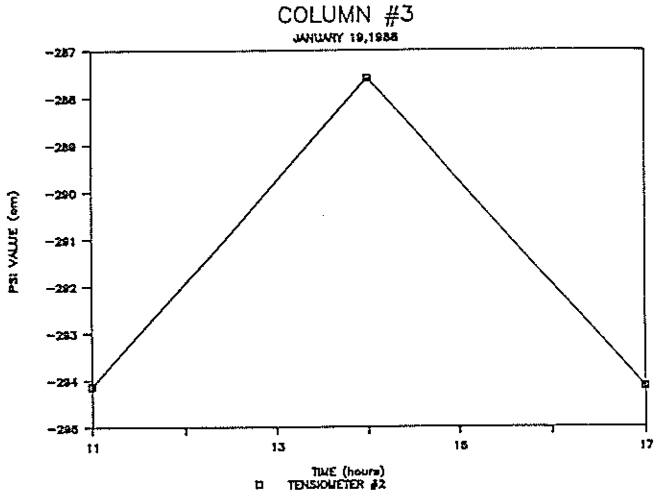
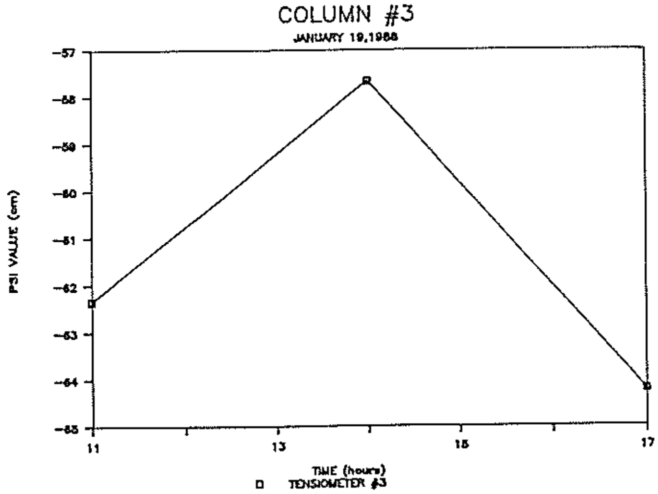
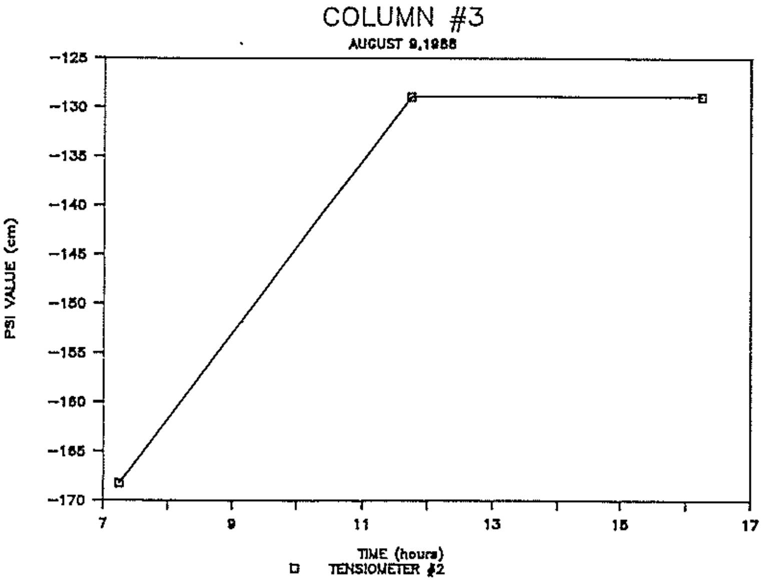
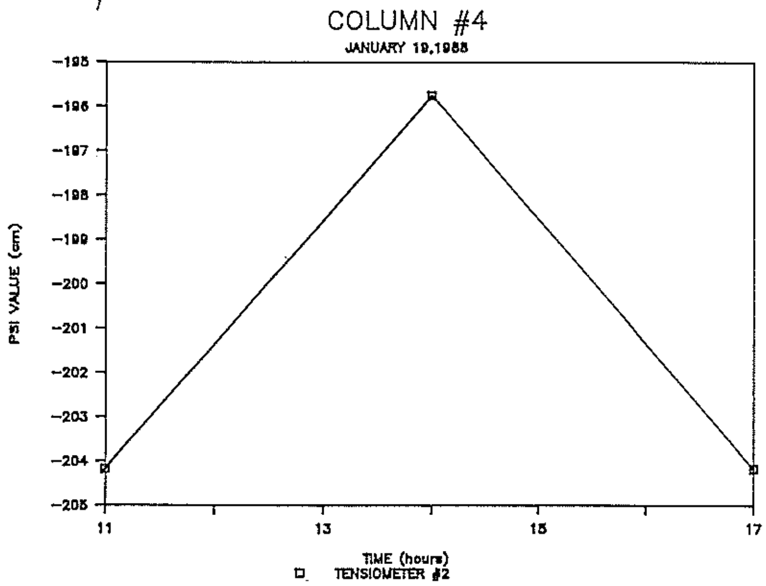
JANUARY 19,1988
PSI VALUE (cm)
-423
-424
-425
-426
-427
-428
-429
-430
-431
-432
-433
-434
-435
11
13
15
17
TIME (hours)
□ TENSIOMETER #1

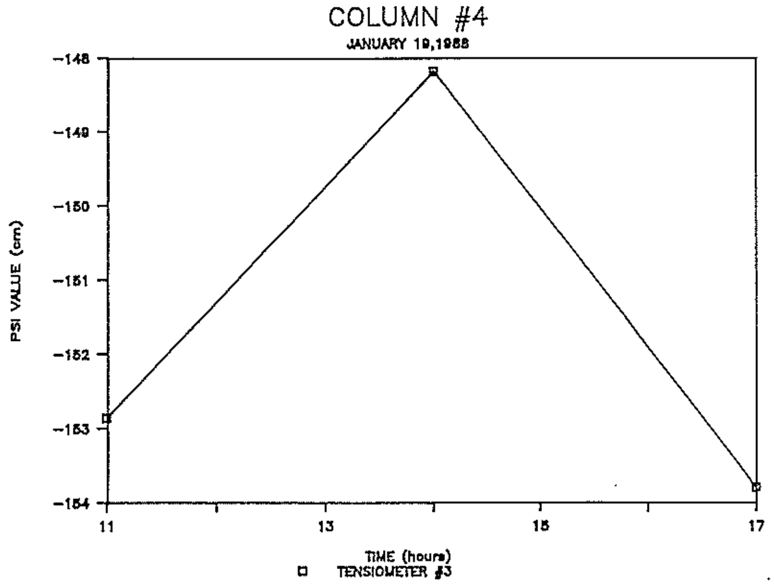

COLUMN #3
JANUARY 19,1988
PSI VALUE (cm)
-287
-288
-289
-290
-291
-292
-293
-294
-295
11
13
15
17
TIME (hours)
□ TENSIOMETER #2


COLUMN #3
JANUARY 19,1988
PSI VALUE (cm)
-57
-58
-59
-60
-61
-62
-63
-64
-65
11
13
15
17
TIME (hours)
□ TENSIOMETER #3


COLUMN #3
AUGUST 9,1988
PSI VALUE (cm)
-125
-130
-135
-140
-145
-150
-155
-160
-165
-170
7
9
11
13
15
17
TIME (hours)
□ TENSIOMETER #2


COLUMN #4

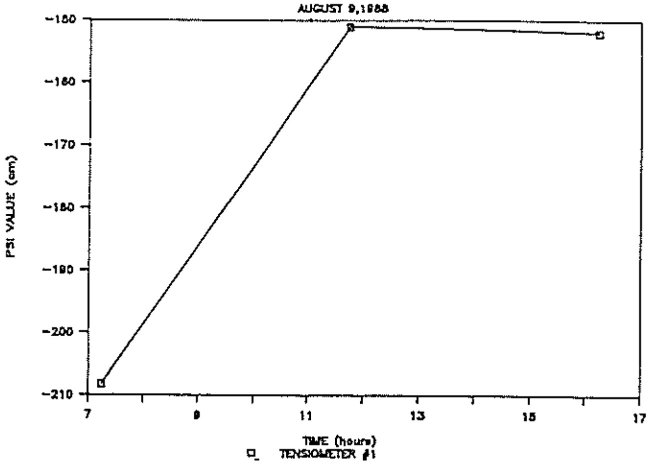
JANUARY 19,1988


COLUMN #4

JANUARY 19,1988

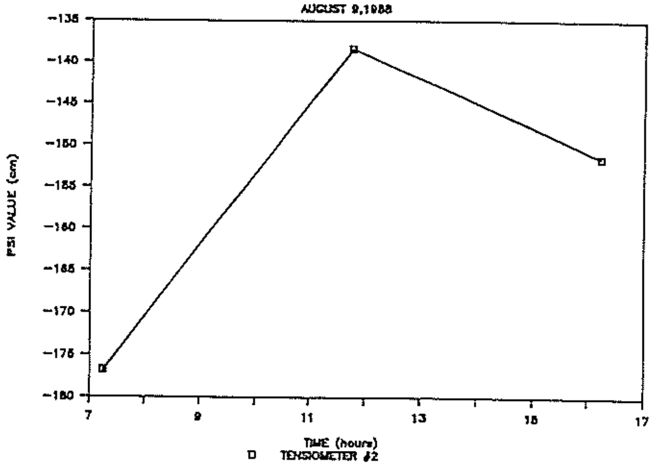
COLUMN #4

AUGUST 9,1988



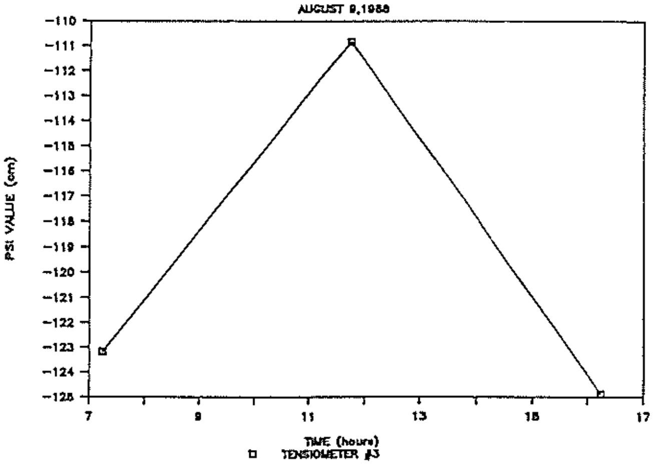
COLUMN #4

AUGUST 9,1988



COLUMN #4

AUGUST 9,1988



APPENDIX D

PRECIPITATION & EVAPORATION (CM)

PREC = precipitation (cm)
PAN EV = measured pan evaporation (cm)
PANADJ. = meas. pan evap. + precip. (total pan evap.)
.7PANADJ = corrected total pan evaporation

DATE	JULIAN DAYS	PREC	PAN EV	PANADJ	.7PANADJ
2/18/85	49.0	0.001	0.000	0.001	0.001
2/19/85	50.0	0.000	0.000	0.000	0.000
2/20/85	51.0	0.000	0.000	0.000	0.000
2/27/85	58.0	0.230	3.228	3.458	2.421
3/1/85	60.0	0.000	0.000	0.000	0.000
3/4/85	63.0	0.000	0.000	0.000	0.000
3/7/85	66.0	0.000	0.000	0.000	0.000
3/12/85	71.0	0.000	0.000	0.000	0.000
3/19/85	78.0	1.370	2.710	4.080	2.856
3/23/85	82.0	0.000	0.000	0.000	0.000
3/25/85	84.0	0.000	0.000	0.000	0.000
3/29/85	88.0	0.000	0.000	0.000	0.000
4/1/85	91.0	0.000	0.000	0.000	0.000
4/19/85	109.0	0.000	0.000	0.000	0.000
4/22/85	112.0	0.000	0.000	0.000	0.000
4/25/85	115.0	0.000	0.000	0.000	0.000
4/29/85	119.0	0.000	0.000	0.000	0.000
5/2/85	122.0	0.150	2.143	2.293	1.605
5/6/85	126.0	0.000	0.000	0.000	0.000
5/10/85	130.0	0.000	0.000	0.000	0.000
5/13/85	133.0	0.000	0.000	0.000	0.000
5/16/85	136.0	3.310	4.728	8.038	5.627
5/20/85	140.0	0.000	0.000	0.000	0.000
5/24/85	144.0	0.280	3.057	3.337	2.336
5/28/85	148.0	0.000	0.000	0.000	0.000
5/30/85	150.0	0.560	5.657	6.217	4.352
6/2/85	153.0	0.000	0.000	0.000	0.000
6/6/85	157.0	0.000	0.000	0.000	0.000
6/10/85	161.0	0.000	0.000	0.000	0.000
6/13/85	164.0	0.000	0.000	0.000	0.000
6/21/85	172.0	0.580	7.543	8.123	5.686
6/24/85	175.0	0.000	0.000	0.000	0.000
6/28/85	179.0	0.000	0.000	0.000	0.000
7/1/85	182.0	0.000	0.000	0.000	0.000
7/3/85	184.0	0.000	0.000	0.000	0.000
7/8/85	189.0	0.000	0.000	0.000	0.000
7/11/85	192.0	0.070	8.543	8.613	6.029
7/15/85	196.0	0.000	0.000	0.000	0.000
7/18/85	199.0	0.000	0.000	0.000	0.000
7/23/85	204.0	0.000	0.000	0.000	0.000
7/25/85	206.0	1.490	6.157	7.647	5.353
7/30/85	211.0	0.000	0.000	0.000	0.000
8/1/85	213.0	1.780	4.357	6.137	4.296
8/5/85	217.0	0.000	0.000	0.000	0.000
8/8/85	220.0	0.710	4.029	4.739	3.317
8/9/85	221.0	0.000	0.000	0.000	0.000
8/13/85	225.0	0.410	3.943	4.353	3.047
8/19/85	231.0	0.000	0.000	0.000	0.000
8/22/85	234.0	0.000	0.000	0.000	0.000
8/26/85	238.0	0.000	0.000	0.000	0.000
8/29/85	241.0	0.000	0.000	0.000	0.000
9/2/85	245.0	0.000	0.000	0.000	0.000
9/5/85	248.0	0.000	0.000	0.000	0.000
9/9/85	252.0	1.040	9.429	10.469	7.328
9/12/85	255.0	0.000	0.000	0.000	0.000
9/17/85	260.0	0.920	4.314	5.234	3.664
9/19/85	262.0	0.000	0.000	0.000	0.000
9/23/85	266.0	1.400	1.550	2.950	2.065
9/30/85	273.0	0.460	3.200	3.660	2.562
10/7/85	280.0	0.000	0.000	0.000	0.000
10/14/85	287.0	0.000	0.000	0.000	0.000
10/17/85	290.0	0.000	0.000	0.000	0.000
10/21/85	294.0	6.830	0.760	7.590	5.313
10/29/85	302.0	0.000	0.000	0.000	0.000
11/6/85	310.0	0.000	0.000	0.000	0.000
11/13/85	317.0	0.940	1.444	2.384	1.669
11/20/85	324.0	0.000	0.000	0.000	0.000
11/27/85	331.0	0.000	0.000	0.000	0.000
12/5/85	339.0	0.000	0.000	0.000	0.000
12/13/85	347.0	0.000	0.000	0.000	0.000
12/22/85	356.0	0.000	0.000	0.000	0.000
12/31/85	365.0	0.000	0.000	0.000	0.000
1/3/86	3.0	0.000	0.000	0.000	0.000
1/11/86	11.0	0.000	0.000	0.000	0.000
1/16/86	16.0	0.000	0.000	0.000	0.000
1/22/86	22.0	0.000	0.000	0.000	0.000
1/30/86	30.0	0.000	0.000	0.000	0.000
2/6/86	37.0	0.390	1.891	2.281	1.597
2/11/86	42.0	0.000	0.000	0.000	0.000
2/19/86	50.0	2.950	3.148	6.098	4.269
2/27/86	58.0	0.080	4.890	4.970	3.479
3/5/86	64.0	0.000	0.000	0.000	0.000
3/13/86	72.0	0.000	0.000	0.000	0.000
3/19/86	78.0	0.000	0.000	0.000	0.000
3/27/86	86.0	0.000	0.000	0.000	0.000
4/3/86	93.0	0.250	4.809	5.059	3.541
4/10/86	100.0	0.000	0.000	0.000	0.000
4/17/86	107.0	0.000	0.000	0.000	0.000
4/24/86	114.0	0.000	0.000	0.000	0.000
5/1/86	121.0	0.000	0.000	0.000	0.000
5/8/86	128.0	1.290	5.379	6.669	4.668
5/19/86	139.0	0.000	0.000	0.000	0.000
5/27/86	147.0	1.300	7.100	8.400	5.880
6/3/86	154.0	0.000	0.000	0.000	0.000
6/9/86	160.0	0.100	6.083	6.183	4.328
6/16/86	167.0	0.300	7.665	7.965	5.576

6/25/86	176.0	4.600	3.039	7.639	5.347
7/2/86	183.0	1.650	2.963	4.613	3.229
7/9/86	190.0	0.350	4.674	5.024	3.517
7/16/86	197.0	0.000	0.000	0.000	0.000
7/22/86	203.0	2.550	2.473	5.023	3.516
7/30/86	211.0	0.300	5.729	6.029	4.220
8/6/86	218.0	0.000	0.000	0.000	0.000
8/13/86	225.0	2.000	3.745	5.745	4.022
8/25/86	237.0	1.200	7.725	8.925	6.247
9/2/86	245.0	1.100	3.273	4.373	3.061
9/8/86	251.0	0.000	4.145	4.145	2.901
9/15/86	258.0	1.300	2.690	3.990	2.793
9/22/86	265.0	0.150	4.331	4.481	3.137
9/29/86	272.0	0.200	2.521	2.721	1.905
10/13/86	286.0	8.080	-1.463	6.617	4.632
10/21/86	294.0	0.0	2.417	2.417	1.692
10/28/86	301.0	0.100	2.755	2.855	1.999
11/4/86	308.0	0.000	2.766	2.766	1.936
11/11/86	315.0	3.270	-0.980	2.290	1.603
11/18/86	322.0	0.200	2.272	2.472	1.730
11/25/86	329.0	0.100	0.740	0.840	0.588
12/3/86	337.0	0.000	1.753	1.753	1.227
12/11/86	345.0	0.000	2.044	2.044	1.431
12/29/86	363.0	0.900	0.695	1.595	1.116
1/7/87	7.0	0.375	0.000	0.375	0.263
1/20/87	20.0	0.000	0.000	0.000	0.000
1/28/87	28.0	0.000	0.430	0.430	0.301
2/3/87	34.0	0.000	0.458	0.458	0.321
2/11/87	42.0	0.000	0.457	0.457	0.320
2/18/87	49.0	0.000	0.458	0.458	0.321
2/26/87	57.0	0.000	0.457	0.457	0.320
3/3/87	62.0	0.000	1.762	1.762	1.233
3/18/87	77.0	0.000	1.117	1.117	0.782
3/25/87	84.0	0.152	0.000	0.152	0.107
3/30/87	89.0	0.025	0.000	0.025	0.018
4/4/87	94.0	0.965	0.000	0.965	0.676
4/5/87	95.0	0.152	0.000	0.152	0.107
4/8/87	98.0	0.000	-0.335	-0.335	-0.235
4/15/87	105.0	0.000	1.940	1.940	1.358
4/28/87	118.0	0.000	3.326	3.326	2.328
5/12/87	132.0	0.000	3.326	3.326	2.328
5/15/87	135.0	0.254	0.000	0.254	0.178
5/16/87	136.0	0.203	0.000	0.203	0.142
5/19/87	139.0	0.584	0.000	0.584	0.409
5/23/87	143.0	0.279	0.000	0.279	0.196
5/24/87	144.0	0.102	0.000	0.102	0.071
5/25/87	145.0	0.000	2.240	2.240	1.568
6/4/87	155.0	0.000	2.245	2.245	1.572
6/7/87	158.0	0.737	0.000	0.737	0.516
6/15/87	166.0	0.076	0.000	0.076	0.053
6/23/87	174.0	0.000	2.234	2.234	1.564
6/26/87	177.0	1.321	0.000	1.321	0.924
6/27/87	178.0	0.610	0.000	0.610	0.427
6/28/87	179.0	0.203	0.000	0.203	0.142

7/2/87	183.0	0.000	5.510	5.510	3.857
7/10/87	191.0	0.025	0.000	0.025	0.018
7/13/87	194.0	0.000	8.421	8.421	5.895
7/16/87	197.0	0.178	0.000	0.178	0.124
7/17/87	198.0	0.000	0.000	0.000	0.000
7/23/87	204.0	0.000	5.472	5.472	3.830
7/24/87	205.0	0.229	0.000	0.229	0.160
7/28/87	209.0	0.102	0.000	0.102	0.071
7/31/87	212.0	0.000	6.500	6.500	4.550
8/3/87	215.0	0.025	0.000	0.025	0.018
8/4/87	216.0	1.067	0.000	1.067	0.747
8/5/87	217.0	1.118	0.000	1.118	0.782
8/7/87	219.0	0.000	1.390	1.390	0.973
8/9/87	221.0	0.305	0.000	0.305	0.213
8/13/87	225.0	0.025	0.000	0.025	0.018
8/14/87	226.0	0.000	6.110	6.110	4.277
8/22/87	234.0	1.092	0.000	1.092	0.765
8/23/87	235.0	2.184	0.000	2.184	1.529
8/24/87	236.0	0.533	0.000	0.533	0.373
8/25/87	237.0	0.229	0.000	0.229	0.160
8/26/87	238.0	0.102	0.000	0.102	0.071
8/27/87	239.0	0.000	0.000	0.000	0.000
9/2/87	245.0	0.000	4.000	4.000	2.800
9/5/87	248.0	0.025	0.000	0.025	0.018
9/6/87	249.0	0.000	0.000	0.000	0.000
9/9/87	252.0	0.000	0.000	0.000	0.000
9/14/87	257.0	0.025	0.000	0.025	0.018
9/16/87	259.0	0.000	0.000	0.000	0.000
9/25/87	268.0	0.102	3.500	3.602	2.521
9/26/87	269.0	0.076	0.000	0.076	0.053
9/28/87	271.0	0.000	6.000	6.000	4.200
10/11/87	284.0	0.000	3.900	3.900	2.730
10/14/87	287.0	0.025	1.448	1.473	1.031
10/22/87	295.0		1.676	1.676	1.173
10/23/87	296.0	0.508		0.508	0.356
10/24/87	297.0	0.025		0.025	0.018
10/30/87	303.0	0.356		0.356	0.249
10/31/87	304.0	0.025	0.356	0.381	0.267
11/31/87			4.980	4.980	3.486

PRECIPITATION & EVAPORATION (CM)

DATE	JULIAN DAYS	PREC	PAN EV	PANADJ	.7PANADJ
12/6/87	340.0	0.000	0.000	0.000	0.000
12/14/87	348.0	0.025	0.000	0.025	0.018
12/15/87	349.0	0.000	0.000	0.000	0.000
12/17/87	351.0	0.203	0.000	0.203	0.142
12/18/87	352.0	0.381	0.000	0.381	0.267
12/28/87	362.0	0.229	0.000	0.229	0.160
1/5/88	5.0	0.000	0.000	0.000	0.000
1/13/88	13.0	0.000	0.000	0.000	0.000
1/18/88	18.0	0.152	0.000	0.152	0.107
1/19/88	19.0	0.000	0.400	0.400	0.280
1/26/88	26.0	0.000	0.200	0.200	0.140
2/2/88	33.0	0.000	1.650	1.650	1.155
2/4/88	35.0	0.483	0.000	0.483	0.338
2/5/88	36.0	0.610	0.500	1.110	0.777
2/6/88	37.0	0.000	0.500	0.500	0.350
2/7/88	38.0	0.000	0.500	0.500	0.350
2/8/88	39.0	0.000	0.500	0.500	0.350
2/9/88	40.0	0.000	0.500	0.500	0.350
2/16/88	47.0	0.000	0.500	0.500	0.350
2/17/88	48.0	0.051	0.000	0.051	0.036
2/18/88	49.0	0.000	0.600	0.600	0.420
2/19/88	50.0	0.127	0.000	0.127	0.089
2/23/88	54.0	0.000	1.500	1.500	1.050
2/27/88	58.0	0.203	1.100	1.303	0.912
3/1/88	61.0	0.000	1.100	1.100	0.770
3/3/88	63.0	0.178	0.950	1.128	0.789
3/4/88	64.0	0.025	0.000	0.025	0.018
3/17/88	77.0	0.000	6.650	6.650	4.655
3/24/88	84.0	0.000	3.900	3.900	2.730
3/31/88	91.0	0.025	6.050	6.075	4.253
4/1/88	92.0	0.025	0.510	0.535	0.375
4/2/88	93.0	0.000	0.510	0.510	0.357
4/5/88	96.0	0.000	2.700	2.700	1.890
4/7/88	98.0	0.000	1.550	1.550	1.085
4/12/88	103.0	0.000	3.650	3.650	2.555
4/14/88	105.0	0.025	0.000	0.025	0.018
4/15/88	106.0	0.051	1.550	1.601	1.121
4/16/88	107.0	1.575	0.000	1.575	1.102
4/17/88	108.0	0.051	0.000	0.051	0.036
4/18/88	109.0	0.000	0.000	0.000	0.000
4/19/88	110.0	0.000	0.000	0.000	0.000
4/20/88	111.0	0.000	0.600	0.600	0.420
4/29/88	120.0	0.000	7.250	7.250	5.075
5/6/88	127.0	0.000	7.350	7.350	5.145
5/10/88	131.0	0.000	4.150	4.150	2.905
5/17/88	138.0	0.000	7.210	7.210	5.047
5/24/88	145.0	0.000	5.720	5.720	4.004
6/1/88	153.0	0.000	7.120	7.120	4.984
6/5/88	157.0	0.051	3.500	3.551	2.486
6/6/88	158.0	0.000	1.000	1.000	0.700
6/7/88	159.0	0.000	1.250	1.250	0.875
6/8/88	160.0	0.000	1.250	1.250	0.875
6/10/88	162.0	0.229	0.000	0.229	0.160
6/13/88	165.0	0.000	5.600	5.600	3.920
6/21/88	173.0	0.000	8.700	8.700	6.090
6/23/88	175.0	0.152	0.000	0.152	0.107
6/24/88	176.0	0.025	0.000	0.025	0.018
6/25/88	177.0	1.549	0.000	1.549	1.084
6/28/88	180.0	1.168	0.000	1.168	0.818
6/29/88	181.0	0.000	3.350	3.350	2.345
7/1/88	183.0	0.508	0.000	0.508	0.356
7/2/88	184.0	0.025	0.000	0.025	0.018
7/5/88	187.0	1.804	0.000	1.804	1.263
7/6/88	188.0	0.000	4.700	4.700	3.290
7/7/88	189.0	0.127	0.000	0.127	0.089
7/8/88	190.0	0.559	1.500	2.059	1.441
7/9/88	191.0	0.406	0.000	0.406	0.284
7/10/88	192.0	0.025	0.000	0.025	0.018
7/11/88	193.0	0.330	0.330	0.660	0.462
7/13/88	195.0	0.000	0.600	0.600	0.420
7/19/88	201.0	0.000	6.000	6.000	4.200
7/24/88	206.0	0.051	0.000	0.051	0.036
7/26/88	208.0	0.000	0.500	0.500	0.350
7/27/88	209.0	0.025	0.000	0.025	0.018
7/28/88	210.0	0.787	0.000	0.787	0.551
7/29/88	211.0	0.279	0.000	0.279	0.196
7/31/88	213.0	0.051	0.000	0.051	0.036
8/1/88	214.0	1.219	0.000	1.219	0.853
8/2/88	215.0	0.025	2.900	2.925	2.048
8/4/88	217.0	0.432	0.000	0.432	0.302
8/6/88	219.0	0.025	0.000	0.025	0.018
8/9/88	222.0	0.000		0.000	0.000

APPENDIX E

APPENDIX E.1

MOISTURE CONTENT PROFILE FOR COLUMN #1 (50% TAILINGS/ 50% BENTONITE CAP MATERIAL)

BULK DENSITY: TAILINGS = 1.44 g/cc
50/50 = 1.25 g/cc

POROSITY: TAILINGS = 48.57 %
50/50 = 52.83 %

PARTICLE DENSITY: TAILINGS = 2.80 g/cc
50/50 = 2.65 g/cc

DEPTH	PAN WT	WT PAN & SAMPLE		WT DRY	GRAVIMETRIC	VOLUMETRIC	PERCENT
(cm)	(g)	WET (g)	DRY (g)	SAMPLE (g)	MOISTURE %	MOISTURE %	SATURATION
0-5	3.84	52.66	48.44	44.60	9.46	11.83	22.39
5-10	4.10	46.87	43.43	39.33	8.75	10.93	20.69
10-15	4.28	36.02	33.46	29.18	8.77	10.97	20.76
15-20	4.15	36.35	33.86	29.71	8.38	10.48	19.83
20-25	4.18	43.22	39.14	34.96	11.67	14.59	27.61
25-30	9.54	54.83	51.07	41.53	9.05	11.32	21.42
30-31	4.36	22.02	19.25	14.89	18.60	26.79	55.15
31-32	4.36	24.85	21.30	16.94	20.96	30.18	62.13
32-33	4.00	23.15	19.64	15.64	22.44	32.32	66.54
33-34	4.04	24.50	20.88	16.84	21.50	30.95	63.73
34-36	4.35	25.72	22.47	18.12	17.94	25.83	53.18
36-40	4.14	38.26	35.76	31.62	7.91	11.39	23.44
40-45	4.52	38.00	35.70	31.18	7.38	10.62	21.87
45-50	4.70	41.86	39.25	34.55	7.55	10.88	22.40
50-60	4.36	36.54	34.08	29.72	8.28	11.92	24.54
60-70	4.30	36.97	34.44	30.14	8.39	12.09	24.89
70-80	8.17	55.25	51.49	43.32	8.68	12.50	25.73
80-90	7.96	70.65	65.52	57.56	8.91	12.83	26.42
90-100	9.84	64.23	59.66	49.82	9.17	13.21	27.20
100-110	9.39	56.00	52.02	42.63	9.34	13.44	27.68
110-120	9.86	62.75	58.07	48.21	9.71	13.98	28.78
120-130	5.13	51.92	47.44	42.31	10.59	15.25	31.39
130-140	10.16	56.58	51.49	41.33	12.32	17.73	36.51
140-150	9.57	58.43	53.54	43.97	11.12	16.01	32.97
150-160	9.04	76.05	68.37	59.33	12.94	18.64	38.38
160-170	9.91	81.16	72.18	62.27	14.42	20.77	42.76
170-178	4.23	64.13	55.57	51.34	16.67	24.01	49.43
178-180	4.01	116.34	97.21	93.20	20.53	29.56	60.85

MOISTURE CONTENT PROFILE FOR COLUMN #2 (LOAM/ GRAVEL CAP MATERIAL)

BULK DENSITY: TAILINGS = 1.44 g/cc
LOAM = 1.19 g/cc

POROSITY: TAILINGS = 48.57 %
LOAM = 55.09 %

PARTICLE DENSITY: TAILINGS = 2.80 g/cc
LOAM = 2.65 g/cc

DEPTH (cm)	PAN WT (g)	WT PAN & SAMPLE WET (g)	WT PAN & SAMPLE DRY (g)	WT DRY SAMPLE (g)	GRAVIMETRIC MOISTURE %	VOLUMETRIC MOISTURE %	PERCENT SATURATION
0-5	4.29	97.20	85.11	80.82	14.96	17.80	32.31
5-10	4.17	69.27	60.28	56.11	16.02	19.07	34.61
10-15	4.21	89.41	77.43	73.22	16.36	19.47	35.34
29-30	4.06	20.45	17.92	13.86	18.25	21.72	39.43
30-31	4.21	20.79	19.41	15.20	9.08	13.07	26.92
31-32	4.37	20.13	18.93	14.56	8.24	11.87	24.44
32-33	4.18	21.87	20.46	16.28	8.66	12.47	25.68
33-34	4.15	21.07	19.73	15.58	8.60	12.39	25.50
34-35	3.85	24.09	22.48	18.63	8.64	12.44	25.62
35-40	4.14	39.28	36.45	32.31	8.76	12.61	25.97
40-45	4.19	39.77	36.68	32.49	9.51	13.70	28.20
45-50	4.11	35.17	32.42	28.31	9.71	13.99	28.80
50-55	4.51	41.94	38.56	34.05	9.93	14.29	29.43
55-60	4.14	39.85	36.53	32.39	10.25	14.76	30.39
60-65	4.01	42.90	39.23	35.22	10.42	15.01	30.89
65-70	8.17	83.90	76.60	68.43	10.67	15.36	31.63
70-75	9.88	55.59	51.11	41.23	10.87	15.65	32.22
75-80	8.05	60.40	55.15	47.10	11.15	16.05	33.05
80-90	4.06	38.22	34.67	30.61	11.60	16.70	34.38
90-100	4.14	37.43	33.58	29.44	13.08	18.83	38.77
100-110	4.51	58.79	52.16	47.65	13.91	20.04	41.25
110-120	4.36	42.66	37.14	32.78	16.84	24.25	49.93
120-130	4.00	50.01	42.37	38.37	19.91	28.67	59.03
130-140	4.13	91.74	72.99	68.86	27.23	39.21	80.73
140-150	4.18	68.11	55.65	51.47	24.21	34.86	71.77
150-160	4.20	67.12	54.61	50.41	24.82	35.74	73.58
160-170	4.15	70.50	57.28	53.13	24.88	35.83	73.77
170-180	4.18	59.09	48.16	43.98	24.85	35.79	73.68

MOISTURE CONTENT PROFILE FOR COLUMN #3 (95% TAILINGS/ 5% BENTONITE CAP MATERIAL)

BULK DENSITY: TAILINGS = 1.44 g/cc
95/5 = 1.42 g/cc

POROSITY: TAILINGS = 48.57 %
95/5 = 49.01 %

PARTICLE DENSITY: TAILINGS = 2.80 g/cc
95/5 = 2.785 g/cc

DEPTH	PAN WT	WT PAN & SAMPLE		WT DRY	GRAVIMETRIC	VOLUMETRIC	PERCENT
(cm)	(g)	WET (g)	DRY (g)	SAMPLE (g)	MOISTURE %	MOISTURE %	SATURATION
0-5	4.37	60.98	57.23	52.86	7.09	10.07	20.55
5-10	4.52	65.48	61.14	56.62	7.67	10.88	22.21
10-15	4.04	78.69	73.12	69.08	8.06	11.45	23.36
15-20	4.70	75.64	70.17	65.47	8.35	11.86	24.21
20-25	4.27	85.56	79.08	74.81	8.66	12.30	25.10
25-30	4.14	63.38	58.64	54.50	8.70	12.35	25.20
30-32	4.19	25.58	21.28	17.09	25.16	36.23	74.60
32-34	4.36	28.88	26.09	21.73	12.84	18.49	38.07
34-36	4.36	27.62	25.80	21.44	8.49	12.22	25.17
36-38	4.00	30.63	28.55	24.55	8.47	12.20	25.12
38-40	3.84	42.22	39.26	35.42	8.36	12.03	24.78
40-45	4.30	27.20	25.42	21.12	8.43	12.14	24.99
45-50	4.01	29.13	27.09	23.08	8.84	12.73	26.21
50-60	4.20	44.84	41.52	37.32	8.90	12.81	26.37
60-70	5.12	42.97	39.75	34.63	9.30	13.39	27.57
70-80	4.15	66.16	60.66	56.51	9.73	14.02	28.86
80-90	4.30	36.63	33.68	29.38	10.04	14.46	29.77
90-100	8.16	65.22	59.82	51.66	10.45	15.05	30.99
100-110	9.55	112.36	102.01	92.46	11.19	16.12	33.19
110-120	9.90	51.89	47.63	37.73	11.29	16.26	33.47
120-140	9.02	91.05	80.41	71.39	14.90	21.46	44.19
140-160	10.14	134.44	112.27	102.13	21.71	31.26	64.36
160-180	9.32	160.69	130.52	121.20	24.89	35.85	73.80

MOISTURE CONTENT PROFILE FOR COLUMN #4 (100% TAILINGS CAP MATERIAL)

BULK DENSITY: TAILINGS = 1.44 g/cc POROSITY: TAILINGS = 48.57 %

PARTICLE DENSITY: TAILINGS = 2.80 g/cc

DEPTH (cm)	PAN WT (g)	WT PAN & SAMPLE WET (g)	WT PAN & SAMPLE DRY (g)	WT DRY SAMPLE (g)	GRAVIMETRIC MOISTURE %	VOLUMETRIC MOISTURE %	PERCENT SATURATION
0-5	9.56	190.99	178.51	168.95	7.39	10.64	21.90
5-10	8.14	192.92	179.99	171.85	7.52	10.83	22.31
10-15	9.00	232.45	217.85	208.85	6.99	10.07	20.73
15-20	9.32	235.40	221.19	211.87	6.71	9.66	19.88
20-25	7.86	218.80	205.90	198.04	6.51	9.38	19.31
25-30	9.82	185.16	174.61	164.79	6.40	9.22	18.98
30-31	4.51	51.26	48.12	43.61	7.20	10.37	21.35
31-32	4.20	64.48	59.93	55.73	8.16	11.76	24.21
32-33	4.37	77.98	72.26	67.89	8.43	12.13	24.98
33-34	4.13	64.54	59.79	55.66	8.53	12.29	25.30
34-35	4.11	69.00	63.94	59.83	8.46	12.18	25.07
35-36	4.19	69.84	64.74	60.55	8.42	12.13	24.97
36-37	3.84	55.68	51.68	47.84	8.36	12.04	24.79
37-38	4.00	32.92	30.64	26.64	8.56	12.32	25.37
38-39	4.19	68.74	63.73	59.54	8.41	12.12	24.95
39-40	9.55	67.79	63.18	53.63	8.60	12.38	25.49
40-42.5	4.15	32.05	29.84	25.69	8.60	12.39	25.50
42.5-45	4.14	30.12	28.02	23.88	8.79	12.66	26.07
45-50	4.51	58.31	53.84	49.33	9.06	13.05	26.87
50-55	4.20	54.88	50.61	46.41	9.20	13.25	27.28
55-60	4.36	38.22	35.32	30.96	9.37	13.49	27.77
60-65	3.85	51.63	47.34	43.49	9.86	14.20	29.25
65-70	3.99	46.55	42.74	38.75	9.83	14.16	29.15
70-75	4.13	33.67	30.93	26.80	10.22	14.72	30.31
75-80	4.12	50.66	46.17	42.05	10.68	15.38	31.66
80-85	4.19	45.44	41.37	37.18	10.95	15.76	32.45
85-90	4.23	44.23	40.13	35.90	11.42	16.45	33.86
90-95	8.60	46.24	42.30	33.70	11.69	16.84	34.66
95-100	3.85	44.39	39.95	36.10	12.30	17.71	36.46
100-105	4.15	59.36	53.28	49.13	12.38	17.82	36.69
105-110	4.14	44.57	39.96	35.82	12.87	18.53	38.16
110-115	4.51	53.27	47.52	43.01	13.37	19.25	39.64
115-120	4.20	45.19	40.11	35.91	14.15	20.37	41.94
120-130	4.36	84.34	72.44	68.08	17.48	25.17	51.82
130-137	4.00	71.86	59.44	55.44	22.40	32.26	66.42
137-140	9.87	110.91	90.89	81.02	24.71	35.58	73.26
140-145	9.62	154.66	125.68	116.06	24.97	35.96	74.03
145-150	3.93	143.87	117.74	113.81	22.96	33.06	68.07
150-160	4.15	132.44	108.87	104.72	22.51	32.41	66.73
160-170	3.81	114.58	94.01	90.20	22.80	32.84	67.61
170-180	4.04	115.78	95.02	90.98	22.82	32.86	67.65

APPENDIX E.2

EFFLUENT (ml) FROM COLUMNS

DATE	ELAPSED TIME (days)	COL1	CUM1	COL2	CUM2	COL3	CUM3	COL4	CUM4
9/12/85	204	30.0	30.0	5.0	5.0	0.0	0.0	5.0	5.0
9/23/85	215	108.0	138.0	0.0	5.0	0.0	0.0	5.0	10.0
10/24/85	246	113.0	251.0	0.0	5.0	0.0	0.0	6.0	16.0
11/27/85	280	108.0	359.0	1.5	6.5	0.0	0.0	2.5	18.5
12/31/85	314	105.4	464.4	2.7	9.2	0.0	0.0	7.0	25.5
1/22/86	336	38.0	502.4	2.2	11.4	0.0	0.0	6.4	31.9
2/11/86	356	24.4	526.8	2.8	14.2	0.0	0.0	7.2	39.1
3/7/86	380	19.8	546.6	4.0	18.2	0.0	0.0	4.4	43.5
3/27/86	400	36.4	583.0	3.0	21.2	0.0	0.0	1.4	44.9
4/17/86	421	49.0	632.0	2.0	23.2	0.0	0.0	1.0	45.9
5/8/86	442	62.0	694.0	3.0	26.2	2.5	2.5	5.0	50.9
5/27/86	461	47.0	741.0	3.0	29.2	1.0	3.5	2.0	52.9
6/16/86	481	65.5	806.5	3.0	32.2	1.0	4.5	3.4	56.3
6/25/86	490	35.0	841.5	5.0	37.2	1.0	5.5	4.6	60.9
7/2/86	497	34.0	875.5	4.4	41.6	1.0	6.5	3.8	64.7
7/16/86	511	25.0	900.5	4.8	46.4	0.5	7.0	5.0	69.7
7/28/86	523	46.0	946.5	4.0	50.4	1.0	8.0	4.0	73.7
8/13/86	539	28.5	975.0	4.5	54.9	0.5	8.5	5.0	78.7
9/2/86	559	16.5	991.5	4.5	59.4	0.0	8.5	6.5	85.2
9/22/86	579	24.0	1015.5	5.4	64.8	0.0	8.5	7.6	92.8
10/21/86	608	14.0	1029.5	6.7	71.5	0.0	8.5	6.3	99.1
11/11/86	629	21.4	1050.9	6.8	78.3	0.0	8.5	5.9	105.0
12/11/86	659	10.0	1060.9	8.0	86.3	1.0	9.5	4.2	109.2
12/29/86	677	6.0	1066.9	3.0	89.3	5.6	15.1	6.0	115.2
2/3/87	713	60.0	1126.9	5.0	94.3	4.5	19.6	9.0	124.2
3/3/87	741	28.0	1154.9	7.5	101.8	4.0	23.6	6.0	130.2
7/13/87	873	5.8	1160.7	5.0	106.8	2.6	26.2	17.0	147.2
9/2/87	924	5.0	1165.7	5.0	111.8	5.0	31.2	5.0	152.2
9/28/87	950	6.6	1172.3	5.4	117.2	4.1	35.3	4.0	156.2
1/13/88	1057	0.0	1172.3	0.0	117.2	0.0	35.3	10.0	166.2
1/19/88	1063	0.0	1172.3	7.0	124.2	4.2	39.5	1.6	167.8
2/2/88	1077	0.0	1172.3	3.0	127.2	1.5	41.0	4.0	171.8
2/9/88	1084	0.5	1172.8	0.5	127.7	1.6	42.6	1.5	173.3
2/16/88	1091	0.0	1172.8	0.4	128.1	0.4	43.0	1.1	174.4
3/1/88	1105	0.0	1172.8	0.8	128.9	2.0	45.0	0.0	174.4
3/17/88	1121	0.0	1172.8	2.4	131.3	2.7	47.7	2.3	176.7
3/28/88	1132	0.0	1172.8	2.0	133.3	0.0	47.7	0.0	176.7
4/5/88	1140	0.0	1172.8	3.6	136.9	1.5	49.2	4.8	181.5
4/15/88	1150	0.0	1172.8	4.3	141.2	1.0	50.2	5.8	187.3
5/9/88	1174	0.0	1172.8	5.0	146.2	1.9	52.1	4.4	191.7
5/24/88	1189	0.0	1172.8	1.0	147.2	2.3	54.4	2.4	194.1
6/8/88	1204	0.0	1172.8	0.0	147.2	3.0	57.4	1.6	195.7
6/29/88	1225	0.0	1172.8	0.5	147.7	3.1	60.5	2.7	198.4
7/13/88	1239	0.0	1172.8	0.5	148.2	1.3	61.8	2.1	200.5
7/29/88	1255	0.0	1172.8	0.4	148.6	2.7	64.5	1.3	201.8
8/9/88	1266	0.0	1172.8	2.3	150.9	2.1	66.6	0.8	202.6

APPENDIX E.3

ADDITIONS OF TENSIOMETER FLUID (ml)

DATE	ELAPSED TIME (days)	COL1	CUM1	COL2	CUM2	COL3	CUM3	COL4	CUM 4
9/5/85	197	7.2	7.2		0.0	7.2	7.2		0.0
9/9/85	201	4.6	11.8		0.0	29.0	36.2	49.9	49.9
9/12/85	204	4.6	16.4		0.0	22.6	58.8	12.5	62.4
9/17/85	209	4.2	20.6		0.0	40.0	98.8	13.2	75.6
9/19/85	211		20.6		0.0	8.6	107.4	8.0	83.6
9/23/85	215		20.6		0.0	5.0	112.4	14.0	97.6
9/30/85	222	8.6	29.2		0.0	2.8	115.2	3.1	100.7
10/7/85	229	5.0	34.2	3.8	3.8	3.8	119.0	3.0	103.7
10/14/85	236		34.2	13.2	17.0	10.5	129.5		103.7
10/17/85	239	8.0	42.2		17.0	-	129.5	4.0	107.7
10/29/85	251	7.2	49.4		17.0		129.5	3.0	110.7
11/6/85	259	10.8	60.2	16.8	33.8	4.0	133.5		110.7
11/13/85	266	9.8	70.0	30.0	63.8		133.5	6.0	116.7
11/27/85	280	11.6	81.6		63.8	6.6	140.1	2.4	119.1
12/13/85	296	14.8	96.4	3.8	67.6	3.2	143.3	6.0	125.1
12/22/85	305	2.4	98.8		67.6	3.0	146.3	1.8	126.9
12/31/85	314	8.8	107.6	3.8	71.4	18.4	164.7	6.0	132.9
1/3/86	317		107.6		71.4	1.6	166.3	2.2	135.1
1/11/86	325	4.2	111.8		71.4	12.0	178.3	2.6	137.7
1/16/86	330	7.8	119.6		71.4	7.8	186.1	3.9	141.6
1/22/86	336	2.4	122.0	3.4	74.8		186.1	3.8	145.4
1/27/86	341	3.8	125.8		74.8		186.1		145.4
1/30/86	344		125.8		74.8	3.2	189.3		145.4
2/6/86	351	5.4	131.2		74.8	5.8	195.1	4.8	150.2
2/11/86	356	6.0	137.2		74.8	17.0	212.1	1.6	151.8
2/19/86	364	7.0	144.2	5.4	80.2		212.1	3.5	155.3
2/27/86	372	5.2	149.4	2.8	83.0	2.4	214.5	2.0	157.3
3/5/86	378	7.0	156.4	2.8	85.8	8.4	222.9		157.3
3/13/86	386	12.6	169.0	16.0	101.8	10.0	232.9	4.4	161.7
3/19/86	392		169.0	23.0	124.8	15.0	247.9		161.7
3/27/86	400	11.4	180.4	7.4	132.2	18.4	266.3	7.4	169.1
4/3/86	407	7.4	187.8	3.0	135.2	2.8	269.1	7.0	176.1
4/10/86	414	11.4	199.2	5.5	140.7	11.0	280.1		176.1
4/17/86	421	11.0	210.2	2.0	142.7	10.0	290.1	12.0	188.1
4/24/86	428	11.6	221.8	1.0	143.7	8.0	298.1	7.0	195.1
5/1/86	435	12.0	233.8	9.0	152.7	15.0	313.1	9.5	204.6
5/8/86	442	10.0	243.8	3.0	155.7	23.0	336.1	19.0	223.6
5/19/86	453	10.0	253.8	8.0	163.7	8.0	344.1	9.0	232.6
5/27/86	461	10.5	264.3	3.5	167.2		344.1	6.0	238.6
6/3/86	468	8.4	272.7	2.5	169.7	9.0	353.1	6.4	245.0
6/9/86	474	11.3	284.0	3.6	173.3	8.0	361.1	7.1	252.1
6/16/86	481	22.4	306.4	3.0	176.3	8.0	369.1	7.2	259.3
6/25/86	490	10.0	316.4		176.3	8.5	377.6	6.0	265.3
7/2/86	497	13.5	329.9	4.0	180.3	7.0	384.6		265.3
7/9/86	504	9.4	339.3	3.0	183.3	6.0	390.6	6.4	271.7
7/16/86	511	13.0	352.3	16.0	199.3	7.0	397.6	9.5	281.2
7/22/86	517	8.0	360.3	1.0	200.3	6.5	404.1		281.2
7/30/86	525	14.0	374.3	2.5	202.8	6.5	410.6	9.0	290.2
8/6/86	532	9.0	383.3	7.0	209.8	10.5	421.1	11.5	301.7

DATE	ELAPSED TIME (days)	COL1	CUM1	COL2	CUM2	COL3	CUM3	COL4	CUM 4
8/13/86	539	10.0	393.3		209.8	15.0	436.1	11.0	312.7
8/25/86	551	11.5	404.8	4.0	213.8	10.0	446.1	13.5	326.2
9/8/86	565	12.0	416.8	6.0	219.8	12.0	458.1	11.0	337.2
9/15/86	572	10.0	426.8	40.0	259.8	9.0	467.1	11.5	348.7
9/29/86	586	9.0	435.8	6.5	266.3	10.0	477.1	9.0	357.7
10/13/86	600	7.0	442.8		266.3	2.0	479.1	7.5	365.2
10/21/86	608	2.0	444.8		266.3	6.0	485.1	5.0	370.2
11/4/86	622	33.0	477.8		266.3		485.1		370.2
12/3/86	651		477.8		266.3		485.1	14.0	384.2
12/11/86	659		477.8	7.0	273.3	5.0	490.1		384.2
12/29/86	677	11.5	489.3	6.0	279.3	3.0	493.1		384.2
1/7/87	686		489.3		279.3	-	493.1	4.5	388.7
1/28/87	707	2.0	491.3	51.0	330.3	4.5	497.6	5.0	393.7
2/11/87	721		491.3		330.3	10.0	507.6		393.7
2/26/87	736		491.3		330.3	8.0	515.6		393.7
3/3/87	741		491.3		330.3	6.0	521.6	3.0	396.7
3/18/87	756	4.0	495.3	2.0	332.3	10.0	531.6	9.0	405.7
4/8/87	777		495.3	3.0	335.3	9.0	540.6	7.0	412.7
4/15/87	784		495.3		335.3	11.0	551.6	7.0	419.7
4/28/87	797	5.0	500.3	4.0	339.3	8.0	559.6	12.0	431.7
5/12/87	811		500.3		339.3	10.0	569.6		431.7
5/25/87	824	5.0	505.3	8.0	347.3		569.6	18.0	449.7
6/4/87	834		505.3	5.0	352.3	11.0	580.6	13.0	462.7
6/23/87	853	3.0	508.3		352.3	8.0	588.6	20.0	482.7
7/2/87	862		508.3	5.0	357.3		588.6		482.7
7/13/87	873	14.0	522.3		357.3	9.0	597.6	23.0	505.7
7/23/87	883	6.5	528.8	6.0	363.3	25.0	622.6	7.0	512.7
7/31/87	891		528.8		363.3	7.0	629.6		512.7
8/7/87	898	10.0	538.8	5.0	368.3	6.0	635.6	10.0	522.7
9/2/87	924	8.5	547.3		368.3	14.5	650.1	17.7	540.4
9/9/87	931		547.3		368.3		650.1	5.5	545.9
9/16/87	938	41.0	588.3		368.3		650.1	30.0	575.9
12/6/87	1019		588.3		368.3	25.0	675.1		575.9
1/5/88	1049	25.0	613.3	26.0	394.3	25.0	700.1	20.0	595.9
1/13/88	1057	10.0	623.3		394.3	10.0	710.1		595.9
1/26/88	1070	20.0	643.3	9.0	403.3		710.1		595.9
2/2/88	1077	17.5	660.8		403.3	15.5	725.6	14.0	609.9
2/8/88	1083		660.8	10.0	413.3	10.0	735.6	6.0	615.9
2/9/88	1084	8.0	668.8		413.3	7.0	742.6		615.9
2/16/88	1091	17.8	686.6	5.5	418.8		742.6		615.9
2/23/88	1098	20.0	706.6		418.8		742.6	8.0	623.9
3/1/88	1105	10.5	717.1		418.8	10.0	752.6	6.0	629.9
3/17/88	1121	23.0	740.1	14.0	432.8	34.0	786.6	6.8	636.7
3/24/88	1128	12.0	752.1		432.8	9.0	795.6	8.0	644.7
3/31/88	1135	18.0	770.1		432.8	10.0	805.6	13.5	658.2
4/1/88	1136		770.1	3.0	435.8		805.6		658.2
4/5/88	1140	10.0	780.1	12.0	447.8	8.0	813.6	12.0	670.2
4/7/88	1142		780.1	6.5	454.3		813.6		670.2
4/12/88	1147		780.1	12.0	466.3		813.6		670.2
4/15/88	1150	10.0	790.1	12.5	478.8	17.0	830.6	7.0	677.2
4/18/88	1153		790.1	8.0	486.8		830.6	12.0	689.2

DATE	ELAPSED TIME (days)	COL1	CUM1	COL2	CUM2	COL3	CUM3	COL4	CUM 4
4/29/88	1164	10.0	800.1	9.0	495.8		830.6		689.2
5/6/88	1171	29.5	829.6	7.0	502.8	21.0	851.6	12.5	701.7
5/10/88	1175		829.6		502.8	9.5	861.1	7.0	708.7
5/17/88	1182	9.0	838.6	28.0	530.8	16.0	877.1	7.5	716.2
5/24/88	1189		838.6		530.8	8.0	885.1	13.5	729.7
6/1/88	1197	25.0	863.6		530.8	8.0	893.1	14.0	743.7
6/6/88	1202		863.6		530.8	10.0	903.1	16.0	759.7
6/7/88	1203	8.0	871.6	5.0	535.8		903.1		759.7
6/8/88	1204		871.6		535.8		903.1	6.5	766.2
6/13/88	1209	8.0	879.6	13.0	548.8	18.5	921.6	6.4	772.6
6/21/88	1217	21.6	901.2		548.8	23.0	944.6	6.4	779.0
6/29/88	1225		901.2		548.8	-	944.6	7.0	786.0
7/6/88	1232	28.0	929.2		548.8		944.6	7.0	793.0
7/8/88	1234		929.2		548.8	7.5	952.1	9.0	802.0
7/11/88	1237		929.2		548.8	8.0	960.1	9.0	811.0
7/13/88	1239		929.2	5.0	553.8	9.0	969.1		811.0
7/18/88	1244	9.0	938.2	10.5	564.3	12.0	981.1		811.0
7/26/88	1252	24.5	962.7	24.0	588.3	30.0	1011.1	33.0	844.0
8/9/88	1266								

APPENDIX F

APPENDIX F.1

COLUMN #1 (50% TAILINGS/ 50% BENTONITE CAP MATERIAL)

SOIL EXTRACT ANALYSIS

MID-DEPTH (cm)	GRAVIMETRIC MOISTURE %	WET SOIL (g)	ADDED WATER (g)	DRY SOIL (g)	TOTAL WATER (g)
30.5	18.60	20	10	16.86	13.14
31.5	20.96	20	10	16.53	13.47
32.5	22.44	20	10	16.33	13.67
35.0	17.94	10	10	8.48	11.52
38.0	7.91	10	10	9.27	10.73
42.5	7.38	10	10	9.31	10.69
47.5	7.55	10	10	9.30	10.70
55.0	8.28	10	10	9.24	10.76
65.0	8.39	10	10	9.23	10.77
75.0	8.68	10	10	9.20	10.80
85.0	8.91	10	10	9.18	10.82
95.0	9.17	10	10	9.16	10.84
105.0	9.34	10	10	9.15	10.85
115.0	9.71	10	10	9.12	10.88
125.0	10.59	10	10	9.04	10.96
135.0	12.32	10	10	8.90	11.10
145.0	11.12	10	10	9.00	11.00
155.0	12.94	10	10	8.85	11.15
165.0	14.42	10	10	8.74	11.26
174.0	16.67	15	10	12.86	12.14
179.0	20.53	15	10	12.45	12.55

COLUMN #2 (LOAM/GRAVEL CAP MATERIAL)

SOIL EXTRACT ANALYSIS

MID-DEPTH (cm)	GRAVIMETRIC MOISTURE %	WET SOIL (g)	ADDED WATER (g)	DRY SOIL (g)	TOTAL WATER (g)
29.5	18.25	10	10	8.46	11.54
30.5	9.08	10	10	9.17	10.83
31.5	8.24	10	10	9.24	10.76
32.5	8.66	10	10	9.20	10.80
33.5	8.60	10	10	9.21	10.79
34.5	8.64	10	10	9.20	10.80
37.5	8.76	10	10	9.19	10.81
42.5	9.51	10	10	9.13	10.87
47.5	9.71	10	10	9.11	10.89
52.5	9.93	10	10	9.10	10.90
57.5	10.25	10	10	9.07	10.93
62.5	10.42	10	10	9.06	10.94
67.5	10.67	10	10	9.04	10.96
72.5	10.87	10	10	9.02	10.98
77.5	11.15	10	10	9.00	11.00
85.0	11.60	10	10	8.96	11.04
95.0	13.08	10	10	8.84	11.16
105.0	13.91	10	10	8.78	11.22
115.0	16.84	10	10	8.56	11.44
125.0	19.91	10	10	8.34	11.66
135.0	27.23	20	10	15.72	14.28
145.0	24.21	20	10	16.10	13.90
155.0	24.82	20	10	16.02	13.98
165.0	24.88	20	10	16.02	13.98
175.0	24.85	20	10	16.02	13.98

COLUMN #3 (95% TAILINGS/ 5% BENTONITE CAP MATERIAL)

SOIL EXTRACT ANALYSIS

MID-DEPTH (cm)	GRAVIMETRIC MOISTURE %	WET SOIL (g)	ADDED WATER (g)	DRY SOIL (g)	TOTAL WATER (g)
29.5	8.70	10	10	9.20	10.80
31.0	25.16	10	10	7.99	12.01
33.0	12.84	10	10	8.86	11.14
35.0	8.49	10	10	9.22	10.78
37.0	8.47	10	10	9.22	10.78
39.0	8.36	10	10	9.23	10.77
42.5	8.43	10	10	9.22	10.78
47.5	8.84	10	10	9.19	10.81
55.0	8.90	10	10	9.18	10.82
65.0	9.30	10	10	9.15	10.85
75.0	9.73	10	10	9.11	10.89
85.0	10.04	10	10	9.09	10.91
95.0	10.45	10	10	9.05	10.95
105.0	11.19	10	10	8.99	11.01
115.0	11.29	10	10	8.99	11.01
130.0	14.90	10	10	8.70	11.30
150.0	21.71	15	10	12.32	12.68
170.0	24.89	20	10	16.01	13.99

COLUMN #4 (100% TAILINGS CAP MATERIAL)

SOIL EXTRACT ANALYSIS

MID-DEPTH (cm)	GRAVIMETRIC MOISTURE %	WET SOIL (g)	ADDED WATER (g)	DRY SOIL (g)	TOTAL WATER (g)
29.0	6.40	10	10	9.40	10.60
30.5	7.20	10	10	9.33	10.67
31.5	8.16	10	10	9.25	10.75
32.5	8.43	10	10	9.22	10.78
33.5	8.53	10	10	9.21	10.79
34.5	8.46	10	10	9.22	10.78
35.5	8.42	10	10	9.22	10.78
36.5	8.36	10	10	9.23	10.77
37.5	8.56	10	10	9.21	10.79
38.5	8.41	10	10	9.22	10.78
39.5	8.60	10	10	9.21	10.79
42.5	8.70	10	10	9.20	10.80
47.5	9.06	10	10	9.17	10.83
52.5	9.20	10	10	9.16	10.84
57.5	9.37	10	10	9.14	10.86
62.5	9.86	10	10	9.10	10.90
67.5	9.83	10	10	9.10	10.90
72.5	10.22	10	10	9.07	10.93
77.5	10.68	10	10	9.04	10.96
82.5	10.95	10	10	9.01	10.99
87.5	11.42	10	10	8.98	11.02
95.0	12.00	10	10	8.93	11.07
105.0	12.63	10	10	8.88	11.12
115.0	13.76	10	10	8.79	11.21
125.0	17.48	10	10	8.51	11.49
135.0	22.40	15	10	12.25	12.75
145.0	24.71	20	10	16.04	13.96
155.0	22.51	15	10	12.24	12.76
165.0	22.80	20	10	16.29	13.71
175.0	22.82	20	10	16.28	13.72

APPENDIX F.2

COLUMN #1 (50% TAILINGS/ 50% BENTONITE CAP MATERIAL)

HPLC (mg/l)

MID-DEPTH (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
30.5	40.992	1.006	3.214	6.172	2.716
31.5	25.140	0.767	2.006	3.684	1.605
32.5	15.434	0.415	0.424	1.137	0.000
35.0	19.183	1.616	0.408	1.071	0.000
38.0	4.386	0.586	0.076	0.000	0.000
42.5	0.360	0.000	0.000	0.000	0.000
47.5	0.151	0.000	0.000	0.000	0.000
55.0	0.000	0.000	0.000	0.000	0.000
65.0	0.000	0.000	0.000	0.000	0.000
75.0	0.000	0.000	0.000	0.000	0.000
85.0	0.000	0.000	0.000	0.000	0.000
95.0	0.000	0.000	0.000	0.000	0.000
105.0	0.000	0.000	0.000	0.000	0.000
115.0	0.000	0.000	0.000	0.000	0.000
125.0	0.000	0.000	0.000	0.000	0.000
135.0	0.000	0.000	0.000	0.000	0.000
145.0	0.000	0.000	0.000	0.000	0.000
155.0	0.000	0.000	0.000	0.000	0.000
165.0	0.000	0.000	0.000	0.000	0.000
174.0	0.000	0.000	0.000	0.000	0.000
179.0	0.000	0.000	0.000	0.000	0.000

COLUMN #2 (LOAM/GRAVEL CAP MATERIAL)

HPLC (mg/l)

MID-DEPTH (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
29.5	44.015	7.834	8.784	15.759	16.536
30.5	38.440	4.017	3.444	6.362	6.484
31.5	35.675	0.767	2.705	4.889	4.589
32.5	30.023	0.653	1.684	3.608	3.105
33.5	27.290	0.504	1.346	2.834	3.067
34.5	25.093	0.418	1.089	2.301	1.841
37.5	22.314	0.353	0.697	1.428	1.115
42.5	17.363	0.135	0.174	0.138	0.196
47.5	17.896	0.066	0.046	0.000	0.000
52.5	21.025	0.039	0.000	0.000	0.000
57.5	18.620	0.037	0.000	0.000	0.000
62.5	37.341	0.000	0.000	0.000	0.000
67.5	54.723	0.000	0.000	0.000	0.000
72.5	64.866	0.000	0.000	0.000	0.000
77.5	77.688	0.000	0.000	0.000	0.000
85.0	93.068	0.000	0.000	0.000	0.000
95.0	93.875	0.000	0.000	0.000	0.000
105.0	94.690	0.000	0.000	0.000	0.000
115.0	78.586	0.000	0.000	0.000	0.000
125.0	58.851	0.000	0.000	0.000	0.000
135.0	65.099	0.000	0.000	0.000	0.000
145.0	30.789	0.000	0.000	0.000	0.000
155.0	20.388	0.000	0.000	0.000	0.000
165.0	9.160	0.000	0.000	0.000	0.000
175.0	6.526	0.000	0.000	0.000	0.000

COLUMN #3 (95% TAILINGS/ 5% BENTONITE CAP MATERIAL)

HPLC (mg/l)

MID-DEPTH (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
29.5	34.918	4.491	2.097	4.911	3.397
31.0	33.752	4.110	1.432	2.901	1.724
33.0	16.349	0.826	0.235	0.450	0.000
35.0	26.160	0.812	0.476	1.350	0.795
37.0	32.798	0.578	0.398	0.915	0.557
39.0	38.387	0.439	0.207	0.469	0.271
42.5	43.541	0.265	0.077	0.093	0.000
47.5	41.398	0.031	0.096	0.000	0.000
55.0	26.166	0.000	0.000	0.000	0.000
65.0	16.992	0.000	0.000	0.000	0.000
75.0	6.281	0.000	0.000	0.000	0.000
85.0	3.264	0.000	0.000	0.000	0.000
95.0	1.298	0.000	0.000	0.000	0.000
105.0	0.368	0.000	0.000	0.000	0.000
115.0	0.233	0.000	0.000	0.000	0.000
130.0	0.000	0.000	0.000	0.000	0.000
150.0	0.000	0.000	0.000	0.000	0.000
170.0	0.000	0.000	0.000	0.000	0.000

COLUMN #4 (100% TAILINGS CAP MATERIAL)

HPLC (mg/l)

MID-DEPTH (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
29.0	13.612	2.371	0.655	0.623	0.541
30.5	35.940	2.957	0.429	0.264	0.285
31.5	19.583	1.226	0.172	0.000	0.000
32.5	22.370	1.034	0.153	0.000	0.000
33.5	21.143	0.717	0.009	0.000	0.000
34.5	21.483	0.570	0.187	0.000	0.000
35.5	21.232	0.441	0.057	0.000	0.000
36.5	20.028	0.373	0.075	0.000	0.000
37.5	17.705	0.214	0.060	0.000	0.000
38.5	34.078	0.702	0.044	0.015	0.067
39.5	33.034	0.591	0.020	0.042	0.045
42.5	17.053	0.221	0.055	0.000	0.000
47.5	17.944	0.056	0.022	0.000	0.000
52.5	15.482	0.000	0.203	0.000	0.000
57.5	8.160	0.033	0.139	0.000	0.000
62.5	5.814	0.000	0.000	0.000	0.000
67.5	5.996	0.000	0.000	0.000	0.000
72.5	8.325	0.000	0.000	0.000	0.000
77.5	3.714	0.086	0.000	0.000	0.000
82.5	3.256	0.000	0.000	0.000	0.000
87.5	5.155	0.000	0.000	0.000	0.000
95.0	5.580	0.000	0.000	0.000	0.000
105.0	4.426	0.000	0.000	0.000	0.000
115.0	2.452	0.000	0.000	0.000	0.000
125.0	3.380	0.000	0.000	0.000	0.000
135.0	3.507	0.000	0.000	0.000	0.000
145.0	2.719	0.000	0.000	0.000	0.000
155.0	2.100	0.000	0.000	0.000	0.000
165.0	2.300	0.000	0.000	0.000	0.000
175.0	1.900	0.000	0.000	0.000	0.000

APPENDIX G

APPENDIX G.1

COLUMN #1 (50% TAILINGS/ 50% BENTONITE CAP MATERIAL)

TRACERS (TRACER,g/SOIL,g)

MID-DEPTH (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
30.5	3.19E-05	7.84E-07	2.50E-06	4.81E-06	2.12E-06
31.5	2.05E-05	6.25E-07	1.63E-06	3.00E-06	1.31E-06
32.5	1.29E-05	3.47E-07	3.55E-07	9.51E-07	0.00E+00
35.0	2.61E-05	2.20E-06	5.54E-07	1.46E-06	0.00E+00
38.0	5.08E-06	6.79E-07	8.80E-08	0.00E+00	0.00E+00
42.5	4.13E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
47.5	1.74E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
55.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
75.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
105.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
115.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
125.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
135.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
145.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
155.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
165.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
174.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
179.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

COLUMN #2 (LOAM/GRAVEL CAP MATERIAL)

TRACERS (TRACER,g/SOIL,g)

MID-DEPTH (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
29.5	6.01E-05	1.07E-05	1.20E-05	2.15E-05	2.26E-05
30.5	4.54E-05	4.75E-06	4.07E-06	7.52E-06	7.66E-06
31.5	4.16E-05	8.93E-07	3.15E-06	5.69E-06	5.35E-06
32.5	3.52E-05	7.66E-07	1.98E-06	4.23E-06	3.64E-06
33.5	3.20E-05	5.91E-07	1.58E-06	3.32E-06	3.59E-06
34.5	2.94E-05	4.90E-07	1.28E-06	2.70E-06	2.16E-06
37.5	2.62E-05	4.15E-07	8.19E-07	1.68E-06	1.31E-06
42.5	2.07E-05	1.61E-07	2.07E-07	1.64E-07	2.33E-07
47.5	2.14E-05	7.88E-08	5.49E-08	0.00E+00	0.00E+00
52.5	2.52E-05	4.67E-08	0.00E+00	0.00E+00	0.00E+00
57.5	2.24E-05	4.46E-08	0.00E+00	0.00E+00	0.00E+00
62.5	4.51E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
67.5	6.64E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
72.5	7.90E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
77.5	9.50E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85.0	1.15E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95.0	1.18E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
105.0	1.21E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
115.0	1.05E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
125.0	8.23E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
135.0	5.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
145.0	2.66E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
155.0	1.78E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
165.0	8.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
175.0	5.70E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

COLUMN #3 (95% TAILINGS/ 5% BENTONITE CAP MATERIAL)

TRACERS (TRACER,g/SOIL,g)

MID-DEPTH (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
29.5	4.10E-05	5.27E-06	2.46E-06	5.77E-06	3.99E-06
31.0	5.07E-05	6.18E-06	2.15E-06	4.36E-06	2.59E-06
33.0	2.05E-05	1.04E-06	2.95E-07	5.66E-07	0.00E+00
35.0	3.06E-05	9.50E-07	5.57E-07	1.58E-06	9.30E-07
37.0	3.84E-05	6.76E-07	4.65E-07	1.07E-06	6.51E-07
39.0	4.48E-05	5.12E-07	2.42E-07	5.47E-07	3.16E-07
42.5	5.09E-05	3.10E-07	9.00E-08	1.09E-07	0.00E+00
47.5	4.87E-05	3.65E-08	1.13E-07	0.00E+00	0.00E+00
55.0	3.08E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65.0	2.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
75.0	7.50E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85.0	3.92E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95.0	1.57E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
105.0	4.50E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
115.0	2.86E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
130.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
150.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
170.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

COLUMN #4 (100% TAILINGS CAP MATERIAL)

TRACERS (TRACER,g/SOIL,g)

MID-DEPTH (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
29.0	1.54E-05	2.67E-06	7.39E-07	7.03E-07	6.10E-07
30.5	4.11E-05	3.38E-06	4.91E-07	3.02E-07	3.26E-07
31.5	2.28E-05	1.43E-06	2.00E-07	0.00E+00	0.00E+00
32.5	2.61E-05	1.21E-06	1.79E-07	0.00E+00	0.00E+00
33.5	2.48E-05	8.39E-07	1.05E-08	0.00E+00	0.00E+00
34.5	2.51E-05	6.66E-07	2.19E-07	0.00E+00	0.00E+00
35.5	2.48E-05	5.15E-07	6.66E-08	0.00E+00	0.00E+00
36.5	2.34E-05	4.35E-07	8.75E-08	0.00E+00	0.00E+00
37.5	2.07E-05	2.51E-07	7.03E-08	0.00E+00	0.00E+00
38.5	3.98E-05	8.20E-07	5.14E-08	1.75E-08	7.83E-08
39.5	3.87E-05	6.93E-07	2.34E-08	4.92E-08	5.27E-08
42.5	2.00E-05	2.59E-07	6.46E-08	0.00E+00	0.00E+00
47.5	2.12E-05	6.61E-08	2.62E-08	0.00E+00	0.00E+00
52.5	1.83E-05	0.00E+00	2.40E-07	0.00E+00	0.00E+00
57.5	9.69E-06	3.92E-08	1.65E-07	0.00E+00	0.00E+00
62.5	6.96E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
67.5	7.18E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
72.5	1.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
77.5	4.51E-06	1.04E-07	0.00E+00	0.00E+00	0.00E+00
82.5	3.97E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
87.5	6.33E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95.0	6.92E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
105.0	5.54E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
115.0	3.13E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
125.0	4.56E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
135.0	3.65E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
145.0	2.37E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
155.0	2.19E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
165.0	1.94E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
175.0	1.60E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

APPENDIX G.2

COLUMN #1 (50% TAILINGS/ 50% BENTONITE CAP MATERIAL)

TRACERS (CONC. IN SOIL, mg/l)

MID-DEPTH (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
30.5	171.66	4.21	13.46	25.85	11.37
31.5	97.69	2.98	7.80	14.32	6.24
32.5	57.54	1.55	1.58	4.24	0.00
35.0	145.32	12.24	3.09	8.11	0.00
38.0	64.25	8.58	1.11	0.00	0.00
42.5	5.60	0.00	0.00	0.00	0.00
47.5	2.30	0.00	0.00	0.00	0.00
55.0	0.00	0.00	0.00	0.00	0.00
65.0	0.00	0.00	0.00	0.00	0.00
75.0	0.00	0.00	0.00	0.00	0.00
85.0	0.00	0.00	0.00	0.00	0.00
95.0	0.00	0.00	0.00	0.00	0.00
105.0	0.00	0.00	0.00	0.00	0.00
115.0	0.00	0.00	0.00	0.00	0.00
125.0	0.00	0.00	0.00	0.00	0.00
135.0	0.00	0.00	0.00	0.00	0.00
145.0	0.00	0.00	0.00	0.00	0.00
155.0	0.00	0.00	0.00	0.00	0.00
165.0	0.00	0.00	0.00	0.00	0.00
174.0	0.00	0.00	0.00	0.00	0.00
179.0	0.00	0.00	0.00	0.00	0.00

COLUMN #2 (LOAM/GRAVEL CAP MATERIAL)

TRACERS (CONC. IN SOIL, mg/l)

MID-DEPTH (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
29.5	329.16	58.58	65.69	117.85	123.66
30.5	500.28	52.28	44.82	82.80	84.39
31.5	504.21	10.84	38.23	69.10	64.86
32.5	406.69	8.85	22.81	48.87	42.06
33.5	371.88	6.87	18.34	38.62	41.79
34.5	340.55	5.67	14.78	31.23	24.99
37.5	299.39	4.74	9.35	19.16	14.96
42.5	217.29	1.69	2.18	1.73	2.45
47.5	220.02	0.81	0.57	0.00	0.00
52.5	253.86	0.47	0.00	0.00	0.00
57.5	218.90	0.43	0.00	0.00	0.00
62.5	433.03	0.00	0.00	0.00	0.00
67.5	622.42	0.00	0.00	0.00	0.00
72.5	726.70	0.00	0.00	0.00	0.00
77.5	852.35	0.00	0.00	0.00	0.00
85.0	988.62	0.00	0.00	0.00	0.00
95.0	905.59	0.00	0.00	0.00	0.00
105.0	869.92	0.00	0.00	0.00	0.00
115.0	623.85	0.00	0.00	0.00	0.00
125.0	413.27	0.00	0.00	0.00	0.00
135.0	217.19	0.00	0.00	0.00	0.00
145.0	109.78	0.00	0.00	0.00	0.00
155.0	71.66	0.00	0.00	0.00	0.00
165.0	32.15	0.00	0.00	0.00	0.00
175.0	22.92	0.00	0.00	0.00	0.00

COLUMN #3 (95% TAILINGS/ 5% BENTONITE CAP MATERIAL)

TRACERS (CONC. IN SOIL, mg/l)

MID-DEPTH (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
29.5	471.32	60.62	28.31	66.29	45.85
31.0	201.65	24.55	8.56	17.33	10.30
33.0	160.03	8.09	2.30	4.40	0.00
35.0	360.49	11.19	6.56	18.60	10.96
37.0	452.71	7.98	5.49	12.63	7.69
39.0	536.12	6.13	2.89	6.55	3.78
42.5	603.70	3.67	1.07	1.29	0.00
47.5	551.16	0.41	1.28	0.00	0.00
55.0	346.46	0.00	0.00	0.00	0.00
65.0	216.73	0.00	0.00	0.00	0.00
75.0	77.10	0.00	0.00	0.00	0.00
85.0	39.04	0.00	0.00	0.00	0.00
95.0	15.01	0.00	0.00	0.00	0.00
105.0	4.02	0.00	0.00	0.00	0.00
115.0	2.53	0.00	0.00	0.00	0.00
130.0	0.00	0.00	0.00	0.00	0.00
150.0	0.00	0.00	0.00	0.00	0.00
170.0	0.00	0.00	0.00	0.00	0.00

COLUMN #4 (100% TAILINGS CAP MATERIAL)

TRACERS (CONC. IN SOIL, mg/l)

MID-DEPTH (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
29.0	239.84	41.78	11.54	10.98	9.53
30.5	571.03	46.98	6.82	4.19	4.53
31.5	279.03	17.47	2.45	0.00	0.00
32.5	310.25	14.34	2.12	0.00	0.00
33.5	290.04	9.84	0.12	0.00	0.00
34.5	296.98	7.88	2.59	0.00	0.00
35.5	294.54	6.12	0.79	0.00	0.00
36.5	279.59	5.21	1.05	0.00	0.00
37.5	242.28	2.93	0.82	0.00	0.00
38.5	473.15	9.75	0.61	0.21	0.93
39.5	450.37	8.06	0.27	0.57	0.61
42.5	230.12	2.98	0.74	0.00	0.00
47.5	233.91	0.73	0.29	0.00	0.00
52.5	199.24	0.00	2.61	0.00	0.00
57.5	103.44	0.42	1.76	0.00	0.00
62.5	70.57	0.00	0.00	0.00	0.00
67.5	72.97	0.00	0.00	0.00	0.00
72.5	98.08	0.00	0.00	0.00	0.00
77.5	42.21	0.98	0.00	0.00	0.00
82.5	36.26	0.00	0.00	0.00	0.00
87.5	55.45	0.00	0.00	0.00	0.00
95.0	57.66	0.00	0.00	0.00	0.00
105.0	43.91	0.00	0.00	0.00	0.00
115.0	22.72	0.00	0.00	0.00	0.00
125.0	26.10	0.00	0.00	0.00	0.00
135.0	16.28	0.00	0.00	0.00	0.00
145.0	9.58	0.00	0.00	0.00	0.00
155.0	9.72	0.00	0.00	0.00	0.00
165.0	8.49	0.00	0.00	0.00	0.00
175.0	7.01	0.00	0.00	0.00	0.00

APPENDIX G.3

EFFLUENT DATA

COLUMN #1

DATE	ELAPSED TIME (days)	CONC. (moles/l)	CONC. (mg/l)	VOL. EFF. (ml)	BROMIDE (mg)
9/12/85	204	1.15E-05	0.92	30.0	2.76E-02
6/16/86	481	3.50E-05	2.80	65.5	1.83E-01
6/25/86	490	2.00E-05	1.60	35.0	5.59E-02
7/16/86	511	2.20E-05	1.76	25.0	4.39E-02
7/28/86	523	2.00E-05	1.60	46.0	7.35E-02
8/13/86	539	1.30E-05	1.04	28.5	2.96E-02
9/2/86	559	2.50E-05	2.00	16.5	3.30E-02
9/22/86	579	1.70E-05	1.36	24.0	3.26E-02

RECOVERY OF BROMIDE IN EFFLUENT = 0.479 mg

EFFLUENT DATA

COLUMN #2

DATE	ELAPSED TIME (days)	CONC. (moles/l)	CONC. (mg/l)	VOL. EFF. (ml)	BROMIDE (mg)
9/12/85	204	1.40E-05	1.12	5.0	5.59E-03
6/16/86	481	2.20E-05	1.76	3.0	5.27E-03
6/25/86	490	2.00E-05	1.60	5.0	7.99E-03
7/16/86	511	2.30E-05	1.84	4.8	8.82E-03
7/28/86	523	2.20E-05	1.76	4.0	7.03E-03
8/13/86	539	1.80E-05	1.44	4.5	6.47E-03
9/2/86	559	2.85E-05	2.28	4.5	1.02E-02
9/22/86	579	1.90E-05	1.52	5.4	8.20E-03
9/28/87	950	1.12E-05	0.89	5.4	4.83E-03
1/19/88	1063	5.40E-05	4.31	7.0	3.02E-02
2/2/88	1077	3.20E-05	2.56	3.0	7.67E-03
2/9/88	1084	1.40E-05	1.12	0.5	5.59E-04
3/1/88	1105	1.60E-05	1.28	0.8	1.02E-03
3/17/88	1121	5.70E-05	4.55	2.4	1.09E-02
3/28/88	1132	6.00E-05	4.79	2.0	9.59E-03
4/5/88	1140	6.90E-05	5.51	3.6	1.98E-02
4/15/88	1150	6.90E-05	5.51	4.3	2.37E-02
5/9/88	1174	6.90E-05	5.51	5.0	2.76E-02

RECOVERY OF BROMIDE IN EFFLUENT = 0.101 mg

EFFLUENT DATA

COLUMN #3

DATE	ELAPSED TIME (days)	CONC. (moles/l)	CONC. (mg/l)	VOL. EFF. (ml)	BROMIDE (mg)
6/25/86	490	1.50E-05	1.20	1.0	1.20E-03
12/29/86	677	1.10E-05	0.88	5.6	4.92E-03

RECOVERY OF BROMIDE IN EFFLUENT = 0.006 mg

EFFLUENT DATA

COLUMN #4

DATE	ELAPSED TIME (days)	CONC. (moles/l)	CONC. (mg/l)	VOL. EFF. (ml)	BROMIDE (mg)
6/16/86	481	1.80E-05	1.44	3.4	4.89E-03
6/25/86	490	2.10E-05	1.68	4.6	7.72E-03
7/16/86	511	2.80E-05	2.24	5.0	1.12E-02
7/28/86	523	3.20E-05	2.56	4.0	1.02E-02
8/13/86	539	3.00E-05	2.40	5.0	1.20E-02
9/2/86	559	2.70E-05	2.16	6.5	1.40E-02
9/22/86	579	5.80E-05	4.63	7.6	3.52E-02
11/11/86	629	1.05E-05	0.84	5.9	4.95E-03

RECOVERY OF BROMIDE IN EFFLUENT = 0.100 mg

APPENDIX H

APPENDIX H.1

BATCH RESULTS FOR CALCIUM BROMIDE TRACER IN COPPER MILL TAILINGS MEDIUM (Lewis, 1986).

Summary of batch experiment results (Calcium Bromide in Copper Mill Tailings)

Reference Concentration (moles/liter)	Test A Concentration[1] (moles/liter)	Test B Concentration[2] (moles/liter)	Test C Concentration[2] (moles/liter)
10^{-2}	6.2×10^{-3}	5.8×10^{-3}	5.9×10^{-3}
10^{-3}	6.2×10^{-4}	5.1×10^{-4}	5.1×10^{-4}
10^{-4}	5.0×10^{-5}	5.2×10^{-5}	5.7×10^{-5}
10^{-5}	3.6×10^{-6}	2.8×10^{-6}	4.2×10^{-6}

1) 250.0 sample with 300 ml reference solution added, 5 minute stirring time:

2) 75.0 g sample with 90 ml reference solution added, 8 hours stirring, 16 hours at rest, 8 more hours stirring.

(Lewis, 1986).

Lewis (1986) derived the following equation to correct for the loss of bromide mass in a solution in contact with the copper mill tailings:

$$C_a = 1.14C_o^{0.93}$$

C_a = actual known concentration (moles/l) of the reference solution (ie. the actual, "corrected," concentration).

C_o = observed concentration (moles/l) of the solution after mixing with the copper mill tailings (ie. the measured concentration).

BATCH ISOTHERMS FLUORO-ORGANIC TRACERS

MASS TRACER LOST (ug) per MASS SOIL (g)

EQUILIBRIUM CONC (ug/cc)	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
0.4	-0.38	-0.61	-0.04	-0.29
2.0	-0.05	0.38	0.04	-0.08
10.0	1.79	0.77	0.92	0.63
50.0	10.64	4.17	3.81	1.97
100.0	11.97	-1.04	-0.2	-3.03
500.0	69.73	8.63	8.03	5.65
1000.0	121.61	33.02	29.16	28.14

APPENDIX H.2

COLUMN #1 (50% TAILINGS/ 50% BENTONITE CAP MATERIAL)

RECOVERY OF TRACERS

MASS OF TRACER IN INCREMENT (g)

DEPTH INCREMENT (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
30-31	9.48E-03	2.33E-04	7.43E-04	1.43E-03	6.28E-04
31-32	6.08E-03	1.85E-04	4.85E-04	8.90E-04	3.88E-04
32-34	7.67E-03	2.06E-04	2.11E-04	5.65E-04	0.00E+00
34-36	1.55E-02	1.30E-03	3.29E-04	8.64E-04	0.00E+00
36-40	6.03E-03	8.06E-04	1.04E-04	0.00E+00	0.00E+00
40-45	6.13E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
45-50	2.58E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00

TOTAL RECOVERY OF TRACERS (g)

BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
0.0456	0.0027	0.0019	0.0037	0.0010

PERCENT RECOVERED (%)

BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
N/A	9.1110	6.2406	7.9705	1.6933

COLUMN #2 (LOAM/GRAVEL CAP MATERIAL)

RECOVERY OF TRACERS

MASS OF TRACER IN INCREMENT (g)

DEPTH INCREMENT (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
29-30	1.47E-02	2.62E-03	2.94E-03	5.28E-03	5.54E-03
30-31	1.35E-02	1.41E-03	1.21E-03	2.23E-03	2.27E-03
31-32	1.23E-02	2.65E-04	9.35E-04	1.69E-03	1.59E-03
32-33	1.05E-02	2.27E-04	5.86E-04	1.26E-03	1.08E-03
33-34	9.49E-03	1.75E-04	4.68E-04	9.86E-04	1.07E-03
34-35	8.74E-03	1.46E-04	3.79E-04	8.01E-04	6.41E-04
35-40	3.89E-02	6.16E-04	1.22E-03	2.49E-03	1.94E-03
40-45	3.07E-02	2.38E-04	3.07E-04	2.44E-04	3.46E-04
45-50	3.17E-02	1.17E-04	8.15E-05	0.00E+00	0.00E+00
50-55	3.74E-02	6.94E-05	0.00E+00	0.00E+00	0.00E+00
55-60	3.33E-02	6.62E-05	0.00E+00	0.00E+00	0.00E+00
60-65	6.70E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65-70	9.85E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
70-75	1.17E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
75-80	2.82E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
80-90	3.40E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90-100	3.52E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100-110	3.59E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
110-120	3.12E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
120-130	2.44E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
130-140	1.76E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
140-150	7.89E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
150-160	5.28E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
160-170	2.37E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
170-180	1.69E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

TOTAL RECOVERY OF TRACERS (g)

BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
2.7609	0.0060	0.0081	0.0150	0.0145

PERCENT RECOVERED (%)

BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
N/A	19.8395	27.0746	31.8629	24.1285

COLUMN #3 (95% TAILINGS/ 5% BENTONITE CAP MATERIAL)

RECOVERY OF TRACERS

MASS OF TRACER IN INCREMENT (g)

DEPTH INCREMENT (cm)	BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
29-30	1.20E-02	1.54E-03	7.21E-04	1.69E-03	1.17E-03
30-32	3.01E-02	3.67E-03	1.28E-03	2.59E-03	1.54E-03
32-34	1.22E-02	6.16E-04	1.75E-04	3.36E-04	0.00E+00
34-36	1.82E-02	5.64E-04	3.31E-04	9.37E-04	5.52E-04
36-38	2.28E-02	4.01E-04	2.76E-04	6.35E-04	3.87E-04
38-40	2.66E-02	3.04E-04	1.43E-04	3.25E-04	1.88E-04
40-45	7.55E-02	4.60E-04	1.34E-04	1.61E-04	0.00E+00
45-50	7.23E-02	5.41E-05	1.68E-04	0.00E+00	0.00E+00
50-60	9.15E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
60-70	5.98E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
70-80	2.23E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
80-90	1.16E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90-100	4.66E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100-110	1.34E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
110-120	8.48E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00

TOTAL RECOVERY OF TRACERS (g)

BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
0.3702	0.0076	0.0032	0.0067	0.0038

PERCENT RECOVERED (%)

BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
N/A	25.3700	10.7522	14.1956	6.3883

COLUMN #4 (100% TAILINGS CAP MATERIAL)

RECOVERY OF TRACERS

MASS OF TRACER IN INCREMENT (g)

DEPTH INTERVAL (cm)	BR	m-TFMBA	o-TFMBA	2.6-DFBA	PFBA
28-30	8.89E-03	1.55E-03	4.28E-04	4.07E-04	3.53E-04
30-31	1.19E-02	9.79E-04	1.42E-04	8.74E-05	9.44E-05
31-32	6.60E-03	4.13E-04	5.79E-05	0.00E+00	0.00E+00
32-33	7.57E-03	3.50E-04	5.18E-05	0.00E+00	0.00E+00
33-34	7.17E-03	2.43E-04	3.05E-06	0.00E+00	0.00E+00
34-35	7.27E-03	1.93E-04	6.33E-05	0.00E+00	0.00E+00
35-36	7.18E-03	1.49E-04	1.93E-05	0.00E+00	0.00E+00
36-37	6.77E-03	1.26E-04	2.53E-05	0.00E+00	0.00E+00
37-38	6.00E-03	7.26E-05	2.03E-05	0.00E+00	0.00E+00
38-39	1.15E-02	2.37E-04	1.49E-05	5.07E-06	2.27E-05
39-40	1.12E-02	2.01E-04	6.79E-06	1.43E-05	1.53E-05
40-45	2.90E-02	3.76E-04	9.35E-05	0.00E+00	0.00E+00
45-50	3.07E-02	9.58E-05	3.80E-05	0.00E+00	0.00E+00
50-55	2.65E-02	0.00E+00	3.48E-04	0.00E+00	0.00E+00
55-60	1.40E-02	5.67E-05	2.39E-04	0.00E+00	0.00E+00
60-65	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65-70	1.04E-02	4.26E-04	0.00E+00	0.00E+00	0.00E+00
70-75	1.45E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
75-80	6.52E-03	1.51E-04	0.00E+00	0.00E+00	0.00E+00
80-85	5.75E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85-90	9.17E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90-100	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100-110	1.61E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
110-120	9.05E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
120-130	1.32E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
130-140	1.06E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
140-150	6.85E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
150-160	2.63E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
160-170	8.73E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
170-180	8.01E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00

TOTAL RECOVERY OF TRACERS (g)

BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
0.314	0.006	0.002	0.001	0.000

PERCENT RECOVERED (%)

BR	m-TFMBA	o-TFMBA	2,6-DFBA	PFBA
6.275	18.726	5.170	0.010	0.010

APPENDIX H.3

pH ANALYSIS of EXTRACTS

	COLUMN NUMBER			
DEPTH (cm)	1	2	3	4
28.5				3.76
29.5			5.03	3.72
30.5	6.63	6.65		3.44
31.5		3.96	5.79	3.33
32.5		3,67		3.26
33.5		3.53	5.28	3.22
34.5				3.22
35.0			3.75	
37.5		3.39	3.35	3.25
38.0	4.11			
39.5			4.23	3.29
42.5		3.21	3.19	
52.5				3.26
55.0	3.20			
65.0			3.07	
67.5		3.11		
82.5				2.77
85.0	2.99			
115.0	2.53	2.68	2.52	2.24
135.0		2.28		
145.0	2.23		2.00	2.17
155.0	2.14			
165.0	2.10		2.21	
175.0	1.97	3.09		2.62

pH ANALYSIS of EXTRACTS

	COLUMN NUMBER			
DEPTH (cm)	1	2	3	4
28.5				3.76
29.5			5.03	3.72
30.5	6.63	6.65		3.44
31.5		3.96	5.79	3.33
32.5		3.67		3.26
33.5		3.53	5.28	3.22
34.5				3.22
35.0			3.75	
37.5		3.39	3.35	3.25
38.0	4.11			
39.5			4.23	3.29
42.5		3.21	3.19	
52.5				3.26
55.0	3.20			
65.0			3.07	
67.5		3.11		
82.5				2.77
85.0	2.99			
115.0	2.53	2.68	2.52	2.24
135.0		2.28		
145.0	2.23		2.00	2.17
155.0	2.14			
165.0	2.10		2.21	
175.0	1.97	3.09		2.62