SEASONAL AND SPATIAL VARIATIONS IN SOIL-MOISTURE FLOW AT A SEMI-ARID FIELD SITE

by
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ABSTRACT

The seasonal and spatial variability of unsaturated soil-moisture was studied between December, 1987 and July, 1989, at a semiarid field site near Socorro, New Mexico. The effects of desert plant water uptake on soil-moisture flow was also examined in this study. The field site was instrumented with a variety of monitoring equipment which included; tensiometers, nuetron access tubes to monitor soil-moisture, soil temperature thermistors, and both an automated and a manual weather station. Both seasonal and spatial variabilities of soil-moisture profiles were detected from the nuetron probe measurements. Seasonal variabilities included; increased moisture contents below 300 cm during the rainy season due to a rising water table, and increased infiltration of precipitation during the summer months. Spatial variabilities in soil-moisture profiles included: variable infiltration of precipitation, and variable moisture contents with depth, due to small scale bedding features with varying hydraulic properties. There was no significant horizontal movement of soil-moisture detected in the vicinity of the desert vegetation at the field site.

As part of this study, a water balance was estimated for the time between 7/5/88 and 7/20/89. The results of the study indicated that an accurate measurement of a water balance could not be calculated due to errors inherent in the estimation, and possible errors in the original assumptions. With these possible errors, the water balance parameters were estimated to be: recharge equal to between 0.164 cm/yr and 2.6 cm/yr, precipitation equal to 17.43 cm/yr, change in storage with time equal to 3.28 cm/yr, and evapotranspiration, calculated as the residual of the water balance, ranging from 12.26 cm/yr to 13.75 cm/yr. A tracer test was also conducted between 8/9/88 and 1/24/89 using three organic anions (o-(trifluoromethyl)benzoic acid, 2,6-difluorbenzoic acid, and pentafluorobenzoic acid) and one inorganic salt (calcium bromide). The results of the tracer test show that tracer movement varies with both depth and distance from desert vegetation. The tracers also exhibited a large amount of transverse dispersion which may have been caused by small scale textural discontinuities within the soil profile.

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INTRODUCTION

Determining the magnitude and direction of soil-moisture flow in the unsaturated zone is of great concern to those trying to predict the transport of water and solutes beneath dams, rivers, surface impoundments, hazardous waste sites, and a variety of other environmental settings. The process of estimating the magnitude and direction of unsaturated soil-moisture flow can become extremely difficult if variations in soil-moisture flow occur.

Variations in soil-moisture flow can be seasonal and/or spatial in nature. Seasonal variations in soil-moisture movement can be caused by fluctuations in temperature, variations in the amount and rate of precipitation, and fluctuations in plant water uptake. Spatial variations in soil-moisture flow can be attributed to variations in the amount and type of vegetation,existence of preferential flow paths, heterogeneities within a soil profile, and topographic variations. There has been little research conducted on the importance of seasonal and spatial variations in soil-moisture flow. However, recent studies have suggested that seasonal and spatial variations in soil-moisture flow may be present in a variety of settings (e.g. Kickham, 1987; Bresler and Dagan, 1979).

The purpose of this research project was to investigate the seasonal and spatial variabilities in unsaturated soil-moisture flow at a semi-arid field site, and to determine what effects, if any, these variations have in the estimation of ground-water recharge. The field site was located in the northern tip of the Chihuahuan desert within the Sevilleta National Wildlife Refuge, approximately 24 kilometers north of Socorro, New Mexico (Figure 1). This area is typical of semi-arid environments, with low annual precipitation and high potential evapotranspiration.

Ground-water recharge is considered to be percolating water that enters into the water saturated zone. In humid regions ground-water recharge can amount to a large percentage of the annual precipitation. In semi-arid regions the mean annual potential evapotranspiration of soil-moisture is often greater than the mean annual precipitation. Under these conditions ground-water recharge is commonly considered negligible. Previous studies conducted at the Sevilleta National Wildlife Refuge have determined that ground-water recharge can amount to as much as 20% of the annual precipitation (Knowlton, 1986; and McCord, 1986). In these studies it was found that recharge occurred in spite of the fact that within the Sevilleta National Wildlife Refuge, the mean annual potential evapotranspiration greatly exceeded the annual precipitation. This seems to suggest that for short periods of time during the year, precipitation exceeds actual evapotranspiration. This most commonly occurs during long, steady rains, and periods of snowmelt in the winter season.

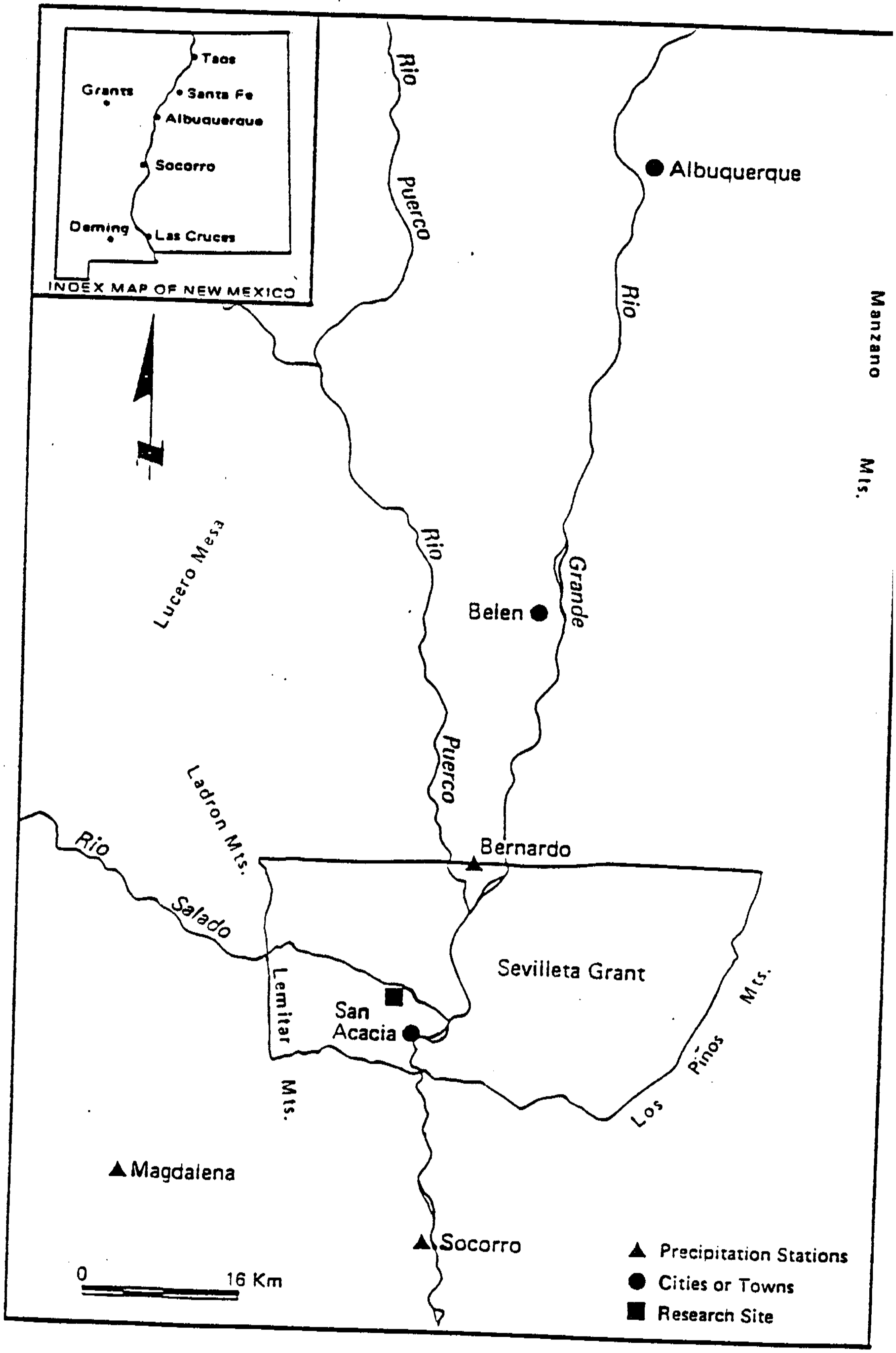


Figure 1. Site location map.

Many different methods have been established to estimate arid-site recharge. These include: the Darcian approach, water content approach, chloride mass balance, tracer tests, temperature gradient method, and lysimetry. In general, most of the methods used to estimate recharge in arid regions are based on the assumption that moisture flows only vertically. This assumption may not be valid in sparsely vegetated desert environments were soil-moisture may move in three dimensions due to plant water uptake. Also, if the soil is composed of heterogeneities it is possible that large deviations from one-dimensional soil moisture flow may occur. Significant errors in the calculation of ground-water recharge can exist if the commonly used one-dimensional conceptual model is used under cases were three-dimensional moisture flow is occurring.

Recent field studies at the Sevilleta National Wildlife Refuge have demonstrated that seasonal and spatial variations in soil-moisture flow are significant within this semi-arid environment. In a study conducted by Kickham (1987), seasonal variations in soil-moisture flow were detected in the vicinity of a desert shrub (Figure 2 and 3). It was found that during the winter, the plant was inactive and one-dimensional soil-moisture flow occurred. During the summer the plant was actively withdrawing moisture from the soil, causing soil-water to flow laterally toward the bush. Lateral flows have also been observed from tracer studies on a hillslope composed of uniform dune sand (Figure 4) (McCord, 1986). The deviation

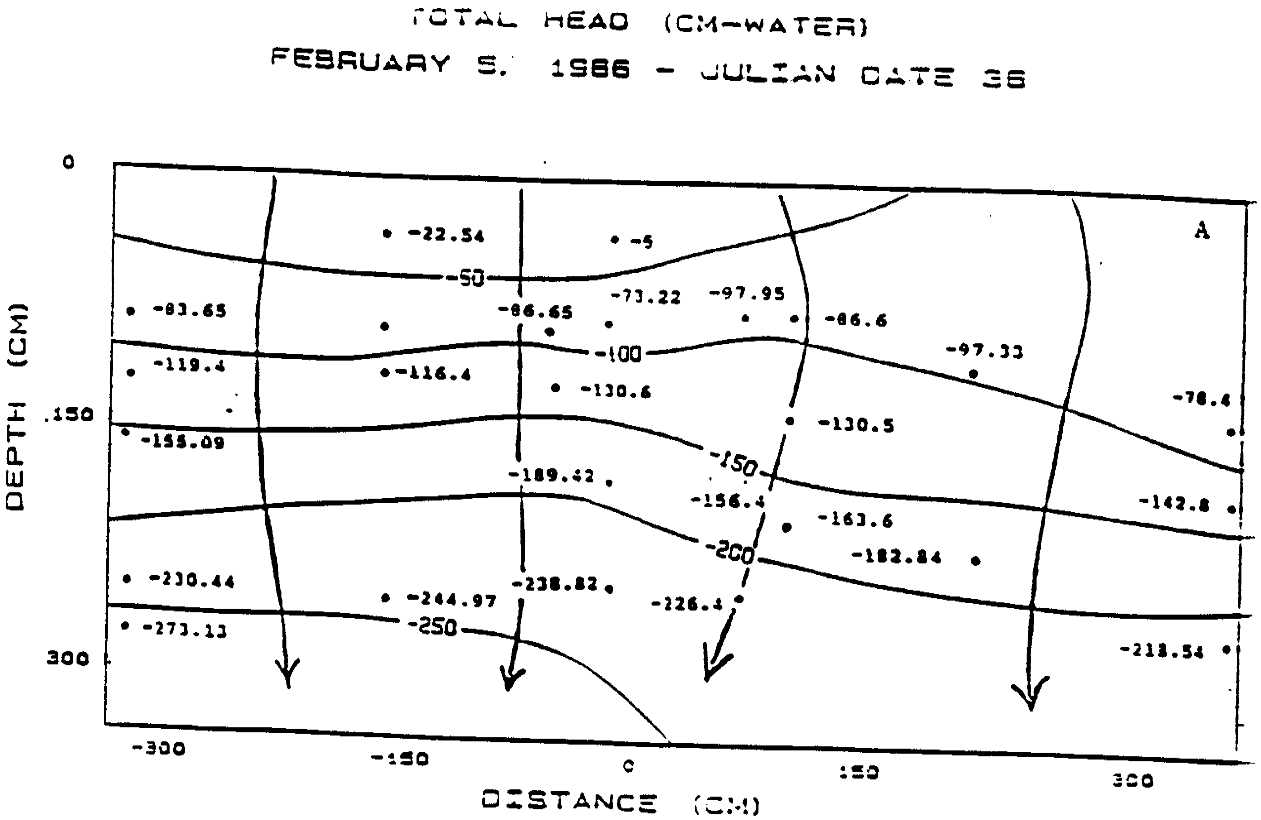


Figure 2. Winter soil-moisture flow

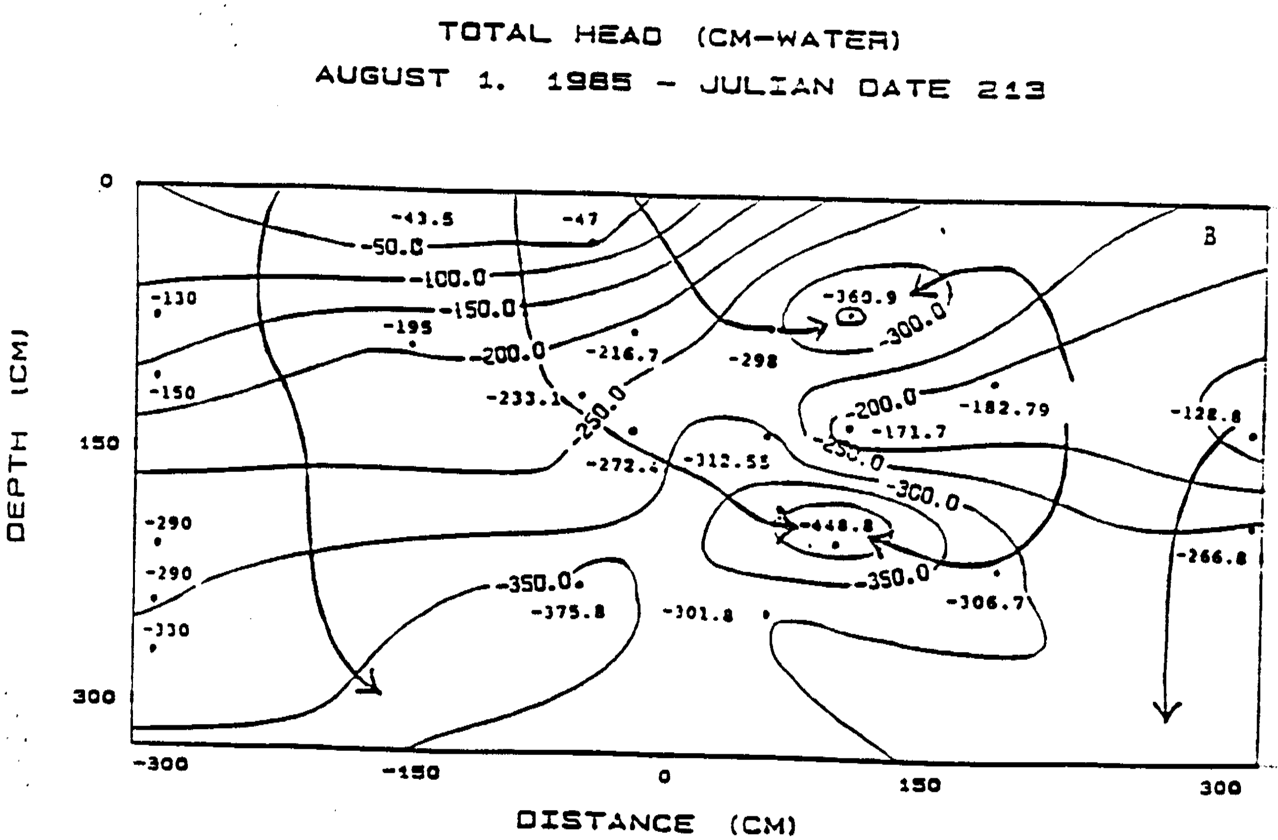


Figure 3. Summer soil-moisture flow

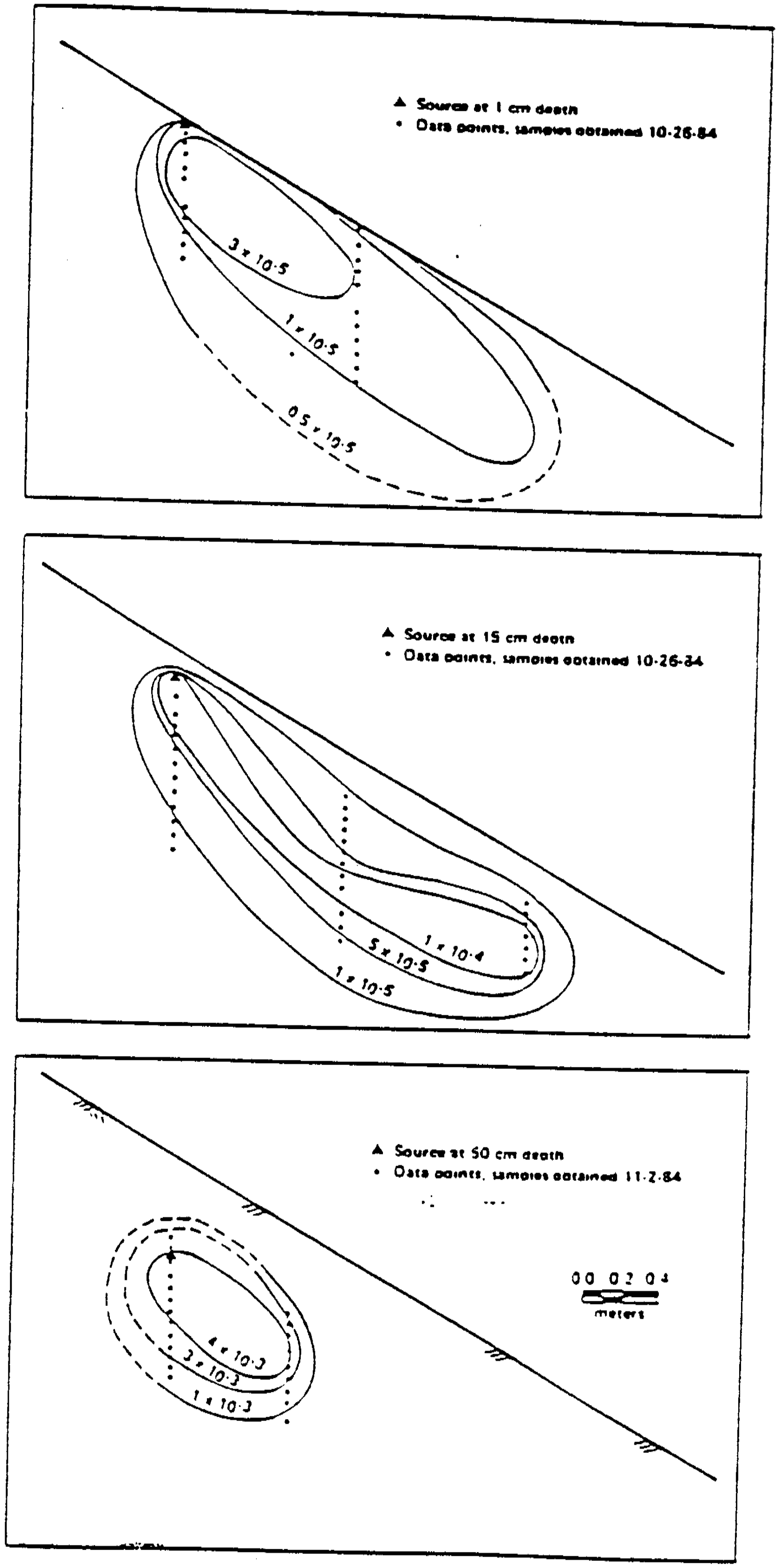


Figure 4. Cross-section showing bromide concentration beneath a sandy hillslope following precipitation.

from one-dimensional flow was believed to be caused by topographic variations, moisture-dependent heterogeneities, or moisture-dependent anisotropies in unsaturated hydraulic conductivities.

The existence of preferential flow paths causes large variations in the spatial distribution of ground-water recharge. The downward rate of soil-water movement determined by tracer measurements is often faster than that predicted from macroscopic velocities calculated from water balances (Rice et al. 1986). This has been found to be due to a large amount of the soil-moisture percolating downward in preferential flow paths. Large deviations from one-dimensional flow have been observed from tracer tests conducted in heterogeneous soils. When downward percolating water reaches a textural discontinuity, soil-moisture may spread laterally. These spatial variations in soil-moisture flow are caused by the varying hydraulic properties that exist at stratigraphic interfaces.

Several objectives were set forth for the course of the research project. First, the effects of plant water uptake on ground-water recharge was investigated. Secondly, seasonal variations in soil-moisture flow was examined. Thirdly, the usefulness of a set of fluorobenzoate tracers as long term tracers of soil-moisture movement in the vadose zone was determined. And finally, the effects of small scale bedding features on unsaturated moisture flow was investigated.

In the first phase of the project a great deal of instrumentation was installed to examine the seasonal and spatial variabilities within the semi-arid field site. This instrumentation was installed at various locations within the site so that differences in vegetative cover and soil type could be analyzed. Tensiometers were used for measuring matric suction, a parameter used in the calculation of hydraulic head and hydraulic gradients. A neutron probe was used to measure volumetric moisture content profiles from within aluminum access tubes. Soil temperature gradients were measured by temperature thermistors. Both an automated and a manual weather station were placed at the site to measure meteorological conditions. This instrumentation provided for a large data base that was crucial in determining variabilities in soil-water movement at the desert research site.

In the second phase of the project, a field tracer test was conducted to investigate spatial variabilities in soil-moisture flow. Three fluorinated benzoic acid derivatives and one inorganic salt were used in the field tracer test. All of the tracers used in this study have been shown to behave conservatively (Bowman, 1984a). The tracers were placed at various locations within the soil profile so that variabilities in soil-water flow at vegetated and unvegetated locations could be compared.

The third and final phase of the project involved excavation of a portion of the research site to investigate the rooting patterns of the native vegetation, and to determine the extent of small scale bedding features within the soil profile. A 1m by 2m by 3m trench was excavated at the end of the field investigation and spatial variabilities in root density, root distribution, and small scale bedding were examined.

The investigation of seasonal and spatial variations of soil-moisture flow within the vadose zone is relevant to a number of processes. For instance, the amount of ground-water recharge into an aquifer is an important quantity needed for water-resource management purposes. Large errors may exist when estimating recharge, if variations in soil-water flow are not taken into account. Seasonal and spatial variabilities in soil-moisture flow are also relevant to the migration of contaminants within the unsaturated zone. In the presence of preferential flow paths, contaminants might funnel into scattered regions within a soil matrix and move toward the water table at a much quicker rate than that predicted from macroscopic soil-water velocities. The existence of heterogeneities may cause contaminants to spread laterally and thus inhibit downward migration. In the presence of desert vegetation, the migration of a contaminant may be affected by seasonal variations in plant water uptake. During the summer, strong lateral gradients may exist towards the bush which would suppress the downward flow of contaminants. In the winter, desert plants may be dormant and contaminants may move vertically downward past the root zone toward the water table. Acquiring information on the seasonal and spatial variations in soil-water transport could play an important role in many hazardous waste cleanup decisions.

RELATED RESEARCH

The amount of research conducted on soil-moisture movement has greatly increased in recent years. This increase is due to a growing awareness of the problems associated with ground-water pollution and depleting water supplies. Recent research into soil-moisture movement has involved water balance studies, recharge studies, solute transport studies, and chemical tracer studies. This section presents a brief discussion of current and historical research that has been conducted on variability in soil-moisture flow.

WATER BALANCE AND RECHARGE

The process of calculating a water balance for a particular site is a time consuming and difficult task. Numerous methods of calculating water balances have been reported throughout the literature. These include: simulation models, balances based on soil water storage changes, water borne tracer studies, lysimeter experiments, balances based on Darcian flux measurements, and simplified water balance models which are used in the absence of detailed soil and plant information. Errors in the calculation of water balances can be extreme, most commonly due to the difficulty in measuring evapotranspiration.

An in-depth review and critique of estimation methods in calculating groundwater recharge in arid regions is presented by Gee and Hillel (1988). This paper explains how various sources of errors are introduced into water balance models. Recharge, when based as a residual in water balance models may result in errors of as much as an order of magnitude. Similar errors can occur when soil water flow models are used due to errors associated with the measurements of tension gradients and soil hydraulic conductivities. It was believed by the authors that tracer tests can only provide qualitative estimates of ground-water recharge. The use of lysimetry was believed to be the best estimate of water balances in arid environments.

The effects of soil spatial variability in the estimation of areal mean water balances was presented by Milly and Eagleson (1986). It was shown through statistical analysis that the variability of the pore size distribution index and permeability have a much larger effect than that of effective porosity on the means and variances of water balance variables. Several regional water balance models were examined by using 50-year records of monthly streamflow at 10 sites in New Jersey (Alley, 1984). The five models that were examined, differ in their treatment of evapotranspiration, soil moisture accounting, and aquifer recharge. The results of this study suggested that extreme caution should be used in attaching physical significance to model parameters.

A comparison of three alternative methods of estimating deep percolation rates was presented by Sammis at al. (1982). The estimation methods for calculating deep percolation rates were, Darcian flux, soil temperature gradients, and tritium concentration profiles in the soil water. Because of the uncertainty in the estimation of evapotranspiration, the water balance method of estimating deep percolation rates was shown to be highly subject to error.

In a paper by Bouwer (1987), an explanation of the common sources of error in evaluating areal groundwater recharge rates from point measurement techniques was presented. The sources of error include the following: the spatial variability of infiltration if rainfall exceeds the infiltration capacity of the soil, the spatial variability of water contents and other parameters in the soil profile, preferential flow, hysteresis due to alternate wetting and drying, and evaporation of water deeper in the vadose zone.

An areal water balance model based on the Darcian flux method of estimating groundwater recharge is presented in Wagenet (1986). In this model, recharge is calculated from soil water matric potentials and unsaturated hydraulic conductivities. The hydraulic conductivities are a function of the moisture contents within the profile, which has been shown to be less hysteretic than hydraulic conductivities based on pressure heads.

It has recently been demonstrated (Rice et al. 1986), that large errors can arise in the estimation of water balances if preferential flow of soil water is occurring within the soil profile. In this study the deep percolation rate calculated from bromide tracer velocities was about five times greater than that determined from a water balance. This large discrepancy between the tracer and water balance rates was believed to be a result of the tracer, and consequently the bulk of the water, moving in preferential paths. Similar findings were reported from a study conducted by Bowman and Rice (1986a). This study was part of an experiment to determine the spatial variability of deep percolation rates in an essentially structureless soil. At the site, the downward rate of water movement determined by tracer measurements was about 2.5 times faster than that predicted by a traditional water balance-water content approach to miscible displacement. This rapid downward movement of percolating water was apparently due to the presence of preferential flow paths within the soil profile. In another study by Bowman and Rice (1986b), the velocity of downward percolating water, measured using concentration profiles of a series of flourobenzoate tracers was compared to the macroscopic velocity calculated from a water balance. Mean water velocities measured with the tracers averaged 60-70% greater than the calculated macroscopic velocities. The results of this study indicate that simple water balance models may overestimate arrival times of surface applied water to groundwater.

Another method of estimating recharge is through the measurement of chloride concentrations of soil water within a soil profile. This method provides a quick and inexpensive means of estimating recharge rates on local, areal, and regional scales. A description of the use of chloride and tritium as indicators of soil-water movement in a semi-arid region is presented by Allison and Hughes (1983). In this paper chloride concentrations of soil water were used to calculate the mean annual amount of deep drainage occurring at a semi-arid site in southern Australia. In a study conducted by Farrington and Bartle (1985), water and chloride balances were calculated for a coastal deep sandy soil of southwestern Australia. Results from this study indicated that the long term estimate of groundwater recharge at the site, using the chloride balance, was very similar to the average value obtained using the water balance method. A chloride balance method was used to compare recharge rates of three vegetated sites in a study performed by Sharma and Craig (1987). It was shown that under the native vegetated site, preferential flow contributed to over 50% of the recharge, while the site vegetated with young pines showed very little evidence of preferential flow. It was believed that under the native woodland site a stable system of preferred pathways existed and that under the pine site the preferred pathways were destructed due to the clearing of the native vegetation. An estimation of groundwater recharge using chloride, deuterium, and oxygen-18 profiles in a deep coastal sand of western Australia was performed by Sharma and Hughes (1985). Considerable spatial variability in the depth distributions of Cl^-, deuterium, and O_{18}, in the unsaturated zone suggested that a considerable amount of groundwater recharge was occurring through the movement of water in preferred pathways. A steady-state model of water and chloride movement, which included the effects of diffusion was presented in a paper by Johnston (1987a). The recharge rates estimated from chloride concentrations in the saturated zone were as much as two orders of magnitude greater than those estimated above the water table. It was concluded that preferred water flow in structural and textural heterogeneities was the dominant method of recharge. In a later paper by Johnston (1987b), it was shown that errors are introduced by using an aerially uniform estimate of chloride flux density when there is obvious variability in water flow.

In a study conducted by Stone and McGurk (1985), the chloride method was applied to three sites in New Mexico to estimate the recharge rates and evaluate the variability of recharge with landscape setting. In a study by Mattick et al. (1987), groundwater recharge rates were quantified using bomb Cl_{36}, bomb tritium, and chloride as soil-water tracers. Groundwater recharge rates based on the chloride mass balance where considerably lower than those estimated by a soil physics study. Differences where believed to be attributed to lateral components of flow and differences in liquid and solute transport. If lateral flow is occurring in the vadose zone, the chloride method will yield recharge estimates that are lower than the actual recharge because the method assumes one-dimensional vertical flow.

When estimating a water balance it is necesary to know the limitations and assumptions associated with the method being used. The largest errors are related to the quantification of evapotranspiration and thus this parameter is commonly calculated as the residual of the water balance. If variabilty in soil-moisture flow is not taken into account large errors in water balance estimations can occur. The various methods of estimating recharge often assume one dimensional flow and should be used with caution in cases were variability in soil-moisture flow is present.

SOLUTE TRANSPORT STUDIES

The movement of solutes in a porous media is governed by three processes: advection, mechanical dispersion, and molecular diffusion. Numerous studies have been conducted in the laboratory to ascertain the processes of solute transport in various porous media. Both saturated and unsaturated field experiments have been performed in recent years to gain a better understanding of solute transport in undisturbed soil profiles. The newest research into solute transport deals with simulation studies and numerical modelling.

Solute transport has been researched for many years. One of the first and most complete studies in solute transport was presented in a series of papers by Nielsen and Biggar. In the first paper (Nielsen and Biggar, 1961), the process of miscible displacement of a tracer was studied in various porous materials under saturated and unsaturated conditions and different average flow velocities. It was shown that under field conditions (where soil-water velocities are low) the effects of hydrodynamic dispersion and diffusion cannot be neglected in solute transport. Microscopic distributions of flow velocities were studied in the second paper of the series (Biggar and Nielsen, 1962). In these experiments, tritium and chloride were used as tracers in soil columns under steady state flow conditions. Variations in tracer breakthrough curves were explained on the basis of adsorption, ion exchange, pore geometry, and diffusion rates. In the final paper (Nielsen and Biggar, 1962), several analytical models for miscible displacement in porous material were examined. All of the models studied in this paper assumed that there was no chemical or physical interactions between solute, liquid, and porous material. It was shown that these models were unsatisfactory due to the physical and chemical interactions that were occurring in the porous material during miscible displacement. A review of the processes of diffusion and dispersion in porous media was presented by Perkins et al. (1963). The effects of an immobile phase and transverse diffusion were examined in this paper.

More recent studies of solute transport have dealt with an array of increasingly complex problems. In a study by Yule and Gardner (1978), the relationship between the longitudinal and transverse dispersion coefficients for an unsaturated Plainfield sand was determined by the use of laboratory columns. The effect of pore size on the diffusion coefficient for acetic acid in soil was examined in a study conducted by Saxena et al. (1974). The ratio of the actual porous system diffusion coefficient and the free solution diffusion coefficient was calculated to be an exponential relationship of the pore radius. The results from this study suggested that the rate of diffusion was significantly reduced for particle sizes of less than silt size, due to viscous drag on closely spaced pore walls. A theoretical approach to the processes of solute dispersion in a heterogenous soil at the field scale was presented by Dagen and Bresler (1979). In their paper, the soil was envisioned as a series of homogeneous vertical columns differing in their soil properties. Each vertical column was assigned a different hydraulic conductivity, creating a heterogeneous field in the horizontal direction. Solute spreading in each profile was represented by solutions to the convection-dispersion equations, but the concentration distribution in the entire field showed much larger variations due to soil heterogeneity in the horizontal direction.

An intermediate scale experiment at Los Alamos National Labs (Springer et al. 1988) was designed to investigate solute transport through a backfill material used at waste sites in Los Alamos. Both saturated and unsaturated experiments were conducted with 6 m x 3 m caissons of galvanized metal corrugated pipe filled with porous material. These experiments revealed a scale dependency of dispersivity with depth. Dispersivities were seen to increase with depth possibly due to heterogeneities within the soil profile.

Field scale studies of solute transport have predominately dealt with saturated cases, but recently a growing number of unsaturated studies have been undertaken, due to the increasing interest in vadose zone transport processes. The processes of interest include: preferential flow, plant water uptake, mobile-immobile water phase, lateral flows due to soil heterogeneities, ion exclusion, degradation, and sorption. For example, solute transport of two conservative tracers, bromide and chloride, was studied in a stony field soil under natural conditions by Schulin et al. (1987). In this study the tracers were applied evenly in pulses at the top of the field profile. The bromide showed extensive lateral redistribution while the chloride only showed minor redistribution. The differences in the solute distributions were believed to have been caused by root water uptake. The bromide was applied half a year earlier than the chloride and had traveled a full year when the first sampling took place. The chloride had only traveled for one winter season and thus missed the effects of root water uptake, while the bromide traveled during both seasons. The effects of root water uptake was believed to have enhanced lateral movement and suppressed vertical displacement of the solutes and water.

A field solute transport study performed under coupled saturated-unsaturated conditions was conducted by Van Ommen and Dijksma (1988). Preferential flow in the subsoil at this site caused an accelerated breakthrough of the bromide pulse. The existence of preferential flow paths were indicated by the presence of soil heterogeneities and water repellent layers throughout the profile. Preferential flow was also detected in a field study in the Central Sand Area of Wisconsin (Kung, 1988). Water was found to be flowing in concentrated flow paths within the root zone at this site. These flow paths occupied only a minor portion of the soil matrix in the vadose zone but accounted for a major portion of the solute transport. Dyes emplaced at this site showed evidence of lateral movement caused by textural discontinuities. The dyes apparently accumulated and moved laterally in an upper fine sand layer before penetrating downward into a coarse sand layer that was located directly below the fine layer. Another field study that examined solute transport variations due to heterogeneities in soil textures was performed by Bresler and

Dagan (1979). The concentration profile in this unsaturated experiment extended to a much larger degree than that predicted by a conventional diffusion-convection equation in a homogeneous fictitious field. It was concluded that because the solute spread due to field heterogeneity was much larger than the spread caused by the pore-scale hydrodynamic dispersion that the latter can be neglected. An unsaturated field study conducted in New Mexico at a stratified heterogeneous site by Flanigan (1989), showed that significant lateral spreading of a nonreactive bromide tracer occurred due to varying hydraulic properties at stratigraphic interfaces.

Many studies (e.g. Biggar and Nielsen, 1976; Van De Pol et al. 1977), have shown that pore water velocities and apparent diffusion coefficients are log normally distributed. From these studies it was determined that if the commonly used estimate of calculating solute mass flux within a soil profile is used (water flux x solute concentration), substantial errors can be made when calculating the amount of solute leaching past a given soil depth due to the log normal distribution of pore water velocity and the apparent diffusion coefficient.

The most recent research into solute transport involves the modelling of water and solute transport in both saturated and unsaturated systems. This field of research involves simulation studies, computer modelling, stochastic analysis, and validation studies.

A comprehensive investigation of the basic processes of water and solute transport in the vadose zone was presented by Nielsen et al. (1986). A review of the various deterministic mathematical models that are being used to describe these processes was also presented. These processes include: temperature fluctuations, salinity effects, hysteresis, retardation, and microbial influences. Several analytical and numerical solutions are referenced throughout this paper.

A review of the recent progress in modelling water flow and solute transport in the vadose zone was completed by van Genuchten and Jury (1987). A variety of deterministic models that are based on the classical Richards equation for unsaturated water flow and the Fickian-based convection-dispersion equation for solute transport were determined to be of questionable use in field studies. The problems with these models arise due to preferential flow through soil macropores and spatial variability in soil hydraulic properties.

Computer simulation studies on the effects of macroscopic dispersion for a uniform heterogeneous porous media under conditions of one-dimensional flow were undertaken by Schwartz (1977). It was found from these simulation studies that the magnitude of the dispersion is proportional to the permeability contrasts within the medium. A study was conducted to simulate the results of a field experiment on pesticide and tracer leaching in both vegetated and non vegetated areas (Hutson et al. 1988). Results from this study indicated that as leaching increased, the agreement between predicted and observed chemical behavior decreased owing to complex flow paths and processes within the field soil. In the field study, a large amount of a bromide tracer that was emplaced on the soil surface was retained in the upper surface soil layer, possibly due to uptake by plants. A simulation was performed to try and support this hypothesis. In the simulation, the bromide was assumed to be adsorbed by plants in the transpiration stream. From this simulation it was shown that about 70% of the bromide applied could be adsorbed by the plants , which possibly explains why so much of the bromide was retained in the surface layers.

A deterministic-stochastic model for field scale solute transport was compared to measured values from two field experiments in a study completed by Jaynes et al. (1988). Model predictions on bromide leaching agreed well with measured data from a leaching study on a sandy loam soil. For the second experiment, the model underestimated the solute spreading, which may have been the result of difficulties in estimating the effect of evaporation on the distribution of effective infiltration. A simplified stochastic model of solute transport in unsaturated heterogeneous fields was developed by Bresler and Dagan (1981). From this work, it was concluded that average concentration profiles in an unsaturated field cannot be modelled as the solution of the convective-diffusion equation with constant coefficients. It was found that the dominant spreading mechanism for the soil used in this study was soil heterogeneity combined with convection. A study conducted by Feddes et al. (1974), compared data obtained from water balance studies on water uptake by the roots of red cabbage with results obtained from a modified numerical model. A simulation study was run for a period of 7 weeks. The results of this study failed to show agreement between the calculated weekly moisture content profiles and the measured weekly moisture content profiles, indicating that modifications within the model were needed to improve the predictive capabilities of the model. A series of model validation studies were conducted by Jury et al. (1988). This paper presents the results of model validation studies from a number of field experiments with mobile anionic tracers and nonionic adsorbing pesticides.

The references listed above are by no means a complete list of the experiments that have been undertaken in solute transport. However, it does indicate that further studies need to be conducted in field settings to predict more accurately the transport of solutes in complex, large scale systems. Recent field studies have investigated increasingly complex solute transport cases. These include study of prefferential flow, plant water uptake, mobile-immobile water phase, lateral flow due to heterogeneities, degredation, sorption, and ion exclusion. The most current field of research in solute transport involves simulation studies, computer modelling, stochastic analysis, and validation studies. This field of research combined with field scale studies will greatly increase our knowledge of the process of solute transport in both saturated and unsaturated conditions.

Only very limited research has been conducted on three-dimensional soil-moisture flow in desert environments. With the increased storage of hazardous wastes in desert environments there is a need for further research into soil-moisture flow in arid environments.

FLUOROBENZOATE TRACERS

The use of fluorobenzoates as soil-water tracers of soil water movement has not been experimented until recently. The three fluorinated benzoic acid derivatives that were used in this study, o-(trifluoromethyl)benzoic acid (o-TFMBA), 2,6-difluorobenzoic acid (2,6-DFBA), and pentafluorobenzoic acid (PFBA), have shown great promise as soil water tracers. These tracers have been shown to be resistent to chemical and microbial degradation in natural environments. The fluorobenzoate tracers are found to be very promising when multiple tracing tests or exotic tracers are needed.

The sorption properties of the three fluorobenzoate tracers were investigated in a study conducted for the Los Alamos National Laboratory (Walter, 1982). Two batch isotherms were conducted with the fluorobenzoates and a tuff material. These results indicated that no adsorption occurred. Laboratory and field experiments using the fluorobenzoates were performed by Bowman (1984b). In this study, the sorption and mobility characteristics of the fluorobenzoates were compared to those of bromide, which served as an index tracer. In the laboratory studies it was shown through the use of batch sorption and column mobility studies that all of the tracers were conservative and were not sorbed. Results from a trickle irrigation field experiment also indicated that the fluorobenzoate tracers behaved very similar to bromide. Another advantage of the use of the fluorobenzoate tracers is that they can be analyzed quickly and simultaneously with other anionic species via a high performance liquid chromatographer. The high performance liquid chromatographic technique is described by Bowman (1984a). The analytical procedure was proven to be a rapid and accurate method of analyzing soil extracts. In a study conducted at New Mexico Tech (Gibbens, 1988), the mobility and degradation characteristics of a group of fluorinated benzoic acid derivatives were examined. Batch and column studies from this experiment indicated that the fluorobenzoic tracers had similar mobility and stability characteristics with those of bromide. A field aquifer test from this study displayed no loss of mass of any of the fluorobenzoates, the results also indicated that the fluorobenzoates had similar mobility characteristics with that of bromide.

A field column study at New Mexico Tech was undertaken to determine the effectiveness of different cover materials in reducing infiltration into mill tailings (Williamson, 1988). In this study, four field columns were packed with copper mill tailings and capped with four different cover materials. These included a 50-50 mixture of tailings and bentonite clay, a 95-5 mixture of tailings and bentonite, a fine-textured soil underlain by gravel, and 100% tailings. Bromide and four fluorinated organic tracers were added to the base of the cap material. Results from this study indicated that the 5% bentonite cap material was nearly as effective in reducing infiltration as the 50% bentonite cap material. The bromide was found to be a good tracer, whereas the fluorinated organics behaved poorly possibly due to the low pH of the copper mill tailings medium. In a current project being conducted at New Mexico Tech (Grabka et al. 1988), a group of fluorobenzoate tracers are being used in an unsaturated trickle irrigation study designed to simulate seepage from a lined surface impoundment. The field site consists of heterogeneous silty sand and sand strata. Through the use of the fluorobenzoate tracers, the degree of lateral spreading due to varying hydraulic properties at stratigraphic interfaces will be examined. Also, if mixing between various tracers occurs, this can be detected from the use of a high performance liquid chromatographic technique.

PREVIOUS STUDIES AT THE SEVILLETA

Numerous hydrologic studies have been conducted in recent years within Sevilleta National Wildlife Refuge (Figure 5). These include field and laboratory research under both saturated and unsaturated conditions. These studies have greatly enhanced our knowledge of the hydrologic processes that are occurring within semi-arid areas.

The spatial variability of the hydrologic parameters of soils at the Sevilleta was examined by Leavitt (1986). In this study the spatial variability of hydraulic conductivity, d_{10}, d_{50}, uniformity coefficient, and coefficient of curvature were analyzed from 280 samples taken from 12 transects within fluvial and dune sand facies in part of the Sevilleta. Variogram analysis, kriging methods, and multiple regression techniques were used to characterize the variability in soil parameters. Results from this study indicated that each unit predominately consists of uniform fine to medium grained sands. Because of the geologic and hydrologic uniformity of the soils within and between units, variogram and kriging analyses failed to predict characteristic soil parameters at unsampled locations.

A statistical and stochastic analysis of hydraulic conductivity and particle size in a fluvial sand at the Sevilleta was performed by Byers and Stephens (1983). A correlation was found between the log of the hydraulic conductivity and the ten percent finer particle size. Results

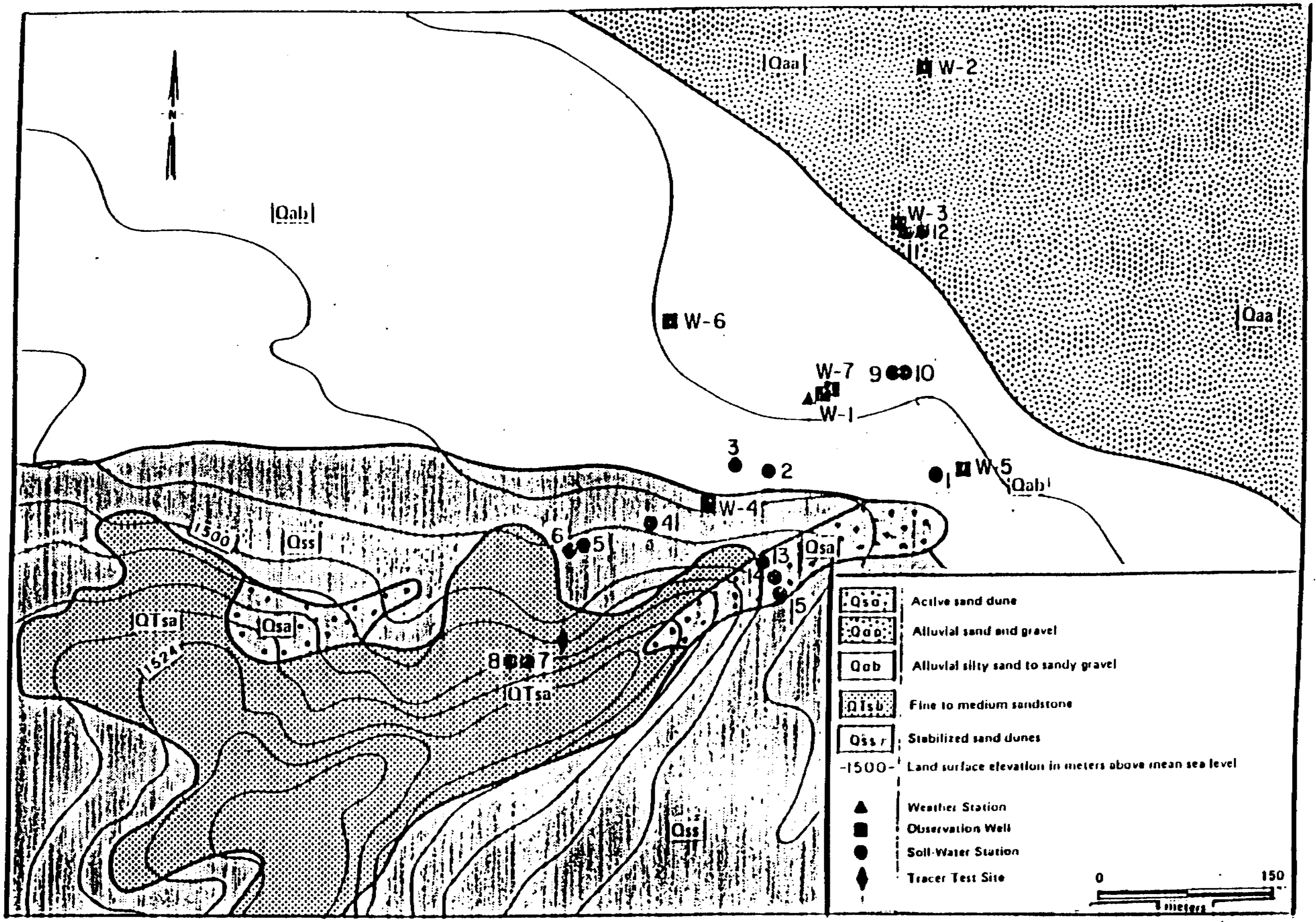


Figure 5. Surficial geology and instrumentation network at Sevilleta National Wildlife Refuge (Machette, 1978).

from stochastic analysis using the autocorrelation function and spectral analysis indicated that the log of hydraulic conductivity and particle size are characterized by dissimilar spatial correlation structures in the vertical direction. Variogram analysis indicated that the log of hydraulic conductivity and the 10% finer particle size were relatively isotropic in the horizontal plane, but were markedly anisotropic in the vertical plane. This is a result of horizontal thin-layered beds that are present within the fluvial sand.

A field study was conducted at the Sevilleta to study ephemeral stream infiltration and recharge (Cox, 1988). The processes of infiltration and groundwater recharge were examined at two ephemeral streams in New Mexico. It was found that full hydraulic connection to the underlying aquifer is dependent on the type of sediment lining the channel, duration of flow and height of stage, local channel characteristics, and depth to groundwater. Results indicated that the ephemeral stream within the Sevilleta (Rio Salado) was much more effective in recharging the underlying aquifer than an ephemeral stream that was located to the north of the Sevilleta (Rio Puerco). This was primarily due to the Rio Salado's wide braided nature and coarse channel.

The influence of entrapped air on field determinations of hydraulic conductivity in the vadose zone was examined in an experiment conducted by Stephens et al. (1983). Field estimations of saturated hydraulic conductivity, K_s, were determined by instantaneous profile tests, air-entry permeameter tests, and borehole infiltration tests. Carbon dioxide was injected into the soil prior to infiltration to eliminate entrapped air within the profile. It was found that the carbon dioxide treatment in the air-permeameter caused the calculated K_s to approximately double. From these results it was concluded that entrapped air has a significant influence on infiltration rate, K_s, hydraulic gradients, and unsaturated soil characteristics.

An evaluation of closed-form analytical models to calculate the conductivity of an undisturbed core of fine sand from the Sevilleta was completed by Stephens and Rehfeldt (1985). Data from a calculated soil-water characteristic curve was used to predict relative hydraulic conductivity in a computer code of closed-form analytical solutions developed by van Genuchten for the theoretical models of Burdine and Mualem. From a sensitivity analysis it was shown that the calculated conductivities appeared to be sensitive to the value of residual moisture content that is chosen. Results of the study indicated that predicted conductivities may differ by more than an order of magnitude, depending on the choice of residual moisture content.

An extensive field study of natural ground-water recharge at the Sevilleta was conducted by Knowlton (1984). Methods of estimating groundwater recharge included a pressure head based

Darcian approach, a water content based Darcian approach, and a temperature gradient method. Averaging the recharge rates yielded a value of 2.30 cm/yr. Evapotranspiration rates were estimated by a water balance method and a micro-lysimeter experiment. The micro-lysimeter technique appeared to over-estimate evaporation rates. Soil bromide tracer experiments were performed in the field with the intent of mapping out wetting front advances after precipitation events; but, due to dispersion and redistribution of the bromide tracer evaluations proved to be very difficult.

Topographic controls on ground-water recharge at the Sevilleta were examined in a project conducted by McCord (1986). From the results of a bromide tracer test that was conducted in an eolian deposit, it was shown that strong lateral components of unsaturated water flow exist on sandy hillslopes. This lateral flow was found to enhance recharge beneath topographically concave locations. Recharge was calculated by two different methods: neutron logging and the Darcian approach. Recharge calculated at topographically concave locations was found to be several orders of magnitude greater than sloping or hilltop locations with similar lithology and vegetation.

The process of water uptake by desert plants was examined at the Sevilleta by Kickham (1987). It was observed that topographic, meteorological, and seasonal changes had notable effects on the hydraulic head gradient and soil-water content around plants. During the plants dormant season the soil-water moved primarily vertically downward, but during certain periods of the plants active growing season, strong lateral flow components existed. Due to the variability in soil moisture movement around the plants, infiltration rates were observed to vary significantly immediately around the plant indicating that one-dimensional, vertical flow assumptions may be invalid during certain times of the year.

The studies that have been conducted at the Sevilleta will provide a great deal of hydrogeologic information that will be used in the current study to help us better understand the hydrologic processes that take place throughout the duration of the project.

SITE DESCRIPTION

The research site chosen is located approximately 24 kilometers north of Socorro, New Mexico, within the Sevilleta National Wildlife Refuge. The site is approximately 4.8 kilometers west of Interstate 25 along the south side of the Rio Salado, an ephemeral stream with a wide, shallow channel. This portion of the refuge occupies a small area of only 1.3 square kilometers (Figure 1).

Reasons for selecting this area to conduct our research include the following:

1. The topographic surface gradient is relatively small, ranging from two feet per one hundred feet, to an approximately level surface. Lateral flow due to surface topographic gradients can thus be neglected.

2. The soil within the research site is uniform and quite permeable which brings about rapid infiltration of precipitation.

3. Both of the above characteristics lead to negligible surface runoff.

4. The vegetation types have been identified by Ted Stans, the Sevilleta National Wildlife Refuge manager. These include the following shrubs: four-wing saltbush, indigo bush, creosote bush, mesquite, snakeweed, sacatone, and annual mustard. Other plant and cacti species include: salt ceder,

juniper, yucca, gramma grass, spectacle pod, desert willow, primrose, night shade, sand sage, bind weed, scorpion plant, globe willow, indian rice grass, and prickly pear. Figure 6 shows the vegetation present at the site. The vegetation at the site consists predominately of four wing-saltbush (Atriplex canescens) and a small amount of indigo bush (Dalea scoparia).

5. Both vegetated and unvegetated areas are located within the site. Thus, seasonal and spatial variations in soil moisture flow can be compared at both areas to determine if sparse desert vegetation has an effect on unsaturated moisture flow.

6. The water table is located at a significant depth below land surface. The effects of seasonal fluctuations in the water table will not affect measurements of matric potential within the site.

7. Detailed meteorological data has been collected from both automated, and manual weather stations at the Sevilleta since before 1984.

8. The area within the Sevilleta National Wildlife Refuge is fully fenced and locked at all times. The area is also routinely monitored by refuge employees. These measures provide a means of protecting the scientific equipment at the site.

9. The area has been thoroughly mapped by Machette (1978). In his map (Figure 7), Machette has defined four separate soil

Figure 6. Vegetation present at field site

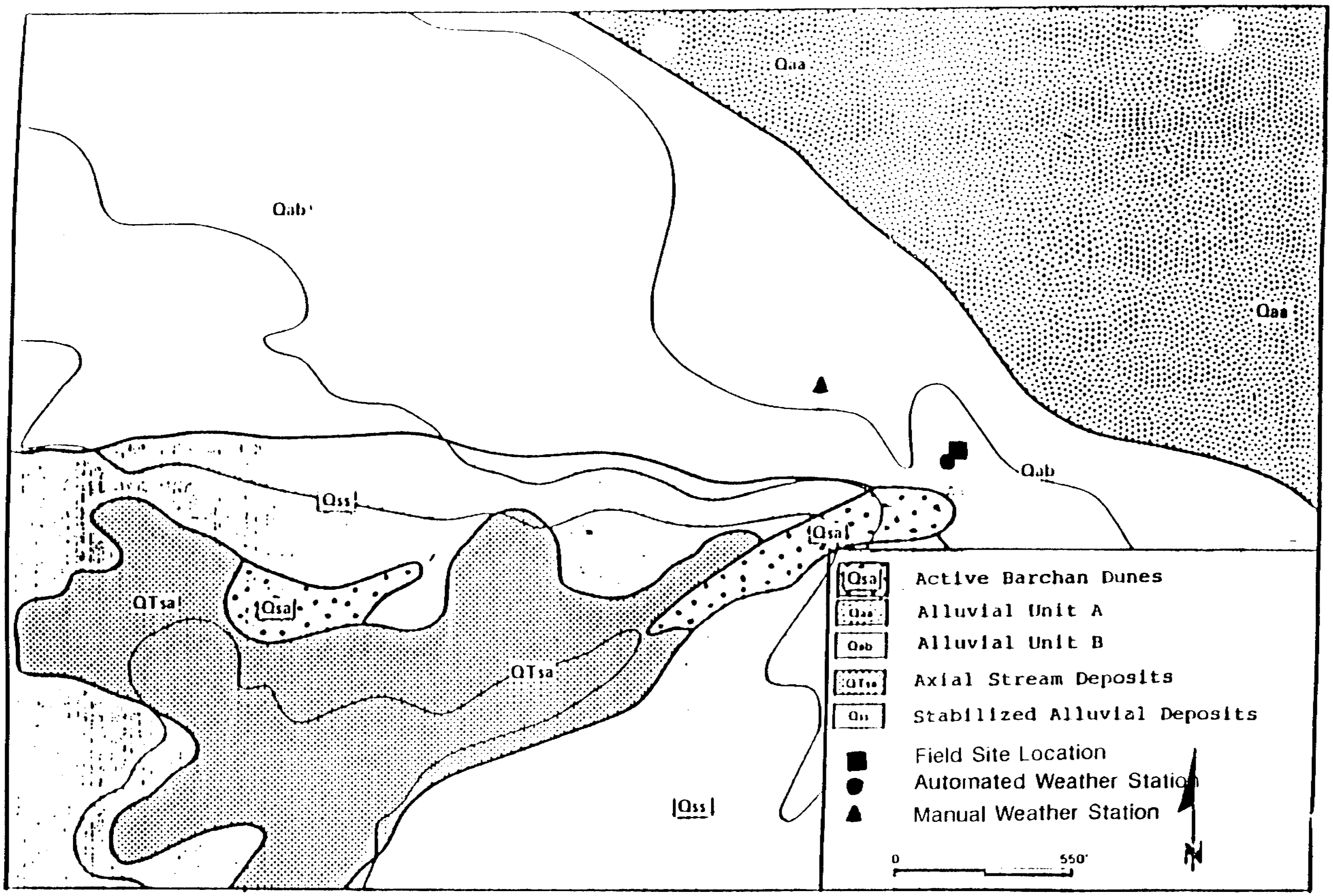


Figure 7. Surficial geology, site location, and weather station locations

types within the Sevilleta. The field site location is also shown on this map. Also, during the initial site selection, 5 cm diameter holes were hand augered to a depth of approximately 450 cm at each side of the field site . From this, information on the subsurface geology at the site was obtained (Figures 8, 9, 10, and 11).

10. Portions of the area around the site have been used for some previous research. Tracer tests were conducted by (McCord, 1986; Knowlton, 1984). Borehole infiltration tests were performed by (Stephens et al. 1983). Numerous field and laboratory studies on soil characterization have also been conducted. These studies have greatly enhanced our knowledge of the hydrologic processes that are occurring within the Refuge.

11. The geology, vegetation, meteorolgy, and hydrologic characteristics of the site are similar to a large portion of the south, south-central Rio Grande valley. Thus, the results of this study may be representative of a large area of southern New Mexico.

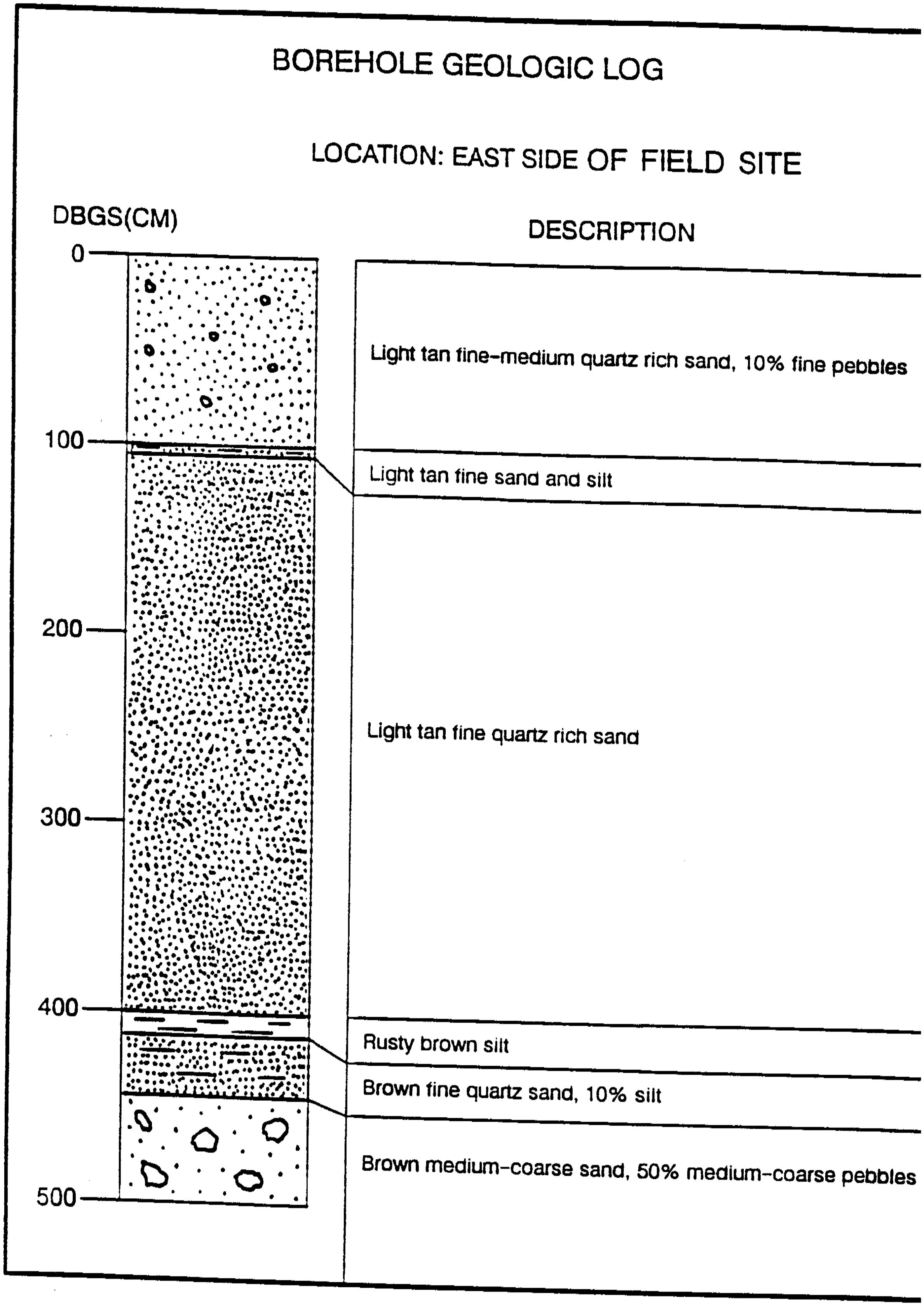


Figure 8. Subsurface geology of the east side of field plot.

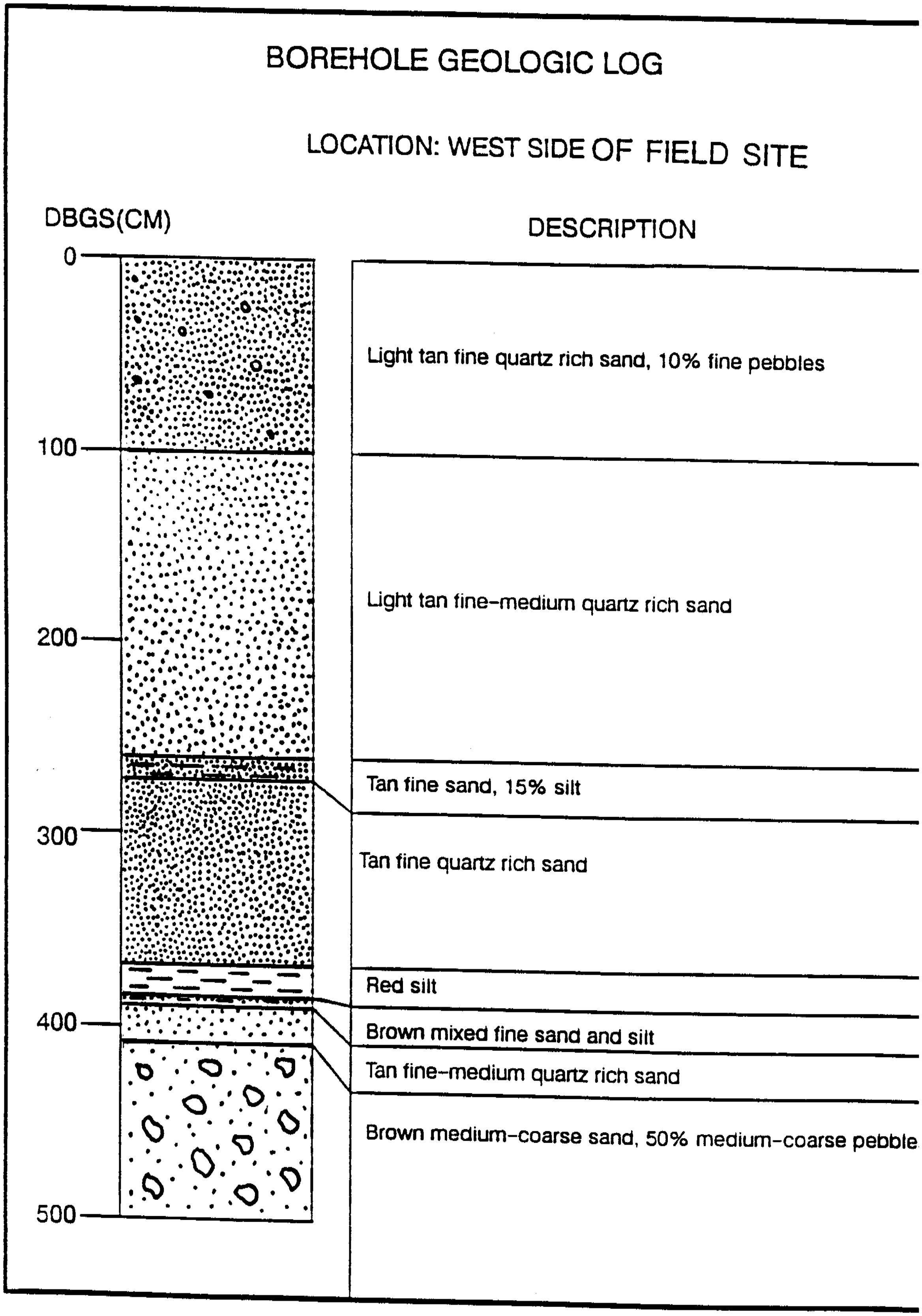


Figure 9. Subsurface geology of the west side of field plot.

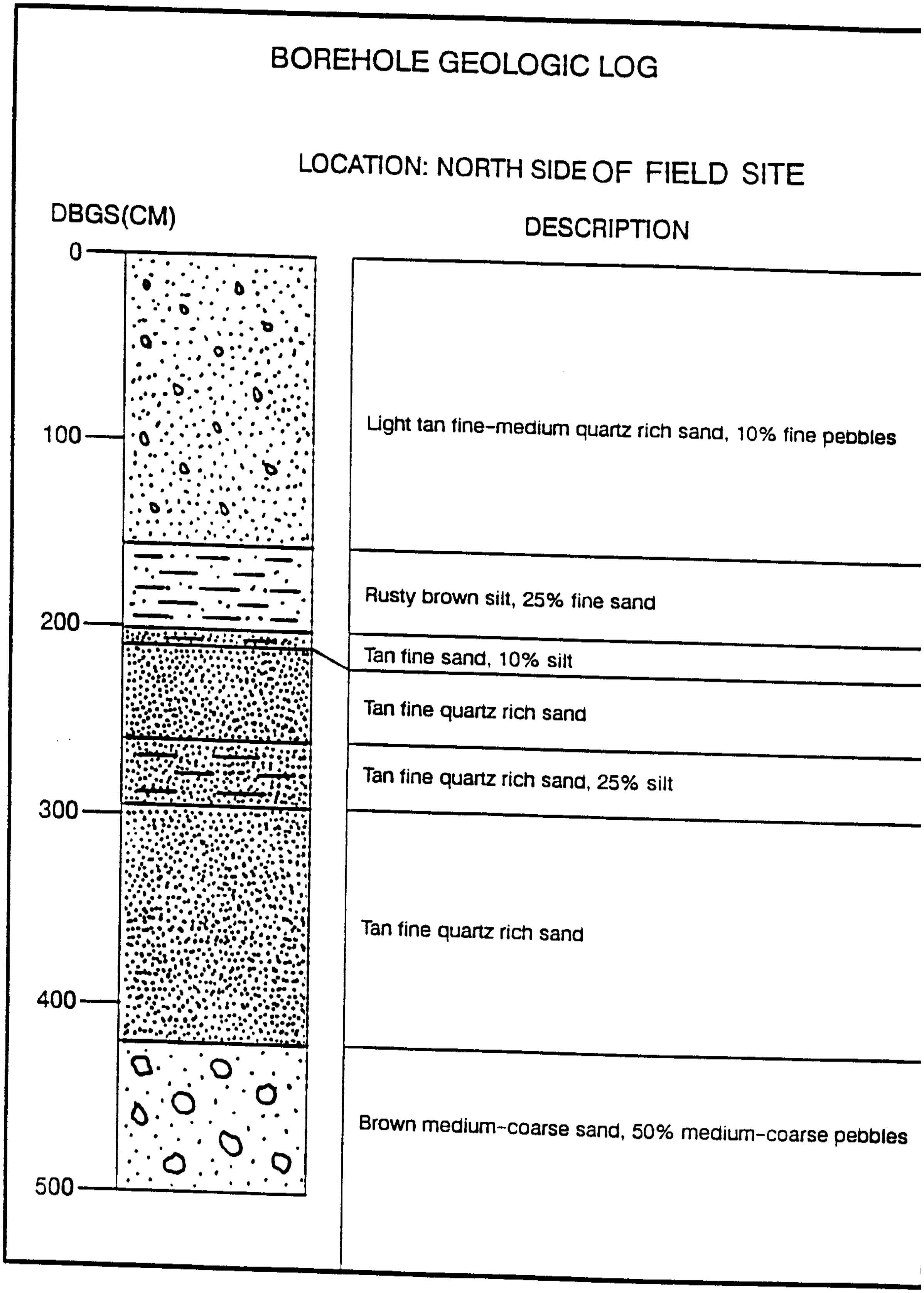


Figure 10. Subsurface geology of the north side of field plot.

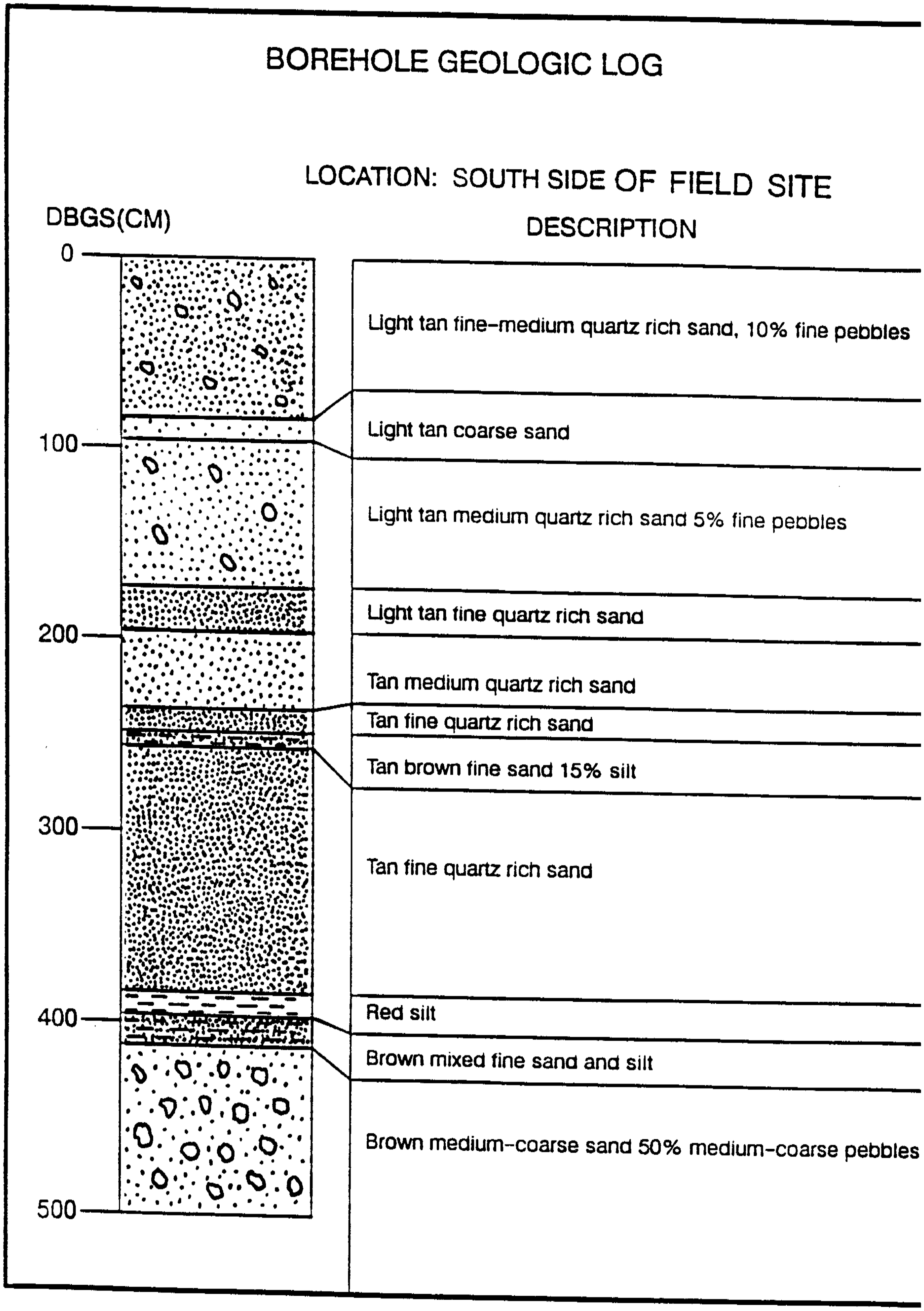


Figure 11. Subsurface geology of the south side of field plot.

THEORY

A variety of methods can be used to determine the extent of seasonal and spatial variabilities of soil-moisture flow within a given soil profile. One method that was used in this study to determine the seasonal and spatial variabilty in soil-moisture flow was through a water balance estimation. Spatial variability in soil-moisture movement was also estimated through the use of chemical tracers.

Water Balance

Water balance is a summation of the transient states of inflows, outflows, and storage changes of water within a given volume of soil. The equation for water balance is stated as:

$$(P - ET - R - I - RU)dxdy = \int_0^x \int_0^y \int_0^z \frac{d\theta}{dt} dxdydz \qquad (1)$$

where,

P = precipitation rate (L^3/L^2T)
ET = evapotranspiration rate (L^3/L^2T)
R = recharge rate (L^3/L^2T)
I = interflow rate (L^3/L^2T)
RU = surface water runoff rate (L^3/L^2T)
$\int_0^x \int_0^y \int_0^z \frac{d\theta}{dt} dxdydz$ = cummulative changes in storage (L^3/T)

The individual components which make up the cummulative changes in storage are shown in a unit cell of soil in Figure 12. Precipitation enters the soil profile in

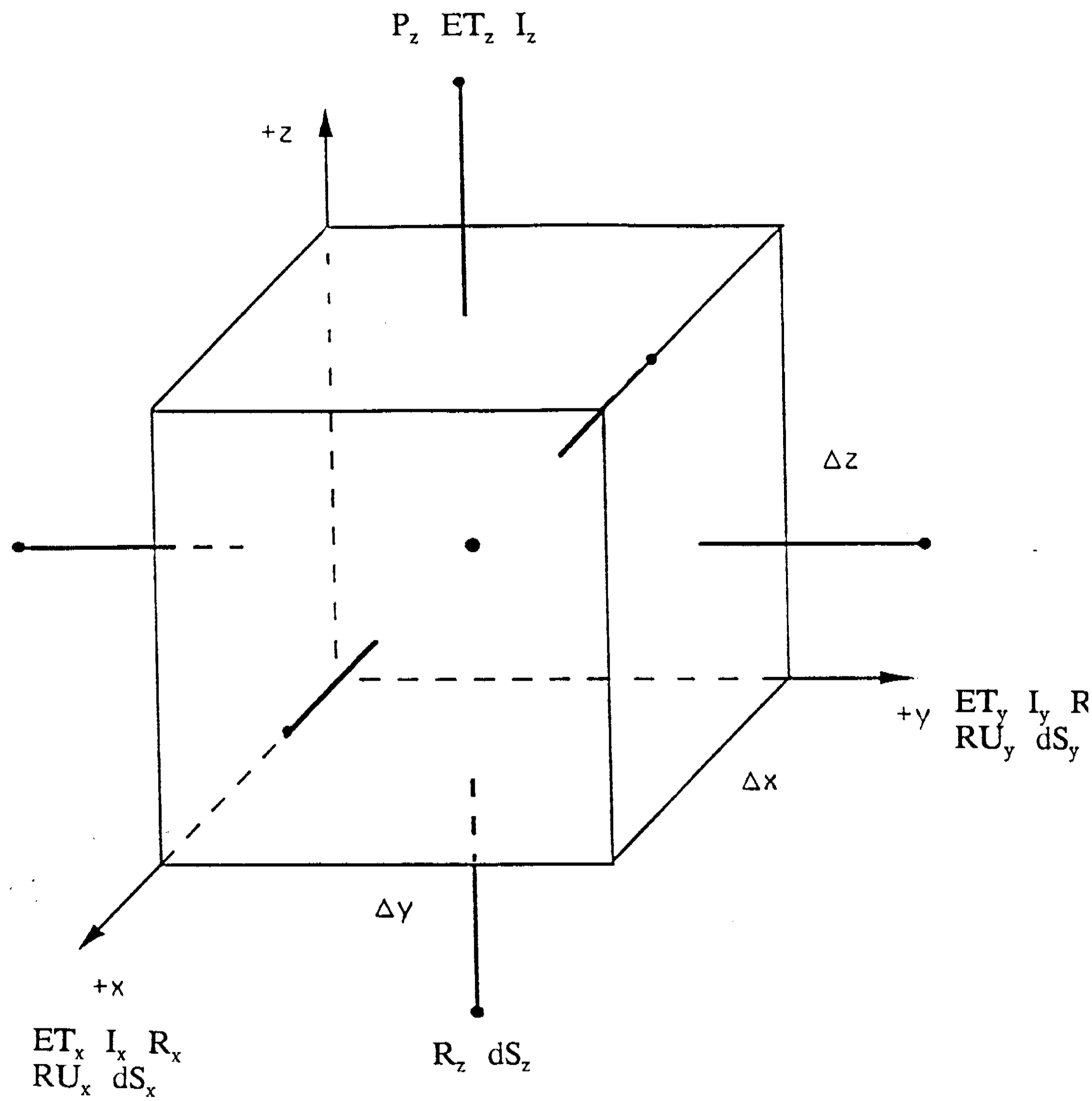


Figure 12. Unit cell with components that make up cummulative changes in storage.

the z direction. Evapotranspiration can occur in three dimensions, through both transpiration from vegetation and evaporation from within the soil profile. Recharge can also occur in three dimensions due to lateral flows of soil moisture. Interflow consists of both saturated and unsaturated flow and is commonly thought of as occurring in the horizontal plane, but small vertical componants are also commonly present. Surface water runoff is restricted to the horizontal plane.

In general it is often assumed that soil-moisture flows one-dimensionally downward. This assumption may be invalid for many cases were textural heterogeneities or preferrential flow paths are present within a soil profile. Soil-moisture up-take by vegetation may also invalidate the one-dimensional soil-moisture flow assumption. The directionality of soil-moisture flow can be determined by estimating the cummulative changes in storage in three-dimensions (Figure 13). By calculating a water balance through time, an estimation of seasonal and spatial variability in soil-moisture flow can be accomplished.

If the assumption of one-dimensional soil-moisture flow is determined to be valid, the process of estimating a water balance is greatly reduced. This can be seen in Equation 2 where now the estimation of cummulative changes in storage is reduced to a one-dimensional analysis.

$$P - ET - R - I - RU = \int_0^z \frac{d\theta}{dt} dz \qquad (2)$$

where,

P= precipitation rate (L^3/L^2T)
ET= evavotranspiration rate (L^3/L^2T)
R= recharge rate (L^3/L^2T)
I= interflow rate (L^3/L^2T)

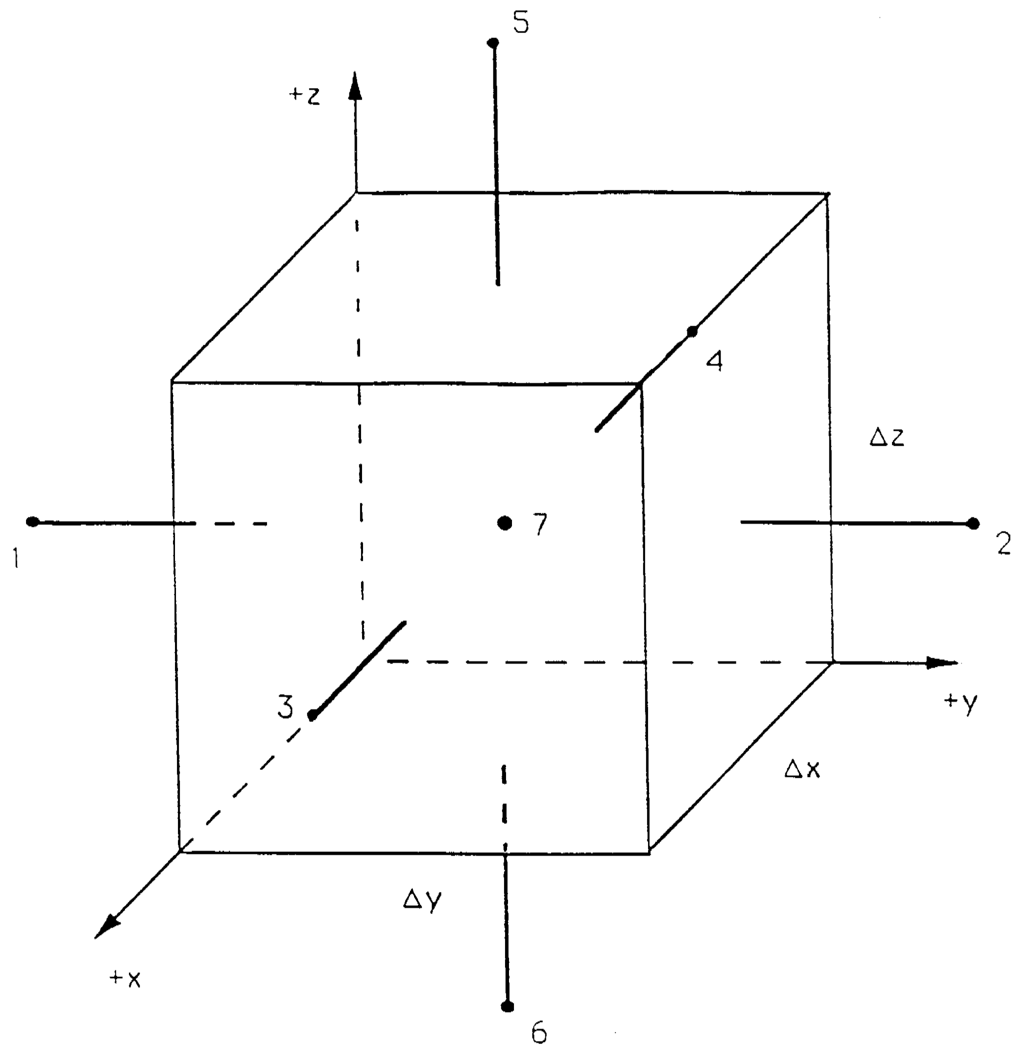


Figure 13. Hypothetical cube of soil used to estimate directionality of soil-moisture flow.

RU = surface water runoff rate (L^3/L^2T)

$\int_o^z \frac{d\theta}{dt} dz$ = cummulative changes in storage (L^3/L^2T)

Solute Transport

One method commonly used to estimate the magnitude and direction of soil-moisture flow is through the use of chemical tracers. The method involves the application of a known quantity of chemical tracer within the soil profile and then with time, measure the depth distribution of the tracer concentration. The magnitude and direction of tracer displacement can then be used to estimate the extent of spatial variability in soil-moisture movement.

When a pulse of non-reactive tracer is applied to a homogeneous soil profile exhibiting steady, unsaturated flow in the z direction, the vertical distribution of the tracer in the profile can be described by the dispersion equation.

$$\frac{dC(z,t)}{dt} = D_L \frac{d^2C}{dz^2} - v\frac{dC}{dz} + D_T\left[\frac{d^2C}{dx^2} + \frac{d^2C}{dy^2}\right] \qquad (3)$$

where,

$C(z,t)$ = average tracer concentration at depth z and time t (M/L^3)

D_L = longitudinal hydrodynamic dispersion coefficient (L^2/T)

D_T = transverse hydrodynamic dispersion coefficient

v = average pore water velocity (L/T)

v = q/θ where q is the flux per unit area of porous medium and θ is the volumetric moisture content

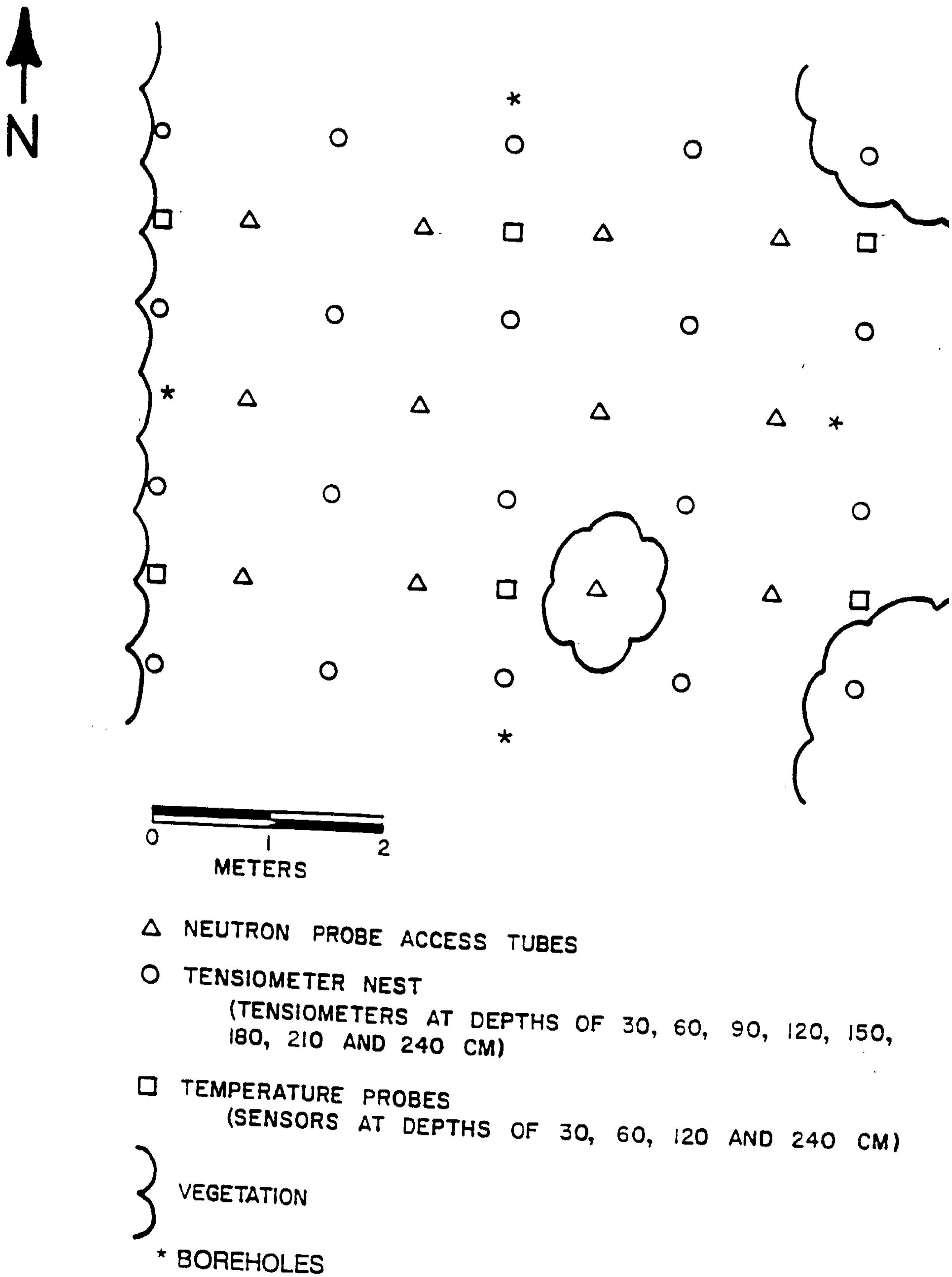
This equation assumes that soil-moisture flow and moisture contents are constant in time and space, and that the tracer is non-reactive within the soil profile. In solute transport studies, the later portion of the equation involving the transverse dispersion coefficient is commonly neglected. In these cases it is assumed that longitudinal dispersion is much greater than transverse dispersion. This may not be the case if spatial variabilities in soil texture, or spatial variabilities in plant water uptake are present within a soil profile.

SITE INSTRUMENTATION:

The field site was instrumented with various equipment designed to measure numerous hydrological parameters. Weather data was collected from both an automated and a manual weather station. Soil temperature was recorded by temperature thermistors, placed at various depths within the soil profile. Matric suction was measured by tensiometers that were installed at various depths within the field site profile. From these measurements, hydraulic head and hydraulic gradients were calculated. Soil moisture content was measured by a neutron probe. A planar map of temperature probe, tensiometer, and neutron access tube locations is presented in Figure 14. The initial exploratory borehole locations (Figures 8-11) are also shown on this figure.

Weather Stations

An automated weather station was located on the south edge of the field site. This station contained a 21X micrologger used in the recording and storage of weather data (Campbell Scientific, Logan, Utah). A multiplexer (Campbell Scientific) was also connected to the 21X micrologger. The multiplexer allowed up to 32 readings to be recorded from one channel of the 21X micrologger. Readings recorded by the data logger included: precipitation, air temperature, soil



FIELD SITE LAYOUT

Figure 14 Field site instrumentation and borehole locations.

temperature, wind speed, wind direction, relative humidity, and solar radiation. For a more in-depth discussion on the automated weather station, see (Hicks, 1989).

The manual weather station was located near the center of the basin, approximately 25 meters to the west of the study site. The meteorological equipment at this site included: a tipping bucket rain gauge accurate to 0.02 cm, a maximum minimum thermometer accurate to 0.5 degrees celsius, a standard class A evaporation pan equipped with a hook gauge accurate to 0.001 cm, and a totalizing anemometer for reading cumulative wind velocities.

Moisture Content

At the research site, the neutron scattering technique was employed to indirectly measure soil water content. This technique is rapid and non-destructive, which allows for repeated measurements of the gravimetric, or volumetric, moisture content of the soil.

The neutron probe used at the site was (model 503-DR, Campbell Pacific Nuclear, West Pacheco, CA). The radiation source consists of a 50 millicurie americium-241/beryllium source. Numerous calibrations of the neutron probe have been calculated for the Sevilleta National Wildlife Refuge. Of these, the calibration by McCord, (1986) was determined to be the most adequate for our site, and this calibration was used throughout the duration of the study. The calculated calibration curve is presented in Figure 15. From the calibration, a functional relationship between probe reading and actual moisture content is obtained. The neutron probe measures the water content of the soil in a sphere with a radius of about 15 cm around the americium/beryllium source. The size of the sphere varies with the soils moisture content. Under dry soil conditions, the sphere of influence is larger than what would be found under moist soil conditions.

To facilitate the use of the neutron scattering technique, thin-walled aluminum access tubes (5 cm in diameter) were installed within the research site (Figure 16). The tubes were installed 150 cm apart in a square grid network. Tube layout was designed to minimize the difficulty of calculations involving moisture content data. The neutron access tubes were installed by hand augering holes with a 6 cm auger bit. The bottom of the access tubes were capped with rubber stoppers and sealed with silicone adhesive to prevent moisture from seeping into the tubes and possibly altering the water content readings. After inserting the access tube, the annular space was carefully backfilled with native material to ensure proper contact between the soil and access tubing. The neutron access tubes were installed to a maximum depth of 480 cm. Exceptions occurred whenever hand augering proved incapable of breaking through a gravel zone that was present at the base of the field plot.

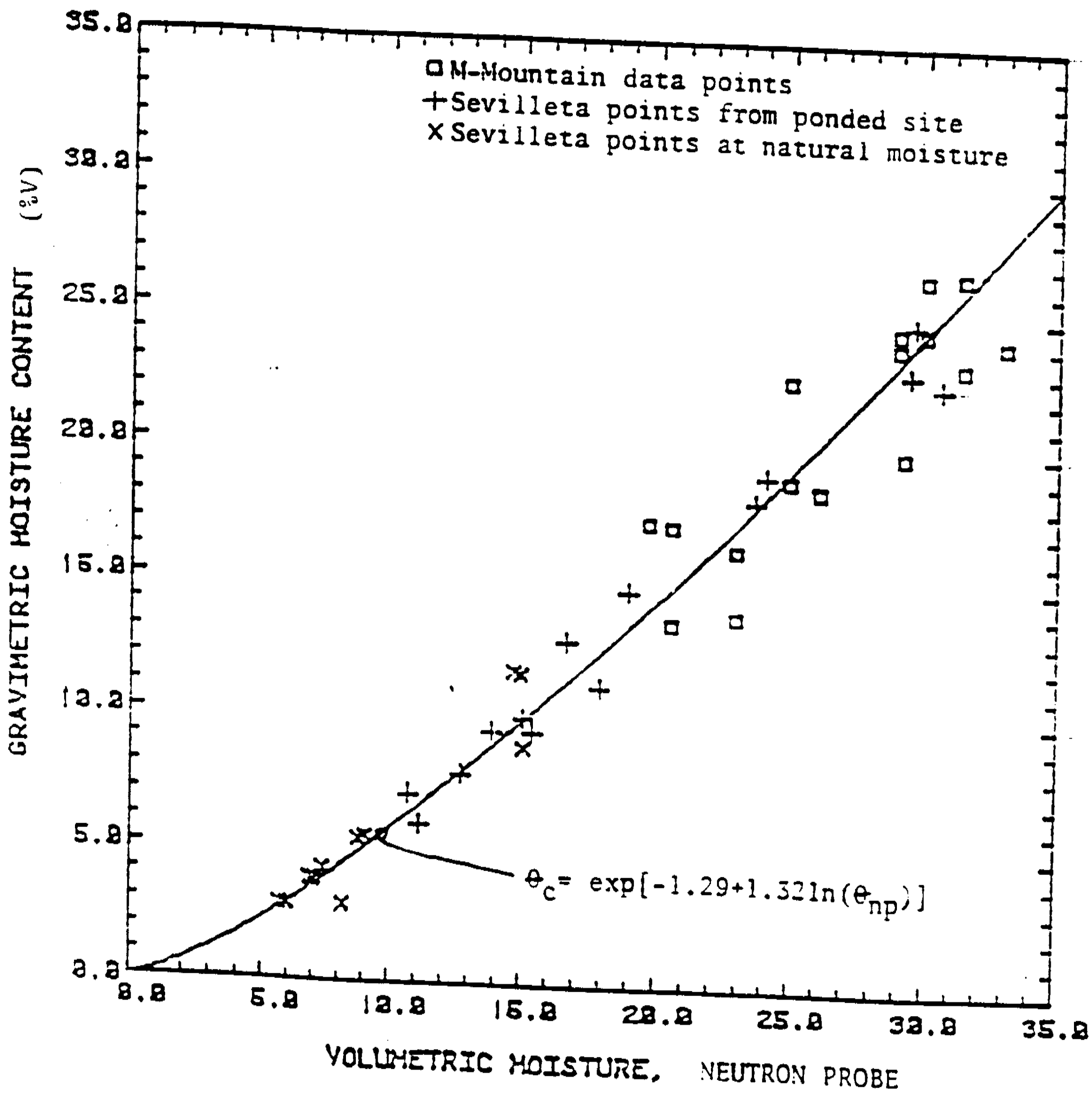
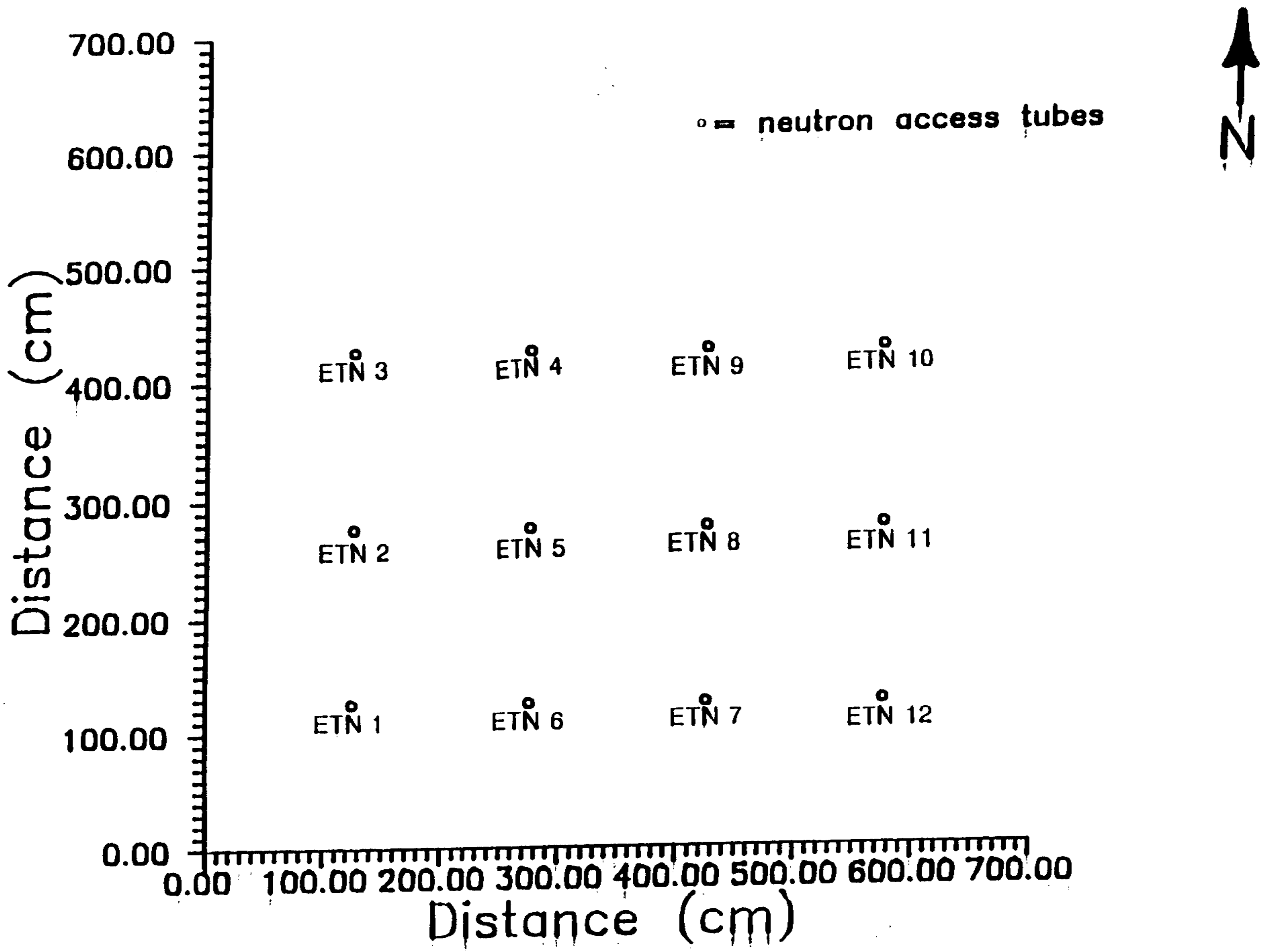


Figure 15 Neutron probe calibration curve (McCord, 1986).



700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Distance (cm)
0.00 100.00 200.00 300.00 400.00 500.00 600.00 700.00
Distance (cm)
∘ = neutron access tubes
N
ETN 1
ETN 2
ETN 3
ETN 4
ETN 5
ETN 6
ETN 7
ETN 8
ETN 9
ETN 10
ETN 11
ETN 12

Pressure Head

Tensiometry was used to determine the soil-moisture potentials at the research site. All of the tensiometers used on this project were constructed and tested in the laboratory. The tensiometers were comprised of a 1.27 cm diameter , 1 bar ceramic porous cup, 1.27 cm diameter schedule 80 PVC pipe, 1.27 cm diameter PVC coupling, 1.27 cm diameter clear acrylic tubing, 1.27 cm diameter PVC threaded endcap, and a number 30 septum rubber stopper. The design of the tensiometer is shown in Figure 17.

The tensiometers were filled with ethylene glycol (Peak antifreeze) and placed within the soil profile. An antifreeze solution was used in this study to prevent the tensiometers from freezing and cracking during the harsh winter months. It was determined in a laboratory experiment by Knowlton (1986), that antifreeze filled tensiometers behaved very similar to water filled tensiometers. When the antifreeze filled porous cup comes into hydraulic contact with the soil water, the two fluids will equilibrate through the pores of the ceramic cup. Initially, the antifreeze in the tensiometer is at atmospheric pressure, but when the tensiometer is placed into unsaturated soil at subatmospheric pressures, a suction is created which draws fluid out of the tensiometer. The loss of fluid from the porous cup decreases the pressure within the tensiometer. This pressure was measured in the small air gap above the tensiometer fluid by a portable electric pressure transducer

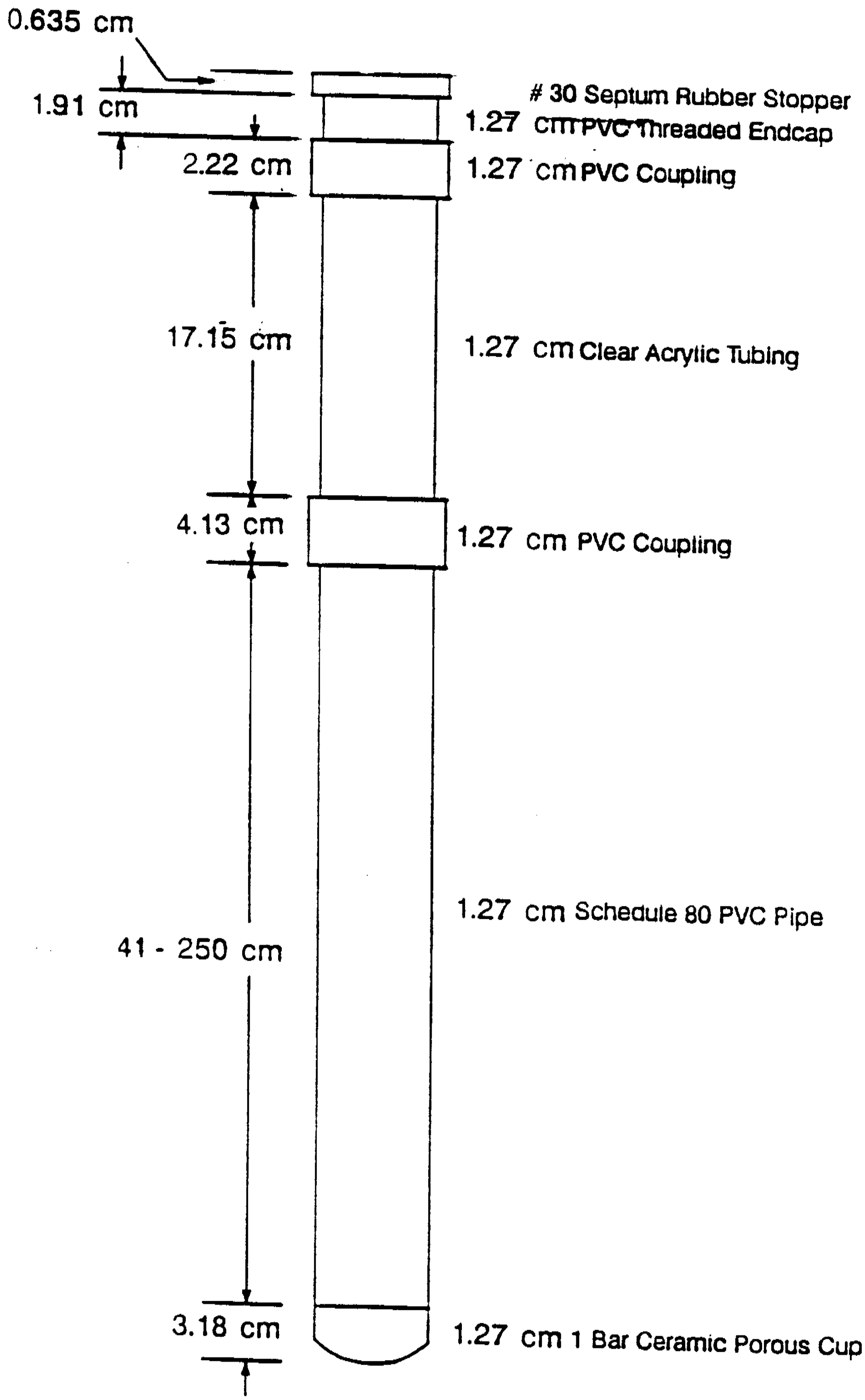


Figure 17 Tensiometer design.

(Tensimeter, Soil Moisture Measurement Systems, Tucson, Arizona). Through the measurement of pressures within the tensiometers, matric suction, hydraulic head, and hydraulic gradients could be determined. A more detailed explanation of tensiometry is presented by (Cassell and Klute, 1986).

The research site was instrumented with twenty nests of tensiometers, with each nest containing eight tensiometers (Figure 18). In each nest, the tensiometers ranged in depth from 30 cm to 240 cm below datum, with a vertical spacing of 30 cm. The tensiometers were inserted with the aid of a 1.90 cm diameter tensiometer insertion tool. Native material was carefully backfilled into the annular space to ensure good contact between the ceramic cup and the surrounding porous media. The tensiometer nests were spaced 150 cm apart in a square grid pattern. This pattern minimized the difficulty of calculations involving pressure head. Also, the nest layout was designed to detect any effects of soil water uptake by desert plants at the site. A more detailed description of the tensiometer layout at the site, and investigations conducted on the tensiometers is presented by (Hicks, 1989).

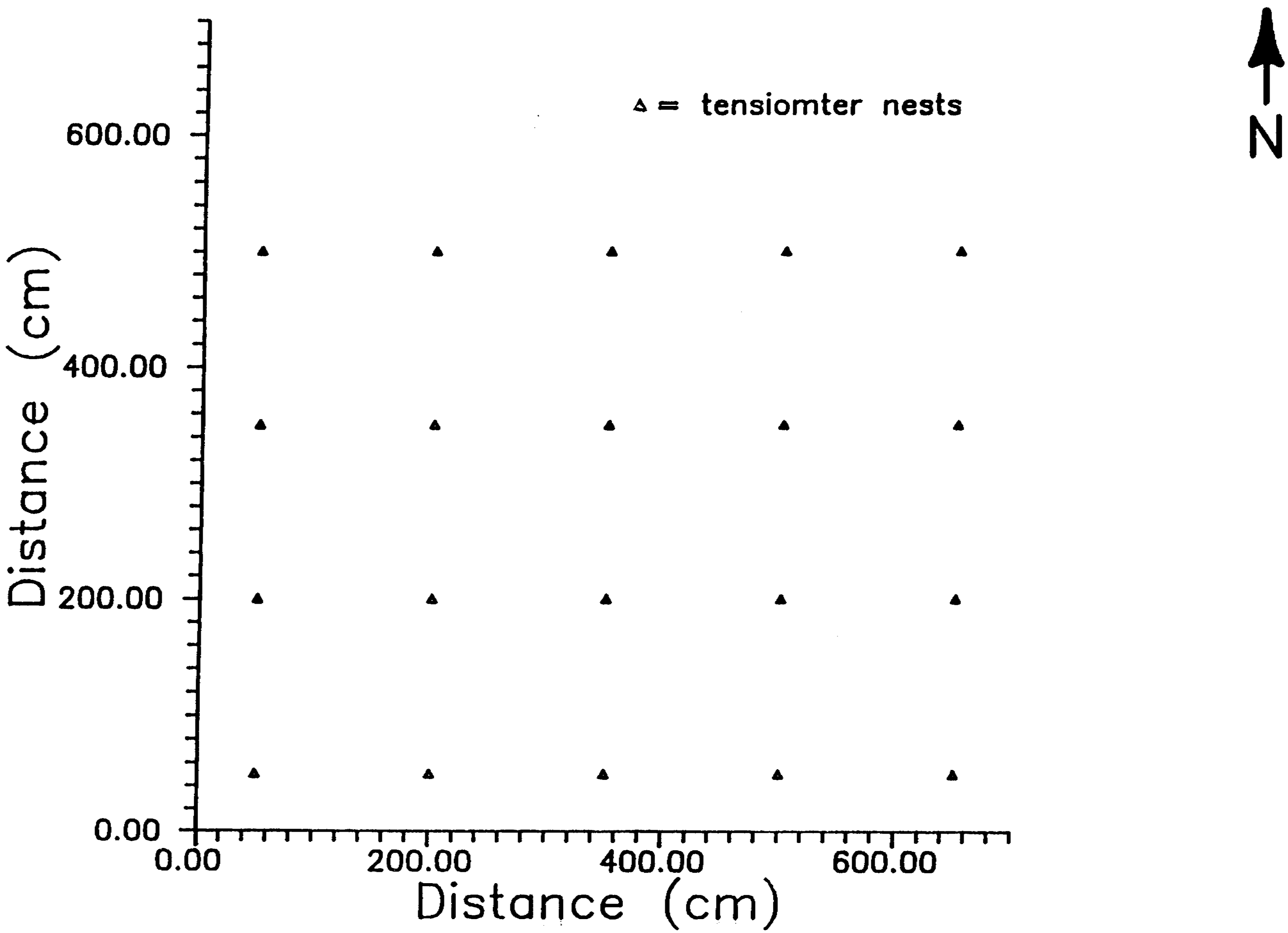


Figure 18. Tensiometer nest locations

FIELD MONITORING

The instrumentation at the study site was monitored at various time increments throughout the study period. Continuous measurements were made with the use of recording charts and a 21X micrologger. Manual observations were taken on weekly, bi-weekly, and monthly increments.

Recordings at the manual weather station began in December of 1987 and continued until July of 1989. During this time, the instrumentation within the station was monitored continuously on a regular basis. The tipping bucket rain gauge had a seven day recording chart and was changed once a week. The anemometer, max-min thermometer, and evaporation pan were also recorded once a week. A leak occurred in the evaporation pan in early May of 1989. During this time (5/9/89 to 6/5/89) no recordings of potential evaporation were made.

The automated weather station recorded continuous one hour measurements of air temperature, soil temperature, wind speed, wind direction, solar radiation, relative humidity, and precipitation. These recordings were stored in a 21X micrologger for periods of up to one month. The automated station was installed in October of 1987 and the following month measurements began. There were periods in the winters of this investigation when power failure caused complete loss of data storage. The power source to the 21X was six D-cell batteries, and under the extreme cold periods the output from the batteries was insufficient to maintain data storage within the micrologger. Recordings from the automated weather station continued until July of 1989.

Measurement of the tensiometers began in March of 1988. The tensiometers were measured bi-weekly for the majority of the projects duration. During the latter portion of the project, measurements were conducted on a monthly basis. It was believed that monthly measurements were sufficient during this portion of the study, due to the large data base that had already been assembled. The tensiometers were filled with a 50-50 solution of water and ethylene glycol to prevent the tensiometers from cracking during the winter freezes. This solution was used throughout the duration of the project to prevent any inconsistencies that may have arisen from using a water solution in the summer and a 50-50 mixture of ethylene glycol mixture in the winter. The tensiometers were serviced on a regular basis and kept filled with the 50-50 mixture. During the latter portion of the experiment, an increase in tensiometer failure began to occur. It was believed that the adhesive holding the individual parts of the tensiometer was beginning to deteriorate. This caused some of the tensiometers to loose their suction and drain their contents. Measurements of the tensiometers continued until July of 1989.

Measurement of the water content profiles began in

February of 1988. At this time only a small portion of the measurements were being made because the access tubes used in the measurement of water content were still being installed. It was not until August of 1988 that a complete moisture content profile could be measured. Each access tube contained a small pouch filled with a desiccant ($CaCl_2$) to prevent the condensation of moisture within the tube. Measurements of soil moisture content were made on a bi-weekly basis for the majority of the study. As with the tensiometer measurements, during the latter portion of the project the measurement of moisture content profiles was conducted on a monthly basis. Measurement of the moisture content profiles continued until July of 1989.

METHODS OF ANALYSIS

To determine if seasonal and/or spatial variabilities in unsaturated soil-moisture flow were occurring at the field site, a series of field and laboratory investigations were conducted. Through the laboratory investigations, spatial variabilities in hydrologic and geologic properties of the field site were determined. The field investigations provided a means of estimating possible seasonal and spatial variations in soil-moisture flow within the soil profile. The field investigations involved a tracer test to determine if spatial variabilities in soil-moisture flow were occurring within the field site. Different methods were used to estimate seasonal and spatial variabilities in ground-water recharge.

Site Characterization

All of the samples analyzed were obtained from the initial drilling of holes for the placement of aluminum access tubes used in the measurement of field moisture contents. A total of 59 samples were collected at 30 cm intervals starting at 30 cm below ground surface and extending to a maximum depth of 480 cm at locations ETN-1 through ETN-12 (Figure 16). Laboratory tests were conducted to determine field saturated hydraulic conductivity, particle size distribution, and theta-psi relationships. Experimental equipment included a constant head permeameter, sieves and sieve shaker, pressure plate, and hanging columns.

The constant head permeameter used was a (model K-605, Eijkelkamp). This permeameter is designed to hold fifteen 100 cc undisturbed soil samples taken by a metal ring sampler. The metal ring samples were covered at the base by fine mesh screens and fitted with rubber gaskets and plastic holders before being placed into the permeameter. Samples were kept capped after collection from the field to prevent disturbance of the soil samples. If the samples are not kept capped, evaporation of the sample will occur and subsequent shrinkage and or cracking of the soil may cause piping. All values of conductivity were corrected for viscosity and density at 20 degrees celsius.

After placement of the samples in the permeameter, the water level in the reservoir (below the bottom of the samples) was slowly raised. Care was taken in wetting the samples slowly to prevent air entrapment and piping. If the samples are wetted too fast, piping may occur from the upward movement of entrapped air within the sample which disturbs the natural soil structure and creates artificial flow paths and higher conductivities. Rapid wetting may also cause some air to be trapped within the soil pores, which blocks the flow of water and subsequently produces a low reading of hydraulic conductivity.

Other causes of sample disturbance are dissolution of salt precipitates and algal growth. The tap water used in the permeameter had a lower TDS than the soil water. This imbalance might enhance dissolution of salt precipitates within the sample, thus causing an increase in the hydraulic conductivity. Algal growth occurs when the sample has remained in the reservoir for long durations. Andrews (1982) conducted an experiment to determine the equilibration time for the measurement of saturated conductivity. In this study a rapid drop in conductivity was detected at approximately 240 hours. This rapid drop was attributed to the growth of algae within the pores of the soil.

After the samples were placed in the permeameter, they were left there for a period of 24 hours. This was done for the purpose of having some consistent equilibration time for all of the samples. After this initial equilibration time, recordings of hydraulic conductivity were made on a regular basis. The measurements of hydraulic conductivity are relative values, related to the duration of time of the experiment.

The sieves used were U.S.A Standard Testing Sieves, and the sieve shaker was a model CL-390-K, Soiltest. Through the use of this equipment, particle size distribution parameters were determined. Since most of the soil samples collected contained less than five percent material passing the 200 sieve, it was determined that hydrometer tests were unnecessary in the calculation of particle size parameters. Previous studies on the sand from the Sevilleta, Laevitt (1986), and Andrews (1982), have also come to the same conclusions.

A total of 15 samples were analyzed for particle size distributions. These samples were collected from the initial drilling of the hole for the placement of the ETN-3 aluminum access tube. Sample depths range from 30 cm below ground surface to 450 cm below ground surface at increments of 30 cm. The samples were first air dried and then placed into the sieves. Eight sieve sizes were used to separate the soil into grain sizes of 2.0, 0.85, 0.425, 0.25, 0.15, 0.106, 0.075, and less than 0.075 millimeters. After placement into the sieves, the samples were shaken for approximately ten minutes and subsequently weighed to determine the mass of material retained in each sieve. From this data, particle size distribution parameters were calculated.

With the combined use of hanging columns and a pressure plate apparatus, soil moisture characteristic curves were determined. The hanging column consists of a Buchner funnel, ceramic plate, tubing, rubber stoppers, and a burette. In this procedure, the Buchner funnel and burette are connected by teflon tubing and filled with de-aired water to ensure that no entrapped air exists. A 100 cc ring sample was placed onto the ceramic plate, and the annular space was filled to the top of the ring sample with de-aired water. The sample was submerged in water and allowed to set for approximately 24 hours to ensure complete saturation of the sample. After this initial saturation, the water in the annular space was drained to the point were there was no water standing on the ceramic plate. The Buchner funnel and burette were both sealed by rubber stoppers to ensure that no evaporation occurred during the experiment. The burette was first incrementally lowered (drainage) and then incrementally raised (imbibition) to determine the soil moisture characteristic curve (theta-psi). This procedure was followed for all of the samples collected.

The pressure plate apparatus used was a 15 bar ceramic plate extractor (model 1500, Soil Moisture Equipment Corp., Santa Barbara, CA). Through this experimental technique, an approximation of residual moisture contents of 31 samples collected from 30 cm below ground surface to 450 cm below ground surface were obtained. Twelve samples were placed onto the pre-saturated 15 bar ceramic plate. In order to insure complete saturation of the samples, de-aired water was added to the annular space and allowed to stand for 24 hours. The water was then syphoned out, and the apparatus was sealed and locked. Compressed nitrogen was then added to the pressure vessel containing the samples. The pressure within the cell was increased to a maximum of 15.2 bars and maintained at this level for the remainder of the experiment. The experiment was completed when there was no water detected flowing out of the drainage ports. The experiments completion time ranged between 72 hours and 168 hours, depending on the hydrologic properties of the soils under investigation. At this point, the residual moisture content of the samples had been reached.

The samples were then removed from the ceramic plate and immediately weighed, oven dried, and reweighed to determine the residual moisture content of the samples.

Water Balance Analysis

As previously discussed in the theoretical section, water balance is a summation of the transient states of inflows, outflows, and storage changes of water within a given volume of soil. The parameters involved in the water balance equation (Equation 1) include: precipitation, evapotranspiration, recharge, interflow, surface water runoff, and cummulative changes in storage.

At the site under study, surface water runoff was negligible due to the high permeability of the soils. Interflow was also assumed to be negligible, owing to the level surface at the site and lack of an impeding layer directly below ground surface. Precipitation was measured from both automated and manual weather stations at the site. Cumulative changes in storage were estimated using volumetric moisture content data obtained from neutron probe measurements. Evapotranspiration is the most difficult parameter to measure. This parameter combines both bare soil evaporation and plant transpiration into one quantity. Without the use of a weighing lysimeter, evapotranspiration can only be estimated by empirical or theoretical equations. With the quantification of recharge, an estimate of evapotranspiration can be obtained.

Cumulative changes in storage were determined by integrating the volumetric moisture profile over the depth interval 30-300 cm below ground surface to obtain a total volume of water stored in that depth interval. This interval was chosen because moisture content readings began at 30 cm and increased moisture contents due to the rising water table were not detected at 300 cm depth but below this depth moisture content increases due to a rising water table were detected. The volume of water in storage can be stated mathematically:

$$V_{storage} = [1/n(\sum_{30}^{300}\theta_i)]D_t \qquad (4)$$

where,

$V_{storage}$ = Volume of water in storage (L^3)

θ = Volumetric moisture content at ith depth (L^3/L^3)

D_t = Total volume of integration (L^3)

n = Total number of θ measurements

Any decrease in the $V_{storage}$ would indicate a loss of moisture stored within the profile, whereas, any increase in $V_{storage}$ would indicate an increase in moisture stored within the profile. Loss of moisture can be attributed to either evaporation, transpiration, downward drainage, or net lateral flow outward. Moisture increases can be caused by either infiltration from above, net lateral flow inward, or upward flow due to water table rise. The volumetric moisture integration was applied to all twelve moisture content monitoring locations. Measurements of moisture content were taken every 30 centimeters, from 30 centimeters, to a maximum depth of 480 centimeters below land surface.

Recharge

Recharge to the water table was estimated by a variety of methods. These include: 1) use of moisture contents at depth to calculate deep percolation. 2) apply hydraulic conductivities estimated by two different methods to Darcy's equation. First by using empirically derived equations of $K(\theta)$ vs θ and $K(\Psi)$ vs Ψ that were determined from an instantaneous profile test previously conducted at the Sevilleta and secondly from temperature corrected $K(\theta)$ values determined from laboratory investigations conducted on core samples collected at the Sevilleta. 3) measurement of a chloride mass balance.

Deep Drainage Method. To estimate ground-water recharge from moisture content profiles, the differences in moisture contents from one monitoring period to the next were calculated for all depths in which moisture content readings were taken. These readings began at a depth of 30 cm and continued to a depth of 390 cm at increments of 30 cm. Below 390 cm depth the effect of water table fluctuations were evident, and thus below this depth recharge could not be calculated. To estimate deep percolation, a depth interval of 210 to 270 cm was chosen. It was at this depth that evaporation and transpiration were assumed to be negligible with respect to the inflows, outflows, and changes in storage. If change in storage in-between monitoring periods is positive, then the depth interval has gained water in storage. If the depth interval has experienced a net loss in storage then drainage has occurred. Tensiometric data from within the profile indicate that below 210 cm the hydraulic gradient is downward throughout the year (Figure 19, 20, 21, and 22). Based on these assumptions, conservative estimates of deep drainage were calculated. All negative changes in storage that were calculated throughout the duration of the study were summed to obtain the conservative estimates of deep percolation.

Darcian Flux Methods. In this portion of the recharge investigation, recharge was calculated by two methods, both based on Darcy's equation. The estimation methods differed in the means by which hydraulic conductivity was calculated.

The first method that was employed to estimate ground-water recharge was through the use of a $K(\theta)$ and $K(\Psi)$ relationship that was determined from previous research at the Sevilleta. During this study (Knowlton, 1984) an instantaneous profile test was performed at a location about 10 m southwest of the field site currently under study (Figure 23). The instantaneous profile method is advantageous in that measurements of insitu conductivities can be determined from undisturbed soils (Hillel, 1980). From the instantaneous

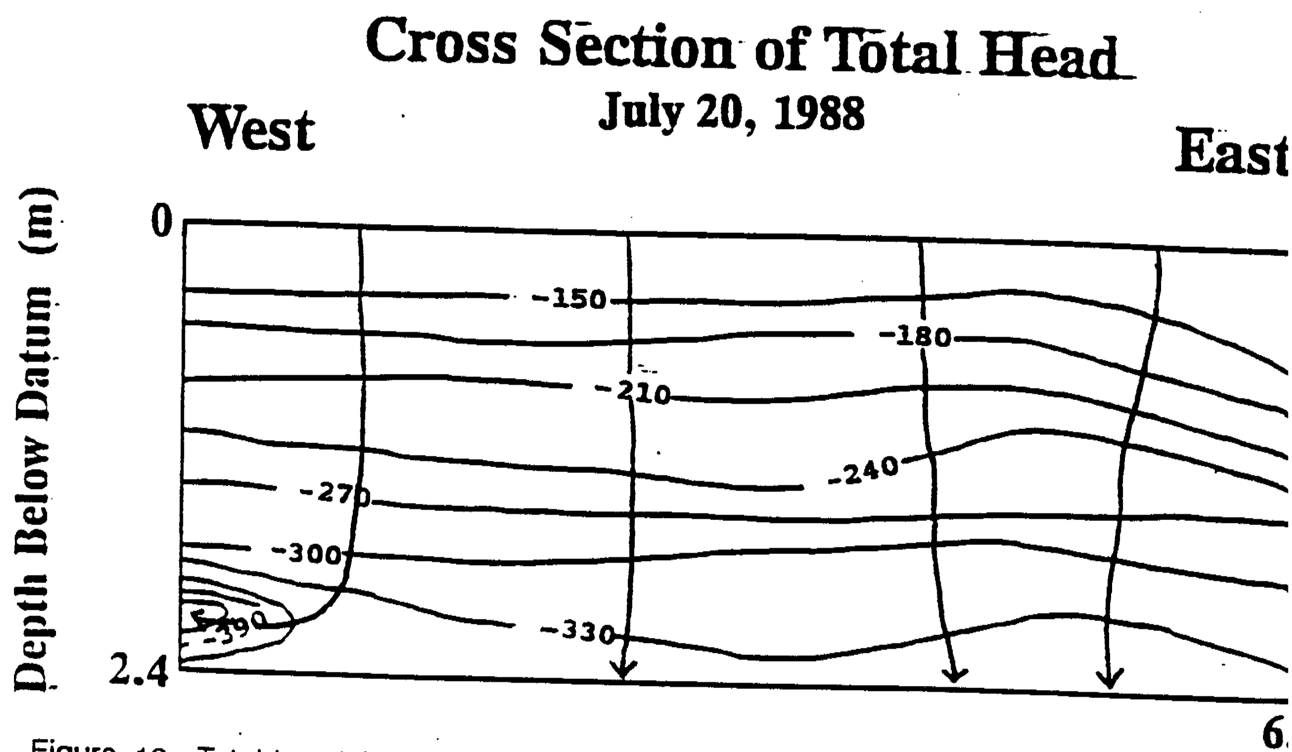


Figure 19 Total head field and soil-moisture flow directions on 7/20/88 (Hicks, 1990).

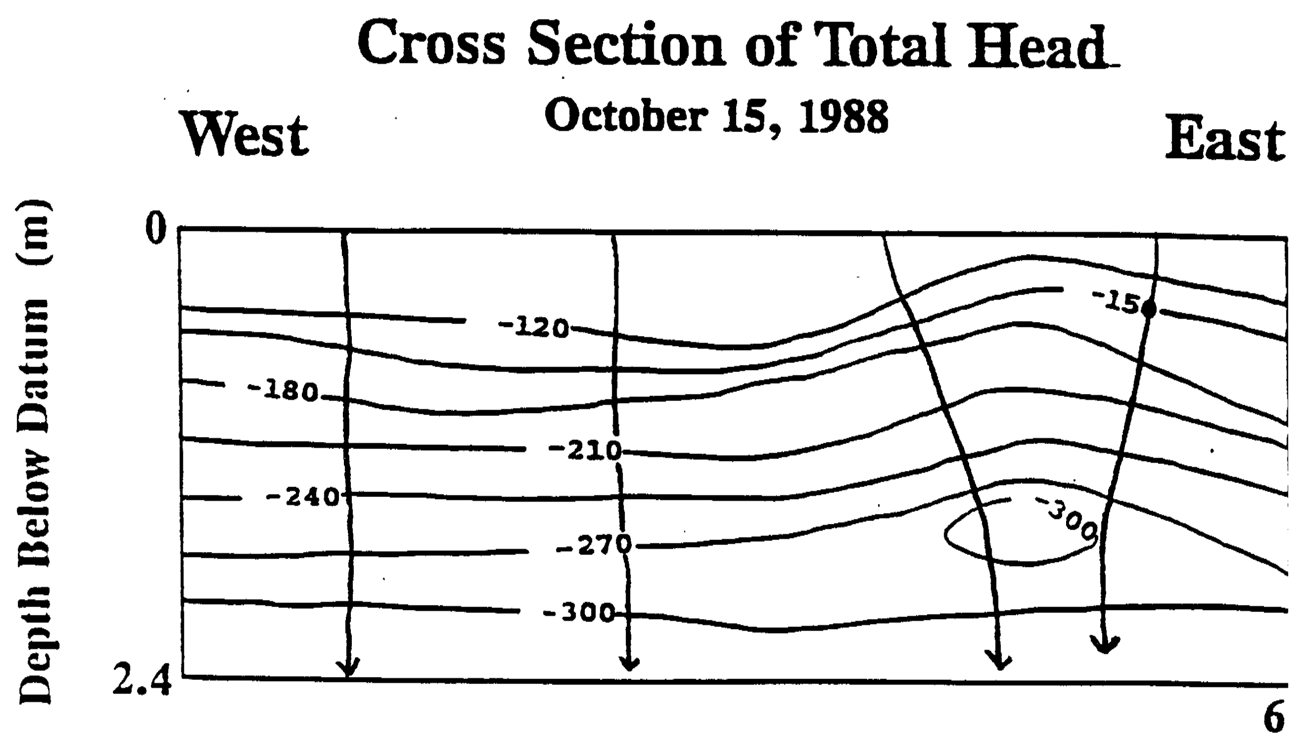


Figure 20 Total head field and soil-moisture flow directions on 10/15/88 (Hicks, 1990)

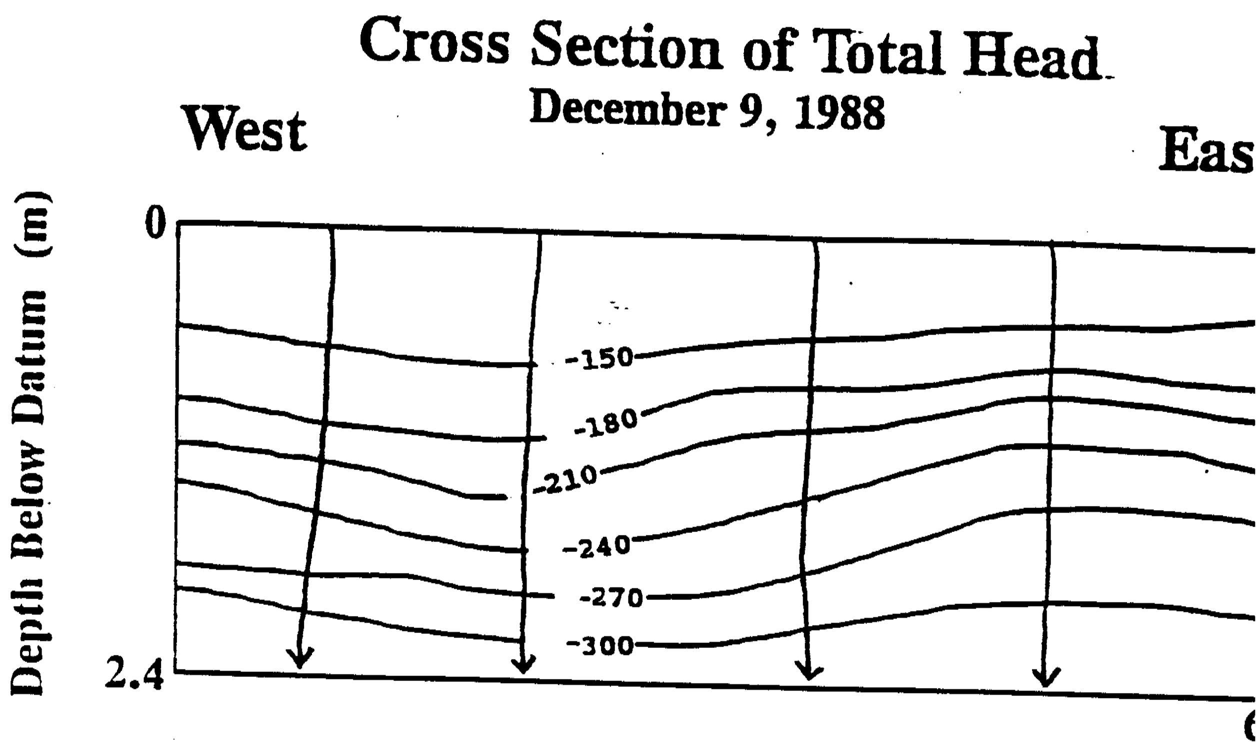


Figure 21 Total head field and soil-moisture flow directions on 12/09/88 (Hicks, 199C

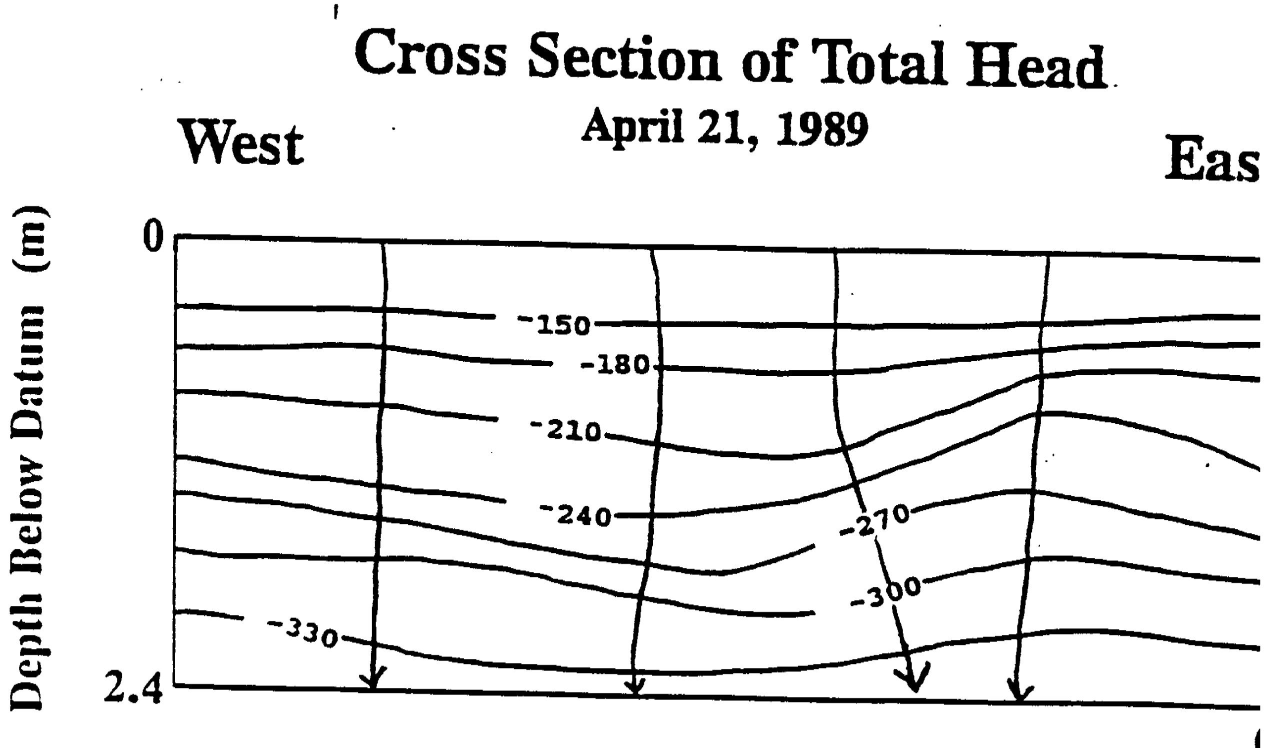


Figure 22 Total head field and soil-moisture flow directions on 4/21/89 (Hicks, 1990

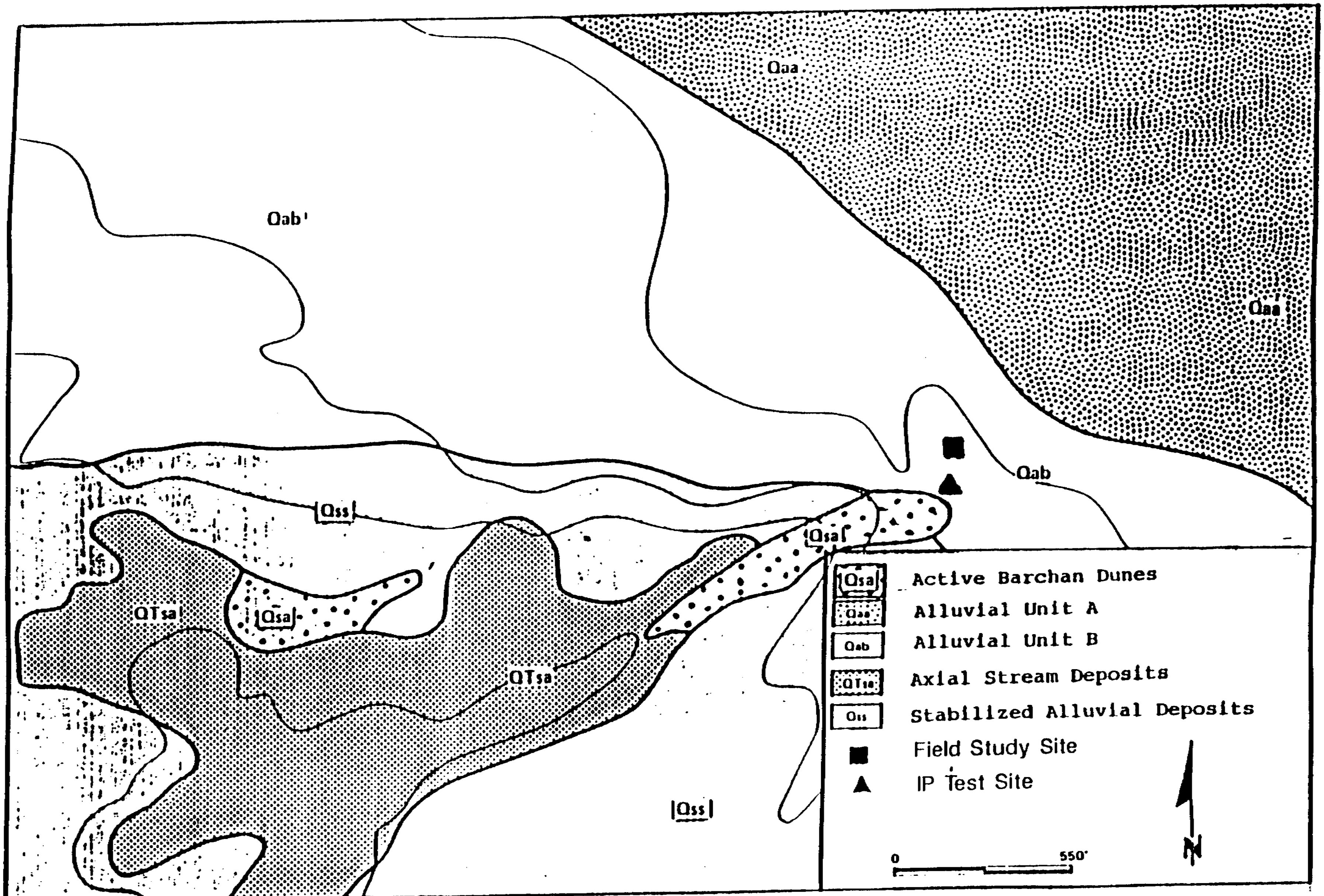


Figure 23. Previous IP test location.

profile test, relationships between calculated hydraulic conductivity and water content (Figure 24), and calculated hydraulic conductivity versus pressure head (Figure 25) were established. Linear regressions through the data revealed the following relationships for hydraulic conductivity in (cm/s) (Knowlton, 1984):

$$K(\theta) = 6.79 \times 10^{-10} \exp(83.84\theta), \; (r^2 = 0.71) \quad (5)$$
with θ in (cm^3/cm^3)

$$K(\Psi) = 0.5601 \exp(0.02030\Psi), \; (r^2 = 0.88) \quad (6)$$
with Ψ in centimeters of water

The $K(\theta)$ relationship that was determined from the instantaneous profile test was used in Darcy's equation to estimate the downward fluxes of water within the soil profile. Darcy's equation for one dimensional vertical unsaturated moisture flow is stated mathematically:

$$q_z = K(\theta) \times i \quad (7)$$

where,

q_z = Darcian flux in the vertical direction (L/T)

$K(\theta)$ = vertical unsaturated hydraulic conductivity as a function of volumetric moisture content (L/T)

i = vertical hydraulic gradient (L/L)

Tensiometric data from throughout the field site was used to calculate the hydraulic gradient over discrete time intervals. An attempt was made to determine the fluxes in

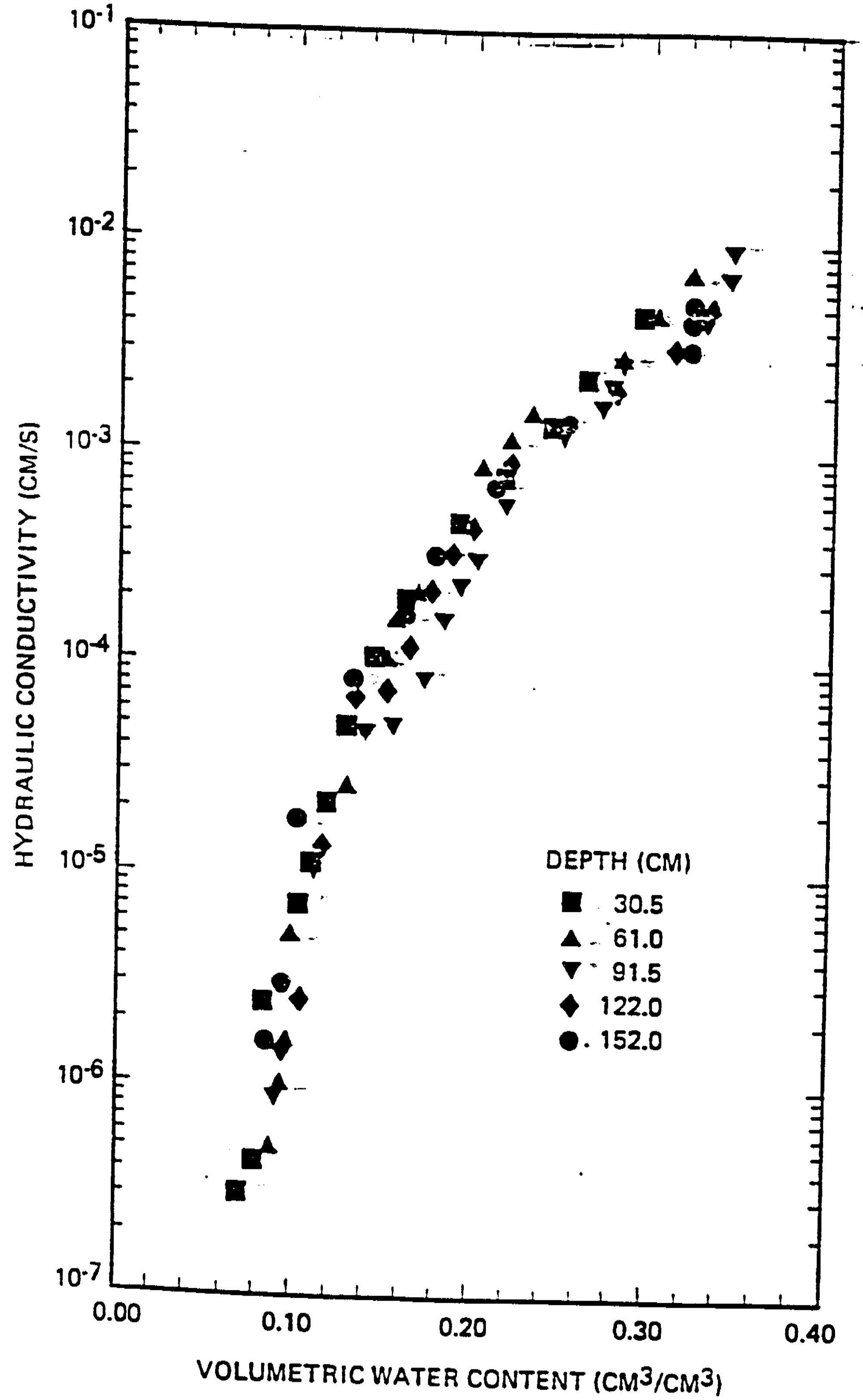


FIGURE 24 Hydraulic conductivity versus water content (Knowlton, 1984).

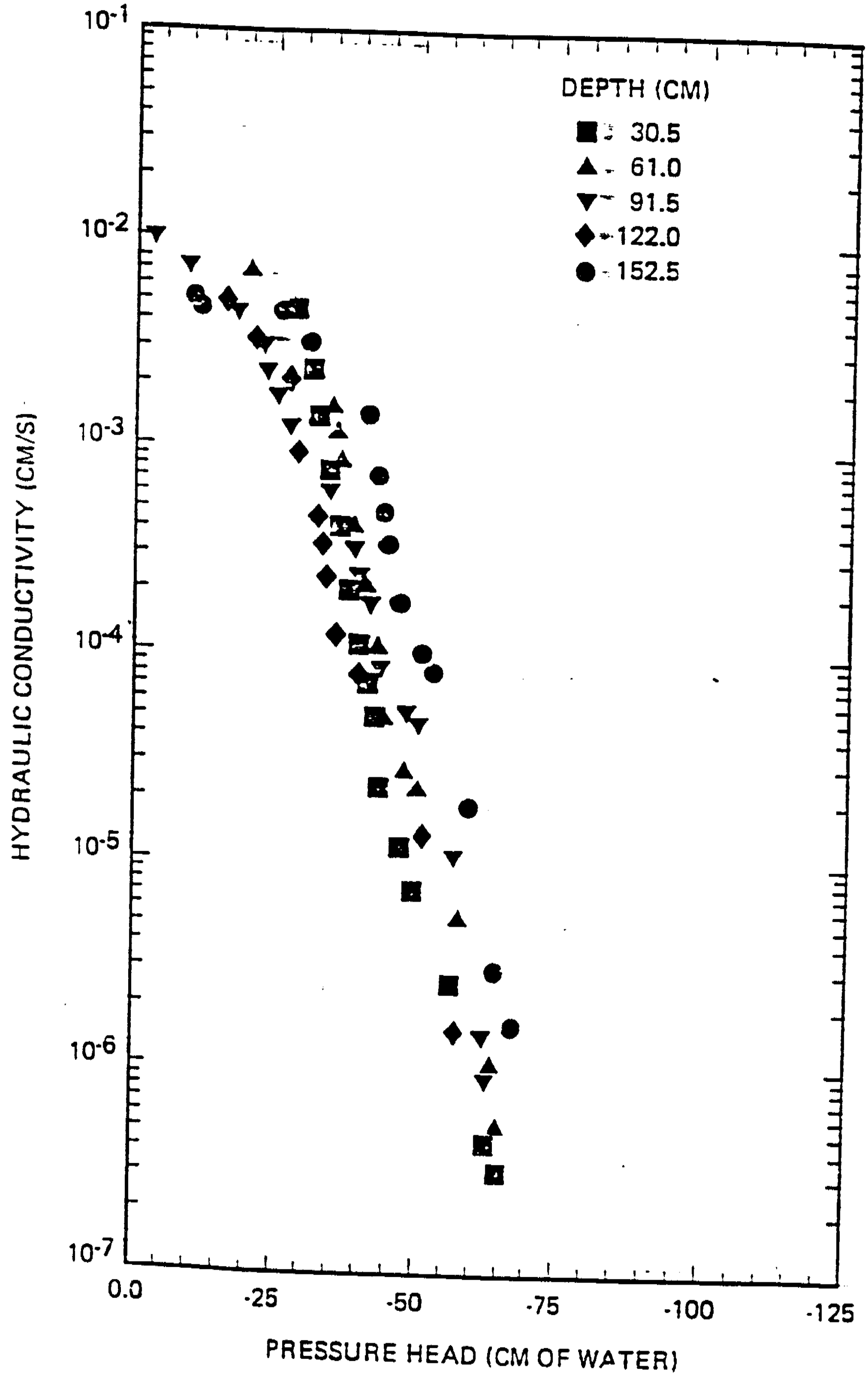


FIGURE 25 Hydraulic conductivity versus pressure head (Knowlton, 1984).

three dimensions through the tensiometric data. To do this, the field was hypothetically divided into six 150 cm by 150 cm cells (Figure 26). Within each cell there were 5 cubes that started at the 60 cm depth below datum and continued to a depth of 210 cm below datum at increments of 30 cm (Figure 27). Each cell contained tensiometers at depths of 30, 60, 90, 120, 180, 210, and 240 cm below datum. Datum was chosen to be the mean surface elevation at the site. All elevations were surveyed in from a nearby section marker. Average moisture contents for each side face were calculated from neutron access tubes that were located on all four sides of each cube. Fluxes were calculated across all six faces of each cube. An estimation of ground-water recharge was obtained from calculated downward fluxes of each of the deepest cubes within the profile. For a further description of recharge estimations based on unsaturated hydraulic conductivities determined from previous instantaneous profile tests at the Sevilleta, see Hicks (1989).

The second approach that was used to estimate ground-water recharge, based on Darcy's equation, was through the estimation of unsaturated hydraulic conductivities from ring samples collected within the soil profile. Soil-moisture characteristic curves for the fluvial sands were obtained from laboratory tests using Buchner funnel hanging columns and a 15 bar pressure plate apparatus. Unsaturated hydraulic conductivities were calculated from the relationship between

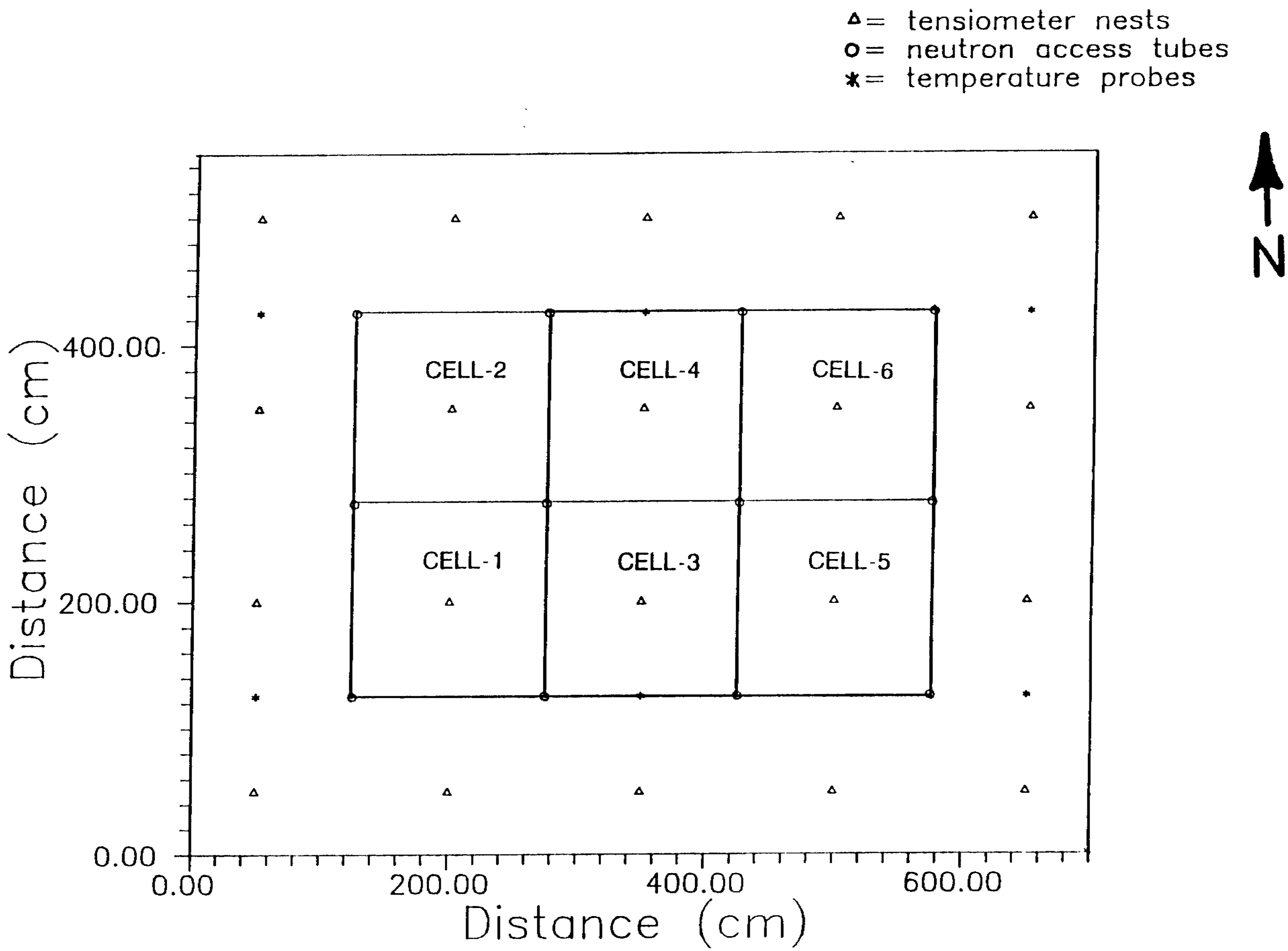


Figure 26 Planer map of theoretical cell network.

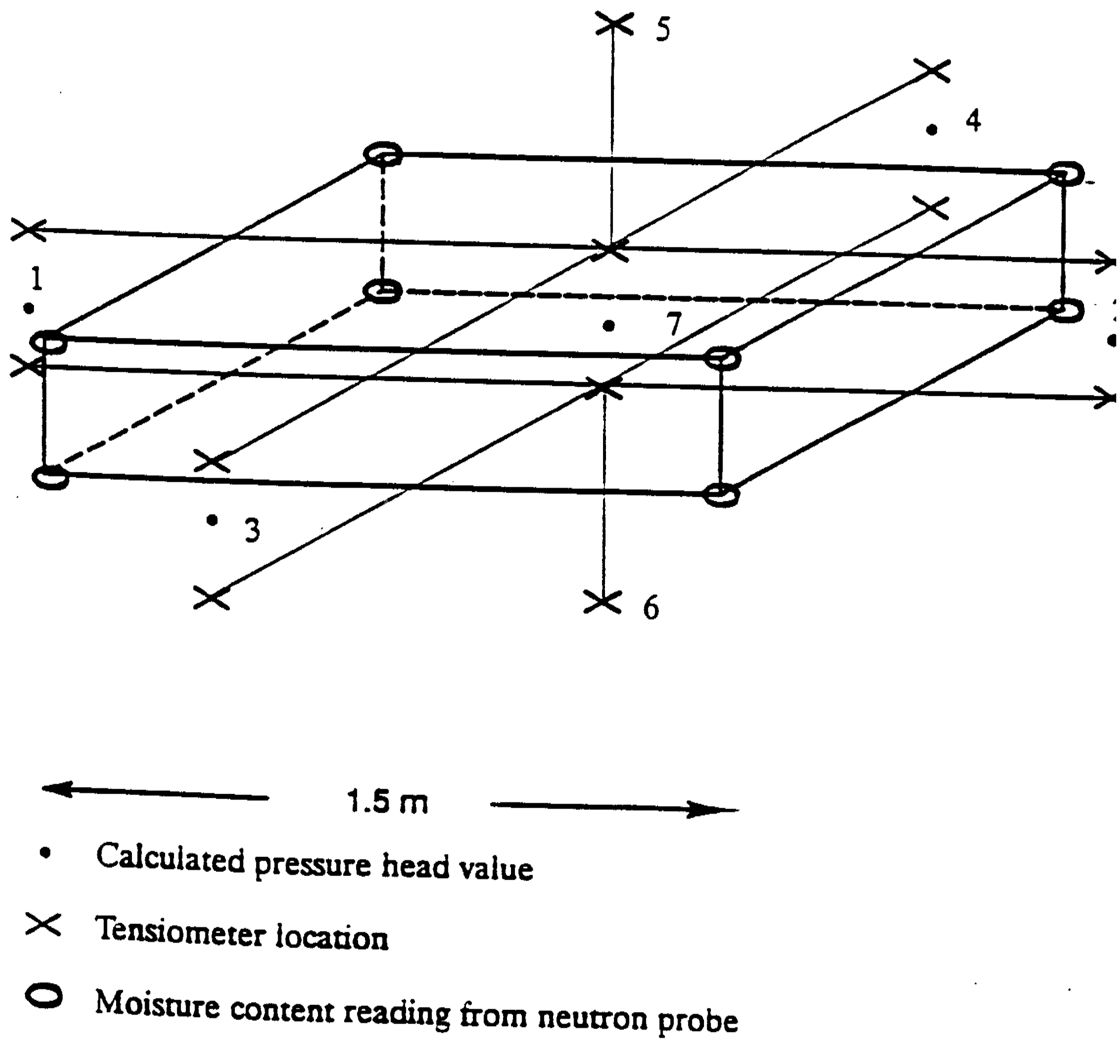


Figure 27 Hypothetical cube (Hicks, 1990).

moisture content and pressure head, which was obtained from hanging column and pressure plate data. This data was used to predict relative hydraulic conductivity (K_r) in a computer code of closed-form analytical solutions developed by van Genuchten (1978), for the theoretical model of Mualem (1976).

$$K_r = \theta^{-1/2}[\int_0^\theta (1/\Psi_z)dz/\int_0^1(1/\Psi_z)dz]^2 \qquad (8)$$

where, $K_r = K(\theta)/K_s$

Ψ = pressure head (L)

θ = Volumetric moisture content (-)

K_r = Relative hydraulic conductivity (-)

$K(\theta)$ = Hydraulic conductivity as a function of θ (L/T)

K_s = Saturated hydraulic conductivity (L/T)

The equation to predict conductivity is based upon a two parameter fit to observed soil-moisture characteristic curve data. The two parameters, α and n, are influenced by the choice of residual moisture content and saturated water content. From a statistical analysis that was performed on K_s data from throughout the field profile, the soil at the field site was considered uniform in hydraulic conductivity (Appendix A). Due to the apparent uniformity of the soil, the theta-psi data was compiled, and from this data a single calculation of unsaturated hydraulic conductivity was obtained. The calculated $K(\theta)$ data was used in Darcy's equation to estimate recharge. All of the $K(\theta)$ values were corrected for insitu temperatures that were determined from soil temperature thermistors. Soil temperatures thermistors were located at six different locations within the field site at depths of 30 cm, 60 cm, 120 cm, and 240 cm below ground surface (Figure 14). Soil temperatures were recorded daily and from this data monthly averages were calculated for the purpose of obtaining temperature corrected hydraulic conductivities (Appendix B). Daily soil temperatures are presented in Hicks, 1989. The hydraulic head gradient was calculated between the 210 and 240 cm depth interval. This depth corresponded to the deepest tensiometers within the soil profile.

Chloride Mass Balance Method

The final method that was used to estimate recharge was through the chloride mass balance method. In this method recharge can be estimated from chloride concentrations of soil-water within a given profile. To calculate recharge from this method it is assumed that soil-water flows one-dimensionally, and that the concentration of chloride in rainfall and dryfall is known and does not change with time.

Soil samples were collected throughout the field site by driving 1.5 cm inner diameter conduit into the soil to a desired depth. Soil samples were then obtained from the conduit and analyzed in the laboratory to determine chloride concentration distributions. Recharge was then calculated from the following equation:

$$R = (C_o \times P)/CL_{sw} \qquad (9)$$

where, R = recharge rate (L/T)

P = average annual precipitation (L/T)

C_o = chloride concentration in precipitation and dry fall (M/L^3)

CL_{sw} = chloride concentration in soil-water (M/L^3)

The chloride mass balance method of estimating recharge is relatively fast, simple, and inexpensive. But, the assumptions inherent in the analysis may not be valid in the field site under study. Previous studies at the Sevilleta have shown evidence of lateral flows. If lateral flows are present then the assumption of one-dimensional flow will be invalid. The concentration of chloride in precipitation is based on measurements taken in Socorro. The area within the Sevilleta containes numerous sand dunes, and as a result, has a high concentration of suspended particles. For this reason dryfall may be more important at the Sevilleta. Also, all of the measurements are based on short term records of chloride in precipitation. Therefore the assumption that the concentration of rainfall and dryfall is known and does not change with time may also be invalid, because of the lack of chloride concentration data of precipitation from within the

Sevilleta. For a more detailed discussion of the chloride mass balance method, see Hicks (1989).

Field Tracer Test

Another approach taken in this study to determine if significant lateral flow occurs was through the use of chemical tracers. Three organic anions, and one inorganic salt were used in the field tracer test. The organic anions used were, o-(trifluoromethyl)benzoic acid (o-TFMBA), 2,6-difluorobenzoic acid (2,6-DFBA), and pentafluorobenzoic acid (PFBA). The structures of the organic anions are shown in Figure 28a. The inorganic tracer used was calcium bromide.

The tracers that were chosen for this investigation have previously been used at the Sevilleta National Wildlife Refuge. An extensive evaluation of the organic anions used in this experiment was conducted by (Bowman, 1984). In this study, the sorption and mobility characteristics of the organic anions were compared to that of bromide. Batch isotherms and column experiments from this study indicated that the organic anions behave very similar to that of bromide (Figure 28b and 28c). All of the tracers used in this study have been shown to behave conservatively. With the quartz rich sandy material at the site, anion exclusion was believed to be a negligible factor in the behavior of the tracers within the soil profile. From the above information, it was assumed that the tracers moved very similar to the soil water a)

b)

c)

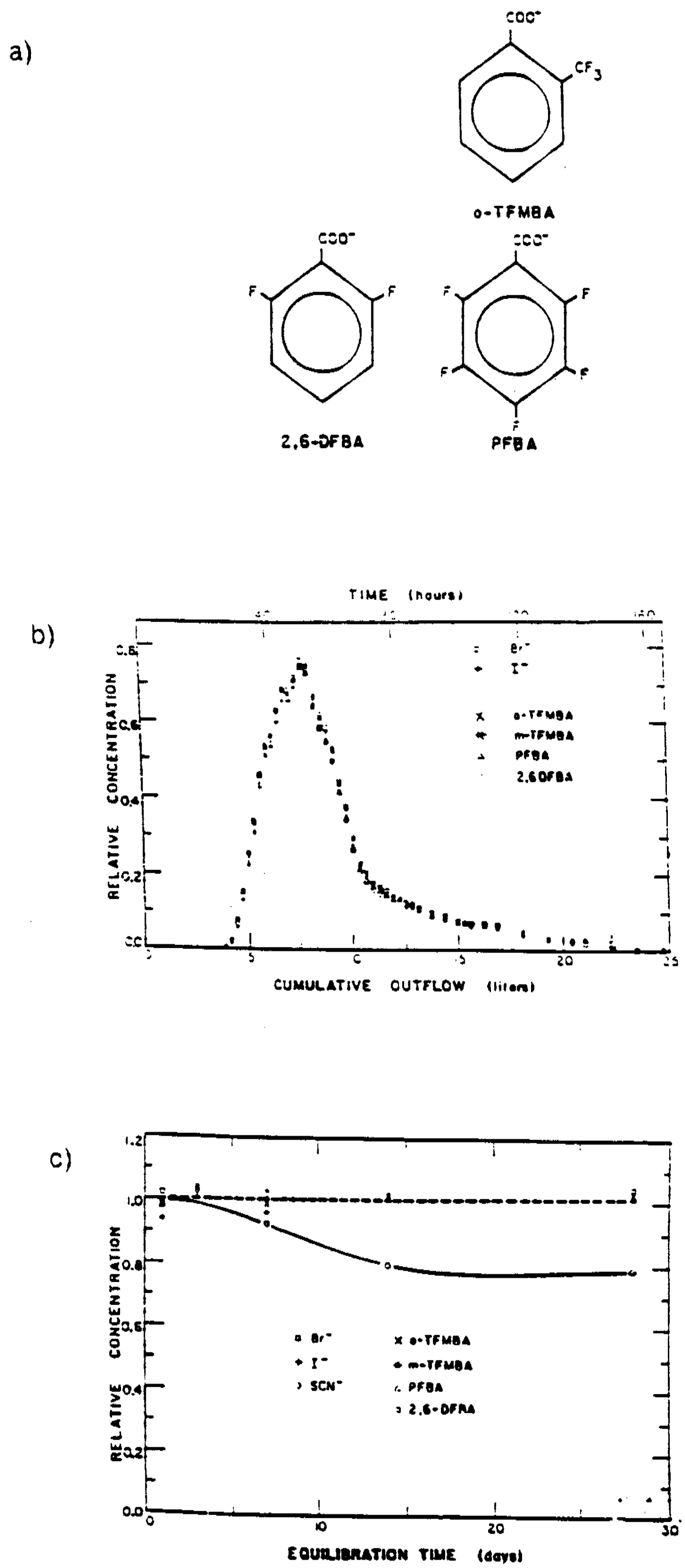


Figure 28 a) Organic anion structures b) Breakthrough curves for the fluorobenzoic trac and bromide c)Batch isotherms for the fluorobenzoic tracers and bromide (Bowman, 1 within the profile.

The tracer test was conducted as follows. In early August (8/9/88), the tracers were placed within the soil profile. In order to achieve this, the tracers were mixed with distilled and de-ionized water, and sodium hydroxide. The sodium hydroxide was added to ensure complete dissolution of the solid tracers within the highly concentrated tracer solutions. All of the tracer solutions had a concentration of 100,000 ppm. The tracers were emplaced by driving 1.5 cm inner diameter thin-walled conduit into the soil at an angle of sixty degrees relative to the surface (Figure 29). After the conduit was driven to the desired depth, and the hole completely free of obstructions, another piece of conduit having the same length and diameter was lowered down the hole. The second piece of conduit had teflon tubing running down the center of the tube, sealed at both ends by rubber stoppers. Approximately 12.5 ml of tracer solution was injected slowly into the teflon tubing by a graduated syringe. After the solution was fully injected into the soil, the conduit was pulled up and the hole carefully backfilled with native material. This procedure was followed for all of the holes drilled at the site.

The tracers were emplaced at four different locations within the field site (Figure 30). Two of the locations were in unvegetated areas, and the other two were in vegetated areas. The locations were chosen to detect soil moisture flow

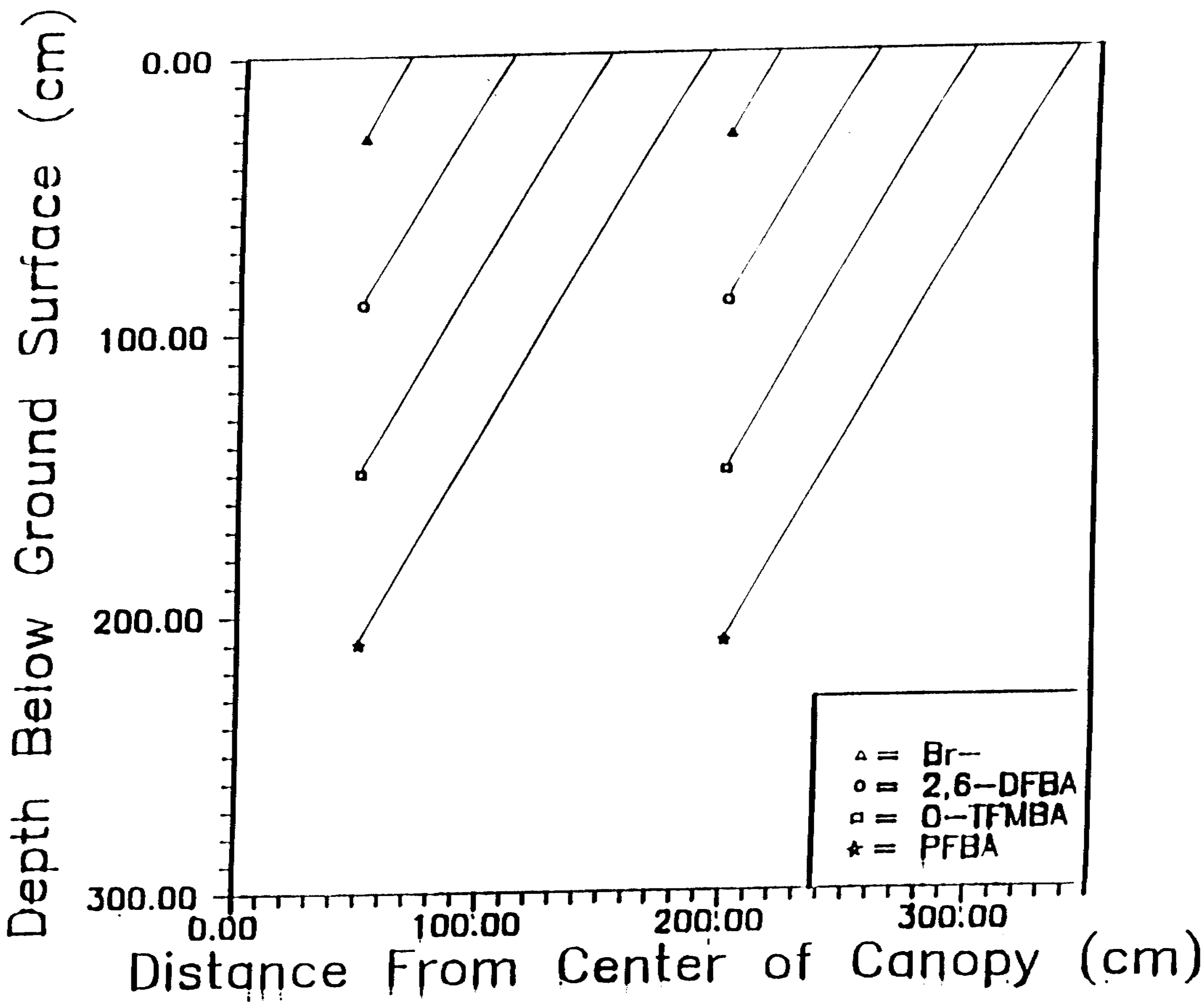


Figure 29 Locations of the conduit used in the emplacement of the tracers.

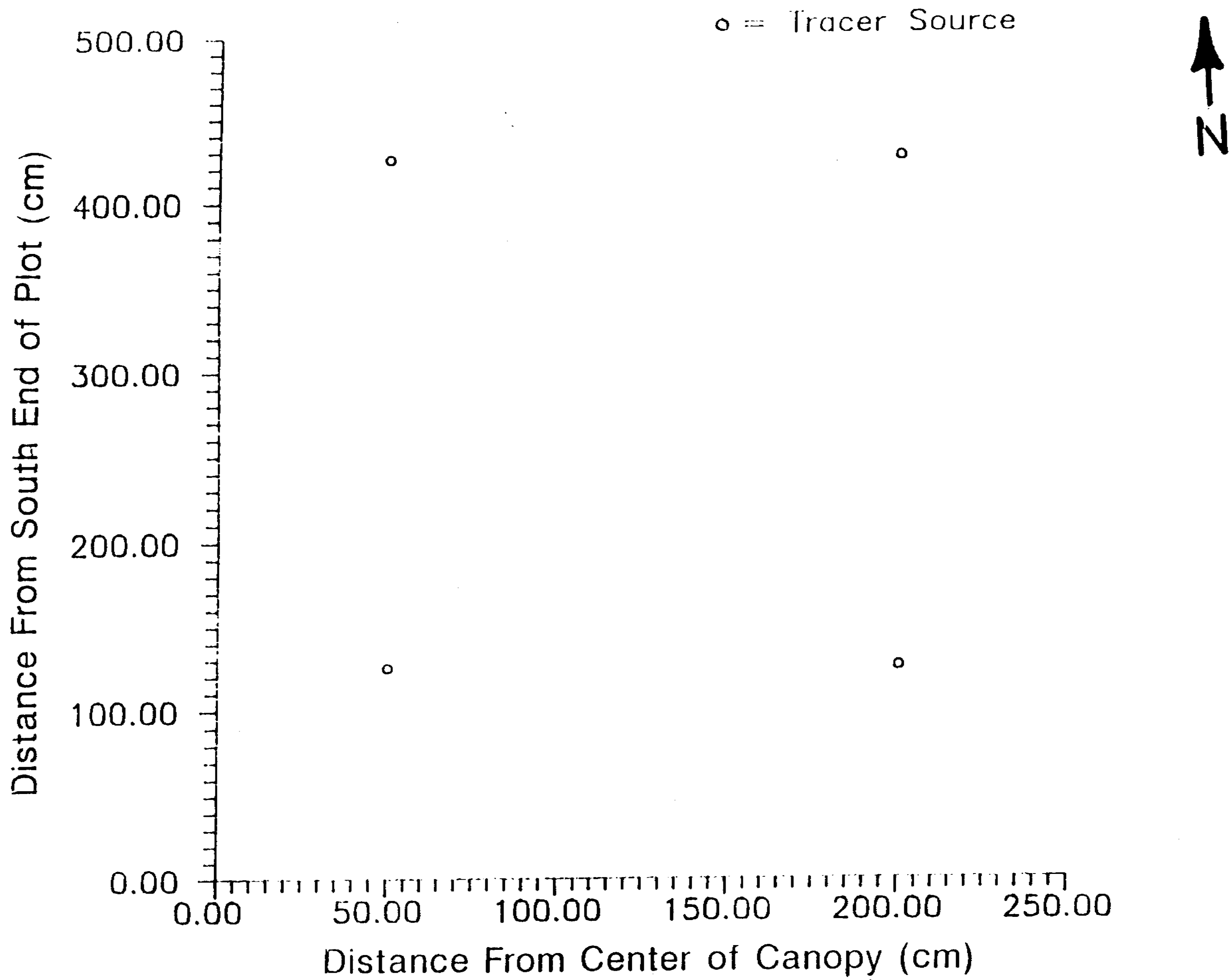
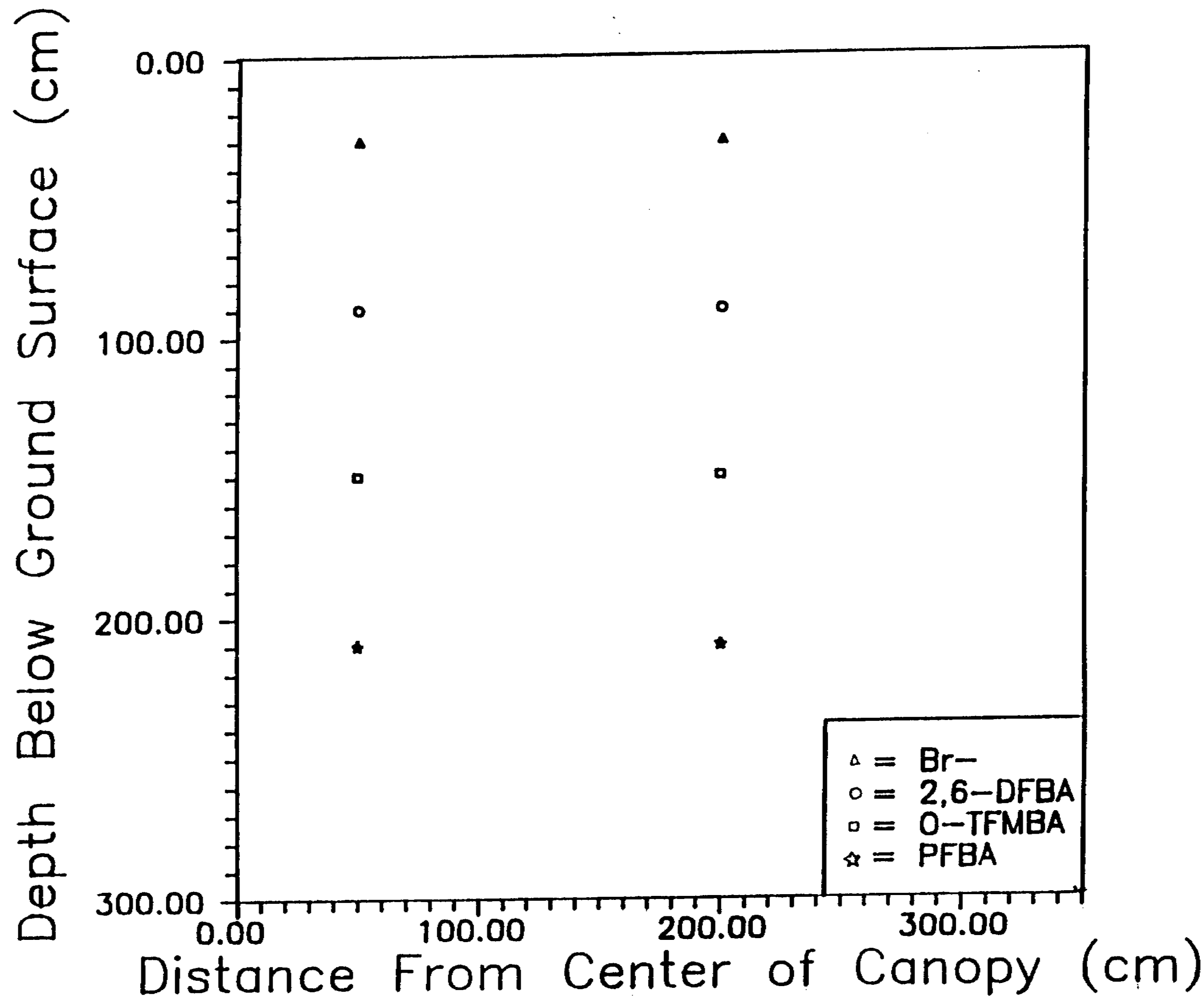


Figure 20. Planar map of tracer source locations

variations between the vegetated and unvegetated areas. These include, variations in: recharge, extent of lateral flow, and evaporative fluxes. The tracer test was also designed to estimate the area over which desert plants at the site withdraw soil moisture. At each of the tracer locations, all four tracers were placed in a vertical arrangement. The bromide tracer was placed at a depth of 30 cm, 2,6-DFBA at 90 cm, o-TFMBA at 150 cm, and PFBA at 210 cm (Figure 31). The tracers were placed within the profile in this fashion to ensure that if vertical mixing of the tracers did occur, it could be detected.

The tracers were sampled on the 169th day of the tracer test (1/24/89). The sampling procedure consisted of driving 1.5 cm inner diameter thin-walled tubing vertically into the soil to a depth of 300 cm. Samples were taken directly on top of the original tracer emplacement, and at distances of 15 cm to 60 cm from the original emplacement. These continuous samples were sectioned immediately after arriving from the field site, to prevent tracer migration within the continuous samples. The sectioned samples were weighed and placed into centrifuge tubes. Next, a known volume of distilled de-ionized water was added to the samples. The resulting mixture was then shaken for ten minutes to promote solute dissolution, and then it was centrifuged for another ten minutes to separate the soil particles from the liquid. A small volume of liquid was removed for chemical analysis. Tracer



Depth Below Ground Surface (cm)
0.00
100.00
200.00
300.00
Distance From Center of Canopy (cm)
0.00
100.00
200.00
300.00
△ = Br−
○ = 2,6−DFBA
□ = O−TFMBA
☆ = PFBA

concentrations were quantified using a high performance liquid chromatographer. This technique allowed for the simultaneous quantification of bromide, o-TFMBA, 2,6-DFBA, and PFBA.

RESULTS

The results of the site characterization and field investigations are presented below. The site characterization section includes laboratory results of: constant head permeameter, hanging columns, particle size analysis, and 15 bar pressure plate moisture contents. The field monitoring section contains results of moisture content monitoring, pressure head monitoring, and the tracer test.

Site Characterization

Laboratory experiments were conducted throughout the duration of the study to determine hydraulic conductivity, particle size distribution, and theta-psi relationships. The samples that were used in the experiments were obtained from the initial drilling of holes for the placement of neutron access tubes within the field site. The results of the laboratory tests are presented in Appendix A.

The best estimation of the mean of hydraulic conductivity should represent an effective hydraulic conductivity. Effective hydraulic conductivity is defined as the value of hydraulic conductivity which, when substituted for a random distribution of actual hydraulic conductivity values in a soil, results in the same flow rate as the original system under the same boundary conditions (Bouwer, 1969). It has been determined in previous research (Cardwell and Parsons, 1945) that the effective saturated hydraulic conductivity has a value between the arithmetic and harmonic mean. Following this reasoning, the geometric mean of hydraulic conductivity was considered to be the best mean. Soil variability was determined by taking the mean and variance of the natural logarithm of the hydraulic conductivities. A total of 59 samples were collected at 30 cm intervals starting at 30 cm below ground surface and extending to a maximum depth of 480 cm at locations ETN-1 through ETN-12 (Figure 16).

The geometric mean was determined to be 9.50×10^{-3} cm/sec with the corresponding variance of Ln-transformed hydraulic conductivity being 0.694. The results of the statistical analysis are shown in Figure 32. A number of studies that have previously been conducted at the Sevilleta have found similar results. For example, in a study by Stephens et al. (1983), estimations of hydraulic conductivity in undisturbed soil profiles were obtained from both instantaneous profile tests and borehole infiltration experiments. The calculated hydraulic conductivities were 9.50×10^{-3} cm/sec for the instantaneous profile test and 9.00×10^{-3} cm/sec for the borehole infiltration experiments. A set of 271 ring samples were collected in an experiment designed to investigate geologic predictors of hydraulic conductivity in the fluvial sands of the Sevilleta (Byers, 1982). The calculated saturated hydraulic conductivity in the vertical direction was

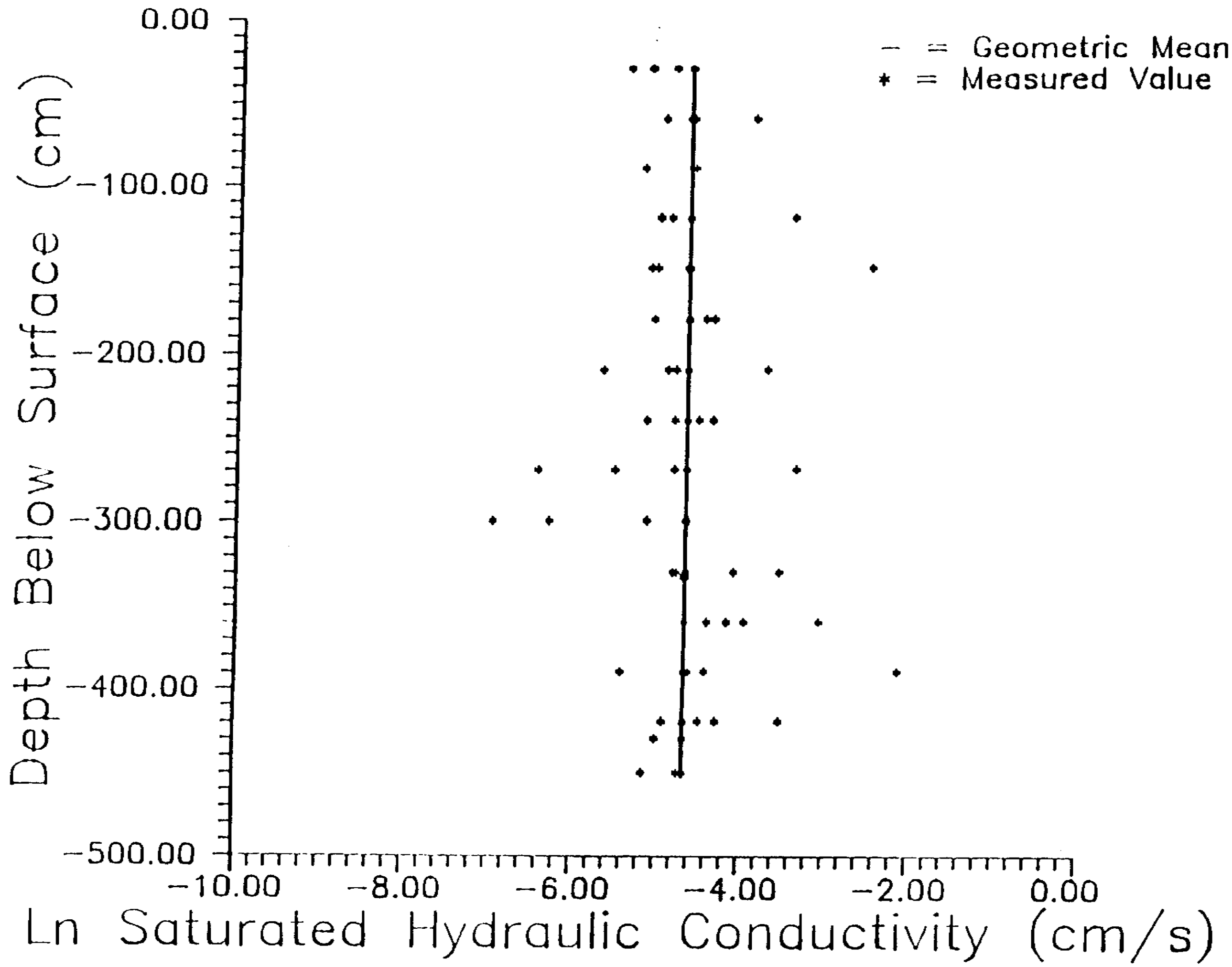


FIGURE 32 Ln Saturated Hydraulic Conductivity Versus Depth

9.00×10^{-3} cm/sec, whereas, in the horizontal, K_S was determined to be 1.60×10^{-2} cm/sec.

For all studies on earth materials, the variance of Ln K has been shown to fall in the general range of 0.05 to 6.0, which corresponds to a standard deviation of Ln K between 0.2 and 2.5. Results from the current study have determined the variance to be 0.69, which would be expected from the homogeneous appearance of the soil profiles at the study site. Rogowski (1972) considered soils to be uniform with depth or over an area if the standard deviation of the natural logarithmic hydraulic conductivity was less than 0.7. The calculated standard deviation of the natural logarithmic hydraulic conductivity in this study was 0.83. A substantial amount of the variance in Ln K was introduced from samples obtained from a high conductivity mixed sand and cobble layer located at the bottom of the soil profile, and a low conductivity mixed sand and silt layer located at approximately 300 cm depth. If these samples are removed from the data set, then Rogowski's criteria for uniformity is met.

Particle-size distribution, uniformity coefficient, and coefficient of curvature were determined from 15 grab samples collected from the initial hand augering of the hole for the placement of the ETN-3 aluminum access tube. The calculated values of d_{10}, d_{30}, d_{50}, d_{60}, uniformity coefficient, and coefficient of curvature for location ETN-3 are presented in Table 1. Uniformity coefficient, C_u, is equal to d_{10}/d_{60},

TABLE 1. Particle Size Distributions

PARTICLE SIZE ANALYSIS

SAMPLE:	ETN3-30	ETN3-60	ETN3-90
DBS(CM):	30.0	60.0	90.0
d10	0.158 (mm)	0.155 (mm)	0.118 (mm)
d30	0.232 (mm)	0.200 (mm)	0.197 (mm)
d50	0.316 (mm)	0.273 (mm)	0.273 (mm)
d60	0.373 (mm)	0.316 (mm)	0.316 (mm)
Cu	2.361	2.039	2.678
Cc	0.913	0.817	1.041

SAMPLE:	ETN3-120	ETN3-150	ETN3-180
DBS(CM):	120.0	150.0	180.0
d10	0.116 (mm)	0.120 (mm)	0.069 (mm)
d30	0.197 (mm)	0.193 (mm)	0.141 (mm)
d50	0.278 (mm)	0.268 (mm)	0.215 (mm)
d60	0.316 (mm)	0.316 (mm)	0.259 (mm)
Cu	2.724	2.633	3.754
Cc	1.059	0.982	1.112

SAMPLE:	ETN3-210	ETN3-240	ETN3-270
DBS(CM):	210.0	240.0	270.0
d10	0.118 (mm)	0.118 (mm)	0.069 (mm)
d30	0.179 (mm)	0.183 (mm)	0.120 (mm)
d50	0.245 (mm)	0.263 (mm)	0.179 (mm)
d60	0.283 (mm)	0.305 (mm)	0.208 (mm)
Cu	2.398	2.585	3.014
Cc	0.959	0.931	1.003

SAMPLE:	ETN3-300	ETN3-330	ETN3-360
DBS(CM):	300.0	330.0	360.0
d10	0.080 (mm)	0.120 (mm)	0.116 (mm)
d30	0.158 (mm)	0.186 (mm)	0.186 (mm)
d50	0.219 (mm)	0.259 (mm)	0.259 (mm)
d60	0.263 (mm)	0.299 (mm)	0.299 (mm)
Cu	3.288	2.492	2.578
Cc	1.187	0.964	0.997

SAMPLE:	ETN3-390	ETN3-420	ETN3-450
DBS(CM):	390.0	420.0	450.0
d10	0.093 (mm)	0.093 (mm)	0.161 (mm)
d30	0.158 (mm)	0.164 (mm)	0.268 (mm)
d50	0.197 (mm)	0.215 (mm)	0.373 (mm)
d60	0.223 (mm)	0.249 (mm)	0.456 (mm)
Cu	2.398	2.677	2.832
Cc	1.204	1.161	0.978

coefficient of curvature, C_c, is equal to $d_{10} \times d_{60}/(d_{30})^2$, and d_j indicates that (j)% of the sample is smaller than this particle diameter. Plots of percent finer versus log particle-size for location ETN-3 are presented in Appendix A. From the sieve analysis it was determined that no samples had more than 10% mass passing the #200 sieve (0.074 mm), thus hydrometer analysis was unnecessary. The low values of uniformity coefficient, coefficient of curvature, and variance of all variables indicates a relatively uniform medium.

Unsaturated hydraulic conductivity was calculated from laboratory tests using hanging columns and a 15 bar pressure plate apparatus. From the laboratory tests, relationships between moisture content and pressure-head for the soils at the study site were calculated from 59 ring samples collected throughout the site at locations ETN1-ETN12. Two samples that had saturated hydraulic conductivities similar to the calculated geometric mean were considered to be representative samples of the soil profile. Soil-moisture characteristic curves for the two representative samples are shown in Figures 33 and 34. The drainage and imbibition curves for the representative samples are combined with all of the calculated theta-psi data in Figures 35a, 35b, 36a, and 36b. Variability in the theta-psi relationships between the two representative samples may be caused by variations in the soil properties of the two samples or sample disturbance during preparation. Sample #22 was taken from a depth of 60 cm and sample #B24 was

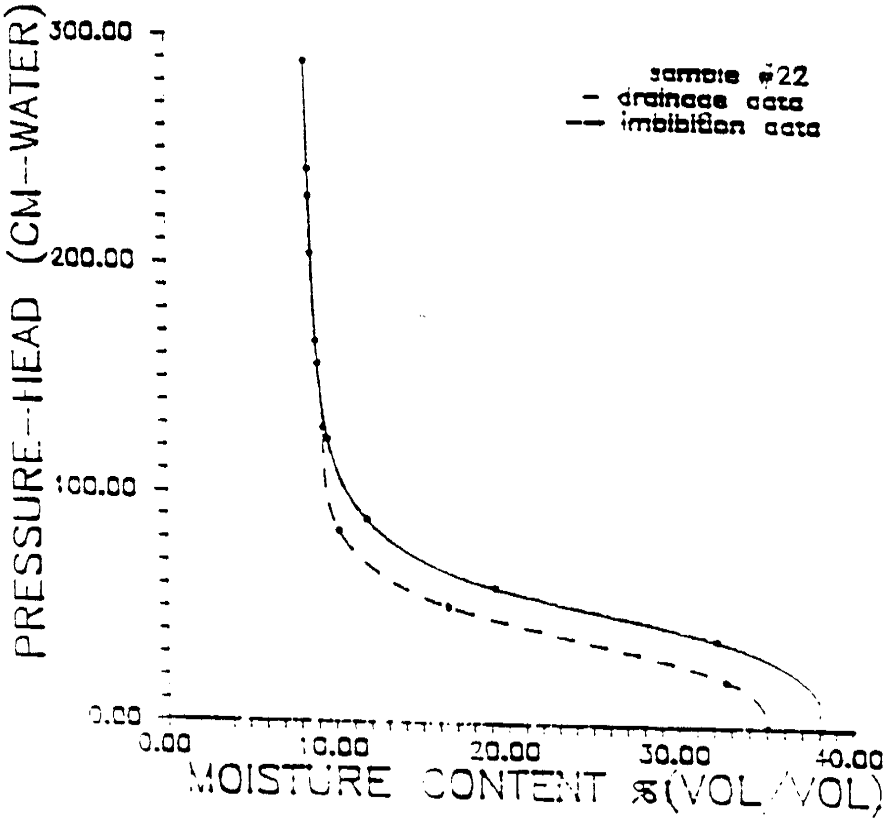


Figure 33 Soil-moisture Characteristic Curve for Sample #22 (60 cm depth)

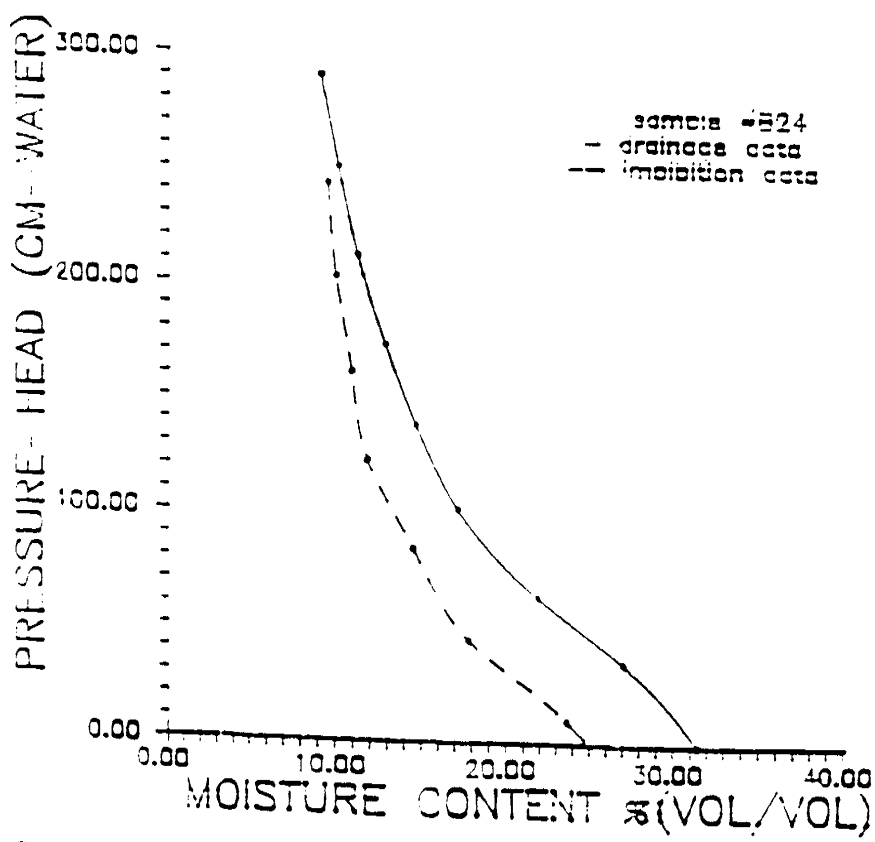
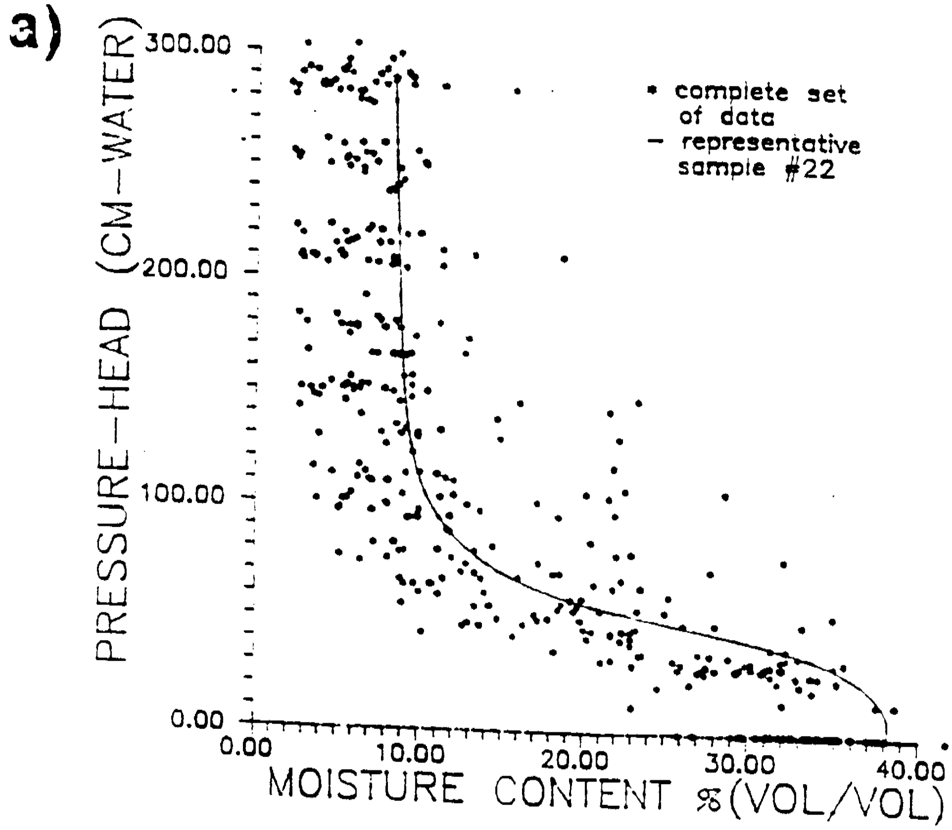


Figure 34 Soil-moisture Characteristic Curve for Sample #B24 (300 cm depth)



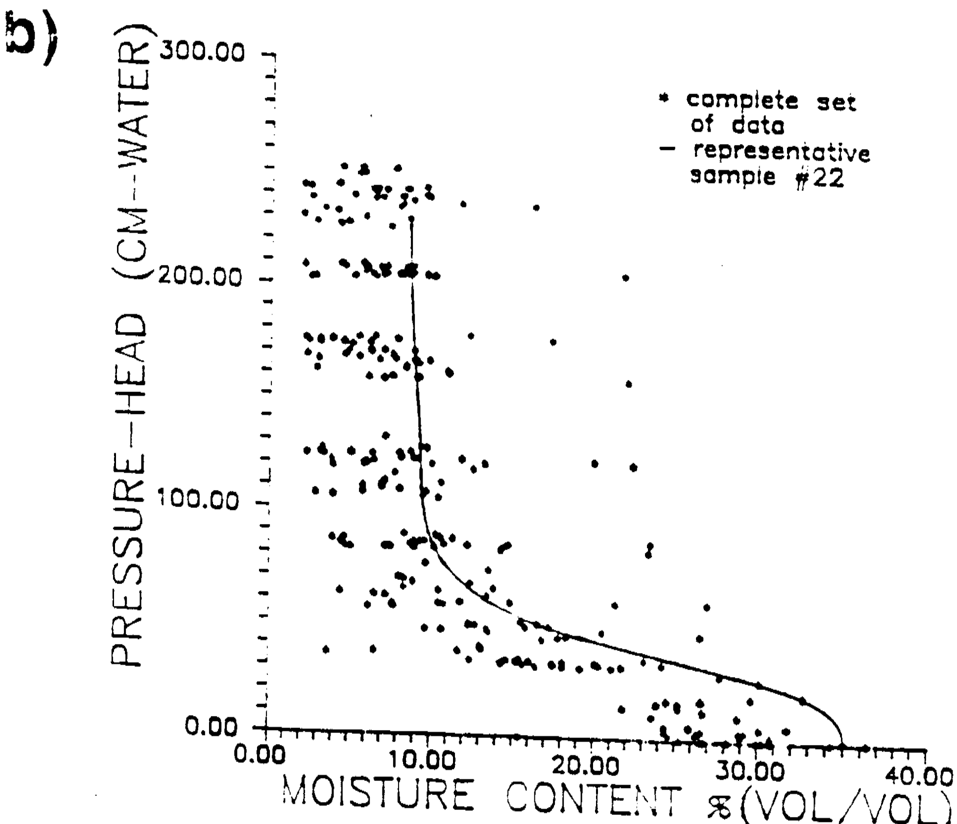


Figure 35 Soil-moisture Characteristic Curves Sample #22 combined With Complete Set of Data a)drainage b)wetting

collected from a depth of 300 cm. Table 2 shows that sample #B24 has a finer particle size distribution than sample #22. The variations in the soil-moisture characteristic curves between representative samples B24 and 22 were believed to be too extreme to use in van Genuchten's computer code of closed-form analytical solutions to approximate $K(\theta)$ versus θ and $K(\Psi)$ versus Ψ relationships that would be characteristic for the entire site.

A second method was employed to estimate an unsaturated hydraulic conductivity that would represent an effective mean of the entire site. In this method, all 59 soil-moisture characteristic curves were combined (Figures 37 and 38). The drainage portions of the characteristic curves were used in van Genuchten's computer code of closed-form analytical solutions to approximate a field average $K(\theta)$ versus θ and $K(\Psi)$ versus Ψ. These results are presented in Appendix A. The values of the fit parameters in van Genuchten's code (α, n, and θ_r) for individual samples and for all samples combined are shown in Table 3. Also shown in Table 3 are the fit parameters estimated from data obtained from a previous instantaneous profile test conducted at the Sevilleta (Stephens and Rehfeldt, 1985). The similarities between the fit parameters from this study and the study cunducted in 1985 suggest that the soil is similar in hydraulic properties, and that the approach to combining all of the soil-moisture characteristic curves into one composite data set is a valid

TABLE 2. Particle Size Distributions for Representative Samples

	Sample #22 60 cm depth	Sample #B24 300 cm depth
d_{10}	0.155 (mm)	0.080 (mm)
d_{30}	0.200 (mm)	0.158 (mm)
d_{50}	0.273 (mm)	0.219 (mm)
d_{60}	0.316 (mm)	0.263 (mm)
Cu	2.039	3.288
Cc	0.817	1.187

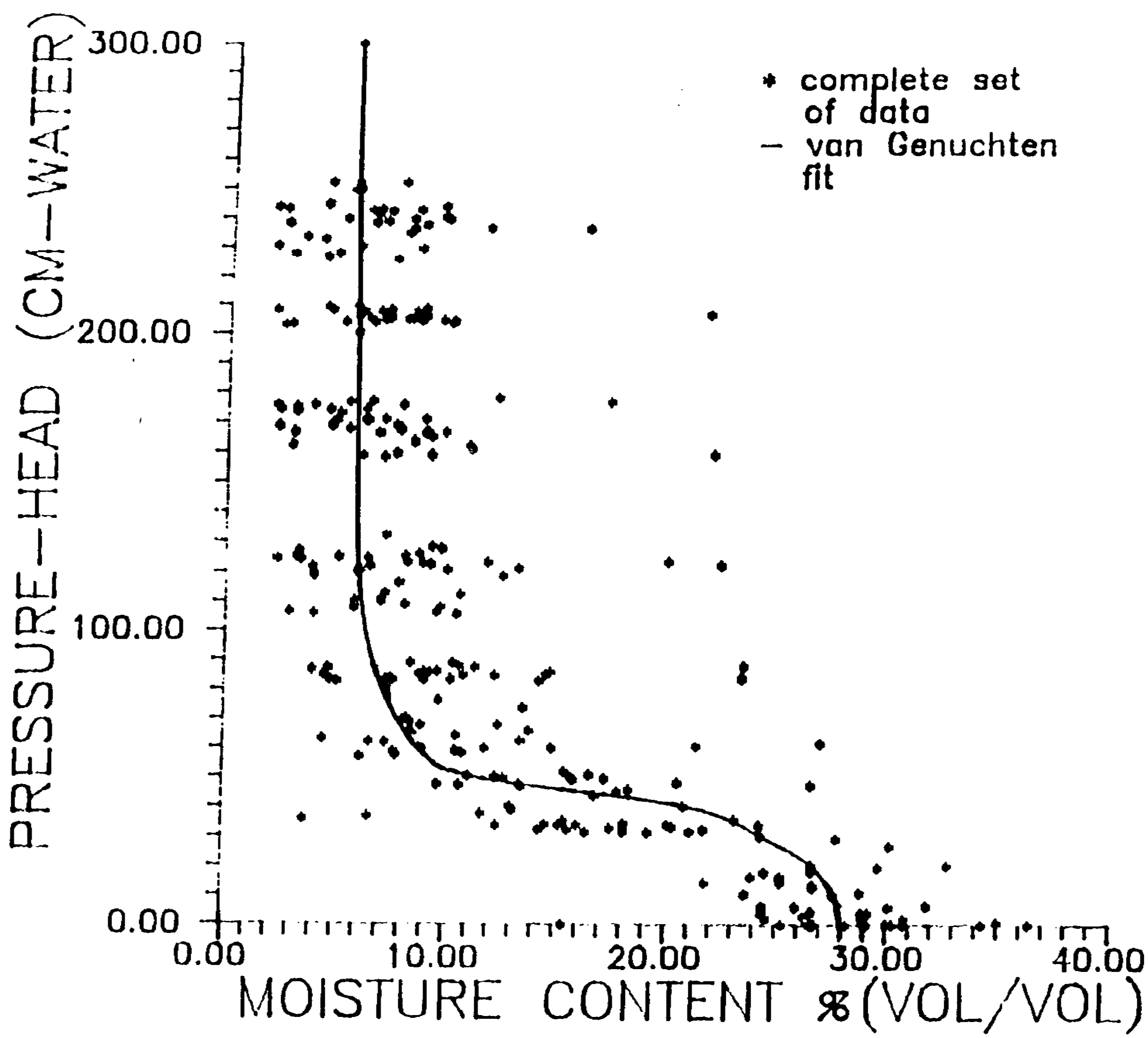


Figure 37 Soil-moisture Characteristic Curve for Complete Set of Data (wetting)

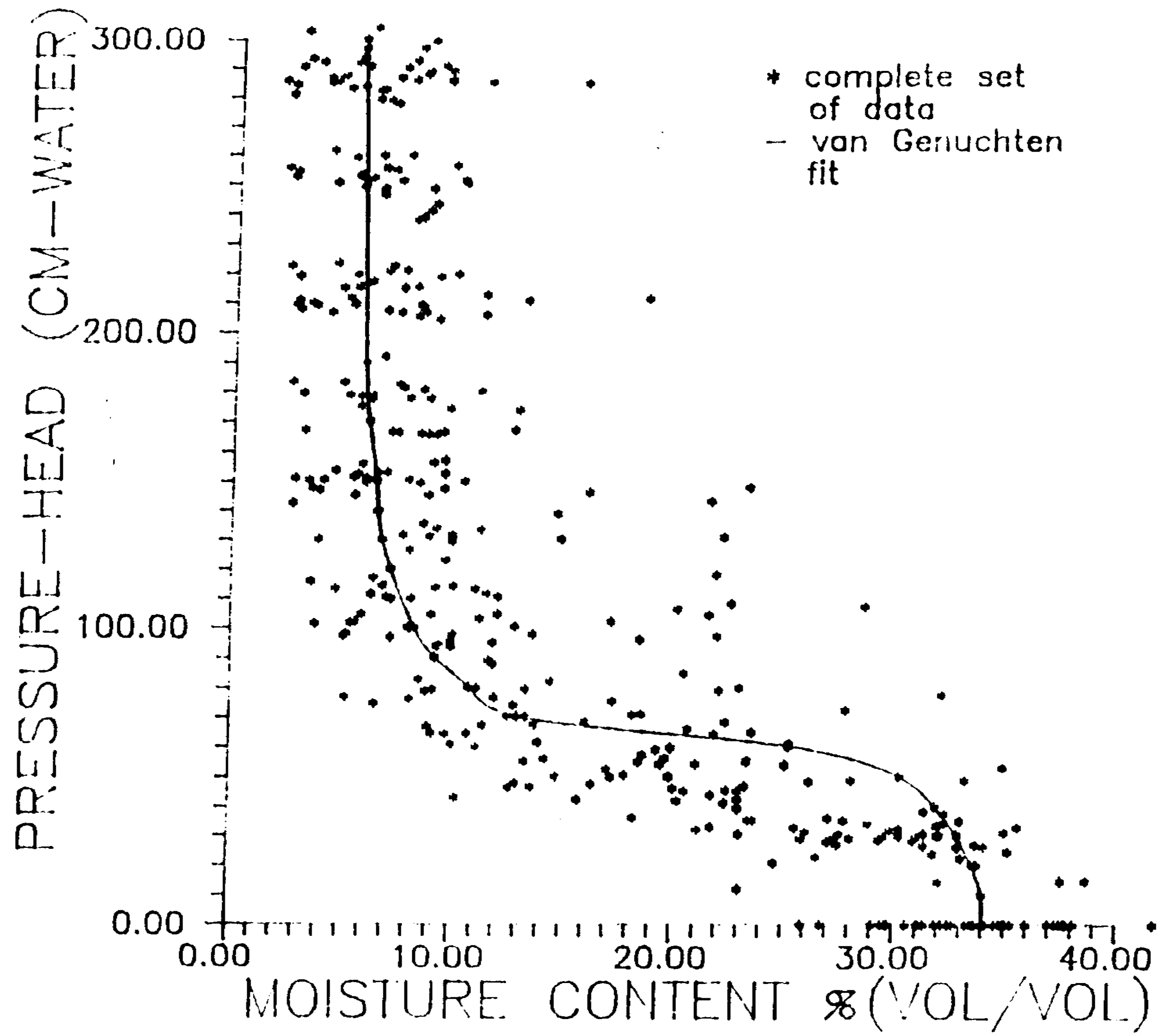


Figure 38 Soil-moisture Characteristic Curve for Complete Set of data (drainage)

TABLE 3. Statistical Analysis of Fit Parameters From Van Genuchten's Computer Model of Closed-form Analytical Solutions

		α (1/cm)	n (0)	θ_r (cm^3/cm^3)
Individual Samples	(mean)	0.0214	2.840	0.0518
	(variance)	$6.2*10^{-6}$	0.131	$2.57*10^{-4}$
Composite Data Set (Drainage)		0.0315	2.324	0.0409
Stephens & Rehfeldt (1985)	(mean)	0.0279	4.05	0.0649
	(variance)	$1.8*10^{-5}$	0.833	$7.10*10^{-4}$

procedure in obtaining an effective mean soil-moisture characteristic curve for the entire site.

Throughout the duration of the project, field moisture contents generally ranged between 3% and 6% in the zone above which influences from the water table were detected. Residual moisture contents calculated from van Genuchten's code for the representative samples (first method) were calculated to be 7.3% for sample #B24 and 5.01% for sample #22. The residual moisture content calculated from van Genuchten's code for the composite data (second method) was found to be 4.1%. These residual moisture contents are very close to the moisture contents measured in the field with the neutron probe. For this reason, a $K(\theta)$ vs θ relationship, developed from van Genuchten's code, could not be used to estimate recharge for the site.

The problem could have originated in laboratory error during the initial measurement of the soil-moisture characteristic curves, or the use of an incorrect calibration equation for the neutron probe. Laboratory errors could have included; improper saturation of the ring samples before being placed on the hanging columns, improper contact between the soil samples and porous plate of both the hanging columns and pressure plate apparatus, disturbing the soil samples during the laboratory tests, and not allowing enough time to reach equilibrium in both the hanging column and pressure plate experiments. The calibration equation that was used was developed by McCord, (1986) at the Sevilleta National Wildlife Refuge. This calibration equation could be producing false low readings of moisture content within the soil profile. If the readings were actually higher, then an estimate of recharge based on van Genuchten's code could be accomplished.

Another possibility is that moisture movement within the vadose zone at the Sevilleta occurs during short intense rain storms when the moisture content within the upper vadose zone temporarily exceeds the residual moisture content of the soil. Thus, moisture movement within the vadose zone at the Sevilleta may be limited to periods when the moisture contents in the vadose zone are temporarily increased due to infiltration of precipitation which displaces some of the antecedent water within the soil.

Pressure heads calculated from the results of tensiometer readings averaged approximately -100 cm (Hicks, 1989). This pressure head corresponds to estimated moisture contents from van Genuchten's code of between 9% and 11% for both the composite data set (Figure 38) and sample #22 (Figure 35a). Sample #B24 had a corresponding moisture content of between 15% and 16% at a pressure head of -100 cm (Figure 36a). All of these moisture contents are significantly greater than those observed in the field. Field moisture contents generally ranged between 3% and 6%, which corresponds to estimated pressure heads from van Genuchten's code of between -2.7×10^4 and -2.5×10^2 cm for both the composite data set and representative sample #22. Representative sample #B24 has a higher residual moisture content than that observed in the field. These discrepancies could be due to problems encountered with the tensiometers in the field. Also, as dicussed previously, laboratory errors during the initial measurement of the soil-moisture characteristic curves, or the use of an incorrect calibration equation for the neutron probe may be the cause of the discrepancies. Problems with the tensiometers included temperature effects, leaky tensiometers, and the use of ethylene glycol as the solution within the tensiometers. For a detailed discussion of the problems associated with the use of tensiometers at the Sevilleta, see Hicks (1989).

Field Monitoring

Data collected at the research site was used to examine various hydrological processes that were occurring throughout the duration of the project. Precipitation was found to be highly variable from season to season, with the wettest period occurring in the months of July, August, and September. Figure 39 shows precipitation versus time for the period starting in 12/87 and ending in 8/89. Precipitation totaled 18.0 cm for 1988, and 7.4 cm occurred from January through August 1989. A historical list of precipitation recorded at the Sevilleta is presented in Table 4. Missing months are periods of time in which precipitation was not recorded.

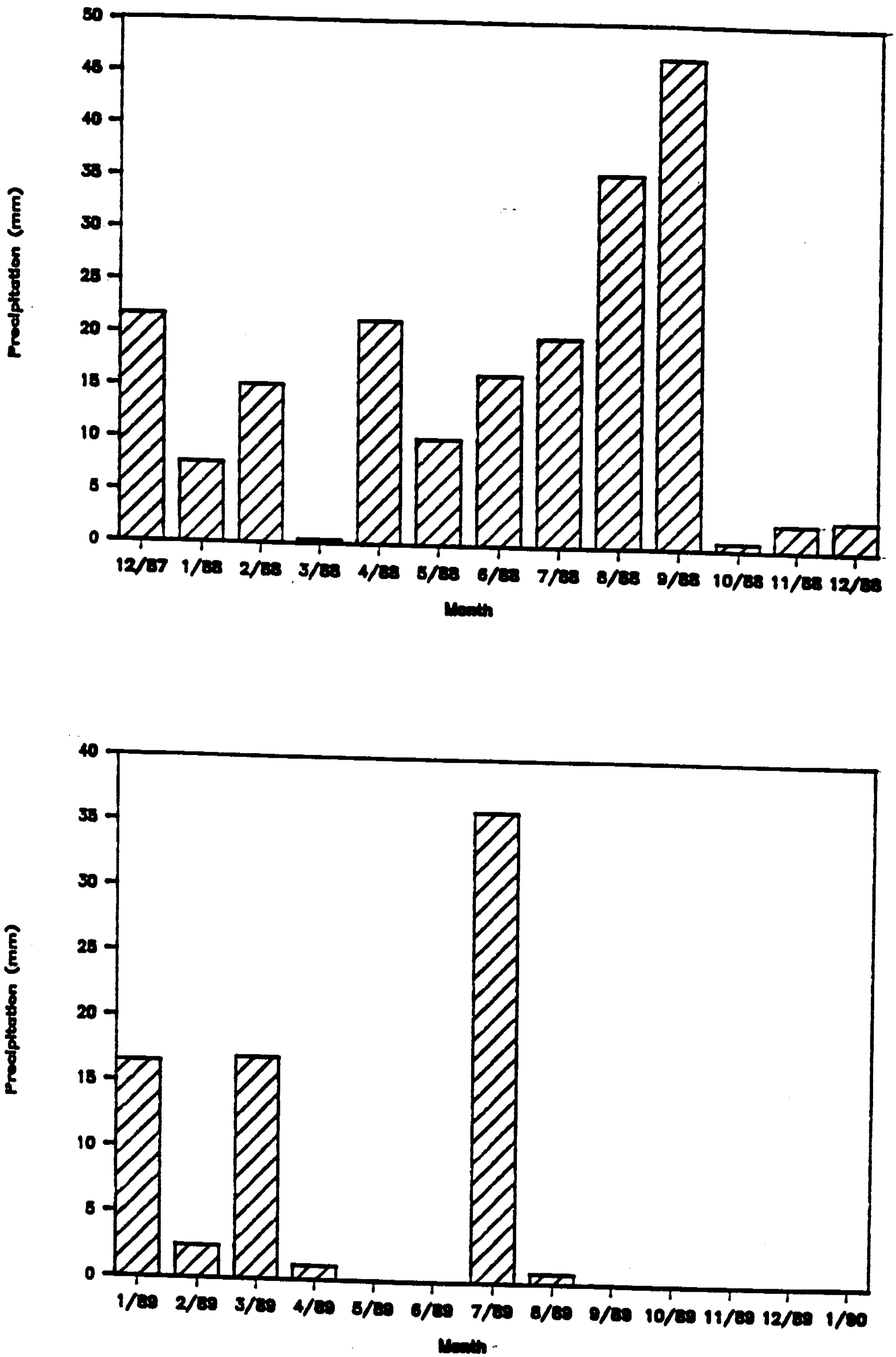


Figure 39 Precipitation Recorded at the Sevilleta From 12/87 to 8/89

TABLE 4. Measured Precipitation at the Sevilleta

Date	Precip. (mm)	Date	Precip. (mm)	Date	Precip. (mm)	Date	Precip. (mm)	Date	Precip. (mm)	Date	Precip. (mm)	Date	Precip. (mm)	Date	Precip (mm)	Month	Monthly Avg.Precip (mm)
		*01/83	44.5	*01/84	7.8	*01/85	3.9	*01/86	5.8	1/87	---	1/88	7.5	1/89	16.5	1	14.33
		*02/83	31.2	*02/84	0.0	*02/85	3.5	*02/86	5.8	2/87	---	2/88	15.0	2/89	2.5	2	9.67
		*03/83	7.85	*03/84	0.4	*03/85	18.3	*03/86	2.3	3/87	---	3/88	0.5	3/89	17.0	3	7.72
		*04/83	3.3	*04/84	0.4	*04/85	19.6	*04/86	2.0	4/87	---	4/88	21.0	4/89	1.5	4	7.97
		*05/83	7.0	*05/84	0.0	*05/85	8.8	*05/86	22.1	5/87	---	5/88	9.0	5/89	0.0	5	7.82
		*06/83	5.7	*06/84	5.8	*06/85	11.6	*06/86	28.8	6/87	---	6/88	15.5	6/89	0.0	6	11.23
		*07/83	10.5	*07/84	2.8	*07/85	15.0	*07/86	17.8	7/87	---	7/88	19.9	7/89	36.0	7	17.0
		*08/83	17.9	*08/84	15.3	*08/85	21.8	*08/86	20.1	8/87	---	8/88	35.0	8/89	1.0	8	18.52
		*09/83	60.9	*09/84	22.3	*09/85	25.0	*09/86	30.5	9/87	---	9/88	47.0			9	37.14
		*10/83	12.4	*10/84	52.5	*10/85	63.2	*10/86	28.0	10/87	---	10/88	1.0			10	31.42
*11/82	18.3	*11/83	9.5	*11/84	17.2	*11/85	2.4	*11/86	17.5	11/87	---					11	11.23
*12/82	32.3	*12/83	5.1	*12/84	31.5	*12/85	---	*12/86	8.0	12/87	22.0					12	16.98

<u>Yearly Averages (cm)</u>

1983	17.99
1984	13.00
1985	17.56
1986	15.73
1988	14.74

* Knowlton, R.G., 1984, Kickham, B.J., 1987, and McCord, J., 1986

It can be seen from Table 4 that precipitation was greater in August of 1988 (35.0 mm) than in August of 1985 (21.8 mm). The strong lateral soil-moisture flows detected toward a lavender bush (Figure 3) by Kickham (1987), could have been the result of increased plant water uptake due to the drier conditions that were present in August of 1985 when the lavender bush data was collected. Drier conditions increase the amount of stress on plants and as a result the plants roots increase the amount of water that is withdrawn from the soil.

Precipitation patterns during the months in which the tracer test was conducted (August through January), and the months immediately prior to the tracer test, appear to be characteristic of the previous years during which precipitation was recorded. For example, it can be seen from Table 4 that the maximum variation in precipitation for the months in which the tracer test was performed occurred between the years of 1985 and 1988 and only amounted to 1.32 cm. This suggests that the tracer test was performed during a period that exhibited precipitation patterns similar to previous years at the Sevilleta.

Monthly potential evaporation data for 1988 are shown in Figure 40, based on measurements of pan evaporation corrected with a class A pan coefficient of 0.7. During 1988, the total potential lake evaporation was calculated to be 116.64 cm. It is evident that although precipitation was high during August

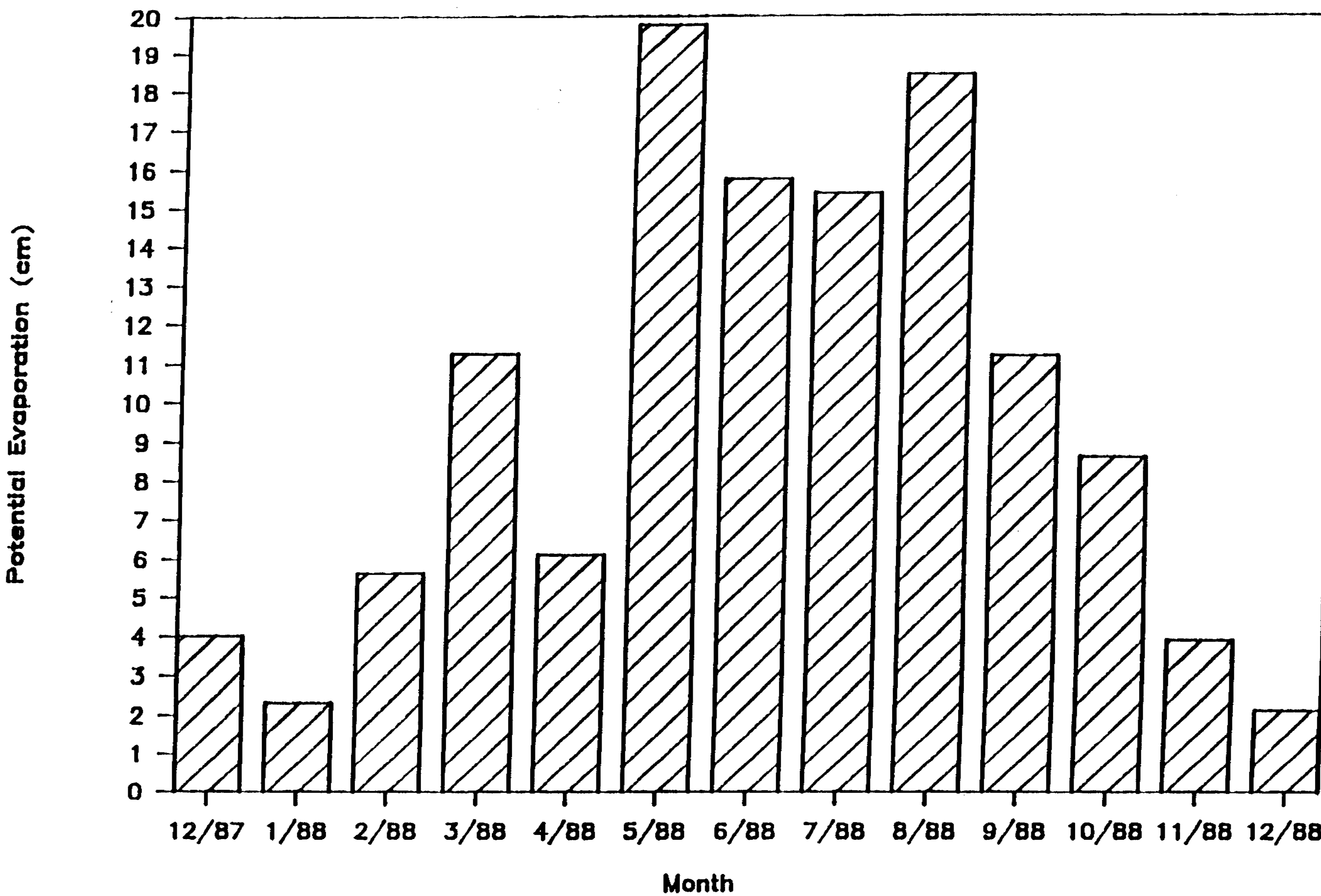


Figure 40. Monthly Potential Evaporation at the Sevilleta From 12/87 to 12/88

and September of 1988, potential evaporation during this same period was a factor of approximately 4 greater. These results seem to suggest that although precipitation was high during August and September of 1988, that evaporation from the upper layers of soil may significantly reduce the amount of moisture infiltrating at depth. The ratio of potential evapotranspiration to precipitation for 1988 was calculated to be approximately 6.5 to 1. On a monthly basis, potential evapotranspiration always exceeded precipitation at the site. Maximum and minimum temperatures for each month are presented in Figures 41a, 41b, 41c, and 41d. It is not uncommon for temperatures to exceed 38 °C during portions of the summer and fall to below freezing in the winter months.

The moisture content data used in this study was collected by means of neutron logging. Readings were taken at a count rate of 16 seconds. At this count rate, the standard deviation of the reading ranges between 2.6% and 2.9% of the reading itself. This deviation was determined by taking a series of 30 consecutive neutron probe readings at a depth of 90 cm within the ETN-5 access tube. The moisture content readings ranged from 2.9% to 3.2% by volume (Table 5). Although this method does not provide for point measurements of moisture contents, it is a rapid and dependable method of obtaining average moisture contents in a sphere about the neutron source. Observing changes in moisture throughout the study period (Appendix B) offered insights into seasonal and

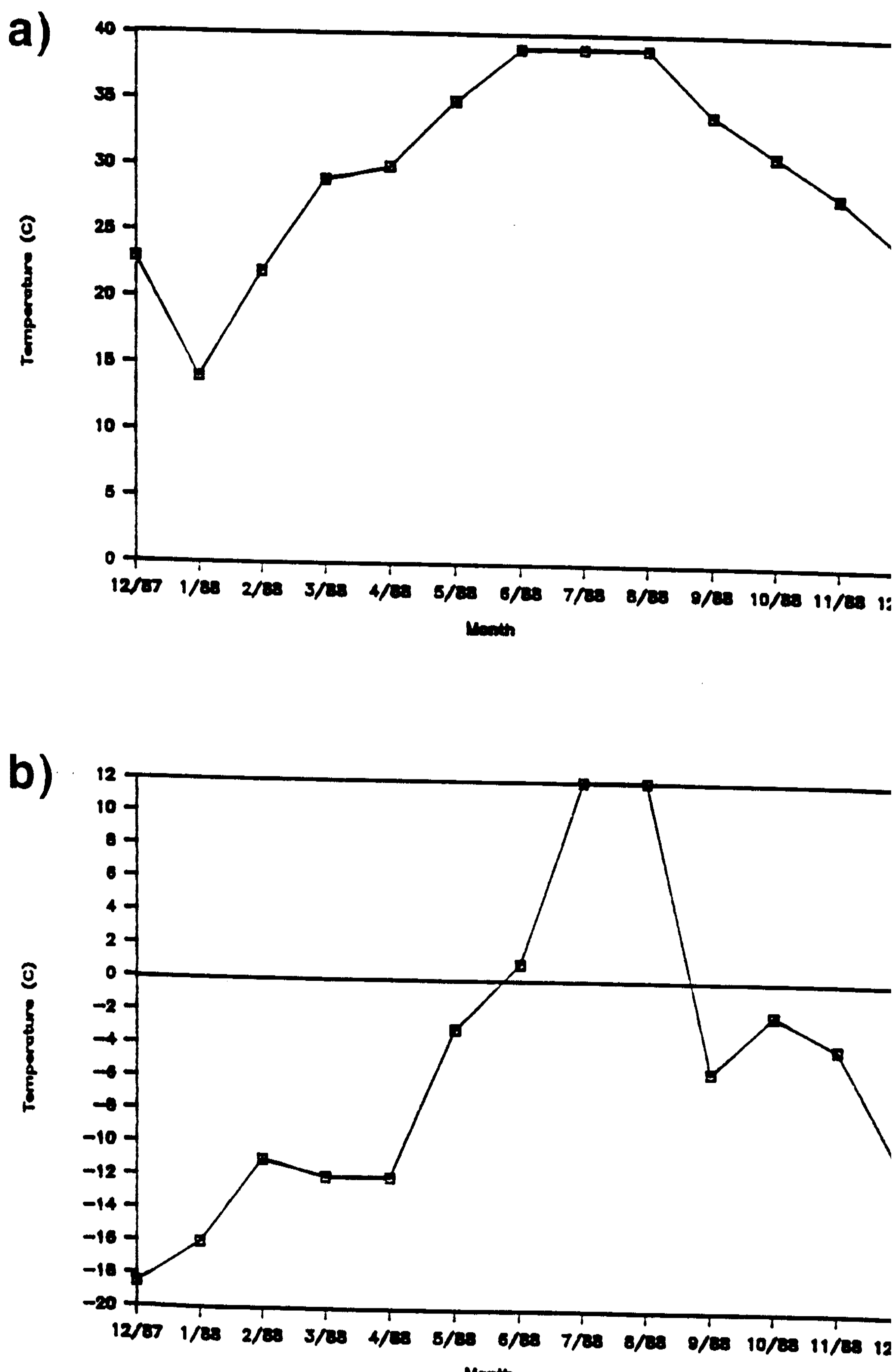
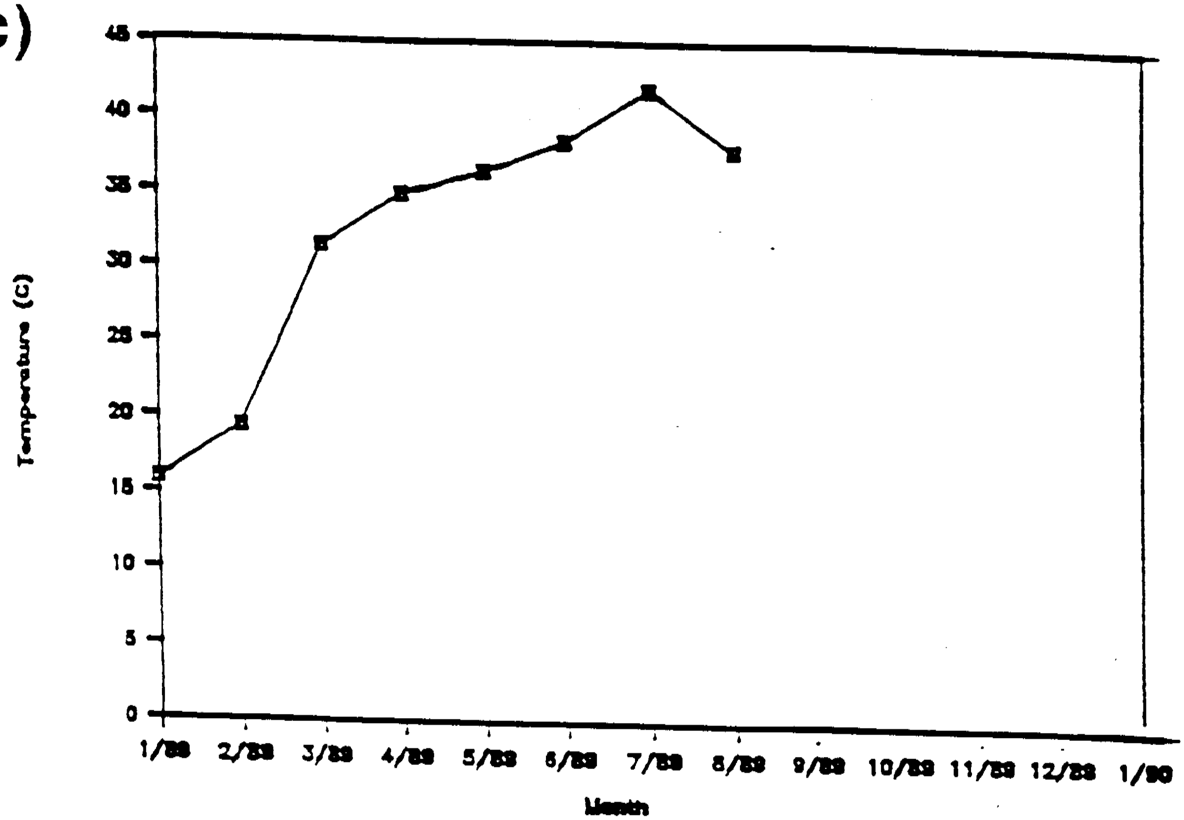


Figure 41. Monthly a)Maximum and b)Minimum Temperatures at the Sevilleta From 12/87 to 12/88.

c)



d)

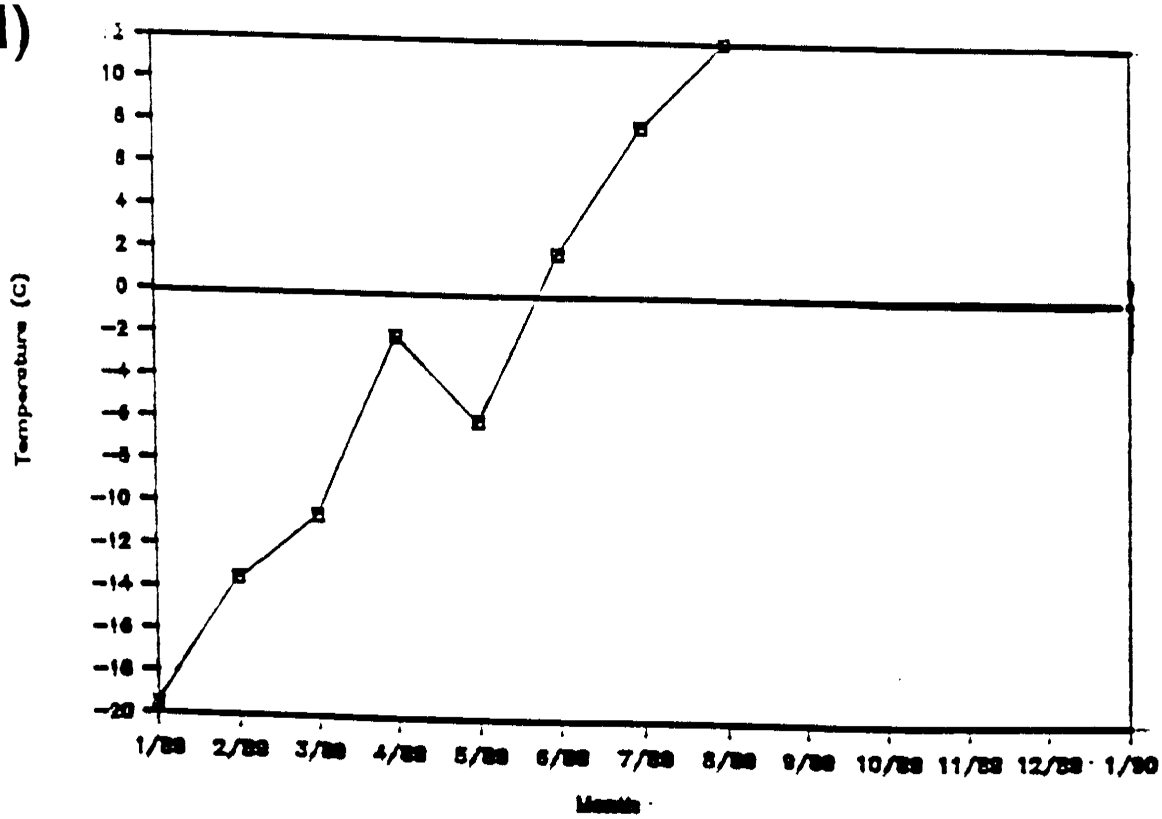


Figure 41 Monthly c)Maximum and d)Minimum Temperatures at the Sevilleta From 1/89 to

Table 5. Nuetron probe moisture contents measured from the same point and time.

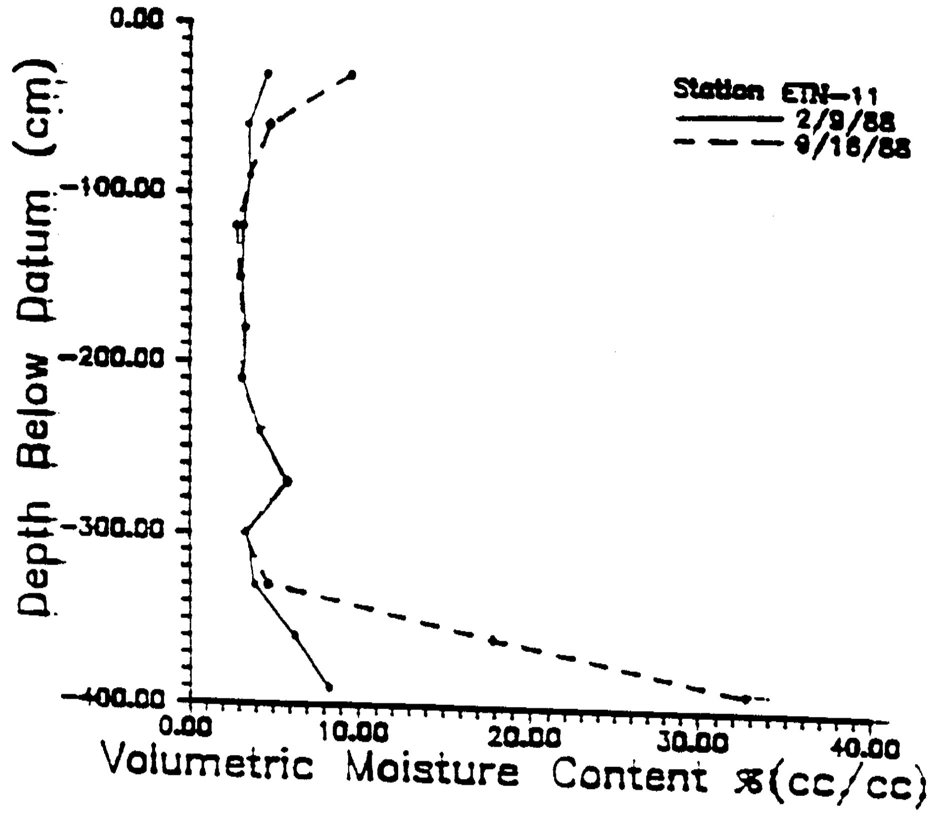
Reading #	% Moisture by Volume	Reading #	% Moisture by Volume
1	3.1	16	3.0
2	3.2	17	3.1
3	3.2	18	3.1
4	3.1	19	3.2
5	3.0	20	3.1
6	3.1	21	3.1
7	2.9	22	3.1
8	2.9	23	3.2
9	3.0	24	3.1
10	3.2	25	3.0
11	3.2	26	3.0
12	3.0	27	3.0
13	3.1	28	3.1
14	3.0	29	3.1
15	3.0	30	3.1

Mean moisture content % vol 3.077

Population standard deviation 0.0844

spatial variabilities in soil-water movement. Moisture content reveals information about moisture losses and gains caused by infiltration, evaporation, and redistribution.

Seasonal variabilities in moisture contents were observed throughout the soil profile. Figure 42a and 42b show moisture content profiles during the summer and winter from two different locations. It is evident that the two profiles are very similar in moisture content versus depth and time. The greatest seasonal variations in moisture contents are detected in the upper 90 cm and lower 300 cm of soil. Variations in the upper 90 cm are attributed to the heavy rains of the late summer. It appears that infiltration from the precipitation events only caused increased moisture within the upper 90 cm of soil. This is further evidenced by Figure 43. This figure presents data collected from access tube location ETN-1 before and after a heavy period of precipitation. During this period, 7/20/89 to 8/8/89, a total of 36.8 mm of rain fell to the surface (approximately 20% of the annual precipitation in 1988), yet moisture content increases were only evident in the upper 60 cm of the soil profile. With no evidence of moisture content increases deeeper than 60 cm as a result of the precipitation events, it is apparent that the precipitation, and associated displaced antecedent water, only penetrated to a depth of 60 cm. The seasonal variation in moisture content observed below 300 cm is due to fluctuations in water table elevation. During the rainy season the Rio Salado, an a)



b)

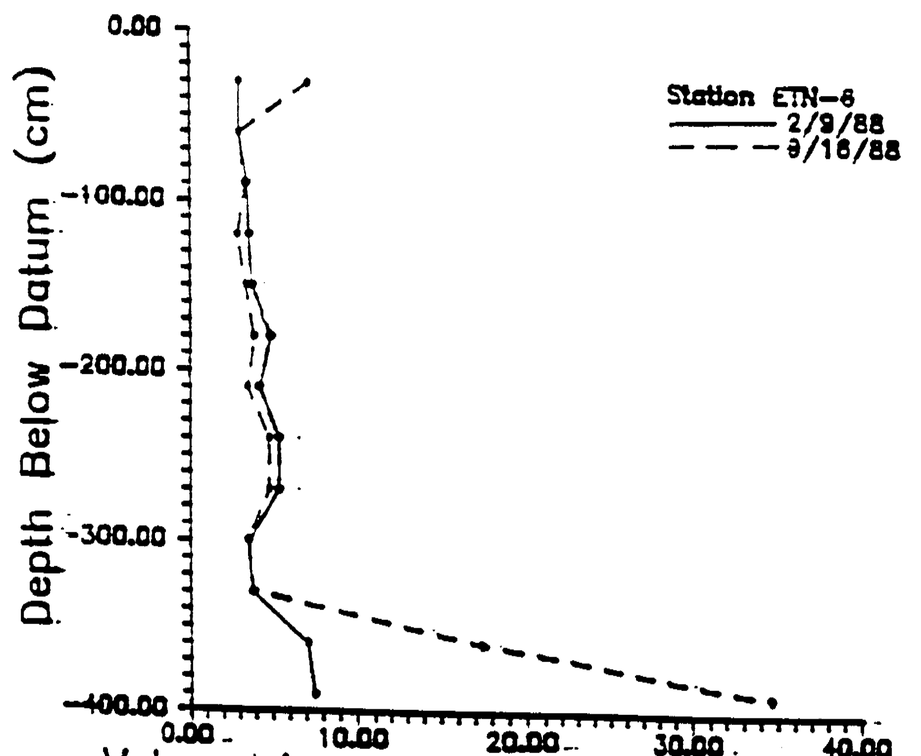


Figure 42 Soil-moisture content profiles determined from the neutron probe. a)ETN-11 b)ETN-6

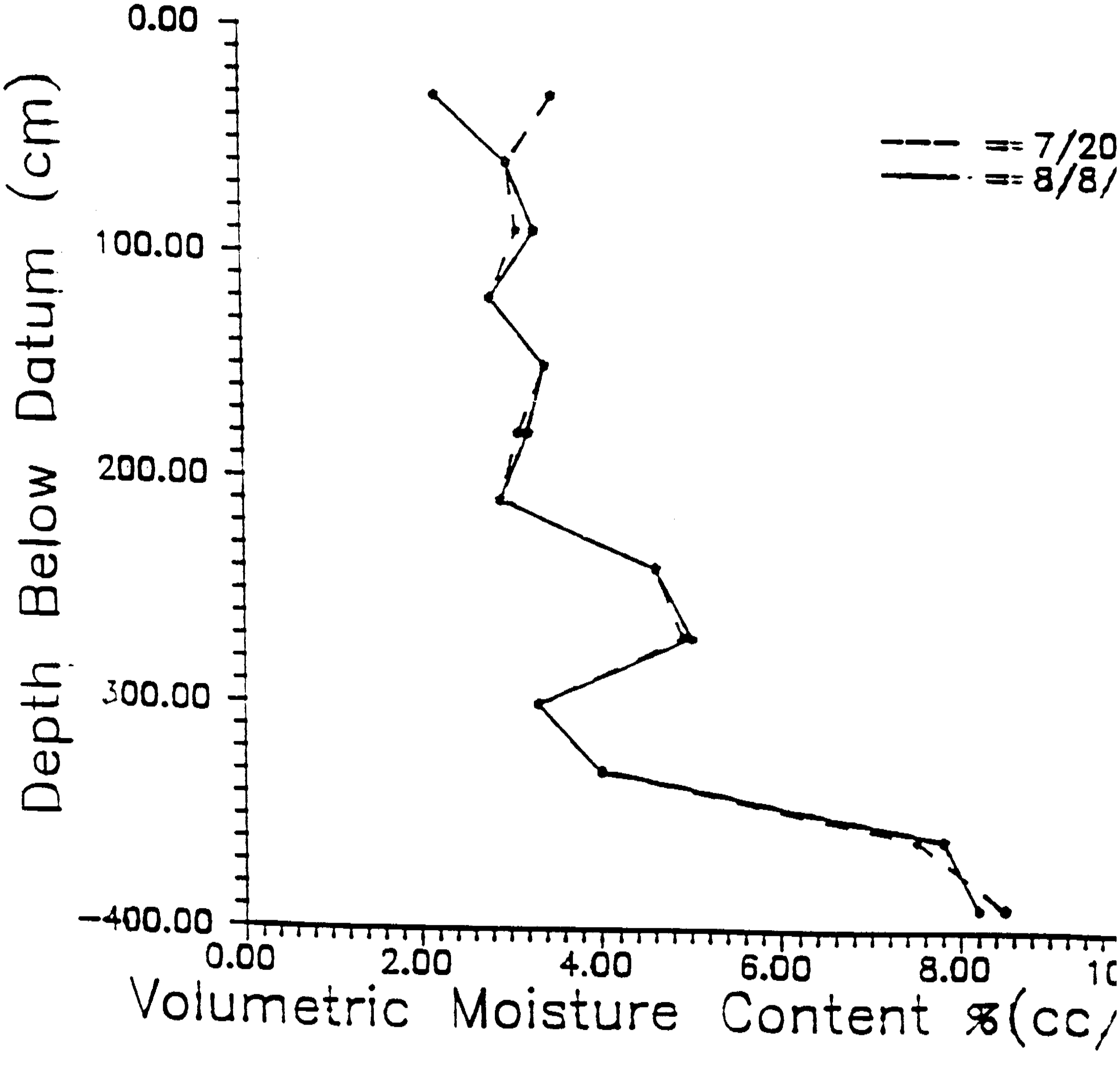


Figure 43 Soil-moisture content profile after heavy precipitation events.

ephemeral stream located approximately 25 m to the north of the field site, commonly flows for periods of days to weeks. During this time the stream is hydraulically connected to the shallow water table below, and as a result the water table slowly rises. Similar results were observed in a study conducted by Cox (1987). In this study, the water table at the Sevilleta was observed to fluctuate by as much as a meter due to recharge from the Rio Salado.

Between 60-300 cm the moisture content profiles from the two locations are very similar in appearance. There is no evidence of seasonal variations in moisture content within this interval, but it is apparent that spatial variations are present. This is evident at the 270 cm depth were an increase in moisture content is observed in both the summer and winter months. This increase in moisture content is believed to be caused by a textural discontinuity that occurs at approximately 270 cm depth. At this depth a mixed fine sand and silt layer was detected during an excavation that took place at the end of the project (Figure 44a and 44b). This textural discontinuity was also evident in particle size analysis, in which the 270 cm depth sample had a finer texture than samples analyzed above and below this depth. The general lack of lateral variations in moisture content indicate that the desert vegetation has little effect on the moisture content distribution within the study site. This suggests that either the desert plants do not use much water at all, or

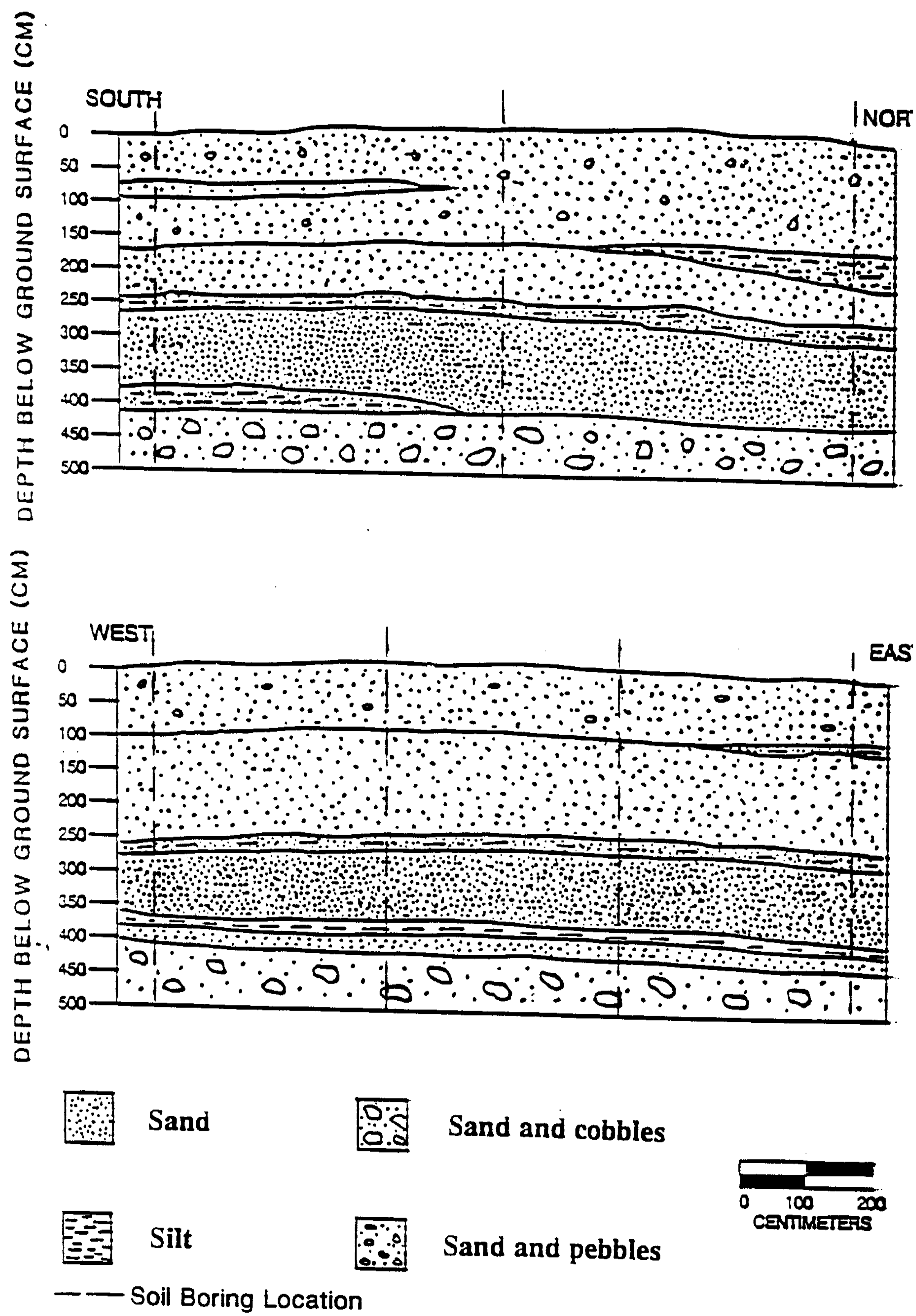


Figure 44 Geologic cross section of site through the center of the plot, south to north (top), and west to east (bottom).

they take up water and this water is quickly replaced by surrounding soil-water.

The hydraulic head data that was used in this study was collected by means of porous-cup tensiometers. This data was used to examine possible variations in soil-water flow within the field site. These variations include: seasonal and spatial variations due to plant water uptake, and spatial variations due to stratification.

Total head fields for the winter, summer, spring, and fall months of 1988 and 1989 are shown in Figures 19, 20, 21, and 22. The total head fields show a lack of lateral soil-moisture movement due to plant water uptake. This is consistent with moisture content observations in which moisture contents were found to be uniform laterally (Figures 45, and 46). This is in direct contrast to results obtained from a previous study at the Sevilleta by Kickham (1987). In that study, lateral soil-water movement due to plant water uptake was detected during the desert plants active growing season. It was observed during our excavation project that plant roots were distributed in a random fashion, with no apparent relationship between root density and distance from the vegetation. Because the roots were distributed in a complex fashion without distinct root layers, and precipitation was relatively greater in August 1988, it is believed that strong lateral flows toward the desert vegetation were not occurring during the period of monitoring

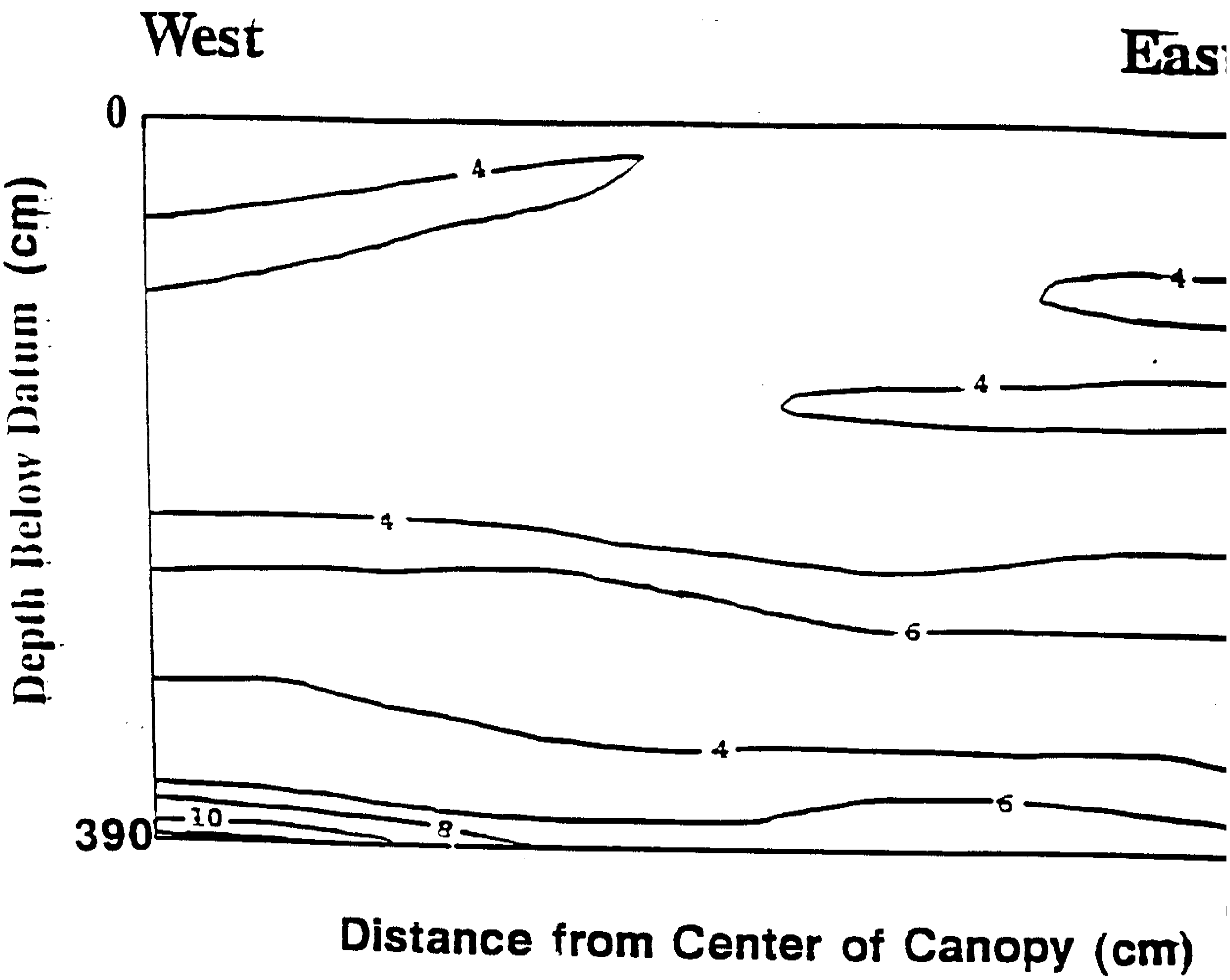


Figure 45 Soil-moisture content cross section on August 20, 1988 from neutron access tubes ETN 2, 5, 8, and 11 (Hicks, 1989)

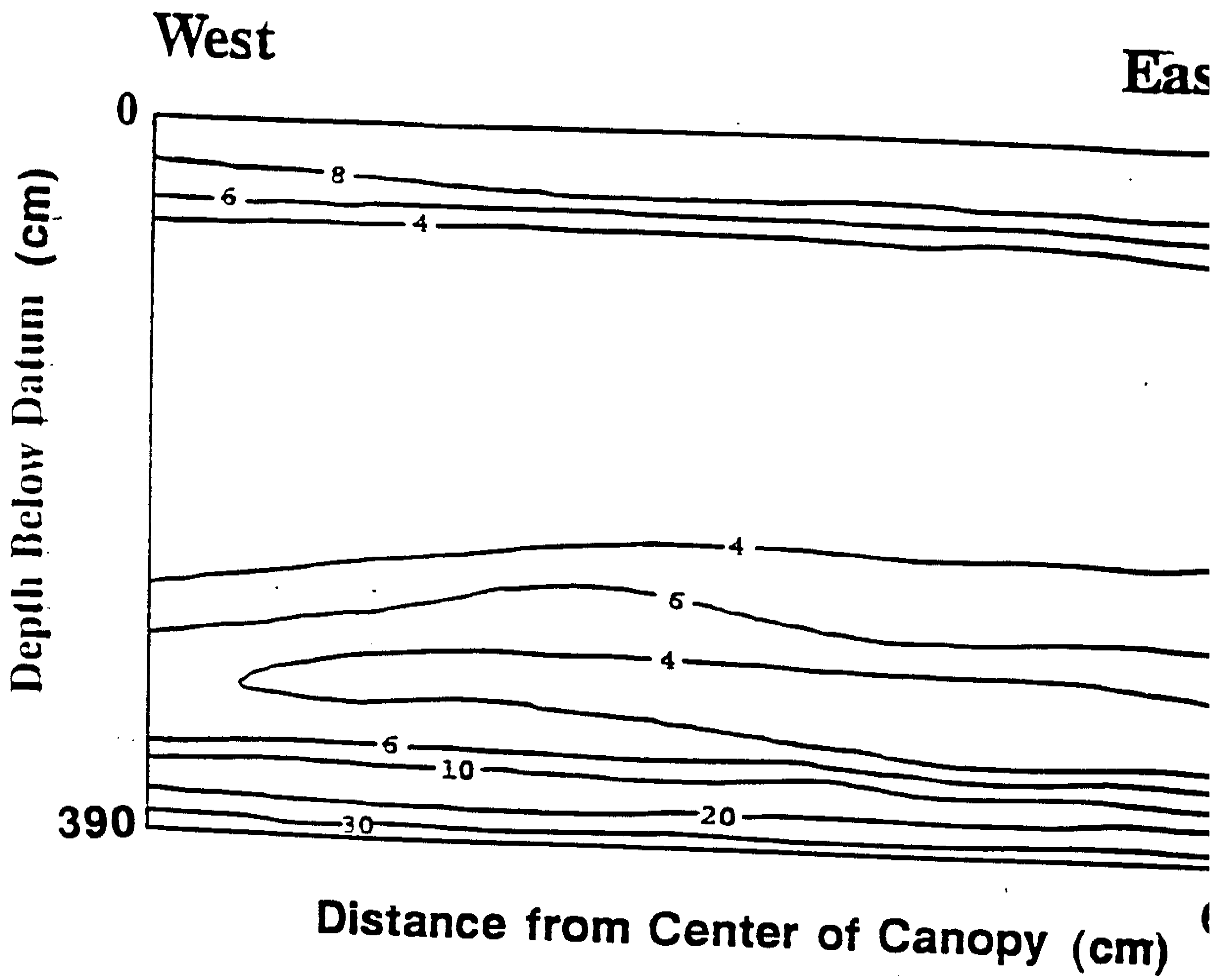


Figure 46 Soil-moisture content cross section on September 16, 1988 fro neutron access tubes ETN 2, 5, 8, and 11 (Hicks, 1989).

in the present study. In another study at the Sevilleta, strong lateral flow was detected on a hillslope (McCord, 1986). Due to the relative level surface at the study site, lateral flows due to topography were also negligible.

Seasonal and spatial variations in soil-moisture flow were detected from pressure head data. Upward movement of soil-moisture was observed in the upper 60 cm of the soil profile at a location directly adjacent to a row of salt-bush (Figure 47). This figure is a vertical cross-section of the total head field on September 2, 1988, during the active growing season. Throughout the rest of the profile, the hydraulic head gradient is approximately unity, indicating vertically downward flow. The results of the cell method (Figure 26) of calculating soil-moisture flow directions (Hicks, 1989), also indicated that upward flow was occurring at approximately 60 cm depth during August and September of 1988 (Figure 48). This upward movement was detected in the same vicinity as in Figure 47. During the winter, spring, early summer, and fall months, a hydraulic head gradient of nearly unity existed in the soil (Figures 19, 20, 21, and 22). The results of the hydraulic head measurements suggest that vertically downward hydraulic head gradients exist for the majority of the year, with upward soil-water movement taking place in the vicinity of the salt-bush during short periods of the summer. Significant spatial variations in hydraulic head due to textural discontinuities were not detected. For a more

STATION ETN-4

NEUTRON TUBE DATA

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DEPTH BELOW DATUM(CM)							
30.0	8.8	8.9	8.9	7.9	6.3	5.5	4.8
60.0	8.4	8.5	8.6	7.7	6.8	6.0	5.9
90.0	5.7	5.9	5.9	5.9	5.8	5.8	5.7
120.0	5.7	5.5	5.5	5.7	5.6	5.4	5.5
150.0	6.5	6.5	6.6	6.6	6.6	6.4	6.5
180.0	6.5	6.6	6.5	6.7	6.6	6.5	6.6
210.0	6.1	6.0	5.9	5.9	6.1	5.7	5.9
240.0	10.4	10.4	10.2	10.4	10.6	10.4	10.4
270.0	11.2	11.2	11.0	11.0	11.1	10.9	11.1
300.0	6.3	6.5	6.3	6.2	6.5	6.4	6.4
330.0	8.9	8.4	8.2	8.2	8.2	7.8	7.8
360.0	10.9	10.4	10.0	10.2	9.8	9.4	9.2
390.0	17.5	16.9	15.3	15.0	14.7	13.8	12.6
420.0	17.1	16.1	13.6	12.8	11.9	10.9	10.0
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME ETN-4	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DPTH BELOW DATUM(M)							
30.0	4.8	4.9	4.9	4.2	3.1	2.6	2.2
60.0	4.6	4.6	4.7	4.1	3.4	2.9	2.8
90.0	2.7	2.9	2.8	2.8	2.8	2.8	2.7
120.0	2.8	2.6	2.6	2.7	2.7	2.5	2.6
150.0	3.2	3.2	3.3	3.3	3.3	3.2	3.3
180.0	3.2	3.3	3.3	3.4	3.3	3.3	3.3
210.0	3.0	2.9	2.9	2.9	3.0	2.7	2.9
240.0	6.1	6.0	5.9	6.0	6.2	6.0	6.1
270.0	6.7	6.6	6.5	6.5	6.6	6.5	6.6
300.0	3.1	3.2	3.1	3.1	3.3	3.2	3.2
330.0	4.9	4.6	4.4	4.4	4.4	4.2	4.2
360.0	6.4	6.1	5.7	5.9	5.6	5.3	5.2
390.0	12.0	11.5	10.1	9.8	9.6	8.8	7.8
420.0	11.7	10.8	8.6	7.9	7.2	6.5	5.7
450.0							
480.0							

STATION ETN-5

NEUTRON TUBE DATA

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DEPTH BELOW							
DATUM(CM)							
30.0				6.6	6.4	6.5	6.
60.0				6.1	6.3	6.4	6.
90.0				6.0	5.9	6.2	6.
120.0				5.9	5.9	5.8	5.
150.0				6.4	6.4	6.6	6.
180.0				6.2	6.1	6.3	6.
210.0				6.3	6.2	6.3	6.
240.0				9.4	9.6	9.6	9.
270.0				9.8	9.7	9.7	10.
300.0				7.0	7.1	7.1	7.
330.0				7.0	6.8	7.0	7.
360.0				9.7	9.8	9.6	9.
390.0				11.7	12.2	11.8	11.
420.0				12.4		12.9	
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME ETN-5	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DPTH BELOW							
DATUM(M)							
30.0				3.3	3.2	3.3	3.
60.0				3.0	3.1	3.2	3.
90.0				2.9	2.9	3.1	3.
120.0				2.8	2.9	2.8	2.
150.0				3.2	3.2	3.3	3.
180.0				3.1	3.0	3.1	3.
210.0				3.1	3.1	3.1	3.
240.0				5.3	5.4	5.4	5.
270.0				5.6	5.5	5.5	5.
300.0				3.6	3.7	3.7	3.
330.0				3.6	3.5	3.6	3.
360.0				5.5	5.6	5.5	5.
390.0				7.1	7.5	7.1	7.
420.0				7.7		8.1	
450.0							
480.0							

STATION ETN-5

NEUTRON TUBE DATA

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DEPTH BELOW DATUM(CM)							
30.0	6.4	5.8	5.7	5.5	5.4	5.5	5.
60.0	6.1	6.1	6.1	5.8	5.9	5.9	5.
90.0	6.0	6.0	5.9	5.7	5.8	5.8	5.
120.0	5.9	6.0	5.9	5.6	5.7	5.5	5.
150.0	6.2	6.1	6.3	6.5	6.3	6.5	6.
180.0	6.4	6.3	6.2	6.0	6.2	6.2	6.
210.0	6.4	6.4	6.4	6.4	6.3	6.2	6.
240.0	9.6	9.4	9.7	9.5	9.3	9.3	9.
270.0	9.3	9.6	9.6	9.5	9.6	9.8	9.
300.0	6.9	6.7	7.2	6.9	7.0	6.8	6.
330.0	7.2	6.9	6.6	6.8	6.7	6.5	6.
360.0	9.4	9.2	9.1	9.0	9.0	8.9	8.
390.0	11.5	11.4	11.6	11.5	11.3	10.9	13.
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME ETN-5	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DPTH BELOW DATUM(M)							
30.0	3.2	2.8	2.7	2.6	2.5	2.6	2.
60.0	3.0	3.0	3.0	2.8	2.9	2.8	2.
90.0	3.0	2.9	2.9	2.8	2.8	2.8	2.
120.0	2.9	2.9	2.9	2.7	2.7	2.6	2.
150.0	3.0	3.0	3.1	3.3	3.1	3.2	3.
180.0	3.2	3.1	3.1	2.9	3.0	3.1	3.
210.0	3.2	3.2	3.2	3.2	3.2	3.1	3.
240.0	5.4	5.3	5.5	5.4	5.3	5.2	5.
270.0	5.2	5.4	5.4	5.3	5.4	5.6	5.
300.0	3.5	3.4	3.7	3.5	3.6	3.5	3.
330.0	3.7	3.5	3.3	3.5	3.4	3.3	3.
360.0	5.3	5.2	5.1	5.0	5.0	4.9	4.
390.0	6.9	6.8	7.0	6.9	6.8	6.4	8.
420.0							
450.0							
480.0							

STATION ETN-5

NEUTRON TUBE DATA

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DEPTH BELOW DATUM(CM)							
30.0	6.5	11.8	13.0	11.6	10.7	10.2	9.
60.0	5.9	6.0	7.3	8.1	8.0	7.8	7.
90.0	6.0	5.8	5.4	5.8	5.4	5.9	5.
120.0	5.8	5.5	5.6	5.6	5.6	5.4	5.
150.0	6.0	6.1	6.1	6.4	6.2	6.2	6.
180.0	6.1	6.1	6.3	5.9	5.9	6.0	6.
210.0	6.3	6.2	6.2	6.4	6.2	6.2	6.
240.0	9.6	9.4	9.3	9.3	9.4	9.5	9.
270.0	9.7	9.8	9.8	9.7	9.6	9.5	9.
300.0	6.7	6.8	6.9	6.6	6.9	6.7	6.
330.0	6.8	7.3	7.7	7.6	7.8	7.7	7.
360.0	15.3	21.8	20.2	16.8	14.3	13.5	11.
390.0	35.0	41.0	41.0	38.8	34.6	29.2	18.
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME ETN-5	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DPTH BELOW DATUM(M)							
30.0	3.3	7.2	8.1	7.0	6.3	5.9	5.
60.0	2.9	2.9	3.8	4.3	4.3	4.1	4.
90.0	2.9	2.8	2.6	2.8	2.6	2.9	2.
120.0	2.8	2.6	2.7	2.7	2.7	2.5	2.
150.0	2.9	3.0	3.0	3.2	3.0	3.1	3.
180.0	3.0	3.0	3.1	2.9	2.9	2.9	3.
210.0	3.1	3.1	3.1	3.2	3.0	3.0	3.
240.0	5.4	5.3	5.2	5.2	5.3	5.3	5.
270.0	5.5	5.6	5.6	5.5	5.5	5.4	5.
300.0	3.4	3.4	3.5	3.3	3.5	3.4	3.
330.0	3.4	3.8	4.1	4.0	4.1	4.1	3.
360.0	10.1	16.1	14.6	11.4	9.2	8.5	6.
390.0	30.1	37.0	37.0	34.4	29.6	23.6	13.
420.0							
450.0							
480.0							

STATION ETN-5

NEUTRON TUBE DATA

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DEPTH BELOW DATUM(CM)							
30.0	9.6	9.6	9.3	8.3	6.7	5.4	4.8
60.0	7.7	7.8	7.7	7.7	6.7	6.1	5.7
90.0	5.6	5.8	6.0	5.9	5.9	5.6	5.6
120.0	5.6	5.5	5.7	5.6	5.5	5.5	5.5
150.0	6.2	6.2	6.3	6.3	6.0	6.0	6.1
180.0	6.0	6.1	6.0	6.1	6.0	6.3	6.0
210.0	6.5	6.4	6.1	6.0	6.1	6.2	6.2
240.0	9.5	9.0	9.3	9.5	9.6	9.7	9.1
270.0	9.7	9.4	9.3	9.5	9.5	9.6	9.5
300.0	6.8	6.7	6.8	6.6	6.8	6.9	6.8
330.0	7.5	7.3	7.2	7.4	7.2	6.9	7.0
360.0	11.2	10.7	10.7	10.5	10.4	9.8	9.4
390.0	15.9	15.7	14.9	14.4	13.7	13.4	12.1
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME ETN-5	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DPTH BELOW DATUM(M)							
30.0	5.4	5.4	5.2	4.5	3.4	2.6	2.2
60.0	4.1	4.2	4.1	4.1	3.4	3.0	2.8
90.0	2.7	2.8	2.9	2.9	2.9	2.7	2.7
120.0	2.7	2.6	2.8	2.7	2.6	2.6	2.6
150.0	3.0	3.1	3.1	3.1	2.9	2.9	3.0
180.0	2.9	3.0	2.9	3.0	2.9	3.1	2.9
210.0	3.2	3.2	3.0	2.9	3.0	3.0	3.1
240.0	5.4	5.0	5.2	5.4	5.4	5.5	5.1
270.0	5.5	5.3	5.2	5.4	5.4	5.4	5.4
300.0	3.5	3.4	3.4	3.3	3.4	3.5	3.4
330.0	4.0	3.8	3.7	3.8	3.7	3.5	3.6
360.0	6.7	6.3	6.3	6.1	6.0	5.6	5.3
390.0	10.6	10.4	9.7	9.3	8.7	8.4	7.4
420.0							
450.0							

STATION ETN-6

NEUTRON TUBE DATA

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DEPTH BELOW DATUM(CM)							
30.0	6.1	6.1	6.1	5.9	6.2	6.2	6.
60.0	6.1	6.2	6.1	6.2	6.1	6.3	6.
90.0	6.8	7.1	6.8	7.0	6.8	7.0	7.
120.0	7.0	6.8	7.2	6.8	7.0	6.9	6.
150.0	7.3	7.1	7.3	7.0	7.4	7.4	7.
180.0	8.8	9.0	8.7	8.8	8.9	8.7	7.
210.0	7.9	7.9	7.8	7.8	7.9	7.8	7.
240.0	9.6	9.9	9.4	9.7	9.5	9.8	8.
270.0	9.5	9.4	9.4	9.2	9.4	9.7	9.
300.0	7.0	7.2	6.9	7.0	7.0	7.1	7.
330.0	7.2	7.2	7.0	7.2	7.2	7.3	7.
360.0	11.7	11.5	11.5	11.8	11.8	11.6	10.
390.0	12.2	12.5	12.4	12.1	11.9	12.1	11.
420.0	12.8			12.5			10.
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME ETN-6	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DPTH BELOW DATUM(M)							
30.0	3.0	3.0	3.0	2.8	3.0	3.0	2.
60.0	3.0	3.0	3.0	3.0	3.0	3.1	3.
90.0	3.5	3.6	3.5	3.6	3.5	3.6	3.
120.0	3.6	3.4	3.7	3.5	3.6	3.5	3.
150.0	3.8	3.7	3.8	3.6	3.9	3.8	3.
180.0	4.9	5.0	4.8	4.9	4.9	4.8	4.
210.0	4.2	4.2	4.2	4.2	4.2	4.2	3.
240.0	5.4	5.7	5.3	5.5	5.3	5.6	4.
270.0	5.4	5.3	5.3	5.1	5.3	5.5	5.
300.0	3.6	3.7	3.5	3.6	3.6	3.6	3.
330.0	3.7	3.7	3.6	3.7	3.7	3.8	3.
360.0	7.1	6.9	6.9	7.1	7.1	7.0	6.
390.0	7.5	7.7	7.7	7.4	7.2	7.4	6.
420.0	8.0			7.7			6.
450.0							
480.0							

STATION ETN-6

NEUTRON TUBE DATA

DATE	5/26/88	6/10/88	6/24/88	7/24/88	7/20/88	8/6/88	8/19/8
TIME	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DEPTH BELOW							
DATUM(CM)							
30.0	6.2	5.9	5.7	5.8	5.9	5.8	5.
60.0	6.2	6.3	6.1	6.1	6.3	5.9	5.
90.0	6.9	6.8	6.8	6.6	6.6	6.6	6.
120.0	6.8	6.6	6.5	6.0	6.1	6.4	6.
150.0	7.1	7.1	6.8	6.9	6.6	6.7	6.
180.0	8.2	8.0	7.7	7.6	7.7	7.5	7.
210.0	7.3	7.5	7.2	7.4	7.2	7.0	6.
240.0	9.4	9.3	9.4	9.2	9.1	9.0	9.
270.0	9.2	9.6	9.1	9.1	8.9	9.1	8.
300.0	7.3	6.9	6.9	6.9	6.7	6.7	6.
330.0	7.0	7.0	6.8	6.9	6.8	6.9	6.
360.0	11.4	11.9	10.9	10.6	10.5	10.1	10.
390.0	11.6	11.7	11.5	10.4	9.5	9.3	12.
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	5/26/88	6/10/88	6/24/88	7/24/88	7/20/88	8/6/88	8/19/8
TIME ETN-6	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DPTH BELOW							
DATUM(M)							
30.0	3.1	2.8	2.8	2.8	2.8	2.8	2.
60.0	3.1	3.1	3.0	3.0	3.1	2.9	2.
90.0	3.5	3.5	3.5	3.3	3.3	3.3	3.
120.0	3.5	3.3	3.3	2.9	3.0	3.2	3.
150.0	3.6	3.6	3.5	3.5	3.3	3.4	3.
180.0	4.4	4.3	4.1	4.0	4.0	3.9	3.
210.0	3.8	3.9	3.7	3.9	3.7	3.6	3.
240.0	5.3	5.2	5.3	5.2	5.1	5.0	5.
270.0	5.2	5.4	5.1	5.1	4.9	5.1	4.
300.0	3.8	3.5	3.5	3.5	3.4	3.4	3.
330.0	3.6	3.6	3.5	3.5	3.4	3.5	3.
360.0	6.9	7.2	6.4	6.2	6.1	5.8	5.
390.0	7.0	7.1	6.9	6.1	5.4	5.3	7.
420.0							
450.0							
480.0							

STATION ETN-6

NEUTRON TUBE DATA

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DEPTH BELOW DATUM(CM)							
30.0	5.9	11.7	12.9	11.7	11.0	10.5	10.
60.0	6.3	6.2	6.6	7.5	7.6	7.7	7.
90.0	6.4	6.5	6.5	6.7	6.6	6.4	6.
120.0	6.3	6.0	6.3	6.0	6.1	6.2	6.
150.0	6.6	6.7	6.8	6.7	6.8	6.6	6.
180.0	7.3	7.5	7.4	7.5	7.4	7.7	7.
210.0	6.9	6.9	7.0	7.0	7.0	6.9	7.
240.0	9.0	8.8	8.8	8.9	8.9	8.8	8.
270.0	9.2	8.7	8.9	9.1	8.9	8.9	9.
300.0	6.7	6.7	6.8	6.9	7.0	6.9	6.
330.0	7.1	7.5	8.2	7.9	8.0	7.8	7.
360.0	17.5	23.1	21.6	18.3	15.6	14.6	13.
390.0	34.0	38.9	39.2	36.7	34.4	29.8	19.
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME ETN-6	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DPTH BELOW DATUM(M)							
30.0	2.9	7.1	8.0	7.1	6.5	6.1	5.
60.0	3.1	3.0	3.3	3.9	4.0	4.0	3.
90.0	3.2	3.3	3.3	3.4	3.3	3.2	3.
120.0	3.1	2.9	3.1	2.9	3.0	3.0	2.
150.0	3.3	3.4	3.5	3.4	3.5	3.3	3.
180.0	3.8	3.9	3.9	3.9	3.9	4.0	3.
210.0	3.5	3.5	3.6	3.6	3.6	3.5	3.
240.0	5.0	4.8	4.8	4.9	4.9	4.9	4.
270.0	5.2	4.8	5.0	5.0	4.9	5.0	5.
300.0	3.4	3.4	3.5	3.5	3.6	3.5	3.
330.0	3.6	3.9	4.4	4.2	4.3	4.1	4.
360.0	12.0	17.4	15.9	12.8	10.4	9.5	8.
390.0	28.9	34.6	34.9	32.0	29.4	24.3	13.
420.0							
450.0							
480.0							

STATION ETN-6

NEUTRON TUBE DATA

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DEPTH BELOW							
DATUM(CM)							
30.0	9.7	9.9	9.6	8.4	6.2	5.5	5.3
60.0	7.7	7.8	8.0	7.7	6.5	6.2	5.5
90.0	6.5	6.7	6.5	6.7	6.9	6.5	6.5
120.0	5.9	6.2	6.1	6.1	6.0	6.1	5.9
150.0	6.7	6.8	6.6	6.8	6.6	6.3	6.4
180.0	7.6	7.4	7.3	7.5	7.4	7.3	7.2
210.0	6.9	6.9	6.9	6.7	6.6	6.6	6.4
240.0	8.7	8.9	8.7	8.7	8.6	8.6	8.5
270.0	9.0	8.8	8.9	9.1	7.0	8.9	8.9
300.0	6.8	6.9	6.8	7.0	7.3	6.6	6.8
330.0	7.8	7.3	7.6	7.6	7.4	7.4	6.9
360.0	13.2	12.7	12.3	11.9	11.8	11.5	10.1
390.0	15.6	14.9	13.9	13.4	13.1	12.5	10.3
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME ETN-6	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DPTH BELOW							
DATUM(M)							
30.0	5.5	5.7	5.5	4.6	3.1	2.6	2.5
60.0	4.1	4.2	4.3	4.1	3.2	3.0	2.6
90.0	3.2	3.4	3.3	3.4	3.5	3.2	3.2
120.0	2.8	3.1	3.0	3.0	3.0	3.0	2.9
150.0	3.4	3.4	3.3	3.4	3.3	3.1	3.2
180.0	4.0	3.8	3.8	3.9	3.9	3.8	3.7
210.0	3.5	3.5	3.5	3.4	3.3	3.3	3.2
240.0	4.8	5.0	4.8	4.8	4.7	4.7	4.6
270.0	5.0	4.9	4.9	5.1	3.6	4.9	4.9
300.0	3.5	3.5	3.4	3.6	3.8	3.3	3.5
330.0	4.2	3.8	4.0	4.0	3.8	3.8	3.5
360.0	8.3	7.9	7.6	7.3	7.2	6.9	5.9
390.0	10.4	9.8	8.8	8.4	8.2	7.7	6.0
420.0							
450.0							

STATION ETN-7

NEUTRON TUBE DATA

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DEPTH BELOW DATUM(CM)							
30.0	5.6	5.8	5.7	6.0	6.1	6.2	6.
60.0	6.3	6.3	6.3	6.4	6.6	6.4	6.
90.0	6.9	6.7	6.8	6.9	6.9	6.9	7.
120.0	6.6	6.5	6.4	6.6	6.6	6.8	6.
150.0	6.9	6.9	7.2	6.9	6.9	7.0	7.
180.0	7.5	7.6	7.5	7.5	7.4	7.7	7.
210.0	7.2	7.1	7.0	7.2	7.0	7.2	7.
240.0	8.2	8.4	8.4	8.6	8.5	8.5	8.
270.0	9.6	9.6	9.5	9.6	9.8	9.8	9.
300.0	7.2	7.5	7.4	7.4	7.6	7.7	7.
330.0	7.5	7.4	7.4	7.5	7.5	7.5	7.
360.0	10.0	9.9	10.1	10.0	10.0	9.9	10.
390.0	12.3	12.3	12.2	12.4	12.1	12.0	12.
420.0	13.0	12.8		12.9		13.0	
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME ETN-7	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DPTH BELOW DATUM(M)							
30.0	2.7	2.8	2.8	2.9	3.0	3.1	3.
60.0	3.1	3.1	3.2	3.2	3.3	3.2	3.
90.0	3.5	3.4	3.4	3.5	3.5	3.5	3.
120.0	3.3	3.2	3.2	3.3	3.3	3.4	3.
150.0	3.5	3.6	3.7	3.5	3.5	3.6	3.
180.0	3.9	4.0	3.9	3.9	3.9	4.0	3.
210.0	3.7	3.7	3.6	3.7	3.6	3.8	3.
240.0	4.4	4.6	4.6	4.7	4.6	4.7	4.
270.0	5.5	5.5	5.3	5.5	5.6	5.6	5.
300.0	3.7	3.9	3.8	3.9	4.0	4.1	3.
330.0	3.9	3.9	3.9	3.9	3.9	3.9	4.
360.0	5.8	5.7	5.8	5.8	5.8	5.7	5.
390.0	7.6	7.6	7.4	7.7	7.4	7.3	7.
420.0	8.2	7.9		8.1		8.1	
450.0							
480.0							

STATION ETN-7

NEUTRON TUBE DATA

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DEPTH BELOW DATUM(CM)							
30.0	5.7	5.2	5.2	5.3	5.0	5.2	5.
60.0	6.6	6.4	6.5	6.0	6.3	6.3	6.
90.0	6.9	6.8	6.7	6.7	6.6	6.8	6.
120.0	6.4	6.4	6.4	6.3	6.2	6.0	6.
150.0	6.8	6.9	6.5	6.7	6.8	6.4	6.
180.0	7.6	7.4	7.0	7.0	7.0	7.1	6.
210.0	7.1	7.3	6.8	7.0	6.7	6.7	6.
240.0	8.2	8.5	8.2	7.9	8.1	7.8	8.
270.0	9.5	9.6	9.5	9.5	9.7	9.8	9.
300.0	7.6	7.3	7.3	7.3	7.6	7.4	7.
330.0	7.3	7.6	7.2	6.9	7.0	6.5	6.
360.0	10.0	9.7	9.7	9.2	9.0	8.8	8.
390.0	11.8	11.6	11.7	11.6	10.2	9.7	13.
420.0		12.7	12.1	12.4			
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME ETN-7	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DPTH BELOW DATUM(M)							
30.0	2.7	2.4	2.4	2.5	2.3	2.4	2.
60.0	3.3	3.2	3.3	2.9	3.1	3.1	3.
90.0	3.5	3.4	3.4	3.4	3.3	3.4	3.
120.0	3.2	3.2	3.2	3.1	3.1	2.9	3.
150.0	3.4	3.6	3.2	3.4	3.4	3.2	3.
180.0	4.0	3.8	3.6	3.6	3.6	3.6	3.
210.0	3.7	3.8	3.4	3.6	3.4	3.4	3.
240.0	4.4	4.7	4.4	4.2	4.4	4.2	4.
270.0	5.4	5.5	5.4	5.4	5.5	5.6	5.
300.0	4.0	3.8	3.8	3.8	4.0	3.8	4.
330.0	3.8	4.0	3.7	3.5	3.6	3.3	3.
360.0	5.8	5.5	5.5	5.1	5.0	4.9	4.
390.0	7.1	7.0	7.1	7.0	5.9	5.5	8.
420.0		7.9	7.4	7.6			
450.0							
480.0							

STATION ETN-7

NEUTRON TUBE DATA

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DEPTH BELOW							
DATUM(CM)							
30.0	5.9	9.5	10.3	9.3	9.1	8.6	8.
60.0	6.3	6.5	11.9	12.4	11.9	11.4	10.
90.0	6.6	6.6	6.8	7.7	7.7	8.1	8.
120.0	6.2	6.5	6.2	6.3	6.2	6.2	6.
150.0	6.5	6.5	6.5		6.6	6.5	6.
180.0	7.0	6.7	6.8	6.7	7.0	6.7	6.
210.0	6.5	8.0	6.4	6.4	6.9	6.5	6.
240.0	8.0	9.4	7.9	8.3	8.0	7.9	8.
270.0	9.6	9.6	9.7	9.4	9.6	9.6	9.
300.0	7.6	7.6	7.3	7.3	7.2	7.5	7.
330.0	6.9	8.2	8.2	8.2	8.3	8.3	8.
360.0	14.9	22.6	19.9	16.8	14.2	13.0	11.
390.0	35.3	37.4	37.7	36.8	33.2	28.7	18.
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME ETN-7	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DPTH BELOW							
DATUM(M)							
30.0	2.9	5.4	5.9	5.2	5.1	4.7	4.
60.0	3.1	3.3	7.2	7.6	7.3	6.9	6.
90.0	3.3	3.3	3.4	4.0	4.1	4.4	4.
120.0	3.1	3.3	3.0	3.1	3.1	3.1	3.
150.0	3.3	3.3	3.3		3.3	3.3	3.
180.0	3.6	3.4	3.5	3.4	3.6	3.4	3.
210.0	3.3	4.3	3.2	3.2	3.5	3.2	3.
240.0	4.3	5.3	4.2	4.5	4.3	4.2	4.
270.0	5.5	5.4	5.5	5.3	5.4	5.4	5.
300.0	4.0	4.0	3.8	3.8	3.7	3.9	3.
330.0	3.5	4.4	4.4	4.4	4.5	4.5	4.
360.0	9.7	16.9	14.3	11.4	9.1	8.1	7.
390.0	30.4	32.9	33.1	32.1	28.1	23.2	12.
420.0							
450.0							
480.0							

STATION ETN-7

NEUTRON TUBE DATA

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DEPTH BELOW							
DATUM(CM)							
30.0	8.1	8.0	8.5	7.3	5.8	5.2	4.9
60.0	10.9	10.7	10.4	10.0	7.8	6.3	6.1
90.0	8.0	8.3	8.4	8.4	7.6	6.9	6.5
120.0	6.2	6.2	6.4	6.4	6.1	6.2	5.9
150.0	6.6	6.5	6.4	6.6	6.6	6.6	6.3
180.0	6.7	6.7	6.8	7.0	7.1	6.6	6.7
210.0	6.2	6.3	6.3	6.4	6.3	6.1	6.3
240.0	8.0	7.9	8.0	7.9	8.2	7.6	7.9
270.0	9.4	9.6	9.6	9.4	9.5	9.5	9.4
300.0	7.3	7.5	7.7	7.5	7.4	7.3	7.2
330.0	8.0	8.1	7.8	7.7	7.4	7.5	7.0
360.0	11.2	11.0	10.8	7.8	10.6	9.8	9.0
390.0	15.6	14.9	13.9	10.6	13.0	11.6	10.2
420.0				13.3			
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME ETN-7	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DPTH BELOW							
DATUM(M)							
30.0	4.4	4.3	4.6	3.8	2.8	2.4	2.2
60.0	6.5	6.3	6.0	5.8	4.1	3.1	3.0
90.0	4.3	4.5	4.5	4.6	4.0	3.6	3.2
120.0	3.0	3.1	3.2	3.2	3.0	3.0	2.8
150.0	3.3	3.3	3.2	3.3	3.3	3.3	3.2
180.0	3.4	3.4	3.4	3.6	3.6	3.3	3.4
210.0	3.0	3.1	3.1	3.2	3.1	3.0	3.2
240.0	4.3	4.2	4.3	4.2	4.4	4.0	4.2
270.0	5.3	5.4	5.4	5.3	5.4	5.4	5.3
300.0	3.8	3.9	4.1	3.9	3.8	3.8	3.7
330.0	4.3	4.3	4.1	4.1	3.9	4.0	3.6
360.0	6.7	6.5	6.4	4.1	6.2	5.6	5.0
390.0	10.3	9.7	8.9	6.2	8.1	7.0	5.9
420.0							
450.0							

STATION ETN-8

NEUTRON TUBE DATA

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DEPTH BELOW DATUM(CM)							
30.0			6.0	6.1	6.5	6.6	6.
60.0			6.4	6.4	6.5	6.5	6.
90.0			7.0	6.6	6.9	7.0	6.
120.0			6.1	6.3	6.2	6.0	6.
150.0			6.7	7.3	7.1	7.3	7.
180.0			7.1	7.2	7.0	7.2	7.
210.0			6.6	6.8	6.9	6.7	6.
240.0			8.9	9.1	8.8	8.8	9.
270.0			8.9	9.1	9.2	9.3	9.
300.0			6.9	6.8	6.8	6.9	7.
330.0			7.8	7.7	7.8	7.9	7.
360.0			12.8	12.7	12.2	12.6	12.
390.0			13.9	13.9	13.6	13.7	
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME ETN-8	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DPTH BELOW DATUM(M)							
30.0			2.9	3.0	3.3	3.3	3.
60.0			3.2	3.2	3.3	3.3	3.
90.0			3.6	3.3	3.5	3.6	3.
120.0			3.0	3.1	3.0	2.9	3.
150.0			3.4	3.8	3.7	3.8	3.
180.0			3.6	3.7	3.6	3.7	3.
210.0			3.3	3.5	3.5	3.4	3.
240.0			4.9	5.1	4.8	4.9	5.
270.0			4.9	5.0	5.2	5.3	5.
300.0			3.5	3.5	3.4	3.5	3.
330.0			4.1	4.0	4.2	4.2	4.
360.0			8.0	7.9	7.5	7.8	7.
390.0			8.9	8.9	8.6	8.7	
420.0							
450.0							
480.0							

STATION ETN-8

NEUTRON TUBE DATA

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DEPTH BELOW							
DATUM(CM)							
30.0	6.2	6.0	5.8	5.6	5.6	5.4	5.
60.0	6.1	6.5	6.2	6.5	6.4	6.1	6.
90.0	6.8	6.7	6.6	6.7	6.6	6.8	6.
120.0	6.2	5.9	6.1	6.0	5.7	6.0	6.
150.0	7.3	6.9	7.0	7.1	6.8	6.9	6.
180.0	6.9	6.7	6.4	6.5	6.7	6.6	6.
210.0	6.7	6.3	6.1	6.1	6.1	6.2	8.
240.0	6.7	8.9	8.9	8.5	8.5	8.4	8.
270.0	9.0	9.0	9.3	9.0	9.0	9.0	9.
300.0	9.1	6.6	7.1	6.7	6.9	6.5	6.
330.0	6.6	7.5	7.6	7.6	7.6	7.4	7.
360.0	7.7	12.2	11.7	11.9	11.5	11.6	11.
390.0	12.0	13.6	13.0	13.1			
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME ETN-8	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DPTH BELOW							
DATUM(M)							
30.0	3.0	2.9	2.8	2.7	2.7	2.6	2.
60.0	3.0	3.2	3.1	3.2	3.2	3.0	3.
90.0	3.5	3.4	3.3	3.4	3.3	3.4	3.
120.0	3.0	2.9	3.0	2.9	2.8	2.9	3.
150.0	3.8	3.6	3.6	3.6	3.5	3.5	3.
180.0	3.5	3.4	3.2	3.3	3.4	3.3	3.
210.0	3.4	3.1	3.0	3.0	3.0	3.0	4.
240.0	3.4	4.9	4.9	4.6	4.7	4.6	4.
270.0	5.0	5.0	5.2	5.0	5.0	5.0	5.
300.0	5.1	3.3	3.7	3.4	3.5	3.3	3.
330.0	3.3	3.9	4.0	4.0	4.0	3.8	3.
360.0	4.1	7.5	7.1	7.3	6.9	7.0	6.
390.0	7.3	8.6	8.1	8.2			
420.0							
450.0							
480.0							

STATION ETN-8

NEUTRON TUBE DATA

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DEPTH BELOW DATUM(CM)							
30.0	7.1	13.6	12.5	10.8	9.9	9.5	9.
60.0	6.1	6.6	7.8	8.2	7.8	7.7	7.
90.0	6.5	6.6	6.6	6.5	6.4	6.5	6.
120.0	6.0	6.0	6.2	5.9	5.8	6.1	5.
150.0	6.6	6.8	6.8	7.0	6.9	6.7	6.
180.0	6.5	6.5	6.7	6.5	6.4	6.5	6.
210.0	6.2	6.2	6.2	6.0	6.1	6.4	6.
240.0	8.5	8.3	8.7	8.7	8.6	8.5	8.
270.0	9.2	8.8	8.8	9.1	9.0	8.8	8.
300.0	6.6	6.6	6.6	6.6	6.7	6.9	6.
330.0	7.9	9.3	10.1	9.2	9.0	8.8	8.
360.0	19.2	24.6	23.5	20.5	18.3	17.3	14.
390.0		39.0	38.3	37.6	34.5	29.3	20.
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME ETN-8	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DPTH BELOW DATUM(M)							
30.0	3.6	8.6	7.7	6.4	5.7	5.4	5.
60.0	3.0	3.3	4.2	4.4	4.1	4.1	4.
90.0	3.3	3.3	3.3	3.3	3.2	3.2	3.
120.0	2.9	2.9	3.1	2.8	2.8	3.0	2.
150.0	3.3	3.5	3.4	3.6	3.5	3.4	3.
180.0	3.2	3.2	3.4	3.2	3.2	3.3	3.
210.0	3.1	3.1	3.1	2.9	3.0	3.2	3.
240.0	4.6	4.5	4.8	4.8	4.7	4.7	4.
270.0	5.1	4.9	4.9	5.0	5.0	4.9	4.
300.0	3.3	3.3	3.3	3.3	3.4	3.5	3.
330.0	4.2	5.2	5.9	5.2	5.0	4.8	4.
360.0	13.6	18.9	17.8	14.9	12.8	11.9	9.
390.0		34.7	33.9	33.0	29.4	23.7	14.
420.0							
450.0							
480.0							

STATION ETN-8

NEUTRON TUBE DATA

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DEPTH BELOW DATUM(CM)							
30.0	9.1	9.0	9.2	8.3	6.6	5.3	4.9
60.0	7.6	7.8	8.0	7.6	7.2	6.5	6.0
90.0	6.6	6.6	6.7	6.6	6.9	6.6	6.6
120.0	5.9	5.9	5.9	6.2	6.0	6.1	5.8
150.0	6.7	6.8	6.8	7.0	6.8	6.6	6.8
180.0	6.3	6.5	6.5	6.4	6.4	6.4	6.4
210.0	6.1	6.1	6.1	6.1	6.1	5.9	6.0
240.0	8.9	8.5	8.5	8.5	8.6	8.4	8.4
270.0	8.9	9.0	9.1	8.9	9.2	8.8	9.0
300.0	6.6	6.9	6.7	6.8	6.9	6.6	6.6
330.0	8.3	8.1	8.3	8.1	8.2	7.6	7.6
360.0	14.3	13.9	13.6	13.3	13.1	13.0	12.6
390.0	18.0	17.0	16.6	15.9	15.1	13.9	13.1
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME ETN-8	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DPTH BELOW DATUM(M)							
30.0	5.1	5.0	5.1	4.5	3.3	2.5	2.2
60.0	4.0	4.1	4.3	4.0	3.7	3.2	3.0
90.0	3.3	3.3	3.4	3.3	3.5	3.3	3.3
120.0	2.9	2.9	2.9	3.0	2.9	3.0	2.8
150.0	3.4	3.5	3.4	3.6	3.4	3.3	3.4
180.0	3.1	3.3	3.3	3.2	3.2	3.2	3.2
210.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9
240.0	4.9	4.6	4.6	4.7	4.7	4.5	4.6
270.0	5.0	5.0	5.0	4.9	5.1	4.8	5.0
300.0	3.3	3.5	3.4	3.4	3.5	3.3	3.3
330.0	4.5	4.4	4.5	4.4	4.4	4.0	4.0
360.0	9.2	8.9	8.6	8.4	8.2	8.1	7.8
390.0	12.5	11.6	11.2	10.6	9.9	8.8	8.2
420.0							
450.0							

STATION ETN-9

NEUTRON TUBE DATA

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DEPTH BELOW							
DATUM(CM)							
30.0				6.4	6.5	6.7	6.
60.0				6.2	6.2	6.5	6.
90.0				6.5	6.0	6.6	6.
120.0				5.9	6.0	6.0	6.
150.0				7.1	7.3	7.4	7.
180.0				6.1	6.2	6.5	6.
210.0				5.6	5.6	5.7	5.
240.0				8.4	8.4	8.2	8.
270.0				10.3	10.4	10.4	10.
300.0				6.2	6.2	6.2	6.
330.0				6.6	6.8	6.9	6.
360.0				10.4	10.0	10.0	10.
390.0				11.8	11.8	11.9	11.
420.0					9.8	9.7	9.
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME ETN-9	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DPTH BELOW							
DATUM(M)							
30.0				3.2	3.2	3.4	3.
60.0				3.1	3.0	3.3	3.
90.0				3.2	2.9	3.3	3.
120.0				2.9	2.9	2.9	2.
150.0				3.6	3.8	3.9	3.
180.0				3.0	3.1	3.2	3.
210.0				2.7	2.7	2.8	2.
240.0				4.6	4.6	4.4	4.
270.0				6.0	6.1	6.1	6.
300.0				3.1	3.1	3.0	3.
330.0				3.3	3.4	3.5	3.
360.0				6.0	5.8	5.8	5.
390.0				7.2	7.1	7.2	6.
420.0					5.6	5.5	5.
450.0							
480.0							

STATION ETN-9

NEUTRON TUBE DATA

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DEPTH BELOW DATUM(CM)							
30.0	6.3	6.2	5.8	5.6	5.6	5.4	5.
60.0	6.3	6.3	6.2	6.1	6.1	6.0	6.
90.0	6.3	6.3	6.4	6.4	5.9	6.0	5.
120.0	6.0	6.0	6.1	6.0	7.3	5.7	5.
150.0	7.4	7.5	7.5	7.2	6.3	7.2	7.
180.0	6.1	6.1	6.1	6.2	5.8	6.2	6.
210.0	5.8	5.8	5.7	5.8	8.5	5.9	5.
240.0	8.1	8.5	8.3	8.5	10.4	8.6	8.
270.0	10.5	10.6	10.4	10.5	6.7	10.4	10.
300.0	6.5	6.2	6.2	6.2	6.9	6.2	6.
330.0	7.0	6.8	6.8	6.7	9.8	6.8	6.
360.0	10.1	9.7	9.9	9.8	10.6	9.8	9.
390.0	11.6	11.7	11.5	11.0	9.2	11.0	14.
420.0		9.6	9.6	9.2			
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME ETN-9	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DPTH BELOW DATUM(M)							
30.0	3.1	3.1	2.8	2.7	2.7	2.6	2.
60.0	3.1	3.1	3.1	3.0	3.0	2.9	3.
90.0	3.1	3.1	3.2	3.2	2.9	2.9	2.
120.0	2.9	2.9	3.0	2.9	3.8	2.8	2.
150.0	3.9	3.9	3.9	3.7	3.1	3.7	3.
180.0	3.0	3.0	3.0	3.1	2.8	3.0	3.
210.0	2.8	2.8	2.7	2.8	4.6	2.9	2.
240.0	4.4	4.6	4.5	4.7	6.0	4.7	4.
270.0	6.1	6.2	6.0	6.1	3.4	6.1	6.
300.0	3.2	3.0	3.0	3.1	3.5	3.1	3.
330.0	3.6	3.5	3.5	3.4	5.6	3.5	3.
360.0	5.8	5.6	5.7	5.6	6.2	5.6	5.
390.0	7.0	7.1	6.9	6.5	5.2	6.5	9.
420.0		5.5	5.5	5.2			
450.0							
480.0							

STATION ETN-9

NEUTRON TUBE DATA

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DEPTH BELOW DATUM(CM)							
30.0	7.5	14.2	12.4	10.7	9.6	9.5	9.
60.0	5.9	6.7	9.6	9.7	9.4	8.9	8.
90.0	5.8	5.9	5.8	5.8	6.1	5.9	5.
120.0	5.7	5.9	5.9	5.9	5.6	5.9	5.
150.0	7.2	7.2	7.2	7.3	7.2	7.2	7.
180.0	6.1	6.3	6.1	6.0	6.2	6.2	6.
210.0	5.9	5.8	5.8	5.7	5.4	5.6	5.
240.0	8.6	8.4	8.6	8.5	8.3	8.6	8.
270.0	10.3	10.6	10.4	10.7	10.1	10.7	10.
300.0	6.4	6.5	6.5	6.2	6.4	6.5	6.
330.0	6.9	7.2	7.6	7.7	7.4	7.6	7.
360.0	16.1	23.5	21.0	17.7	14.7	13.4	12.
390.0	34.5	36.6	36.1	33.9	27.7	24.2	17.
420.0			40.3	39.6		38.7	18.
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME ETN-9	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DPTH BELOW DATUM(M)							
30.0	3.9	9.2	7.7	6.3	5.5	5.4	5.
60.0	2.9	3.4	5.4	5.5	5.3	5.0	4.
90.0	2.8	2.9	2.8	2.8	3.0	2.9	2.
120.0	2.8	2.8	2.8	2.9	2.7	2.9	2.
150.0	3.7	3.7	3.7	3.8	3.7	3.7	3.
180.0	3.0	3.1	3.0	2.9	3.1	3.0	2.
210.0	2.8	2.8	2.8	2.7	2.6	2.7	2.
240.0	4.7	4.6	4.7	4.6	4.5	4.7	4.
270.0	6.0	6.2	6.0	6.3	5.8	6.3	6.
300.0	3.2	3.3	3.3	3.0	3.2	3.2	3.
330.0	3.5	3.7	4.0	4.0	3.9	4.0	3.
360.0	10.8	17.8	15.3	12.2	9.5	8.5	7.
390.0	29.5	31.9	31.3	28.8	22.1	18.5	11.
420.0			36.2	35.3		34.3	12.
450.0							
480.0							

STATION ETN-9

NEUTRON TUBE DATA

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DEPTH BELOW DATUM(CM)							
30.0	9.0	8.8	9.2	8.2	7.0	5.7	5.2
60.0	8.7	8.4	8.6	7.6	6.9	6.3	6.0
90.0	5.9	6.0	6.0	6.2	5.8	5.8	5.8
120.0	5.6	5.7	5.7	5.9	5.8	5.8	5.6
150.0	7.2	7.1	7.0	7.1	7.5	7.0	7.0
180.0	6.0	6.0	6.1	6.3	6.0	5.9	6.0
210.0	5.8	5.7	5.8	5.8	5.6	5.9	5.6
240.0	8.2	8.4	8.4	8.4	8.4	8.3	8.3
270.0	10.4	10.1	10.1	10.4	10.4	10.2	10.2
300.0	6.2	6.1	6.5	6.4	6.2	6.4	6.0
330.0	7.2	7.5	7.3	7.2	7.2	6.9	6.8
360.0	11.6	11.9	11.1	10.9	10.5	10.1	9.8
390.0	15.0	14.7	13.6	13.1	12.7	12.6	11.4
420.0	14.7	13.3	12.3	11.4	10.7	10.0	9.3
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME ETN-9	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DPTH BELOW DATUM(M)							
30.0	5.0	4.9	5.2	4.4	3.6	2.8	2.
60.0	4.8	4.6	4.7	4.0	3.5	3.1	2.
90.0	2.9	2.9	2.9	3.0	2.8	2.8	2.
120.0	2.7	2.7	2.7	2.9	2.8	2.8	2.
150.0	3.7	3.6	3.6	3.6	3.9	3.6	3.
180.0	2.9	2.9	3.0	3.1	2.9	2.9	2.
210.0	2.8	2.7	2.8	2.8	2.7	2.9	2.
240.0	4.4	4.5	4.5	4.6	4.6	4.5	4.
270.0	6.1	5.8	5.9	6.1	6.1	5.9	5.
300.0	3.0	3.0	3.3	3.2	3.1	3.2	2.
330.0	3.7	3.9	3.8	3.7	3.7	3.5	3.
360.0	7.0	7.2	6.6	6.5	6.2	5.8	5.
390.0	9.8	9.6	8.6	8.2	7.9	7.8	6.
420.0	9.6	8.4	7.6	6.9	6.3	5.7	5.
450.0							
480.0							

STATION ETN-10

NEUTRON TUBE DATA

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DEPTH BELOW DATUM(CM)							
30.0				5.9	5.9	6.4	6.
60.0				6.4	6.6	6.3	6.
90.0				7.0	6.9	6.8	6.
120.0				5.9	5.6	5.9	6.
150.0				6.8	7.3	7.2	7.
180.0				6.2	6.2	6.3	6.
210.0				6.0	6.2	6.3	6.
240.0				8.2	8.2	8.5	8.
270.0				10.2	9.9	10.2	10.
300.0				6.6	6.3	6.4	6.
330.0				6.4	6.6	6.8	6.
360.0				9.4	9.2	9.6	9.
390.0				11.7	11.6	11.6	11.
420.0						10.4	
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME ETN-10	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DPTH BELOW DATUM(M)							
30.0				2.9	2.9	3.2	3.
60.0				3.2	3.3	3.1	3.
90.0				3.6	3.5	3.5	3.
120.0				2.9	2.7	2.8	3.
150.0				3.5	3.8	3.7	3.
180.0				3.1	3.1	3.1	3.
210.0				2.9	3.1	3.1	3.
240.0				4.4	4.4	4.7	4.
270.0				5.9	5.7	5.9	5.
300.0				3.3	3.1	3.2	3.
330.0				3.2	3.3	3.5	3.
360.0				5.3	5.1	5.4	5.
390.0				7.1	7.0	7.0	7.
420.0						6.1	
450.0							
480.0							

STATION ETN-10

NEUTRON TUBE DATA

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DEPTH BELOW							
DATUM(CM)							
30.0	6.6	6.5	6.1	6.0	5.6	5.5	5.
60.0	6.6	6.6	6.3	6.5	6.2	6.3	6.
90.0	6.6	6.8	6.8	6.6	6.8	6.5	6.
120.0	5.7	5.7	5.9	5.6	6.0	5.3	5.
150.0	6.9	6.9	6.9	6.9	6.8	6.9	6.
180.0	6.1	6.3	6.2	6.2	6.2	6.2	6.
210.0	5.9	6.0	6.0	6.1	6.1	6.1	6.
240.0	8.4	8.6	8.5	8.2	8.2	8.5	8.
270.0	10.2	10.1	10.1	10.3	10.3	10.1	10.
300.0	6.5	6.4	6.4	6.3	6.4	6.0	6.
330.0	6.6	6.5	6.5	6.3	6.2	6.2	6.
360.0	9.2	9.5	9.1	9.0	8.5	8.3	8.
390.0	11.7	11.8	11.1	11.2	10.9	10.4	11.
420.0		10.2	9.9	9.6			
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME ETN-10	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DPTH BELOW							
DATUM(M)							
30.0	3.3	3.3	3.0	2.9	2.7	2.6	2.
60.0	3.3	3.3	3.1	3.2	3.1	3.1	3.
90.0	3.3	3.5	3.4	3.3	3.4	3.3	3.
120.0	2.8	2.8	2.8	2.7	2.9	2.5	2.
150.0	3.5	3.5	3.5	3.6	3.5	3.5	3.
180.0	3.0	3.1	3.1	3.1	3.1	3.1	3.
210.0	2.8	2.9	2.9	3.0	3.0	3.0	3.
240.0	4.6	4.7	4.7	4.4	4.4	4.6	4.
270.0	5.9	5.8	5.8	6.0	6.0	5.9	5.
300.0	3.3	3.2	3.2	3.1	3.2	2.9	3.
330.0	3.3	3.2	3.3	3.1	3.1	3.1	3.
360.0	5.1	5.4	5.1	5.0	4.7	4.5	4.
390.0	7.1	7.1	6.6	6.7	6.4	6.1	6.
420.0		5.9	5.7	5.5			
450.0							
480.0							

STATION ETN-10

NEUTRON TUBE DATA

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DEPTH BELOW							
DATUM(CM)							
30.0	7.3	13.9	12.2	11.1	9.9	9.3	9.
60.0	6.3	6.8	12.2	12.2	11.8	11.2	10.
90.0	6.5	6.3	6.7	9.4	7.5	7.7	7.
120.0	5.8	5.7	5.7	5.4	5.5	5.8	5.
150.0	6.9	6.8	7.2	6.9	6.9	7.0	6.
180.0	6.3	6.2	6.2	6.0	6.1	6.1	6.
210.0	6.3	6.1	6.3	5.9	6.3	6.3	5.
240.0	8.6	8.5	8.4	8.3	8.5	8.8	8.
270.0	10.5	10.1	10.2	10.1	10.1	10.0	10.
300.0	6.5	6.6	6.3	6.3	6.3	6.3	6.
330.0	6.3	7.1	7.6	7.5	7.2	7.2	7.
360.0	14.0	21.9	20.0	16.7	13.8	12.7	11.
390.0	32.0	37.4	37.3	33.8	29.7	26.4	
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME ETN-10	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DPTH BELOW							
DATUM(M)							
30.0	3.8	8.9	7.5	6.6	5.7	5.2	5.
60.0	3.1	3.4	7.5	7.5	7.2	6.7	6.
90.0	3.2	3.1	3.4	5.3	3.9	4.0	4.
120.0	2.8	2.7	2.7	2.5	2.6	2.8	2.
150.0	3.5	3.5	3.7	3.5	3.5	3.6	3.
180.0	3.1	3.1	3.1	2.9	3.0	3.0	2.
210.0	3.1	3.0	3.1	2.9	3.1	3.1	2.
240.0	4.7	4.6	4.6	4.5	4.6	4.8	4.
270.0	6.2	5.8	5.9	5.8	5.8	5.8	5.
300.0	3.2	3.3	3.1	3.1	3.1	3.1	3.
330.0	3.1	3.7	4.0	3.9	3.7	3.7	3.
360.0	9.0	16.2	14.3	11.3	8.8	7.9	6.
390.0	26.7	32.7	32.7	28.7	24.2	20.7	
420.0							
450.0							
480.0							

STATION ETN-10

NEUTRON TUBE DATA

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DEPTH BELOW							
DATUM(CM)							
30.0	9.0	8.8	8.7	8.1	6.9	6.0	5.0
60.0	10.6	10.4	9.8	9.0	8.2	7.2	6.4
90.0	7.7	7.7	8.1	7.5	7.3	7.0	6.5
120.0	5.4	5.6	5.6	5.5	5.6	5.6	5.4
150.0	6.9	7.0	6.8	6.8	7.0	6.7	7.0
180.0	6.2	6.1	5.9	6.2	6.2	5.9	5.9
210.0	6.2	6.0	6.0	6.2	6.0	6.1	6.1
240.0	8.4	8.5	8.6	8.4	8.6	8.6	8.4
270.0	10.0	10.3	10.3	10.1	10.1	9.8	10.0
300.0	6.4	6.2	6.4	6.5	6.3	6.7	6.4
330.0	7.2	7.0	7.3	7.1	6.9	6.9	6.8
360.0	10.8	10.7	10.2	10.6	10.3	9.7	9.2
390.0	16.0	14.9	14.0	13.6	12.9	12.3	11.5
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME ETN-10	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DPTH BELOW							
DATUM(M)							
30.0	5.0	4.8	4.8	4.4	3.6	2.9	2.3
60.0	6.2	6.1	5.6	5.0	4.4	3.7	3.2
90.0	4.1	4.1	4.3	3.9	3.8	3.6	3.3
120.0	2.6	2.7	2.6	2.6	2.7	2.7	2.5
150.0	3.5	3.6	3.4	3.5	3.6	3.4	3.6
180.0	3.1	3.0	2.9	3.1	3.0	2.9	2.9
210.0	3.0	2.9	2.9	3.1	2.9	3.0	3.0
240.0	4.6	4.7	4.7	4.6	4.7	4.7	4.6
270.0	5.8	6.0	5.9	5.8	5.8	5.6	5.8
300.0	3.2	3.1	3.2	3.3	3.1	3.4	3.2
330.0	3.7	3.6	3.8	3.7	3.5	3.5	3.4
360.0	6.3	6.3	5.9	6.2	6.0	5.5	5.2
390.0	10.7	9.7	9.0	8.7	8.0	7.6	6.9
420.0							
450.0							

STATION ETN-11

NEUTRON TUBE DATA

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DEPTH BELOW DATUM(CM)							
30.0	8.4	8.5	9.2	9.2	8.7	8.9	8.
60.0	6.9	6.9	7.0	7.0	7.0	6.9	6.
90.0	7.1	7.1	7.3	7.3	7.1	7.2	7.
120.0	6.4	6.4	6.3	6.2	6.2	6.3	6.
150.0	6.3	6.4	6.3	6.4	6.5	6.5	6.
180.0	6.7	6.7	6.7	6.8	6.8	6.9	6.
210.0	6.4	6.5	6.3	6.2	6.3	6.3	6.
240.0	7.8	8.1	8.1	8.1	7.7	8.0	8.
270.0	10.3	10.1	10.3	10.3	10.4	10.4	10.
300.0	6.7	6.9	6.7	6.8	6.6	7.0	7.
330.0	7.5	7.2	7.6	7.1	7.3	7.6	7.
360.0	10.7	10.5	10.7	10.6	10.9	10.5	10.
390.0	13.2	13.3	12.6	13.0	12.8	12.9	12.
420.0	11.2	11.3	10.6	10.5	10.6	10.4	10.
450.0	14.1	14.2		13.0			
480.0							

CORRECTED MOISTURE CONTENT

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME ETN-11	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DPTH BELOW DATUM(M)							
30.0	4.6	4.7	5.2	5.2	4.8	4.9	4.
60.0	3.5	3.6	3.6	3.6	3.6	3.5	3.
90.0	3.6	3.7	3.8	3.8	3.6	3.7	3.
120.0	3.2	3.2	3.1	3.0	3.1	3.1	3.
150.0	3.1	3.2	3.1	3.2	3.2	3.3	3.
180.0	3.4	3.4	3.4	3.5	3.4	3.6	3.
210.0	3.2	3.2	3.1	3.1	3.1	3.1	3.
240.0	4.2	4.4	4.3	4.3	4.1	4.3	4.
270.0	5.9	5.8	6.0	6.0	6.0	6.1	5.
300.0	3.4	3.5	3.4	3.5	3.3	3.6	3.
330.0	3.9	3.7	4.0	3.7	3.8	4.0	3.
360.0	6.3	6.1	6.3	6.2	6.4	6.1	6.
390.0	8.3	8.4	7.8	8.1	8.0	8.0	8.
420.0	6.6	6.8	6.2	6.1	6.2	6.0	5.
450.0	9.0	9.1		8.1			
480.0							

STATION ETN-11

NEUTRON TUBE DATA

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DEPTH BELOW DATUM(CM)							
30.0	8.1	7.8	6.9	6.2	6.0	5.8	5.
60.0	7.0	7.3	7.2	6.3	7.0	6.7	6.
90.0	7.2	7.0	7.4	6.6	7.0	6.9	6.
120.0	6.1	6.2	6.2	6.8	6.1	5.9	5.
150.0	6.4	6.4	6.2	6.4	6.4	6.3	6.
180.0	6.8	6.7	6.4	6.8	6.6	6.3	6.
210.0	6.5	6.2	6.1	6.7	6.2	6.2	6.
240.0	9.1	8.1	8.1	8.0	7.6	7.9	8.
270.0	10.3	10.6	10.2	8.8	10.3	10.2	10.
300.0	6.8	6.6	6.7	6.1	6.7	6.7	6.
330.0	7.0	7.4	7.0	6.7	7.2	7.0	7.
360.0	10.1	10.5	10.3	10.2	10.8	9.9	10.
390.0	12.4	12.4	12.2	10.7	12.0	11.9	13.
420.0		9.2	9.1	11.1			
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME ETN-11	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DPTH BELOW DATUM(M)							
30.0	4.3	4.1	3.5	3.1	2.9	2.8	2.
60.0	3.6	3.8	3.7	3.1	3.6	3.4	3.
90.0	3.7	3.6	3.9	3.3	3.6	3.5	3.
120.0	3.0	3.0	3.1	3.4	3.0	2.9	2.
150.0	3.2	3.2	3.0	3.2	3.2	3.1	3.
180.0	3.4	3.4	3.2	3.5	3.3	3.1	3.
210.0	3.3	3.0	3.0	3.4	3.0	3.1	3.
240.0	5.1	4.3	4.4	4.3	4.0	4.2	4.
270.0	6.0	6.2	5.9	4.8	6.0	5.9	6.
300.0	3.4	3.3	3.4	3.0	3.4	3.4	3.
330.0	3.6	3.9	3.6	3.4	3.7	3.6	3.
360.0	5.8	6.1	6.0	5.9	6.4	5.7	5.
390.0	7.6	7.6	7.5	6.3	7.3	7.3	8.
420.0		5.2	5.1	6.6			
450.0							
480.0							

STATION ETN-11

NEUTRON TUBE DATA

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DEPTH BELOW DATUM(CM)							
30.0	9.8	14.6	11.8	10.3	9.3	9.0	8.
60.0	6.8	8.7	13.2	12.1	11.4	10.6	10.
90.0	6.8	7.0	7.4	7.7	7.7	6.1	7.
120.0	6.0	5.8	5.8	6.1	5.8	5.9	5.
150.0	6.3	6.1	6.3	6.1	6.4	6.2	5.
180.0	6.5	6.5	6.4	6.4	6.4	6.4	6.
210.0	6.0	6.2	6.1	6.1	5.9	6.0	5.
240.0	7.9	7.8	7.9	7.8	8.0	8.1	7.
270.0	10.3	10.1	10.5	10.6	10.3	10.5	10.
300.0	6.9	6.6	6.8	6.5	6.7	6.9	6.
330.0	7.7	8.6	8.9	8.5	8.6	8.5	8.
360.0	18.2	23.7	21.6	18.9	15.9	14.6	12.
390.0	33.8	37.3	37.7	36.8	33.3	28.2	19.
420.0				42.3		40.3	27.
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME ETN-11	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DPTH BELOW DATUM(M)							
30.0	5.6	9.5	7.1	6.0	5.3	5.0	4.
60.0	3.5	4.8	8.3	7.4	6.9	6.2	5.
90.0	3.5	3.6	3.9	4.1	4.1	3.0	4.
120.0	2.9	2.8	2.8	3.0	2.8	2.9	2.
150.0	3.1	3.0	3.1	3.0	3.2	3.1	2.
180.0	3.2	3.3	3.2	3.2	3.2	3.2	3.
210.0	2.9	3.1	3.0	3.0	2.9	2.9	2.
240.0	4.2	4.2	4.2	4.1	4.2	4.3	4.
270.0	6.0	5.8	6.2	6.2	6.0	6.1	6.
300.0	3.5	3.3	3.5	3.3	3.4	3.5	3.
330.0	4.1	4.7	4.9	4.7	4.7	4.7	4.
360.0	12.7	17.9	15.9	13.3	10.6	9.4	7.
390.0	28.7	32.7	33.2	32.1	28.2	22.6	14.
420.0				38.6		36.3	21.
450.0							
480.0							

STATION ETN-11

NEUTRON TUBE DATA

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DEPTH BELOW DATUM(CM)							
30.0	8.4	8.4	8.2	7.5	6.5	5.8	5.3
60.0	9.8	9.7	9.6	8.2	7.6	6.5	5.9
90.0	7.5	7.6	7.5	7.6	7.4	6.6	6.6
120.0	6.0	5.8	5.8	5.7	6.0	5.7	5.6
150.0	6.0	6.1	6.2	6.1	6.1	5.9	5.8
180.0	6.2	6.5	6.3	6.4	6.5	6.4	6.2
210.0	6.0	6.0	5.7	6.0	6.0	5.8	5.9
240.0	7.9	7.8	7.8	7.8	7.5	7.8	7.9
270.0	10.3	10.0	10.5	10.5	10.3	10.2	10.2
300.0	6.7	6.7	6.9	6.8	6.6	6.8	6.5
330.0	7.6	7.5	7.5	7.8	7.8	7.5	7.4
360.0	11.9	11.7	11.5	11.3	11.0	10.7	10.4
390.0	16.6	15.6	14.9	14.8	14.1	12.5	11.6
420.0	19.0	16.6	13.9	12.8	11.9	10.4	9.2
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME ETN-11	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DPTH BELOW DATUM(M)							
30.0	4.6	4.6	4.4	3.9	3.3	2.8	2.5
60.0	5.6	5.5	5.4	4.4	4.0	3.2	2.9
90.0	3.9	4.0	3.9	4.0	3.9	3.3	3.3
120.0	2.9	2.8	2.8	2.7	2.9	2.7	2.7
150.0	2.9	3.0	3.0	3.0	3.0	2.9	2.8
180.0	3.1	3.2	3.1	3.2	3.2	3.2	3.1
210.0	3.0	2.9	2.8	2.9	2.9	2.8	2.9
240.0	4.2	4.1	4.2	4.1	4.0	4.1	4.2
270.0	6.0	5.8	6.2	6.1	6.0	5.9	5.9
300.0	3.4	3.4	3.5	3.5	3.3	3.5	3.3
330.0	4.0	3.9	3.9	4.1	4.1	4.0	3.9
360.0	7.3	7.1	6.9	6.7	6.5	6.3	6.0
390.0	11.2	10.3	9.7	9.6	9.1	7.8	7.0
420.0	13.4	11.2	8.8	7.9	7.2	6.1	5.1
450.0							
480.0							

STATION ETN-12

NEUTRON TUBE DATA

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DEPTH BELOW DATUM(CM)							
30.0	5.9	6.0	6.2	6.3	6.4	6.2	6.
60.0	6.4	6.3	6.1	6.6	6.2	6.6	6.
90.0	6.8	6.7	6.5	7.0	6.8	6.7	6.
120.0	7.1	7.2	7.1	7.1	7.2	7.1	7.
150.0	6.6	6.8	6.7	6.6	6.5	6.9	6.
180.0	7.4	7.4	7.4	7.3	7.6	7.4	7.
210.0	6.8	6.9	6.8	6.6	7.2	6.5	6.
240.0	8.0	8.1	7.8	7.9	7.6	8.1	8.
270.0	9.0	9.1	8.7	8.8	9.1	8.9	9.
300.0	6.7	6.3	6.4	6.3	6.4	6.6	6.
330.0	7.1	7.1	7.1	7.2	7.1	7.5	7.
360.0	11.8	11.6	11.6	11.4	11.2	11.4	11.
390.0	12.7	12.8	13.0	12.8	12.7	12.8	12.
420.0	13.7	13.7		13.3			
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	2/9/88	2/16/88	3/1/88	3/22/88	4/5/88	4/19/88	5/11/8
TIME ETN-12	1510	1114	1120	1040	1059	1100	
MCHI	1.13	1.08	0.85	1.18	0.88	1.01	0.8
STANDARD CT	10221	10260	10257	10386	10436	10315	1026
DPTH BELOW DATUM(M)							
30.0	2.9	3.0	3.1	3.1	3.2	3.1	3.
60.0	3.2	3.1	3.0	3.3	3.1	3.3	3.
90.0	3.4	3.4	3.3	3.6	3.4	3.4	3.
120.0	3.7	3.7	3.6	3.7	3.7	3.7	3.
150.0	3.3	3.5	3.4	3.3	3.3	3.5	3.
180.0	3.9	3.9	3.8	3.8	4.0	3.9	3.
210.0	3.5	3.5	3.4	3.3	3.7	3.3	3.
240.0	4.2	4.4	4.1	4.2	4.0	4.4	4.
270.0	5.0	5.0	4.8	4.9	5.1	5.0	5.
300.0	3.4	3.1	3.2	3.1	3.2	3.3	3.
330.0	3.6	3.7	3.6	3.7	3.7	3.9	3.
360.0	7.2	7.0	7.0	6.9	6.7	6.8	7.
390.0	7.9	8.0	8.1	8.0	7.9	8.0	7.
420.0	8.7	8.7		8.4			
450.0							
480.0							

STATION ETN-12

NEUTRON TUBE DATA

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DEPTH BELOW DATUM(CM)							
30.0	6.9	6.7	6.2	6.1	5.9	5.7	5.
60.0	6.4	6.5	6.4	6.3	6.3	6.2	6.
90.0	6.8	6.7	6.7	6.2	6.7	6.5	6.
120.0	7.3	7.1	7.1	6.8	7.0	7.0	6.
150.0	6.6	6.5	6.5	6.5	6.4	6.4	6.
180.0	7.1	7.4	6.9	6.8	6.7	7.1	7.
210.0	6.8	7.0	6.8	6.7	8.2	6.8	6.
240.0	8.2	7.9	8.0	8.0	9.0	8.0	8.
270.0	8.8	8.9	9.0	6.1	6.4	9.4	8.
300.0	6.5	6.3	6.3	6.7	6.6	6.3	6.
330.0	7.0	7.0	6.8	10.1	9.6	6.6	6.
360.0	11.1	10.8	10.3	10.7	10.1	9.3	9.
390.0	12.5	11.8	10.9	11.1	10.9	10.0	16.
420.0		12.6	11.5				
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	5/26/88	6/10/88	6/24/88	7/5/88	7/20/88	8/6/88	8/19/8
TIME	700	700	700	700	700	700	70
MCHI	0.99	0.86	1.14	0.95	0.97	0.88	0.8
STANDARD CT	10355	10312	10319	10346	10279	10283	1034
DPTH BELOW DATUM(M)							
30.0	3.5	3.4	3.1	3.0	2.9	2.8	2.
60.0	3.2	3.3	3.2	3.1	3.1	3.0	3.
90.0	3.4	3.4	3.4	3.1	3.4	3.3	3.
120.0	3.8	3.7	3.6	3.4	3.6	3.6	3.
150.0	3.3	3.2	3.2	3.2	3.2	3.2	3.
180.0	3.6	3.9	3.6	3.5	3.4	3.7	3.
210.0	3.4	3.6	3.5	3.4	4.4	3.5	3.
240.0	4.4	4.2	4.3	4.3	5.0	4.3	4.
270.0	4.8	4.9	5.0	3.0	3.2	5.3	4.
300.0	3.3	3.1	3.1	3.4	3.3	3.1	3.
330.0	3.6	3.6	3.5	5.8	5.4	3.3	3.
360.0	6.6	6.4	6.0	6.3	5.8	5.2	5.
390.0	7.7	7.2	6.5	6.6	6.5	5.7	10.
420.0		7.8	6.9				
450.0							
480.0							

STATION ETN-12

NEUTRON TUBE DATA

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DEPTH BELOW							
DATUM(CM)							
30.0	6.1	11.1	11.7	10.1	9.4	8.7	8.
60.0	6.4	6.4	7.8	9.0	9.2	9.1	8.
90.0	6.5	6.7	6.5	6.5	6.7	6.6	6.
120.0	6.9	7.0	6.9	7.2	6.8	6.8	7.
150.0	6.3	6.4	6.4	6.4	6.3	6.5	6.
180.0	6.8	6.8	7.0	6.8	6.8	6.9	6.
210.0	6.5	6.4	6.6	6.6	6.8	6.6	6.
240.0	8.1	8.1	7.8	7.9	7.9	8.1	8.
270.0	9.3	9.2	9.2	9.3	9.1	9.2	9.
300.0	6.5	6.3	6.3	6.3	6.3	6.3	6.
330.0	6.6	8.0	8.2	7.9	7.8	7.7	7.
360.0	17.5	24.6	22.8	19.3	16.6	15.4	13.
390.0	34.6	37.3	37.9	36.8	34.1	30.4	20.
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88	12/9/8
TIME ETN-12	700	700	700	700	700	900	80
MCHI	1.49	0.92	1.07	0.86	1.07	1.06	0.8
STANDARD CT	10285	10313	10301	10289	10280	10285	1029
DPTH BELOW							
DATUM(M)							
30.0	3.0	6.6	7.1	5.8	5.3	4.8	4.
60.0	3.2	3.2	4.1	5.0	5.1	5.1	4.
90.0	3.2	3.4	3.3	3.2	3.4	3.3	3.
120.0	3.5	3.6	3.5	3.7	3.5	3.4	3.
150.0	3.2	3.2	3.2	3.2	3.1	3.2	3.
180.0	3.5	3.5	3.6	3.4	3.5	3.5	3.
210.0	3.3	3.2	3.3	3.3	3.4	3.3	3.
240.0	4.3	4.3	4.2	4.2	4.2	4.4	4.
270.0	5.2	5.1	5.1	5.2	5.1	5.2	5.
300.0	3.2	3.1	3.1	3.2	3.1	3.1	3.
330.0	3.3	4.2	4.4	4.2	4.1	4.1	4.
360.0	12.1	18.8	17.0	13.7	11.2	10.2	8.
390.0	29.5	32.7	33.3	32.1	29.0	25.0	14.
420.0							
450.0							
480.0							

STATION ETN-12

NEUTRON TUBE DATA

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DEPTH BELOW							
DATUM(CM)							
30.0	8.5	8.3	8.2	7.5	6.9	6.1	5.4
60.0	9.0	8.8	8.8	7.8	7.6	6.8	6.4
90.0	6.6	6.6	6.6	6.7	6.8	6.7	6.4
120.0	6.8	6.7	6.7	6.8	6.9	6.7	6.7
150.0	6.3	6.3	6.3	6.2	6.4	6.1	6.1
180.0	6.8	6.6	6.6	6.9	6.7	6.5	6.4
210.0	6.6	6.6	6.8	6.7	6.8	6.6	6.2
240.0	8.1	7.9	8.1	8.1	8.0	8.0	8.0
270.0	8.7	9.0	9.1	8.8	8.9	8.9	9.0
300.0	6.4	6.5	6.5	6.6	6.9	6.4	6.4
330.0	7.5	7.5	7.4	7.3	7.3	7.1	7.1
360.0	13.0	12.4	12.3	11.9	11.6	11.1	10.8
390.0	16.7	15.7	14.8	14.5	13.7	12.1	11.5
420.0							
450.0							
480.0							

CORRECTED MOISTURE CONTENT

DATE	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
TIME ETN-12	830	800	830	900	900	800	800
MCHI	0.88	1.07	0.93	0.95	1.08	0.96	0.83
STANDARD CT	10321	10315	10284	10275	10246	10260	10230
DPTH BELOW							
DATUM(M)							
30.0	4.6	4.5	4.4	3.9	3.5	3.0	2.6
60.0	5.0	4.9	4.9	4.2	4.0	3.4	3.2
90.0	3.3	3.3	3.3	3.4	3.4	3.4	3.2
120.0	3.4	3.4	3.4	3.5	3.5	3.4	3.4
150.0	3.1	3.1	3.1	3.1	3.2	3.0	3.0
180.0	3.5	3.3	3.3	3.5	3.4	3.3	3.2
210.0	3.3	3.3	3.5	3.4	3.4	3.3	3.0
240.0	4.4	4.2	4.3	4.4	4.3	4.2	4.3
270.0	4.8	5.0	5.0	4.9	4.9	4.9	5.0
300.0	3.2	3.3	3.3	3.3	3.5	3.2	3.2
330.0	3.9	4.0	3.9	3.8	3.8	3.6	3.6
360.0	8.1	7.6	7.6	7.2	7.0	6.6	6.4
390.0	11.4	10.4	9.6	9.4	8.7	7.4	6.9
420.0							
450.0							

STORAGE ESTIMATIONS

STORAGE ESTIMATIONS

AVERAGE MOISTURE CONTENTS AT ith DEPTH

DPTH BELOW DATUM(CM)	7/5/88	7/20/88	8/6/88	8/19/88	9/2/88	9/16/88	9/30/88	10/15/88	10/29/88	11/11/88
30.00	2.5	2.4	2.4	2.6	3.6	7.2	7.0	6.1	5.5	5.2
60.00	2.8	2.9	2.8	3.1	3.1	3.3	4.9	5.2	5.1	4.9
90.00	3.0	3.0	3.0	3.2	3.1	3.2	3.2	3.5	3.3	3.3
120.00	2.8	2.8	2.7	3.0	3.0	3.0	3.0	3.0	2.9	3.0
150.00	3.2	3.0	3.1	3.3	3.3	3.3	3.3	3.3	3.3	3.3
180.00	3.2	3.1	3.1	3.4	3.4	3.4	3.4	3.4	3.4	3.4
210.00	3.0	3.2	2.9	3.3	3.2	3.2	3.2	3.1	3.2	3.1
240.00	4.4	4.6	4.4	4.8	4.8	4.9	4.8	4.8	4.8	4.8
270.00	4.9	4.8	5.2	5.5	5.3	5.5	5.5	5.5	5.5	5.5
300.00	3.1	3.2	3.0	3.4	3.4	3.4	3.4	3.4	3.5	3.4

Storage(CM)	8.85E+01	8.91E+01	8.82E+01	9.64E+01	9.81E+01	1.09E+02	1.13E+02	1.12E+02	1.09E+02	1.08E+02
dS (CM)		5.42E-01	-8.63E-01	8.16E+00	1.72E+00	1.11E+01	3.90E+00	-1.60E+00	-2.04E+00	-1.57E+00
dS/dT (CM/YR)		3.28								

dS = change in storage

dS/dT = change in storage with time

STORAGE ESTIMATIONS

AVERAGE MOISTURE CONTENTS AT ith DEPTH

DPTH BELOW DATUM(CM)	12/9/88	1/18/89	2/13/89	3/24/89	4/21/89	5/9/89	6/7/89	7/20/89
30.00	4.9	4.8	4.8	4.8	4.1	3.2	2.6	2.3
60.00	4.7	4.7	4.7	4.6	4.2	3.7	3.2	2.9
90.00	3.4	3.3	3.4	3.4	3.4	3.4	3.2	3.1
120.00	2.9	2.9	2.9	2.9	3.0	2.9	2.9	2.8
150.00	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2
180.00	3.3	3.3	3.3	3.3	3.4	3.4	3.3	3.3
210.00	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0
240.00	4.7	4.8	4.7	4.7	4.8	4.8	4.7	4.7
270.00	5.5	5.5	5.5	5.5	5.5	5.3	5.4	5.5
300.00	3.4	3.4	3.4	3.4	3.4	3.5	3.4	3.3
Storage(CM	1.06E+02	1.06E+02	1.06E+02	1.06E+02	1.03E+02	9.88E+01	9.43E+01	9.20E+01
dS (CM)	-1.79E+00	-3.47E-01	-8.78E-02	-1.60E-01	-2.37E+00	-4.38E+00	-4.49E+00	-2.31E+00

dS = change in storage

dS/dT = change in storage with time

APPENDIX C

TRACER TEST RESULTS

TRACER CONCENTRATIONS WITHIN THE PROFILE.

TRACER LOCATION	SAMPLE DEPTH (CM)	CONC. Br- (PPM)	CONC. 2,6-DFBA (PPM)
B 0			
	0-20	0	0
	20-23	6.6	0
	23-26	16.9	0
	26-30	12.4	0
	33-36	63	0
	36-40	132.8	0
	40-43	101.1	0
	43-46	52.3	0
	46-50	68.5	0
	53-56	57.8	0
	56-60	72.3	0
	60-63	68.5	0
	63-66	50.9	0
	66-70	53.8	0
	70-73	52.6	0
	73-76	47.2	0
	76-80	50.3	120.8
	80-83	55.7	2363.3
	83-86	51.3	6353.9
	86-90	56.6	2911
	90-93	49.3	719.4
	93-96	55.7	369.5
	96-100	57.8	374.1
	100-103	38.9	103.3
	103-106	12.2	5
	106-110	6.9	0.9
	110-113	0	0
	113-116	0	0
	116-120	0	0
	140-143	0	0
	143-146	0	0
	146-150	0	0

note: B 0 equals sample from tracer location B, 0 cm offset.

TRACER CONCENTRATIONS WITHIN THE PROFILE.

TRACER LOCATION	SAMPLE DEPTH (CM)	CONC. Br- (PPM)	CONC. 2,6-DFBA (PPM)
B 15W			
	0-20	0	0
	20-25	0.8	0
	25-30	2.2	0
	35-40	48.8	0
	40-45	63.2	0
	45-50	77.1	0
	50-55	65.5	0
	55-60	49.7	0
	60-65	58.3	0
	65-70	55.9	0
	70-75	53.7	0
	75-80	60.4	1.3
	80-85	47.9	8.7
	85-90	54.4	9.6
	90-95	52.1	3.3
	95-100	50.6	2.8
	100-105	28.5	1.8
	105-110	5.8	0.7
	110-115	0	0.6
	115-120	0	0
	120-125	0	0
	125-130	0	0
	130-135	0	0
	135-140	0	0
	140-145	0	0
	145-150	0	0

note: B15W equals sample from tracer location B, 15 cm offset to the west.

TRACER CONCENTRATIONS WITHIN THE PROFILE.

TRACER LOCATION	SAMPLE DEPTH (CM)	CONC. Br- (PPM)	CONC. 2,6-DFBA (PPM)
B 15E			
	0-20	0	0
	20-25	0.11	0
	25-30	6.17	0
	30-35	8.66	0
	35-40	42.38	0
	40-45	55.71	0
	45-50	61.87	0
	50-55	53.12	0
	55-60	58.97	0
	60-65	52.25	0
	65-70	51.06	0
	70-75	60.48	0
	75-80	57.43	1.87
	80-85	55.9	5.74
	85-90	52	4.72
	90-95	68.4	4.74
	95-100	48.64	3.8
	100-105	34.84	3.39
	105-110	13.62	1.55
	110-115	0	0.13
	115-120	0	0
	120-125	0	0
	125-130	0	0
	130-135	0	0
	135-140	0	0
	140-145	0	0
	145-150	0	0

note: B 15E equals sample from tracer location B, 15 cm offset to the east.

TRACER CONCENTRATIONS WITHIN THE PROFILE.

TRACER LOCATION	SAMPLE DEPTH (CM)	CONC. Br- (PPM)	CONC. 2,6-DFBA (PPM)
B 30W			
	10 - 26	0	0
	26-30	0.61	0
	40-43	8.61	0
	43-46	84.97	0
	46-50	97.96	0
	50-53	98.12	0
	53-56	65.13	0
	56-60	88.19	0
	60-63	53.7	0
	63-66	57.4	0
	66-70	96.82	0
	70-73	83.78	0
	73-76	50.97	0
	76-80	59.2	0
	80-83	49.7	0
	83-86	61.2	0
	86-90	55.3	0.13
	90-93	19.6	0
	93-96	0	0.72
	96-100	0	0
	100-103	0	0.09
	103-106	0	0
	106-110	0	0
	140-143	0	0
	143-146	0	0
	146-150	0	0
	150-153	0	0
	153-156	0	0

note: B 30W equals sample from tracer location B, 30 cm offset to the west.

TRACER CONCENTRATIONS WITHIN THE PROFILE.

TRACER LOCATION	SAMPLE DEPTH (CM)	CONC. Br- (PPM)	CONC. 2,6-DFBA (PPM)
B 30E			
	0-20	0	0
	20-25	0	0
	25-30	0.23	0
	30-35	7.31	0
	35-40	8.69	0
	40-45	8.7	0
	45-50	8.98	0
	50-55	4.76	0
	55-60	27.46	0
	60-65	53.75	0
	65-70	58.06	0
	70-75	54.12	0
	75-80	50.44	0
	80-85	30.16	0.19
	85-90	27.69	0.33
	90-95	24.04	0.49
	95-100	8.06	0.37
	100-105	3.9	0.12
	105-110	0	0
	110-115	0	0
	115-120	0	0
	120-125	0	0
	125-130	0	0
	130-135	0	0
	135-140	0	0
	140-145	0	0
	145-150	0	0

note: B 30E equals sample from tracer location B, 30 cm offset to the east.

TRACER CONCENTRATIONS WITHIN THE PROFILE.

TRACER LOCATION	SAMPLE DEPTH (CM)	CONC. Br- (PPM)	CONC. 2,6-DFBA (PPM)
C 0			
	0-20	0	0
	20-25	10.3	0
	25-30	15.8	0
	30-35	17.1	0
	35-40	22	0
	40-45	16.3	0
	45-50	15.6	0
	50-55	34.6	0
	55-60	89.2	0
	60-65	102.5	0
	65-70	110.4	0
	70-75	119.3	0
	75-80	158.5	0.9
	80-85	137.2	6.1
	85-90	127.9	302.7
	90-95	120.4	283.1
	95-100	106.5	109.9
	100-105	78.2	388.2
	105-110	43.8	2826.9
	110-115	13.9	405.5
	115-120	8.6	259.6
	120-125	3.5	36.6
	125-130	1.4	4.6
	130-135	0	0
	135-140	0	0
	140-145	0	0
	145-150	0	0

note: C 0 equals sample from tracer location C, 0 cm offset.

TRACER CONCENTRATIONS WITHIN THE PROFILE.

TRACER LOCATION	SAMPLE DEPTH (CM)	CONC. Br- (PPM)	CONC. 2,6-DFBA (PPM)
C 15W			
	0-20	0	0
	20-25	9.5	0
	25-30	21.7	0
	30-35	18.9	0
	35-40	16.6	0
	40-45	25.3	0
	45-50	30	0
	50-55	24.8	0
	55-60	22.1	0
	60-65	67.9	0
	65-70	69.5	0
	70-75	109.4	0
	75-80	117.6	0
	80-85	54.9	9.4
	85-90	62	10.1
	90-95	67.3	8.5
	95-100	58.7	12.9
	100-105	13.3	48.2
	105-110	13.8	49
	110-115	12.7	36.6
	115-120	10.1	7.3
	120-125	0.2	3.1
	125-130	0	0.4
	130-135	0	0
	135-140	0	0
	140-145	0	0
	145-150	0	0

note: C 15W equals sample from tracer location C, 15 cm offset to the west.

TRACER CONCENTRATIONS WITHIN THE PROFILE.

TRACER LOCATION	SAMPLE DEPTH (CM)	CONC. Br- (PPM)	CONC. 2,6-DFBA (PPM)
C 15E			
	0-20	0	0
	20-25	5.3	0
	25-30	15.6	0
	30-35	16.3	0
	35-40	25.3	0
	40-45	22.8	0
	45-50	25.2	0
	50-55	37.9	0
	55-60	43.1	0
	60-65	77.4	0
	65-70	101.4	0
	70-75	98.2	0
	75-80	72.6	0
	80-85	65.5	4.7
	85-90	65.2	4.9
	90-95	58.8	5.3
	95-100	50.3	6.9
	100-105	28.1	6.6
	105-110	7.9	6.2
	110-115	5.6	7.9
	115-120	2.2	1.5
	120-125	0	0.5
	125-130	0	0
	130-135	0	0
	135-140	0	0
	140-145	0	0
	145-150	0	0

note: C 15E equals sample from tracer location C, 15 cm offset to the east.

TRACER CONCENTRATIONS WITHIN THE PROFILE.

TRACER LOCATION	SAMPLE DEPTH (CM)	CONC. Br- (PPM)	CONC. 2,6-DFBA (PPM)
C 30W			
	0-20	0	0
	20-25	3.1	0
	25-30	5.8	0
	30-35	6.7	0
	35-40	8.4	0
	40-45	14.1	0
	45-50	21	0
	50-55	29.5	0
	55-60	25.8	0
	60-65	36.9	0
	65-70	51.3	0
	70-75	64.1	0
	75-80	61.5	0
	80-85	57.3	0
	85-90	52.2	0
	90-95	39.4	4
	95-100	26.6	2.2
	100-105	12.6	1.7
	105-110	2.1	2.6
	110-115	0.4	3.6
	115-120	0	0.6
	120-125	0	0
	125-130	0	0
	130-135	0	0
	135-140	0	0
	140-145	0	0
	145-150	0	0

note: C 30W equals sample from tracer location C, 30 cm offset to the west.

TRACER CONCENTRATIONS WITHIN THE PROFILE.

TRACER LOCATION	SAMPLE DEPTH (CM)	CONC. Br- (PPM)	CONC. 2,6-DFBA (PPM)
C 30E			
	0-20	0	0
	20-25	1.7	0
	25-30	1.6	0
	30-35	1.4	0
	35-40	0.7	0
	40-45	0.9	0
	45-50	1.6	0
	50-55	1.8	0
	55-60	1.5	0
	60-65	2.3	0
	65-70	1.5	0
	70-75	1.2	0
	75-80	3.4	0
	80-85	2.8	0
	85-90	0.7	5.2
	90-95	1.9	3.8
	95-100	2.1	1.1
	100-105	0.1	1.7
	105-110	0	1.4
	110-115	0	1.2
	115-120	0	1.4
	120-125	0	0
	125-130	0	0
	130-135	0	0
	135-140	0	0
	140-145	0	0
	145-150	0	0

note: C 30E equals sample from tracer location C, 30 cm offset to the east.