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An Arid Zone Lysimeter Facility for Performance Assessment and Closure Investigations at the Nevada Test Site

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ABSTRACT

Two precision weighing lysimeters were installed near the Area 5 Radioactive Waste Management Site (RWMS) on the Nevada Test Site to provide support for investigations of water, solute, and heat fluxes in the near-surface of the soil. The lysimeters consist of soil tanks with a volume of 16 m^3 mounted on a sensitive scale. One lysimeter was revegetated with native shrubs whereas the other was kept bare to simulate a non-vegetated waste cover. Data consisting of physical and hydrological properties of the lysimeter soils, thermal and moisture conditions in the lysimeters, and atmospheric boundary conditions are being collected for calibrating and verifying computer models for simulating the flow of water and heat in the near surface alluvium at the Area 5 RWMS. This effort will provide site-specific models for demonstration of "no migration" of constituents to the water table. Moisture and thermal conditions in the lysimeters are monitored daily using time domain reflectometry probes and thermocouple psychrometers. Daily evaporation and evapotranspiration are calculated from the lysimeter scales. Meteorological variables are monitored by sensors mounted on a 3-meter tower adjacent to the lysimeters. An array of soil-solution samplers to be installed through the side of the soil tank will allow studies of waste mobility under natural conditions. Conceptual designs for closure at the RWMS are focused on using an upper layer of repacked native alluvium, which can be tested with the lysimeters. In addition, performance of other components such as a capillary barrier can be tested by installing a scaled version in one of the lysimeter tanks.

INTRODUCTION

Weighing lysimeters are an important tool for characterizing near surface transport processes, including the measurement of evapotranspiration (Howell et al., 1987; Marek et al., 1988). Two precision weighing lysimeters were installed near the Area 5 Radioactive Waste Management Site (RWMS) on the Nevada Test Site (NTS) to provide support for investigations of water, solute, and heat fluxes in the near-surface of the soil. Data from the weighing lysimeters, physical and hydrological properties of the lysimeter soils, and atmospheric boundary conditions are being collected for calibrating and verifying computer models for simulating the flow of water and heat in the near surface of alluvium at the Area 5 RWMS. This effort will provide site-specific models for demonstration of "no migration" of constituents to the water table.

The lysimeters consist of soil tanks with a volume of 16 m^3 mounted on a sensitive scale. The top of the soil tank is flush with the ground surface and access to the side of the soil tank is provided through an underground entry (refer to Figure 1). During installation of the lysimeters, soil was removed in lifts, screened, and set aside for repacking. The soil lifts were repacked in order to simulate the natural stratigraphy. One lysimeter was revegetated with native shrubs whereas the other was kept bare to simulate a non-vegetated waste cover.

SITE DESCRIPTION

The lysimeter facility is located approximately 400 m west of the Area 5 RWMS on the NTS, which is located in the northern Frenchman Flat in southern Nevada. Frenchman Flat is a closed basin. The RWMS is at an elevation of 976 m on a bajada of the Massachusetts Mountains at the intersection of three alluvial fans on a slope of about 1° (Istok et al., 1994).

The NTS lies in a region that is transitional between the Great Basin Desert and the Mohave Desert. The climate of the area is characterized by a large number of cloudless days, low precipitation, and high daily temperatures, especially in the summer. Annual average precipitation is approximately 125 mm. The majority of rain falls during two peak seasons, with a greater peak in the winter and a lesser one occurring during the summer months.

MATERIALS AND METHODS

Each of the weighing lysimeters were instrumented with eight time domain reflectometry (TDR) probes to measure volumetric soil water content (storage component of the water balance) at depths of 10, 20, 30, 50, 70, 110, 140, and 170 cm; and 10 thermocouple psychrometers (TCP's) to measure soil water potential and soil temperature at depths of 10, 20, 30, 40, 50, 70, 90, 110, 140, and 170 cm. The approximate placement of these sensors within the lysimeters is illustrated in Figure 2. TDR and TCP data are collected daily.

Core samples were collected from the lysimeters in 10-cm increments from 0 to 2 m depths for characterization of physical and hydrologic properties. The physical property analysis included dry bulk density and porosity. The hydrologic property analysis included water retention relations, saturated hydraulic conductivity, and hydraulic conductivity-saturation relations.

The boundary conditions at the ground surface are provided by collecting hourly averages of micrometeorological parameters from a 3-meter micrometeorology instrumentation stand located next to the lysimeter facility. Inputs of water from precipitation are recorded with tipping bucket rain gauges and hourly averages of evaporation and evapotranspiration are obtained from the weighing lysimeters.

PRELIMINARY RESULTS

Precipitation and evaporation data have been collected for nearly two years, thus providing a clear picture of the water balance of the area for the past two years. Figure 3 illustrates monthly precipitation measured at four stations located at approximately the four corners (NW, NE, SW, and SE) of the RWMS, and monthly evaporation (measured in the bare-soil lysimeter), and evapotranspiration (measured in the vegetated lysimeter) for the period of September 1994 to August 1995.

Winter rain amounts were greater than evaporation (E) and evapotranspiration (ET) during the months of December 1994, and January 1995. Data were not available for the vegetated lysimeter in February 1995. Monthly ET totals were greater than monthly precipitation totals after February 1995, and monthly E totals were greater than monthly precipitation totals after March 1995.

The data period presented resulted in an annual precipitation total of 186 mm, which is approximately 50 percent higher than the annual average amount of 125 mm. The ET total amount was 320 mm, and the E total amount was 158 mm. These results indicate that although annual precipitation was greater than bare-soil evaporation, it was far less than annual evapotranspiration, thus illustrating that plant water use is a significant component of the water balance, and therefore that plants may prove to be an essential component in cover designs.

The resulting pattern of soil water distribution from this annual cycle of wetting and drying is illustrated in Figure 4 for the vegetated lysimeter. The soil water content profile prior to the winter rains was consistently dry. Prior to 1995, TDR probes were not installed in the top 50 cm of the lysimeters. Following the winter rains, elevated soil water content values were found in the top meter of both lysimeters. Redistribution over the next new months resulted in increased soil water contents at depth. Later in the year, after a period of drying, the soil water content profile returned to a consistently dry state, with volumetric water content values at approximately six percent in the bare-soil lysimeter, and three percent in the vegetated lysimeter (Figure 4). The presence of plant cover enabled considerably more soil drying than occurred with a bare-soil cover.

DISCUSSION

Preliminary results indicate that actual ET rates exceed precipitation rates for this region, even though precipitation was 150 percent of normal for the test period. Weighing lysimeter data indicate that each annual input of precipitation is entirely removed by annual ET, thus indicating conditions of zero recharge, and indicating ideal conditions for location of a RWMS, and demonstration of "no migration" of constituents to the water table.

Future plans for the lysimeter facility include studies of waste mobility under natural conditions using an array of soil-solution samplers to be installed through the side of the soil tank. In addition, conceptual designs for closure at the RWMS will be tested at the lysimeter facility, because most conceptual designs are focused on using an upper layer of repacked native alluvium, as is found in the lysimeters. Performance of other conceptual designs such as a capillary barrier can also be tested by installing a scaled version in one of the lysimeter tanks.

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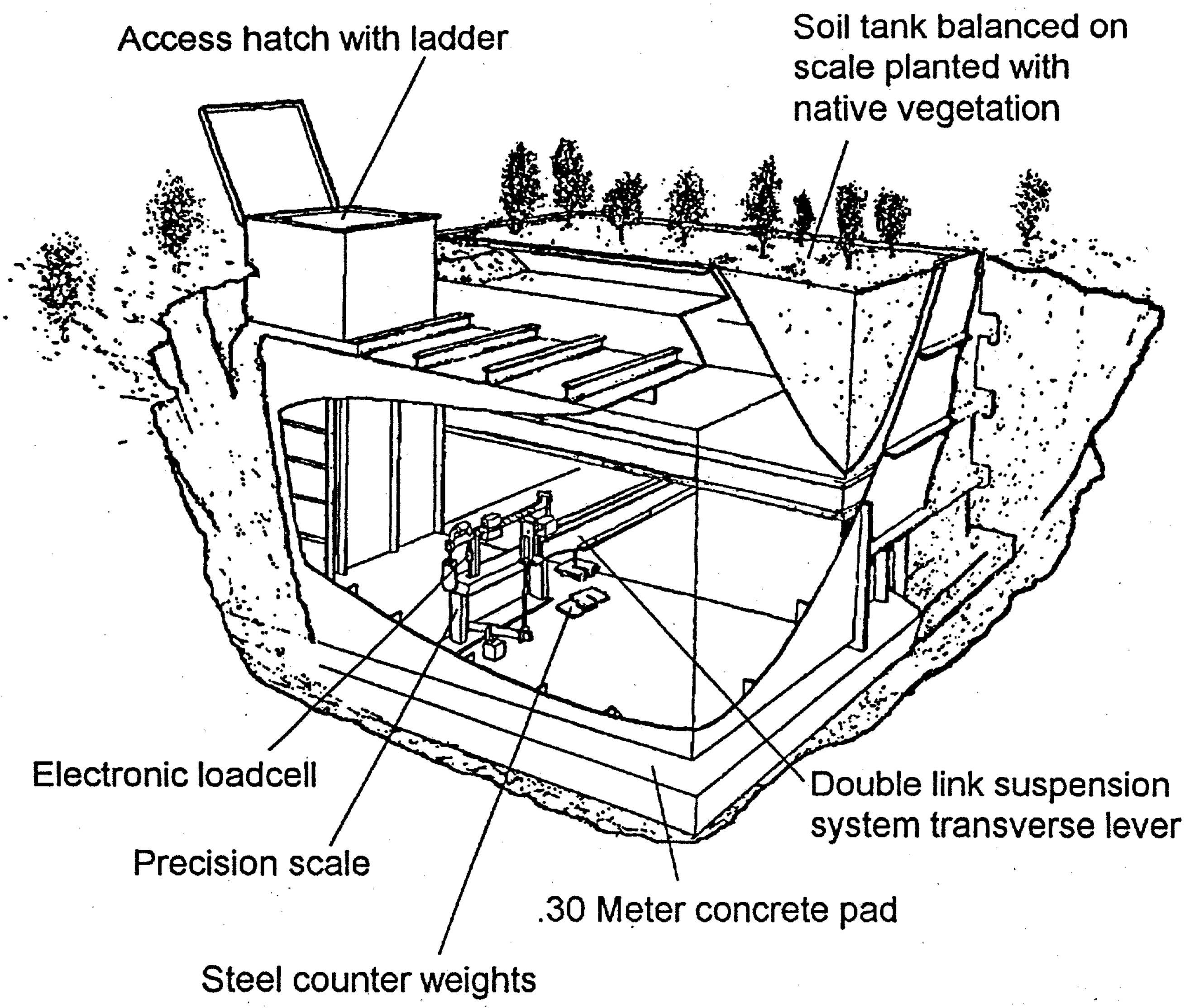

Figure 1. View of a vegetated weighing lysimeter showing the soil tank and scale assembly (from Precision Lysimeters, Red Bluff, CA).

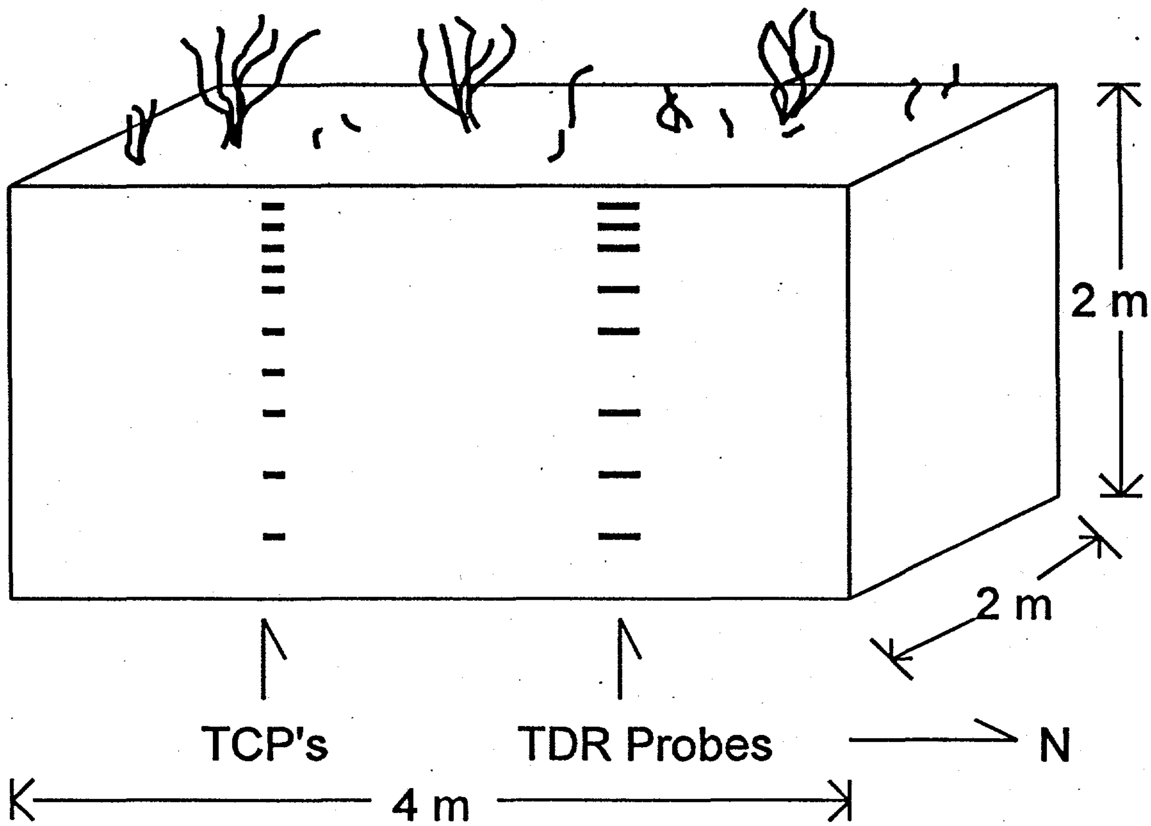

Figure 2. Schematic diagram of the vegetated lysimeter with approximate placement of the 10 thermocouple psychrometers (TCP's) and 8 TDR probes. TCP's are located at depths of 10, 20, 30, 40, 50, 70, 90, 110, 140, and 170 cm, while TDR probes are located at depths of 10, 20, 30, 50, 70, 110, 140, and 170 cm. All TCP's and TDR probes are buried at least 80 cm away from the lysimeter walls.

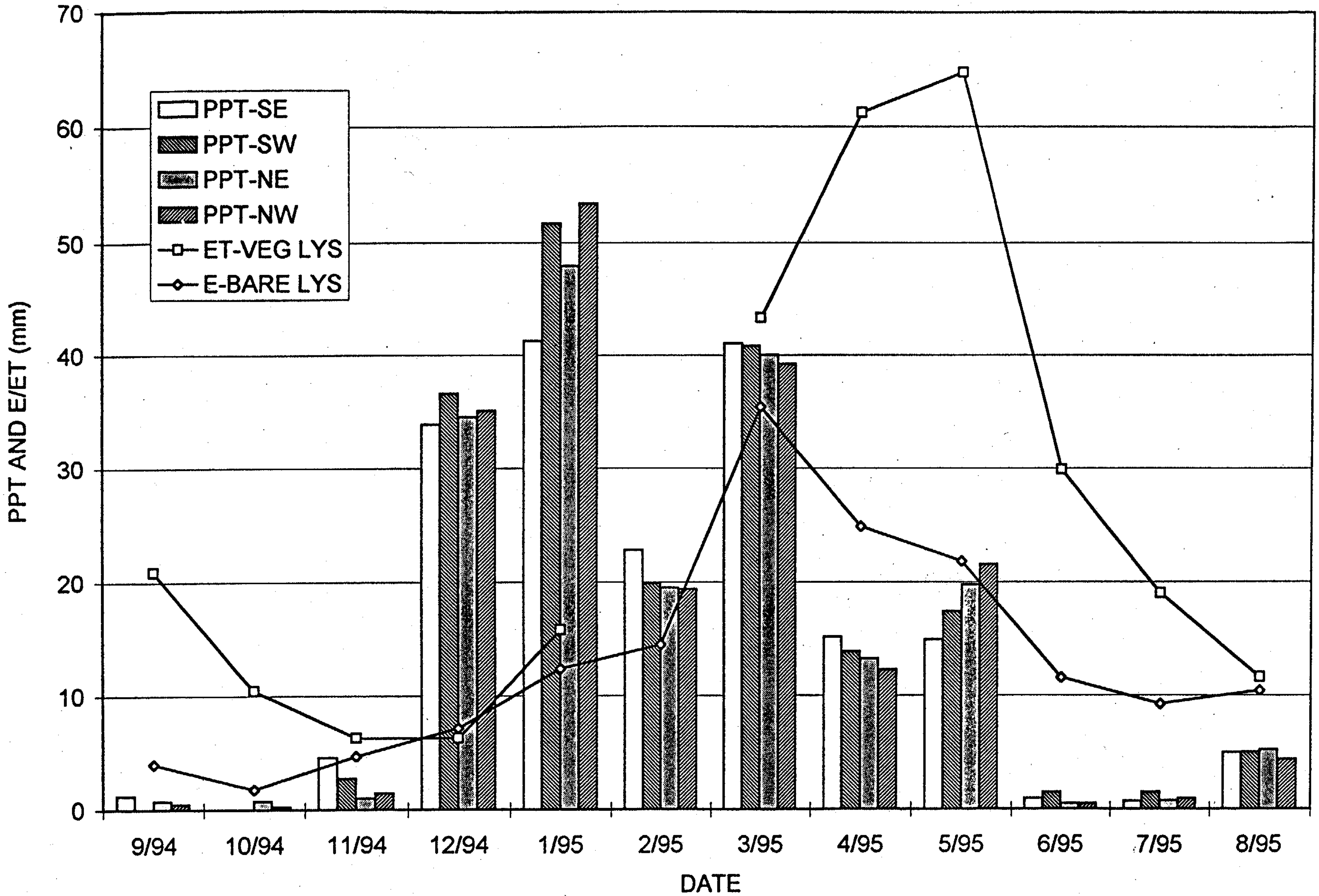

Figure 3. Summary of monthly totals of precipitation at the four rain gauges surrounding the Area 5 RWMS, and monthly totals of evaporation and evapotranspiration recorded by the two weighing lysimeters.

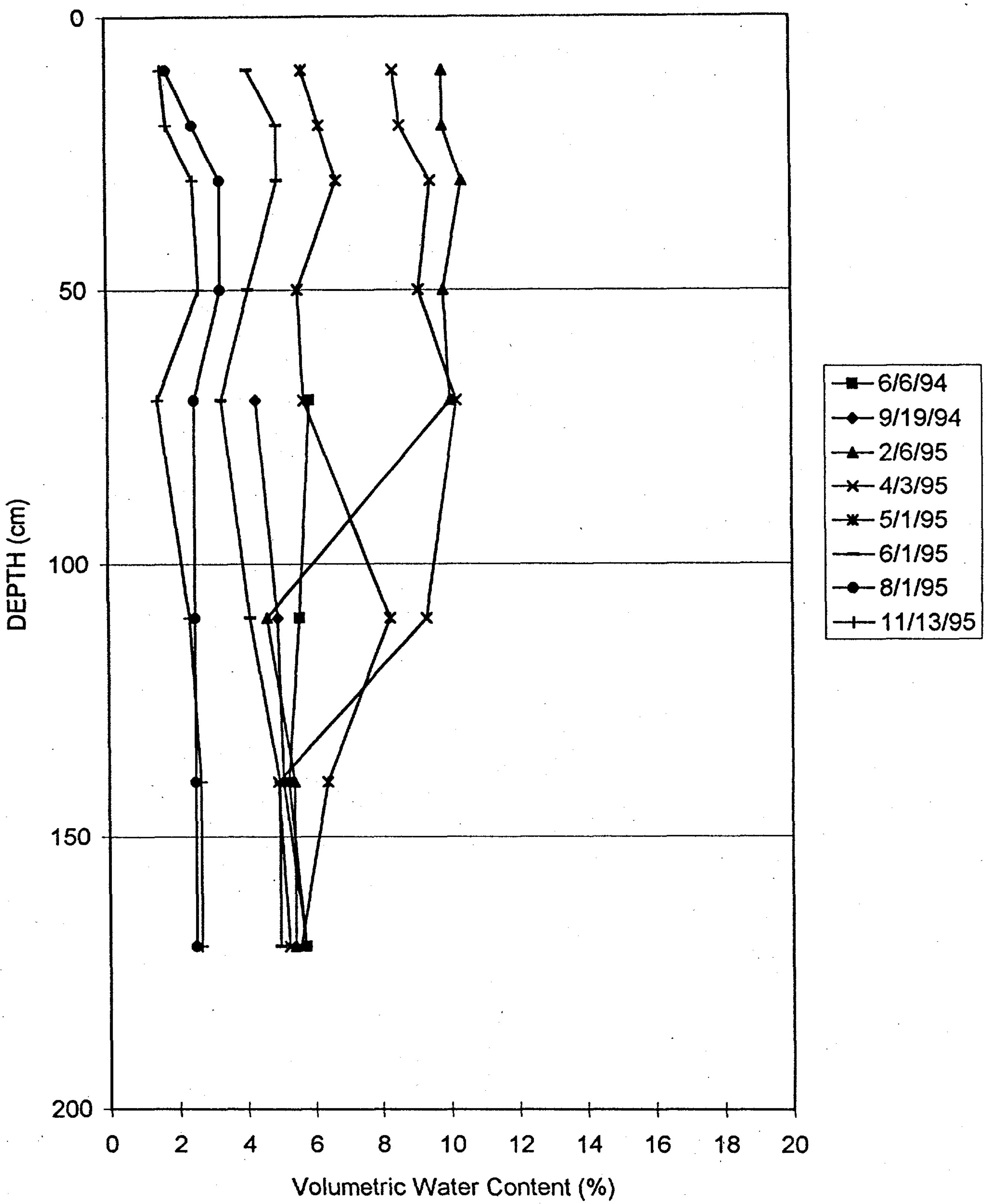

Figure 4. Vegetated weighing lysimeter water content profiles with time. TDR probes were not installed in the top 50 cm of the lysimeter before 1995.