The Field Lysimeter Test Facility (FLTF) at the Hanford Site: Installation and Initial Tests

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February 1989

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Pacific Northwest Laboratory
Richland, Washington 99352

EXECUTIVE SUMMARY

Pacific Northwest Laboratory (PNL) and Westinghouse Hanford Company (WHC) have cooperated to develop the Hanford Site Protective Barrier Development Program. The objectives of this program are to test barrier design concepts and to demonstrate a barrier design that meets established performance criteria for use in isolating wastes disposed of near-surface at the Hanford Site. Specifically, the program is designed to assess how well the barriers perform in controlling biointrusion, water infiltration, and erosion, as well as evaluating interactions between environmental variables and design factors of the barriers. To assess barrier performance and design with respect to infiltration control, field lysimeters and small- and large-scale field plots are planned to test the performance of specific barrier designs under actual and modified (enhanced precipitation) climatic conditions.

As part of these efforts, PNL and WHC jointly developed the plans and built the Field Lysimeter Test Facility (FLTF). This facility is located in the 600 Area of the Hanford Site just east of the 200 West Area and adjacent to the Hanford Meteorological Station. The FLTF data will be used to assess the effectiveness of selected protective barrier configurations in controlling water infiltration. The facility consists of 14 drainage lysimeters (2 m dia x 3 m deep) and four precision weighing lysimeters (1.5 m x 1.5 m x 1.7 m deep). The lysimeters are buried at grade and aligned in a parallel configuration, with nine lysimeters on each side of an underground instrument chamber. The lysimeters were filled with materials to simulate a multilayer protective barrier system. Data gathered from the FLTF will be used to compare key barrier components and to calibrate and test models for predicting long-term barrier performance.

Water infiltration tests at the FLTF are designed to test the interactions of vegetation, surface gravel, soil thickness, and precipitation changes on drainage from a multilayer soil system. The FLTF tests consist of seven treatments:

1. ambient precipitation, vegetated soil (1.5 m deep)
2. ambient precipitation, bare soil (1.5 m deep)

3. twice average precipitation, vegetated soil (1.5 m deep)
4. twice average precipitation, bare soil (1.5 m deep)
5. ambient precipitation, surface gravel admix/vegetation (1.5 m deep)
6. ambient precipitation, vegetated soil (1.0 m deep)
7. precipitation-to-breakthrough, bare soil (1.5 m deep).

These treatments are replicated in both the drainage and weighing lysimeters. Details of the construction, backfill, instrumentation, and initial testing for the FLTF are provided in this document.

The experimental design of the FLTF allows drainage to be measured directly from each of the 18 lysimeters by gravimetric weighing of the out-flow water. Water balance components are also measured. A neutron probe is used to measure storage changes in the top 1.5 m of each lysimeter. The four weighing-lysimeters are used to measure both precipitation and evapotranspiration with a precision of ± 0.02 mm water. Additional climate data (e.g., solar radiation, air temperature, humidity, wind speed, etc.) for the FLTF are available from the adjacent Hanford Meteorological Station.

In November 1987, tests were begun to measure water infiltration, evapotranspiration (ET), redistribution within the soil profile and drainage. These water balance tests are planned to continue through 1995. Vegetation representative of the native plant community was seeded and transplanted onto 10 of the 18 lysimeters. The report documents the water balance for each of the 18 lysimeters. Surface evaporation and ET rates in irrigated and non-irrigated lysimeters were significant in the winter months. Water losses by ET during the winter and early spring were sufficiently high to maintain a water deficiency in the surface soil, thus preventing drainage. The vegetated lysimeters exhibited more water loss for the 8-month (November 1987 through June 1988) test period than the bare surface (nonvegetated) lysimeters. Only the two lysimeters treated to breakthrough (D09-7 and D11-7) yielded drainage during the 8-month test period. The expected precision of replicated drainage tests is ± 1 L (equivalent to ± 0.04 cm water).

Data on the hydraulic properties of the materials used as the soil cover in the FLTF are required as input to simulate the FLTF barrier tests using computer modeling. These data include saturated hydraulic conductivity,

water retention characteristics, and selected physical properties, such as bulk density and particle-size analysis, which are useful in characterizing the variability of soil materials. Laboratory data on the hydraulic properties of the surface soil materials taken from the McGee Ranch and used to fill the FLTF lysimeters indicate that the soil material has a relatively uniform texture (loam to silt loam) throughout all lysimeters and that available water storage in 150 cm of soil for all the test samples exceeds 42 cm of water (or more than 2.5 times the average precipitation of 16 cm/yr). The water retention characteristics of this soil are described by analytical expressions (Van Genuchten parameters) that can be used in computer simulations of the lysimeter water balance using the UNSAT-H model. Field data are currently being obtained to evaluate moisture storage profiles and to measure saturated hydraulic conductivity by in-place testing. These data will be compared to previous laboratory tests to establish correlations (where possible) to relate field-measured properties to such laboratory-determined properties as particle-size analysis, hydraulic conductivity, and water retention.

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ABBREVIATIONS

<u>Units of Measure</u>		<u>Hanford Site Terms</u>	
d	day	ALE	Arid Lands Ecology (Reserve)
dia	diameter	BWTF	Buried Waste Test Facility
cm	centimeter	HMS	Hanford Meteorological Station
cm ³	cubic centimeter	PNL	Pacific Northwest Laboratory
g	gram	WHC	Westinghouse Hanford Company
h	hour	DOE	U.S. Department of Energy
k	kilo (prefix, 10 ³)		
kg	kilogram		
kg/m ³	kilogram per cubic meter		
kg-wt	kilogram-weight		
L	liter		
lb	pound		
m	meter		
mg	milligram		
mL	milliliter		
mm	millimeter		
yr	year		
wt	weight		

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1.0 INTRODUCTION

Large volumes of radioactive waste currently are buried at the Hanford Site in a variety of near-surface disposal facilities ranging from simple soil-covered trenches to million-gallon tanks. Permanent disposal options include exhuming the waste and placing it in a deep geologic repository, in situ immobilization (i.e., in situ vitrification), and isolation from environmental forces (i.e., barriers). Placing protective barriers over waste sites has been proposed as an engineering alternative to exhuming wastes and relocating them. The Record of Decision (53 FR 12449-53) on disposal of Hanford defense high-level, transuranic and tank wastes commits to placement of a protective barrier over low-activity double-shell tank waste that has been disposed of in near-surface grout vaults. These protective barriers are being designed to limit plant and animal intrusion and to restrict water infiltration to levels below prescribed limits. By controlling the infiltration of water, the barrier can also control the release and transport of radionuclides through the vadose zone to ground water. These barriers will be essential to long-term (10,000-year design life) protection of the environment without monitoring, maintenance, or active institutional controls.

Westinghouse Hanford Company (WHC) is formulating barrier performance standards based on needs specified in the Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes Final Environmental Impact Statement (USDOE 1987). Important technical considerations include selecting, evaluating, and demonstrating barrier materials, barrier systems, and emplacement methods that will meet the requirements of the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and Washington State. The Hanford Site Protective Barrier Development Program was developed jointly by WHC and the Pacific Northwest Laboratory (PNL) with objectives to test barrier design concepts and to demonstrate barrier designs that meet established performance criteria. Plans are now being made to evaluate specific barrier designs using lysimeters and small- and large-scale field plots.

Individual tasks of the program address specific issues related to barrier design and performance. The program tasks include assessments of 1) biointrusion control, 2) water infiltration control, 3) erosion control,

4) barrier construction materials, 5) physical stabilization (subsidence), 6) human intrusion control, 7) field monitoring and model validation, 8) natural analogues, and 9) climate change effects. In addition, interactions between environmental and design factors that may cause disruption or degradation of the barrier are also addressed. Specifically, the effects of biointrusion on water infiltration will be studied, as well as the effects of erosion control (i.e., surface gravel additions) on plant growth and water infiltration and storage. These program tasks are presented in detail in the Protective Barrier and Warning Marker System Development Plan (Adams and Wing 1986).

The Field Lysimeter Test Facility (FLTF) was built during FY 1987 near the Hanford Meteorological Station (HMS) (see Figure 1.1) to evaluate how well the barrier system will limit water infiltration. The facility contains 14 drainage lysimeters and 4 weighing lysimeters. This facility will provide data for direct comparison of key barrier components, and specific data sets will be used to calibrate and test models that will accurately predict long-term barrier performance.

The amount of yearly precipitation not removed by evapotranspiration and available to move through waste sites at Hanford is at present unknown. The lysimeters used at the FLTF will allow direct measurement of water that passes through the barrier system. Using this collected water, we can measure the effectiveness of the barrier system under the environmental conditions experienced during the observation period.

Although the main objective of the lysimeter facility is to assess the effectiveness of selected protective barriers in controlling water infiltration, it will also be used to evaluate the impact of selected engineering changes in the barriers, such as varying the soil thickness and adding gravel at the soil surface. Using gravel to control erosion is one of the current design features that will require testing to assess its impact on the overall effectiveness of the system.

FIGURE 1.1. Location of the Field Lysimeter Test Facility (FLTF) Adjacent to the Hanford Meteorological Station Between the 200 Areas on the Hanford Site

This report documents the construction of the facility and describes in detail the backfilling and instrumentation of each lysimeter. In addition, results of the initial infiltration tests and laboratory determinations of soil properties are presented here.

2.0 DESCRIPTION OF THE FACILITY

The FLTF is located on the Hanford Site near the HMS between the 200-West and 200-East Areas (Figure 1.1) (N 44200 and W 69300 Hanford Site coordinates). The facility is approximately 150 m west-southwest of the main instrument tower at the HMS. The site was chosen because of its proximity to the major waste management areas (200 East and 200 West) at Hanford and the quality-assured climate station from which HMS data are available.

2.1 FIELD LYSIMETER DESIGN

Pacific Northwest Laboratory and WHC staff jointly developed a conceptual design of the FLTF and worked with Kaiser Engineers Hanford Company to finalize the design. This facility is being used as both a research and demonstration facility for the barrier program. The FLTF is constructed from a parallel set of steel tanks buried at grade. Figure 2.1 shows a schematic drawing of one-half of the FLTF. The engineering design drawings for the facility are contained in a set of drawings numbered H-6-5324 through H-6-5333 on file with WHC. These drawings include details of lysimeter construction and the placement of the lysimeters into a completed facility. Figures 2.2 through 2.5 illustrate the overall design features. In addition, Figure 2.2 lists the lysimeters by number and specifies the treatment. The number following the dash indicates the treatment in that lysimeter.

The FLTF contains both drainage and weighing lysimeters. The measurement capabilities of these two types of lysimeters were described previously (Gee and Jones 1985) and appear to be suitable to test barrier performance for water infiltration control. The drainage lysimeters are designed to contain a barrier with a fixed volume (2 m dia x 3 m deep) in which water storage changes are measured using a neutron probe, a gamma probe, and periodic soil sampling. Drainage is measured directly by collecting water from a drain port at the bottom of the lysimeter (Figure 2.6). The weighing lysimeters isolate a soil volume (1.5 m x 1.5 m x 1.6 m deep) and generate a continuous record of weight changes, which, when supplemented with physical observations, can be used to estimate precipitation, evapotranspiration, and

FIGURE 2.1. Schematic Drawing of the Field Lysimeter Test Facility Showing One-Half of the Parallel Configuration of Lysimeters

storage changes. In addition, drainage can also be measured directly by collecting water from a drain port at the bottom of each weighing lysimeter.

2.2 BARRIER TREATMENTS AND MATERIALS

The barrier systems to be tested in the FLTF were selected primarily to 1) demonstrate the effectiveness of a multilayer barrier incorporating a pore-size discontinuity to limit unsaturated flow, 2) collect information on barrier performance under natural and elevated rainfall conditions, and 3) examine effects of vegetation on barrier performance.

Precipitation (the amount of water [rain or snow] added to the soil profile) and evapotranspiration (the amount of water removed through bare soil evaporation and plant transpiration) at the surface of the barrier system are inputs and outputs, respectively. When precipitation (P) is larger than evapotranspiration (ET), soil water storage increases, and, conversely, when ET is larger than P , soil water decreases. The amount of water that can be

Treatment	Precipitation			Surface			Soil Thickness		Lysimeter #
	N ^(a)	2N ^(b)	F ^(c)	Bare	Veg	Admix	1.0 m	1.5 m	
1	X				X			X	W01-1, D04-1, D07-1
2	X			X				X	W02-2, D01-2, D08-2
3		X			X			X	W03-3, D13-3, D14-3
4		X		X				X	W04-4, D10-4, D12-4
5	X				X	X		X	D02-5, D05-5
6	X				X		X		D03-6, D06-6
7				X				X	D09-7, D11-7

^(a)Normal precipitation

^(b)Twice normal precipitation

^(c)Precipitation until failure

FIGURE 2.2. Plan View of the Field Lysimeter Test Facility (FLTTF) and Treatment Descriptions for Each Lysimeter

FIGURE 2.3. Drainage Lysimeter Construction, Top and Side Views

FIGURE 2.4. Weighing Lysimeter Construction, Top and Side Views

FIGURE 2.5. Cutaway Drawing Showing Lysimeter Facility Design

FIGURE 2.6. Cutaway Schematic of Drainage Lysimeter Showing Rock and Soil Layers and Instrument Placement

stored is directly related to depth of the soil and its physical characteristics, such as hydraulic conductivity, water retention, texture, and layering.

All fine soil used in the lysimeters was obtained from an area on the Hanford Site generally referred to as the McGee Ranch (see Figure 1.1). The characterization of these fine soils is described in Last et al. (1987) and in this document. Adequate soil thickness is important for the barrier

system to operate effectively; if the soil layer thickness is insufficient to store yearly precipitation, the soil at the bottom of the soil layer may saturate and drain into lower rock layers. Conversely, if the soil layer is too thick, water may move below the root zone, which will eventually saturate soil at the interface and cause drainage. For typical arid site conditions, the depth of soil that will be effective is thought to be between 1.5 and 2 m. Preliminary modeling efforts using characteristics for a silt loam soil indicate 1.5 m of soil as suitable. Over 10,000 years, a 1.5-m soil thickness may erode; therefore, a 1-m soil depth is being examined to determine if this thickness is still an effective barrier. To minimize the chance of erosion, the addition of an admix of gravel in the top 20 cm was proposed. This admix is being tested in D02-5 and D05-5 for its influence on water storage and subsequent barrier effectiveness.

Barrier performance is controlled by the interaction of several dynamic and static processes associated with climate, soil properties, and plant cover characteristics. All of these variables have a range of values. To test the effectiveness of a barrier system, it is necessary to select discrete values for each variable, then evaluate the barrier's performance. It is also important to note the interaction between variables; for example, increased precipitation may cause increased plant growth or increased gravel cover might cause increased surface moisture, which would, in turn, enhance plant growth. The complexity of this system and the large number of variables affecting the system's performance preclude a complete factorial experiment evaluating each variable and its interaction with every other variable. However, additional tests with 100 additional but smaller (0.3-m-dia) economical tube-type lysimeters are under way which will provide support in analyzing the complex variables that affect water infiltration and wind erosion interactions on barrier performance at the Hanford Site.

Information on barrier performance is collected from treatments that represent a finite and limited set of environmental conditions. It is expected that after a 5- to 7-year period of testing, conclusions can be made regarding the performance of selected barrier designs. Test cases, as monitored in the lysimeters, include a wide range of conditions (e.g., precipitation, surface cover, and soil depth) so that bounding cases for barrier

drainage can be evaluated. From these test cases and monitoring efforts, model calibration and validation data sets can be formulated with which to validate UNSAT-H (Fayer, Gee, and Jones 1986) and other computer codes used to predict barrier performance.

Observations of barrier performance coupled with long-term model simulations will allow optimization of the barrier design. As this optimization effort proceeds, it may be worthwhile to modify treatments in the FLTF to collect information on specific aspects of barrier performance. Past experience with other lysimeter systems at Hanford has shown this type of research facility to be useful far beyond the original funding project or research effort.

Continuity of measurements is important to the success of the project. During the next 5 to 7 years, we expect that much will be learned from these tests about protective barrier performance at Hanford. Seven treatments were selected for evaluation in the FLTF. These treatments were selected to represent the environmental conditions most likely to occur and possible worst-case conditions. Figure 2.2 shows which lysimeters contain which treatments and documents the seven treatments associated with the 18 lysimeters at the FLTF.

Treatments 1, 2, 3, and 4 are used in a 2 x 2 factorial design to distinguish effects of precipitation and soil cover. Precipitation is divided into ambient and twice average. Soil cover is divided into vegetated and nonvegetated. These four treatments are replicated twice in drainage lysimeters and once in weighing lysimeters, using a total of 12 lysimeters.

Two additional main-effect treatments (using four additional lysimeters), with other variables held constant, consist of 1) a comparison of bare soil with a soil containing 15% gravel by weight in the top 20 cm and 2) a comparison of a 1.0- versus 1.5-m-thick soil profile.

The seventh treatment (using two lysimeters) is used to study the behavior of a barrier system when sufficient water is applied to cause failure. Over the short term, this treatment will also provide information on soil hydraulic conductivities and field capacity. After short-term tests are completed, vegetation will be planted on the two lysimeters to indicate how

rapidly these plants can use the water in a very wet profile and how rapidly they can return soil water storage to levels equal to those observed in treatments receiving ambient precipitation.

2.2.1 Treatment 1: 1.5 m of Fine Soil, Ambient Precipitation, and Vegetation

This treatment represents a barrier design that incorporates features of adequate soil-water storage capacity and optimizes soil water loss through evapotranspiration. The barrier system uses 1.5 m of fine soil to store water, receives ambient precipitation, and is vegetated to increase evapotranspirational losses. Treatment 1 serves as the primary demonstration of the effectiveness of the barrier design.

Replication: Weighing lysimeter 1 and drainage lysimeters 4 and 7 (W01-1, D04-1, D07-1).

2.2.2 Treatment 2: 1.5 m of Fine Soil, Ambient Precipitation, No Vegetation

This treatment represents the optimized barrier design without vegetation, as presented in Treatment 1. Under ambient precipitation levels, the barrier should function for several years even in the absence of vegetation. An actual barrier might experience this condition only after range fires or extended droughts. Although this is a transient condition, the lack of vegetation will likely have a significant impact on water balance and must be documented.

Replication: Weighing lysimeter 2 and drainage lysimeters 1 and 8 (W02-2, D01-2, D08-2).

2.2.3 Treatment 3: 1.5 m of Fine Soil, Twice Average Precipitation, and Vegetation

This treatment represents the same optimized barrier design presented in Treatment 1, except the average precipitation is doubled. The vegetation will likely increase as the available water increases, but it will take several years for this vegetation to reach the actual total biomass that could be supported under heavy rainfall conditions.

Replication: Weighing lysimeter 3 and drainage lysimeters 13 and 14 (W03-3, D13-3, D14-3).

2.2.4 Treatment 4: 1.5 m of Fine Soil, Twice Average Precipitation, and No Vegetation

This treatment represents the worst-case condition applied to the barrier system. Treatment 4 receives twice-average precipitation and has no vegetation to remove stored water. Under these conditions some drainage may occur. The elevated rainfall should cause this treatment to reach steady-state condition much more quickly than lysimeters receiving only natural precipitation. The application rate of additional precipitation is discussed in Section 7.0.

Replication: Weighing lysimeter 4 and drainage lysimeters 10 and 12 (W04-4, D10-4, D12-4).

2.2.5 Treatment 5: 1.5 m of Fine Soil with Surface Gravel Admix, Average Precipitation, and Vegetation

Treatment 5 is identical to Treatment 1 except the surface has gravel (22% by weight in the top 20 cm) incorporated to minimize erosion. Using this treatment, we will examine whether surface gravel causes an unacceptable increase in water storage. The addition of gravel mulch may also affect seedling establishment, species composition, density, and community structure. If large differences occur in the vegetation community compared to other treatments containing vegetation, the vegetation may be removed from this treatment. This treatment would then be compared with Treatment 2, which has no vegetation.

Replication: Drainage lysimeters 2 and 5 (D02-5, D05-5).

2.2.6 Treatment 6: 1.0 m of Fine Soil, Ambient Precipitation, and Vegetation

Lysimeters containing this treatment will be used to evaluate how the depth of the fine soil layer affects barrier performance. Under postulated harsh environmental conditions, the soil surface may erode and reduce the soil available for water storage. The removal of 0.5 m of soil is believed to represent a severe erosion scenario during the 10,000-year operation of

the barrier system. In some cases, UNSAT-H computer simulations have indicated better barrier performance with 1 m of soil than with 1.5 m of soil (Fayer 1987). Because the water is stored closer to the surface, it is more readily lost to evapotranspiration and the 1-m barrier appears to be more effective. This is true only when the 1-m soil storage capacity is not exceeded. This treatment will help to demonstrate how well the barrier functions at reduced soil thickness.

Replication: Drainage lysimeters 3 and 6 (D03-6, D06-6).

2.2.7 Treatment 7: 1.5 m of Fine Soil, Precipitation to Breakthrough and No Vegetation

This treatment examines the physical behavior of the barrier system when enough water is added to the system to cause transmission of water through the barrier. Lysimeters receiving Treatment 7 will be covered to prevent evapotranspiration. Hydraulic conductivities, water contents, and gradients in potential will also be measured and used in model validation. As drainage becomes insignificant, soil profile moisture will be measured to determine storage capacity of the soil. After drainage studies are completed, this treatment will be identical to Treatment 1, except that the soil profile will be much wetter. The surface will be uncovered and vegetation introduced; this will demonstrate how fast the barrier system can recover from an extreme, catastrophic rainfall or flooding event.

Replication: Drainage lysimeters 9 and 11 (D09-7, D011-7).

2.2.8 Treatment Summary

The seven treatments are specific to water infiltration. Although these tests address issues related to interaction effects, such as how gravel-admix affects plant growth and water storage, how soil loss affects water storage and plant growth, and how enhanced rainfall affects vegetation and water storage, the treatments do not address issues related to animal intrusion. Animal intrusion testing is being conducted in a companion field study using similar soil cover designs (Adams and Wing 1986).

3.0 INSTALLATION OF LYSIMETERS

Excavation and construction of the FLTF was accomplished between November 1986 and February 1987. Figure 2.2 shows the parallel configuration of the lysimeters, and the lysimeter and treatment number assigned to each tank. During March of 1987, the fine soils designated for use in the barrier system were excavated from the McGee Ranch site and delivered to the FLTF site. The soil stock pile was mixed once using a large front loader. The water content of the soil stock pile was increased from 8% to 14% by weight by the use of sprinklers. This moisture content is close to optimum for compaction (see Figure A.1 in the Appendix). Preliminary leak testing of the facility was completed during April 1987, and the lysimeters were instrumented and backfilled during May and June of 1987.

This section provides details on how lysimeters were leak tested, describes backfilling procedures, and documents the instrumentation placed in each tank. The material layers in the drainage lysimeters were the same for all treatments, except for Treatment 6, which included only 1 m of fine soil. The depths of each material layer and location in reference to the geotextile layer are shown in Figure 2.6.

3.1 FIELD LYSIMETER TEST FACILITY LEAK TESTS

Before shipment from the factory to the test site, the tanks and boxes used for the 18 lysimeters were filled with water and leak tested by the manufacturer with 60 cm of standing water. Inspection at the factory indicated that all tanks bottoms were sealed (i.e., did not leak under a 60-cm water head).

A cement grout was injected underneath each tank to form a solid support under the tank bottom. This injection resulted in a minor bow (center of tank floor raised as much as 0.5 cm) in the tank floor. A second field leak test was performed to confirm that no major tank damage had occurred during construction. Before the lysimeters were tested for leaks, the bottom and inside (up to heights of 20 cm) of each drainage tank and weighing lysimeter box were coated with approximately a 3-mil-thick layer of coal-tar epoxy.

This precaution was taken to seal the bottoms against rusting, which might cause pinhole leaks that could affect drainage.

The lysimeters were filled with water on April 16 and 17, 1987, and one lysimeter was refilled on April 20, 1987, because of a leaking hose. All lysimeters were drained on April 24, 1987.

Each drainage lysimeter was charged with water and allowed to drain freely before beginning the leak test. This ensured that any water that might be retained in the tanks would not affect the results of the leak test. A known amount of water (weighed using a Sauter^(a) 120-kg scale) was then added to cover the bottom of each lysimeter. The depth of water ranged from about 1 to 11 cm of standing water because of the sloping bottom. After 7 days, this water was drained into carboys and reweighed to determine whether the initial and final weights differed significantly. During the waiting period, the tops of the lysimeters were covered with a heavy, polyvinylchloride (PVC)-reinforced plastic sheeting to minimize evaporation. The drained water was approximately 99% of the input water on average. Two tanks returned 98% of the input water. In two cases, the returned water was slightly greater than the input water indicating measurement error or possibly slight flexing of the bottom of the empty lysimeter (see Appendix A). This test suggested that, within the error of the measurement and properly accounting for evaporation losses, there were no leaks. Subsequent tests to evaluate leakage were performed after the lysimeters were filled and are discussed in Appendix A.

3.2 PLACEMENT OF BASALT, GRAVEL, AND SAND LAYERS

Materials were placed in the lysimeters in a systematic fashion. Basalt riprap was placed in the bottom, followed by a sequence of graded gravels and sands and finally covered by fine soil. This "graded" filter was designed to prevent fine soils from sifting into the riprap.

(a) Sauter is a trade name of the Mettler Instrument Co., Heightstown, New Jersey.

As mentioned above, the floors of the lysimeters and approximately 10 cm of the adjoining wall were coated with coal-tar epoxy before any materials were placed in the lysimeters. To avoid marring this coating, a layer of washed basalt riprap (i.e., basalt rock greater than 10 cm in dia) was carefully placed by hand on the bottom of each tank. Then, the 14 drainage tanks were filled with about 1 m of water, and basalt rock was dropped into the tank using a backhoe. The backhoe was able to lower its bucket into the tank so that the rocks dropped 2 m to the bottom of the tank. The water provided a cushion to minimize bouncing and scratching of the riprap material against the coating on the bottoms of the tanks. After the large basalt riprap was brought to the correct level of 195 cm (145 cm in the lysimeters receiving Treatment 6 with only 1 m of fine soil) from the top of the tank, 0.04- to 0.05-m-dia railroad ballast was placed in the next level.

The 0.04- to 0.05-m-dia railroad ballast was loaded with the Bobcat(a) loader; then the loader with driver and material was weighed on a 9080 kg (20,000 lb) capacity platform scale. The material was placed in the lysimeter using the Bobcat, and the weighing and placement process continued with periodic checking for tare weight. The mean weight of 0.04- to 0.05-m-dia railroad ballast necessary to bring the level to 180 cm from the top of the tank was 831 kg. The "graded" filter layer included 1.9-cm gravel, 0.95-cm to 1.27-cm pea gravel, and No. 8 and No. 20-30 sands. The 1.9-cm gravel, pea gravel, and No. 8 and No. 20-30 sands were similarly weighed using the Bobcat loader and platform scale. The mean weights of each of these lifts and the distance from the top of the lift to the top of the tank (numbers in parentheses refer to Treatment 6) are listed below:

1.9-cm gravel	617 kg	170 cm (140)
pea gravel (0.95 cm)	258 kg	165 cm (135)
No. 8 sand (0.24 cm)	235 kg	160 cm (130)
No. 20-30 sand (0.08 to 0.06 cm)	226 kg	155 cm (125)

The actual weights of material used in each lysimeter are presented in Table A.2, Appendix A.

(a) Bobcat is a trade name of the Clark-Melroe Co., Gwinner, South Dakota.

Each of these materials was dumped into the tank and then carefully leveled before the next layer was placed. The neutron/gamma probe ports were set in the 0.04- to 0.05-m-dia railroad ballast and held in place during the process by using a jig. This helped to ensure that the access pipes remained equidistant from one another.

The first drainage tank that was backfilled was an exception to this filling sequence. Lysimeter D09-7 was filled using slightly different methods and materials. Originally, we assumed that we would be able to use basalt and gravels from the Gable Mountain stockpiles. These materials, however, when delivered contained too much soil and debris and could not be washed well enough for use in the tanks. Lysimeter D09-7 was filled with hand-washed and hand-placed basalt from Gable Mountain to a level 185 cm below the top of the tank. Next, a 10-cm lift of hand-picked 0.04- to 0.05-m-dia railroad ballast was placed, bringing the lift level to 175 cm from the top of the tank. Then a 5-cm lift of 1.9-cm gravel-size basalt from Gable Mountain was placed in the tank, bringing the level up to 170 cm. The layers of pea gravel and sand were placed in lysimeter D09-7 as described for the other lysimeters. Because this procedure was too labor intensive, washed materials were procured from an offsite contractor. All other lysimeters used offsite basalt materials (obtained from a borrow pit located in Kennewick, Washington).

It is important to note that clean, washed materials will not be required for construction of an actual barrier; we have used clean materials to simplify the measurement of drainage in the lysimeters. The basalt and rock layers have a small but significant water storage capacity that must be considered because we are attempting to measure drainage volumes of approximately 1200 cm^3 (1.2 L). This drainage volume is equivalent to a water content change of 0.04 vol% in the basalt layer. For this reason, we pre-wet the layers of basalt, rock, and sand to prevent storage of any water draining out of the soil layer. We wet these layers by attaching a fill hose to the bottom drain and injecting water until it was observed on top of the geotextile layer; the hose was then removed and each tank allowed to drain. Excessive fines in the basalt and rock materials would tend to increase storage of water in these layers, so materials were washed before use. Samples

of all of these materials have been placed in 55-gal drums and will be stored for any future characterization work that may be needed.

After the last sand layer had been leveled, a geotextile liner (Mirafi 1000, Mirafi Inc., Charlotte, North Carolina) was placed on top of the sand to prevent any fine soils from sifting into the sand layer. The geotextile is a black, woven, polypropylene material. An electric heat knife was used to cut the circles of geotextile to seal the edges and prevent fraying of the material. These circles were cut to 215 cm in dia to allow 5 to 7 cm of geotextile to lie against the lysimeter wall. The geotextile was attached to the lysimeter walls with silastic caulking to hold the liner in place during backfilling. Two major reasons support the use of a geotextile. First, the sand and gravel layers are thinner than would be used in an actual construction (the layers are present to create the pore size discontinuity and as a backup to the geotextile) and second, the geotextile prevents layer mixing from the extensive foot traffic during instrument placing and initial soil layer placement.

Gravel and sand layers were similarly placed in the weighing lysimeters. However, the size of the weighing lysimeters was a limiting factor, so no 1.9-cm gravel was placed in these. In addition, because the floor of the weighing lysimeters slopes toward the drain, the pea gravel layer reaches only one-half the distance across the bottom of the lysimeter (Figure 3.1). The No. 8 and No. 20-30 sand layers were each placed in 5-cm lifts and leveled as described for the drainage lysimeters. The distance from the top of the weighing lysimeter to the geotextile is about 155 cm.

3.3 PLACEMENT OF FINE SOIL LIFTS

The fine soil from the McGee Ranch site was placed in the drainage lysimeters in a series of 5- to 15-cm lifts. By packing the soil in a number of relatively small lifts, we were better able to control the density of each lift. Before placing any soil in the lysimeters, the depth from the top of the tank to the geotextile was measured in four places and averaged. This value was used as the starting depth to calculate the first lift height.

FIGURE 3.1. Layering Sequence of Sands and Gravels in Weighing Lysimeters

The depth from the top of the tank to the geotextile was approximately 155 cm. This distance of 155 cm from the top of the tank corresponds to a soil depth of 150 cm because the soil surface lies approximately 5 cm below the top of the lysimeters. This configuration of the soil surface was used to minimize losses of fine soils through wind erosion and to allow us to construct an angled buttress of soil around the inner edges of the lysimeter. This buttress of soil slopes from the outer edge of the tank to approximately 7 to 10 cm from the edge and is intended to direct water away from the lysimeter sidewalls, thus preventing preferential flow down the side wall of the lysimeter.

The soil was loaded in the Bobcat loader and weighed on the platform scale. Using this weight, and assuming a moisture content from previously analyzed samples, we calculated the volume which that amount of soil should occupy to achieve a particular density at that moisture content. A wet density value of 1.5 g/cm^3 was used to calculate the first four lifts placed in each lysimeter. Note that the wet density is equal to the dry density plus the volumetric water content. For example, soil with a density of 1.5 g/cm^3 and a water content of $0.10 \text{ cm}^3/\text{cm}^3$ would have a dry (bulk) density of

1.4 g/cm³. The density of 1.5 g/cm³ was used for the bottom lifts because analysis of density samples taken at the McGee Ranch site showed higher density values at depths greater than 1.2 m. A wet density of 1.3 g/cm³ was used to calculate the volume of the remaining lifts. Samples were taken from each bucket load of soil and returned to the laboratory for determination of the actual moisture content. The soil was dropped into the lysimeter, spread, and packed by foot as closely as possible to the calculated lift height required to achieve a particular density.

After each lift was packed and leveled, distances from the top of the tank to two points on the soil surface were measured to determine the actual lift height achieved. If the actual lift height did not agree well with the calculated lift height, further packing was attempted to achieve the desired density. The first four lifts in each lysimeter consisted of only one bucket load of soil, which we attempted to pack to a wet density of 1.5 g/cm³. This amount of soil formed a lift approximately 5 cm in height.

With the exception of the first lift in each tank, the surface density/moisture probe was used to take a density and moisture reading on each lift in two positions--north and south of the neutron and gamma probe access pipes. At every second lift, soil density/moisture samples were taken at the point where the probe rested on the soil surface. These samples were taken by pressing a brass cylinder (approximately 6 cm dia by 7 cm long) into the soil, removing the soil-filled cylinder, and extruding the soil sample from the cylinder into plastic bags. These samples were used to generate calibration curves for the moisture and density probes. This procedure was followed until the final lift was packed and leveled 5 cm from the top of the tank. An angled lip of soil was then packed around the edge of the drainage lysimeter to prevent preferential flow down the sides of the drainage lysimeter. This configuration is shown at the top of Figure 2.6.

The weighing lysimeters were filled by following a similar procedure. The major difference in filling the weighing lysimeters was that in addition to weighing each load of soil before placing it in the lysimeter, we also recorded the weights of soil shown by the scales beneath the weighing lysimeters. These weights did not agree as well as we expected. Some of the

disparity was attributed to rubbing of the lysimeters on the outer tank walls or wedging of soils or gravel alongside the scales. When the lysimeters were moved slightly on the scales by using a bar to shift their position, the weights recorded for the Bobcat on the platform scale and the weighing lysimeter scale were in much better agreement. After completing the final filling operation, our initial check of the scale weights found them to be reproducible to ± 0.5 kg for a total weight change of 220 kg (nonaveraged readings). The operational goal is ± 0.050 kg when averaged for 1 hour.

The Seaman^(a) surface density probe was used to record the density and moisture of each lift, except for the first 5-cm lift, which was too shallow to obtain readings. Soil moisture samples were taken from each bucket load of soil, and moisture and density samples were taken for every other lift from the area where the probe rested on the soil surface.

Another difference between the weighing and drainage lysimeters is that the weighing lysimeters have a 10-cm-high Plexiglas^(b) lip bolted to the outside of the lysimeter wall at the top. The top of this lip is even with the ground level. The plastic reduces the amount of thermal loading to the soil surface. At the point below the soil surface where the two materials are bolted together, the joint also forms a barrier to preferential flow that might occur down the sides of the lysimeter walls. The soil surface in the weighing lysimeters is configured in the same manner as that in the drainage lysimeters. An angled buttress of soil, 5 cm in height, was formed at the lysimeter wall to prevent preferential drainage (see Figure 2.6).

3.4 INSTRUMENTATION AND MEASUREMENT TECHNIQUES

Accurate measurements of drainage and other water-balance parameters are critical to the success of the FLTF in determining the effectiveness of barriers. A list of measurements and their expected accuracy was prepared and

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(a) Seaman Nuclear Company, Oak Creek, Wisconsin.

(b) Plexiglas is a trade name of Rohn and Haas, Co., Philadelphia, Pennsylvania.

included in the experimental plan (Kirkham and Gee 1987). Over the next several years, measurements will be obtained and calibration data collected, which will allow us to refine these estimates.

All of the lysimeters are instrumented with access wells for neutron and gamma probe measurements, tensiometers, and an array of copper constantan thermocouples appropriate for that treatment. In addition, particular treatments are equipped with arrays of thermocouple psychrometers at different depths. The positions of these sensors in each lysimeter are outlined in the detailed description of each lysimeter and locations and placement are shown in Figure 2.6.

3.5 NEUTRON/GAMMA PROBE AND ACCESS WELLS

Near the center of each lysimeter, three access ports are situated in a triangular configuration. These access wells are 5.08-cm I.D. aluminum pipe with a compression fitting (TP5-2 test plug) in the bottom. During the backfilling, the pipes were held in place 30 cm apart by using a jig. The access wells extend through the sand and gravel layers and the bottom of the pipe rests in the 0.04- to 0.05-m-dia railroad ballast. These access wells are used with both a neutron probe to measure volumetric water content of soils as well as a gamma probe to measure density.

A surface neutron/gamma probe (Seaman Nuclear, SN-A340)^(a) was used to estimate moisture content and density during construction. Calibration data for this probe are presented in Appendix A.

3.6 TENSIOMETERS

Tensiometers measure soil water tension or suction directly by measuring the pressure in the soil water (Hillel 1982). The measurements are typically reported in either cm water or mbars pressure. This measurement is achieved by connecting a water-filled, porous ceramic material, which is in direct contact with the soil material, to a pressure gauge or transducer. As long as water bonds to water or tensiometer material does not break, the soil

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(a) Seaman Nuclear Company, Oak Creek, Wisconsin.

water matric potential (the negative of suction or tension) can be measured. Tensiometers, however, generally fail at soil water tensions greater than about 700 cm water. Tensiometers of this type--a porous ceramic cup connected to a rubber septum via a 2.2-cm-dia PVC pipe--were purchased from Soil Measurement Systems, Las Cruces, New Mexico. The tensiometer unit is filled with water, after it has been determined that the moisture content has increased to above 18 vol% in the surrounding soil. Below that level, the tensions are too high to permit operation of the tensiometers (i.e., the laboratory analysis suggests that tensions at lower water contents exceed 700 cm water). When the soil is wet enough, as indicated by neutron probe readings or direct sampling, the tensiometer is filled and the water columns stoppered with the rubber septum.

Each lysimeter contains three tensiometers: one at 150 cm below the soil surface, one at 100 cm below the soil surface, and one at 50 cm below the soil surface. The porous ceramic cup of each tensiometer was placed 45 cm from the tank wall. The tensiometers were installed through 2.54-cm-dia holes drilled through the tank walls at 152.5 cm, 102.5 cm, and 20 cm from the top of the tank. These holes in the lysimeter walls were sealed with silastic around the tensiometer to prevent leakage. The two lowermost tensiometers were installed at a slight angle upward from the ceramic tip to prevent air entrapment in the PVC tubing linking the porous ceramic cup to the septum end of the tensiometer. These two tensiometers pass through the lysimeter wall into the underground facility.

The tensiometers at the 50-cm depth inside the lysimeters extend upward and out through the lysimeter walls at a point 20 cm below the soil surface. From this point they are surrounded, insulated, and protected by 3-in. PVC pipes that extend to the soil surface.

3.7 THERMOCOUPLES

Thermocouples (copper/constantan) were installed in each lysimeter to monitor vertical and horizontal temperature gradients in selected lysimeters. Thermocouples are monitored continuously with a CR7 (Campbell Scientific Inc., Logan, Utah) datalogger, with selected measurements output hourly and

slower changing measurements output daily. Thermocouples were checked during installation to ensure that temperatures measured were correct. The particular array and arrangement of thermocouples installed in each lysimeter is detailed in the individual discussion of each lysimeter.

Thermocouples were installed in the lysimeters by feeding the wires through 1.27-cm holes drilled through the tank walls. When installing the thermocouples at the 150-cm soil depth, a 1-cm layer of soil was placed between the thermocouple and the geotextile. For the vertical arrays, the thermocouple junction was placed in each lysimeter at a distance 30 cm from the tank sidewall. Horizontal arrays were placed in as straight a line as possible across the lysimeter at the appropriate depth. Horizontal arrays that were placed in the basalt layer were encased in Tygon^(a) tubing to prevent the riprap material from abrading the wires. The thermocouple junctions were fed through slits in the tubing and projected out 5 cm perpendicular to the Tygon support tube to ensure an accurate reading. Care was also taken to place the tubing far enough away from the probe ports to ensure that neutron probe readings would not be affected by the hydrogen in the plastic tubing.

In addition, two chromel-constantan thermocouples encased in stainless steel were placed in the soils surrounding the lysimeter facility. Readings from these thermocouples may be used to compare soil temperatures outside the facility with temperatures inside the lysimeters.

3.8 THERMOCOUPLE PSYCHROMETER

The thermocouple psychrometer (TCP) measures total water potential (including matric and osmotic). A brief description of the operation of a thermocouple psychrometer is given in Hillel (1982) and detail related to operational use is provided by Rawlins and Campbell (1986). It is suitable for measurements of total water potentials less (more negative) than -0.1 MPa (-1 bar). This device consists of two thermocouple junctions of different mass made from chromel-constantan thermocouple wire placed inside a wire

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(a) Tygon is a registered trade name of the U.S. Stoneware Co., Akron, Ohio.

(stainless steel) screen cage. The dimensions of the cage are approximately 0.5 cm in dia by 1.0 cm in length. The device is placed in soil to a desired depth, and soil is packed around the TCP unit so that soil water vapor equilibrates with the water vapor (humidity) in the screen cage. The TCP is designed so that the small junction is cooled for a short period of time, which causes condensation of water vapor on it. Following cooling, a measurable voltage is generated as the condensed water evaporates and cools the thermocouple junction of smaller mass. The voltage is a function of the evaporation rate (wet-bulb depression), which is, in turn, a function of the vapor pressure in equilibrium with surrounding soil. The calibration of the TCP is obtained when tests of wet-bulb depressions over known salt solutions with specified water potentials produce voltage versus water potential curves. Factory calibration values are presented in Table A.3, Appendix A, for most of the TCPs used in the lysimeters.

Because plant water uptake in the vegetated lysimeters is expected to dry the soil below the range where tensiometers will work (i.e., below a matric potential of -0.07 MPa), the TCP units will be used. They work in the range from -0.1 to -8.0 MPa. For the fine soil used in the lysimeters, this range allows measurement of water contents ranging from about 4 wt% to above 10 wt%.

Arrays of TCPs were installed at four depths in the weighing lysimeters that hold vegetated treatments: three at 150 cm from the soil surface, three at 100 cm from the soil surface, three at 50 cm from the soil surface, and three at 30 cm from the soil surface. Arrays of TCPs were installed at three depths in the weighing lysimeters that have bare surface treatments: three at 150 cm, three at 100 cm, three at 50 cm. The additional array in the vegetated treatments is intended to monitor the soil water potential of the root zone of the common perennial grasses that are part of the vegetative cover on the lysimeters. The TCPs are monitored on a CR7 datalogger and the TCP program is listed in Appendix A.

3.9 ROOT OBSERVATION TUBES/RHIZOTRONS

Root observation tubes were installed in those lysimeters containing vegetated treatments. The tubes are constructed of clear glass, 5.4 cm in dia, and are marked and numbered at 5-cm depth intervals. The bottoms of the tubes are sealed. These ports will be used with a small down-hole video camera to observe root development and activity through time.

4.0 DETAILED LYSIMETER DESCRIPTIONS

The following section characterizes each lysimeter as it was filled during May or June 1987, including the results of laboratory analyses performed for the soils in that lysimeter, results of field measurements taken while filling the lysimeter, and an outline of the placement of sensors in the lysimeter. All 18 lysimeters are equipped with three neutron/gamma probe access wells in a triangular configuration.

Table A.4 in Appendix A gives the density and moisture measurements for all samples for all drainage lysimeters. Soil samples were analyzed for particle size, saturated hydraulic conductivity, and water retention. Results from completed analyses are presented in Section 6.0 and in Appendix A.

Legends for all lysimeter moisture profiles contain the following labels:

GRAV CAN = the gravimetric moisture content determined for the small core sample

GRAV BAG = a composite grab sample taken before compacting the soil in each

VOL CAN = $\text{GRAV CAN} \times \text{bulk density for that sample}$

VOL NP = volumetric moisture data taken with surface neutron moisture probe.

Each label is repeated twice as two samples were taken generally from the north or south side of the lysimeter in the case of the CAN and NP data, and one BAG from each bobcat bucket load of soil (usually two bucket loads per lift).

The legend for all of the following lysimeter density profiles contains the following labels: WET-CAN = the wet soil density in the core, SEAMAN = density value determined using surface moisture/density probe, SCALE = soil density estimated from weights of bobcat loads of soil, DRY-CAN = correction of the WET-CAN data to dry soil density. As previously described, the legends are repeated for two samples for each lift.

4.1 DRAINAGE LYSIMETER 1 (D01-2)

D01-2 is a replicate of Treatment 2: 1.5 m of fine soil, ambient precipitation, and bare surface. This lysimeter contains three tensiometers installed at depths 150 cm, 100 cm, and 50 cm below the soil surface and thermocouples installed at the same depths. Figures 4.1 and 4.2 show the density and moisture profile of the backfill in this lysimeter.

4.2 DRAINAGE LYSIMETER 2 (D02-5)

D02-5 is a replicate of Treatment 5: 1.5 m of fine soil with surface gravel admix in the top 20 cm, ambient precipitation, and vegetation. Three tensiometers are installed in this lysimeter at 150 cm, 100 cm, and 50 cm below the soil surface. In addition to vertical thermocouples at 50, 100, and 150 cm, this lysimeter contains two horizontal arrays of thermocouples at 100 cm and 250 cm below the soil surface. The horizontal arrays are composed of a string of thermocouples placed the following distances from the tank wall: 0 (inner tank wall), 5, 10, 50, 100, 150, 190, 195, and 200 cm (outer tank wall). This lysimeter will be vegetated, so it contains a root-observation tube. Figures 4.3 and 4.4 show the density and moisture profiles of the fine soils in this lysimeter.

4.3 DRAINAGE LYSIMETER 3 (D03-6)

D03-6 is a replicate of Treatment 6: 1 m of fine soil layer ambient precipitation, and vegetation. Three tensiometers are installed in the lysimeter at 150, 100, and 50 cm below the soil surface, and thermocouples are installed at the same depths. This lysimeter also has a horizontal array at 100 and 250 cm below the soil surface. The horizontal arrays are composed of a string of thermocouples placed the following distances from the tank wall: 0 (inner tank wall), 5, 10, 50, 100, 150, 190, 195, and 200 cm (outer tank wall). Because this is a vegetated treatment, this lysimeter contains a root observation tube. Figures 4.5 and 4.6 show the density and moisture profiles of the fine soils in this lysimeter.

FIGURE 4.1. Moisture Profile for Lysimeter D01-2

FIGURE 4.2. Density Profile for Lysimeter D01-2

FIGURE 4.3. Moisture Profile for Lysimeter D02-5

FIGURE 4.4. Density Profile for Lysimeter D02-5

FIGURE 4.5. Moisture Profile for Lysimeter D03-6

FIGURE 4.6. Density Profile for Lysimeter D03-6

4.4 DRAINAGE LYSIMETER 4 (D04-1)

D04-1 is a replicate of the optimized barrier system, Treatment 1: 1.5 m of fine soil, ambient precipitation, and vegetated. Again, three tensiometers are installed at 150, 100, and 50 cm below the soil surface. In addition to horizontal arrays of thermocouples at 100 and 250 cm--placed at 0 (inner tank wall), 5, 10, 50, 100, 150, 190, 195, and 200 cm (outer tank wall)--this replicate contains a more complete vertical array of thermocouples. The vertical arrays consist of thermocouples placed 30 cm from the inner tank wall at the following depths below the soil surface: 5, 10, 20, 30, 40, 50, 100, and 150 cm. D04-1 also contains a glass tube for root observation. Figures 4.7 and 4.8 show the density and moisture profiles.

4.5 DRAINAGE LYSIMETER 5 (D05-5)

D05-5 is a replicate of Treatment 5: 1.5 m of fine soil with gravel admix in the top 20 cm, ambient precipitation, and vegetation. Tensiometers were installed at 150, 100, and 50 cm below the soil surface as were thermocouples. The treatment includes a root observation tube. Figures 4.9 and 4.10 show the density and moisture information for the soils placed in this lysimeter.

4.6 DRAINAGE LYSIMETER 6 (D06-6)

D06-6 is the second replicate of Treatment 6: 1 m of fine soil, ambient precipitation, and vegetation. Again, tensiometers and thermocouples were installed at 150, 100, and 50 cm below the soil surface, and a root observation tube was installed. Figures 4.11 and 4.12 show the moisture and density profiles for the backfilled soil.

4.7 DRAINAGE LYSIMETER 7 (D07-1)

D07-1 is the second replicate of Treatment 1: 1.5 m of fine soil, ambient precipitation, and vegetation. This lysimeter did not receive the horizontal and vertical arrays of thermocouples installed in D04-1. Tensiometers and thermocouples were installed at the same three depths: 150, 100, and 50 cm below the soil surface. Because this is a vegetated treatment,

FIGURE 4.7. Moisture Profile for Lysimeter D04-1

FIGURE 4.8. Density Profile for Lysimeter D04-1

FIGURE 4.9. Moisture Profile for Lysimeter D05-5

FIGURE 4.10. Density Profile for Lysimeter D05-5

FIGURE 4.11. Moisture Profile for Lysimeter D06-6

FIGURE 4.12. Density Profile for Lysimeter D06-6

root observation tubes were installed to allow us to document root growth and activity. Figures 4.13 and 4.14 show moisture and density information.

4.8 DRAINAGE LYSIMETER 8 (D08-2)

D08-2 is the second replicate of Treatment 2: 1.5 m of fine soil, ambient precipitation, and bare surface. Tensiometers and thermocouples were installed at 150, 100, and 50 cm from the soil surface. Figures 4.15 and 4.16 show the moisture and density profiles for the lysimeter.

4.9 DRAINAGE LYSIMETER 9 (D09-7)

D09-7 is a replicate of Treatment 7: 1.5 m of fine soil, bare soil surface, and precipitation until breakthrough. Note that the layering in D09-7 is slightly different than the rest of the drainage lysimeters. (See Section 3.0 on placement of basalt, gravel, and sand layers.) This lysimeter contains three tensiometers installed at depths of 150, 100, and 50 cm below the soil surface. Thermocouples are installed at the same depths. Figures 4.17 and 4.18 show the moisture and density profiles for the lysimeter.

4.10 DRAINAGE LYSIMETER 10 (D10-4)

D10-4 is a replicate of Treatment 4: 1.5 m of fine soil, twice average precipitation, and bare soil surface. In addition to tensiometers and thermocouples at 150, 100, and 50 cm below the soil surface, this treatment has a horizontal array of thermocouples at 50 and 250 cm below the soil surface consisting of thermocouples at 0 (inner tank wall), 5, 10, 50, 100, 150, 190, 195, and 200 cm (outer tank wall). The moisture and density profiles for this lysimeter are shown in Figures 4.19 and 4.20.

4.11 DRAINAGE LYSIMETER 11 (D11-7)

D11-7 is the second replicate of Treatment 7: 1.5 m of fine soil, bare soil surface; and precipitation until breakthrough. This lysimeter is also instrumented with tensiometers and thermocouples at 150, 100, and 50 cm below the soil surface. Moisture and density profiles are shown in Figures 4.21 and 4.22.

FIGURE 4.13. Moisture Profile for Lysimeter D07-1

FIGURE 4.14. Density Profile for Lysimeter D07-1

FIGURE 4.15. Moisture Profile for Lysimeter D08-2

FIGURE 4.16. Density Profile for Lysimeter D08-2

FIGURE 4.17. Moisture Profile for Lysimeter D09-7

FIGURE 4.18. Density Profile for Lysimeter D09-7

FIGURE 4.19. Moisture Profile for Lysimeter D10-4

FIGURE 4.20. Density Profile for Lysimeter D10-4

FIGURE 4.21. Moisture Profile for Lysimeter D11-7

FIGURE 4.22. Density Profile for Lysimeter D11-7

4.12 DRAINAGE LYSIMETER 12 (D12-4)

D12-4 is the second replicate of Treatment 4: 1.5 m of fine soil, bare soil surface, and twice average precipitation. This lysimeter contains thermocouples and tensiometers at 150, 100, and 50 cm below the soil surface. Figures 4.23 and 4.24 show the density and moisture profiles for this treatment.

4.13 DRAINAGE LYSIMETER 13 (D13-3)

D13-3 is a replicate of Treatment 3: 1.5 m of fine soil, twice average precipitation, and vegetated. Tensiometers and thermocouples were installed at 150, 100, and 50 cm below the soil surface. This treatment also includes a root observation tube to document root growth and activity. Figures 4.25 and 4.26 show the density and moisture profiles.

4.14 DRAINAGE LYSIMETER 14 (D14-3)

D14-3 is the second replicate of Treatment 3: 1.5 m of fine soil, twice average precipitation, and vegetated. It contains exactly the same sensors as D13-3: tensiometers and thermocouples at 150, 100, and 50 cm below the soil surface; and a root observation tube. Graphs of the moisture and density information are given in Figures 4.27 and 4.28.

4.15 WEIGHING LYSIMETER 1 (W01-1)

W01-1 is the third replicate for Treatment 1, the optimized barrier system: 1.5 m of fine soil, ambient precipitation, and vegetation. As discussed in Section 3.0, the weighing lysimeters were equipped with TCPs. Because this lysimeter will hold a vegetated treatment, three TCPs were placed at each of four depths in the lysimeter--a total of 12 TCPs in this treatment. From an observer's position inside the facility facing the inside wall of the lysimeter about 30 cm from one edge, all four strings of TCPs point directly away from the observer in horizontal lines at depths of 150, 100, 50, and 30 cm. The wires were passed through a 1.27-cm-dia hole drilled in the lysimeter sidewall that faces into the underground facility.

FIGURE 4.23. Moisture Profile for Lysimeter D12-4

FIGURE 4.24. Density Profile for Lysimeter D12-4

FIGURE 4.25. Moisture Profile for Lysimeter D13-3

FIGURE 4.26. Density Profile for Lysimeter D13-3

FIGURE 4.27. Moisture Profile for Lysimeter D14-3

FIGURE 4.28. Density Profile for Lysimeter D14-3

The lysimeter sidewalls that face into the underground portion of the facility are accessible through doors that open into each outer box.

The weighing lysimeters all contain vertical and horizontal arrays of thermocouples. As in the drainage lysimeters, the vertical arrays consist of thermocouples placed 30 cm from the tank wall at the following depths from the soil surface: 5, 10, 20, 30, 40, 50, 100, and 150 cm. The horizontal arrays consist of thermocouples placed 100 cm from the soil surface at 0, 5, 10, 50, 100, 150, 190, 195, and 200 cm from the inner tank wall. Weighing lysimeter 1 had tensiometers installed horizontally at 150 and 100 cm below the soil surface. A tensiometer was installed vertically at the 50-cm depth. The two tensiometers, installed horizontally, penetrate the lysimeter sidewall but not the outer box. The porous ceramic ends of the tensiometers lie 45 cm from the inner lysimeter wall. Access to these instruments for filling the tensiometers and recording measurements is through the doors opening into the underground facility. A root observation tube was also installed in this treatment. Moisture and density profiles for this lysimeter are given in Figures 4.29 and 4.30.

4.16 WEIGHING LYSIMETER 2 (W02-2)

This lysimeter represents the third replicate of Treatment 2: 1.5 m of fine soil, ambient precipitation, and a bare surface. Tensiometers were installed at depths of 150 and 100 cm from the soil surface as described for W01-1. Again, the tensiometer at the 50-cm depth was installed in a vertical position. Arrays of three TCPs were placed as described above for W01-1 at depths of 150, 100, and 50 cm from the soil surface. Because this treatment does not include vegetation, an array of TCPs at 30-cm depth was not installed. Weighing lysimeter 2 contains vertical and horizontal thermocouple arrays identical to those in W01-1. Moisture and density profiles for this lysimeter are given in Figures 4.31 and 4.32.

4.17 WEIGHING LYSIMETER 3 (W03-3)

W03-3 contains the third replicate of Treatment 3: 1.5 m of fine soil, vegetation, and twice average precipitation. This lysimeter contains exactly

FIGURE 4.29. Moisture Profile for Lysimeter W01-1

FIGURE 4.30. Density Profile for Lysimeter W01-1

FIGURE 4.31. Moisture Profile for Lysimeter W02-2

FIGURE 4.32. Density Profile for Lysimeter W02-2

the same instruments as W01-1 in the same configuration. Moisture and density profiles for this lysimeter are shown in Figures 4.33 and 4.34.

4.18 WEIGHING LYSIMETER 4 (W04-4)

W04-4 is the third replicate of Treatment 4: 1.5 m of fine soil, twice average precipitation, and bare surface. This lysimeter contains exactly the same instrumentation as W02-2 described previously. Moisture and density profiles for this lysimeter are shown in Figures 4.35 and 4.36.

FIGURE 4.33. Moisture Profile for Lysimeter W03-3

FIGURE 4.34. Density Profile for Lysimeter W03-3

FIGURE 4.35. Moisture Profile for Lysimeter W04-4

FIGURE 4.36. Density Profile for Lysimeter W04-4

5.0 RAINFALL SIMULATOR

A rainfall simulator, or rainulator, was constructed to apply water uniformly to the soil surface of each of the eight lysimeters that receive more than ambient precipitation. The rainulator is mounted on a carriage assembly, which is driven by an electric motor through a reduction gear. This carriage assembly moves equipment and personnel above the lysimeter facility without contacting the soil surface. Wheels on the carriage assembly run along steel tracks along each edge of the lysimeter facility. The personnel and instrument carrier is mounted to the carriage assembly and can be propelled along the length of the carriage by hand. (A diagram of the rainfall simulator and carriage assembly is shown in Figure 5.1.)

A spray bar attached to the carriage delivers water uniformly to those lysimeters on the west side of the facility that are designed to receive irrigation treatments. The spray bar has six nozzles that disperse the water in a long, narrow elliptic pattern on the soil surface, with a 50% overlap. Water is provided through a hose that is pulled along the ground by the carriage and connected to the pressure-regulated spray bar.

The rainulator was used to apply Columbia River water to treatments 3, 4, and 7, as shown in Table 5.1. The amount of water and the uniformity of its application were measured by placing small, cylindrical rain gauges in four locations along the water application traverse. Water is added until the total amount equals twice the average for the period. Water applied to D09-7 and D11-7 was limited to 2 cm per application to avoid ponding and channeling. A 2-cm application was made each week until breakthrough occurred.

FIGURE 5.1. Rainfall Simulator and Carriage at the Field Lysimeter Test Facility (FLTF)

TABLE 5.1. Water Added to Lysimeters at the Field Lysimeter Test Facility (FLTF)
from November 5, 1987, Through June 21, 1988

Date	D09-7 ^(a) 30946.4 ^(b)	D10-4 30542.4	D11-7 30837.4	D12-4 31290.4	D13-3 30977.6	D14-3 30666.5	W03-3 23424	W04-4 23439
Water Added by Irrigation (cm/H ₂ O)								
11-30-88	0	0.6	0	0.6	0.6	0.6	0	0
12-07-87	0	0	0	0	0	0	0.5	0.5
12-10-87	0	1.9	0	1.8	1.9	1.9	2.5	2.5
12-22-87	0	2.2	0	2.1	2.1	2.2	1.5	1.5
01-25-88	0	1.4	0	1.4	1.4	1.4	1.2	1.2
03-14-88	2.0	0.5	2.0	0.5	0.5	0.5	0.5	0.5
03-21-88	2.0	0.8	2.0	0.8	0.8	0.8	0.8	0.8
03-28-88	2.0	0.8	2.0	0.8	0.8	0.8	0.8	0.8
04-05-88	2.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0
04-11-88	2.0	0.8	2.0	0.8	0.8	0.8	0.8	0.8
04-18-88	2.0	1.5	2.0	1.5	1.5	1.5	1.5	1.5
04-25-88	1.9	1.2	1.9	1.2	1.2	1.2	1.2	1.2
05-02-88	2.0	0	2.0	0	0	0	0	0
05-09-88	2.0	0	2.0	0	0	0	0	0
05-16-88	2.0	0	2.0	0	0	0	0	0
05-23-88	2.0	0	2.0	0	0	0	0	0
05-31-88	2.0	1.9	2.0	1.9	1.9	1.9	1.9	1.9
06-07-88	0	0.4	0	0.4	0.4	0.4	0.4	0.4
06-14-88	0	1.0	0	1.0	1.0	1.0	1.0	1.0
06-21-88	0	1.0	0	1.0	1.0	1.0	1.0	1.0
Water added (in cm)	23.9	16.9	23.9	16.7	16.8	16.8	16.4	16.4
Precipitation	6.6	10.9	6.6	10.9	10.9	10.9	10.9	10.9
TOTALS	30.5	27.7	30.5	27.6	27.7	27.7	27.3	27.3

(a) Lysimeter identification number.

(b) Area of lysimeter in cm².

6.0 HYDRAULIC PROPERTIES

Previous modeling efforts (Fayer et al. 1985; Fayer 1987) have shown that water storage and hydraulic properties of the surface soil largely control water infiltration into and through the barrier. Previous WHC and PNL studies (Myers 1985; Last et al. 1987) have identified the McGee Ranch site, adjacent to the Yakima Barricade, as a potential source of surface soil material for protective barrier testing. Materials taken from McGee Ranch have been used to fill the lysimeters at the FLTF for testing of water infiltration and erosion control.

Hydraulic property data were obtained on selected lysimeters that provide input for model simulations of the FLTF barrier configurations. These data include saturated hydraulic conductivity, water retention characteristics, and selected physical properties, such as bulk density and particle-size analysis, which are useful in characterizing the variability of soil materials. This section documents the hydraulic properties of surface soil materials taken from the McGee Ranch that have been used to fill the FLTF lysimeters. To date, there have been 16 samples of soil materials analyzed. The water storage, water retention, hydraulic conductivity, bulk density, and particle-size analysis data are reported for these soil materials.

6.1 MATERIALS

Sixteen samples of soil material used for the FLTF were analyzed. The soil, taken from the McGee Ranch located just northwest and across Highway 24 from the Yakima Barricade, is a surface soil (tentatively classified as Warden Silt Loam, a Xerollic Camborthid). The soil was taken from the top meter of a borrow at the McGee Ranch (Figure 6.1) and stockpiled near the FLTF for filling of the lysimeters. Samples were chosen based on a range of textures obtained by particle-size analyses from samples taken during the filling operation of the FLTF. The samples were analyzed for hydraulic conductivity and water retention characteristics. Table 6.1 indicates the lysimeters and the lifts from which the samples were taken.

FIGURE 6.1. Map of the McGee Ranch Site

TABLE 6.1. Soil Lift Depths (in cm) for the Drainage Lysimeters at Field Lysimeter Test Facility (FLTF)

Lift Number	D01-2	D02-5	D03-6	D04-1	D05-5	D06-6	D07-1	D08-2	D09-7	D10-4	D11-7	D12-4	D13-3	D14-3
1	155.0	155.0	105.0	155.0	155.0	105.0	155.0	155.0	<u>155.0</u>	155.0	155.0	155.0	155.0	155.0
2	150.2	148.5	99.8	149.9	149.8	99.4	149.8	151.5	<u>143.6</u>	150.6	148.9	150.4	149.3	149.9
3	144.1	142.2	94.5	144.1	<u>143.6</u>	93.2	142.8	147.1	137.4	144.9	142.7	143.8	143.9	144.1
4	138.6	137.1	88.6	<u>138.3</u>	137.5	86.8	<u>136.2</u>	142.3	131.8	<u>140.0</u>	136.2	137.0	137.1	<u>138.8</u>
5	132.7	130.5	81.4	130.7	132.0	80.2	130.3	137.5	<u>121.3</u>	135.2	130.8	131.1	131.5	133.0
6	121.2	120.5	68.3	118.5	122.5	66.3	117.4	126.2	108.1	125.1	<u>117.7</u>	118.0	117.7	120.7
7	109.6	111.0	55.0	105.9	108.8	52.3	103.7	114.6	100.7	111.8	105.2	103.9	104.0	106.7
8	95.6	101.9	41.8	94.5	95.2	38.6	91.4	104.2	89.3	97.6	<u>92.4</u>	88.1	<u>91.3</u>	92.1
9	85.3	90.0	29.8	82.9	81.9	24.9	78.9	92.2	76.6	84.4	78.7	74.8	78.5	78.5
10	<u>73.7</u>	<u>79.4</u>	16.0	<u>69.8</u>	68.9	12.1	65.8	79.5	64.4	70.6	67.4	62.4	66.9	66.7
11	62.8	68.4	5.0	56.9	57.0	4.9	52.0	67.2	51.9	58.7	54.0	49.8	55.4	53.9
12	52.7	57.6	0.0	46.2	42.6	0.0	40.4	56.2	37.6	44.6	42.3	36.3	43.7	39.4
13	42.2	47.5		34.0	29.9		28.5	44.3	25.2	30.9	29.7	24.4	30.9	24.4
14	31.0	37.5		19.8	16.4		16.6	32.0	10.5	18.4	16.2	<u>11.9</u>	17.5	9.5
15	19.8	27.5		4.2	4.9		5.1	<u>20.4</u>	0.0	4.5	4.9	5.0	5.0	5.0
16	8.5	<u>16.5</u>		0.0	0.0		0.0	8.3		0.0	0.0	0.0	0.0	0.0
17	0.0	5.3					0.0							
18		0.0												

Note: Depth measured from bottom of soil layer to top of lysimeter lip. Lip of lysimeter extends about 5 cm above packed soil surface. Underlined samples indicate those selected for hydraulic property measurements.

Results of textural analyses of the soil materials are listed in Table 6.2. All calculations were done using an average particle density of 2.72 g/cm^3 . Soil textures were obtained using the hydrometer procedure (Gee and Bauder 1986). The clay was dispersed by sonic agitation rather than the mechanical mixing described in the standard procedure. Tests are under way to evaluate the effects of sonic vibration for particle dispersion on these soils and will be reported in future PNL documents. The size ranges of particles were: 32 to 44% for sand; 42 to 59% for silt; and 7 to 16% for clay-sized materials. The textures ranged from loam to silt loam.

6.2 METHODS

Methods of measuring hydraulic conductivity are divided into the following three types.

6.2.1 Hydraulic Conductivity: Saturated

Saturated hydraulic conductivity on each of the 16 samples was determined using a falling head method (Klute and Dirksen 1986). In this method, each sample was packed in a container to a density of 1.37 g/cm^3 and enclosed with lids having an inflow valve at one end and an outflow valve at the other end. The inflow valve was connected to a standpipe of a known cross-sectional area and height. The samples were saturated by slowly wetting from the bottom and allowing to stand for 24 hours before any test runs were done. After saturation, an initial head in the standpipe was recorded and water

TABLE 6.2. Textural Analysis of 16 Field Lysimeter Test Facility Samples

<u>Sample</u>	<u>% Sand</u>	<u>% Silt</u>	<u>% Clay</u>	<u>Sample</u>	<u>% Sand</u>	<u>% Silt</u>	<u>% Clay</u>
D02-5-10	32	59	9	D09-7-02	38	52	10
D02-5-16	38	53	9	D09-7-05	40	46	14
D04-1-04	36	57	7	D10-4-04	37	53	10
D04-1-10	44	49	7	D11-7-06	38	52	10
D05-5-03	44	42	14	D11-7-08	34	59	7
D07-1-04	38	52	10	D12-4-14	40	53	7
D08-2-15	43	50	7	D13-3-08	38	52	10
D09-7-01	38	52	10	D14-3-04	33	56	11

was allowed to flow from the standpipe through the sample for a given length of time. The head level in the standpipe, observed at the end of test, was also recorded. Test runs were repeated five times and the values averaged for the calculations. The hydraulic conductivity (K_s) was determined using the following equation:

$$K_s = (a l / A t) \ln(H_1 / H_2)$$

where a = cross-sectional area of the standpipe

l = length of the sample

A = cross-sectional area of the sample

t = time for the hydraulic head to decrease from H_1 to H_2

H_1 and H_2 are hydraulic heads at beginning and end of the test, respectively.

6.2.2 Hydraulic Conductivity: Unsaturated

Solving an unsaturated flow problem requires evaluation of soil hydraulic properties. These properties include, but are not limited to, 1) the relationship between capillary head and moisture content and 2) the dependence of the hydraulic conductivity on moisture content. It is often impossible to determine all data necessary for a complete analysis. As an example, soils data from the Hanford Site are available largely through corings and sieve analyses. Virtually no hydraulic properties of the sediments have been measured directly. Thus, to predict water flow in these sediments, empirical relationships need to be established between known physical properties and hydraulic characteristics, then an estimation of water flow in the vadose zone at the Hanford Site can be made.

Details of the methods (and models) for predicting the unsaturated conductivity are provided in reference articles by Van Genuchten (1980) and Mualem (1986). The required data input for these models are saturated hydraulic conductivity and water retention characteristics (primary drainage curves). Because these data are available on the test samples, parameters can be calculated that describe the unsaturated water characteristics of these materials.

6.2.3 Water Retention

Water retention characteristics were measured using three different techniques. The technique used depended on the applied pressures or soil moisture conditions of the sample. Procedures described by Klute (1986) were followed. For pressures in the very wet range (0 to 150 cm), hanging water columns were used; for the drier range (510 to 4080 cm), pressure plate extractors (Soil Moisture Equipment Corp., Santa Barbara, California) were used. For drier soils, samples were composited, and the water retention was measured as a function of the sample relative humidity (using a CX1 sample changer from Decagon Devices, Ltd., Pullman, Washington).

Samples from the hanging water columns were packed to a density of 1.37 g/cm^3 in cylinders 3 cm high and 5 cm in dia. The samples were placed on the porous plate in Buchner funnels. The funnels were connected to out-flow tubes that regulated the head values. The water loss at each head was measured by weighing the sample in the ring. The samples were allowed to remain saturated for 48 hours before the excess water was drained at 10 cm. The pressure head was increased each time after drainage had ceased, and the sample was weighed. After reaching equilibrium at 150 cm pressure, the samples were weighed and oven-dried to determine the water content.

Water retention characteristics were measured at 510 cm, 1020 cm, and 4080 cm of pressure using a pressure plate extractor. A 1-bar pressure plate (one that has a bubbling pressure or air-entry value in excess of 1 bar of pressure) was used for the 510-cm tests, while a 5-bar plate was used for the other tests. Equilibrium water contents were obtained by packing the samples in container cylinders (density, 1.37 g/cm^3) on a porous ceramic plate where they were saturated for 48 hours. On complete saturation, the plate was placed in the extractor vessel and the internal air pressure raised to the desired test level. Equilibrium was reached when drainage ceased. At the end of each pressure run, each sample (run in triplicate) was carefully weighed and oven-dried to determine the moisture content at that pressure level. This procedure is described in more detail by Klute (1986).

We attempted to use a 15-bar pressure plate for sampling at 15,300 cm applied pressure. The data indicated that the samples did not equilibrate

with the applied pressure (i.e., the water contents were higher than the 4080-cm tests), so these data were not used. Apparently the 15-bar plate has such a low permeability that equilibrium is not achieved in a reasonable (2- to 3-week) test period. Soil samples with a very dry water-retention characteristic (i.e., with water contents lower than "wilting point" to those at air-dry conditions) were composited, and relative humidity of the soil was determined by the dew-point method using a CX1 sample changer.

6.3 RESULTS

Table 6.3 shows the measured saturated hydraulic conductivity values, the saturated water contents, and the calculated porosities for samples that were packed to an average density of 1.37 g/cm^3 . There is more than one order of magnitude difference in saturated hydraulic conductivity, even for these carefully packed cores. The data show that the samples were not fully saturated to the total porosity of $0.496 \text{ cm}^3/\text{cm}^3$, which was calculated from particle and bulk densities.

TABLE 6.3. Hydraulic Conductivity, Saturated Water Content, and Saturation Ratio

<u>Sample</u>	<u>Hydraulic Conductivity (cm/sec)</u>	<u>Saturated Water Content (vol/vol)</u>	<u>Porosity (vol/vol)</u>	<u>Saturation Ratio</u>
D02-5-10	8.11E-05	0.462	0.496	0.93
D02-5-16	8.68E-05	0.455	0.496	0.92
D04-1-04	8.04E-05	0.451	0.496	0.91
D04-1-10	7.14E-05	0.470	0.496	0.95
D05-5-03	8.15E-05	0.469	0.496	0.95
D07-1-04	6.96E-05	0.463	0.496	0.93
D08-2-15	1.04E-04	0.458	0.496	0.92
D09-7-01	1.30E-04	0.469	0.496	0.95
D09-7-02	1.54E-04	0.466	0.496	0.94
D09-7-05	6.87E-05	0.481	0.496	0.97
D10-4-04	1.35E-04	0.455	0.496	0.92
D11-7-06	1.35E-03	0.466	0.496	0.94
D11-7-08	2.04E-03	0.463	0.496	0.93
D12-4-14	3.41E-05	0.474	0.496	0.96
D13-3-08	1.04E-04	0.495	0.496	1.00
D14-3-04	8.60E-05	0.477	0.496	0.96

Table 6.4 shows the parameters resulting from curve fitting of laboratory-measured water retention and hydraulic conductivity data. All the data were fitted simultaneously to obtain the average parameters shown at the bottom of Table 6.4. These parameters are currently being used in UNSAT-H model simulations to represent the fine soil in the FLTF lysimeters. Data will soon be available from the FLTF so that a range of test cases can be analyzed and compared with simulation results. The unsaturated hydraulic conductivity plays an important role in this type of analysis. The water retention characteristics listed in Tables 6.5 and 6.6 show that the soil exhibits water storage values that are over 42 cm of water per 1.5-m depth for all samples. This value was computed by averaging the measured differences between the water contents associated with 100-cm tension and 4080-cm

TABLE 6.4. Curve-Fitting Results for Field Lysimeter Test Facility (FLTF) Laboratory Water Retention and Hydraulic Conductivity Data

Sample	θ_r (cm ³ /cm ³)	θ_s (cm ³ /cm ³)	Alpha (1/cm)	n	Ks (cm/s)
D02-5-10	0.0167	0.496	0.0118	1.4486	5.78E-4
D02-5-16	0.0296	0.496	0.0064	1.6578	4.22E-4
D04-1-04	0.0000	0.496	0.0201	1.3245	1.44E-3
D04-1-10	0.0000	0.496	0.0214	1.3248	6.82E-4
D05-5-03	0.0000	0.496	0.0241	1.3097	8.85E-4
D07-1-04	0.0047	0.496	0.0167	1.3590	7.02E-4
D08-2-15	0.0098	0.496	0.0142	1.3923	1.04E-3
D09-7-01	0.0062	0.496	0.0165	1.3624	1.06E-3
D09-7-02	0.0139	0.496	0.0159	1.4019	1.17E-3
D09-7-05	0.0000	0.496	0.0255	1.3161	4.39E-4
D10-4-04	0.0000	0.496	0.0188	1.3366	1.97E-3
D11-7-06	0.0000	0.496	0.0272	1.3102	1.63E-2
D11-7-08	0.0000	0.496	0.0279	1.2960	3.02E-2
D12-4-14	0.0086	0.496	0.0113	1.3888	2.08E-4
D13-3-08	0.0071	0.496	0.0179	1.3673	1.96E-4
D14-3-04	0.0136	0.496	0.0145	1.4099	4.37E-4
REP1 ⁺⁺	0.0049	0.496	0.0163	1.3716	9.900E-4

θ_r = Residual water content

θ_s = Saturated water content

Alpha and n = Curve-fitting parameters

Ks = Fitted saturated water content

⁺⁺ Parameters currently being used for fine soil hydraulic property description in UNSAT-H barrier simulations.

TABLE 6.5. Water Retention Values for Selected Field Lysimeter Test Facility (FLTF) Soil Samples Volumetric Water Content (vol/vol)

Head (cm) H ₂ O	D02-5 -10	D02-5 -16	D04-1 -04	D04-1 -10	D05-5 -03	D07-1 -04	D08-2 -15	D09-7 -01
0 ^(a)	0.496	0.496	0.496	0.496	0.496	0.496	0.496	0.496
10	0.461	0.486	0.454	0.435	0.441	0.446	0.461	0.461
20	0.438	0.458	0.452	0.423	0.412	0.431	0.440	0.437
30	0.435	0.453	0.416	0.420	0.409	0.426	0.433	0.431
40	0.431	0.450	0.411	0.415	0.406	0.420	0.429	0.425
50	0.428	0.445	0.405	0.410	0.402	0.415	0.426	0.420
60	0.426	0.441	0.403	0.406	0.398	0.412	0.424	0.416
100	0.420	0.437	0.390	0.396	0.391	0.403	0.398	0.391
150	0.392	0.436	0.384	0.366	0.382	0.395	0.388	0.388
510	0.206	0.227	0.223	0.204	0.209	0.203	0.209	0.200
1020	0.163	0.136	0.173	0.176	0.170	0.168	0.180	0.178
4080	0.089	0.096	0.099	0.097	0.102	0.099	0.088	0.102

Volumetric Water Content (vol/vol)

Head (cm) H ₂ O	D09-7 -02	D09-7 -05	D10-4 -04	D11-7 -06	D11-7 -08	D12-4 -14	D13-3 -08	D04-3 -04
0 ^(a)	0.496	0.496	0.496	0.496	0.496	0.496	0.496	0.496
10	0.473	0.446	0.457	0.437	0.459	0.483	0.460	0.495
20	0.433	0.420	0.432	0.411	0.382	0.455	0.435	0.440
30	0.428	0.408	0.421	0.403	0.407	0.447	0.424	0.432
40	0.424	0.404	0.418	0.399	0.400	0.442	0.417	0.423
50	0.419	0.400	0.413	0.396	0.395	0.438	0.412	0.414
60	0.415	0.396	0.411	0.392	0.394	0.434	0.409	0.411
100	0.401	0.386	0.393	0.381	0.386	0.418	0.397	0.400
150	0.373	0.356	0.382	0.374	0.375	0.392	0.370	0.397
510	0.178	0.199	0.209	0.196	0.223	0.241	0.198	0.189
1020	0.165	0.164	0.176	0.160	0.168	0.191	0.169	0.164
4080	0.106	0.097	0.093	0.095	0.099	0.109	0.089	0.098

(a) Water content value at zero pressure computed on basis of total porosity of sample.

tension. These were somewhat arbitrary selections reflecting the upper and lower limit of stored water for this soil. Field measurements are currently being made to confirm these values. This storage estimate of 42 cm is more than 2.5 times the ambient (16 cm) annual precipitation.

Additional laboratory sampling of water retention does not appear to be warranted at the present time. The data are sufficiently similar that

TABLE 6.6. CX1 (Relative Humidity Sensor Data for Composite Field Lysimeter Test Facility (FLTF) Samples)

<u>Volumetric Water Content (vol/vol)</u>	<u>Head (-cm)</u>
0.052	5.48 E + 4
0.044	9.42 E + 4
0.037	1.71 E + 5
0.027	4.95 E + 5
0.018	1.41 E + 6

analysis using any of the individual curves should reflect the response of the entire lysimeter system. Field data collection is an integral part of the program to assess the hydraulic properties of the lysimeter soils. Further field data collection is planned for this project. The field testing program will be described in detail in Section 7.0. In addition to water storage measurements, one of the key tests that is planned for the FLTF is a direct measure of hydraulic conductivity using lysimeters D09-7 and D11-7 (precipitation to breakthrough). These lysimeters will be used as large-scale permeameters where hydraulic conductivity will be measured by using a steady-state, constant-head method. These tests are scheduled to start in FY 1989. Plans are also being made to measure unsaturated hydraulic conductivities in the same lysimeters and to compare these tests with steady-state measurements that are currently being run in the laboratory.

7.0 FIRST YEAR TESTS AND RESULTS

Objectives of the initial tests were to measure water balance on test barriers, assess hydraulic performance, obtain data for calibration of a simulation model, and identify possible design problems. Results reported here are from tests done between November 1987 and mid-June 1988. These results were gathered mainly from tests evaluating barrier hydraulic performance and tests evaluating barrier design.

Tests required calibration and crosschecking of measurements and instruments. For example, water content and tension measurements were compared qualitatively. The water content measurements were taken using a neutron probe. The water tension measurements were taken using tensiometers. The soil desorption characteristic pairs were obtained from laboratory analyses of the McGee Ranch soil (see Section 6.0). Also, lysimeter weight changes were used quantitatively to refine the neutron probe calibration from measurements of soil moisture profiles.

Soil moisture tensions and contents during breakthrough in D09-7 and D11-7 were compared qualitatively with those predicted from the soil moisture desorption characteristic curve. Thus, crosschecking of instruments and measurements was done to help assure the reliability of the protective barrier tests.

Observations and measurements are reported in the following sections.

7.1 WATER BALANCE

Water balance was tabulated for all lysimeters (Table 7.1). Water added by precipitation and irrigation equaled water lost by drainage and evapotranspiration, with the difference accounted as change in storage. The lysimeters are grouped according to treatment, which is described at the bottom of Table 7.1.

Discussion of detailed water balance and infiltration testing of lysimeters is separated into six topics:

1. drainage lysimeters leak tests
2. lysimeter drainage

TABLE 7.1. Water Balance (cm) for the Field Lysimeter Test Facility (FLTf) from November 1, 1987 to June 21, 1988

<u>Treatment</u>	<u>Lysimeter</u>	<u>Precip.</u>	<u>Irrig.</u>	<u>Drain.</u>	<u>ET</u>	<u>Storage</u>
N, V, D ¹	W01-1	10.9	0	0	14.4	-3.5
	D04-1	10.9	0	0	12.9	-2.0
	D07-1	10.9	0	0	13.3	-2.4
N, B, D ¹	W02-2	10.9	0	0	13.8	-2.9
	D01-2	10.9	0	0	10.4	0.5
	D08-2	10.9	0	0	11.4	-0.5
2N, V, D ¹	W03-3	10.9	16.4	0	26.7	0.6
	D13-3	10.9	16.8	0	29.3	-1.6
	D14-3	10.9	16.8	0	28.9	-1.2
2N, B, D ¹	W04-4	10.9	16.4	0	26.7	0.6
	D10-4	10.9	16.9	0	25.9	1.9
	D12-4	10.9	16.7	0	24.6	3.0
N, V, D ¹ Ad	D02-5	10.9	0	0	10.4	0.5
	D05-5	10.9	0	0	11.2	-0.3
N, V, D ²	D03-6	10.9	0	0	15.8	-4.9
	D06-6	10.9	0	0	14.4	-3.5
F, B, D ¹	D09-7	6.6	23.9	0.032	8.5	22.0
	D11-7	6.6	23.9	0.016	7.3	23.2

N -- Ambient precipitation

V -- Vegetated surface

B -- Bare surface

Ad -- Admixture of gravel (22% by weight) in top 20 cm

2N -- Twice average precipitation equals total water

F -- Irrigate until breakthrough

D¹ -- Soil depth is 1.5 m

D² -- Soil depth is 1.0 m.

3. water additions by rainfall simulator
4. weight changes measured by weighing lysimeters
5. neutron probe measurements of soil moisture
6. soil water tension measurements.

7.1.1 Drainage Lysimeter Leak Tests

Satisfactory leak tests were made at the factory. After installation, another leak test was conducted. Results from this test indicated a need for additional leak testing and evaluation.

Three successive leak tests were conducted during the winter months of 1987 and early spring of 1988. The results showed that long presoak and drainage periods were needed to achieve reasonable precision. These leak tests produced more hydraulic pressure in the lysimeters than is expected under experimental conditions.

Our results indicate that lysimeters D02-5 and D06-6 may leak if subjected to pressures as great as those during the test period. Apparent water losses might also be the result of absorption into the porous rock or adsorption onto the dry soil because of distillation (soils in D02-5 and D06-6 were drier than the other lysimeters during leak tests). However, because the lysimeters do not retain water under a hydraulic pressure, but instead are allowed to drain freely, leakage caused by pressure is unlikely. Also, because D02-5 and D06-6 receive only ambient precipitation, they are not expected to yield drainage and, therefore, leakage occurring under hydraulic pressure should not occur. See Appendix A.

7.1.2 Lysimeter Drainage

As discussed in Section 2.0, lysimeters D09-7 and D11-7 had water applied until drainage occurred. Water accumulated in the fine soil until the soil was saturated at the interface between the fine soil and underlying coarse sand. After saturation, water "breakthrough" occurred into the sand and further into the underlying coarse materials, gravels and riprap, causing the lysimeter to drain. During breakthrough, soil water just above the boundary developed a positive pressure. Breakthrough drainage is shown in Table 7.2.

Water received by D09-7 and D11-7 between day 310 in 1987 and day 173 in 1988 was 30.5 cm, raising the water content in the profile at breakthrough as shown in Figure 7.1. The soil water content in the fine soil just above the textural boundary, at the 135-cm depth, exceed 40% by volume. This water

TABLE 7.2. Cumulative Drainage from Lysimeters D09-7 and D11-7

<u>Lysimeter</u>	<u>Drainage (cm H₂O)</u>		
	<u>6/6/88</u>	<u>6/14/88</u>	<u>6/21/88</u>
D09-7	0.38	0.84	0.99
D11-7	0.01	0.33	0.49

FIGURE 7.1. Soil Moisture Profiles in D09-7 and D11-7 on November 4, 1987 and June 7, 1988 (cm depth versus volume %)

content is about 25% more water than was being retained by the soil 50 cm above the textural boundary. Thus, the textural boundary (fine soil/coarse sand) causing a capillary discontinuity appears to be performing according to design.

Potential drainage problems discovered during tests to barrier failure included soil puddling, channeling, and frost heaving. When large amounts of water were applied to the soil surface, the soil tended to puddle (i.e., soil particles suspended by water are redeposited on the surface with the fine overlying the coarse particles). This may cause water to move into cracks or cavities, preferentially. The soil also had a tendency to channel, allowing the water to percolate downward in the profile more rapidly than predicted from soil properties. Frost heaving near the soil surface and along the container edge increased the possibilities for channeling. Some effort was expended to limit the effects of channeling. Backtamping of the soil (with the end of a 1- x 4-in. board or a shovel handle) was practiced on every channel cavity preceding water application. The effects of channeling were limited and apparently caused no premature failure of the barrier. Evidence for this conclusion is shown by similar performance of the barriers in D09-7 and D11-7, despite their differences in channeling.

7.1.3 Water Additions by Rainfall Simulator

The experimental design calls for selected weighing and drainage lysimeters to receive more water than average precipitation. Lysimeters D09-7 and D11-7 were to receive precipitation until barrier failure. Lysimeters D10-4, D12-4, D13-3, D14-3, W03-3 and W04-4 were to receive twice average precipitation.

A project management decision was made to change the wet treatment design to apply twice the long-term average precipitation. This decision was made because of abnormally low precipitation during the early part of 1988. Also, early results from barrier performance were needed. Twice average precipitation is shown in Figure 7.2 and Table 7.3. This change was made beginning March 14, 1988. The objective was to deliver the total amount of water needed by the middle and end of each month. Table 7.4 shows the actual and target amounts of precipitation to be received by the twice average treatment.

7.1.4 Weight Changes Measured by Weighing Lysimeters

The following procedure was devised to certify the performance of the weighing lysimeter scales. Standard weights with calibration traceable to

FIGURE 7.2. Twice Average Precipitation and Actual Water Applied from November 4, 1987 to June 21, 1988 (cm)

TABLE 7.3. Water Accumulation (precipitation plus irrigation) Needed to Achieve Twice Average Precipitation (cm water)

Day	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1	0.0	4.4	9.0	13.6	16.6	18.5	20.5	22.9	25.7	26.4	27.6	29.2
16	2.2	6.7	11.3	15.1	17.5	19.5	21.7	24.3	26.0	27.0	28.4	30.6
31	--	--	--	--	--	--	--	--	--	--	--	32.0

the National Bureau of Standards (NBS) were placed on the center of the soil surface of each lysimeter in 10 equal increments. A 1-volt excitation was applied by the CR7X datalogger^(a) to the full bridge on the torsion bars of the scales. The voltage outputs from the torsion bars on the platform scales

(a) Campbell Scientific, Inc., Logan, Utah.

TABLE 7.4. Total Water Delivery from Precipitation and Application (cm)^(a)

<u>Lysimeter</u>	<u>Precipitation</u>	<u>Irrigation</u>	<u>Total</u>
D09-7	6.6	23.9	30.5
D10-4	10.9	16.8	27.7
D11-7	6.6	23.9	30.5
D12-4	10.9	16.7	27.6
D13-3	10.9	16.7	27.6
D14-3	10.9	16.7	27.7
W03-3	10.9	16.4	27.3
W04-4	10.9	16.4	27.3

(a) Delivery period was from 4 November 1987 through 21 June 1988.

were then read and recorded manually. (They may also be recorded on the CR7X datalogger on the 1500-microvolt range set for high resolution. The voltage signals conditioned for final memory in the datalogger are multiplied by 1 and a -1 offset is added. By programming the datalogger in this manner, one additional digit may be gained in instrument resolution in the final storage of the datalogger. During scale calibration, dataloggers should be set to read weight output every 10 seconds and average six readings each minute.)

Weights recorded manually should show maximum and minimum values measured. The datalogger data were transported from final memory in the datalogger by telephone line to the computer in an office building (Sigma V) where the voltage signal was stored in a data file as transmitted.

The voltage data were transformed by adding the 1 back in, multiplying the sum by ten-thousand and fitting a regression line through the transformed voltage-weight pairs over the calibration range by using the following equation:

$$S = \frac{\text{summation } [(W - W_a)(V - V_a)]}{\text{summation } [(V - V_a)(V - V_a)]} \quad (1-1)$$

where S = slope of the regression line

W = calibration point weight added

W_a = average of all weight added

V = calibration point transformed voltage
Va = average transformed voltage obtained from

$$V_a = (V_1 + V_2 + V_3 + \dots + V_n)/n \quad (1-2)$$

The slope of the regression line was used in the following equation to obtain the initial calibrated weight step for comparison with measured values:

$$W_o = S (V_a - W_a/S) \quad (1-3)$$

where W_o is the beginning calibrated weight step before the first weight is added. All transformed voltage readings were multiplied by the slope and the variation in scale performance was obtained by comparing measured weight values with standard weights added. Deviations of each scale weight from the correct weight value were obtained from Equation 1-4:

$$D = W - (W_o + n W_c) \quad (1-4)$$

where D = the deviation of the observed weight from the calibrated weight
 W = the observed weight at the calibrated weight step ($W_o + n \cdot W_c$)
 n = the number of weights added
 W_c = the calibration weight size.

Ten, 100-lb weights were used during the first calibration by the Hanford Engineering Development Laboratory (HEDL); so, $n = 10$ and $W_c = 100$ in that case. Each of ten, 100-lb weights was applied in turn in a stack on the middle of the soil surface on each weighing lysimeter and the resulting voltage reading was recorded. Then the weights were removed in opposite sequence. Deviations obtained over the range of calibration were plotted with respect to a zero reference line to display scale performance. Manufacturer tolerance is $\pm 0.02\%$, which is 3 lb in 15,000. Accuracy, precision, and hysteresis are displayed in Figures 7.3 through 7.6. We noted that W01-1 was 3 lb beyond tolerance at the 1000-lb addition point, and W03-3 had a 30-lb hysteresis on this short interval test. A graph of the data from

FIGURE 7.3. Weighing Lysimeter W01-1 Calibration Results (deviations in pounds versus weight added)

FIGURE 7.4. Weighing Lysimeter W02-2 Calibration Results (deviations in pounds versus weight added)

FIGURE 7.5. Weighing Lysimeter W03-3 Calibration Results (deviations in pounds versus weight added)

FIGURE 7.6. Weighing Lysimeter W04-4 Calibration Results (deviations in pounds versus weight added)

each lysimeter was transmitted to HEDL for review and certification of each scale, and a calibration interval of 1 year was requested.

The effect of error from W01-1 may be disregarded because hydraulic breakthrough and drainage would occur about 300 lb before the error point was reached. The effects of error from W03-3 are unknown within its 30-lb error range, but until the scale was replaced, its weight changes were compared with those measured by the other weighing lysimeters and with volumetric measurements made using the neutron probe.

Weight data from all four weighing lysimeters were tabulated, graphed, and compared. General agreement between their calibrated weight changes shows similar performance as displayed in Figures 7.7 and 7.8.

A notable difference exists between water loss rates from lysimeters receiving ambient precipitation and those receiving twice average precipitation, especially during periods of surface drying. Spikes appearing in the graph were attributed to the temporary added weight of the neutron probe and operator. Upward offsets in the graphic data were traced through the laboratory record book to water, soil, or plant changes.

7.1.5 Neutron Probe Measurements of Soil Moisture

Soil moisture was measured in two ways in each of the lysimeters at the time they were uncovered near the beginning of November 1987. One set of measurements was made at 5-cm depth intervals using the neutron probe, and the other set was made by gravimetric sampling from the top foot of soil near the center of each lysimeter. To measure the water content, soil samples were weighed, dried, and re-weighed. These water contents were multiplied by the appropriate bulk density measurements taken previously. Each volumetric water content was paired with the appropriate neutron probe reading, and a regression line was fit to the paired data to calibrate the neutron probe, as shown in Figure 7.9. The regression line was then adjusted to pass through a point representing oven-dried soil.

Weight changes caused by water gain and loss in weighing lysimeter W01-1 were used to refine the initial neutron probe calibration, resulting in

FIGURE 7.7. Weighing Lysimeter Weight Record For W01-1 and W02-2 from Day 310 of 1987 to Day 166 of 1988

FIGURE 7.8. Weighing Lysimeter Weight Record For W03-3 and W04-4 from Day 310 of 1987 to Day 166 of 1988

FIGURE 7.9. Neutron Probe Calibration (soil moisture volume % versus neutron probe counts)

the dashed line in Figure 7.9. This process of refinement is continuing, using data from all four weighing lysimeters.

Following calibration, the raw counts taken with the neutron probe may be converted to volumetric water contents for comparisons. Water content profiles developed from neutron probe measurements in weighing lysimeter W01-1 are shown in Figure 7.10, where two profiles are displayed.

The difference between these two profiles should correspond to changes in water weight measured by W01-1 over the same time. Disagreement indicates one or more of the following:

1. neutron probe measures moisture in an unusual way
2. neutron probe calibration is inaccurate
3. the weighing lysimeter scale calibration is inaccurate.

While all three factors may contribute to disagreement, the FLTF disagreement is small as shown in Figure 7.11.

The first source of error may occur as water accumulates either on the soil surface or as drainage at the bottom of the profile. The second source

FIGURE 7.10. Soil Moisture Profiles in W01-1 as Measured by Neutron Probe (volume % versus cm depth)

FIGURE 7.11. Gain or Loss in Water Content Measured by Neutron Probe and Weighing Lysimeter (cm gain or loss versus time by Julian date)

of error results if soil that influences the neutron probe reading is not adequately sampled during calibration or if too few readings are taken to account for variations in radioactive decay.

The third source of error may result if the weighing lysimeter is not removed from its scale to make a full-scale calibration. This source of error was minimized by calibrating the unloaded scale with standard weights from 0 to 7000 lb and then calibrating the loaded scale over the range of use expected. Calibration over a range from ambient to ambient +1000 lb is more than the current ambient use range and is expected to be adequate for this year. Next year, we plan to use small load cells calibrated against proving rings to cover the full load range. This calibration method is considered more accurate than the weight calibration method, which uses 1000-lb weights.

Changes in soil water contents measured by the neutron probe should agree with changes in weight measured by a weighing lysimeter. Figure 7.12 shows the variation between neutron probe and weighing lysimeter measurements for W01-1 for November 5, 1987 through June 6, 1988. Figure 7.13 shows soil water storage for all lysimeters.

FIGURE 7.12. Difference Between Neutron Probe and Weighing Lysimeter Measurements (cm of water)

FIGURE 7.13. Storage Changes in Soil Moisture for All Lysimeters from November 4, 1987 to June 7, 1988 (cm of water versus date)

7.1.6 Soil Moisture Tension Measurements

Tension measurements above 1 m were avoided during the fall and winter months because of the risk of freezing and breaking the tensiometers. However, tensiometers at 1 m and 1.5 m were serviced and monitored beginning 22 December 1987.

Most tensiometers were sensing sufficiently dry soil to cause them to fail. However, drainage lysimeters D09-7 and D11-7 yielded significant performance data during the latter part of their transition to barrier breakthrough. Table 7.5 shows soil moisture tensions from mid-May through mid-June in D09-7 and D11-7.

The negative values in the table indicate water pressure above the textural boundary. Note the return to negative pressure (tension) following drainage and a corresponding decrease in rate of drainage as shown in Table 7.2, for D09-7.

Data from weighing lysimeters, neutron probe, tensiometers, and drainage measurements appear to be in reasonable agreement; the textural breaks in D09-7 and D11-7 are performing according to design.

7.2 VEGETATION RESPONSE

Establishment and growth of plants in the soil layer of the barrier system is important for erosion control, recycling of meteoric water (rain-fall, snowmelt) to the atmosphere, and for aesthetics. Evapotranspiration (ET) of water by vegetation growing on the barrier surface will reduce the amount of water available to drain through the system. To evaluate the effects of vegetation on the water balance within the barrier system, plants

TABLE 7.5. Soil Moisture Tension (cm of water at 135 cm depth)

<u>Lysimeter</u>	<u>Date</u>				
	<u>5/17</u>	<u>6/2</u>	<u>6/7</u>	<u>6/15</u>	<u>6/22</u>
D09-7	5.7	6.8	-2.3	1.7	6.8
D11-7	8.1	-6.1	-1.0	2.0	7.1

have been taken from the McGee Ranch (see Figure 6.1) and transplanted into selected lysimeters as discussed in Section 2.2, where the seven treatments used in the FLTF were described.

7.2.1 Vegetation Establishment

The species transplanted to the lysimeters were chosen from the shrub-dominated plant community growing in fine soil at the McGee Ranch site. This site has been described previously as the location for the fine soil material used in the lysimeters at the FLTF (Last et al. 1987). On some areas of the McGee Ranch site where farming and surface disturbance have occurred, a plant community of annual grass and weeds dominates. However, the presence of shrubs is believed to indicate climax conditions (Daubenmire 1970) and may be more representative of the vegetation that might establish over barriers. Also, the perennial grass species and shrubs of a climax community are deeper-rooted species than the annual grasses and herbs. The ability of deeper-rooted plants to access stored moisture in the fine soil component of the system may be important to barrier performance.

The vegetation transplanted included the perennial grasses, Poa secunda (bluegrass) and Oryzopsis hymenoides (Indian rice grass); Bromus tectorum (cheatgrass), an annual grass; and the shrub Artemisia tridentata (sagebrush). These species were chosen because they, along with Grayia spinosa (spiny hopsage) and Helianthus cusickii (Cusick's sunflower), compose the major portion of the vascular plant cover on undisturbed areas at the McGee Ranch.^(a) Although spiny hopsage is one of the dominant shrubs in the mature plant community at the site, no individuals were transplanted because no seedlings or small young individual plants were found within the site.

In disturbed areas, cheatgrass, although an introduced species, is the major component of the community along with other weedy annuals. Cheatgrass readily establishes in any area disturbed by fire, grazing, or anthropogenic

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(a) Kirkham, R. R., S. O. Link, and J. L. Downs. 1986. Characterization of Plant and Soil Parameters for Estimating Evapotranspiration at Fine Soil Sites. Letter Report prepared by Pacific Northwest Laboratory, Richland, Washington, for U.S. Department of Energy and Rockwell Hanford Operations.

(human-caused) mechanisms, and almost certainly will be a significant species in any plant community that is established as part of the protective barrier system.

Plants were transplanted to the lysimeters during the first week of November (November 4, 5, 6, 1987), immediately after removing the plastic covers. At this time of year, the perennial grasses were completely senescent and dormant. The grasses were excavated in clumps, retaining as much soil around the root systems as possible. In addition, the cryptogam layer that covers a large portion of the interplant spaces was retained with the plant material. The plant material was transported in containers to the FLTF the same day and replanted in the lysimeters. Because cheatgrass seeds were abundant in the soil and litter excavated with the perennial grasses, no individuals were transplanted or directly seeded on the lysimeters.

Small sagebrush seedlings were excavated, transported, and planted in the same manner as the grasses. When transplanting the sagebrush, it was important to ensure that original soil was kept with the rooting system to retain mycorrhizal association necessary for the establishment and growth of the shrub. Because the soils in the lysimeters were at a higher moisture content (>15 vol%) than soils under ambient conditions (<10 vol%), it was not necessary to irrigate the transplanted vegetation to ensure that it would establish.

7.2.2 Phenology and Observations

The phenology and growth of vegetation on the lysimeters were observed during the spring 1988 growing season and compared with observations of vegetation growing on the McGee Ranch fine soil site. All of the transplants on the lysimeters except one sagebrush seedling survived and grew vigorously. Because the soils in the lysimeters were much wetter than soils at the McGee Ranch site (Figure 7.14), the timing of the phenological stages or phenophases (Table 7.6) (French and Sauer 1974) of plant development was different for the two sites. However, the onset of active plant growth and germination of cheatgrass seeds occurred at relatively the same time in late February and early March on both the lysimeters and at the McGee Ranch site (Figure 7.15). Bluegrass growing on the lysimeters was green and active with 5 to 7 cm of

(a)

(b)

FIGURE 7.14. Comparison of Soil Moisture Profile at McGee Ranch Site and at Field Lysimeter Test Facility a) Soil Moisture Profile in March at the Two Sites, b) Soil Moisture Profile in June/July at the Two Sites

TABLE 7.6. Definitions of 14 Phenophases for Short Grass Prairie Species After French and Sauer (1974)

<u>Phase Number</u>	<u>Phenophase Description</u>
1	Pre-emergence growth/winter dormancy
2	First visible growth
3	First leaves fully expanded
4	Middle leaves fully visible
5	First leaves senescent; middle leaves fully expanded
6	Late leaves fully expanded
7	Developing floral buds; middle-late vegetative
8	Mature floral buds; late vegetative
9	Floral buds and open flowers
10	Buds, flowers, and green fruit
11	Buds, flowers, green fruit, and ripe fruit
12	Green fruit and ripe fruit
13	Ripe fruit and dispersing seeds
14	Flowering-induced dormancy

shoot growth on March 5. Bluegrass had initiated growth at the McGee Ranch site on March 2, 1988, and was green and active with about 5 cm of new growth.

Phenological changes are greatly influenced by soil water as plants progress toward senescence during the growing season (Sauer 1978). By mid-May 1988, the bluegrass had set seed and senesced at the McGee Ranch site, but the bluegrass on the FLTF still showed active growth. Cheatgrass had also set seed and senesced by mid-May at the McGee site while growth of cheatgrass was still quite vigorous on the lysimeters at that time. In fact, a secondary growth stage of cheatgrass occurred on the lysimeters as late as July 1, 1988, with new green shoots and tillers showing through plants completely senesced. Figure 7.15 shows the difference in phenological development of bluegrass and cheatgrass at the McGee Ranch site and on the lysimeters using the convention of French and Sauer (1974).

It appears the extra moisture available in the soil profiles in the lysimeters had allowed the lysimeter vegetation to remain vigorous longer and

(a)

(b)

FIGURE 7.15. Comparison of Phenological Development of a) *Bromus tectorum* and b) *Poa secunda* at McGee Ranch and Field Lysimeter Test Facility (FLTF)

produce more biomass than comparably sized plants in the natural community. In particular, new shoot growth of sagebrush was greater on the lysimeters (mean of 22.3 ± 4.2 cm) than new shoot growth of sagebrush at the McGee Ranch site (mean of 6.5 ± 1.3 cm). Leaf density of the transplanted sagebrush was also significantly greater. Sagebrush growth on the lysimeters continued vigorously without ephemeral leaf drop and senescence through the month of May and into July, while sagebrush at the McGee site began to lose ephemeral leaves in late May. In addition, the sagebrush at the McGee Ranch had initiated floral stems and were heavily budded early in July, while sagebrush in the lysimeters showed no evidence of floral initiation.

Indian ricegrass persisted without significant senescence and without seed drop into the month of July on the lysimeters, while at the McGee Ranch site the ricegrass persisted throughout the month of June, but began to senesce during June and dropped seed early in July.

The phenological development of all of the grasses seems to be affected by the available soil water. The availability of soil water on the lysimeters allowed the grasses to delay seed set and flowering-induced dormancy relative to the grasses in the McGee Ranch community. However, it is interesting to note that the bluegrass on the lysimeters began to senesce and deteriorate during early June, even on the lysimeters, where soil water was not a limiting factor to growth of the grass. In addition, most of the cheatgrass on the lysimeters set seed and senesced during June as well, again while the availability of soil moisture did not appear to be a limiting factor. A number of other environmental factors such as temperature, length of day, solar radiation, and water stress resulting from increasing root resistance with age may also affect phenological development, even though soil moisture may be adequate (Kramer 1983).

Phenology of the lysimeter vegetation will continue to be observed to evaluate the effects of soil water availability on plant development and growth. Other measures of plant growth such as leaf area, root growth and density, plant/soil water relations, and gas exchange will be considered.

The lysimeters provide a unique opportunity to study the response of the vegetation to different surface covers (gravel admix surface) and to differing climatic regimes.

8.0 COLLECTION AND STORAGE OF DATA FOR THE FIELD LYSIMETER TEST FACILITY

Data from the FLTF are collected and documented in one of two ways: 1) collected and recorded manually, such as field observations and laboratory data, and 2) gathered using computers, such as data received from sensors connected to the dataloggers or data resulting from computer simulations. The key information from these data sets is stored on the Hanford Protective Barriers (HPB) MicroVAX^(a). All of these data are stored using RS/1^(b) software except UNSAT-H model outputs, which are stored as binary or text files.

8.1 DATA COLLECTION

The types of data collected from the FLTF are listed with the collection method in Table 8.1. Data collected manually are recorded in laboratory record books and entered manually into the FLTF database.

The collection of data by the datalogger is controlled by user-generated programs. The data collected directly by the datalogger include readings from weighing lysimeters, weighing lysimeter platform scales, and temperatures. Thermocouple psychrometers are connected to the dataloggers, but these data have not been analyzed. A sample program listing is provided in Appendix B. Data collected by the dataloggers are transmitted automatically on a daily schedule via telephone connection to a file on an IBM PC/AT^(c) personal computer (PC) in the laboratory. This data file is copied to a master file on the PC, sorted, and transmitted to the project MicroVAX the same day. This process involves using software packages developed specifically for the Campbell Scientific (CSI)^(d) dataloggers as well as simple command statements in batch files. Examples of the files required for using the CSI software, TERM and TELCOM, are also given in

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- (a) MicroVAX is a registered trade name of the Digital Equipment Corp., Maynard, Massachusetts.
  - (b) RS/1 is a registered trade name of BBN Software Products Corp., Cambridge, Massachusetts.
  - (c) IBM PC/AT is a registered trade name of International Business Machines Corp., Armonk, New York.
  - (d) Campbell Scientific Inc., Logan, Utah.

TABLE 8.1. Parameters Measured at Field Lysimeter Test Facility (FLTF) and Method of Data Collection

<u>Parameter</u>	<u>Collection Method</u>
Soil temperature	Copper/constantan thermocouple connected to datalogger
Soil water potential	Tensiometers read manually, thermocouple psychrometers connected to datalogger
Soil moisture	Neutron probe measurements taken manually Gravimetric samples taken manually
Weighing lysimeter weights	Readings from scales connected to datalogger
Drainage	Scale readings of weight of water taken manually
Vegetative cover, phenology, and water use	Observations and manual measurements

Appendix B. Figure 8.1 illustrates the flow of data from the field to the HPB MicroVAX. Figure 8.2 shows how data collected manually and automatically are transmitted or entered, manipulated, and stored on the HPB MicroVAX and the FLTF database.

Note that the sorted data files transferred from the PC data collection station reside in a transfer account on the HPB MicroVAX. These files are stored there until they can be read into RS/1 and plots generated to visually inspect data for errors or inconsistencies. The data are evaluated in graphic form because the quantity of data collected is so large that review of individual data points is not feasible.

8.2 FLTF DATABASE

As discussed, the data collected from the FLTF are stored using RS/1 software. The RS/1 package is an information handling system with advanced statistical and graphic output capabilities to aid in data analysis. A number of RS/1 procedures (simple command streams written in RPL, the command language used by RS/1) have been written to read, manipulate, plot, and assist in manual entry of pertinent data. Listings of these procedures and a short description of their use are included in Appendix C.

FIGURE 8.1. Data Flow from Collection at the Field Lysimeter Test Facility (FLTF) Through Transmission to Laboratory

FIGURE 8.2. Detailed Description of Data Flow, Manipulation, and Final Storage in the Field Lysimeter Test Facility (FLTF) Database

The RS/1 software application for the database on the barriers project uses a simple set of user-controlled relationships to organize and maintain the database. Although RS/1 is not a relational database, relationships are maintained by categorizing the data by type into specific sub-directories and using a strictly consistent nomenclature to identify data sets. Figure 8.3 presents the directory structure and provides a description of the contents of each directory.

8.2.1 Automatically Collected Data

Data files received from the datalogger are read on an IBM PC/AT each day as they are received. The data are sorted according to the time resolution of the measurements and transferred to the project MicroVAX. The hourly files are read into RS/1 on a timely basis using a simple program (RS/1 procedure) called FLTFHREAD_1. This procedure reads the data from the operating system file into an RS/1 table as shown in Tables 8.2 and 8.3. In addition, the procedure adds data to several summary tables, adds data to the graphs of weighing lysimeter data, and generates plots of the data. The procedure FLTFDREAD_1 is used to read in daily averages of the data and add these data to summary tables as well.

8.2.2 Manually Collected Data

The major portion of the manually collected data consists of neutron probe readings. These data are collected and stored on a digital readout unit in the field and logged in the laboratory notebook. The readout unit, which contains a memory (storage), is brought from the field, connected to the PC, and the data are then telecommunicated to a file on the computer using a capture option of the software. This file is edited to delete some nonessential lines in the file and subsequently transmitted to the project MicroVAX. These files are named in the following manner: 'F' to indicate the FLTF site; 'day, month, year'; and an extension '.dat' to indicate that the file has been edited. For example, data collected on June 10, 1988, at the FLTF site would be named as follows: F10JUN88.DAT--indicating that the file had been edited and is ready to transfer to the MicroVAX and read into RS/1.

FLTF Database

HPB MicroVAX -- Barriers Project

FIGURE 8.3. Organization of the Field Lysimeter Test Facility (FLTF) Database

TABLE 8.2. Example of an Edited File of Neutron Probe Data Ready for Transfer into RS/1

MODEL	STD	KDATA	DEPTH														
503A-230	829	1	17														
ID	M17	M16	M15	M14	M13	M12	M11	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1
441	0	0	0	0	4591	7094	11823	11596	11102	11259	11486	11272	10937	10572	8963	4919	11652
442	0	0	0	0	4107	6042	11602	11142	10945	10889	10428	10494	10392	10258	8918	4612	11878
443	0	0	0	0	0	0	0	3995	4996	11724	13042	12317	11216	10929	9927	5319	11832
444	0	0	0	0	4400	6454	12254	12518	11739	12104	11296	10184	10452	10298	9189	5380	11827
445	0	0	0	0	5044	6150	12367	12181	11554	10629	9964	10211	11158	11509	9382	4362	11900
446	0	0	0	0	0	0	0	3541	4580	10719	12671	12079	11278	10918	9550	5361	11851
447	0	0	0	0	4206	6472	12635	12540	12000	11012	11232	10947	10467	10704	9778	5708	11990
448	0	0	0	0	4376	6661	11627	11239	10774	10324	10125	10352	10245	10277	9415	4401	11969
4491	5092	13071	20948	18788	17341	17779	18155	18392	20439	20019	17426	13637	9080	10298	16705	17943	11757
4492	6039	17876	20367	18470	17645	17744	17570	18141	19175	19516	18003	14464	10281	11661	17537	18009	11915
4493	9226	20787	19541	17603	16686	17860	17412	18578	18899	20211	18707	14942	9702	10635	17517	18615	11868
4410	0	0	0	0	4515	7188	14485	14477	13726	13073	13083	12964	12484	11667	11399	5264	11646
44111	5174	12490	20105	17864	17300	17987	17926	17356	17364	17367	16863	13311	8836	10115	19043	18027	11615
44112	5797	17995	19672	17486	17719	17700	18002	18473	18453	17883	17242	13631	9539	11046	17541	18867	11775
44113	8379	19898	18614	17674	17406	17409	17487	17113	17240	17538	16949	14255	10363	11610	18455	18735	11870
4412	0	0	0	0	4584	6654	13109	12899	12064	12024	12584	12394	12480	12677	12252	6657	11870
4413	0	0	0	0	4515	6700	13467	13494	12708	12501	12468	12057	11686	11475	11058	6028	11882
44141	4542	9477	14330	13444	12269	12540	12768	12243	11836	11465	9264	7368	5949	9324	17803	17875	11669
44142	5214	12538	14546	13421	12971	13046	12211	12031	11955	11347	9802	7748	6260	9467	16969	18825	11722
44143	7009	14262	13885	13049	12696	12873	12863	12000	11999	11062	9758	7555	6085	9402	18425	19093	11773
44011	0	8168	12197	11996	12051	12324	11882	11497	11477	11051	9014	7403	6223	9887	18719	19376	12003
44012	0	10349	12299	12258	11586	12120	11571	11711	11864	11152	9306	7924	6844	10456	19654	17782	12117
44013	0	11576	12072	11711	11553	11907	11467	11547	11450	10339	8946	7021	5807	9473	16626	19148	11889
4402	0	0	0	0	0	7917	11539	12702	12822	12648	11944	12128	12099	11265	10063	5043	11893
44031	0	9302	13111	12835	13441	13613	13404	13252	12252	11500	8586	6280	4774	7815	15890	18079	11602
44032	0	11493	13486	13460	13115	13878	13348	13056	12181	11429	9351	6758	5022	8212	15738	16833	11585
44033	0	12215	12914	12616	13095	13143	12835	12847	11772	10434	8832	6891	5487	8891	16330	18455	11790
4404	0	0	0	0	0	9235	14178	14228	13851	13584	13800	13471	13223	12904	11572	5108	11799

TABLE 8.3. Example of Neutron Probe Count Data as Stored in an RS/1 Table in the Database

Neutron Probe Data for the FLTF Site at 15-cm intervals on May 04, 1988

0 NOTE 6-23-88	1 ST. MEAN STANDARD	2 END MEAN STANDARD	3 DEPTH	4 D01	5 D02	6 D03	7 D04	8 D05	9 D06	10 D07	11 D08	12 D09-S	13 D10
1 Probe:	11703.00	11588.00	20	11652	11878	11832	11827	11900	11851	11990	11969	11868	11646
2 503_DR			0	4919	4612	5319	5380	4362	5361	5708	4401	9702	5264
3 H33115140	0.91	0.81	-15	8963	8918	9927	9189	9382	9550	9778	9415	20211	11399
4 Time:			-30	10572	10258	10929	10298	11509	10918	10704	10277	18899	11667
5 16 sec.			-45	10937	10392	11216	10452	11158	11278	10467	10245	18578	12484
6 Taken by:			-60	11272	10494	12317	10184	10211	12079	10947	10352	17412	12964
7 CJ KEMP			-75	11486	10428	13042	11296	9964	12671	11232	10125	17860	13083
8 Entered by:			-90	11259	10889	11724	12104	10629	10719	11012	10324	16686	13073
9 MJ KANYID			-105	11102	10945	4998	11739	11554	4580	12000	10774	17603	13726
10 by Computer			-120	11596	11142	3995	12518	12181	3541	12540	11239	19541	14477
11 Processed by:			-135	11823	11602		12254	12367		12635	11627	20787	14485
12 FLTFNP_2			-150	7094	6042		6454	6150		6472	6661	9226	7188
13 Slope:			-160	4591	4107		4400	5044		4206	4376		4515
14 0.0017													
15 Offset:													
16 -1.4400													
17 MSF->	11645.50												

0 NOTE 6-23-88	14 D11-S	15 D12	16 D13	17 D14-S	18 W01-S	19 W02	20 W03-S	21 W04
1 Probe:	11870	11870	11882	11773	11889	11893	11790	11799
2 503_DR	10363	6657	6028	6085	5807	5043	5487	5108
3 H33115140	17538	12252	11058	11062	10339	10063	10434	11572
4 Time:	17240	12677	11475	11999	11450	11265	11772	12904
5 16 sec.	17113	12480	11686	12000	11547	12099	12847	13223
6 Taken by:	17487	12394	12057	12863	11467	12128	12835	13471
7 CJ KEMP	17409	12584	12468	12873	11907	11944	13143	13800
8 Entered by:	17406	12024	12501	12696	11553	12648	13095	13584
9 MJ KANYID	17674	12064	12708	13049	11711	12822	12616	13851
10 by Computer	18614	12899	13494	13885	12072	12702	12914	14228
11 Processed by:	19898	13109	13467	14262	11576	11539	12215	14178
12 FLTFNP_2	8379	6654	6700	7009		7917		9235
13 Slope:		4584	4515					
14 0.0017								
15 Offset:								
16 -1.4400								
17 MSF->								

Note that depth -150 cm for the Weighing Lysimeters is actually depth -145 cm. Storage calculations use -145 cm as the interval and not -150 cm.

An RS/1 procedure called FLTFNP_1 is used to read in the neutron probe counts from the operating system file. This procedure also performs simple manipulations of the data to organize the data into different directories (see Figure 8.3) and calculate percent moisture from the raw counts (Table 8.4), calculate storage using the calculated values of percent moisture (Table 8.5), add storage data to summary tables for each lysimeter, and generate graphic data for each lysimeter (Figure 8.4).

Other data that are collected manually (i.e., tensiometer data, drainage data, and any observations concerning the vegetation on the lysimeters) are also entered into RS/1 manually. No procedures have been developed at this time for manipulating these data structures, but a procedure will be developed for entering the drainage data and calculating cumulative drainage through time. As shown in Figure 8.3, these data are stored in the directories according to the particular type data.

TABLE 8.4. Example of Processed Neutron Probe Data in the Field Lysimeter Test Facility (FLTF): Calculated Percent Moisture

Neutron Probe Data for the FLTF Site at 15-cm intervals on May 04, 1988

0 NOTE 6-23-88	1 ST. MEAN STANDARD	2 END MEAN STANDARD	3 DEPTH	4 D01	5 D02	6 D03	7 D04	8 D05	9 D06	10 D07	11 D08	12 D09-S	13 D10
1 Probe:	11703.00	11588.00	20	18.37	18.75	18.67	18.67	18.79	18.71	18.94	18.91	18.74	18.36
2 503_DR			0	6.92	6.40	7.60	7.71	5.98	7.67	8.26	6.04	15.05	7.51
3 H33115140	0.91	0.81	-15	13.80	13.72	15.44	14.18	14.51	14.80	15.18	14.57	32.92	17.94
4 Time:			-30	16.53	16.00	17.14	16.07	18.13	17.12	16.76	16.03	30.69	18.39
5 16 sec.			-45	17.15	16.23	17.63	16.33	17.53	17.73	16.35	15.98	30.14	19.78
6 Taken by:			-60	17.72	16.40	19.50	15.87	15.92	19.09	17.17	16.16	28.16	20.60
7 CJ KEMP			-75	18.09	16.29	20.73	17.76	15.50	20.10	17.65	15.77	28.92	20.80
8 Entered by:			-90	17.70	17.07	18.49	19.14	16.63	16.78	17.28	16.11	26.93	20.78
9 MJ KANYID			-105	17.43	17.17	7.05	18.52	18.20	6.35	18.96	16.88	28.49	21.89
10 by Computer			-120	18.27	17.50	5.35	19.84	19.27	4.58	19.88	17.67	31.78	23.17
11 Processed by:			-135	18.66	18.28		19.39	19.58		20.04	18.33	33.90	23.18
12 FLTFNP_2			-150	10.62	8.83		9.53	9.01		9.56	9.88	14.24	10.78
13 Slope:			-160	6.36	5.54		6.04	7.13		5.71	6.00		6.24
14 0.0017													
15 Offset:													
16 -1.4400													
17 MSF->	11645.50												

0 NOTE 6-23-88	14 D11-S	15 D12	16 D13	17 D14-S	18 W01-S	19 W02	20 W03-S	21 W04
1 Probe:	18.74	18.74	18.76	18.57	18.77	18.78	18.60	18.62
2 503_DR	16.18	9.88	8.81	8.90	8.43	7.13	7.89	7.24
3 H33115140	28.37	19.39	17.36	17.37	16.14	15.67	16.30	18.23
4 Time:	27.87	20.11	18.07	18.96	18.03	17.71	18.57	20.50
5 16 sec.	27.65	19.78	18.43	18.96	18.19	19.13	20.40	21.04
6 Taken by:	28.29	19.63	19.06	20.43	18.05	19.18	20.38	21.46
7 CJ KEMP	28.16	19.95	19.76	20.44	18.80	18.86	20.90	22.02
8 Entered by:	28.15	19.00	19.81	20.14	18.20	20.06	20.82	21.65
9 MJ KANYID	28.61	19.07	20.16	20.74	18.47	20.36	20.01	22.11
10 by Computer	30.20	20.49	21.50	22.16	19.08	20.15	20.51	22.75
11 Processed by:	32.39	20.85	21.45	22.81	18.24	18.18	19.33	22.66
12 FLTFNP_2	12.80	9.87	9.95	10.48		12.02		14.26
13 Slope:		6.35	6.24					
14 0.0017								
15 Offset:								
16 -1.4400								
17 MSF->								

Note that depth -150 cm for the Weighing Lysimeters is actually depth -145 cm. Storage calculations use -145 cm as the interval and not -150 cm.

TABLE 8.5. Summary Table Showing Moisture Storage for Lysimeter D01

Moisture Storage in D1 in Centimeters of Water										
0		1 04-NOV-87	2 02-DEC-87	3 18-DEC-87	4 08-JAN-88	5 21-JAN-88	6 05-FEB-88	7 18-FEB-88	8 02-MAR-88	9 18-MAR-88
1	20	2.733810	2.734830	2.853660	3.007170	2.811840	2.796795	2.787360	2.898795	2.923785
2	0	0.891690	1.100280	2.089935	2.386245	2.271240	1.680005	1.220130	1.040610	0.995220
3	-15	1.616400	1.765830	2.585855	2.722335	3.228765	2.984475	2.416590	2.154960	2.078970
4	-30	2.194995	2.113905	2.638695	2.488755	3.049755	2.731005	2.787725	2.642775	2.500740
5	-45	2.393895	2.332950	2.622120	2.512980	2.774865	2.846265	2.731005	2.759565	2.621865
6	-60	2.489775	2.519865	2.534655	2.560665	2.636145	2.786850	2.761095	2.788125	2.715460
7	-75	2.643030	2.613960	2.637165	2.661135	2.636145	2.757525	2.786850	2.752425	2.752170
8	-90	2.515785	2.680515	2.656035	2.550720	2.575965	2.586930	2.623395	2.627220	2.593050
9	-105	2.496150	2.544600	2.529300	2.579535	2.543835	2.581065	2.630280	2.593050	2.655780
10	-120	2.612940	2.630790	2.612940	2.663940	2.664960	2.693520	2.642010	2.768745	2.730240
11	-135	2.921745	2.849580	2.813880	2.798580	2.796030	2.786850	2.804955	2.822805	2.799090
12	-150	1.729875	2.412765	2.308725	1.754100	1.586055	1.608240	1.625580	1.553415	1.583250
13	-160	0.674190	0.663480	0.667390	0.649370	0.651750	0.645120	0.655150	0.631010	0.633050
14										
15	TOT-75CM	11.338095	11.346510	13.018290	12.945870	14.325675	14.106120	13.463265	13.097850	12.669195
16	75-160CM	12.950685	13.781730	13.588270	12.996245	12.818595	12.901725	12.981370	12.996245	12.994460
17	TOT STOR	27.914280	28.968350	31.550155	31.335530	32.227350	31.464645	30.452125	30.033500	29.582660
18	TOT SOIL_S	24.288780	25.128240	26.866560	25.942115	27.144270	27.007845	26.444635	26.094095	25.663655
0		10 20-APR-88	11 04-MAY-88	12 18-MAY-88	13 02-JUN-88	14 15-JUN-88				
1	20	2.817450	2.731260	2.709330	2.692500	2.681790				
2	0	0.962580	1.014345	0.798360	0.865425	0.704520				
3	-15	1.998390	2.045565	1.915280	1.906335	1.837740				
4	-30	2.467590	2.455680	2.359725	2.339325	2.293680				
5	-45	2.540520	2.548935	2.492835	2.474985	2.487225				
6	-60	2.519865	2.634360	2.634870	2.611920	2.614725				
7	-75	2.519355	2.688930	2.684340	2.613705	2.650680				
8	-90	2.561685	2.631045	2.601465	2.600190	2.557880				
9	-105	2.650170	2.591010	2.610900	2.562705	2.574435				
10	-120	2.821785	2.716980	2.742735	2.686635	2.704995				
11	-135	2.972235	2.774865	2.790930	2.785065	2.774865				
12	-150	1.521540	1.568970	1.505220	1.595490	1.500375				
13	-160	0.613670	0.620470	0.633390	0.626930	0.608910				
14										
15	TOT-75CM	12.045720	12.373650	12.087030	11.946270	11.884050				
16	75-160CM	13.141085	12.903340	12.884640	12.857015	12.721440				
17	TOT STOR	28.968835	29.022595	28.479380	28.361210	27.991800				
18	TOT SOIL_S	25.186805	25.276990	24.971670	24.803285	24.605490				

FIGURE 8.4. Graph Showing Soil Moisture Profile for Lysimeter D1

9.0 RECOMMENDATIONS

The FLTF is now completing its first year of operation. Results of initial monitoring of the lysimeters show expected differences in water balance that reflect the imposed surface conditions (i.e., bare surface, vegetation, gravel admixture, etc.). Data support the protective barrier concept in that a fine soil surface appears entirely adequate to recycle precipitation (both ambient and twice average precipitation) without allowing drainage, even under conditions where lysimeter surfaces are bare. While the present data support the concept of the protective barrier, the confirmation of barrier performance will require additional years of testing. To make all of the lysimeters fully functional and to optimize test results over the lifetime of the project, the following recommendations are made with respect to the operation of the FLTF in future years.

1. Continuity in Measuring Water Balance. Continued collection of key data related to water balance parameters (i.e., precipitation, evapotranspiration, soil water storage, drainage) is essential to maximize the use of the FLTF. The data collection should continue uninterrupted for the lifetime of the project (at least another 5 years). Because the facility offers a unique capability for measuring each of the water balance parameters independently, conventional assumptions related to estimating drainage or recharge can be tested rigorously. The measurements necessary to calculate water balance for each of the treatments include: water storage, determined using neutron probe techniques; water storage and evapotranspiration, obtained using weighing lysimeter weight-change data; precipitation, determined using standard raingauges located at the HMS (adjacent to the facility); irrigation, measured with weighing lysimeters or with clearview raingauges placed directly on the lysimeters; and drainage, measured by direct weighing of outflow water from the bottom of the lysimeters. This continuous data set will allow us to assess the effects of climatic changes on temporal (daily, weekly,

monthly, seasonal, annual) variations of water balance for the test barrier configurations. The data sets will be used to calibrate and validate computer models needed to predict long-term performance of protective barriers at the Hanford Site.

It is recommended that the neutron probe measurements be continued on a biweekly basis and that irrigation be applied biweekly (except for below-freezing winter periods) to maintain the twice average precipitation treatments. It is also recommended that the scale measurements of weight changes in the weighing lysimeters be collected continuously and at least hourly data be averaged and stored for each weighing lysimeter. These data should be transmitted automatically to the laboratory for storage in raw data files and subsequently processed and displayed graphically at least weekly.

2. Scale Calibration. The two large platform scales, which are an integral part of weighing lysimeters W01-1 and W03-3, appeared not to perform to manufacturer specifications when they were calibrated early in 1988. These scales should be checked and recalibrated. If the scales still do not perform to desired specifications, they should be repaired or replaced. Based on observations from the other two weighing lysimeters (W02-2 and W04-4), a weight resolution of less than 0.5 kg in 10,000 kg appears possible and the scales appear linear over the operational range of the lysimeters (0 to 8,000 kg). An annual calibration of these scales is recommended and is currently scheduled with the onsite calibrations laboratory (HEDL).
3. Water Content Profiles with Gamma Scanner. When the gamma probe, which has been ordered from Troxler, Inc., is received, the scanning of water contents should be initiated. This probe was received in September 1988. After calibration tests and thermal stability checks, the gamma scanner will be used to measure the water contents in the upper 155 cm of each of the lysimeters. The gamma scanner measurements should resolve moisture contents more precisely than neutron probe measurements at the interface between fine soil and coarse sand.

4. Vegetation and Root Zone Monitoring. The establishment and response of the vegetation growing on the lysimeters during the period of November 1987 through June 1988 is documented in this report. Continued monitoring is recommended to assess growth and response of lysimeter vegetation to the particular soil and climatic variables of the selected barrier treatments. Phenological (growth-stage) responses should be documented at least on a monthly basis during the year and biweekly during the spring and summer growing seasons. Biomass production and gas exchange measurements should be made on a seasonal basis as should measurements of root growth and development. With the use of a down-well video camera, the root growth patterns of the plants growing on the lysimeters can be documented. The root growth patterns will provide a qualitative assessment of the root zone depth, expected areas of greatest plant water removal, and the time dependence of water extraction by plants.

We also recommend that nonradioactive (stable) isotope analyses be performed on selected plant tissues taken periodically from vegetation growing on the lysimeters. Although stable isotope analysis provides only a qualitative assessment of potential for water removal by plants, using isotopic tracers such as ^{15}N or measuring the $^{12}\text{C}/^{13}\text{C}$ ratios in plant leaves would provide confirmation of the plant nutrient and water-use efficiency status. Such measurements are currently being obtained on shrubs and grasses on the Hanford Site at several Arid Land Ecology study sites as part of a separate DOE program. This information, obtained for selected plant samples taken from the lysimeters, would be valuable in comparing the productivity and water use of plants growing on undisturbed landscapes to plants growing on protective barriers.

5. Visual Inspection of Barrier Configuration. As part of the FLTF original design, several 30-cm-dia by 300-cm-long clear plastic columns were proposed to be inserted in the facility and located adjacent to the drainage lysimeter network. Original funding did not permit the purchase or the filling of these demonstration lysimeters. We recommend

installation and filling of two plastic columns, one with vegetation and one bare, to show the configuration and layer sequence of materials in drainage lysimeters.

6. Water Potential and Temperature Profiles. Water potential (thermocouple psychrometer) and temperature (thermocouple) data collected to date have not been analyzed. These data will be analyzed during FY 1989, if funding is available. This analysis will require developing acceptability criteria for factory-calibrated TCPs that have been placed in the soil profile. A probable procedure will be the use of factory calibrations to convert the voltage output from the TCPs into water potential (expressed in MPa pressure units) and then compare these data with neutron probe or gamma probe water content data for a field-measured water retention curve. These data can then be compared to the laboratory-determined water potential-water content characteristics. Because TCPs are used primarily for dry soil conditions, data should be obtained during late summer or fall, at points in the soil profile where the soil water content is well below 13 vol% (i.e., where the water potential is below -0.2 MPa). During our tests, the soil was wetted to an average water content well above 15 vol%, and it took time for the soil to dry to a condition where the TCP data were meaningful. It would be very helpful to review the TCP data early in FY 1989 to assure that there is an adequate calibration procedure established. The thermocouple (TC) data can be analyzed in a more straight forward way because the data are output directly in temperature units. These data can be used to determine the effects of the various treatments on the thermal regime of the barrier. It is expected that these data will be compiled and reviewed in early FY 1989.
7. Leak Tests. Drainage lysimeters were leak tested and appear to be leak free, except for D02-5 and D06-6. While the tests show water losses in excess of 1 L from these two lysimeters, sources other than leakage could account for these measurements. These include vapor transport into dry soil and slow but measurable water imbibition by the basalt riprap. It is important to resolve this issue so drainage measurements

will be unequivocal, particularly for those lysimeters that are expected to drain in future years. Efforts should be expended during the next year to develop an improved test for leakage.

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APPENDIX A

CHARACTERIZATION DATA FOR THE FIELD LYSIMETER TEST FACILITY

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INITIAL IN-PLACE LEAK TEST

Initial leak test results are recorded in Laboratory Record Book (LRB) BNW-5137 on pages 23-39. Each lysimeter was covered with plastic to prevent evaporative loss. Each lysimeter was filled and then drained to measure the amount of water required to cover the entire sloping floor and to measure the amount of water retained in floor depressions following drainage. Each lysimeter was then filled with a measured weight of water, ranging from 150 to 250 kg, and allowed to set for approximately a week. At the end of the week, the water was drained, weighed, and discarded.

Negative differences shown in Table A.1 probably result from continued drainage of water input to fill depressions in the tank bottom and possible flexing of the tank bottom. Estimated water loss by evaporation during the

TABLE A.1. Initial In-Place Leak Tests of Field Lysimeter
Test Facility Lysimeters in April 1987 (in g)

<u>0 Lysimeter</u>	<u>1 Input</u>	<u>2 Drained</u>	<u>3 Difference</u>
1 D01	152999	152317	682
2 D02	168462	167865	597
3 D03	173159	172387	772
4 D04	187257	185986	1271
5 D05	175131	174640	491
6 D06	157952	154447	3505
7 D07	170898	167346	3552
8 D08	162678	160283	2395
9 D09	169269	169365	-96
10 D10	171050	170495	555
11 D11	187058	188500	-1442
12 D12	169926	169136	790
13 D13	178509	176672	1837
14 D14	173509	172332	1177

Negative differences probably are attributable to continued drainage of water input to fill tank bottom.

test period (7 days) was 0.5 mm water for each lysimeter (this is equivalent to 0.07 mm/d or about 3% of the maximum water loss of 2 mm/d that could occur under the climatic conditions that existed during the test period). The 0.5 mm (0.05 cm) water loss is equivalent to about 1.51 L of water in a lysimeter 2 m in dia. The error in this estimate could be as much as 100% (i.e., as much as 3 L of water loss by evaporation and as little as 0.7 L). The water loss data can be explained by evaporation in all but two lysimeters. It is also possible that the bottoms of lysimeters D06-6 and D07-1 flexed during emptying and as a result held an apparently significant amount of water. However, based solely on the leak test data we cannot rule out the possibility of a pinhole leak in lysimeters D06-6 and D07-1.

SUBSEQUENT IN-PLACE LEAK TESTS

The first of this series of three tests was conducted using lysimeters D08-2 through D14-3. A barrel was filled with about 90 kg of water and the water transferred to each lysimeter for 24 hours. The water was then drained for 30 minutes back to the barrel, weighed and the weight recorded. The same water was placed back in the lysimeter for another 24 hours. At the end of the 24-hour test period the water was again drained for 30 minutes, weighed and the weight recorded. The difference between initial and final drainage water weights was attributed to leakage.

In the second test we used twice the amount water (180 kg) used for the first test. A 1-week presoak time was used. Lysimeters were drained for 1 hour and drainage water was weighed. The weighed water was then placed back in the same lysimeter and left there 1 week. Then, each lysimeter was drained for 1 hour, and the drainage water was again weighed (see Table A.2).

The third test was completed for lysimeters D01-2 through D07-1. Lysimeters D02-5 and D06-6 are the only ones that did not return the entire amount of water following 3 days of drainage. The third test used a soak time of 1 month and a drain time of 3 days followed by a test time of 1 month and a final drainage time of 3 days. These three tests followed similar procedures, but were different from the initial in-place test.

Test results in Table A.2 show the net water input and drainage for each lysimeter and the difference due to leakage or storage. Following the difference, a column shows how much additional drainage occurred in the following 3 days. Finally, there is a column showing how much difference exists between the amount of water stored and the amount drained during the following 3 days. Negative numbers in this last column indicate that some of the water from the presoak was recovered.

Table A.3 is a record of material weight placed in the lysimeters. Table A.4 shows the factory calibration values for the thermocouple psychrometers placed in the lysimeters at the FLTF. Table A.5 extends from page A.7 to page A.26 and shows density and moisture information for each drainage lysimeter. Table A.6 shows density and moisture data for the weighing lysimeters. Table A.7 contains a summary of soil textures in drainage lysimeters. Table A.8 presents a basis for computation of particle size ordinates. Figure A.1 shows a Proctor density curve for the McGee Ranch soil used in the FLTF. Figure A.2 shows an example of particle size analysis of soil used in drainage lysimeter D01-02. Figure A.3 shows soil density data and calibration curves for the Seaman Nuclear Probe.

TABLE A.2. Drainage Lysimeter Leak Tests (weights in kg)

Lysimeter	Test #1				Test #2				Test #3			
	Net		Difference		Net		Difference		Net		Difference	
	Input	Drained or Storage	3 - Day Drainage	3 - Day Difference	Input	Drained or Storage	3 - Day Drainage	3 - Day Difference	Input	Drained or Storage	3 - Day Drainage	3 - Day Difference
D1	157.884	157.847	0.767	3.194	-2.437	166.894	161.119	5.775	0.89	-3.115		
D2	164.865	162.559	1.586	1.454	0.052	165.592	161.57	3.932	2.211	1.721		
D3	170.81	169.13	1.68	1.973	-0.293	162.894	158.835	4.059	5.816	-1.767		
D4	167.66	166.697	0.963	3.113	-2.15	166.825	164.661	2.164	3.455	-1.291		
D5	174.435	174.036	0.399	1.828	-1.429	170.65	168.587	2.143	2.989	-0.766		
D6	156.591	151.912	4.679	1.832	2.847	162.315	156.195	6.12	0.118	6.002		
D7	170.406	169.356	1.05	3.063	-2.013	165.849	160.987	4.942	5.3	-0.358		
D8	82.288	81.861	0.339	1.312	-0.973	174.689	173.588	1.101	2.036	-0.935		
D9	88.358	88.182	0.176	1.237	-1.061	174.586	173.532	1.054	1.427	-0.373		
D10	84.357	84.189	0.168	1.277	-1.109	173.177	172.255	0.922	1.732	-0.81		
D11	87.142	87.051	0.091	3.067	-2.976	174.687	173.979	0.708	2.512	-1.084		
D12	86.855	86.737	0.118	1.584	-1.466	166.544	165.721	0.823	1.877	-1.054		
D13	84.572	84.431	0.141	1.445	-1.384	171.855	170.911	0.944	1.821	-0.877		
D14	86.959	86.737	0.222	1.403	-1.181	170.218	169.384	0.834	1.811	-1.047		

TABLE A.3. Weights (kg) of Material Lifts Used in Each Lysimeter

0 Note: RRK	1 D1	2 D2	3 D3	4 D4	5 D5	6 D6
8/24/87	PG 73, 72, 68, 67	PG 71, 68, 66	PG 71, 70, 69, 66	PG 71, 69, 65	PG 71, 70, 69, 65	PG 63, 64
1						
2 20/30 Sand	211.8	232	242	253	242	232
3 No. 8 Sand	237.0	242	234	243	241	246
4 Tare + Pea Gravel	215.0	272	192	270	246	296
5 3/4" Gravel	621.0	634	774	709	597	564
6 1-3" Rock	893.0	708	835	946	549	720
0 Note: RRK	7 D7	8 D8	9 D9	10 D10	11 D11	12 D12
8/24/87	PG 73, 72, 69, 65	PG 76, 75, 74, 67	PG 59	PG 76, 75, 70, 67	PG 59, 60, 62, 63	PG 75, 74 69, 67
1						
2 20/30 Sand	216	196	230.4	229.0	221.0	206
3 No. 8 Sand	239	217	241.8	228.4	253.0	222
4 Tare + Pea Gravel	191	340	287.5	276.0	239.0	250
5 3/4" Gravel	668	562		529.0	606.0	628
6 1-3" Rock	869	935		834.0	970.1	934
0 Note: RRK	13 D13	14 D14				
8/24/87	PG 74, 69, 67	PG 76, 75, 68				
1						
2 20/30 Sand	226.0	228				
4 Tare + Pea Gravel	200.7	249				
5 3/4" Gravel	297.0	278				
6 1-3" Rock	647.0	486				
	805.0	815				

TABLE A.4. Factory Calibration Values for
Thermocouple Psychrometer

PSY FAC CAL 30R x 3C
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<u>1 Serial Number</u>	<u>2 Graph Scale</u>	<u>3 Micro Volts</u>
29489	59	11.8
29490	63	12.6
29491	62	12.4
29492	63	12.6
29493	64	12.8
29494	62	12.4
29495	62	12.4
29496	63	12.6
29497	62	12.4
29498	62	12.4
29499	61	12.2
29500	63	12.6
29501	60	12.0
29502	62	12.4
29503	62	12.4
29504	63	12.6
29505	63	12.6
29506	62	12.4
29507	63	12.6
29508	63	12.6
29509	61	12.2
29510	63	12.6
29511	62	12.4
29512	59	11.8
29513	63	12.6
29514	62	12.4
29515	63	12.6
29516	62	12.4
29517	63	12.6
29518	62	12.4

TABLE A.5. Summary of Density and Moisture Information for Each Drainage Lysimeter

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FLTF_DEN_H2O 193R x 49C

Ø fix dry density	1 DEPTHS	2 TARE grams	3 WET WT grams	4 DRY WT grams	5 % H2O	6 % VOL H2O	7 CORE #	8 CORE VOL cc	9 DENSITY WET CAN	10 DENSITY DRY CAN	11 DENSITY COUNTS
1 D01#01N	-150.20	72.35	411.40	368.86	0.14	0.19	2	219.18	1.547	1.353	4980
2 D01#02N	-144.10	72.35	411.40	368.86	0.14	0.19	2	219.18	1.547	1.353	4803
3 D01#03N	-138.60	70.51	411.36	371.33	0.13	0.18	2	219.18	1.555	1.372	4891
4 D01#04N	-132.75	70.51	411.36	371.33	0.13	0.18	2	219.18	1.555	1.372	4816
5 D01#05N	-121.25	76.29	411.90	369.38	0.15	0.19	2	219.18	1.531	1.337	4907
6 D01#06N	-109.65	76.29	411.90	369.38	0.15	0.19	2	219.18	1.531	1.337	4927
7 D01#07N	-95.65	71.60	406.62	366.78	0.13	0.18	2	219.18	1.529	1.347	4889
8 D01#08N	-85.35	71.60	406.62	366.78	0.13	0.18	2	219.18	1.529	1.347	4890
9 D01#09N	-73.70	70.93	420.42	379.99	0.13	0.18	2	219.18	1.595	1.410	4887
10 D01#10N	-62.85	70.93	420.42	379.99	0.13	0.18	2	219.18	1.595	1.410	4839
11 D01#11N	-52.70	72.27	403.09	366.16	0.13	0.17	2	219.18	1.509	1.341	4880
12 D01#12N	-42.25	72.27	403.09	366.16	0.13	0.17	2	219.18	1.509	1.341	4886
13 D01#13N	-31.05	72.63	403.82	368.31	0.12	0.16	2	219.18	1.511	1.349	4864
14 D01#14N	-19.85	72.63	403.82	368.31	0.12	0.16	2	219.18	1.511	1.349	4933
15 D01#15N	-8.55	71.84	407.86	372.99	0.12	0.16	2	219.18	1.533	1.374	4772
16 D01#16N	-5.00	71.84	407.86	372.99	0.12	0.16	2	219.18	1.533	1.374	4643
17 D02#01N	-148.50	69.79	426.31	375.84	0.16	0.23	2	219.18	1.627	1.396	4890
18 D02#02N	-142.25	69.79	426.31	375.84	0.16	0.23	2	219.18	1.627	1.396	5020
19 D02#03N	-137.15	69.80	392.83	354.80	0.13	0.17	2	219.18	1.474	1.300	4851
20 D02#04N	-130.50	69.80	392.83	354.80	0.13	0.17	2	219.18	1.474	1.300	4843
21 D02#05N	-120.50	73.56	413.46	375.97	0.12	0.17	2	219.18	1.551	1.380	5021
22 D02#06N	-111.00	73.56	413.46	375.97	0.12	0.17	2	219.18	1.551	1.380	4911
23 D02#07N	-101.90	71.15	406.50	373.92	0.11	0.16	2	219.18	1.530	1.301	4913
24 D02#08N	-90.00	71.15	406.50	373.92	0.11	0.16	2	219.18	1.530	1.301	5036
25 D02#09N	-79.40	72.32	395.99	383.05	0.11	0.15	2	219.18	1.477	1.326	5005
26 D02#10N	-68.40	72.32	395.99	383.05	0.11	0.15	2	219.18	1.477	1.326	4900
27 D02#11N	-57.60	71.75	427.21	383.01	0.14	0.20	2	219.18	1.622	1.420	4720
28 D02#12N	-47.50	72.33	432.42	387.55	0.14	0.20	2	219.18	1.643	1.438	4804
29 D02#13N	-37.55	72.33	432.42	387.55	0.14	0.20	2	219.18	1.643	1.438	4919
30 D02#14N	-27.50	73.52	406.86	367.04	0.14	0.18	2	219.18	1.521	1.339	4921
31 D02#15N	-16.55	73.52	406.86	367.04	0.14	0.18	2	219.18	1.521	1.339	4958
32 D02#16N	-5.30	69.94	416.07	369.12	0.16	0.21	2	219.18	1.579	1.365	4859
33 D03#01N	-99.80	71.44	434.82	384.42	0.16	0.23	2	219.18	1.658	1.428	4813
34 D03#02N	-94.50	71.44	434.82	384.42	0.16	0.23	2	219.18	1.658	1.428	4715
35 D03#03N	-88.60	71.68	414.33	368.24	0.16	0.21	2	219.18	1.563	1.353	5049
36 D03#04N	-81.45	71.68	414.33	368.24	0.16	0.21	2	219.18	1.563	1.353	4784
37 D03#05N	-68.35	72.25	412.06	371.70	0.13	0.18	2	219.18	1.550	1.366	4872
38 D03#06N	-55.00	72.25	412.06	371.70	0.13	0.18	2	219.18	1.550	1.366	4854
39 D03#07N	-41.85	70.68	404.78	365.25	0.13	0.18	2	219.18	1.524	1.344	4856
40 D03#08N	-29.85	71.04	397.69	359.13	0.13	0.18	1	211.94	1.541	1.359	4841
41 D03#09N	-16.00	71.04	397.69	359.13	0.13	0.18	1	211.94	1.541	1.359	4250
42 D03#10N	-5.05	70.39	422.08	378.10	0.14	0.21	1	211.94	1.659	1.452	4688
43 D04#01N	-149.90	70.39	422.08	378.10	0.14	0.21	1	211.94	1.659	1.452	4801
44 D04#02N	-144.10	73.50	406.82	369.52	0.13	0.18	1	211.94	1.573	1.397	5012
45 D04#03N	-138.35	73.50	406.82	369.52	0.13	0.18	1	211.94	1.573	1.397	4757
46 D04#04N	-130.75	70.77	396.18	348.26	0.17	0.23	1	211.94	1.535	1.309	4909
47 D04#05N	-118.50	70.77	396.18	348.26	0.17	0.23	1	211.94	1.535	1.309	4788
48 D04#06N	-106.95	68.95	376.37	347.41	0.10	0.14	1	211.94	1.451	1.314	4916
49 D04#07N	-94.55	68.95	376.37	347.41	0.10	0.14	1	211.94	1.451	1.314	4672
50 D04#08N	-82.90	71.78	410.58	364.31	0.16	0.22	1	211.94	1.599	1.380	4711
51 D04#09N	-69.85	71.78	410.58	364.31	0.16	0.22	1	211.94	1.599	1.380	
52 D04#10N	-56.95										
53 D04#11N	-46.25										
54 D04#12N	-34.05										

TABLE A.5. (contd)

FLTf_DEN_H2O 193R x 49C

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0 fix dry density	12 DENSITY DAILY STAND	13 CR DEN DAILY	14 CR DEN MEAN	15 COL14+-.0508 +3.003	16 MOISTURE COUNTS	17 MOISTURE DAILY STND	18 CR H2O DAILY	19 CR H2O MEAN	20 col18+.4968 -.2145
1 D01#01N	2189.50					938.50			
2 D01#02N	2189.50	2.274	2.246	1.528	835	938.50	0.890	0.887	0.226
3 D01#03N	2189.50	2.194	2.167	1.580	826	938.50	0.880	0.877	0.221
4 D01#04N	2189.50	2.234	2.206	1.554	831	938.50	0.885	0.883	0.224
5 D01#05N	2189.50	2.200	2.172	1.576	809	938.50	0.862	0.859	0.212
6 D01#06N	2189.50	2.241	2.213	1.549	789	938.50	0.841	0.838	0.202
7 D01#07N	2189.50	2.250	2.222	1.543	745	938.50	0.794	0.791	0.179
8 D01#08N	2189.50	2.233	2.205	1.555	791	938.50	0.843	0.840	0.203
9 D01#09N	2181.00	2.242	2.206	1.554	799	940.50	0.850	0.849	0.207
10 D01#10N	2181.00	2.241	2.204	1.555	765	940.50	0.813	0.813	0.189
11 D01#11N	2181.00	2.219	2.183	1.569	789	940.50	0.839	0.838	0.202
12 D01#12N	2181.00	2.238	2.201	1.557	798	940.50	0.848	0.848	0.206
13 D01#13N	2181.00	2.240	2.204	1.555	776	940.50	0.825	0.824	0.195
14 D01#14N	2181.00	2.230	2.194	1.562	779	940.50	0.828	0.828	0.196
15 D01#15N	2181.00	2.262	2.225	1.541	794	940.50	0.844	0.843	0.204
16 D01#16N	2181.00	2.188	2.153	1.589	769	940.50	0.818	0.817	0.191
17 D02#01N									
18 D02#02N	2189.50	2.121	2.094	1.627	909	938.50	0.969	0.966	0.265
19 D02#03N	2189.50	2.233	2.206	1.554	802	938.50	0.855	0.852	0.209
20 D02#04N	2189.50	2.293	2.264	1.516	762	938.50	0.812	0.809	0.187
21 D02#05N	2189.50	2.216	2.188	1.566	785	938.50	0.836	0.834	0.200
22 D02#06N	2181.00	2.221	2.185	1.568	815	940.50	0.867	0.866	0.215
23 D02#07N	2181.00	2.302	2.265	1.515	801	940.50	0.852	0.851	0.208
24 D02#08N	2181.00	2.252	2.215	1.548	758	940.50	0.806	0.805	0.185
25 D02#09N	2181.00	2.253	2.216	1.547	745	940.50	0.792	0.791	0.179
26 D02#10N	2181.00	2.309	2.272	1.511	747	940.50	0.794	0.794	0.180
27 D02#11N	2181.00	2.295	2.258	1.520	813	940.50	0.864	0.864	0.214
28 D02#12N	2181.00	2.247	2.210	1.551	817	940.50	0.869	0.868	0.216
29 D02#13N	2181.00	2.164	2.129	1.605	826	940.50	0.878	0.877	0.221
30 D02#14N	2181.00	2.203	2.167	1.580	789	940.50	0.839	0.838	0.202
31 D02#15N	2181.00	2.255	2.219	1.546	769	940.50	0.818	0.817	0.191
32 D02#16N	2181.00	2.256	2.220	1.545	776	940.50	0.825	0.824	0.195
33 D03#01N									
34 D03#02N	2213.80	2.240	2.236	1.534	838	944.80	0.887	0.890	0.228
35 D03#03N	2213.80	2.195	2.192	1.563	815	944.80	0.863	0.866	0.215
36 D03#04N	2213.80	2.174	2.171	1.577	808	944.80	0.855	0.858	0.212
37 D03#05N	2213.80	2.130	2.127	1.606	854	944.80	0.904	0.907	0.236
38 D03#06N	2263.75	2.230	2.278	1.507	844	923.25	0.914	0.897	0.231
39 D03#07N	2263.75	2.113	2.158	1.586	799	923.25	0.865	0.849	0.207
40 D03#08N	2263.75	2.152	2.198	1.560	784	923.25	0.849	0.833	0.199
41 D03#09N	2263.75	2.144	2.190	1.565	811	923.25	0.878	0.861	0.213
42 D03#10N	2263.75	2.145	2.190	1.564	774	923.25	0.838	0.822	0.194
43 D04#01N									
44 D04#02N	2219.00	2.182	2.184	1.569	825	938.50	0.879	0.876	0.221
45 D04#03N	2219.00	1.915	1.917	1.744	841	938.50	0.896	0.893	0.229
46 D04#04N	2200.00	2.131	2.115	1.614	890	951.00	0.936	0.945	0.255
47 D04#05N	2200.00	2.182	2.166	1.581	830	951.00	0.873	0.882	0.223
48 D04#06N	2200.00	2.278	2.261	1.518	739	951.00	0.777	0.785	0.175
49 D04#07N	2200.00	2.162	2.146	1.594	857	951.00	0.901	0.910	0.238
50 D04#08N	2200.00	2.231	2.214	1.549	844	951.00	0.887	0.897	0.231
51 D04#09N	2200.00	2.176	2.160	1.584	794	951.00	0.835	0.843	0.204
52 D04#10N	2200.00	2.235	2.218	1.547	719	951.00	0.756	0.764	0.165
53 D04#11N	2213.80	2.110	2.107	1.619	884	944.80	0.936	0.939	0.252
54 D04#12N	2213.80	2.128	2.125	1.607	879	944.80	0.930	0.934	0.249

A.8

TABLE A.5. (contd)

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FLTF_DEN_H2O 193R x 49C											
Ø fix dry density	21 TARE	22 WET WT	23 DRY WT	24 % H2O	25 % VOL H2O	26 CORE #	27 CORE VOL	28 DENSITY WET CAN	29 DENSITY DRY CAN	30 DENSITY COUNTS	31 DENSITY DAILY STAND
1 D01#01N	72.150	416.56	372.08	0.15	0.20	2	219.18	1.57	1.37	4912	2189.50
2 D01#02N										4906	2189.50
3 D01#03N	70.870	417.29	375.80	0.14	0.19	2	219.18	1.58	1.39	4745	2189.50
4 D01#04N										4758	2189.50
5 D01#05N	70.850	417.01	378.38	0.13	0.18	2	219.18	1.58	1.40	4889	2189.50
6 D01#06N										4973	2189.50
7 D01#07N	69.070	424.84	381.44	0.14	0.20	2	219.18	1.62	1.43	4847	2189.50
8 D01#08N										4864	2181.00
9 D01#09N	71.900	401.20	366.59	0.12	0.16	2	219.18	1.50	1.34	4919	2181.00
10 D01#10N										4897	2181.00
11 D01#11N	70.170	408.18	366.35	0.14	0.19	2	219.18	1.54	1.35	4821	2181.00
12 D01#12N										4864	2181.00
13 D01#13N	71.060	412.82	372.52	0.13	0.18	2	219.18	1.56	1.38	4844	2181.00
14 D01#14N										4892	2181.00
15 D01#15N	71.750	414.28	374.86	0.13	0.18	2	219.18	1.56	1.38	4806	2181.00
16 D01#16N											
17 D02#01N	70.080	406.19	369.77	0.12	0.17	2	219.18	1.53	1.37	4816	2189.50
18 D02#02N										4888	2189.50
19 D02#03N	70.780	396.41	358.95	0.13	0.17	2	219.18	1.49	1.31	4870	2189.50
20 D02#04N										4991	2189.50
21 D02#05N	70.560	415.84	379.65	0.12	0.17	2	219.18	1.58	1.41	4820	2181.00
22 D02#06N										4894	2181.00
23 D02#07N	71.240	413.84	376.48	0.12	0.17	2	219.18	1.56	1.39	5217	2181.00
24 D02#08N										4964	2181.00
25 D02#09N	70.840	419.54	378.01	0.14	0.19	2	219.18	1.59	1.40	4948	2181.00
26 D02#10N										4925	2181.00
27 D02#11N	72.330	431.30	390.67	0.13	0.19	2	219.18	1.64	1.45	4729	2181.00
28 D02#12N										4876	2181.00
29 D02#13N	69.730	407.15	368.29	0.13	0.18	2	219.18	1.54	1.36	5002	2181.00
30 D02#14N										4780	2181.00
31 D02#15N	69.830	409.22	371.96	0.12	0.17	2	219.18	1.55	1.38	4882	2181.00
32 D02#16N											
33 D03#01N	71.650	432.81	381.79	0.16	0.23	2	219.18	1.65	1.42	4735	2213.80
34 D03#02N										4752	2213.80
35 D03#03N										4767	2213.80
36 D03#04N	70.680	435.82	386.44	0.16	0.23	2	219.18	1.67	1.44	4799	2213.80
37 D03#05N										4857	2263.75
38 D03#06N	70.330	399.04	354.80	0.16	0.20	2	219.18	1.50	1.30	4942	2263.75
39 D03#07N										4962	2263.75
40 D03#08N	70.230	410.19	368.24	0.14	0.19	2	219.18	1.55	1.36	4753	2263.75
41 D03#09N										4807	2263.75
42 D03#10N	71.120	409.60	368.36	0.14	0.19	2	219.18	1.54	1.36		
43 D04#01N											
44 D04#02N	69.890	410.77	370.83	0.13	0.19	1	211.94	1.61	1.42	4805	2219.00
45 D04#03N										4903	2219.00
46 D04#04N	71.160	430.47	387.68	0.14	0.20	1	211.94	1.70	1.49	4619	2200.00
47 D04#05N										4984	2200.00
48 D04#06N	70.400	407.82	367.98	0.14	0.19	1	211.94	1.56	1.38	4713	2200.00
49 D04#07N										4817	2200.00
50 D04#08N	70.900	395.70	348.56	0.17	0.22	1	211.94	1.53	1.31	4916	2200.00
51 D04#09N										5014	2200.00
52 D04#10N	70.420	388.81	355.01	0.12	0.16	1	211.94	1.50	1.34	4726	2213.80
53 D04#11N										4777	2213.80
54 D04#12N	70.600	403.11	363.21	0.14	0.19	1	211.94	1.57	1.38		

TABLE A.5. (contd)

FLT_FEN_H20 193R x 49C

0 fix dry density	32 CR DEN DAILY	33 CR DEN MEAN	34 COL34*- +3.003	35 MOISTURE COUNTS	36 MOISTURE DAILY STND	37 CR H2O DAILY	38 CR H2O MEAN	39 col 37*- -.2145	40 H2O % A GRAB
1 D01#01N	2.243	2.216	1.548	853	938.50	0.909	0.906	0.235	0.14
2 D01#02N	2.241	2.213	1.549	867	938.50	0.913	0.910	0.238	0.15
3 D01#03N	2.167	2.140	1.597	823	938.50	0.877	0.874	0.220	0.14
4 D01#04N	2.173	2.146	1.593	847	938.50	0.903	0.900	0.232	0.13
5 D01#05N	2.233	2.205	1.555	829	938.50	0.883	0.881	0.223	0.13
6 D01#06N	2.271	2.243	1.530	791	938.50	0.843	0.840	0.203	0.14
7 D01#07N	2.214	2.186	1.567	816	938.50	0.869	0.867	0.216	0.13
8 D01#08N	2.230	2.194	1.562	781	940.50	0.830	0.830	0.197	0.13
9 D01#09N	2.265	2.219	1.546	781	940.50	0.830	0.830	0.197	0.13
10 D01#10N	2.245	2.209	1.562	748	940.50	0.795	0.795	0.180	0.13
11 D01#11N	2.210	2.175	1.575	809	940.50	0.859	0.859	0.212	0.13
12 D01#12N	2.230	2.194	1.562	773	940.50	0.822	0.821	0.193	0.11
13 D01#13N	2.221	2.185	1.568	783	940.50	0.833	0.832	0.199	0.13
14 D01#14N	2.221	2.185	1.568	783	940.50	0.833	0.832	0.199	0.13
15 D01#15N	2.243	2.207	1.554	679	940.50	0.722	0.721	0.144	0.12
16 D01#16N	2.204	2.168	1.579	758	940.50	0.805	0.805	0.185	0.12
17 D02#01N	2.200	2.172	1.576	779	938.50	0.830	0.828	0.196	0.14
18 D02#02N	2.232	2.205	1.555	761	938.50	0.811	0.808	0.187	0.14
19 D02#03N	2.224	2.197	1.560	778	938.50	0.829	0.828	0.196	0.12
20 D02#04N	2.280	2.251	1.524	789	938.50	0.841	0.838	0.202	0.13
21 D02#05N	2.210	2.174	1.576	769	940.50	0.818	0.817	0.191	0.13
22 D02#06N	2.244	2.208	1.553	815	940.50	0.867	0.866	0.216	0.14
23 D02#07N	2.276	2.239	1.532	773	940.50	0.822	0.821	0.193	0.12
24 D02#08N	2.392	2.363	1.457	760	940.50	0.808	0.807	0.186	0.11
25 D02#09N	2.269	2.232	1.537	806	940.50	0.867	0.866	0.211	0.13
26 D02#10N	2.258	2.222	1.544	780	940.50	0.829	0.829	0.197	0.15
27 D02#11N	2.168	2.133	1.602	793	940.50	0.843	0.842	0.204	0.14
28 D02#12N	2.230	2.199	1.558	784	940.50	0.834	0.833	0.199	0.13
29 D02#13N	2.293	2.256	1.521	766	940.50	0.814	0.814	0.180	0.13
30 D02#14N	2.192	2.156	1.587	760	940.50	0.808	0.807	0.186	0.12
31 D02#15N	2.238	2.202	1.557	749	940.50	0.796	0.796	0.181	0.10
32 D02#16N	2.139	2.136	1.600	925	944.80	0.979	0.983	0.273	0.17
33 D03#01N	2.147	2.144	1.595	863	944.80	0.913	0.917	0.241	0.16
34 D03#02N	2.153	2.150	1.591	814	944.80	0.862	0.865	0.215	0.13
35 D03#03N	2.168	2.165	1.581	885	944.80	0.937	0.940	0.252	0.16
36 D03#04N	2.146	2.191	1.564	812	923.25	0.880	0.883	0.214	0.15
37 D03#05N	2.183	2.229	1.539	823	923.25	0.891	0.874	0.220	0.15
38 D03#06N	2.192	2.238	1.533	793	923.25	0.859	0.842	0.204	0.16
39 D03#07N	2.100	2.144	1.595	828	923.25	0.897	0.880	0.222	0.15
40 D03#08N	2.123	2.168	1.579	790	923.25	0.856	0.839	0.202	0.13
41 D03#09N	2.165	2.167	1.579	849	938.50	0.905	0.902	0.233	0.12
42 D03#10N	2.210	2.212	1.550	809	938.50	0.862	0.859	0.212	0.15
43 D04#01N	2.100	2.084	1.635	866	951.00	0.911	0.920	0.242	0.14
44 D04#02N	2.265	2.248	1.526	799	951.00	0.840	0.849	0.207	0.16
45 D04#03N	2.142	2.126	1.607	810	951.00	0.887	0.860	0.213	0.15
46 D04#04N	2.190	2.173	1.576	844	951.00	0.896	0.897	0.231	0.16
47 D04#05N	2.235	2.218	1.547	862	951.00	0.875	0.905	0.235	0.14
48 D04#06N	2.279	2.262	1.517	763	951.00	0.802	0.884	0.224	0.13
49 D04#07N	2.135	2.132	1.603	874	944.80	0.925	0.928	0.247	0.15
50 D04#08N	2.155	2.155	1.588	821	944.80	0.869	0.872	0.219	0.16

TABLE A.5. (contd)

FLT_F_DEN_H20 193R x 49C

0 fix dry density	41 H2O % B GRAB	42 MEAN	43 LIFT HEIGHT	44 LIFT VOL CM3	45 WET LIFT WT GM	46 DRY LIFT WT GM	47 DENSITY SCALE	48 DENSITY CAN MEAN	49 DENSITY SEAMAN MEAN
1 D01#01N		0.14	4.80	150796	276000	241600	1.83	1.36	1.54
2 D01#02N		0.14	6.10	191637	293000	256038	1.53		1.56
3 D01#03N		0.15	5.50	172788	296000	257732	1.71	1.38	1.58
4 D01#04N		0.14	5.85	183783	285000	249760	1.55		1.58
5 D01#05N	0.16	0.14	11.50	361283	557000	487310	1.54	1.37	1.55
6 D01#06N	0.14	0.14	11.60	364425	545000	478665	1.50		1.54
7 D01#07N	0.13	0.13	14.00	439823	656000	579256	1.49	1.39	1.56
8 D01#08N	0.14	0.14	10.30	323584	475000	417690	1.47		1.56
9 D01#09N	0.12	0.12	11.65	365996	545000	403698	1.49	1.38	1.55
10 D01#10N	0.12	0.12	10.85	340863	506000	450698	1.48		1.56
11 D01#11N	0.12	0.12	10.15	318872	483000	429524	1.51	1.35	1.57
12 D01#12N	0.15	0.14	10.45	328296	498000	438245	1.52		1.56
13 D01#13N	0.12	0.12	11.20	351858	505000	452242	1.44	1.36	1.56
14 D01#14N	0.13	0.13	11.20	351858	508000	449473	1.44		1.55
15 D01#15N	0.13	0.12	11.30	355000	549000	488811	1.55	1.38	1.58
16 D01#16N	0.12	0.12	3.50	109956	165000	147196	1.50		1.60
17 D02#01N		0.50	6.50	204204	332000		1.63	1.38	1.55
18 D02#02N		0.25	6.25	196350	315000		1.60		1.54
19 D02#03N		0.10	6.10	160221	274000		1.71	1.31	1.55
20 D02#04N		0.12	6.65	208916	310000	271572	1.48		1.57
21 D02#05N	0.12	0.12	10.00	314159	475000	423011	1.51	1.39	1.53
22 D02#06N	0.13	0.13	9.50	298451	442000	390883	1.48		1.54
23 D02#07N	0.11	0.12	9.10	285885	460000	404630	1.61	1.39	1.50
24 D02#08N	0.12	0.12	11.90	373850	558000	499787	1.49		1.52
25 D02#09N	0.12	0.12	10.60	333009	499000	446451	1.50	1.36	1.53
26 D02#10N	0.13	0.13	11.00	345575	501000	443270	1.45		1.58
27 D02#11N	0.13	0.14	10.80	339292	511000	446713	1.51	1.44	1.58
28 D02#12N	0.14	0.14	10.10	317301	464000	406499	1.46		1.55
29 D02#13N	0.14	0.13	9.95	312588	480000	422913	1.54	1.40	1.57
30 D02#14N	0.13	0.13	10.05	315730	482000	426567	1.53		1.55
31 D02#15N	0.13	0.12	10.95	344004	501000	445693	1.46	1.36	1.55
32 D02#16N	0.13	0.13	11.25	353429	548000	484328	1.55		1.57
33 D03#01N	0.16	0.16	5.20	163363	320000	276852	1.96	1.39	1.57
34 D03#02N	0.17	0.17	5.30	166504	307000	262267	1.84		1.58
35 D03#03N	0.15	0.15	5.90	185354	295000	256995	1.59	1.43	1.58
36 D03#04N	0.13	0.13	7.15	224624	326000	288889	1.45		1.59
37 D03#05N	0.15	0.16	13.10	411549	637000	551176	1.55	1.33	1.54
38 D03#06N	0.15	0.15	13.35	419403	641000	555070	1.53		1.56
39 D03#07N	0.15	0.16	13.15	413119	621000	541455	1.50	1.36	1.55
40 D03#08N	0.13	0.14	12.00	376991	578000	505488	1.53		1.58
41 D03#09N	0.14	0.14	13.85	435111	645000	564156	1.48	1.35	1.57
42 D03#10N	0.13	0.13	10.95	344004	512000	452308	1.49		1.57
43 D04#01N	0.12	0.12	5.10	160221	308000	275718	1.92	1.39	1.65
44 D04#02N	0.12	0.12	5.80	182212	298000	266209	1.64		1.62
45 D04#03N	0.15	0.15	5.75	180642	298000	259349	1.65	1.47	1.58
46 D04#04N	0.14	0.14	7.60	238761	346000	304840	1.50		1.52
47 D04#05N	0.14	0.15	12.25	384845	576000	499986	1.49	1.39	1.60
48 D04#06N	0.14	0.14	12.55	394270	586000	511637	1.56		1.56
49 D04#07N	0.15	0.16	11.40	358142	558000	481823	1.49	1.31	1.57
50 D04#08N	0.16	0.15	11.65	365996	545000	473755	1.50		1.61
51 D04#09N	0.11	0.12	13.05	409978	614000	546801	1.48	1.33	1.53
52 D04#10N	0.10	0.11	12.90	405265	601000	540075	1.45		1.61
53 D04#11N	0.14	0.15	10.70	336150	489000	426048	1.44	1.38	1.60
54 D04#12N	0.14	0.15	12.20	383274	552000	479359	1.44		

TABLE A.5. (contd)

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FLT_FEN_H2O 193R x 49C

Ø fix dry density	1 DEPTHS	2 TARE grams	3 WET WT grams	4 DRY WT grams	5 % H2O	6 % VOL H2O	7 CORE #	8 CORE VOL cc	9 DENSITY WET CAN	10 DENSITY DRY CAN	11 DENSITY COUNTS
55 D04#13N	-19.80										4817
56 D04#14N	-4.20	70.98	393.38	356.92	0.13	0.17	1	211.94	1.521	1.349	4870
57 D05#01N	-149.85										
58 D05#02N	-143.65	295.55	652.68	607.04	0.15	0.21	2	219.18	1.629	1.421	4674
59 D05#03N	-137.55										
60 D05#04N	-132.00	299.75	646.61	603.61	0.14	0.20	2	219.18	1.583	1.386	4953
61 D05#05N	-122.50										4869
62 D05#06N	-108.85	69.37	405.32	366.59	0.13	0.18	2	219.18	1.533	1.356	4800
63 D05#07N	-95.25										4854
64 D05#08N	-81.95	70.32	376.90	344.36	0.12	0.15	2	219.18	1.399	1.250	4914
65 D05#09N	-68.90										4886
66 D05#10N	-57.05	70.49	402.88	372.18	0.10	0.14	2	219.18	1.517	1.376	4833
67 D05#11N	-42.65										4893
68 D05#12N	-29.90	69.16	421.46	385.12	0.12	0.17	2	219.18	1.607	1.442	4771
69 D05#13N	-16.45										4988
70 D05#14N	-4.95	72.19	443.24	394.82	0.15	0.22	2	219.18	1.693	1.472	4809
71 D06#01N	-99.45										
72 D06#02N	-93.20	72.65	392.40	355.22	0.13	0.18	1	211.94	1.509	1.333	4774
73 D06#03N	-86.80										4781
74 D06#04N	-80.20	69.37	412.98	367.98	0.15	0.21	1	211.94	1.621	1.409	4728
75 D06#05N	-66.30										4901
76 D06#06N	-52.35	71.22	389.15	350.68	0.14	0.18	1	211.94	1.500	1.319	4840
77 D06#07N	-38.60										4897
78 D06#08N	-24.95	77.59	382.30	348.58	0.12	0.16	1	211.94	1.438	1.279	4854
79 D06#09N	-12.15										4743
80 D06#10N	-4.95	70.64	390.67	353.83	0.13	0.17	1	211.94	1.510	1.336	4890
81 D07#01N	-149.80										
82 D07#02N	-142.80	73.32	419.11	374.37	0.15	0.20	2	219.18	1.578	1.374	4722
83 D07#03N	-136.25										4814
84 D07#04N	-130.35	70.73	429.37	385.44	0.14	0.20	2	219.18	1.636	1.436	4776
85 D07#05N	-117.45										4820
86 D07#06N	-103.75	71.24	423.09	382.24	0.13	0.19	2	219.18	1.605	1.419	4848
87 D07#07N	-91.40										4849
88 D07#08N	-78.90	71.22	434.47	388.13	0.15	0.21	2	219.18	1.657	1.446	4850
89 D07#09N	-65.80										4852
90 D07#10N	-52.05	71.61	415.53	376.06	0.13	0.18	2	219.18	1.569	1.389	4862
91 D07#11N	-40.40										4704
92 D07#12N	-28.55	73.07	415.03	368.79	0.16	0.21	2	219.18	1.560	1.349	4878
93 D07#13N	-16.65										4773
94 D07#14N	-5.15	69.23	437.52	384.45	0.17	0.24	2	219.18	1.680	1.438	4664
95 D08#01N	-151.55										
96 D08#02N	-147.10	69.41	409.76	371.88	0.13	0.18	1	211.94	1.606	1.427	4901
97 D08#03N	-142.30										5035
98 D08#04N	-137.55	70.27	394.39	361.26	0.11	0.16	1	211.94	1.529	1.373	4938
99 D08#05N	-126.25										5028
100 D08#06N	-114.60	71.86	402.39	365.07	0.13	0.18	1	211.94	1.560	1.383	4913
101 D08#07N	-104.25										4940
102 D08#08N	-92.25	70.72	393.56	359.56	0.12	0.16	1	211.94	1.523	1.363	4945
103 D08#09N	-79.50										4891
104 D08#10N	-67.20	71.64	408.49	370.66	0.13	0.18	1	211.94	1.592	1.414	4942
105 D08#11N	-56.25										4856
106 D08#12N	-44.30	69.91	389.57	358.15	0.11	0.15	1	211.94	1.508	1.360	5067
107 D08#13N	-32.05										4762
108 D08#14N	-20.45	68.83	389.04	351.45	0.13	0.18	1	211.94	1.511	1.333	4953

TABLE A.5. (contd)

FLTF_DEN_H2O 193R x 49C		14-FEB-89 10:41 Page 7									
Ø fix dry density	12 DENSITY DAILY STAND	13 CR DEN DAILY	14 CR DEN MEAN	15 COL14*-6508 +3.003	16 MOISTURE COUNTS	17 MOISTURE DAILY STAND	18 CR H2O DAILY	19 CR H2O MEAN	20 col18*.4966 -2146		
55 D04#13N	2213.80	2.176	2.173	1.576	832	944.80	0.881	0.884	0.224		
56 D04#14N	2213.80	2.200	2.197	1.560	794	944.80	0.840	0.843	0.204		
57 D05#01N											
58 D05#02N	2181.00	2.143	2.108	1.618	854	940.50	0.908	0.907	0.236		
59 D05#03N	2181.00										
60 D05#04N	2181.00	2.271	2.234	1.536	819	940.50	0.871	0.870	0.218		
61 D05#05N	2181.00	2.232	2.196	1.560	819	940.50	0.871	0.870	0.218		
62 D05#06N	2259.25	2.125	2.165	1.581	788	926.75	0.848	0.835	0.200		
63 D05#07N	2259.25	2.149	2.190	1.565	782	926.75	0.844	0.831	0.198		
64 D05#08N	2259.25	2.175	2.217	1.547	782	926.75	0.822	0.809	0.187		
65 D05#09N	2259.25	2.163	2.204	1.555	721	926.75	0.778	0.766	0.166		
66 D05#10N	2259.25	2.139	2.180	1.571	755	926.75	0.815	0.802	0.184		
67 D05#11N	2259.25	2.168	2.207	1.553	840	926.75	0.908	0.892	0.229		
68 D05#12N	2259.25	2.112	2.152	1.589	775	926.75	0.836	0.823	0.194		
69 D05#13N	2219.60	2.247	2.250	1.525	694	954.00	0.727	0.737	0.152		
70 D05#14N	2219.60	2.167	2.169	1.578	859	954.00	0.900	0.912	0.239		
71 D06#01N											
72 D06#02N	2263.75	2.109	2.153	1.589	817	923.25	0.885	0.868	0.216		
73 D06#03N	2263.75	2.112	2.167	1.587	865	923.25	0.937	0.919	0.242		
74 D06#04N	2263.75	2.089	2.133	1.602	893	923.25	0.949	0.949	0.267		
75 D06#05N	2263.75	2.165	2.211	1.551	835	923.25	0.904	0.887	0.226		
76 D06#06N	2263.75	2.182	2.228	1.539	819	923.25	0.887	0.870	0.218		
77 D06#07N	2263.75	2.123	2.168	1.579	830	923.25	0.899	0.882	0.223		
78 D06#08N	2263.75	2.144	2.190	1.565	795	923.25	0.861	0.845	0.205		
79 D06#09N	2263.75	2.095	2.139	1.598	747	923.25	0.809	0.794	0.180		
80 D06#10N	2263.75	2.168	2.206	1.554	771	923.25	0.835	0.819	0.192		
81 D07#01N											
82 D07#02N	2219.60	2.127	2.130	1.554	864	954.00	0.906	0.918	0.241		
83 D07#03N	2219.60	2.169	2.172	1.577	869	954.00	0.911	0.923	0.244		
84 D07#04N	2219.60	2.152	2.154	1.588	852	954.00	0.893	0.905	0.235		
85 D07#05N	2219.60	2.172	2.174	1.575	810	954.00	0.849	0.860	0.213		
86 D07#06N	2219.60	2.184	2.187	1.567	777	954.00	0.814	0.825	0.195		
87 D07#07N	2219.60	2.185	2.187	1.566	763	954.00	0.789	0.800	0.183		
88 D07#08N	2200.00	2.205	2.188	1.566	837	951.00	0.880	0.889	0.227		
89 D07#09N	2200.00	2.205	2.189	1.565	837	951.00	0.880	0.889	0.227		
90 D07#10N	2200.00	2.210	2.193	1.563	801	951.00	0.842	0.851	0.208		
91 D07#11N	2200.00	2.138	2.122	1.609	831	951.00	0.874	0.883	0.224		
92 D07#12N	2200.00	2.217	2.200	1.558	870	951.00	0.915	0.924	0.244		
93 D07#13N	2200.00	2.170	2.153	1.589	799	951.00	0.849	0.849	0.207		
94 D07#14N	2200.00	2.120	2.104	1.621	894	951.00	0.940	0.950	0.257		
95 D08#01N											
96 D08#02N	2189.50	2.238	2.211	1.551	764	938.50	0.814	0.812	0.189		
97 D08#03N	2189.50	2.300	2.271	1.511	773	938.50	0.824	0.821	0.193		
98 D08#04N	2189.50	2.255	2.227	1.540	781	938.50	0.832	0.830	0.197		
99 D08#05N	2189.50	2.296	2.268	1.513	753	938.50	0.802	0.800	0.183		
100 D08#06N	2189.50	2.244	2.216	1.547	771	938.50	0.822	0.819	0.192		
101 D08#07N	2189.50	2.256	2.228	1.539	801	938.50	0.853	0.851	0.208		
102 D08#08N	2189.50	2.259	2.231	1.538	726	938.50	0.774	0.771	0.168		
103 D08#09N	2181.00	2.243	2.206	1.554	745	940.50	0.792	0.791	0.179		
104 D08#10N	2181.00	2.266	2.229	1.539	748	940.50	0.795	0.795	0.180		
105 D08#11N	2181.00	2.227	2.190	1.564	753	940.50	0.801	0.800	0.183		
106 D08#12N	2181.00	2.323	2.286	1.502	708	940.50	0.752	0.752	0.159		
107 D08#13N	2181.00	2.183	2.148	1.592	826	940.50	0.878	0.877	0.221		
108 D08#14N	2181.00	2.271	2.234	1.536	740	940.50	0.787	0.786	0.176		

TABLE A.5. (contd)

FLTF_DEN_H2O 193R x 49C

0 fix dry density	21 TARE	22 WET WT	23 DRY WT	24 % H2O	25 % VOL H2O	26 CORE #	27 CORE VOL	28 DENSITY WET CAN	29 DENSITY DRY CAN	30 DENSITY COUNTS	31 DENSITY DAILY STAND
55 D04#13N	71.720	399.67	355.39	0.16	0.21	1	211.94	1.55	1.34	4647	2213.80
56 D04#14N	71.720	399.67	355.39	0.16	0.21	1	211.94	1.55	1.34	4832	2213.80
57 D05#01N	101.090	481.14	427.67	0.16	0.24	2	219.18	1.73	1.49	4682	2181.00
58 D05#02N	101.090	481.14	427.67	0.16	0.24	2	219.18	1.73	1.49	4757	2181.00
59 D05#03N	104.360	440.35	399.08	0.14	0.19	2	219.18	1.53	1.34	4906	2181.00
60 D05#04N	104.360	440.35	399.08	0.14	0.19	2	219.18	1.53	1.34	4870	2259.25
61 D05#05N	74.420	411.81	369.43	0.14	0.19	2	219.18	1.54	1.35	4777	2259.25
62 D05#06N	74.420	411.81	369.43	0.14	0.19	2	219.18	1.54	1.35	4966	2259.25
63 D05#07N	70.140	401.60	366.05	0.12	0.16	2	219.18	1.51	1.35	4901	2259.25
64 D05#08N	70.140	401.60	366.05	0.12	0.16	2	219.18	1.51	1.35	4802	2259.25
65 D05#09N	69.230	402.22	368.68	0.11	0.15	2	219.18	1.52	1.37	4667	2259.25
66 D05#10N	69.230	402.22	368.68	0.11	0.15	2	219.18	1.52	1.37	4739	2259.25
67 D05#11N	69.870	434.76	388.26	0.15	0.21	2	219.18	1.66	1.45	4903	2219.60
68 D05#12N	69.870	434.76	388.26	0.15	0.21	2	219.18	1.66	1.45	4744	2219.60
69 D05#13N	71.550	440.35	391.68	0.15	0.22	2	219.18	1.68	1.46	4872	2263.75
70 D05#14N	71.550	440.35	391.68	0.15	0.22	2	219.18	1.68	1.46	4661	2263.75
71 D06#01N	77.690	410.69	374.41	0.12	0.17	1	211.94	1.57	1.40	4549	2263.75
72 D06#02N	77.690	410.69	374.41	0.12	0.17	1	211.94	1.57	1.40	4738	2263.75
73 D06#03N	74.400	440.69	390.79	0.16	0.24	1	211.94	1.73	1.49	4814	2263.75
74 D06#04N	74.400	440.69	390.79	0.16	0.24	1	211.94	1.73	1.49	4653	2263.75
75 D06#05N	71.070	397.45	360.17	0.13	0.18	1	211.94	1.54	1.36	4831	2263.75
76 D06#06N	71.070	397.45	360.17	0.13	0.18	1	211.94	1.54	1.36	4744	2263.75
77 D06#07N	69.863	400.26	366.78	0.11	0.16	1	211.94	1.56	1.40	4723	2263.75
78 D06#08N	69.863	400.26	366.78	0.11	0.16	1	211.94	1.56	1.40	4697	2219.60
79 D06#09N	72.310	395.36	362.79	0.11	0.15	1	211.94	1.52	1.37	4767	2219.60
80 D06#10N	71.770	428.93	384.66	0.14	0.20	2	219.18	1.63	1.43	4671	2219.60
81 D07#01N	69.870	427.25	381.64	0.15	0.21	2	219.18	1.63	1.42	4758	2219.60
82 D07#02N	69.870	427.25	381.64	0.15	0.21	2	219.18	1.63	1.42	4688	2219.60
83 D07#03N	71.700	434.99	390.22	0.14	0.20	2	219.18	1.66	1.45	4731	2219.60
84 D07#04N	67.890	408.86	367.98	0.14	0.19	2	219.18	1.56	1.37	4926	2200.00
85 D07#05N	67.890	408.86	367.98	0.14	0.19	2	219.18	1.56	1.37	4881	2200.00
86 D07#06N	71.460	424.08	379.89	0.14	0.20	2	219.18	1.61	1.41	4833	2200.00
87 D07#07N	69.310	414.47	366.88	0.16	0.22	2	219.18	1.57	1.36	4922	2200.00
88 D07#08N	69.310	414.47	366.88	0.16	0.22	2	219.18	1.57	1.36	4835	2200.00
89 D07#09N	69.100	436.99	384.39	0.17	0.24	2	219.18	1.68	1.44	4749	2200.00
90 D07#10N	70.660	405.11	366.42	0.13	0.18	1	211.94	1.58	1.40	4660	2200.00
91 D07#11N	72.310	409.18	370.07	0.13	0.18	1	211.94	1.59	1.40	5048	2189.50
92 D07#12N	70.780	398.56	361.87	0.13	0.17	1	211.94	1.55	1.37	4778	2189.50
93 D07#13N	70.690	395.29	355.94	0.14	0.19	1	211.94	1.53	1.35	5041	2189.50
94 D07#14N	71.590	394.91	358.19	0.14	0.18	1	211.94	1.53	1.34	4897	2189.50
95 D08#01N	70.740	418.63	373.55	0.15	0.21	1	211.94	1.64	1.43	4861	2189.50
96 D08#02N	71.570	417.07	376.57	0.13	0.18	1	211.94	1.63	1.45	4973	2189.50
97 D08#03N	70.690	395.29	355.94	0.14	0.19	1	211.94	1.53	1.35	4885	2181.00
98 D08#04N	70.690	395.29	355.94	0.14	0.19	1	211.94	1.53	1.35	5023	2181.00
99 D08#05N	71.590	394.91	358.19	0.14	0.18	1	211.94	1.53	1.34	4872	2181.00
100 D08#06N	70.740	418.63	373.55	0.15	0.21	1	211.94	1.64	1.43	4793	2181.00
101 D08#07N	71.570	417.07	376.57	0.13	0.18	1	211.94	1.63	1.45	4852	2181.00
102 D08#08N	70.690	395.29	355.94	0.14	0.19	1	211.94	1.53	1.35	4969	2181.00
103 D08#09N	71.590	394.91	358.19	0.14	0.18	1	211.94	1.53	1.34		
104 D08#10N	70.740	418.63	373.55	0.15	0.21	1	211.94	1.64	1.43		
105 D08#11N	71.570	417.07	376.57	0.13	0.18	1	211.94	1.63	1.45		
106 D08#12N	70.690	395.29	355.94	0.14	0.19	1	211.94	1.53	1.35		
107 D08#13N	71.590	394.91	358.19	0.14	0.18	1	211.94	1.53	1.34		
108 D08#14N	70.740	418.63	373.55	0.15	0.21	1	211.94	1.64	1.43		

TABLE A.5. (contd)

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FLT_DEN_H20 193R x 49C

Ø fix dry density	32 CR DEN DAILY	33 CR DEN MEAN	34 COL34+-.6568 +3.003	35 MOISTURE COUNTS	36 MOISTURE DAILY STND	37 CR H2O DAILY	38 CR H2O MEAN	39 col 37*.4966 -.2145	40 H2O % A GRAB
55 D04#13N	2.099	2.096	1.626	885	944.80	0.937	0.940	0.252	0.14
56 D04#14N	2.183	2.180	1.571	834	944.80	0.883	0.886	0.225	0.13
57 D05#01N									0.15
58 D05#02N	2.147	2.112	1.616	846	940.50	0.900	0.899	0.232	0.15
59 D05#03N					940.50				0.15
60 D05#04N	2.181	2.146	1.594	831	940.50	0.884	0.883	0.224	0.13
61 D05#05N	2.249	2.213	1.549	824	940.50	0.876	0.875	0.220	1.20
62 D05#06N	2.156	2.197	1.560	814	926.75	0.878	0.865	0.215	0.14
63 D05#07N	2.114	2.155	1.588	810	926.75	0.874	0.860	0.213	0.15
64 D05#08N	2.198	2.240	1.532	737	926.75	0.795	0.783	0.174	0.11
65 D05#09N	2.169	2.211	1.551	774	926.75	0.835	0.822	0.194	0.14
66 D05#10N	2.125	2.168	1.580	743	926.75	0.802	0.789	0.177	0.11
67 D05#11N	2.066	2.105	1.620	850	926.75	0.917	0.903	0.234	0.14
68 D05#12N	2.098	2.138	1.599	879	926.75	0.948	0.934	0.249	0.15
69 D05#13N	2.209	2.212	1.560	729	954.00	0.764	0.774	0.170	0.08
70 D05#14N	2.137	2.140	1.597	858	954.00	0.899	0.911	0.238	0.14
71 D06#01N									0.13
72 D06#02N	2.152	2.198	1.560	795	923.25	0.861	0.845	0.205	0.10
73 D06#03N	2.059	2.103	1.622	871	923.25	0.943	0.925	0.245	0.16
74 D06#04N	2.009	2.052	1.655	913	923.25	0.989	0.970	0.267	0.14
75 D06#05N	2.093	2.137	1.595	882	923.25	0.965	0.937	0.251	0.14
76 D06#06N	2.127	2.172	1.577	799	923.25	0.865	0.849	0.207	0.14
77 D06#07N	2.055	2.099	1.624	864	923.25	0.938	0.918	0.241	0.14
78 D06#08N	2.134	2.179	1.572	752	923.25	0.815	0.799	0.182	0.14
79 D06#09N	2.096	2.140	1.597	797	923.25	0.863	0.847	0.206	0.11
80 D06#10N	2.086	2.130	1.604	752	923.25	0.815	0.799	0.182	0.12
81 D07#01N									0.11
82 D07#02N	2.116	2.130	1.604	864	954.00	0.906	0.918	0.241	0.17
83 D07#03N	2.148	2.119	1.611	864	954.00	0.908	0.918	0.241	0.15
84 D07#04N	2.104	2.107	1.591	804	954.00	0.917	0.929	0.247	0.14
85 D07#05N	2.144	2.146	1.619	864	954.00	0.906	0.918	0.241	0.14
86 D07#06N	2.112	2.115	1.593	864	954.00	0.906	0.918	0.241	0.13
87 D07#07N	2.131	2.134	1.614	863	954.00	0.905	0.917	0.241	0.13
88 D07#08N	2.239	2.222	1.601	826	954.00	0.866	0.877	0.221	0.11
89 D07#09N	2.219	2.202	1.544	817	951.00	0.859	0.868	0.216	0.15
90 D07#10N	2.197	2.219	1.567	826	951.00	0.869	0.877	0.221	0.13
91 D07#11N	2.237	2.220	1.571	826	951.00	0.869	0.877	0.221	0.13
92 D07#12N	2.198	2.181	1.545	838	951.00	0.879	0.888	0.227	0.19
93 D07#13N	2.159	2.142	1.571	869	951.00	0.903	0.912	0.239	0.15
94 D07#14N	2.118	2.102	1.596	813	951.00	0.855	0.864	0.214	0.14
95 D08#01N									0.15
96 D08#02N	2.308	2.277	1.622	887	951.00	0.933	0.942	0.253	0.11
97 D08#03N	2.213	2.186	1.507	765	938.50	0.815	0.813	0.189	0.12
98 D08#04N	2.182	2.155	1.567	811	938.50	0.864	0.861	0.213	0.11
99 D08#05N	2.302	2.274	1.587	805	938.50	0.858	0.855	0.210	0.11
100 D08#06N	2.237	2.209	1.509	811	938.50	0.864	0.861	0.213	0.16
101 D08#07N	2.220	2.237	1.552	781	938.50	0.832	0.830	0.197	0.12
102 D08#08N	2.271	2.243	1.563	763	938.50	0.802	0.800	0.183	0.11
103 D08#09N	2.240	2.243	1.530	770	938.50	0.820	0.818	0.192	0.12
104 D08#10N	2.303	2.266	1.556	755	940.50	0.803	0.802	0.184	0.11
105 D08#11N	2.234	2.198	1.515	785	940.50	0.835	0.834	0.200	0.15
106 D08#12N	2.198	2.162	1.560	782	940.50	0.831	0.831	0.198	0.13
107 D08#13N	2.225	2.189	1.583	812	940.50	0.863	0.863	0.214	0.13
108 D08#14N	2.276	2.241	1.565	772	940.50	0.821	0.820	0.193	0.14
			1.531	785	940.50	0.835	0.834	0.200	0.13

TABLE A.5. (contd)

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FLT_FEN_H2O 193R x 49C

0 fix dry density	41 H2O % B GRAB	42 MEAN	43 LIFT HEIGHT	44 LIFT VOL CM3	45 WET LIFT WT GM	46 DRY LIFT WT GM	47 DENSITY SCALE	48 DENSITY CAN MEAN	49 DENSITY SEAMAN MEAN
55 D04#13N	0.15	0.14	14.25	447677	684000	580150	1.48	1.34	1.60
56 D04#14N	0.14	0.14	15.60	490088	699000	614767	1.43	1.34	1.57
57 D05#01N	0.15	0.15	4.60	144513	266000	232153	1.84	1.48	1.62
58 D05#02N	0.15	0.15	6.20	194779	304000	263696	1.66	1.48	1.62
59 D05#03N	0.15	0.15	6.10	191637	319000	278426	1.66	1.37	1.56
60 D05#04N	0.13	0.13	5.55	174358	303000	268600	1.74	1.37	1.56
61 D05#05N	0.15	0.15	9.50	298451	470000	280896	1.57	1.35	1.55
62 D05#06N	0.15	0.15	13.65	428827	620000	541159	1.45	1.35	1.57
63 D05#07N	0.12	0.12	13.60	427257	629000	554095	1.47	1.30	1.58
64 D05#08N	0.13	0.12	13.30	417832	619000	550960	1.48	1.30	1.54
65 D05#09N	0.11	0.12	13.05	409378	625000	556063	1.52	1.37	1.55
66 D05#10N	0.12	0.11	11.85	372279	567000	500129	1.50	1.37	1.58
67 D05#11N	0.15	0.15	14.40	452389	676000	590392	1.49	1.45	1.59
68 D05#12N	0.15	0.15	12.75	400553	609000	530364	1.52	1.45	1.59
69 D05#13N	0.08	0.08	13.45	422544	629000	579750	1.49	1.47	1.54
70 D05#14N	0.15	0.15	11.50	361283	553000	481257	1.53	1.47	1.59
71 D06#01N	0.13	0.13	5.55	174358	295000	260194	1.69	1.37	1.57
72 D06#02N	0.10	0.10	6.25	196350	309000	281218	1.57	1.37	1.57
73 D06#03N	0.16	0.16	6.40	201062	332000	287288	1.65	1.45	1.60
74 D06#04N	0.15	0.15	6.60	207345	309000	268930	1.49	1.45	1.63
75 D06#05N	0.19	0.16	13.90	436081	679000	584447	1.55	1.34	1.58
76 D06#06N	0.14	0.14	13.95	438252	684000	580720	1.52	1.34	1.58
77 D06#07N	0.14	0.14	13.75	431969	667000	584925	1.54	1.34	1.60
78 D06#08N	0.12	0.13	13.65	428827	628000	554673	1.46	1.34	1.57
79 D06#09N	0.15	0.13	12.80	402124	616000	545687	1.53	1.35	1.60
80 D06#10N	0.12	0.12	7.20	226195	298000	266492	1.32	1.35	1.58
81 D07#01N	0.11	0.11	5.20	163363	312000	280800	1.91	1.40	1.58
82 D07#02N	0.17	0.17	7.00	219911	348000	296337	1.58	1.40	1.61
83 D07#03N	0.15	0.15	6.55	205774	329000	285583	1.60	1.43	1.58
84 D07#04N	0.14	0.14	5.90	185354	305000	267593	1.65	1.43	1.60
85 D07#05N	0.14	0.14	12.90	405265	608000	534021	1.50	1.44	1.58
86 D07#06N	0.13	0.13	13.70	430398	647000	574510	1.50	1.44	1.59
87 D07#07N	0.12	0.12	12.35	387987	578000	517168	1.49	1.41	1.58
88 D07#08N	0.13	0.14	12.50	392699	578000	505061	1.47	1.41	1.55
89 D07#09N	0.14	0.14	13.10	411549	615000	540371	1.49	1.40	1.56
90 D07#10N	0.15	0.14	13.75	431969	640000	561420	1.48	1.40	1.57
91 D07#11N	0.09	0.14	11.65	365996	540000	473223	1.48	1.36	1.58
92 D07#12N	0.14	0.14	11.85	372279	557000	487465	1.50	1.36	1.56
93 D07#13N	0.13	0.13	11.90	373650	556000	490136	1.49	1.44	1.59
94 D07#14N	0.13	0.14	11.50	361283	570000	499601	1.58	1.44	1.62
95 D08#01N	0.11	0.11	3.45	103385	274000	246529	2.53	1.41	1.53
96 D08#02N	0.12	0.12	4.45	139801	232000	207139	1.66	1.41	1.53
97 D08#03N	0.11	0.11	4.80	150796	219000	198143	1.45	1.39	1.54
98 D08#04N	0.11	0.11	4.75	149226	220000	197492	1.47	1.39	1.56
99 D08#05N	0.14	0.15	11.30	355000	515000	448091	1.45	1.38	1.51
100 D08#06N	0.13	0.12	11.65	365996	539000	479238	1.47	1.38	1.55
101 D08#07N	0.12	0.11	10.35	325155	460000	412791	1.41	1.35	1.55
102 D08#08N	0.14	0.13	12.00	378991	540000	388312	1.43	1.35	1.53
103 D08#09N	0.12	0.12	12.75	400553	578000	518162	1.44	1.38	1.55
104 D08#10N	0.14	0.14	12.30	366416	561000	490755	1.45	1.38	1.53
105 D08#11N	0.13	0.13	10.95	344004	495000	436393	1.44	1.39	1.56
106 D08#12N	0.13	0.13	11.95	375420	550000	486820	1.47	1.39	1.54
107 D08#13N	0.14	0.14	12.25	384845	534000	468290	1.39	1.39	1.58
108 D08#14N	0.13	0.13	11.60	364425	523000	463531	1.44	1.39	1.53

TABLE A.5. (contd)

FLTF_DEN_H2O 193R x 49C

Ø fix dry density	1 DEPTHS	2 TARE grams	3 WET WT grams	4 DRY WT grams	5 % H2O	6 % VOL H2O	7 CORE #	8 CORE VOL cc	9 DENSITY WET CAN	10 DENSITY DRY CAN	11 DENSITY COUNTS
109 D08#15N	-8.30	70.06	392.43	357.08	0.12	0.17	1	211.94	1.521	1.354	4992
110 D09#01N	-143.60	101.18	454.89	406.82	0.16	0.23	1	211.94	1.669	1.442	4761
111 D09#02N	-137.40	300.02	636.12	592.30	0.15	0.21	1	211.94	1.586	1.379	4921
112 D09#03N	-131.85										5007
113 D09#04N	-121.35	154.90	478.55	437.10	0.15	0.20	1	211.94	1.527	1.332	4934
114 D09#05N	-106.15										4811
115 D09#06N	-100.70	313.73	657.76	614.60	0.14	0.20	1	211.94	1.623	1.420	5066
116 D09#07N	-89.35										4774
117 D09#08N	-76.60	70.29	402.93	358.72	0.15	0.21	1	211.94	1.570	1.361	4921
118 D09#09N	-64.45										5015
119 D09#10N	-51.90	70.21	391.44	355.68	0.13	0.17	1	211.94	1.516	1.347	4713
120 D09#11N	-37.60										4768
121 D09#12N	-25.25	69.40	384.06	346.14	0.14	0.18	1	211.94	1.485	1.306	
122 D09#13N	-10.55										
123 D09#14N	-5.00										
124 D10#01N	-150.60										4925
125 D10#02N	-144.90	71.53	416.16	378.27	0.12	0.17	2	219.18	1.572	1.399	4879
126 D10#03N	-140.05										4916
127 D10#04N	-135.25	69.38	406.27	367.85	0.13	0.18	2	219.18	1.537	1.362	4878
128 D10#05N	-126.15										4805
129 D10#06N	-111.80	76.42	409.49	376.85	0.11	0.15	2	219.18	1.520	1.371	4800
130 D10#07N	-97.65										4799
131 D10#08N	-84.45	67.89	424.53	376.15	0.16	0.22	2	219.18	1.627	1.406	4883
132 D10#09N	-70.65										4892
133 D10#10N	-58.70	69.35	409.44	373.81	0.12	0.16	2	219.18	1.552	1.389	4922
134 D10#11N	-44.60										5009
135 D10#12N	-30.90	71.79	398.18	369.99	0.09	0.13	2	219.18	1.489	1.361	4919
136 D10#13N	-18.45	72.30	429.33	382.57	0.15	0.21	2	219.18	1.629	1.416	4727
137 D10#14N	-4.50	70.78	425.65	380.80	0.14	0.20	2	219.18	1.619	1.414	
138 D11#01N	-148.90										4845
139 D11#02N	-142.70	71.85	417.01	373.97	0.14	0.20	2	219.18	1.575	1.378	4873
140 D11#03N	-136.25										4758
141 D11#04N	-130.80	70.48	417.50	377.63	0.13	0.18	2	219.18	1.593	1.401	4848
142 D11#05N	-117.75										4825
143 D11#06N	-105.25	73.31	419.82	377.38	0.14	0.19	2	219.18	1.581	1.387	4901
144 D11#07N	-92.40										4735
145 D11#08N	-78.70	70.73	420.87	378.05	0.14	0.20	2	219.18	1.597	1.402	4873
146 D11#09N	-67.45										4742
147 D11#10N	-54.00	70.10	414.41	380.01	0.11	0.16	2	219.18	1.571	1.414	4853
148 D11#11N	-42.30										4815
149 D11#12N	-29.75	70.24	420.56	377.55	0.14	0.20	2	219.18	1.598	1.402	4783
150 D11#13N	-16.25										4864
151 D11#14N	-4.90	70.55	402.90	366.55	0.12	0.17	2	219.18	1.516	1.350	
152 D12#01N	-150.40										4957
153 D12#02N	-143.85	69.04	386.33	344.90	0.15	0.20	1	211.94	1.497	1.302	4796
154 D12#03N	-137.05										4975
155 D12#04N	-131.15	70.36	387.09	352.41	0.12	0.16	1	211.94	1.494	1.331	4868
156 D12#05N	-118.05										4944
157 D12#06N	-103.90	77.67	397.26	365.49	0.11	0.15	1	211.94	1.508	1.358	4965
158 D12#07N	-88.15										4861
159 D12#08N	-74.85	68.96	389.56	358.41	0.11	0.15	1	211.94	1.513	1.366	4922
160 D12#09N	-62.40										5081
161 D12#10N	-49.80	71.39	374.11	345.63	0.10	0.13	1	211.94	1.428	1.294	
162 D12#11N	-36.35										

TABLE A.5. (contd)

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FLTF_DEN_H2O 193R x 49C													
Ø fix dry density	12 DENSITY DAILY STAND	13 CR DEN	14 CR DEN	15 COL14*-6568 +3.003	16 MOISTURE COUNTS	17 MOISTURE DAILY STND	18 CR H2O DAILY	19 CR H2O MEAN	20 col18*.4968 -2145				
		DAILY	MEAN										
109 D08#15N	2181.00	2.289	2.252	1.524	734	940.50	0.780	0.780	0.173				
110 D09#01N	2212.50			1.592	858			0.911	0.238				
111 D09#02N	2212.50	2.152	2.148	1.545	835			0.887	0.226				
112 D09#03N	2212.50	2.224	2.220	1.520	853			0.906	0.235				
113 D09#04N	2212.50	2.263	2.259	1.520	828			0.880	0.222				
114 D09#05N	2212.50	2.230	2.226	1.541	835			0.887	0.226				
115 D09#06N	2212.50	2.174	2.170	1.578	788			0.837	0.201				
116 D09#07N	2189.50	2.314	2.285	1.502	843	938.50	0.840	0.898	0.230				
117 D09#08N	2189.50	2.180	2.163	1.589	840	938.50	0.895	0.895	0.229				
118 D09#09N	2189.50	2.180	2.153	1.589	741	938.50	0.790	0.787	0.176				
119 D09#10N	2189.50	2.248	2.220	1.545	741	938.50	0.790	0.787	0.176				
120 D09#11N	2189.50	2.262	2.290	1.517	758	938.50	0.808	0.805	0.185				
121 D09#12N	2189.50	2.153	2.128	1.607	761	938.50	0.811	0.808	0.187				
122 D09#13N	2189.50	2.178	2.151	1.590									
123 D09#14N	2189.50												
124 D10#01N	2259.25	2.180	2.222	1.544	787	926.75	0.849	0.836	0.201				
125 D10#02N	2259.25	2.160	2.201	1.557	794	926.75	0.857	0.843	0.204				
126 D10#03N	2259.25	2.176	2.218	1.547	800	926.75	0.863	0.850	0.208				
127 D10#04N	2259.25	2.159	2.200	1.558	774	926.75	0.835	0.822	0.194				
128 D10#05N	2259.25	2.127	2.167	1.579	745	926.75	0.804	0.791	0.179				
129 D10#06N	2259.25		2.165	1.581	862		0.916	0.916	0.240				
130 D10#07N	2219.60	2.159	2.162	1.583	844	954.00	0.885	0.897	0.231				
131 D10#08N	2219.60	2.162	2.165	1.581	791	954.00	0.829	0.840	0.203				
132 D10#09N	2219.60	2.200	2.203	1.556	814	954.00	0.853	0.865	0.215				
133 D10#10N	2219.60	2.249	2.252	1.524	676	954.00	0.709	0.718	0.142				
134 D10#11N	2219.60	2.257	2.259	1.519	687	954.00	0.720	0.730	0.148				
135 D10#12N	2219.60	2.216	2.219	1.546	866	954.00	0.908	0.920	0.242				
136 D10#13N	2219.60	2.130	2.132	1.603	806	954.00	0.845	0.856	0.211				
137 D10#14N	2219.60												
138 D11#01N	2219.60	2.183	2.185	1.568	860	954.00	0.901	0.914	0.239				
139 D11#02N	2219.60	2.195	2.198	1.559	837	954.00	0.877	0.889	0.227				
140 D11#03N	2219.60	2.144	2.146	1.593	830	954.00	0.870	0.882	0.223				
141 D11#04N	2219.60	2.184	2.187	1.567	865	954.00	0.907	0.919	0.242				
142 D11#05N	2219.60	2.174	2.176	1.573	838	954.00	0.878	0.890	0.228				
143 D11#06N	2219.60	2.228	2.211	1.551	787	951.50	0.827	0.836	0.201				
144 D11#07N	2200.00	2.152	2.136	1.600	883	951.50	0.928	0.938	0.251				
145 D11#08N	2200.00	2.155	2.139	1.559	882	951.50	0.927	0.937	0.251				
146 D11#09N	2200.00	2.215	2.198	1.598	780	951.50	0.820	0.829	0.197				
147 D11#10N	2200.00	2.155	2.139	1.565	799	951.50	0.840	0.849	0.207				
148 D11#11N	2200.00	2.206	2.189	1.576	819	951.50	0.861	0.870	0.218				
149 D11#12N	2200.00	2.189	2.172	1.566	860	951.50	0.904	0.914	0.239				
150 D11#13N	2200.00	2.174	2.158	1.586	860	951.50	0.904	0.914	0.239				
151 D11#14N	2200.00	2.211	2.194	1.562	774	951.50	0.813	0.822	0.194				
152 D12#01N	2259.25	2.194	2.236	1.534	857	926.75	0.925	0.910	0.238				
153 D12#02N	2259.25	2.123	2.163	1.582	846	926.75	0.913	0.899	0.232				
154 D12#03N	2259.25	2.202	2.244	1.529	800	926.75	0.863	0.850	0.208				
155 D12#04N	2259.25	2.154	2.195	1.561	758	926.75	0.816	0.805	0.185				
156 D12#05N	2259.25	2.156	2.197	1.560	766	926.75	0.760	0.748	0.157				
157 D12#06N	2259.25	2.188	2.230	1.538	784	926.75	0.784	0.772	0.169				
158 D12#07N	2259.25	2.198	2.240	1.532	727	926.75	0.756	0.745	0.155				
159 D12#08N	2259.25	2.162	2.193	1.563	701	926.75	0.771	0.782	0.174				
160 D12#09N	2219.60	2.218	2.220	1.545	736	954.00	0.872	0.884	0.224				
161 D12#10N	2219.60	2.289	2.292	1.498	832	954.00							
162 D12#11N	2219.60												

TABLE A.5. (contd)

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FLTF_DEN_H2O 193R x 49C											
Ø fix dry density	21 TARE	22 WET WT	23 DRY WT	24 % H2O	25 % VOL H2O	26 CORE #	27 CORE VOL	28 DENSITY WET CAN	29 DENSITY DRY CAN	30 DENSITY COUNTS	31 DENSITY DAILY STAND
109 D08#15N	69.060	403.12	364.73	0.13	0.18	1	211.94	1.58	1.40	4840	2181.00
110 D09#01N	154.910	495.44	448.90	0.16	0.22	1	211.94	1.61	1.39		2212.50
111 D09#02N	103.650	443.07	396.80	0.16	0.22	1	211.94	1.60	1.38	4981	2212.50
112 D09#03N										4931	2212.50
113 D09#04N	103.650	443.07	396.80	0.16	0.22	1	211.94	1.60	1.38	4886	2212.50
114 D09#05N										4714	2212.50
115 D09#06N	107.360	454.32	407.89	0.15	0.22	1	211.94	1.64	1.42	4779	2212.50
116 D09#07N										4911	2189.50
117 D09#08N	72.280	390.07	353.04	0.13	0.17	1	211.94	1.50	1.32	4896	2189.50
118 D09#09N										4832	2189.50
119 D09#10N	70.480	394.60	358.59	0.12	0.17	1	211.94	1.53	1.36	4816	2189.50
120 D09#11N										4927	2189.50
121 D09#12N	70.680	379.77	341.87	0.14	0.18	1	211.94	1.46	1.28	5031	2189.50
122 D09#13N										4712	2189.50
123 D09#14N											
124 D10#01N											
125 D10#02N	71.140	435.96	392.24	0.14	0.20	2	219.18	1.68	1.47	4657	2259.25
126 D10#03N										4744	2259.25
127 D10#04N	71.420	424.09	382.78	0.13	0.19	2	219.18	1.61	1.42	4677	2259.25
128 D10#05N										4961	2259.25
129 D10#06N	70.920	415.10	376.48	0.13	0.18	2	219.18	1.57	1.39	4807	2259.25
130 D10#07N										4759	
131 D10#08N	71.500	430.35	383.38	0.15	0.21	2	219.18	1.64	1.42	4773	2219.60
132 D10#09N										4783	2219.60
133 D10#10N	70.510	384.41	369.10			2	219.18	1.43	1.36	4876	2219.60
134 D10#11N										4869	2219.60
135 D10#12N	71.080	396.84	365.77	0.11	0.14	2	219.18	1.49	1.34	4939	2219.60
136 D10#13N										4844	2219.60
137 D10#14N										4940	2219.60
138 D11#01N											
139 D11#02N	71.860	408.44	366.16	0.14	0.19	2	219.18	1.54	1.34	4905	2219.60
140 D11#03N										4919	2219.60
141 D11#04N	72.260	406.70	370.99	0.12	0.16	2	219.18	1.53	1.36	4873	2219.60
142 D11#05N										4885	2219.60
143 D11#06N	70.070	409.35	372.46	0.12	0.17	2	219.18	1.55	1.38	4860	2219.60
144 D11#07N										4774	2200.00
145 D11#08N	70.230	410.08	370.97	0.13	0.18	2	219.18	1.55	1.37	4830	2200.00
146 D11#09N										4919	2200.00
147 D11#10N	70.460	413.76	373.42	0.13	0.18	2	219.18	1.57	1.38	4892	2200.00
148 D11#11N										4828	2200.00
149 D11#12N	70.090	407.19	368.37	0.13	0.18	2	219.18	1.54	1.36	4799	2200.00
150 D11#13N										4930	2200.00
151 D11#14N	71.710	402.30	361.20	0.14	0.19	2	219.18	1.51	1.32	4935	2200.00
152 D12#01N											
153 D12#02N	70.270	410.22	364.41	0.16	0.22	1	211.94	1.60	1.39	4925	2259.25
154 D12#03N										4874	2259.25
155 D12#04N	69.770	400.27	358.53	0.14	0.20	1	211.94	1.56	1.36	4969	2259.25
156 D12#05N										4984	2259.25
157 D12#06N	69.950	407.42	370.26	0.12	0.18	1	211.94	1.59	1.42	4892	2259.25
158 D12#07N										4899	2259.25
159 D12#08N	70.620	398.68	365.13	0.11	0.16	1	211.94	1.55	1.39	4989	2259.25
160 D12#09N										2259.25	
161 D12#10N	70.230	387.38	356.44	0.11	0.15	1	211.94	1.50	1.35	4868	2219.60
162 D12#11N										4832	2219.60

TABLE A.5. (contd)

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FLT_FEN_H2O 193R x 49C

0 fix dry density	32 CR DEN DAILY	33 CR DEN MEAN	34 COL34*- +3.003	35 MOISTURE COUNTS	36 MOISTURE DAILY STND	37 CR H2O DAILY	38 CR H2O MEAN	39 col 37*- -.2145	40 H2O % A GRAB
109 D08#15N	2.219	2.183	1.569	781	940.50	0.830	0.830	0.197	0.12
110 D09#01N									0.15
111 D09#02N	2.251	2.247	1.527	860			0.914	0.239	0.14
112 D09#03N	2.229	2.224	1.542	830			0.882	0.223	0.16
113 D09#04N	2.208	2.204	1.555	848			0.901	0.233	0.15
114 D09#05N	2.131	2.126	1.606	879			0.934	0.249	0.16
115 D09#06N	2.160	2.156	1.587	909			0.966	0.265	0.16
116 D09#07N	2.243	2.215	1.548	828	938.50	0.882	0.880	0.222	0.14
117 D09#08N	2.236	2.209	1.552	802	938.50	0.865	0.852	0.209	0.13
118 D09#09N	2.207	2.180	1.571	807	938.50	0.860	0.857	0.211	0.14
119 D09#10N	2.200	2.172	1.576	781	938.50	0.832	0.830	0.197	0.14
120 D09#11N	2.250	2.222	1.543	776	938.50	0.827	0.824	0.195	0.14
121 D09#12N	2.298	2.269	1.512	793	938.50	0.845	0.842	0.204	0.15
122 D09#13N	2.152	2.126	1.607	745	938.50	0.794	0.791	0.179	0.11
123 D09#14N					938.50			0.179	0.12
124 D10#01N								0.12	0.14
125 D10#02N	2.061	2.101	1.623	840	926.75	0.908	0.892	0.229	0.15
126 D10#03N	2.100	2.140	1.597	798	926.75	0.861	0.848	0.206	0.12
127 D10#04N	2.070	2.110	1.617	835	926.75	0.901	0.887	0.226	0.13
128 D10#05N	2.196	2.238	1.533	788	926.75	0.850	0.837	0.201	0.12
129 D10#06N	2.128	2.168	1.579	782	926.75	0.844	0.831	0.198	0.12
130 D10#07N		2.147	1.593	862			0.916	0.240	0.15
131 D10#08N	2.150	2.153	1.589	870	954.00	0.912	0.924	0.244	0.16
132 D10#09N	2.155	2.168	1.588	842	954.00	0.883	0.894	0.230	0.13
133 D10#10N	2.197	2.199	1.558	795	954.00	0.833	0.845	0.205	0.15
134 D10#11N	2.194	2.196	1.560	701	954.00	0.735	0.745	0.155	0.10
135 D10#12N	2.225	2.228	1.540	692	954.00	0.725	0.735	0.151	0.09
136 D10#13N	2.182	2.185	1.568	866	954.00	0.908	0.920	0.242	0.16
137 D10#14N	2.226	2.228	1.539		954.00			0.13	0.13
138 D11#01N					954.00			0.10	0.10
139 D11#02N	2.210	2.213	1.550	811	954.00	0.850	0.861	0.213	0.16
140 D11#03N	2.216	2.219	1.546	792	954.00	0.830	0.841	0.203	0.11
141 D11#04N	2.195	2.198	1.559	792	954.00	0.830	0.841	0.203	0.12
142 D11#05N	2.201	2.204	1.556	807	954.00	0.846	0.857	0.211	0.15
143 D11#06N	2.190	2.192	1.563	829	954.00	0.869	0.881	0.223	0.16
144 D11#07N	2.170	2.163	1.589	877	951.50	0.922	0.932	0.248	0.10
145 D11#08N	2.195	2.179	1.572	823	951.50	0.865	0.874	0.220	0.15
146 D11#09N	2.236	2.219	1.546	860	951.50	0.904	0.914	0.239	0.17
147 D11#10N	2.224	2.207	1.554	785	951.50	0.825	0.834	0.200	0.12
148 D11#11N	2.195	2.178	1.573	790	951.50	0.830	0.839	0.202	0.15
149 D11#12N	2.181	2.165	1.581	779	951.50	0.819	0.828	0.198	0.16
150 D11#13N	2.241	2.224	1.542	845	951.50	0.888	0.898	0.231	0.13
151 D11#14N	2.243	2.226	1.541	811	951.50	0.852	0.861	0.213	0.15
152 D12#01N									
153 D12#02N	2.180	2.222	1.544	849	926.75	0.916	0.902	0.233	0.13
154 D12#03N	2.157	2.199	1.559	840	926.75	0.906	0.892	0.229	0.11
155 D12#04N	2.199	2.241	1.531	833	926.75	0.899	0.885	0.225	0.11
156 D12#05N	2.206	2.248	1.526	806	926.75	0.870	0.856	0.211	0.11
157 D12#06N	2.165	2.207	1.554	754	926.75	0.814	0.801	0.183	0.10
158 D12#07N	2.168	2.210	1.552	721	926.75	0.778	0.765	0.166	0.11
159 D12#08N	2.208	2.250	1.525	702	926.75	0.757	0.746	0.156	0.13
160 D12#09N				721	926.75	0.778	0.766	0.166	0.13
161 D12#10N	2.193	2.196	1.561	738	954.00	0.774	0.784	0.175	0.10
162 D12#11N	2.177	2.180	1.571	818	954.00	0.857	0.869	0.217	0.16

TABLE A.5. (contd)

FLT_FEN_H20 193R x 49C

Ø fix dry density	41 H2O % B GRAB	42 MEAN	43 LIFT HEIGHT	44 LIFT VOL CM3	45 WET LIFT WT GM	46 DRY LIFT WT GM	47 DENSITY SCALE	48 DENSITY CAN MEAN	49 DENSITY SEAMAN MEAN
109 D08#15N	0.11	0.12	12.15	381704	556000	498235	1.46	1.37	1.55
110 D09#01N	0.16	0.15	11.40	358142	586000	508979	1.64	1.41	1.56
111 D09#02N		0.14	6.20	194779	302000	264397	1.55	1.38	1.54
112 D09#03N		0.16	5.55	174358	297000	255230	1.70		1.54
113 D09#04N	0.15	0.15	10.50	329867	507000	440720	1.54	1.38	1.57
114 D09#05N	0.16	0.15	13.20	414690	627000	543682	1.51		1.58
115 D09#06N		0.16	7.45	234049	330000	284824	1.41	1.42	1.53
116 D09#07N	0.12	0.13	11.35	356571	542000	479310	1.52		1.57
117 D09#08N	0.14	0.14	12.75	400553	554000	486699	1.38	1.34	1.58
118 D09#09N	0.14	0.14	12.15	381704	589000	498054	1.49		1.58
119 D09#10N	0.13	0.14	12.55	394270	583000	516552	1.49	1.35	1.53
120 D09#11N	0.15	0.14	14.30	449248	600000	576929	1.47		1.56
121 D09#12N	0.14	0.14	12.35	387987	581000	507698	1.50	1.29	1.60
122 D09#13N	0.12	0.12	14.70	461814	650000	582258	1.41		
123 D09#14N		0.12	5.50	172788	258000	230397	1.49		
124 D10#01N		0.14	4.40	138230	269000	236398	1.95	1.43	1.58
125 D10#02N		0.16	5.70	179071	270000	235394	1.51		1.58
126 D10#03N		0.12	4.85	162367	252000	224182	1.65	1.39	1.55
127 D10#04N		0.13	4.80	150796	248000	219654	1.64		1.58
128 D10#05N	0.13	0.13	10.10	317301	461000	409213	1.45	1.38	1.59
129 D10#06N	0.11	0.11	13.35	419433	612000	550292	1.48	1.41	1.58
130 D10#07N	0.17	0.16	14.15	444535	675000	583930	1.52		1.57
131 D10#08N	0.14	0.15	13.20	414690	648000	564555	1.56	1.38	1.58
132 D10#09N	0.14	0.13	13.80	433540	637000	562053	1.47		1.54
133 D10#10N	0.13	0.14	11.95	375420	578000	506917	1.54	1.35	1.53
134 D10#11N	0.07	0.08	14.10	442985	640000	590325	1.44	1.42	1.57
135 D10#12N	0.10	0.09	13.70	430398	606000	554416	1.41	1.41	1.58
136 D10#13N	0.15	0.15	12.45	391128	618000	535152	1.58		1.57
137 D10#14N	0.12	0.12	13.95	438262	633000	563022	1.44	1.38	1.56
138 D11#01N		0.10	6.10	191637	324000	293312	1.69		1.55
139 D11#02N		0.16	6.20	194779	283000	243324	1.45	1.38	1.58
140 D11#03N		0.11	6.45	202633	295000	264909	1.67		1.56
141 D11#04N		0.12	5.45	171217	286000	264802	1.46	1.38	1.57
142 D11#05N	0.13	0.14	13.05	409978	596000	523558	1.45	1.38	1.57
143 D11#06N	0.13	0.15	12.50	392699	586000	511273	1.49	1.39	1.59
144 D11#07N	0.11	0.10	12.85	403695	600000	543631	1.49	1.40	1.55
145 D11#08N	0.12	0.13	13.70	430398	612000	539289	1.42		1.58
146 D11#09N	0.17	0.17	11.25	353429	571000	488292	1.62	1.38	1.58
147 D11#10N	0.14	0.13	13.45	422544	609000	539904	1.44	1.40	1.57
148 D11#11N	0.13	0.14	11.70	367566	568000	499214	1.55	1.38	1.58
149 D11#12N		0.15	12.55	394270	628000	506107	1.59	1.34	1.55
150 D11#13N	0.14	0.14	13.50	424115	583000	464238	1.37		1.54
151 D11#14N	0.15	0.14	11.35	356571	528000	464238	1.48	1.35	1.53
152 D12#01N		0.15	5.47	171845	306000	266242	1.78	1.34	1.56
153 D12#02N		0.13	6.55	205774	321000	263258	1.66		1.57
154 D12#03N		0.11	6.80	213628	298000	271674	1.39	1.35	1.53
155 D12#04N		0.11	5.90	185354	301000	532991	1.62	1.39	1.56
156 D12#05N	0.11	0.11	13.10	411549	592000	575553	1.44	1.38	1.54
157 D12#06N	0.12	0.11	14.15	444535	640000	571361	1.44		1.53
158 D12#07N	0.08	0.09	15.75	494801	589000	530199	1.41	1.32	1.55
159 D12#08N	0.09	0.11	13.30	417832	583000	527706	1.49		1.53
160 D12#09N	0.08	0.10	12.45	391128	561000	508129	1.42	1.61	1.53
161 D12#10N	0.10	0.10	12.60	395841	681000	589501	1.61		
162 D12#11N	0.15	0.16	13.45	422544					

TABLE A.5. (contd)

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FLTF_DEN_H2O 193R x 49C

Ø fix dry density	1 DEPTHS	2 TARE grams	3 WET WT grams	4 DRY WT grams	5 % H2O	6 % VOL H2O	7 CORE #	8 CORE VOL cc	9 DENSITY WET CAN	10 DENSITY DRY CAN	11 DENSITY COUNTS
163 D12#12N	-24.45	69.76	396.80	361.10	0.12	0.17	1	211.94	1.543	1.375	4989
164 D12#13N	-11.95										5087
165 D12#14N	-5.00	70.72	400.00	364.04	0.12	0.17	1	211.94	1.554	1.384	4852
166 D13#01N	-149.30										
167 D13#02N	-143.90	71.77	394.48	355.48	0.14	0.18	1	211.94	1.523	1.339	4931
168 D13#03N	-137.15										4783
169 D13#04N	-131.55										4944
170 D13#05N	-117.70										4924
171 D13#06N	-104.05	69.01	382.89	345.35	0.14	0.18	1	211.94	1.481	1.304	4845
172 D13#07N	-91.30										4988
173 D13#08N	-78.55	71.15	409.56	372.25	0.12	0.18	1	211.94	1.597	1.421	4974
174 D13#09N	-66.90										5087
175 D13#10N	-56.40	69.61	387.29	353.99	0.12	0.16	1	211.94	1.499	1.342	4940
176 D13#11N	-43.70										4904
177 D13#12N	-30.90	69.94	402.83	363.48	0.13	0.19	1	211.94	1.571	1.385	4857
178 D13#13N	-17.55	70.70	416.32	376.26	0.13	0.19	1	211.94	1.626	1.437	4974
179 D13#14N	-5.00	72.30	393.56	353.34	0.14	0.19	1	211.94	1.516	1.326	4883
180 D14#01N	-149.90										
181 D14#02N	-144.10	69.16	408.97	365.22	0.15	0.21	1	211.94	1.603	1.397	5039
182 D14#03N	-138.80										4985
183 D14#04N	-133.05	71.04	391.26	354.01	0.13	0.18	1	211.94	1.511	1.335	5008
184 D14#05N	-120.70										4788
185 D14#06N	-106.75	74.40	408.72	368.61	0.14	0.19	1	211.94	1.577	1.388	4919
186 D14#07N	-92.15										4925
187 D14#08N	-78.55	70.89	405.47	360.57	0.15	0.21	1	211.94	1.579	1.367	4877
188 D14#09N	-66.70										4979
189 D14#10N	-53.90	71.68	398.78	357.67	0.14	0.19	1	211.94	1.543	1.349	4994
190 D14#11N	-39.40										4772
191 D14#12N	-24.40	72.13	384.20	346.32	0.14	0.18	1	211.94	1.472	1.294	4799
192 D14#13N	-9.55										4731
193 D14#14N	-5.00	69.20	396.05	353.40	0.15	0.20	1	211.94	1.542	1.341	4717

TABLE A.5. (contd)

FLTF_DEN_H20 193R x 49C		14-FEB-89 10:41 Page 17									
Ø fix dry density	12 DENSITY DAILY STAND	13 CR DEN DAILY	14 CR DEN MEAN	15 COL14-- +3.003	16 MOISTURE COUNTS	17 MOISTURE DAILY STAND	18 CR H2O DAILY	19 CR H2O MEAN	20 col18-- -2.145	21 CR H2O MEAN	22 CR H2O MEAN
163 D12#12N	2219.60	2.248	2.250	1.525	758	954.00	0.795	0.805	0.185	0.805	0.185
164 D12#13N	2219.60	2.292	2.295	1.496	729	954.00	0.764	0.774	0.170	0.774	0.170
165 D12#14N	2219.60	2.186	2.189	1.565	769	954.00	0.806	0.817	0.191	0.817	0.191
166 D13#01N	2219.60										
167 D13#02N	2219.60	2.222	2.224	1.542	815	954.00	0.854	0.866	0.215	0.866	0.215
168 D13#03N	2219.60	2.155	2.158	1.586	810	954.00	0.849	0.860	0.213	0.860	0.213
169 D13#04N	2219.60	2.227	2.230	1.538	809	954.00	0.848	0.859	0.212	0.859	0.212
170 D13#05N	2219.60	2.218	2.221	1.544	798	954.00	0.836	0.848	0.206	0.848	0.206
171 D13#06N	2200.00	2.202	2.185	1.568	833	951.50	0.875	0.885	0.225	0.885	0.225
172 D13#07N	2200.00	2.267	2.250	1.525	813	951.50	0.864	0.864	0.214	0.864	0.214
173 D13#08N	2200.00	2.261	2.244	1.529	761	951.50	0.800	0.808	0.187	0.808	0.187
174 D13#09N	2200.00	2.312	2.295	1.496	792	951.50	0.832	0.841	0.203	0.841	0.203
175 D13#10N	2200.00	2.245	2.228	1.539	786	951.50	0.826	0.835	0.200	0.835	0.200
176 D13#11N	2200.00	2.229	2.212	1.550	836	951.50	0.879	0.888	0.227	0.888	0.227
177 D13#12N	2200.00	2.208	2.191	1.564	767	951.50	0.806	0.815	0.190	0.815	0.190
178 D13#13N	2200.00	2.261	2.244	1.529	801	951.50	0.842	0.851	0.208	0.851	0.208
179 D13#14N	2200.00	2.220	2.203	1.556	808	951.50	0.849	0.858	0.212	0.858	0.212
180 D14#01N	2200.00										
181 D14#02N	2213.80	2.276	2.273	1.510	818	944.80	0.860	0.869	0.217	0.869	0.217
182 D14#03N	2213.80	2.252	2.249	1.526	829	944.80	0.877	0.881	0.223	0.881	0.223
183 D14#04N	2213.80	2.262	2.259	1.519	802	944.80	0.849	0.852	0.209	0.852	0.209
184 D14#05N	2213.80	2.163	2.160	1.594	836	944.80	0.885	0.888	0.227	0.888	0.227
185 D14#06N	2213.80	2.222	2.219	1.546	872	944.80	0.923	0.926	0.245	0.926	0.245
186 D14#07N	2213.80	2.225	2.222	1.544	818	944.80	0.866	0.869	0.217	0.869	0.217
187 D14#08N	2213.80	2.203	2.200	1.558	830	944.80	0.878	0.882	0.223	0.882	0.223
188 D14#09N	2263.75	2.199	2.240	1.528	772	923.25	0.836	0.820	0.193	0.820	0.193
189 D14#10N	2263.75	2.206	2.263	1.523	830	923.25	0.899	0.882	0.223	0.882	0.223
190 D14#11N	2263.75	2.108	2.153	1.589	796	923.25	0.862	0.846	0.205	0.846	0.205
191 D14#12N	2263.75	2.120	2.165	1.561	853	923.25	0.924	0.906	0.235	0.906	0.235
192 D14#13N	2263.75	2.090	2.134	1.591	828	923.25	0.897	0.880	0.222	0.880	0.222
193 D14#14N	2263.75	2.084	2.128	1.605	832	923.25	0.901	0.884	0.224	0.884	0.224

TABLE A.5. (contd)

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FLTF_DEN_H2O 193R x 49C												
Ø fix dry density	21 TARE	22 WET WT	23 DRY WT	24 % H2O	25 % VOL H2O	26 CORE #	27 CORE VOL	28 DENSITY WET CAN	29 DENSITY DRY CAN	30 DENSITY COUNTS	31 DENSITY DAILY STAND	
163 D12#12N	69.170	391.14	358.37	0.11	0.15	1	211.94	1.52	1.36	5051	2219.60	
164 D12#13N										4973	2219.60	
165 D12#14N	70.860	380.13	352.13	0.10	0.13	1	211.94	1.46	1.33	4817	2219.60	
166 D13#01N											2219.60	
167 D13#02N	71.730	398.90	361.91	0.13	0.17	1	211.94	1.54	1.37	5158	2219.60	
168 D13#03N										4980	2219.60	
169 D13#04N	76.410	418.12	377.80	0.13	0.19	1	211.94	1.61	1.42	4980	2219.60	
170 D13#05N										4850	2219.60	
171 D13#06N	70.490	392.51	354.50	0.13	0.18	1	211.94	1.52	1.34	4904	2200.00	
172 D13#07N										5005	2200.00	
173 D13#08N	73.710	388.55	355.03	0.12	0.16	1	211.94	1.49	1.33	4928	2200.00	
174 D13#09N										5002	2200.00	
175 D13#10N	69.870	394.10	357.85	0.13	0.17	1	211.94	1.53	1.36	4954	2200.00	
176 D13#11N										4909	2200.00	
177 D13#12N	70.200	399.87	363.09	0.13	0.17	1	211.94	1.56	1.38	4870	2200.00	
178 D13#13N										4708	2200.00	
179 D13#14N	69.310	425.06	374.42	0.17	0.24	1	211.94	1.68	1.44		2200.00	
180 D14#01N										5102	2213.80	
181 D14#02N	70.140	382.97	345.41	0.14	0.18	1	211.94	1.48	1.30	4923	2213.80	
182 D14#03N										4981	2213.80	
183 D14#04N	70.730	390.77	351.30	0.14	0.19	1	211.94	1.51	1.32	4788	2213.80	
184 D14#05N										4768	2213.80	
185 D14#06N	71.140	416.95	372.42	0.15	0.21	1	211.94	1.63	1.42	4746	2213.80	
186 D14#07N										5037	2213.80	
187 D14#08N	71.360	408.00	366.60	0.14	0.20	1	211.94	1.59	1.39	4889	2263.75	
188 D14#09N										4872	2263.75	
189 D14#10N	71.440	406.36	367.20	0.13	0.18	1	211.94	1.58	1.40	4746	2263.75	
190 D14#11N										4836	2263.75	
191 D14#12N	70.970	409.18	370.34	0.13	0.18	1	211.94	1.60	1.41	4718	2263.75	
192 D14#13N										4800	2263.75	
193 D14#14N	71.640	397.35	361.07	0.13	0.17	1	211.94	1.54	1.37			

TABLE A.5. (contd)

FLT_FEN_H20 193R x 49C

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Ø fix dry density	32 CR DEN DAILY	33 CR DEN MEAN	34 COL34*- +3.003	35 MOISTURE COUNTS	36 MOISTURE DAILY STND	37 CR H2O DAILY	38 CR H2O MEAN	39 col 37*.4966 -.2145	40 H20 % A GRAB
163 D12#12N	2.276	2.278	1.507	769	954.00	0.806	0.817	0.191	0.12
164 D12#13N	2.240	2.243	1.530	770	954.00	0.807	0.818	0.192	0.12
165 D12#14N	2.170	2.173	1.576	780	954.00	0.818	0.829	0.197	0.14
166 D13#01N					954.00			0.11	0.11
167 D13#02N	2.324	2.327	1.475	817	954.00	0.856	0.868	0.216	0.15
168 D13#03N	2.244	2.246	1.528	767	954.00	0.794	0.804	0.185	0.15
169 D13#04N	2.244	2.246	1.528	802	954.00	0.841	0.852	0.209	0.14
170 D13#05N	2.185	2.188	1.566	803	954.00	0.842	0.853	0.209	0.12
171 D13#06N	2.229	2.212	1.550	799	951.50	0.840	0.849	0.207	0.13
172 D13#07N	2.275	2.258	1.520	802	951.50	0.843	0.852	0.209	0.14
173 D13#08N	2.240	2.223	1.543	766	951.50	0.795	0.803	0.184	0.12
174 D13#09N	2.274	2.256	1.521	826	951.50	0.867	0.876	0.221	0.16
175 D13#10N	2.252	2.235	1.535	793	951.50	0.833	0.842	0.204	0.09
176 D13#11N	2.231	2.214	1.549	816	951.50	0.867	0.866	0.215	0.16
177 D13#12N	2.214	2.197	1.560	753	951.50	0.791	0.800	0.183	0.14
178 D13#13N	2.214	2.197	1.560	804	951.50	0.845	0.854	0.210	0.17
179 D13#14N	2.140	2.124	1.608	848	951.50	0.891	0.901	0.233	0.19
180 D14#01N					951.50			0.14	0.14
181 D14#02N	2.305	2.301	1.491	802	944.80	0.849	0.852	0.209	0.15
182 D14#03N	2.224	2.221	1.544	858	944.80	0.908	0.911	0.238	0.16
183 D14#04N	2.250	2.247	1.527	800	944.80	0.847	0.850	0.208	0.14
184 D14#05N	2.163	2.160	1.584	834	944.80	0.883	0.886	0.226	0.12
185 D14#06N	2.154	2.151	1.590	821	944.80	0.869	0.872	0.219	0.14
186 D14#07N	2.144	2.141	1.597	850	944.80	0.900	0.903	0.234	0.14
187 D14#08N	2.275	2.272	1.511	827	944.80	0.875	0.878	0.222	0.18
188 D14#09N	2.160	2.205	1.556	757	923.25	0.820	0.804	0.185	0.15
189 D14#10N	2.152	2.198	1.560	825	923.25	0.894	0.876	0.221	0.14
190 D14#11N	2.097	2.141	1.597	833	923.25	0.902	0.885	0.225	0.14
191 D14#12N	2.136	2.181	1.570	804	923.25	0.871	0.854	0.210	0.14
192 D14#13N	2.084	2.128	1.605	796	923.25	0.862	0.846	0.205	0.15
193 D14#14N	2.120	2.165	1.591	772	923.25	0.836	0.820	0.193	0.14

TABLE A.5. (contd)

FLT DEN H2O 193R x 49C

Ø fix dry density	41 H2O % B GRAB	42 MEAN	43 LIFT HEIGHT	44 LIFT VOL CM3	45 WET LIFT WT GM	46 DRY LIFT WT GM	47 DENSITY SCALE	48 DENSITY CAN MEAN	49 DENSITY SEAMAN MEAN
163 D12#12N	0.12	0.12	11.90	373850	549000	490142	1.47	1.37	1.52
164 D12#13N	0.12	0.12	12.50	392699	584000	522046	1.49	1.49	1.51
165 D12#14N		0.14	7.00	219911	328000	287123	1.49	1.36	1.57
166 D13#01N	0.11	0.11	6.70	179071	269000	243112	1.50		
167 D13#02N	0.15	0.15	5.40	169646	302000	262504	1.78	1.35	1.51
168 D13#03N	0.15	0.15	6.75	212058	327000	285362	1.54		1.56
169 D13#04N	0.14	0.14	5.60	175929	266000	232200	1.51	1.42	1.53
170 D13#05N	0.15	0.14	13.85	435111	619000	544016	1.42		1.56
171 D13#06N	0.15	0.14	13.85	428827	640000	502925	1.49	1.32	1.56
172 D13#07N	0.13	0.13	12.75	400553	601000	530538	1.50		1.52
173 D13#08N	0.11	0.12	12.75	400553	573000	513557	1.43	1.37	1.54
174 D13#09N	0.10	0.13	11.65	365998	532000	470027	1.45		1.51
175 D13#10N	0.13	0.11	11.50	361283	543000	486572	1.50	1.35	1.54
176 D13#11N	0.14	0.15	11.70	367566	575000	498410	1.56		1.55
177 D13#12N	0.16	0.15	12.80	402124	589000	512896	1.46	1.38	1.56
178 D13#13N	0.14	0.16	13.35	419403	592000	511671	1.41	1.44	1.54
179 D13#14N	0.19	0.19	12.55	394270	594000	511671	1.50	1.38	1.58
180 D14#01N		0.14	5.80	182212	308000	270906	1.69		1.50
181 D14#02N		0.15	5.80	182212	256000	222411	1.40	1.35	1.50
182 D14#03N		0.16	5.30	186504	263000	226740	1.58		1.54
183 D14#04N		0.14	5.75	180642	278000	244074	1.54	1.33	1.52
184 D14#05N	0.15	0.13	12.35	387987	576000	508002	1.48		1.58
185 D14#06N	0.15	0.15	13.95	439252	640000	556292	1.48	1.40	1.57
186 D14#07N	0.12	0.13	14.60	458673	682000	602016	1.49		1.57
187 D14#08N	0.16	0.17	13.00	427257	632000	539585	1.48	1.38	1.53
188 D14#09N	0.10	0.13	11.85	372279	542000	480899	1.46		1.54
189 D14#10N	0.14	0.14	12.80	462124	575000	503914	1.43	1.37	1.54
190 D14#11N	0.13	0.14	14.50	455531	608000	587862	1.47		1.59
191 D14#12N	0.14	0.14	15.00	471239	693000	608052	1.47	1.35	1.58
192 D14#13N	0.15	0.15	14.85	466527	582000	506241	1.25		1.60
193 D14#14N		0.14	4.55	142942	222000	195305	1.55	1.35	1.59

TABLE A.6. Moisture and Density Data for the Weighing Lysimeters

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FLTF_WL_DEN_H2O 35R x 20C

Ø SAMPLE	1	2	DEPTHS	3	TARE	4	WET WT	5	DRY WT	6	CORE VOL	7	H2O % GRAV	8	H2O % VOL	9	DENSITY DRY G/CM3	10	DENSITY WET G/CM3	11	BEGIN S DATA	12	DEPTHS
1	W1_02N	N	-139.55	70.21	424.92	382.60	219.19	0.135	0.193	1.425	1.618	S	-142.75										
2	W1_04N	N	-119.45	69.89	432.92	393.48	219.19	0.122	0.186	1.476	1.666	S	-128.20										
3	W1_06N	N	-110.20	71.02	414.96	369.29	219.19	0.153	0.208	1.361	1.569	S	-110.90										
4	W1_08N	N	-97.60	69.11	416.58	372.27	219.19	0.146	0.202	1.383	1.585	S	-93.20										
5	W1_10N	N	-80.75	70.59	429.92	382.78	219.19	0.151	0.215	1.424	1.639	S	-77.40										
6	W1_12N	N	-61.10	72.11	419.79	374.37	219.19	0.150	0.207	1.379	1.588	S	-61.25										
7	W1_14N	N	-42.75	77.66	434.88	384.77	219.19	0.163	0.229	1.402	1.630	S	-44.35										
8	W1_16N	N	-21.75	69.31	409.68	367.42	219.19	0.142	0.193	1.360	1.553	S	-27.00										
9	W1_18N	N	-5.35	69.33	433.98	385.86	219.19	0.152	0.220	1.444	1.684	S	-5.00										
10	W2_02N	N	-141.00	70.61	407.09	367.45	219.19	0.134	0.181	1.354	1.535	S	-141.00										
11	W2_04N	N	-124.00	72.23	426.66	376.67	219.19	0.144	0.200	1.389	1.589	S	-124.00										
12	W2_06N	N	-102.90	71.71	425.15	379.36	219.19	0.149	0.209	1.404	1.612	S	-102.90										
13	W2_08N	N	-82.35	70.26	411.31	370.70	219.19	0.135	0.185	1.371	1.558	S	-82.35										
14	W2_10N	N	-65.00	69.64	431.40	384.46	219.19	0.149	0.214	1.435	1.650	S	-65.00										
15	W2_12N	N	-46.40	71.02	441.34	385.36	219.19	0.178	0.255	1.434	1.689	S	-46.40										
16	W2_14N	N	-28.30	70.62	413.97	365.45	219.19	0.165	0.221	1.345	1.566	S	-28.30										
17	W2_16N	N	-5.00	72.21	420.17	375.03	219.19	0.149	0.206	1.382	1.587	S	-5.00										
18	W3_02N	N	-139.75	72.04	390.49	359.97	211.95	0.106	0.144	1.358	1.502	S	-139.75										
19	W3_04N	N	-122.50	70.71	382.27	352.76	211.95	0.105	0.139	1.331	1.470	S	-122.50										
20	W3_06N	N	-101.65	70.86	396.25	367.33	211.95	0.136	0.184	1.352	1.535	S	-101.65										
21	W3_08N	N	-83.40	69.12	429.21	380.64	211.95	0.156	0.229	1.470	1.699	S	-83.40										
22	W3_10N	N	-58.70	70.63	415.77	372.08	211.95	0.145	0.206	1.422	1.628	S	-58.70										
23	W3_12N	N	-36.10	72.04	411.27	362.91	211.95	0.168	0.228	1.372	1.601	S	-36.10										
24	W3_13N	N	-22.30	77.66	421.05	381.47	211.95	0.130	0.187	1.434	1.621	S	-22.30										
25	W3_14N	N	-16.95	71.65	407.31	368.84	211.95	0.129	0.182	1.402	1.584	S	-16.95										
26	W3_15N	N	-5.20	72.15	412.05	368.80	211.95	0.146	0.204	1.400	1.604	S	-5.20										
27	W4_02N	N	-139.55	71.17	408.29	369.72	219.19	0.129	0.176	1.362	1.538	S	-139.55										
28	W4_04N	N	-119.45	69.83	389.00	355.16	219.19	0.119	0.154	1.302	1.456	S	-119.45										
29	W4_06N	N	-110.20	70.19	405.97	372.17	219.19	0.112	0.154	1.378	1.532	S	-110.20										
30	W4_08N	N	-97.60	71.65	415.01	374.73	219.19	0.133	0.184	1.383	1.566	S	-97.60										
31	W4_09N	N	-80.75	77.58	418.59	369.58	219.19	0.140	0.187	1.332	1.519	S	-80.75										
32	W4_10N	N	-61.10	69.94	414.87	370.36	219.19	0.148	0.203	1.371	1.574	S	-61.10										
33	W4_12N	N	-42.75	69.29	415.41	373.09	219.19	0.139	0.193	1.366	1.579	S	-42.75										
34	W4_14N	N	-21.75	71.38	411.56	369.22	219.19	0.142	0.193	1.359	1.552	S	-21.75										
35	W4_16N	N	-5.35	71.73	433.87	389.31	219.19	0.140	0.203	1.449	1.652	S	-5.35										

DATA FROM BNV 51377 AND BNV 51375
VOLUME OF CORE #1 = 73 mm H x 60.8 mm D
VOLUME OF CORE #2 = 75 mm H x 61.0 mm D

TABLE A.6. (contd)

FLTFL WL_DEN_H2O 35R x 20C

Ø SAMPLE	13 TARE	14 WET WT	15 DRY WT	16 CORE VOL	17 H2O % GRAV	18 H2O % VOL	19 DENSITY DRY G/CM3	20 DENSITY WET G/CM3
1 W1_02N	70.35	420.41	374.80	219.19	0.150	0.208	1.389	1.597
2 W1_04N	70.64	428.89	384.19	219.19	0.143	0.204	1.430	1.634
3 W1_06N	72.31	411.39	369.68	219.19	0.140	0.190	1.357	1.547
4 W1_08N	70.81	414.23	371.27	219.19	0.143	0.198	1.371	1.567
5 W1_10N	69.38	414.23	369.44	219.19	0.149	0.204	1.369	1.573
6 W1_12N	71.45	426.34	379.93	219.19	0.147	0.207	1.407	1.615
7 W1_14N	74.44	435.55	385.89	219.19	0.159	0.227	1.421	1.647
8 W1_16N	69.94	421.41	376.69	219.19	0.146	0.204	1.399	1.603
9 W1_18N	77.72	436.68	387.98	219.19	0.157	0.222	1.415	1.638
10 W2_02N	72.17	410.89	369.38	219.19	0.140	0.189	1.358	1.545
11 W2_04N	71.65	417.73	372.86	219.19	0.149	0.205	1.374	1.579
12 W2_06N	71.06	411.27	367.23	219.19	0.149	0.201	1.351	1.552
13 W2_08N	70.33	407.73	371.59	219.19	0.120	0.165	1.374	1.539
14 W2_10N	70.70	417.85	380.72	219.19	0.120	0.189	1.414	1.584
15 W2_12N	72.32	440.19	385.42	219.19	0.175	0.250	1.428	1.678
16 W2_14N	72.18	428.76	378.11	219.19	0.162	0.221	1.368	1.627
17 W2_16N	71.22	419.66	371.17	219.19	0.112	0.155	1.387	1.541
18 W3_02N	71.41	398.11	366.29	211.95	0.125	0.172	1.372	1.544
19 W3_04N	69.44	396.63	360.26	211.95	0.138	0.188	1.364	1.552
20 W3_06N	69.12	398.01	358.25	211.95	0.144	0.198	1.376	1.573
21 W3_08N	70.84	404.32	362.38	211.95	0.141	0.194	1.380	1.575
22 W3_10N	69.45	403.20	362.00	211.95	0.134	0.192	1.437	1.629
23 W3_12N	71.40	416.65	375.90	211.95	0.124	0.176	1.417	1.593
24 W3_13N	74.40	412.12	374.80	211.95	0.133	0.185	1.417	1.574
25 W3_14N	71.05	404.61	365.44	211.95	0.129	0.178	1.389	1.562
26 W3_15N	69.86	400.95	363.14	211.95	0.112	0.148	1.384	1.467
27 W4_02N	72.27	393.93	361.59	219.19	0.117	0.161	1.328	1.467
28 W4_04N	70.65	407.97	372.72	219.19	0.117	0.161	1.378	1.539
29 W4_05N	70.36	405.33	373.83	219.19	0.104	0.144	1.385	1.528
30 W4_06N	71.06	399.10	361.62	219.19	0.129	0.171	1.326	1.497
31 W4_08N	69.37	407.55	366.54	219.19	0.142	0.192	1.351	1.543
32 W4_10N	71.58	429.32	381.70	219.19	0.154	0.217	1.415	1.632
33 W4_12N	77.70	415.61	373.89	219.19	0.141	0.190	1.351	1.542
34 W4_14N	73.30	430.90	389.38	219.19	0.131	0.189	1.442	1.631
35 W4_16N								

DATA FROM BNW 51377 AND BNW 51375
VOLUME OF CORER #1 = 73 mm H x 60.8 mm D
VOLUME OF CORER #2 = 75 mm H x 61.0 mm D

TABLE A.7. Summary of Textural Analyses (% Sand, Silt, and Clay)
for FLTF Drainage Lysimeters

SUMMARY 94R x 4C

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TABULATION OF FLTF TEXTURAL ANALYSIS

Ø 8	1 S	2 Si	3 C	4	Ø 8	1 S	2 Si	3 C	4
1 FLTF D01_02	35	56	9	SILT LOAM	53 FLTF D08_15	43	50	7	SILT LOAM
2 FLTF D01_06	37	55	8	SILT LOAM	54 FLTF D09_10	36	55	9	SILT LOAM
3 FLTF D01_10	38	52	10	SILT LOAM	55 FLTF D09_12	37	55	8	SILT LOAM
4 FLTF D01_12	37	53	10	SILT LOAM	56 FLTF D09_01A	37	47	16	LOAM
5 FLTF D01_14	37	53	10	SILT LOAM	57 FLTF D09_01B	38	47	15	LOAM
6 FLTF D01_16	37	52	11	SILT LOAM	58 FLTF D09_01	38	52	10	SILT LOAM
7 FLTF D02_06	40	49	11	LOAM	59 FLTF D09_02	38	52	10	SILT LOAM
8 FLTF D02_08	40	48	12	LOAM	60 FLTF D09_02X	37	51	12	SILT LOAM
9 FLTF D02_10	32	59	9	SILT LOAM	61 FLTF D09_03X	37	54	9	SILT LOAM
10 FLTF D02_12	39	51	10	SILT LOAM	62 FLTF D09_04A	40	49	11	LOAM
11 FLTF D02_14	39	51	10	SILT LOAM	63 FLTF D09_04B	37	53	10	SILT LOAM
12 FLTF D02_16	38	53	9	SILT LOAM	64 FLTF D09_04	38	53	9	SILT LOAM
13 FLTF D03_02	35	56	9	SILT LOAM	65 FLTF D09_05A	40	46	14	LOAM
14 FLTF D03_06	38	53	9	SILT LOAM	66 FLTF D09_05B	38	49	13	LOAM
15 FLTF D03_10	36	56	8	SILT LOAM	67 FLTF D09_06	43	47	10	LOAM
16 FLTF D04_02	35	55	10	SILT LOAM	68 FLTF D09_06X	43	47	10	LOAM
17 FLTF D04_04	36	57	7	SILT LOAM	69 FLTF D10_13	41	50	9	SILT LOAM
18 FLTF D04_06	36	55	9	SILT LOAM	70 FLTF D10_14	38	54	8	SILT LOAM
19 FLTF D04_08	35	57	8	SILT LOAM	71 FLTF D10_02	37	54	9	SILT LOAM
20 FLTF D04_10	44	49	7	LOAM	72 FLTF D10_04	37	53	10	SILT LOAM
21 FLTF D04_14	36	56	8	SILT LOAM	73 FLTF D10_06	39	52	9	SILT LOAM
22 FLTF D05_01X	39	48	13	LOAM	74 FLTF D10_08	36	53	11	SILT LOAM
23 FLTF D05_02	35	54	11	SILT LOAM	75 FLTF D10_10	39	51	10	SILT LOAM
24 FLTF D05_02X	38	49	13	LOAM	76 FLTF D10_12	39	52	9	SILT LOAM
25 FLTF D05_03X	44	42	14	LOAM	77 FLTF D11_02	40	50	10	SILT LOAM
26 FLTF D05_04	37	53	10	SILT LOAM	78 FLTF D11_04	42	48	10	LOAM
27 FLTF D05_04X	40	46	14	LOAM	79 FLTF D11_06	38	52	10	SILT LOAM
28 FLTF D05_05A	37	49	14	LOAM	80 FLTF D11_08	34	59	7	SILT LOAM
29 FLTF D05_05B	37	49	14	LOAM	81 FLTF D11_12	37	53	10	SILT LOAM
30 FLTF D05_06	39	53	8	SILT LOAM	82 FLTF D12_02	37	54	9	SILT LOAM
31 FLTF D05_08	37	54	9	SILT LOAM	83 FLTF D12_04	38	53	9	SILT LOAM
32 FLTF D05_10	39	53	8	SILT LOAM	84 FLTF D12_06	39	52	9	SILT LOAM
33 FLTF D05_12	36	55	9	SILT LOAM	85 FLTF D12_08	33	58	9	SILT LOAM
34 FLTF D05_14	36	54	10	SILT LOAM	86 FLTF D12_14	40	53	7	SILT LOAM
35 FLTF D06_02	33	57	10	SILT LOAM	87 FLTF D13_04	46	45	9	LOAM
36 FLTF D06_06	34	55	11	SILT LOAM	88 FLTF D13_08	38	52	10	SILT LOAM
37 FLTF D06_08	37	54	9	SILT LOAM	89 FLTF D13_13	44	47	9	LOAM
38 FLTF D06_14	36	55	9	SILT LOAM	90 FLTF D13_02	38	54	8	SILT LOAM
39 FLTF D07_06	41	51	8	SILT LOAM	91 FLTF D14_02	34	56	10	SILT LOAM
40 FLTF D07_08	42	49	9	LOAM	92 FLTF D14_04	33	56	11	SILT LOAM
41 FLTF D07_10	42	49	9	LOAM	93 FLTF D14_08	36	54	10	SILT LOAM
42 FLTF D07_12	39	52	9	SILT LOAM	94 FLTF D14_14	35	55	10	SILT LOAM
43 FLTF D07_14	35	54	11	SILT LOAM					
44 FLTF D07_02	35	56	9	SILT LOAM					
45 FLTF D07_04	38	52	10	SILT LOAM					
46 FLTF D08_02	42	49	9	LOAM					
47 FLTF D08_04	39	52	9	SILT LOAM					
48 FLTF D08_06	40	53	7	SILT LOAM					
49 FLTF D08_08	39	53	8	SILT LOAM					
50 FLTF D08_10	39	53	8	SILT LOAM					
51 FLTF D08_12	40	52	8	SILT LOAM					
52 FLTF D08_14	39	53	8	SILT LOAM					

TABLE A.8. Example of Data Table for Particle Size Analysis (weight in grams)

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FLT_D01_02 33R x 15C

Model for Computation of Particle Size Ordinates

Ø	SAMPLE	1	Ps	2	Time	3	Temp	4	Soil and Sieve Wt	5	Sieve Wt	6	Soil or Reading	7	Blank or Soil Sum	8	n	9	Theta	10	C	11	X. Part Size
	WEIGHT																						
1	40		2.72																				2000.000
2	NORTH								108.61		108.61		0.00		0.00								1000.000
3	SAMPLE								107.53		107.42		0.11		0.11								500.000
4									105.47		104.62		0.85		0.96								250.000
5									99.59		98.64		0.95		1.91								100.000
6									99.28		98.62		2.66		4.57								75.000
7									99.39		95.51		3.88		8.45								53.000
8									92.91		87.54		5.37		13.82								46.000
9		1.0					20.9					27.40		4.80		0.010122			46.09	22.6			27.700
10		3.0					20.9					20.90		4.80		0.010122			48.13	16.1			15.600
11		10.0					21.0					15.80		4.80		0.010098			49.61	11.0			9.270
12		29.5					21.2					12.90		4.80		0.010049			50.35	8.1			6.556
13		60.0					21.4					11.00		4.80		0.010001			50.78	6.2			5.376
14		90.0					21.5					10.00		4.80		0.009977			51.00	5.2			4.655
15		120.0					21.7					9.60		4.80		0.009930			50.99	4.8			1.348
16		1440.0					22.6					7.10		4.30		0.009720			51.15	2.8			
17																							
18	[1.0]		2.72																				2000.000
19	SOUTH								108.61		108.61		0.00		0.00								1000.000
20	SAMPLE								107.46		107.42		0.04		0.04								500.000
21									105.32		104.62		0.70		0.74								250.000
22									99.53		98.64		0.89		1.63								100.000
23									99.38		96.62		2.76		4.39								75.000
24									99.55		95.51		4.04		8.43								53.000
25									93.03		87.54		5.49		13.92								45.900
26		1.0					20.9					28.00		4.80		0.010122			45.90	23.2			27.700
27		3.0					20.9					20.90		4.80		0.010122			48.13	16.1			15.600
28		10.0					21.0					15.90		4.80		0.010098			49.58	11.1			9.290
29		29.5					21.2					12.50		4.80		0.010049			50.46	7.7			6.558
30		60.0					21.4					10.90		4.80		0.010001			50.80	6.1			5.376
31		90.0					21.5					10.00		4.80		0.009977			51.00	5.2			4.655
32		120.0					21.7					9.30		4.80		0.009930			51.00	4.5			1.348
33		1440.0					22.6					7.10		4.30		0.009720			51.15	2.8			

TABLE A.8. (contd)

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FLT_D01_02 33R x 15C

Model for Computation of Particle Size Ordinates

Ø SAMPLE WEIGHT	12 P (%)	13 X. Avg	14 P. Avg	15 TEXTURE ANALYSIS
1 40				35% SAND
2 NORTH	100.00	2000.000	100.00	56% SILT
3 SAMPLE	99.73	1000.000	99.82	9% CLAY
4	97.60	500.000	97.88	SILT LOAM
5	95.23	250.000	95.58	
6	88.58	100.000	88.80	
7	78.87	75.000	78.90	
8	65.45	53.000	65.32	
9	50.50	40.000	57.25	
10	40.25	27.750	40.25	
11	27.50	15.000	27.03	
12	20.25	9.280	19.75	
13	15.50	6.557	15.37	
14	13.00	5.376	13.00	
15	12.00	4.659	11.63	
16	7.00	1.348	7.00	
17				
18 [1,0]				
19 SOUTH	100.00			
20 SAMPLE	99.90			
21	98.15			
22	95.93			
23	89.02			
24	78.92			
25	65.20			
26	58.00			
27	40.25			
28	27.75			
29	19.25			
30	15.25			
31	13.00			
32	11.25			
33	7.00			

MC GEEE RANCH
OPTIMUM MOISTURE, MAXIMUM DENSITY CURVE

FIGURE A.1. Proctor Density

FIGURE A.2. Particle Size Analysis FLTF D01-02

FIGURE A.3. Calibration Data for the Seaman Nuclear Probe

APPENDIX B

PROGRAM LISTINGS AND LABELS FOR FIELD LYSIMETER TEST FACILITY DATALOGGERS

APPENDIX B

PROGRAM LISTINGS AND LABELS FOR FIELD LYSIMETER TEST FACILITY DATALOGGERS

Two programs are listed on the following pages for the Campbell Scientific, Inc. dataloggers used at the FLTF. The first program listing is for the main program run for the facility. The second, shorter program listing is run on a periodic basis to gather data from the thermocouple psychrometers.

Program:modified by RRK 13/JUL/88 for new boards
 Flag Usage:1 = 1 min, 2 = 10 min scale output
 Input Channel Usage:
 Excitation Channel Usage:
 Continuous Analog Output Usage:
 Control Port Usage:
 Pulse Input Channel Usage:
 Output Array Definitions:

```

*      1      Table 1 Programs
01: 10      Sec. Execution Interval

01: P78      Resolution
01: 1      High Resolution

02: P9      Full BR w/Compensation
01: 4      Reps
02: 8      5000 mV slow EX Range
03: 1      1500 uV slow BR Range
04: 1      IN Card
05: 1      IN Chan
06: 1      EX Card
07: 1      EX Chan
08: 1      Meas/EX
09: 1000    mV Excitation
10: 1      Loc [:WL-1      ]
11: 1      Mult
12: -1      Offset

03: P17      Panel Temperature
01: 1      IN Card
02: 5      Loc [:PAN.TEMP.]

04: P14      Thermocouple Temp (DIFF)
01: 94      Reps
02: 4      50 mV slow Range
03: 2      IN Card
04: 3      IN Chan
05: 1      Type T (Copper-Constantan)
06: 5      Ref Temp Loc PAN.TEMP.
07: 6      Loc [:SCALE 1TC]
08: 1      Mult
09: 0      Offset

05: P14      Thermocouple Temp (DIFF)
01: 2      Reps
02: 4      50 mV slow Range
03: 8      IN Card
04: 13     IN Chan
05: 3      Type K (Chromel-Alumel)
06: 5      Ref Temp Loc PAN.TEMP.
07: 100    Loc :
08: 1      Mult
09: 0      Offset

06: P23      Select I/O Module
01: 3      Module No. (1,2,3,4)
  
```

FIGURE B.1. Example of Datalogger Program for Field
 Lysimeter Test Facility

17: P71	Average
01: 7	Reps
02: 24	Loc W3-H0TC
18: P71	Average
01: 9	Reps
02: 56	Loc W3-V1TC
19: P71	Average
01: 2	Reps
02: 78	Loc W3-NS105
20: P71	Average
01: 9	Reps
02: 156	Loc
21: P71	Average
01: 10	Reps
02: 186	Loc
22: P71	Average
01: 3	Reps
02: 94	Loc D13-V50TC
23: P72	Totalize
01: 2	Reps
02: 207	Loc
24: P92	If time is
01: 0	minutes into a
02: 1440	minute interval
03: 10	Set flag 0 (output)
25: P19	Signature
01: 206	Loc :
26: P80	Year
27: P77	Real Time
01: 110	Day,Hour-Minute
28: P70	Sample
01: 1	Rep
02: 206	Loc
29: P71	Average
01: 99	Reps
02: 1	Loc WL-1
30: P71	Average
01: 99	Reps
02: 100	Loc
31: P71	Average
01: 6	Reps
02: 200	Loc

FIGURE B.1. (contd)

07:	P17	Panel Temperature
01:	4	IN Card
02:	205	Loc :
08:	P14	Thermocouple Temp (DIFF)
01:	84	Reps
02:	4	50 mV slow Range
03:	1	IN Card
04:	1	IN Chan
05:	1	Type T (Copper-Constantan)
06:	205	Ref Temp Loc
07:	102	Loc :
08:	1	Mult
09:	0	Offset
09:	P14	Thermocouple Temp (DIFF)
01:	19	Reps
02:	4	50 mV slow Range
03:	7	IN Card
04:	1	IN Chan
05:	1	Type T (Copper-Constantan)
06:	205	Ref Temp Loc
07:	186	Loc :
08:	1	Mult
09:	0	Offset
10:	P3	Pulse
01:	2	Reps
02:	1	IN Card
03:	1	Pulse Input Chan
04:	2	Switch Closure
05:	207	Loc :
06:	1	Mult
07:	0	Offset
11:	P92	If time is
01:	0	minutes into a
02:	60	minute interval
03:	10	Set flag 0 (output)
12:	P80	Year
13:	P77	Real Time
01:	110	Day,Hour-Minute
14:	P71	Average
01:	16	Reps
02:	1	Loc WL-1
15:	P71	Average
01:	9	Reps
02:	38	Loc W1-V1TC
16:	P71	Average
01:	2	Reps
02:	74	Loc W1-NS105

FIGURE B.1. (contd)

32:	P72	Totalize
01:	2	Reps
02:	207	Loc
33:	P	End Table 1
*	2	Table 2 Programs
01:	10	Sec. Execution Interval
01:	P78	Resolution
01:	1	High Resolution
02:	P91	If Flag
01:	11	1 is set
02:	1	Call Subroutine 1
03:	P91	If Flag
01:	12	2 is set
02:	2	Call Subroutine 2
04:	P	End Table 2
*	3	Table 3 Subroutines
01:	P85	Beginning of Subroutine
01:	1	Subroutine Number
02:	P92	If time is
01:	0	minutes into a
02:	1	minute interval
03:	10	Set flag 0 (output)
03:	P80	Year
04:	P77	Real Time
01:	110	Day,Hour-Minute
05:	P71	Average
01:	4	Reps
02:	1	Loc WL-1
06:	P95	End
07:	P85	Beginning of Subroutine
01:	2	Subroutine Number
08:	P92	If time is
01:	0	minutes into a
02:	10	minute interval
03:	10	Set flag 0 (output)
09:	P80	Year
10:	P77	Real Time
01:	110	Day,Hour-Minute

FIGURE B.1. (contd)

11:	P71	Average
01:	4	Reps
02:	1	Loc WL-1
12:	P95	End
13:	P	End Table 3
*	4	Mode 4 Output Options
01:	11	(Tape ON) (Printer ON)
02:	0	Printer 300 Baud
*	A	Mode 10 Memory Allocation
01:	350	Input Locations
02:	350	Intermediate Locations
*	C	Mode 12 Security
01:	0	Security Disabled
02:	0	Security Code

Input Location Assignments (with comments):

(Key: T=Table Number   E=Entry Number   L=Location Number)

T:	E:	L:	
1:	2:	1:	Loc [:WL-1]
1:	3:	5:	Loc [:PAN.TEMP.]
1:	4:	6:	Loc [:SCALE 1TC]
1:	5:	100:	Loc :
1:	8:	102:	Loc :
1:	9:	186:	Loc :
1:	7:	205:	Loc :
1:	25:	206:	Loc :
1:	10:	207:	Loc :

FIGURE B.1. (contd)

1:WL-1	51:W2-V30TC
2:WL-2	52:W2-V40TC
3:WL-3	53:W2-V50TC
4:WL-4	54:W2-V100TC
5:PAN.TEMP.	55:W2-V150TC
6:SCALE 1TC	56:W3-V1TC
7:SCALE 2TC	57:W3-V5TC
8:SCALE 3TC	58:W3-V10TC
9:SCALE 4TC	59:W3-V20TC
10:W1-H0TC	60:W3-V30TC
11:W1-H10TC	61:W3-V40TC
12:W1-H50TC	62:W3-V50TC
13:W1-H76TC	63:W3-V100TC
14:W1-H101TC	64:W3-V150TC
15:W1-H142TC	65:W4-V1TC
16:W1-H152TC	66:W4-V5TC
17:W2-H0TC	67:W4-V10TC
18:W2-H10TC	68:W4-V20TC
19:W2-H50TC	69:W4-V30TC
20:W2-H76TC	70:W4-V30TC
21:W2-H101TC	71:W4-V50TC
22:W2-H142TC	72:W4-V100TC
23:W2-H152TC	73:W4-V150TC
24:W3-H0TC	74:W1-NS105
25:W3-H10TC	75:W1-SS105
26:W3-H50TC	76:W2-NS105
27:W3-H76TC	77:W2-SS105
28:W3-H101TC	78:W3-NS105
29:W3-H142TC	79:W3-SS105
30:W3-H152TC	80:W4-NS105
31:W4-H0TC	81:W4-SS105
32:W4-H10TC	82:D5-V50TC
33:E4-H50TC	83:D5-V100TC
34:W4-H76TC	84:D5-V150TC
35:W4-H101TC	85:D6-V50TC
36:W4-H142TC	86:V6-V100TC
37:W4-152TC	87:D6-V150TC
38:W1-V1TC	88:D7-V50TC
39:W1-V5TC	89:D7-V100TC
40:W1-V10TC	90:D7-V150TC
41:W1-V20TC	91:D12-V50TC
42:W1-V30TC	92:D12-V100
43:W1-V40TC	93:D12-V150
44:W1-V50TC	94:D13-V50TC
45:W1-V100TC	95:D13-V100
46:W1-V150TC	96:D13-V150
47:W2-V1TC	97:D14-V50TC
48:W2-V5TC	98:D14-V100
49:W2-V10TC	99:D14-V150
50:W2-V20TC	

FIGURE B.1. (contd)

TERM Ver 3.1   Datalogger Type: None
NoCom: 0 baud   Option: None

```
Telecommunication Parameters For Station: A:FLT7X  
Datalogger Type: Extended 21X; CR7X  
Use Asynchronous Communications Adapter: I/O address 218H  
Communications Baud Rate: 300
```

```
Interface Device:
#1: Hayes Modem      Number: 32176
```

TERM Ver 3.1   Datalogger Type: Extended 21X; CR7X
218H: 300 baud   Option: None

TERM OPTIONS

- ```
C - Call station A:FLTF7X
T - Terminal emulator
D - Download program to datalogger
S - Save program from datalogger
M - Monitor Input Locations
R - Receive a file
E - Edit station parameters
Q - Quit
```

Option:

**FIGURE B.2** Example of the TERM Station File and TERM Monitoring Options.

Station File Name: a:flt7x

Datalogger or Command Type: 21X; CR7X                      Security Code: 0  
Data Collection Method: Since Last Call; Append File;  
Nbr of Arrays to Backup on First Call: 2  
Data File Format: Comma Delineated ASCII  
Fix Datalogger Clock Using PC Clock: No  
Primary Call Interval (minutes): 1440  
Recovery Call Interval #1 (minutes): 15  
Repetitions of Recovery Interval #1: 4  
Recovery Call Interval #2 (minutes): 1440  
Maximum Time Call Will Take (minutes): 60  
Next Time To Call: 7-27-1988 0:02:00

Interface Devices:  
I/O Address 218H              Baud Rate: 300  
Hayes Smartmodem              Number: 32176

FIGURE B.3 Example of the Parameters Set in the TELCOM Station File

## APPENDIX C

### DIRECTORIES OF BARRIERS DATABASE

## APPENDIX C

### DIRECTORIES OF BARRIERS DATABASE

This Appendix contains a listing of data contained in the Hanford Site Protective Barriers FLTF Database. Comments are included to clarify the contents of each directory.

## Top-level Directory

|                |       |
|----------------|-------|
| BARRIER DEMO   | Table |
| BBN_SLIDEGRAPH | Graph |
| DATA_SUM       | Table |
| DEMO           | Graph |
| RPLLIST        | Table |

This is the default directory, only temporary tables should be stored here.

## Directory: @DENSITY

|                 |       |
|-----------------|-------|
| D01_DEN         | Graph |
| D01_H2O         | Graph |
| D01_H2O_DATA    | Table |
| D02_DEN         | Graph |
| D02_H2O         | Graph |
| D03_DEN         | Graph |
| D03_H2O         | Graph |
| D04_DEN         | Graph |
| D04_H2O         | Graph |
| D05_DEN         | Graph |
| D05_H2O         | Graph |
| D06_DEN         | Graph |
| D06_H2O         | Graph |
| D07_DEN         | Graph |
| D07_H2O         | Graph |
| D08_DEN         | Graph |
| D08_H2O         | Graph |
| D08_H2O_DATA    | Table |
| D09_DEN         | Graph |
| D09_H2O         | Graph |
| D09_H2O_DATA    | Table |
| D10_DEN         | Graph |
| D10_H2O         | Graph |
| D10_H2O_DATA    | Table |
| D11_DEN         | Graph |
| D11_H2O         | Graph |
| D11_H2O_DATA    | Table |
| D12_DEN         | Graph |
| D12_H2O         | Graph |
| D12_H2O_DATA    | Table |
| D13_DEN         | Graph |
| D13_H2O         | Graph |
| D14_DEN         | Graph |
| D14_H2O         | Graph |
| DAILY_TANK_STD  | Table |
| DEN_COM         | Graph |
| DEN_DAY         | Graph |
| DEN_DAY_STAT    | Table |
| DEN_MEAN        | Graph |
| DEN_MEAN_STAT   | Table |
| DNAME           | Table |
| FLTF_ALL        | Table |
| FLTF_ALL_B      | Table |
| FLTF_DEN_H2O    | Table |
| FLTF_WL_DEN_H2O | Table |
| FLTF_WT_DEN_H2O | Table |
| H2O_DAY         | Graph |

Both density and water content data are found here

|                      |       |
|----------------------|-------|
| H2O_DAY_STAT         | Table |
| H2O_MEAN_GRAV        | Graph |
| H2O_MEAN_STAT        | Table |
| H2O_MEAN_VOL         | Graph |
| H2O_MEAN_VOL_STAT    | Table |
| JUNK                 | Graph |
| LH                   | Table |
| LHT                  | Table |
| LIFT_DEN_H2O_CAN     | Table |
| LIFT_H2O             | Table |
| LIFT_LABELS          | Table |
| MARK_BACK            | Table |
| MARK_FLTF_ALL        | Table |
| MCGEE_PROCTOR        | Graph |
| MCGEE_PROCTOR_DEN    | Table |
| SC                   | Graph |
| SCALE_SEAMAN         | Graph |
| SEAMAN_STD           | Table |
| SEAMAN_STD_DENSITY_T | Graph |
| TEMP1                | Graph |
| TLABEL               | Table |
| W01_DEN              | Graph |
| W01_H2O              | Graph |
| W02_DEN              | Graph |
| W02_H2O              | Graph |
| W03_DEN              | Graph |
| W03_H2O              | Graph |
| W04_DEN              | Graph |
| W04_H2O              | Graph |
| WL_SOUTH_ONLY        | Table |

## Directory: @DIMENSIONS

Physical measurements made during construction are here.

|              |       |
|--------------|-------|
| FILL         | Table |
| LEAK_TEST    | Table |
| LH           | Table |
| LHD          | Table |
| LHDELTA      | Table |
| LIFT HEIGHTS | Table |
| SCALE        | Table |
| SCALE1       | Graph |
| SCALE1A      | Graph |
| SCALE2       | Graph |
| SCALE3       | Graph |
| SCALE4       | Graph |
| SCALEA       | Table |
| SCALE_CAL    | Table |
| WET_WT_DRAIN | Table |

## Directory: @FLT7X

Data collected from the data loggers at FLT7 are stored here.

|                |       |
|----------------|-------|
| BBN_SLIDEGRAPH | Graph |
| F02DEC88_MM    | Table |
| F02MAR88_MM    | Table |
| F05FEB88_MM    | Table |
| F05MAY88_MM    | Table |
| F06APR88_MM    | Table |
| F08JAN88_MM    | Table |

|                 |       |
|-----------------|-------|
| F18FEB88_MM     | Table |
| F18MAR88_MM     | Table |
| F20APR88_MM     | Table |
| F2121987MM      | Table |
| F2121987MMG     | Graph |
| F21JAN88_MM     | Table |
| FLTF307_KG      | Table |
| FLTFHDEPTH      | Table |
| FLTFHOURLABELS  | Table |
| FLTFHOURLABELS2 | Table |
| FLTFH_001       | Table |
| FLTFH_002       | Table |
| FLTFH_003       | Table |
| FLTFH_004       | Table |
| FLTFH_005       | Table |
| FLTFH_006       | Table |
| FLTFH_011       | Table |
| FLTFH_012       | Table |
| FLTFH_013       | Table |
| FLTFH_014       | Table |
| FLTFH_026       | Table |
| FLTFH_039       | Table |
| FLTFH_050       | Table |
| FLTFH_054       | Table |
| FLTFH_058       | Table |
| FLTFH_064       | Table |
| FLTFH_068       | Table |
| FLTFH_070       | Table |
| FLTFH_072       | Table |
| FLTFH_073       | Table |
| FLTFH_074       | Table |
| FLTFH_075       | Table |
| FLTFH_076       | Table |
| FLTFH_090       | Table |
| FLTFH_094       | Table |
| FLTFH_096       | Table |
| FLTFH_102       | Table |
| FLTFH_121       | Table |
| FLTFH_129       | Table |
| FLTFH_139       | Table |
| FLTFH_151       | Table |
| FLTFH_164       | Table |
| FLTFH_164_BCK   | Table |
| FLTFH_175       | Table |
| FLTFH_ALL       | Table |
| FLTFH_ALL1      | Table |
| FLTFH_ALL2      | Table |
| FLTFH_ALLG      | Graph |
| FLTFH_CUMM      | Graph |
| FLTFH_KGG       | Graph |
| FLTFH_KGGBKUP   | Graph |
| FLTFH_KGS       | Table |
| FLTFH_KGS_DIFF  | Table |
| FLTFH_LBS       | Table |
| FLTFH_LBSG      | Graph |
| FLTFH_LBSGOLD   | Graph |
| FLTFH_MM        | Table |
| FLTFH_RAW       | Table |

|             |        |
|-------------|--------|
| FLTFH_SAV   | Table  |
| FLTFH_WT    | Graph  |
| FLTFKG_1    | Graph  |
| FLTFKG_2    | Graph  |
| FLTFMM1     | Table  |
| FLTFWL1200  | Table  |
| FLTFWL1900  | Table  |
| FLTFWL700   | Table  |
| FLTFWL_TEMP | Table  |
| FLTF_MM     | Graph  |
| FLTF_W1_W2  | Graph  |
| FLTF_W3_W4  | Graph  |
| JUNK        | Table  |
| MICHAEL     | Threed |
| MICHAEL2    | Threed |
| MICHAEL3    | Threed |
| PSYFLTF     | Table  |
| RPLDIR      | Table  |
| RRK1        | Graph  |
| RRKWT       | Graph  |
| TEMPF       | Table  |
| WL2COMP     | Table  |
| WL2COMP_G   | Graph  |
| WLFLTFH     | Table  |
| WLFLTFH_WT  | Table  |

## Directory: @FLTF7X@FLTF7X\_87

Data logger data for 1987

|           |       |
|-----------|-------|
| FLTFH_194 | Table |
| FLTFH_236 | Table |
| FLTFH_289 | Table |
| FLTFH_292 | Table |
| FLTFH_320 | Table |
| FLTFH_338 | Table |
| FLTFH_344 | Table |
| FLTFH_352 | Table |
| FLTFH_364 | Table |
| FLTFH_365 | Table |

## Directory: @FLTF7X@FLTFCAL

Data logger calibration data

|              |       |
|--------------|-------|
| F031488_CAL  | Table |
| FLTF2CAL_064 | Table |
| FLTFCAL_064  | Table |
| FLTFCAL_064G | Graph |
| FLTFCAL_TMP  | Table |
| FLTFH_CAL    | Table |
| TEMPCAL      | Graph |
| TEMPCAL_T    | Graph |
| TEMPG        | Graph |
| TEMP_CAL     | Table |

## Directory: @FLTF7X@FLTFDAY

Average values for day output

|             |       |
|-------------|-------|
| ALL_D14_V   | Graph |
| ALL_D4_H100 | Graph |
| ALL_D4_H250 | Graph |
| ALL_D4_V    | Graph |



|                  |       |
|------------------|-------|
| ALL_W1_H         | Graph |
| ALL_W1_V         | Graph |
| ALL_W2_H         | Graph |
| ALL_W2_V         | Graph |
| BBN_SLIDEGRAPH   | Graph |
| D328_D4          | Table |
| D328_D4H         | Table |
| D328_D4H_G       | Graph |
| D328_D4_G        | Graph |
| D_231            | Table |
| D_328            | Table |
| D_344            | Table |
| D_352            | Table |
| FLTFDAY          | Table |
| FLTFD_001        | Table |
| FLTFD_002        | Table |
| FLTFD_008        | Table |
| FLTFD_009        | Table |
| FLTFD_010        | Table |
| FLTFD_011        | Table |
| FLTFD_012        | Table |
| FLTFD_013        | Table |
| FLTFD_014        | Table |
| FLTFD_015        | Table |
| FLTFD_016        | Table |
| FLTFD_017        | Table |
| FLTFD_018        | Table |
| FLTFD_019        | Table |
| FLTFD_020        | Table |
| FLTFD_021        | Table |
| FLTFD_050        | Table |
| FLTFD_051        | Table |
| FLTFD_052        | Table |
| FLTFD_053        | Table |
| FLTFD_054        | Table |
| FLTFD_055        | Table |
| FLTFD_056        | Table |
| FLTFD_057        | Table |
| FLTFD_058        | Table |
| FLTFD_061        | Table |
| FLTFD_314        | Table |
| FLTFD_363        | Table |
| FLTFD_364        | Table |
| FLTFD_365        | Table |
| FLTFD_ALL        | Table |
| FLTFD_ALL_D7_V   | Graph |
| FLTFD_ALL_SCALES | Graph |
| FLTFD_ALL_W1_V   | Graph |
| FLTFD_SAV        | Table |
| FLTFLABLE_DAY    | Table |
| FLTFTMP          | Table |
| F_306            | Table |
| F_306_SCALE      | Graph |
| F_306_SCALET     | Graph |
| F_314            | Table |
| G_NAMES          | Table |
| HORTEMP          | Graph |
| MEL              | Table |

|             |        |
|-------------|--------|
| MEL_D14_V   | Graph  |
| MEL_D4_H100 | Graph  |
| MEL_D4_H250 | Graph  |
| MEL_D4_V    | Graph  |
| MEL_W1_H    | Graph  |
| MEL_W1_V    | Graph  |
| MEL_W2_H    | Graph  |
| MEL_W2_V    | Graph  |
| MIKE        | Graph  |
| TD328_D4    | Threed |
| TEMP        | Table  |

Directory: @FLTF7X@FLTFHOUR

Average hourly data

Directory: @FLTF7X@FLTFPLT

Summary plots

|             |       |
|-------------|-------|
| FLTF435_D13 | Graph |
| FLTF435_D4  | Graph |
| FLTF435_WL1 | Graph |
| FLTF435_WL3 | Graph |
| FLTF440_D13 | Graph |
| FLTF440_D4  | Graph |
| FLTF440_WL1 | Graph |
| FLTF440_WL3 | Graph |
| FLTF494_D13 | Graph |
| FLTF494_D4  | Graph |
| FLTF494_WL1 | Graph |
| FLTF494_WL3 | Graph |

Directory: @FLTFNP

Neutron moisture probe data

|                |       |
|----------------|-------|
| CALF29JUN88CAL | Table |
| F02DEC87       | Table |
| F02JUN88       | Table |
| F02JUN88CAL    | Table |
| F02MAR88       | Table |
| F04MAY88       | Table |
| F04MAY88CAL    | Table |
| F04NOV87A      | Table |
| F05FEB88       | Table |
| F06APR88       | Table |
| F06APR88CAL    | Table |
| F08JAN88       | Table |
| F10MAY88       | Table |
| F10MAY88CAL    | Table |
| F15JUN88       | Table |
| F15JUN88CAL    | Table |
| F18DEC87       | Table |
| F18FEB88       | Table |
| F18MAR88       | Table |
| F18MAY88       | Table |
| F18MAY88CAL    | Table |
| F20APR88       | Table |
| F20APR88ACAL   | Table |
| F20APR88CAL    | Table |
| F21JAN88       | Table |
| F22JUN88       | Table |

|                      |       |
|----------------------|-------|
| F22JUN88CAL          | Table |
| F23MAR88             | Table |
| F23MAR88CAL          | Table |
| F24MAY88             | Table |
| F24MAY88CAL          | Table |
| F29JUN88A            | Table |
| F7JUN88              | Table |
| F7JUN88C             | Table |
| F7JUN88CAL           | Table |
| FFT                  | Table |
| FIGURE_WL1           | Graph |
| FILENAME             | Table |
| FITFUN_EVALUATIONS   | Table |
| FLTFNP               | Table |
| FLTF_MCGEE_COMP      | Graph |
| FLTF_MCG_COMP2       | Graph |
| H20CM1A              | Graph |
| H20CM1               | Graph |
| H20CM2               | Graph |
| H20CM2A              | Graph |
| H20PERC1             | Graph |
| H20PERC2             | Graph |
| MELGRAPH             | Table |
| MELGRAPHG            | Graph |
| MIKESDATA            | Table |
| MIKETEST             | Table |
| MIKETEST2            | Graph |
| RAW_COUNTF29JUN88_RA | Table |
| RPLLIST              | Table |
| SLIDE051088G         | Graph |
| SLIDE051088G2        | Graph |
| SLIDE051188G         | Graph |
| SLIDE051188G2        | Graph |
| SLIDE051288TC        | Graph |
| SLIDE051288WL        | Graph |
| SLIDE051288WL2       | Graph |
| TEMP                 | Table |
| TT                   | Table |

## Directory: @FLTFNP@CAL

Neutron moisture probe  
calibration data

|         |       |
|---------|-------|
| D10CAL  | Table |
| D10DATA | Graph |
| D11CAL  | Table |
| D11DATA | Graph |
| D12CAL  | Table |
| D12DATA | Graph |
| D13CAL  | Table |
| D13DATA | Graph |
| D14CAL  | Table |
| D14DATA | Graph |
| D1CAL   | Table |
| D1DATA  | Graph |
| D2CAL   | Table |
| D2DATA  | Graph |
| D3CAL   | Table |
| D3DATA  | Graph |
| D4CAL   | Table |

|              |       |
|--------------|-------|
| D4DATA       | Graph |
| D5CAL        | Table |
| D5DATA       | Graph |
| D6CAL        | Table |
| D6DATA       | Graph |
| D7CAL        | Table |
| D7DATA       | Graph |
| D8CAL        | Table |
| D8DATA       | Graph |
| D9CAL        | Table |
| D9DATA       | Graph |
| F29JUN88ACAL | Table |
| W1CAL        | Table |
| W1DATA       | Graph |
| W2CAL        | Table |
| W2DATA       | Graph |
| W3CAL        | Table |
| W3DATA       | Graph |
| W4CAL        | Table |
| W4DATA       | Graph |

Directory: @FLTFNP@H20CM

Neutron moisture probe data  
converted to cm of water

|            |       |
|------------|-------|
| F02DEC87D  | Table |
| F02JUN88D  | Table |
| F02MAR88D  | Table |
| F04MAY88D  | Table |
| F04NOV87AD | Table |
| F05FEB88D  | Table |
| F08JAN88D  | Table |
| F15JUN88D  | Table |
| F18DEC87D  | Table |
| F18FEB88D  | Table |
| F18MAR88D  | Table |
| F18MAY88D  | Table |
| F20APR88D  | Table |
| F21JAN88D  | Table |
| F29JUN88AD | Table |
| FILENAME   | Table |

Directory: @FLTFNP@MOIST

Neutron moisture probe data  
converted to percent water

|            |       |
|------------|-------|
| F02DEC87C  | Table |
| F02JUN88C  | Table |
| F02MAR88C  | Table |
| F04MAY88C  | Table |
| F04NOV87AC | Table |
| F05FEB88C  | Table |
| F07JUN88C  | Table |
| F08JAN88C  | Table |
| F15JUN88C  | Table |
| F18DEC87C  | Table |
| F18FEB88C  | Table |
| F18MAR88C  | Table |
| F18MAY88C  | Table |
| F20APR88C  | Table |
| F21JAN88C  | Table |
| F29JUN88AC | Table |

|            |       |
|------------|-------|
| FIGURE_7_1 | Graph |
| FILENAME   | Table |
| TEMP2      | Table |

Directory: @FLT FNP@NPDATA

Neutron moisture probe data  
total storage.

|               |        |
|---------------|--------|
| D10_3D        | Threed |
| D10_TOT_CM    | Table  |
| D10_TOT_CM_3D | Table  |
| D11_TOT_CM    | Table  |
| D12_TOT_CM    | Table  |
| D13_TOT_CM    | Table  |
| D14_TOT_CM    | Table  |
| D1_TOT_CM     | Table  |
| D2_TOT_CM     | Table  |
| D3_TOT_CM     | Table  |
| D4_TOT_CM     | Table  |
| D5_TOT_CM     | Table  |
| D6_TOT_CM     | Table  |
| D7_TOT_CM     | Table  |
| D8_TOT_CM     | Table  |
| D9_TOT_CM     | Table  |
| DEPTH         | Table  |
| DEPTH1        | Table  |
| FILENAME      | Table  |
| FLTFSUMNAMES  | Table  |
| T1CM          | Graph  |
| T1CMG         | Graph  |
| T2CM          | Graph  |
| T2CMG         | Graph  |
| T3CM          | Graph  |
| T3CMG         | Graph  |
| T4CM          | Graph  |
| T4CMG         | Graph  |
| T5CM          | Graph  |
| T5CMG         | Graph  |
| T6CM          | Graph  |
| T6CMG         | Graph  |
| T7CM          | Graph  |
| T7CMG         | Graph  |
| W01_TOT_CM    | Table  |
| W02_TOT_CM    | Table  |
| W03_TOT_CM    | Table  |
| W04_TOT_CM    | Table  |

Directory: @FLT FNP@NPGRAPH

|               |       |
|---------------|-------|
| F02DEC87CG    | Graph |
| F02DEC87DGD1  | Graph |
| F02DEC87DGD10 | Graph |
| F02DEC87DGD11 | Graph |
| F02DEC87DGD12 | Graph |
| F02DEC87DGD13 | Graph |
| F02DEC87DGD14 | Graph |
| F02DEC87DGD2  | Graph |
| F02DEC87DGD3  | Graph |
| F02DEC87DGD4  | Graph |
| F02DEC87DGD5  | Graph |

|                |       |
|----------------|-------|
| F02DEC87DGD6   | Graph |
| F02DEC87DGD7   | Graph |
| F02DEC87DGD8   | Graph |
| F02DEC87DGD9   | Graph |
| F02DEC87DOWL1  | Graph |
| F02DEC87DOWL2  | Graph |
| F02DEC87DOWL3  | Graph |
| F02DEC87DOWL4  | Graph |
| F04NOV87ACG    | Graph |
| F04NOV87ADGD1  | Graph |
| F04NOV87ADGD10 | Graph |
| F04NOV87ADGD11 | Graph |
| F04NOV87ADGD12 | Graph |
| F04NOV87ADGD13 | Graph |
| F04NOV87ADGD14 | Graph |
| F04NOV87ADGD2  | Graph |
| F04NOV87ADGD3  | Graph |
| F04NOV87ADGD4  | Graph |
| F04NOV87ADGD5  | Graph |
| F04NOV87ADGD6  | Graph |
| F04NOV87ADGD7  | Graph |
| F04NOV87ADGD8  | Graph |
| F04NOV87ADGD9  | Graph |
| F04NOV87ADOWL1 | Graph |
| F04NOV87ADOWL2 | Graph |
| F04NOV87ADOWL3 | Graph |
| F04NOV87ADOWL4 | Graph |
| F08JAN88CG     | Graph |
| F08JAN88DGD1   | Graph |
| F08JAN88DGD10  | Graph |
| F08JAN88DGD11  | Graph |
| F08JAN88DGD12  | Graph |
| F08JAN88DGD13  | Graph |
| F08JAN88DGD14  | Graph |
| F08JAN88DGD2   | Graph |
| F08JAN88DGD3   | Graph |
| F08JAN88DGD4   | Graph |
| F08JAN88DGD5   | Graph |
| F08JAN88DGD6   | Graph |
| F08JAN88DGD7   | Graph |
| F08JAN88DGD8   | Graph |
| F08JAN88DGD9   | Graph |
| F08JAN88DOWL1  | Graph |
| F08JAN88DOWL2  | Graph |
| F08JAN88DOWL3  | Graph |
| F08JAN88DOWL4  | Graph |
| F18DEC87CG     | Graph |
| F18DEC87DGD1   | Graph |
| F18DEC87DGD10  | Graph |
| F18DEC87DGD11  | Graph |
| F18DEC87DGD12  | Graph |
| F18DEC87DGD13  | Graph |
| F18DEC87DGD14  | Graph |
| F18DEC87DGD2   | Graph |
| F18DEC87DGD3   | Graph |
| F18DEC87DGD4   | Graph |
| F18DEC87DGD5   | Graph |
| F18DEC87DGD6   | Graph |

|               |       |
|---------------|-------|
| F18DEC87DGD7  | Graph |
| F18DEC87DGD8  | Graph |
| F18DEC87DGD9  | Graph |
| F18DEC87DGWL1 | Graph |
| F18DEC87DGWL2 | Graph |
| F18DEC87DGWL3 | Graph |
| F18DEC87DGWL4 | Graph |
| F21JAN88CG    | Graph |
| F21JAN88DGD1  | Graph |
| F21JAN88DGD10 | Graph |
| F21JAN88DGD11 | Graph |
| F21JAN88DGD12 | Graph |
| F21JAN88DGD13 | Graph |
| F21JAN88DGD14 | Graph |
| F21JAN88DGD2  | Graph |
| F21JAN88DGD3  | Graph |
| F21JAN88DGD4  | Graph |
| F21JAN88DGD5  | Graph |
| F21JAN88DGD6  | Graph |
| F21JAN88DGD7  | Graph |
| F21JAN88DGD8  | Graph |
| F21JAN88DGD9  | Graph |
| F21JAN88DGWL1 | Graph |
| F21JAN88DGWL2 | Graph |
| F21JAN88DGWL3 | Graph |
| F21JAN88DGWL4 | Graph |

Directory: @FLTFNP@RAW\_COUNT

-----  
F29JUN88A\_RAW            Table

Directory: @FLTF\_DRAINAGE            Drainage data

Directory: @FLTF\_VEG            Vegetation characterization data

-----  
ARTR\_88            Table  
ARTR\_88\_MEAS      Table  
FLTF\_PHEN88       Table  
MCGEE\_PHEN88      Table  
PHENOL\_BROMUS      Graph  
PHENOL\_COMP88      Graph  
PHENOL\_ORYZOPSIS   Graph  
PHENOL\_POA        Graph

Directory: @H2OCONTENT            Volumetric and gravimetric moisture  
----- data taken during construction  
are found in subdirectories.

Directory: @H2OCONTENT@GRAV

-----  
D01\_H2O            Table  
FLTF\_SEA\_NS        Table  
LH                  Table  
LH2                Table  
LIFT\_H2O           Table  
LIFT\_H2O\_BAG       Table

Directory: @H2OCONTENT@PACIFICNUC

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|         |       |
|---------|-------|
| CPN STD | Table |
| D01WDM  | Table |
| D02WDM  | Table |
| D03WDM  | Table |
| D04WDM  | Table |
| D05WDM  | Table |
| D06WDM  | Table |
| D07WDM  | Table |
| D08WDM  | Table |
| D09WDM  | Table |
| D10WDM  | Table |
| D11WDM  | Table |
| D12WDM  | Table |
| D13WDM  | Table |
| D14WDM  | Table |

Directory: @H2OCONTENT@SEAMANNUC

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|                     |       |
|---------------------|-------|
| FLTF                | Table |
| SEAMAN STD          | Table |
| SEAMAN STD MOISTURE | Graph |
| SEAMAN VS GRAV      | Graph |
| SEAMAN VS GRAV STAT | Table |
| SEAMAN VS H2O VOL   | Graph |
| SVV DAILY           | Graph |
| SVV DAILY STAT      | Table |
| SVV STAT            | Table |
| TEMP                | Table |



## Directory: @MCGEE

Data from field studies at McGee Ranch.

|                  |       |
|------------------|-------|
| ARTR_88_MCGEE    | Table |
| M11JUL88         | Table |
| M11JUL88C        | Table |
| M11JUL88C_G      | Graph |
| M27MAR88C        | Table |
| MCGEE_ARTR_MEAS  | Table |
| MCGRAIN88        | Graph |
| MCGRAIN_88       | Table |
| MCGRAIN_88C      | Table |
| MCG_88_RH        | Graph |
| MCG_88_TEMP      | Graph |
| MCG_88_WS        | Graph |
| MEASURES         | Table |
| MG060188         | Table |
| MGDATA           | Table |
| MGRAIN88_MAR_JUN | Graph |
| MG_HIGH          | Table |
| PSYA             | Table |
| PSYAG            | Graph |
| PSYB             | Table |
| TEMP             | Table |
| TMP              | Table |

## Directory: @PARTSIZE

Particle size information for soil samples, each lysimeter has a sub-directory.

|              |       |
|--------------|-------|
| AT2W1517_488 | Table |
| AT2W1822_488 | Table |
| ATW1517_488  | Table |
| CODYPSIZE    | Table |
| CODYPSIZEG   | Graph |
| LIST         | Table |
| PSCALC1      | Model |
| PSCALC1COPY  | Model |
| PSCALC2      | Model |
| PSCALC2COPY  | Model |
| PSIZEG       | Graph |
| PSIZEGCOPY   | Graph |
| SLIST        | Table |
| SUMMARY      | Table |
| TESTG        | Graph |
| TESTT        | Table |
| TESTT1       | Table |
| TOSHIT       | Table |

## Directory: @PARTSIZE@D01

|             |       |
|-------------|-------|
| FLT_D01_02G | Table |
|-------------|-------|

## Directory: @PARTSIZE@D02

|             |       |
|-------------|-------|
| FLT_D02_06  | Table |
| FLT_D02_06G | Graph |
| FLT_D02_08  | Table |
| FLT_D02_08G | Graph |
| FLT_D02_10  | Table |

|             |       |
|-------------|-------|
| FLT_D02_10G | Graph |
| FLT_D02_12  | Table |
| FLT_D02_12G | Graph |
| FLT_D02_14  | Table |
| FLT_D02_14G | Graph |
| FLT_D02_16  | Table |
| FLT_D02_16G | Graph |

## Directory: @PARTSIZE@D03

|             |       |
|-------------|-------|
| FLT_D03_02  | Table |
| FLT_D03_02G | Graph |
| FLT_D03_06  | Table |
| FLT_D03_06G | Graph |
| FLT_D03_10  | Table |
| FLT_D03_10G | Graph |

## Directory: @PARTSIZE@D04

|             |       |
|-------------|-------|
| FLT_D04_02  | Table |
| FLT_D04_02G | Graph |
| FLT_D04_04  | Table |
| FLT_D04_04G | Graph |
| FLT_D04_06  | Table |
| FLT_D04_06G | Graph |
| FLT_D04_08  | Table |
| FLT_D04_08G | Graph |
| FLT_D04_10  | Table |
| FLT_D04_10G | Graph |
| FLT_D04_14  | Table |
| FLT_D04_14G | Graph |
| LIST        | Table |

## Directory: @PARTSIZE@D05

|              |       |
|--------------|-------|
| FLT_D05_01X  | Table |
| FLT_D05_01XG | Graph |
| FLT_D05_02   | Table |
| FLT_D05_02G  | Graph |
| FLT_D05_02X  | Table |
| FLT_D05_02XG | Graph |
| FLT_D05_03X  | Table |
| FLT_D05_03XG | Graph |
| FLT_D05_04   | Table |
| FLT_D05_04G  | Graph |
| FLT_D05_04X  | Table |
| FLT_D05_04XG | Graph |
| FLT_D05_05A  | Table |
| FLT_D05_05AG | Graph |
| FLT_D05_05B  | Table |
| FLT_D05_05BG | Graph |
| FLT_D05_06   | Table |
| FLT_D05_06G  | Graph |
| FLT_D05_08   | Table |
| FLT_D05_08G  | Graph |
| FLT_D05_10   | Table |
| FLT_D05_10G  | Graph |
| FLT_D05_12   | Table |

|             |       |
|-------------|-------|
| FLT_D05_12G | Graph |
| FLT_D05_14  | Table |
| FLT_D05_14G | Graph |
| LIST        | Table |

## Directory: @PARTSIZE@D06

|             |       |
|-------------|-------|
| FLT_D06_02  | Table |
| FLT_D06_02G | Graph |
| FLT_D06_06  | Table |
| FLT_D06_06G | Graph |
| FLT_D06_08  | Table |
| FLT_D06_08G | Graph |
| FLT_D06_14  | Table |
| FLT_D06_14G | Graph |

## Directory: @PARTSIZE@D07

|             |       |
|-------------|-------|
| FLT_D07_02  | Table |
| FLT_D07_02G | Graph |
| FLT_D07_04  | Table |
| FLT_D07_04G | Graph |
| FLT_D07_06  | Table |
| FLT_D07_06G | Graph |
| FLT_D07_08  | Table |
| FLT_D07_08G | Graph |
| FLT_D07_10  | Table |
| FLT_D07_10G | Graph |
| FLT_D07_12  | Table |
| FLT_D07_12G | Graph |
| FLT_D07_14  | Table |
| FLT_D07_14G | Graph |
| LIST        | Table |

## Directory: @PARTSIZE@D08

|             |       |
|-------------|-------|
| FLT_D08_02  | Table |
| FLT_D08_02G | Graph |
| FLT_D08_04  | Table |
| FLT_D08_04G | Graph |
| FLT_D08_06  | Table |
| FLT_D08_06G | Graph |
| FLT_D08_08  | Table |
| FLT_D08_08G | Graph |
| FLT_D08_10  | Table |
| FLT_D08_10G | Graph |
| FLT_D08_12  | Table |
| FLT_D08_12G | Graph |
| FLT_D08_14  | Table |
| FLT_D08_14G | Graph |
| FLT_D08_15  | Table |
| FLT_D08_15G | Graph |
| LIST        | Table |

## Directory: @PARTSIZE@D10

|             |       |
|-------------|-------|
| FLT_D10_02  | Table |
| FLT_D10_02G | Graph |

## Variable

|             |       |
|-------------|-------|
| FLT_D10_04  | Table |
| FLT_D10_04G | Graph |
| FLT_D10_06  | Table |
| FLT_D10_06G | Graph |
| FLT_D10_08  | Table |
| FLT_D10_08G | Graph |
| FLT_D10_10  | Table |
| FLT_D10_10G | Graph |
| FLT_D10_12  | Table |
| FLT_D10_12G | Graph |
| FLT_D10_13  | Table |
| FLT_D10_13G | Graph |
| FLT_D10_14  | Table |
| FLT_D10_14G | Graph |
| LIST        | Table |

### Directory: @PARTSIZE@D11

|             |       |
|-------------|-------|
| FLT_D11_02  | Table |
| FLT_D11_02G | Graph |
| FLT_D11_04  | Table |
| FLT_D11_04G | Graph |
| FLT_D11_06  | Table |
| FLT_D11_06G | Graph |
| FLT_D11_08  | Table |
| FLT_D11_08G | Graph |
| FLT_D11_12  | Table |
| FLT_D11_12G | Graph |

### Directory: @PARTSIZE@D12

|             |       |
|-------------|-------|
| FLT_D12_02  | Table |
| FLT_D12_02G | Graph |
| FLT_D12_04  | Table |
| FLT_D12_04G | Graph |
| FLT_D12_06  | Table |
| FLT_D12_06G | Graph |
| FLT_D12_08  | Table |
| FLT_D12_08G | Graph |
| FLT_D12_14  | Table |
| FLT_D12_14G | Graph |

### Directory: @PARTSIZE@D13

|             |       |
|-------------|-------|
| FLT_D13_02  | Table |
| FLT_D13_02G | Graph |
| FLT_D13_04  | Table |
| FLT_D13_04G | Graph |
| FLT_D13_08  | Table |
| FLT_D13_08G | Graph |
| FLT_D13_13  | Table |
| FLT_D13_13G | Graph |

### Directory: @PARTSIZE@D14

|             |       |
|-------------|-------|
| FLT_D14_02  | Table |
| FLT_D14_02G | Graph |
| FLT_D14_04  | Table |

|             |       |
|-------------|-------|
| FLT_D14_04G | Graph |
| FLT_D14_08  | Table |
| FLT_D14_08G | Graph |
| FLT_D14_14  | Table |
| FLT_D14_14G | Graph |

Directory: @PARTSIZE@DDD

Data from soil stock pile.

|             |       |
|-------------|-------|
| FLT_DDD_0E  | Table |
| FLT_DDD_OEG | Graph |
| FLT_DDD_OW  | Table |
| FLT_DDD_OWG | Graph |
| FLT_DDD_NE  | Table |
| FLT_DDD_NEG | Graph |
| FLT_DDD_NW  | Table |
| FLT_DDD_NWG | Graph |
| FLT_DDD_SC  | Table |
| FLT_DDD_SCG | Graph |
| FLT_DDD_SE  | Table |
| FLT_DDD_SEG | Graph |
| FLT_DDD_SW  | Table |
| FLT_DDD_SWG | Graph |

Directory: @PARTSIZE@GJ

Barrier data for Grand Junction Colorado soils.

|           |       |
|-----------|-------|
| AW_VS_H2O | Graph |
| GJ_MIX    | Table |
| GJ_MIXG   | Graph |

Directory: @PARTSIZE@LAB

Directory: @PARTSIZE@MARK

Data for soil samples taken during infiltrometer tests.

|          |       |
|----------|-------|
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