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THE NEVADA TEST SITE

**UNSATURATED ZONE CHARACTERIZATION OF THE AREA 5
RADIOACTIVE WASTE MANAGEMENT SITE**

**PHASE I
PRELIMINARY LABORATORY STUDIES FOR THE DETERMINATION
OF SOIL MOISTURE CHARACTERISTIC CURVES
AND UNSATURATED HYDRAULIC CONDUCTIVITIES**

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ABSTRACT

Six undisturbed soil samples of near-surface sediments were collected from the Radioactive Waste Management Site (RWMS) for physical and hydrologic characterization in the laboratory. Of these samples, three were obtained from the wall of Pit No. 3 and three from the floor.

Physical properties measured on all samples were dry bulk density (ρ_b) and solid particle density (ρ_s). Average dry bulk densities for the wall and floor samples were 1.47 g/cm³ and 1.45 g/cm³, while solid particle densities were 2.34 g/cc and 2.53 g/cc, respectively. Based on these values, the average porosity for the wall samples was computed to be 0.372 and for the floor samples, 0.427.

Moisture content-pressure head relations for each sample were determined using the pressure plate method. The moisture characteristic curves generated from these data have shapes similar to those of a silty sand, with volumetric moisture contents of less than 7% at 33.4 bars.

Unsaturated hydraulic conductivity was estimated using the computer model of van Genuchten (1978), which is based on the theoretical developments of Mualem (1976). Results indicate that at near-surface in situ moisture contents, the unsaturated hydraulic conductivity for both wall and floor samples is less than 10⁻⁸ cm/sec.

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UNSATURATED ZONE CHARACTERIZATION OF THE AREA 5 RADIOACTIVE WASTE MANAGEMENT SITE

PHASE I PRELIMINARY LABORATORY STUDIES FOR THE DETERMINATION OF SOIL MOISTURE CHARACTERISTIC CURVES AND UNSATURATED HYDRAULIC CONDUCTIVITIES

1.0 INTRODUCTION

- 1.1 **Purpose and Scope.** Characterization of the Nevada Test Site (NTS) Area 5 Radioactive Waste Management Site (RWMS) is being performed in support of performance assessment (PA) studies as required under Title 40 Code of Federal Regulations (CFR) 191, U.S. Department of Energy (DOE) Order 5820.2A, and other federal and state regulations. Characterization data will be used in numerical modeling studies of flow and transport to determine the potential for radionuclide migration to the accessible environment.

In particular, parameter values for the physical, chemical, and hydrologic properties of unsaturated sediments in the vadose zone need to be determined. These parameter values constitute key inputs to numerical flow and transport models and therefore are the focus of this unsaturated zone characterization.

The Reynolds Electrical & Engineering Co., Inc. (REECo) Defense Waste Management Department (DWMD) Special Projects Section (SPS) has organized characterization efforts into four distinct phases. Phase I involves preliminary laboratory work to obtain physical and hydrologic parameter values of core samples using techniques currently in existence, which adhere to written standards or widely accepted practices among hydrologists and soil scientists. Additionally, a portion of the laboratory studies will be devoted to the development of new methods, procedures, and equipment to more accurately determine the unsaturated hydraulic characteristics of the sediments under laboratory conditions. Phase II, which will run concurrently with Phase I, will be a field testing program in which various hydraulic and physical parameters are obtained from the in situ soils. Parameter values obtained in the field will be compared with those obtained from laboratory cores. Results of these comparisons will be used to verify the laboratory results, extend the spatial domain of measurement, and assist in directing further studies. Phase III will

encompass preliminary numerical model evaluations using the data obtained from the laboratory and field studies. Phase IV will be the full model development, evaluation, and calibration.

- 1.2 **Site Description.** The RWMS is located in Frenchman Flat, a closed surface water basin (Figure 1). The basin is characterized by low mountain ranges surrounding a playa lake (Frenchmen Lake). Exposed rocks in the area that serve as the source of the alluvial fill in the basin consist of Tertiary volcanic tuff and ash flows with associated Paleozoic carbonate and quartzite. Bedrock units include sedimentary carbonate, quartzite and sandstone units, ash flow tuffs, tufaceous sandstone, volcanic breccia, and claystone. The alluvial fill covering the bedrock is more than 600 m thick in the center of the basin.

The climate is arid, with an average rainfall of approximately 12 cm/yr and potential evaporation of > 200 cm/yr. Vegetative cover is sparse, and little soil development has taken place. Near-surface soil moisture remains low throughout the year, ranging between 3 and 9% volumetric.

The basin is underlain by an alluvial aquifer with the water table at approximately 270 m below land surface (BLS). The regional aquifer, which is hydraulically connected to the overlying alluvial aquifer, is contained within Paleozoic carbonates. Discharge of the regional groundwater is believed to occur at Ash Meadows, approximately 50 kilometers southwest of Frenchman Flat.

- 1.3 **Previous Research.** A number of studies defining the regional and local geology, climate, hydrogeology, and soils have been performed. Some of the major works of interest are: Carr, et al. (1974), Case et al. (1984), French (1983, 1986), Kearl (1982), Metcalf (1983), Romney et al. (1973, 1981), Winograd et al. (1971), and Winograd and Thordarson (1975).

Field and laboratory measurements of the hydraulic properties of alluvial near-surface sediments have been reported by various authors [Mehuys et al. (1975), Kearl (1982), Romney et al. (1973), and Tyler et al. (1986)]. Mehuys et al. (1975), in their study to determine the effects of stone content on the unsaturated hydraulic conductivity of Rock Valley gravelly sandy loam, used the transient outflow method [Weeks and Richards (1967)] to define the relationship between volumetric moisture content (θ), pressure head (Ψ), and unsaturated

Figure 1. Location map of the RWMS and surrounding basin areas [from Kearl (1982)].

hydraulic conductivity. The results of their study are shown in Figures 2 and 3. Kearl (1982) studied the relationship between θ , Ψ , and $K(\theta, \Psi)$, hydraulic conductivity as a function of either volumetric moisture content or pressure head, for a site near the RWMS using the moisture retention data of Romney et al. (1973) and laboratory measurements of saturated hydraulic conductivity (K_s). The K_s measurements were made on cores taken near the RWMS, while the moisture retention data were for soils taken at several different locations in Frenchman Flat. In his approach, Kearl (1982) took the mean volumetric moisture content values of 52 separate soil samples at 0, 1/3, 1 and 15 bar water potentials, along with the mean K_s value of soils near the RWMS, and applied the soil hydraulic model of Mualem (1976) to derive the $K(\theta)$ curve. This curve is presented in Figure 4.

Tyler et al. (1986) measured the particle size distributions of 14 core samples taken from the Area 3 U3fd subsidence crater. Using the average d_{10} values of these samples and an empirical relationship suggested by Bear (1972), they calculated an average K_s for the soil profile under the crater. To derive $K(\theta, \Psi)$, Tyler et al. (1986) employed the methods of Campbell (1974) and Clapp and Hornberger (1978), which are also based on soil textural properties and empirical coefficients. They did not present tabular or graphical representations of the relationship between $K(\theta)$ or $K(\Psi)$.

As may be noted from the foregoing review of previous work, no study to date has measured all of the relevant hydraulic and physical properties necessary for determining the unsaturated hydraulic conductivity function for soils underlying the Area 5 RWMS. The current study is therefore the preliminary step in addressing the need for a site specific database from which the characterization and modeling efforts can follow.

2.0 SAMPLE COLLECTION

- 2.1 Rational for Location of Sample Sites. Two sets of three soil samples (six samples total) were collected from different locations within Pit No. 3 of the Area 5 RWMS. The first set of samples was collected from different points along the pit wall, at a depth of approximately 107 cm. The second set of samples was collected from beneath the pit floor, at a total depth of approximately 10 m below the natural ground surface.

Figure 2. Hydraulic conductivity-pressure head relation for Rock Valley Alluvium [from Mehuys et al. (1975)].

Figure 3. Moisture characteristic curve for Rock Valley Alluvium [from Mehuys et al. (1975)].

Figure 4. Hydraulic conductivity as a function of degree of saturation for soil near Area 5 RWMS [from Kearn (1982)].

Floor and wall sample data was compared to determine the differences in physical and hydraulic properties that might arise from compressional loading and shear stress to the pit floor sediments imparted by heavy trucks and stacking machinery traffic. The wall samples would therefore be considered "undisturbed" in reference to a completely natural state, while the floor samples would be considered to have been "disturbed" to some degree. Although the wall samples would not, clearly, be at a "natural" initial moisture content due to the proximity of the sample locations to the open face of the pit, the structural condition of the samples could be assumed to reflect those of a sample in its "undisturbed" condition. Sampling from both floor and wall also provided sample sets high and low in the profile without the need for a geologic boring program.

Additionally, choosing different sample locations within each sample set (floor or wall) was an attempt to obtain, within a relatively small number of samples, both a range of sediment types based on visual attributes (primarily range and size of particles) and a spatial distribution over the area of the pit floor and length of the wall. It is recognized, however, that the number of samples was too small to permit any definitive statistical inferences to be made about the spatial heterogeneity of physical and hydraulic properties.

- 2.2 Sample Collection and Stabilization Procedure. Wall samples were excavated as peds directly from the wall face by using small digging tools. The excavated soil ped was then placed by hand on a transportation base that was pre-marked with vertical, horizontal and azimuth references. This was important since one of the first tests to be performed on the soil cores was to measure K_s in three directions with respect to the principal direction of deposition.

Once on the transportation bases, the samples were taken to the laboratory where they were placed in a PVC sleeve and encasing material of calcium sulfate poured into the annular space and allowed to dry. This encasement procedure was required since the peds were generally of irregular shape. In addition, the encasing material formed a tight bond to the outer soil layer of the ped, preventing channeling during the testing for K_s . An in-depth description of the encasement method may be found in Daffern (1989).

Following encasement, the samples were dry cut into various lengths and at various orientations to the principal direction of deposition. K_s of these sample subsections were then determined using the constant head method. The results are summarized in Table 1. The reader is referred to Daffern (1989) for further details on the hydraulic conductivity measurements.

Table 1. Average K_s values of wall and floor samples in the three principal axis directions.

Orientation to Deposition	Average Saturated Hydraulic Conductivity (cm/sec*10 ⁻³)		
	Wall	Floor	Pit*
Vertical	8.08	9.01	8.55
Horizontal	20.92	41.82	31.37
Perpendicular	19.78	21.37	20.58

* Pit samples are also considered floor samples since the pit was excavated in the floor.

3.0 LABORATORY PROCEDURES

- 3.1 In Situ Bulk Density, Particle Density, and Porosity. In situ bulk densities were determined by the wax coating/liquid suspension method, ASTM D1188, "Specific Gravity Using Wax." The in situ water contents were not determined, and therefore the dry bulk densities were not computed.

Particle densities (ρ_s) were determined using the pycnometer method, ASTM D854, "Specific Gravity of Soils." Floor samples were mixed together for a composite determination, as were the wall samples.

Porosity (η) was calculated for wall and floor samples using the average values of bulk and particle densities. No direct measurement of porosity was performed. Due to the lack of dry bulk density values, the average in situ bulk densities were used, making the assumption that the low in situ moisture content would only have a marginal effect on calculated porosities. However, field procedures have been modified to ensure that in the future in situ moisture content is determined for every sample collected.

- 3.2 **Moisture Characteristic Curves.** The moisture characteristic curves for both the wall and floor samples were developed using only soil that passed the No. 10 sieve, as specified under ASTM D3152, "Capillary Moisture Relationships." Soil passing the No. 10 sieve was repacked into six sample rings, three from sieved floor soil and three from sieved wall soil. Using a pressure plate extractor, equilibrium moisture content-pressure head relationships were determined at seven points over the range of 28 cm of water up to approximately 34,000 cm of water. The moisture content at 0 cm of pressure head was assumed to be equal to the calculated porosity, since this parameter was not directly measured. Raw data from all laboratory tests are presented in Appendix A.

4.0 METHODS OF DATA ANALYSIS

- 4.1 **Moisture Characteristic Curves.** Two composite moisture characteristic curves were determined, one for the pit wall and one for the pit floor. This was done by taking the average volumetric moisture content of the three sieved and repacked samples for either the pit floor or wall at each pressure step and by applying a non-linear least squares fitting computer code developed by Van Genuchten (1978) to generate the characteristic curve. The calculated value of moisture content, which is compared to the observed value for the least-squares error analysis, is based on Mualem theory by the equation (Mualem 1976a):

$$\theta = \theta_r + \frac{(\theta_s - \theta_r)}{\left[1 + (\alpha \Psi)^n \right]^m} \quad (1)$$

where θ is the calculated volumetric moisture content at the applied pressure head; Ψ , α , and n are fitting parameters; θ_r and θ_s are the residual and saturated volumetric moisture contents, respectively; and $m = 1 - 1/n$. The parameter α is inversely related to the air-entry pressure of the soil, and n is related to the slope of θ vs. $\log \Psi$. The computer code was used to perform the least-squares fitting, with observed values of $\theta - \Psi$, θ_s , and estimates of α , n , and θ_r as input. Relatively few iterations are required for solution convergence, and output is in terms of fitted values for α , n , and θ_r , with associated confidence intervals. Computer runs were done in which the program

was allowed to optimize the value of θ_r , since this approach resulted in lower sum of squares error. Allowing the program to optimize θ_r values was considered acceptable since the resulting values were very close to those measured at - 3 bars water potential.

- 4.2 **Unsaturated Hydraulic Conductivity.** Mualem (1976) described the theoretical basis for a procedure used to estimate unsaturated hydraulic conductivity from moisture characteristic curves according to the equation:

$$K_r = S_e^{1/2} \left[\frac{\int_0^{S_e} \frac{1}{\Psi(x)} dx}{\int_0^1 \frac{1}{\Psi(x)} dx} \right]^2 \quad (2)$$

where K_r = relative hydraulic conductivity, $\Psi = \Psi(S_e)$ is the pressure head, given here as a function of dimensionless volumetric moisture content:

$$S_e = \frac{(\theta - \theta_r)}{(\theta_s - \theta_r)} \quad (3)$$

The expression relating dimensionless moisture content to the pressure head, and thus the moisture characteristic curve, is given by:

$$S_e = \left[\frac{1}{1 + (\alpha \Psi)^n} \right]^m \quad m = 1 - 1/n \quad (4)$$

where α and n are obtained by non-linear least squares fitting, as described previously.

5.0 RESULTS

- 5.1 **Bulk Density, Particle Density and Porosity.** Table 2 gives the results of laboratory determinations of bulk density, particle density and porosity.

Table 2. Average bulk density, particle density, and porosity of wall and floor samples.

	Bulk Density (g/cm ³)	Particle Density (g/cm ³)	Porosity (cm ³ /cm ³)
Wall samples	1.47	2.34	.372
Floor samples	1.45	2.53	.427

5.2 **Moisture Characteristic Curves.** Table 3 gives the experimental values obtained from laboratory measurements of moisture content-pressure head equilibrium points. The values given in the table for moisture content represent the average of the three samples tested for either the wall or floor. These data are shown plotted in Figures 5 and 6 along with the least-squares curve fit. As would be expected, the two curves are very similar in their general shape. The data in Table 3 indicate that the range of pore size is greater for the floor samples.

Table 3. Moisture content-pressure head relationship for wall and floor samples.

Pressure Head		Moisture Content			
cm of water	bars	Wall Samples		Floor Samples	
		volumetric (cm ³ /cm ³)	saturation (fractional)	volumetric (cm ³ /cm ³)	saturation (fractional)
00.0	0.00	.372	1.00	.427	1.00
30.6	0.03	.372	1.00	.243	0.59
40.8	0.04	.341	0.92	.144	0.34
61.2	0.06	.311	0.84	.139	0.33
71.4	0.07	.199	0.53	.127	0.30
153.0	0.15	.183	0.49	----	----
336.5	0.33	----	----	.159	0.37
12236.9	12.00	----	----	.075	0.18
15092.2	14.80	.097	0.26	----	----
34059.5	33.40	.050	0.13	----	----
34090.1	33.43	----	----	.049	0.11

Figure 5. Composite pressure head-moisture content relation for wall samples.

Figure 6. Composite pressure head-moisture content relation for floor samples.

Also, the largest pores of the floor samples are bigger than the largest ones in the wall samples, as indicated by the low air-entry value of the floor samples (≤ 30 cm of water). There also seems to be some skew in the pore size distribution of the floor samples as compared to the wall samples from the fact that moisture contents in the floor samples dropped at a slower rate than those for the wall samples after the initial air-entry drainage had occurred.

The volumetric moisture content for both wall and floor samples is approximately 0.05 at 33 bars. Neutron logging data from the field show near-surface moisture content values to be in this range, so it can be assumed that in situ pressure heads in the near-surface are less than or near this value (pressure heads being negative in this case). Thermocouple psychrometer data from the Beatty low-level waste site also confirm this conclusion (Nichols, 1986).

There appears to be one experimental error in the floor sample data, since moisture contents increase after the pressure step to 336.5 cm of water. The error could not be located in the original data, and therefore this datum was eliminated in developing the moisture characteristic curve as well as in the calculation of unsaturated hydraulic conductivity.

- 5.3 Unsaturated Hydraulic Conductivity. The optimized α , n , and θ_r parameters are shown in Table 4. The parameters α and n , along with the values of θ_s and θ_r , are used in the Mualem (1976) soil hydraulic model [equations (1), (2), and (4)] to derive the moisture characteristic curve and to calculate unsaturated hydraulic conductivity as a function of either moisture content or pressure head.

Table 4. Optimized values of the α , n , and θ_r parameters.

	α	n	θ_r (cm ³ /cm ³)
Wall samples	.01568	2.2348	.06099
Floor samples	.04813	2.5576	.06422

Unsaturated hydraulic conductivity, plotted as functions of pressure head, volumetric moisture content, and fractional saturation for both wall and floor samples, are shown in Figures 7 through 12.

The curves of unsaturated hydraulic conductivity vs. volumetric moisture content (Figures 7 and 10) reveal several important characteristics of the soils. First, the curves for composite wall and floor samples have almost the same shape. This is an expected result, and a further indication of the similarity in physical and hydrologic behavior. Second, unsaturated hydraulic conductivity drops only 3-4 orders of magnitude for reductions in moisture content from saturation to approximately 0.12 (cm^3/cm^3). Below 0.12 (cm^3/cm^3), a 5% reduction in moisture content [0.12-0.07 (cm^3/cm^3)] results in a further drop of approximately 5 orders of magnitude. For moisture content changes from 0.07 to 0.06 (cm^3/cm^3), unsaturated hydraulic conductivity essentially drops to zero. Since field measured values of volumetric moisture content are in the range of 0.06 to 0.12 (cm^3/cm^3), in situ unsaturated hydraulic conductivity ranges between approximately 10^{-18} to 10^{-5} cm/sec.

The curves of unsaturated hydraulic conductivity vs. pressure head (Figures 9 and 12) would indicate that in the ranges of conductivities expected (10^{-18} to 10^{-5} cm/sec), the pressure head should range from approximately -60,000 cm of water up to -600 cm of water. Since there is no site-specific pressure head data available at this time, these values cannot be confirmed.

6.0 SUMMARY AND CONCLUSIONS

Six undisturbed soil samples were tested in the laboratory for physical and hydraulic properties. The results indicate that the samples from the wall and floor of the pit are similar, both physically and hydrologically. In addition, the values obtained for the various physical and hydraulic parameters compare favorably with those published in the general literature for similar types of soils.

For the range of moisture contents measured in the field, it is expected that in situ pressure heads are quite low and would be expected to range in the thousands of cm of negative pressure. From this fact, the thermocouple psychrometer is the recommended instrument for measuring pressure heads. In terms of flow and transport, vapor

Figure 7. Hydraulic conductivity vs. volumetric moisture content, composite wall samples.

Figure 8. Hydraulic conductivity vs. fractional saturation, composite wall samples.

Figure 9. Hydraulic conductivity vs. pressure head, composite wall samples.

Figure 10. Hydraulic conductivity vs. volumetric moisture content, composite floor samples.

Figure 11. Hydraulic conductivity vs. fractional saturation overlapping composite floor samples.

Figure 12. Hydraulic conductivity vs. pressure head, composite floor samples.

phase movement may comprise a large fraction of the soil water movement at these very low moisture contents and pressure heads. Nonvolatile compounds, such as calcium carbonate, would be precipitated and bound to the solid media.

7.0 FUTURE WORK

More undisturbed core will be taken from several different areas and depths in order to begin to determine the spatial variability of unsaturated hydraulic conductivity. A large number of samples are needed in order to obtain statistical parameters with high degrees of certainty. In particular, enough samples will be taken in order to obtain the probability distribution functions of the α and n Mualem parameters.

APPENDIX A
LABORATORY DATA

Bulk Density, Particle Density, and Porosity

SPECIFIC GRAVITY USING WAX COATING ASTM D1188-71	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I. D. NO. <u>51080</u> DATE <u>1-12-89</u>
WALL		
Requested by <u>L. Ebeling</u> User/Agency <u>REECO</u> Material <u>Native</u> Project <u>RWMP</u> Location <u>A --5 Pit #3</u> Sampled by <u>D. Daffern</u> Date Sampled <u>07/27/88</u> Tested by <u>D. Daffern</u> Computed by <u>D. Daffern</u> Checked by _____ Information transmitted to <u>N/A</u> By _____ How _____ Date _____		
LAB. NO. <u>4796, 4797, 4798</u> WT. UNCOATED MATERIAL: <u>45.20</u> WET WEIGHT: _____ WT. COATED MATERIAL: <u>49.16</u> DRY WEIGHT: _____ WT. COATED MATERIAL IN WATER: <u>15.98</u> WATER WEIGHT: _____ Bulk Density : <u>1.555</u> % MOISTURE: <u>N/A</u> <p align="center">Bulk Density - 1.555 gm/cc = 97.03 lb/ft³</p>		
LAB. NO. <u>4796, 4797, 4798</u> WT. UNCOATED MATERIAL: <u>147.36</u> WET WEIGHT: _____ WT. COATED MATERIAL: <u>162.25</u> DRY WEIGHT: _____ WT. COATED MATERIAL IN WATER: <u>43.66</u> WATER WEIGHT: _____ Bulk Density : <u>1.429</u> % MOISTURE: <u>N/A</u> <p align="center">Bulk Density - 1.429 gm/cc = 89.17 lb/ft³</p>		
LAB. NO. <u>4796, 4797, 4798</u> WT. UNCOATED MATERIAL: <u>86.00</u> WET WEIGHT: _____ WT. COATED MATERIAL: <u>94.38</u> DRY WEIGHT: _____ WT. COATED MATERIAL IN WATER: <u>26.33</u> WATER WEIGHT: _____ Bulk Density : <u>1.449</u> % MOISTURE: <u>N/A</u> <p align="center">Bulk Density - 1.449 gm/cc = 90.42 lb/ft³</p>		
LAB. NO. <u>4796, 4797, 4798</u> WT. UNCOATED MATERIAL: <u>169.71</u> WET WEIGHT: _____ WT. COATED MATERIAL: <u>182.22</u> DRY WEIGHT: _____ WT. COATED MATERIAL IN WATER: <u>52.41</u> WATER WEIGHT: _____ Bulk Density : <u>1.449</u> % MOISTURE: <u>N/A</u> <p align="center">Bulk Density - 1.449 gm/cc = 90.42 lb/ft³</p>		
SPECIFIC GRAVITY = WT. UNCOATED MAT. ÷ [WT. COATED MAT. - WT. COATED MAT. IN WATER - ($\frac{\text{WT. COATED MAT. - WT. UNCOATED MAT.}}{\text{SPECIFIC GRAVITY OF WAX}}$)]		
REMARKS: <p align="center">Average Bulk Density - 91.76 lb/ft³ Wax Density - .9623</p>		

FORM 3844 (6/74)

Figure A-1. Specific Gravity-Bulk Density Data (Wall).

SPECIFIC GRAVITY USING WAX COATING ASTM D1188-71	HOLMES & HARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I. D. NO. <u>51054</u> DATE <u>03/28/89</u>
FLOOR		
Requested by <u>L. Ebeling</u> User/Agency <u>REECO</u> Material <u>Native</u> Project <u>RWMP</u> Location <u>Area 5</u> Sampled by <u>D. Daffern</u> Date Sampled <u>03/02/89</u> Tested by <u>D. Daffern</u> Computed by <u>D. Daffern</u> Checked by _____ Information transmitted to <u>N/A</u> By <u>N/A</u> How <u>N/A</u> Date <u>N/A</u>		
LAB. NO. <u>3463</u> WT. UNCOATED MATERIAL: <u>68.40 gm</u> WET WEIGHT: <u>N/A</u> WT. COATED MATERIAL: <u>79.29 gm</u> DRY WEIGHT: <u>N/A</u> WT. COATED MATERIAL IN WATER: <u>23.00 gm</u> WATER WEIGHT: <u>N/A</u> Bulk Density: <u>1.518</u> % MOISTURE: <u>N/A</u> Water Temperature <u>19.1° C</u>		
LAB. NO. <u>3463</u> WT. UNCOATED MATERIAL: <u>31.37</u> WET WEIGHT: <u>N/A</u> WT. COATED MATERIAL: <u>36.93</u> DRY WEIGHT: <u>N/A</u> WT. COATED MATERIAL IN WATER: <u>9.68</u> WATER WEIGHT: <u>N/A</u> Bulk Density: <u>1.458</u> % MOISTURE: <u>N/A</u> Water Temperature <u>19.1° C</u>		
LAB. NO. <u>3463</u> WT. UNCOATED MATERIAL: <u>9.82</u> WET WEIGHT: <u>N/A</u> WT. COATED MATERIAL: <u>11.83</u> DRY WEIGHT: <u>N/A</u> WT. COATED MATERIAL IN WATER: <u>2.68</u> WATER WEIGHT: <u>N/A</u> Bulk Density: <u>1.388</u> % MOISTURE: <u>N/A</u> Water Temperature <u>19.1° C</u>		
LAB. NO. <u>3463</u> WT. UNCOATED MATERIAL: <u>8.72</u> WET WEIGHT: <u>N/A</u> WT. COATED MATERIAL: <u>10.05</u> DRY WEIGHT: <u>N/A</u> WT. COATED MATERIAL IN WATER: <u>2.63</u> WATER WEIGHT: <u>N/A</u> Bulk Density: <u>1.441</u> % MOISTURE: <u>N/A</u> Water Temperature <u>19.1° C</u>		
$\text{SPECIFIC GRAVITY} = \frac{\text{WT. UNCOATED MAT.} + \left[\frac{\text{WT. COATED MAT.} - \text{WT. COATED MAT. IN WATER}}{\text{SPECIFIC GRAVITY OF WAX}} \right]}{\text{WT. COATED MAT.} - \text{WT. COATED MAT. IN WATER}}$		
REMARKS: FLOOR SAMPLES Equipment Used: <u>Mettler PK 4800, Cal Due: 06/22/89</u> <div style="text-align: right;"> Average Bulk Density = <u>1.451 gm/cc</u> <u>90.56 lb/cu ft</u> </div>		

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Figure A-2. Specific Gravity-Bulk Density (Floor).

Moisture Content - Pressure Head

TEST NO.	WATER POTENTIAL (psi)	WATER POTENTIAL (bars *)	WATER POTENTIAL (cm of H ₂ O)	WET WEIGHT (gm)	DRY WEIGHT (gm)	TARE WEIGHT (gm)	PORE VOLUME SATURATION (%)	VOLUMETRIC MOISTURE (%)
1	0.44	0.03	30.6	53.54	46.11	17.77	100.0	37.2
2	0.44	0.03	30.6	53.16	45.71	17.54	100.0	37.2
3	0.44	0.03	30.6	51.18	44.25	17.81	100.0	37.2
4	0.58	0.04	40.8	54.02	47.58	17.79	85.5	31.8
5	0.58	0.04	40.8	56.61	48.59	17.56	100.0	37.2
6	0.58	0.04	40.8	56.02	48.85	17.81	89.8	33.4
7	0.87	0.06	61.2	49.25	44.17	17.79	76.1	28.3
8	0.87	0.06	61.2	52.12	45.74	17.70	80.0	33.5
9	0.87	0.06	61.2	50.27	44.59	17.95	84.3	31.4
10	1.02	0.07	71.4	47.98	44.50	17.80	51.5	19.2
11	1.02	0.07	71.4	47.71	43.99	17.54	55.6	20.7
12	1.02	0.07	71.4	47.68	44.15	17.84	53.0	19.7
13	2.18	0.15	153.0	50.19	46.68	17.78	48.0	17.9
14	2.18	0.15	153.0	49.85	46.15	17.53	51.1	19.0
15	2.18	0.15	153.0	49.37	45.83	17.81	48.4	18.0
16	214.7	14.8	15092.2	46.69	44.93	17.79	25.6	9.5
17	214.7	14.8	15092.2	47.23	45.39	17.56	26.1	9.7
18	214.7	14.8	15092.2	46.88	45.02	17.81	27.0	10.1
19	484.4	33.4	34059.5	46.29	45.20	16.07	14.8	5.5
20	484.4	33.4	34059.5	44.76	43.85	16.29	13.1	4.9
21	484.4	33.4	34059.5	44.10	43.23	16.18	12.7	4.7

0.372 = Undisturbed Sample Porosity
1.47 = Undisturbed Sample Bulk Volume
2.34 = Sample Grain Density

* - BAR = 14.495 psi

Figure A-5. Capillary Moisture Relationship for DWMD Pit No. 3 (Wall).

TEST NO.	WATER POTENTIAL (psi)	WATER POTENTIAL (bars *)	WATER POTENTIAL (cm of H ₂ O)	WET WEIGHT (gm)	DRY WEIGHT (gm)	TARE WEIGHT (gm)	PORE VOLUME SATURATION (%)	VOLUMETRIC MOISTURE (%)
1	0.44	0.03	30.6	46.82	42.45	16.11	56.4	24.0
2	0.44	0.03	30.6	45.41	41.43	16.84	55.0	23.4
3	0.44	0.03	30.6	45.84	41.45	16.56	59.9	25.5
4	0.58	0.04	40.8	45.34	42.50	16.22	36.7	15.6
5	0.58	0.04	40.8	46.16	43.41	16.20	34.3	14.6
6	0.58	0.04	40.8	47.55	44.97	16.33	30.6	13.0
7	0.87	0.06	61.2	45.74	43.15	16.13	32.6	13.9
8	0.87	0.06	61.2	45.54	42.96	15.90	32.4	13.8
9	0.87	0.06	61.2	46.06	43.41	15.15	33.0	14.1
10	1.02	0.07	71.4	45.20	42.83	16.31	29.0	12.3
11	1.02	0.07	71.4	46.36	43.04	16.26	28.7	12.7
12	1.02	0.07	71.4	47.50	44.90	16.35	30.9	13.2
13	4.8	0.33	336.5	44.11	42.2	17.78	26.6	11.3
14	4.8	0.33	336.5	49.85	46.15	17.53	43.9	18.7
15	4.8	0.33	336.5	49.37	45.93	17.81	41.6	17.7
16	174.0	12.0	12236.9	44.64	43.20	16.24	18.1	7.7
17	174.0	12.0	12236.9	45.40	43.98	16.04	17.3	7.4
18	174.0	12.0	12236.9	46.09	44.63	16.27	17.5	7.4
19	484.9	33.43	34090.1	45.67	44.74	16.10	11.0	4.7
20	484.9	33.43	34090.1	45.26	44.30	16.29	11.6	5.0
21	484.9	33.43	34090.1	44.76	43.83	16.29	11.5	4.9

0.427 = Undisturbed Sample Porosity
 1.45 = Undisturbed Sample Bulk Volume
 2.53 = Sample Grain Density

* - 1 BAR = 14.495 psi

Figure A-6. Capillary Moisture Relationship for DWMD Pit No. 3 (Floor).

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