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DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Hydraulic Properties of Los Alamos National Laboratory Technical Area 21, Operable Unit 1106 Soil Samples

Prepared for

Los Alamos National Laboratory

Los Alamos, New Mexico

August 7, 1997

RECEIVED
OCT 30 2003
By EK

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ER ID NO. 76085 ***Date Received:*** 10/30/2003 ***Processor:*** EMR ***Page Count:*** 76

Privileged: (Y/N) N ***Record Category:*** P

FileFolder: N/A

Correction: (Y/N) N ***Corrected No.*** 0 ***Corrected By Number:*** 0

Administrative Record: (Y/N) Y

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Miscellaneous Comments:

REFERENCED

#76085

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Summary

The Hydrologic Testing and Research Laboratory at Daniel B. Stephens & Associates, Inc. (DBS&A) has completed testing on the Los Alamos National Laboratory soil samples as summarized in Table 1. Tables 2 through 5 give the results of the specified analyses. Raw laboratory data and graphical plots of data (where appropriate) are contained in the appendix.

All samples were received in good condition and in ample quantities to perform all testing procedures requested. All testing results were evaluated subjectively for consistency and reasonableness. DBS&A does not assume any responsibility for interpretations or analyses bases on the data enclosed, nor can we guarantee that these data are fully representative of the undisturbed materials at the field site. We recommend that careful evaluation of these laboratory results be made for your particular application.

Table 1. Summary of Tests Performed

Laboratory Sample Number	Initial Soil Properties[1] (ρ_0, θ, ϕ)	Saturated Hydraulic Conductivity[2]		Moisture Characteristics[3]				Unsaturated Hydraulic Conductivity	Particle Size[4]			Effective Porosity	Particle Density	Air Permeability	Atterberg Limits	Proctor Compaction
		CH	FH	HC	PP	TH	RH		DS	WS	H					
0121-97-1321	X	X		X	X	X		X								
0121-97-1322	X	X		X	X	X		X								
0121-97-1323	X	X		X	X	X		X								
0121-97-1324	X	X		X	X	X		X								
0121-97-1325	X	X		X	X	X		X								
0121-97-1326	X	X		X	X	X		X								
0121-97-1327	X	X		X	X	X		X								

[1] ρ_0 = Initial moisture content, θ = Dry bulk density, ϕ = Calculated porosity
[2] CH = Constant head, FH = falling head
[3] HC = Hanging column, PP = Pressure plate, TH = Thermocouple psychrometer, RH = Relative humidity box
[4] DS = Dry sieve, WS = Wet sieve, H = Hydrometer

Table 2. Summary of Initial Moisture Content, Dry Bulk Density Wet Bulk Density and Calculated Porosity

Sample Number	Initial Moisture Content Gravimetric (%, g/g)	Initial Moisture Content Volumetric (%, cm^3/cm^3)	Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
0121-97-1321	18.1	24.3	1.34	1.58	49.4
0121-97-1322	22.1	29.0	1.31	1.60	50.6
0121-97-1323	20.8	26.8	1.29	1.56	51.3
0121-97-1324	25.9	30.9	1.19	1.50	55.1
0121-97-1325	18.5	24.0	1.30	1.54	51.0
0121-97-1326	20.2	25.3	1.25	1.51	52.7
0121-97-1327	18.6	23.3	1.25	1.49	52.7

Table 3. Summary of Saturated Hydraulic Conductivity Tests

Sample Number	K_{sat} (cm/sec)	Method of Analysis	
		Constant Head	Falling Head
0121-97-1321	7.3E-03	X	
0121-97-1322	5.2E-03	X	
0121-97-1323	9.5E-03	X	
0121-97-1324	9.9E-03	X	
0121-97-1325	1.1E-02	X	
0121-97-1326	9.4E-03	X	
0121-97-1327	6.5E-03	X	

Table 4. Summary of Moisture Characteristics of the Initial Drainage Curve

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
0121-97-1321	0	45.6
	10	44.6
	41	28.9
	82	24.8
	255	20.5
	3263	14.9
	17541	9.8
0121-97-1322	0	41.1
	11	39.9
	42	30.4
	82	27.3
	255	23.6
	3161	15.3
	12951	11.1
0121-97-1323	0	41.0
	13	38.3
	40	27.2
	82	22.0
	255	19.6
	3467	13.2
	20804	8.7
0121-97-1324	0	46.0
	13	42.8
	40	32.1
	82	25.5
	255	22.7
	3059	18.1
	14991	12.9

Table 4. Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
0121-97-1325	0	38.6
	14	37.3
	40	25.5
	82	22.5
	255	19.5
	3263	15.9
	13869	11.0
0121-97-1326	0	45.7
	10	41.7
	41	30.0
	82	26.6
	255	23.0
	2957	15.4
	13053	9.4
0121-97-1327	0	43.4
	11	42.3
	42	28.3
	82	25.3
	255	21.6
	3263	16.5
	11932	11.7

Table 5. Summary of Calculated Unsaturated Hydraulic Properties

Sample Number	α (cm^{-1}) Calculated Value	α 95% Confidence Limits Lower	α 95% Confidence Limits Upper	N (dimensionless) Calculated Value	N 95% Confidence Limits Lower	N 95% Confidence Limits Upper	θ_r (%)	θ_s (%)
0121-97-1321	0.0630	-0.0580	0.1839	1.5452	0.7807	2.3097	0.1111	0.4680
0121-97-1322	0.0696	-0.0780	0.2172	1.2635	0.8088	1.7181	0.0587	0.4186
0121-97-1323	0.0648	-0.0559	0.1854	1.4773	0.8198	2.1348	0.0932	0.4179
0121-97-1324	0.0580	-0.0371	0.1530	1.5759	0.8311	2.3207	0.1440	0.4661
0121-97-1325	0.0537	-0.0605	0.1678	1.6415	0.5091	2.7738	0.1300	0.3950
0121-97-1326	0.1175	-0.1464	0.3814	1.2545	0.8356	1.6735	0.0431	0.4622
0121-97-1327	0.0618	-0.0689	0.1925	1.5432	0.6778	2.4087	0.1296	0.4448

Appendix A

Initial Moisture Content, Bulk Density, and Porosity

Summary of Initial Moisture Content, Dry Bulk Density Wet Bulk Density and Calculated Porosity

Sample Number	Initial Moisture Content Gravimetric (%, g/g)	Initial Moisture Content Volumetric (%, cm^3/cm^3)	Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
0121-97-1321	18.1	24.3	1.34	1.58	49.4
0121-97-1322	22.1	29.0	1.31	1.60	50.6
0121-97-1323	20.8	26.8	1.29	1.56	51.3
0121-97-1324	25.9	30.9	1.19	1.50	55.1
0121-97-1325	18.5	24.0	1.30	1.54	51.0
0121-97-1326	20.2	25.3	1.25	1.51	52.7
0121-97-1327	18.6	23.3	1.25	1.49	52.7

DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name: LANL
Job Number: 7813.01
Sample Number: 0121-97-1321
Ring Number: 1321
Depth: 18.4-18.8

Test Date: 16-May-97

Field weight of sample* (g): 1062.54
Tare weight, ring (g): 252.37
Tare weight, cap/plate/epoxy (g): 114.04

Dry weight of sample (g): 589.31
Sample volume (cm^3): 439.26
Assumed particle density: 2.65

Initial Volumetric Moisture Content (% vol): 24.3

Initial Gravimetric Moisture Content (% g/g): 18.1

Dry bulk density (g/cm^3): 1.34

Wet bulk density (g/cm^3): 1.58

Calculated Porosity (% vol): 49.4

Percent Saturation: 49.3

Comments:

* Weight including tares

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name: LANL
Job Number: 7813.01
Sample Number: 0121-97-1322
Ring Number: 1322
Depth: 18.8-19.2

Test Date: 16-May-97

Field weight of sample* (g): 1389.61
Tare weight, ring (g): 335.28
Tare weight, cap/plate/epoxy (g): 114.05

Dry weight of sample (g): 769.98
Sample volume (cm^3): 587.94
Assumed particle density: 2.65

Initial Volumetric Moisture Content (% vol): 29.0

Initial Gravimetric Moisture Content (% g/g): 22.1

Dry bulk density (g/cm^3): 1.31

Wet bulk density (g/cm^3): 1.60

Calculated Porosity (% vol): 50.6

Percent Saturation: 57.3

Comments:

* Weight including tares

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name: LANL
Job Number: 7813.01
Sample Number: 0121-97-1323
Ring Number: 1323
Depth: 19.2-19.6

Test Date: 16-May-97

Field weight of sample* (g): 1085.25
Tare weight, ring (g): 256.86
Tare weight, cap/plate/epoxy (g): 114.06

Dry weight of sample (g): 591.55
Sample volume (cm^3): 458.27
Assumed particle density: 2.65

Initial Volumetric Moisture Content (% vol): 26.8

Initial Gravimetric Moisture Content (% g/g): 20.8

Dry bulk density (g/cm^3): 1.29

Wet bulk density (g/cm^3): 1.56

Calculated Porosity (% vol): 51.3

Percent Saturation: 52.2

Comments:

* Weight including tares

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

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ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name: LANL
Job Number: 7813.01
Sample Number: 0121-97-1324
Ring Number: 1324
Depth: 19.6-20.0

Test Date: 16-May-97

Field weight of sample* (g): 1124.40
Tare weight, ring (g): 289.25
Tare weight, cap/plate/epoxy (g): 114.07

Dry weight of sample (g): 572.65
Sample volume (cm^3): 481.12
Assumed particle density: 2.65

Initial Volumetric Moisture Content (% vol): 30.9

Initial Gravimetric Moisture Content (% g/g): 25.9

Dry bulk density (g/cm^3): 1.19

Wet bulk density (g/cm^3): 1.50

Calculated Porosity (% vol): 55.1

Percent Saturation: 56.0

Comments:

* Weight including tares

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

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ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name: LANL
Job Number: 7813.01
Sample Number: 0121-97-1325
Ring Number: 1325
Depth: 21.4-21.8

Test Date: 15-May-97

Field weight of sample* (g): 1349.56
Tare weight, ring (g): 334.13
Tare weight, cap/plate/epoxy (g): 114.00

Dry weight of sample (g): 760.60
Sample volume (cm^3): 585.68
Assumed particle density: 2.65

Initial Volumetric Moisture Content (% vol): 24.0

Initial Gravimetric Moisture Content (% g/g): 18.5

Dry bulk density (g/cm^3): 1.30

Wet bulk density (g/cm^3): 1.54

Calculated Porosity (% vol): 51.0

Percent Saturation: 47.2

Comments:

* Weight including tares

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name: LANL
Job Number: 7813.01
Sample Number: 0121-97-1326
Ring Number: 1326
Depth: 21.8-22.2

Test Date: 16-May-97

Field weight of sample* (g): 1011.87
Tare weight, ring (g): 243.92
Tare weight, cap/plate/epoxy (g): 114.07

Dry weight of sample (g): 544.07
Sample volume (cm^3): 434.11
Assumed particle density: 2.65

Initial Volumetric Moisture Content (% vol): 25.3

Initial Gravimetric Moisture Content (% g/g): 20.2

Dry bulk density (g/cm^3): 1.25

Wet bulk density (g/cm^3): 1.51

Calculated Porosity (% vol): 52.7

Percent Saturation: 48.0

Comments:

* Weight including tares

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name: LANL
Job Number: 7813.01
Sample Number: 0121-97-1327
Ring Number: 1327
Depth: 22.2-22.6

Test Date: 15-May-97

Field weight of sample* (g): 1320.38
Tare weight, ring (g): 331.41
Tare weight, cap/plate/epoxy (g): 114.02

Dry weight of sample (g): 737.65
Sample volume (cm^3): 588.71
Assumed particle density: 2.65

Initial Volumetric Moisture Content (% vol): 23.3

Initial Gravimetric Moisture Content (% g/g): 18.6

Dry bulk density (g/cm^3): 1.25

Wet bulk density (g/cm^3): 1.49

Calculated Porosity (% vol): 52.7

Percent Saturation: 44.2

Comments:

* Weight including tares

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

Appendix B

Saturated Hydraulic Conductivity

Summary of Saturated Hydraulic Conductivity Tests

Sample Number	K_{sat} (cm/sec)	Method of Analysis	
		Constant Head	Falling Head
0121-97-1321	7.3E-03	X	
0121-97-1322	5.2E-03	X	
0121-97-1323	9.5E-03	X	
0121-97-1324	9.9E-03	X	
0121-97-1325	1.1E-02	X	
0121-97-1326	9.4E-03	X	
0121-97-1327	6.5E-03	X	

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Saturated Hydraulic Conductivity
Constant Head Method

Job name: LANL
Job number: 7813.01
Sample number: 0121-97-1321
Ring number: 1321
Depth: 18.4-18.8

Type of water used: TAP
Collection vessel tare (g): 10.96
Sample length (cm): 7.68
Sample diameter (cm): 8.54
Sample x-sectional area (cm^2): 57.21

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm^3)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
27-May-97	09:04:54	20.0	2.8	29.9	18.9	120	7.5E-03	7.5E-03
27-May-97	09:06:54							
Test # 2:								
28-May-97	08:31:24	20.5	2.7	29.0	18.1	120	7.5E-03	7.4E-03
28-May-97	08:33:24							
Test # 3:								
29-May-97	16:30:00	20.5	2.8	37.0	26.1	180	6.9E-03	6.9E-03
29-May-97	16:33:00							

***Average Ksat* (cm/sec):** **7.3E-03**

Comments:

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

Saturated Hydraulic Conductivity
Constant Head Method

Job name: LANL
Job number: 7813.01
Sample number: 0121-97-1322
Ring number: 1322
Depth: 18.8-19.2

Type of water used: TAP
Collection vessel tare (g): 11.25
Sample length (cm): 10.19
Sample diameter (cm): 8.57
Sample x-sectional area (cm^2): 57.68

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm^3)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
22-May-97	10:37:00	21.0	6.2	22.3	11.1	60	5.3E-03	5.1E-03
22-May-97	10:38:00							
Test # 2:								
27-May-97	09:13:54	20.0	0.8	17.0	5.7	240	5.3E-03	5.3E-03
27-May-97	09:17:54							
Test # 3:								
28-May-97	08:32:01	20.5	0.9	15.9	4.7	180	5.1E-03	5.0E-03
28-May-97	08:35:01							

***Average Ksat* (cm/sec):** **5.2E-03**

Comments:

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

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ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Saturated Hydraulic Conductivity
Constant Head Method

Job name: LANL
Job number: 7813.01
Sample number: 0121-97-1323
Ring number: 1323
Depth: 19.2-19.6

Type of water used: TAP
Collection vessel tare (g)*:* 10.63
Sample length (cm)*:* 7.94
Sample diameter (cm)*:* 8.57
Sample x-sectional area (cm^2)*:* 57.72

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm^3)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
19-May-97	08:09:02	21.0	6.2	47.2	36.6	88	9.2E-03	9.0E-03
19-May-97	08:10:30							
Test # 2:								
20-May-97	08:26:44	21.5	6.2	37.4	26.8	60	9.9E-03	9.6E-03
20-May-97	08:27:44							
Test # 3:								
21-May-97	15:09:04	21.0	6.2	37.9	27.2	60	1.0E-02	9.8E-03
21-May-97	15:10:04							

Average Ksat* (cm/sec)*: **9.5E-03**

Comments:

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Saturated Hydraulic Conductivity
Constant Head Method

Job name: LANL
Job number: 7813.01
Sample number: 0121-97-1324
Ring number: 1324
Depth: 19.6-20.0

Type of water used: TAP
Collection vessel tare (g): 11.25
Sample length (cm): 8.37
Sample diameter (cm): 8.56
Sample x-sectional area (cm^2): 57.52

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm^3)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
19-May-97	08:09:17	21.0	5.9	53.1	41.8	108	9.5E-03	9.3E-03
19-May-97	08:11:05							
Test # 2:								
20-May-97	08:27:20	21.5	5.8	35.9	24.6	60	1.0E-02	9.9E-03
20-May-97	08:28:20							
Test # 3:								
22-May-97	10:21:40	21.0	5.8	36.8	25.5	60	1.1E-02	1.0E-02
22-May-97	10:22:40							

***Average Ksat* (cm/sec): 9.9E-03**

Comments:

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Saturated Hydraulic Conductivity
Constant Head Method

Job name: LANL
Job number: 7813.01
Sample number: 0121-97-1325
Ring number: 1325
Depth: 21.4-21.8

Type of water used: TAP
Collection vessel tare (g): 10.82
Sample length (cm): 10.15
Sample diameter (cm): 8.57
Sample x-sectional area (cm^2): 57.68

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm^3)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
19-May-97	08:13:22	21.0	2.6	39.2	28.4	192	1.0E-02	9.8E-03
19-May-97	08:16:34							
Test # 2:								
20-May-97	08:30:30	21.5	2.7	25.7	14.8	90	1.1E-02	1.0E-02
20-May-97	08:32:00							
Test # 3:								
22-May-97	10:37:11	21.0	2.7	32.7	21.9	120	1.2E-02	1.2E-02
22-May-97	10:39:11							

***Average Ksat* (cm/sec):** **1.1E-02**

Comments:

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Saturated Hydraulic Conductivity
Constant Head Method

Job name: LANL
Job number: 7813.01
Sample number: 0121-97-1326
Ring number: 1326
Depth: 21.8-22.2

Type of water used: TAP
Collection vessel tare (g): 10.63
Sample length (cm): 7.51
Sample diameter (cm): 8.58
Sample x-sectional area (cm^2): 57.78

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm^3)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
22-May-97	10:27:16	20.0	3.4	25.7	15.0	60	9.6E-03	9.5E-03
22-May-97	10:28:16							
Test # 2:								
27-May-97	09:11:21	20.0	3.2	38.9	28.2	120	9.6E-03	9.5E-03
27-May-97	09:13:21							
Test # 3:								
28-May-97	08:31:46	20.5	3.3	38.8	28.2	120	9.3E-03	9.1E-03
28-May-97	08:33:46							

***Average Ksat* (cm/sec):** **9.4E-03**

Comments:

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Saturated Hydraulic Conductivity
Constant Head Method

Job name: LANL
Job number: 7813.01
Sample number: 0121-97-1327
Ring number: 1327
Depth: 22.2-22.6

Type of water used: TAP
Collection vessel tare (g): 11.32
Sample length (cm): 10.19
Sample diameter (cm): 8.58
Sample x-sectional area (cm^2): 57.77

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm^3)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
22-May-97	10:36:48	21.0	1.6	18.4	7.1	118	6.6E-03	6.4E-03
22-May-97	10:38:46							
Test # 2:								
27-May-97	09:14:14	20.0	1.1	20.7	9.4	240	6.3E-03	6.3E-03
27-May-97	09:18:14							
Test # 3:								
28-May-97	08:32:17	20.5	1.0	18.3	6.9	180	6.8E-03	6.7E-03
28-May-97	08:35:17							

***Average Ksat* (cm/sec):** **6.5E-03**

Comments:

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

Appendix C

Moisture Characteristics

Summary of Moisture Characteristics of the Initial Drainage Curve

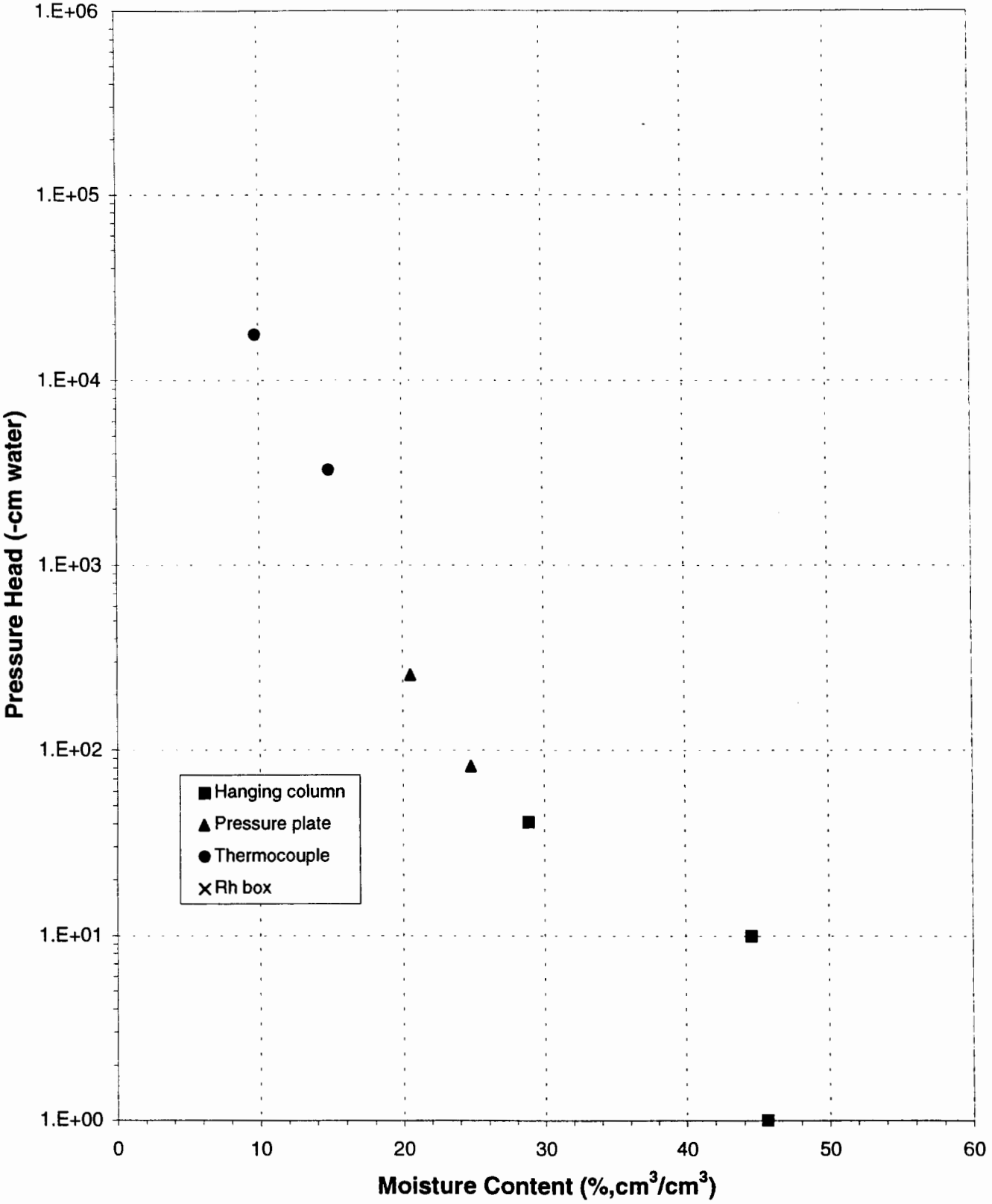
Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
0121-97-1321	0	45.6
	10	44.6
	41	28.9
	82	24.8
	255	20.5
	3263	14.9
	17541	9.8
0121-97-1322	0	41.1
	11	39.9
	42	30.4
	82	27.3
	255	23.6
	3161	15.3
	12951	11.1
0121-97-1323	0	41.0
	13	38.3
	40	27.2
	82	22.0
	255	19.6
	3467	13.2
	20804	8.7
0121-97-1324	0	46.0
	13	42.8
	40	32.1
	82	25.5
	255	22.7
	3059	18.1
	14991	12.9

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
0121-97-1325	0	38.6
	14	37.3
	40	25.5
	82	22.5
	255	19.5
	3263	15.9
	13869	11.0
0121-97-1326	0	45.7
	10	41.7
	41	30.0
	82	26.6
	255	23.0
	2957	15.4
	13053	9.4
0121-97-1327	0	43.4
	11	42.3
	42	28.3
	82	25.3
	255	21.6
	3263	16.5
	11932	11.7

Water Retention Data Points

Sample Number: 0121-97-1321



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ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: LANL
Job Number: 7813
Sample Number: 0121-97-1322
Ring Number: 1322
Depth: 18.8-19.2

Dry wt. of sample (g): 769.98
Tare wt., screen & clamp (g): 2.77
Tare wt., ring (g): 335.28
Tare wt., epoxy (g): 0.00
Sample volume (cm^3): 587.94

Saturated weight at 0 cm tension* (g): 1349.85
Volume of water† in saturated sample (cm^3): 241.82
Saturated moisture content (% vol): 41.13

	Date/Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content† (% vol)
Hanging column:	03-Jun-97 / 15:30	1349.85	0.00	41.13
	06-Jun-97 / 16:45	1342.56	11.00	39.89
	09-Jun-97 / 10:00	1286.88	42.00	30.42
Pressure plate:	11-Jun-97 / 10:00	1268.77	81.58	27.34
	18-Jun-97 / 08:00	1246.86	254.95	23.61

Dry weight of thermocouple sample* (g): 1235.35
Tare weight, jar (g): 465.37
Sample bulk density (g/cm^3): 1.31

	Date/Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content† (% vol)
Thermocouple:	17-Jul-97 / 10:30	1325.53	3161.4	15.34
	18-Jul-97 / 12:45	1300.64	12951.5	11.10

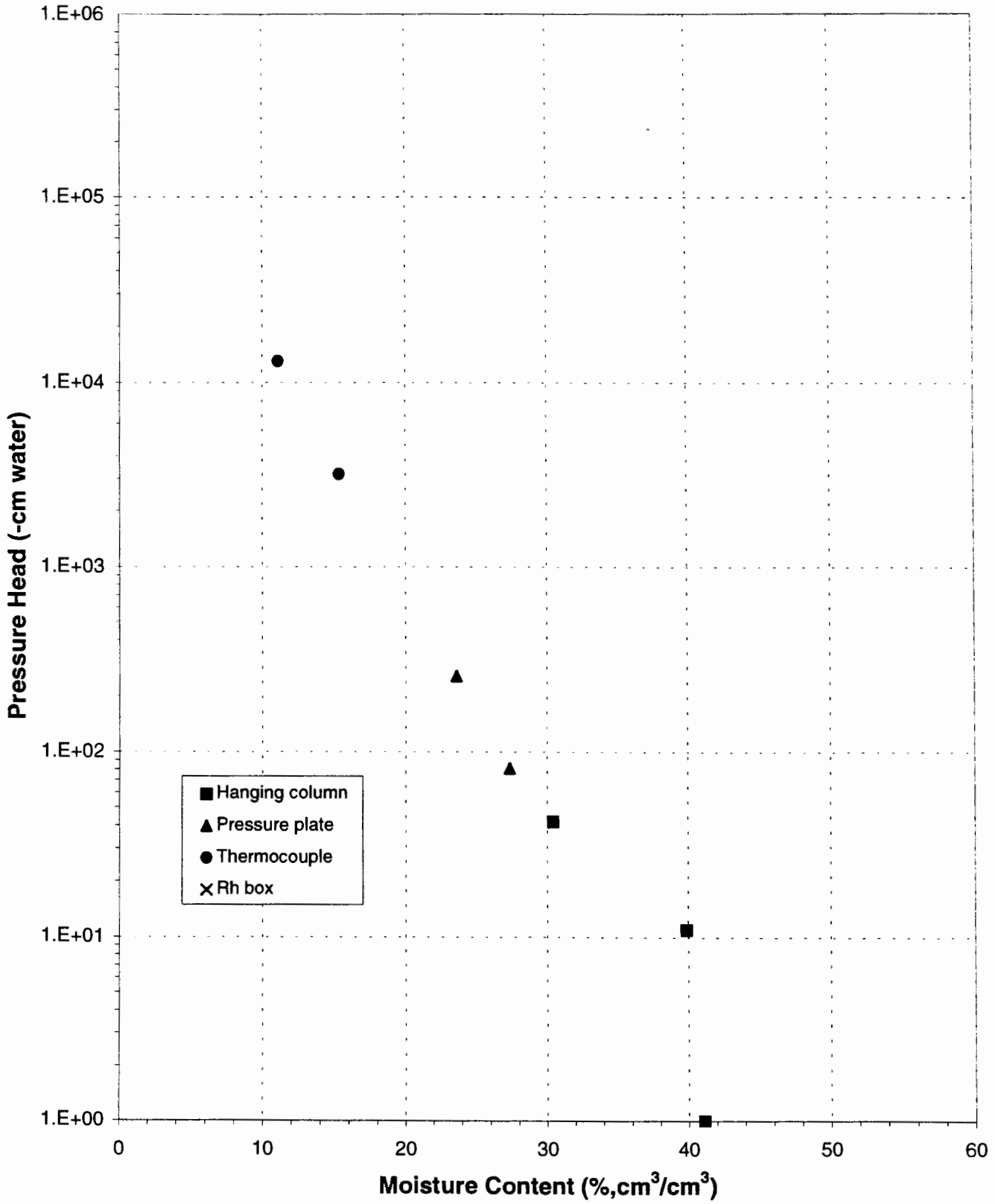
Comments:

* Weight including tares
† Assumed density of water is 1.0 g/cm^3

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

Water Retention Data Points

Sample Number: 0121-97-1322



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ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: LANL
Job Number: 7813
Sample Number: 0121-97-1323
Ring Number: 1323
Depth: 19.2-19.6

Dry wt. of sample (g): 591.55
Tare wt., screen & clamp (g): 29.39
Tare wt., ring (g): 256.86
Tare wt., epoxy (g): 0.00
Sample volume (cm^3): 458.27

Saturated weight at 0 cm tension* (g): 1065.88
Volume of water† in saturated sample (cm^3): 188.08
Saturated moisture content (% vol): 41.04

	Date/Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content† (% vol)
Hanging column:	21-May-97 / 16:30	1065.88	0.00	41.04
	27-May-97 / 10:10	1053.43	12.50	38.32
	30-May-97 / 12:30	1002.61	40.00	27.23
Pressure plate:	06-Jun-97 / 16:30	978.66	81.58	22.01
	11-Jun-97 / 09:30	967.45	254.95	19.56

Dry weight of thermocouple sample* (g): 992.05
Tare weight, jar (g): 400.50
Sample bulk density (g/cm^3): 1.29

	Date/Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content† (% vol)
Thermocouple:	17-Jul-97 / 10:30	1052.50	3467.3	13.19
	18-Jul-97 / 12:50	1032.12	20803.9	8.74

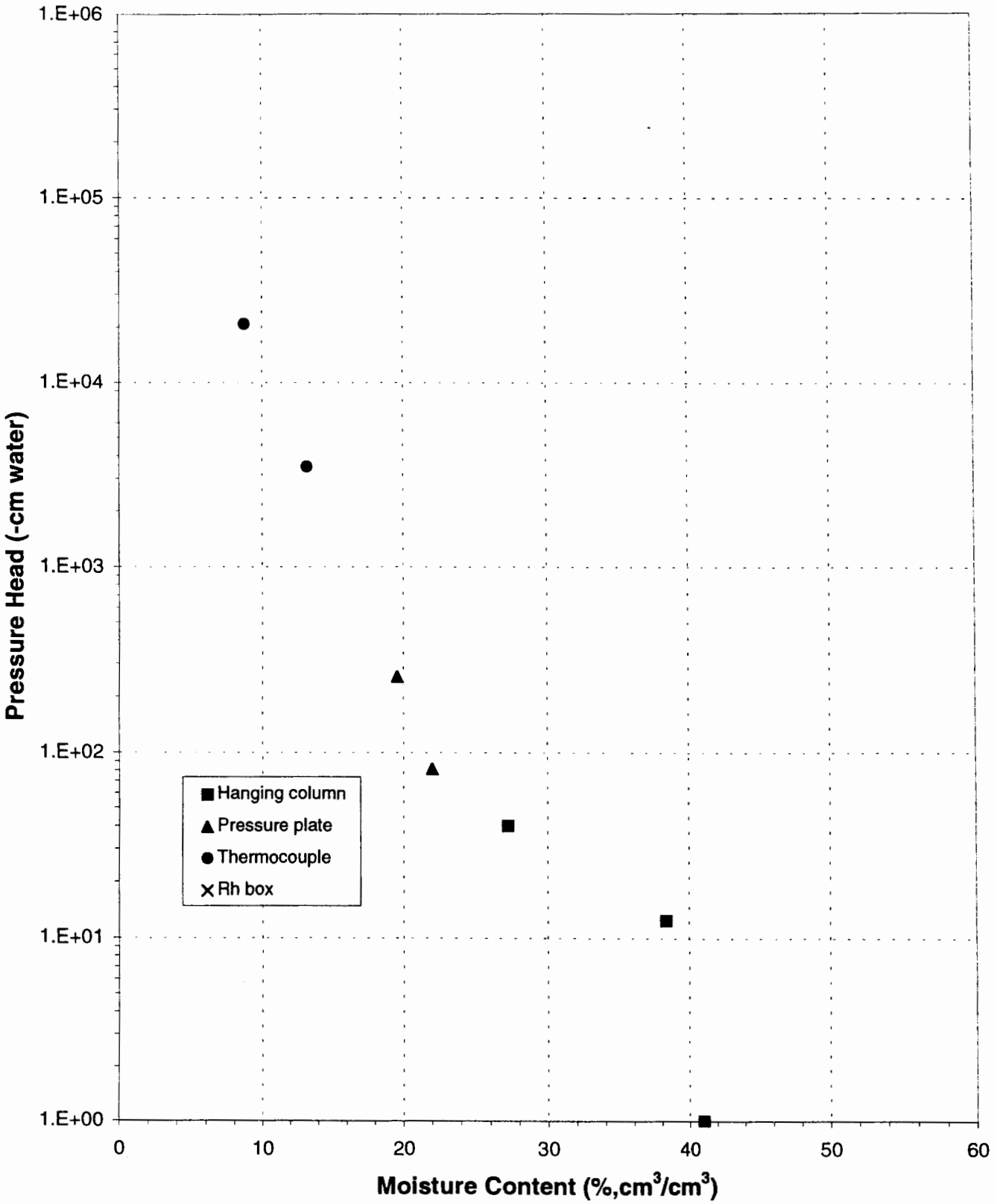
Comments:

* Weight including tares
† Assumed density of water is 1.0 g/cm^3

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

Water Retention Data Points

Sample Number: 0121-97-1323



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Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: LANL
Job Number: 7813
Sample Number: 0121-97-1324
Ring Number: 1324
Depth: 19.6-20.0

Dry wt. of sample (g): 572.65
Tare wt., screen & clamp (g): 29.80
Tare wt., ring (g): 289.25
Tare wt., epoxy (g): 0.00
Sample volume (cm^3): 481.12

Saturated weight at 0 cm tension* (g): 1112.90
Volume of water† in saturated sample (cm^3): 221.20
Saturated moisture content (% vol): 45.98

	Date/Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content† (% vol)
Hanging column:	22-May-97 / 16:30	1112.90	0.00	45.98
	27-May-97 / 10:10	1097.40	12.50	42.75
	30-May-97 / 13:00	1045.92	40.00	32.05
Pressure plate:	06-Jun-97 / 10:30	1014.36	81.58	25.49
	11-Jun-97 / 09:15	1000.94	254.95	22.71

Dry weight of thermocouple sample* (g): 1001.16
Tare weight, jar (g): 428.51
Sample bulk density (g/cm^3): 1.19

	Date/Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content† (% vol)
Thermocouple:	17-Jul-97 / 10:30	1088.08	3059.4	18.07
	18-Jul-97 / 12:50	1063.11	14991.1	12.88

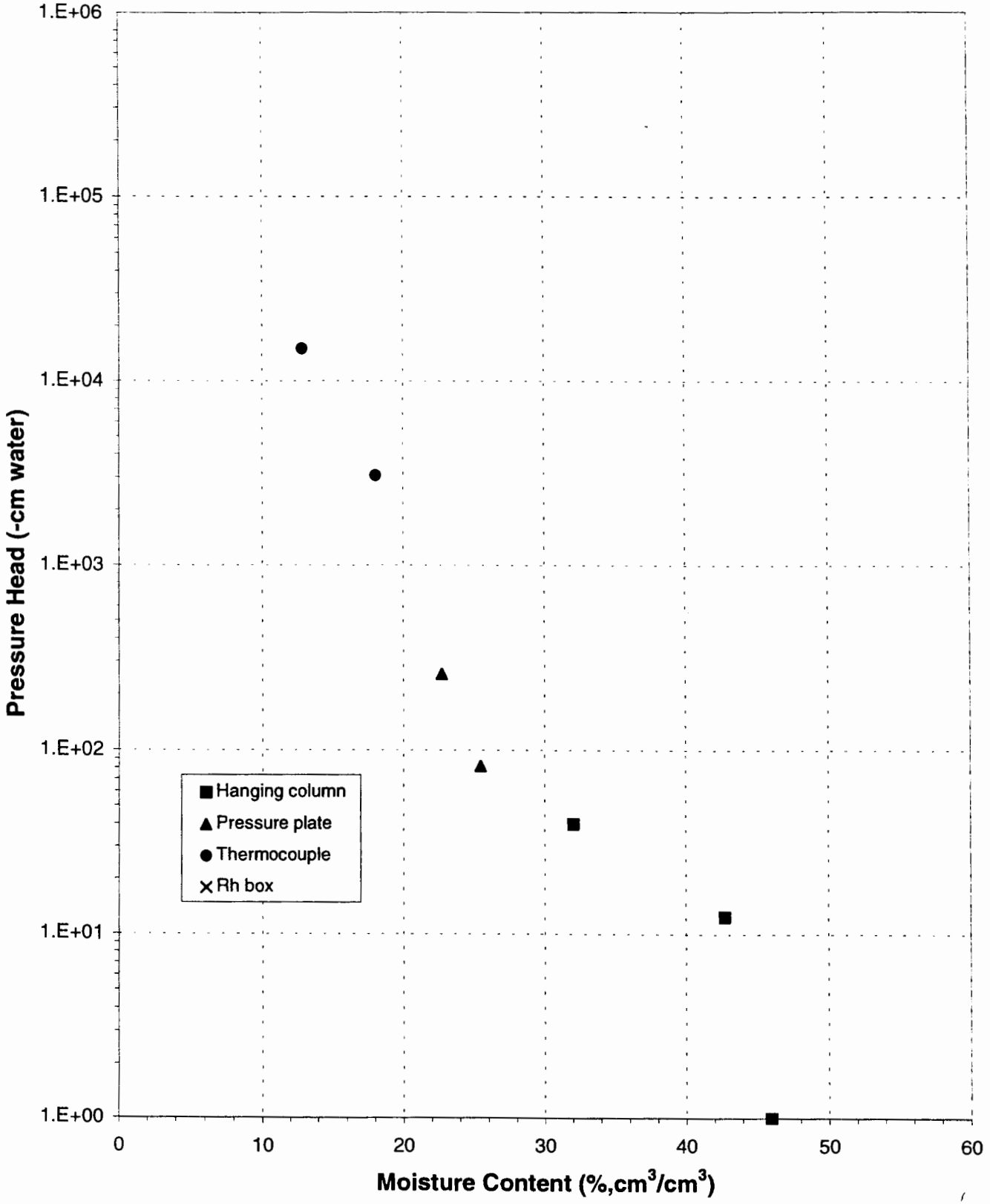
Comments:

* Weight including tares
† Assumed density of water is 1.0 g/cm^3

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

Water Retention Data Points

Sample Number: 0121-97-1324



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Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: LANL
Job Number: 7813
Sample Number: 0121-97-1325
Ring Number: 1325
Depth: 21.4-21.8

Dry wt. of sample (g): 760.60
Tare wt., screen & clamp (g): 39.80
Tare wt., ring (g): 334.13
Tare wt., epoxy (g): 0.00
Sample volume (cm^3): 585.68

Saturated weight at 0 cm tension* (g): 1360.41
Volume of water† in saturated sample (cm^3): 225.88
Saturated moisture content (% vol): 38.57

	Date/Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content† (% vol)
Hanging column:	22-May-97 / 11:30	1360.41	0.00	38.57
	27-May-97 / 10:05	1352.86	13.50	37.28
	30-May-97 / 12:30	1283.92	40.00	25.51
Pressure plate:	06-Jun-97 / 16:30	1266.35	81.58	22.51
	11-Jun-97 / 09:20	1248.96	254.95	19.54

Dry weight of thermocouple sample* (g): 1190.33
Tare weight, jar (g): 429.73
Sample bulk density (g/cm^3): 1.30

	Date/Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content† (% vol)
Thermocouple:	17-Jul-97 / 10:45	1283.23	3263.4	15.86
	18-Jul-97 / 12:55	1254.83	13869.3	11.01

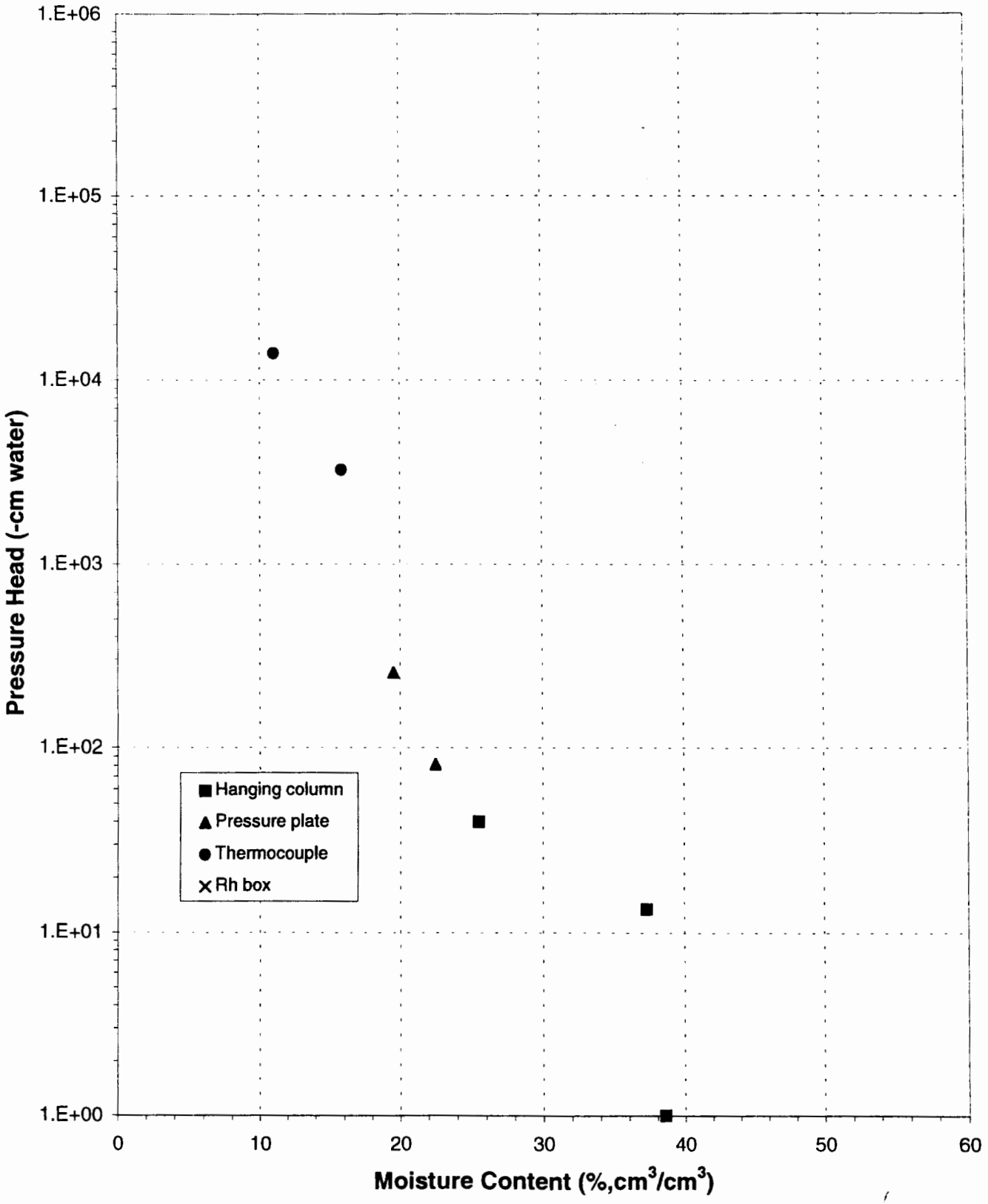
Comments:

* Weight including tares
† Assumed density of water is 1.0 g/cm^3

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

Water Retention Data Points

Sample Number: 0121-97-1325



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Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: LANL
Job Number: 7813
Sample Number: 0121-97-1326
Ring Number: 1326
Depth: 21.8-22.2

Dry wt. of sample (g): 544.07
Tare wt., screen & clamp (g): 2.66
Tare wt., ring (g): 243.92
Tare wt., epoxy (g): 0.00
Sample volume (cm^3): 434.11

Saturated weight at 0 cm tension* (g): 988.98
Volume of water† in saturated sample (cm^3): 198.33
Saturated moisture content (% vol): 45.69

	Date/Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content† (% vol)
Hanging column:	03-Jun-97 / 15:30	988.98	0.00	45.69
	06-Jun-97 / 15:30	971.74	10.00	41.72
	09-Jun-97 / 10:00	920.98	41.00	30.02
Pressure plate:	11-Jun-97 / 10:00	906.32	81.58	26.65
	18-Jun-97 / 08:00	890.33	254.95	22.96

Dry weight of thermocouple sample* (g): 973.16
Tare weight, jar (g): 429.09
Sample bulk density (g/cm^3): 1.25

	Date/Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content† (% vol)
Thermocouple:	17-Jul-97 / 10:45	1040.07	2957.4	15.41
	18-Jul-97 / 13:00	1013.91	13053.4	9.39

Comments:

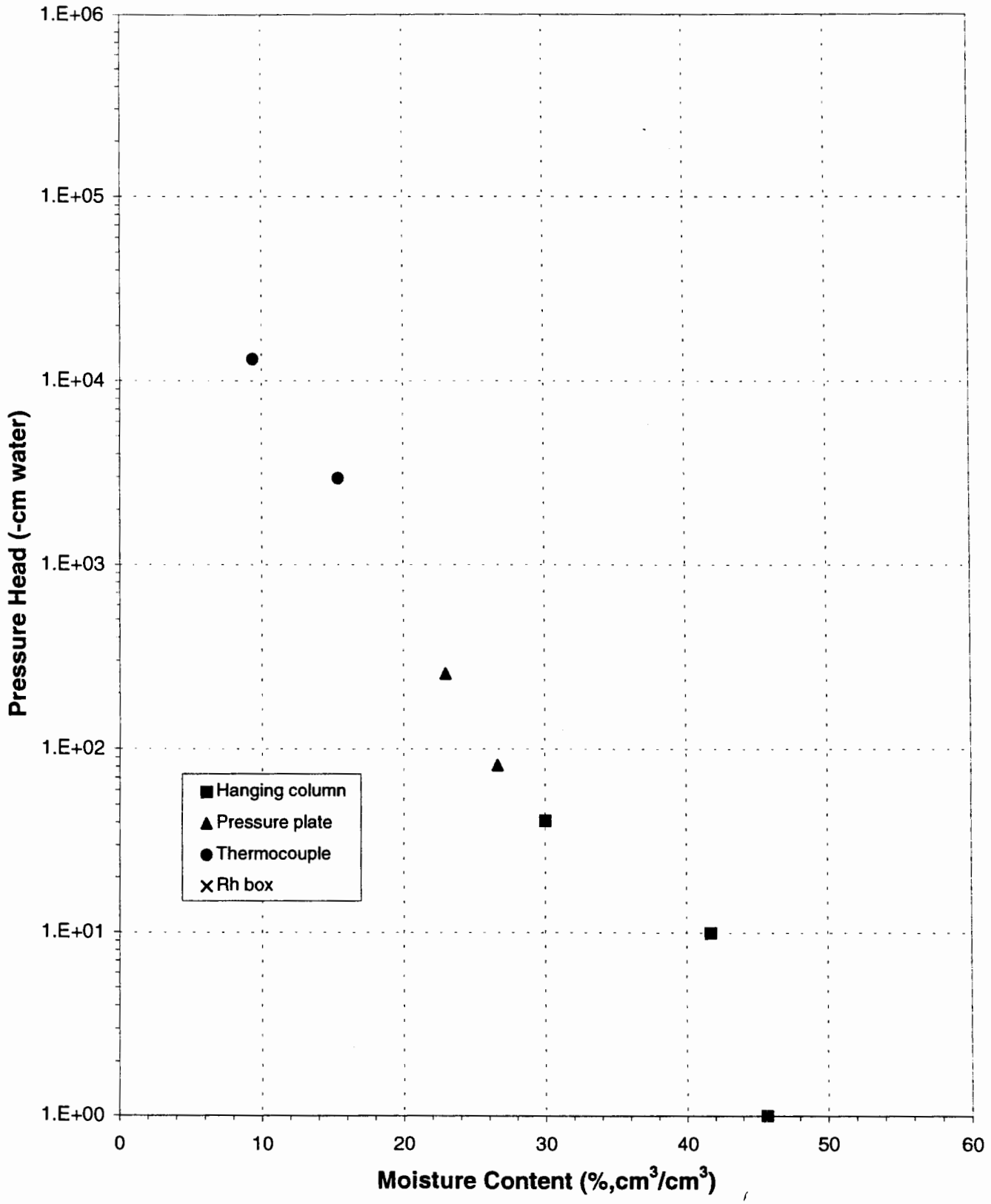
* Weight including tares

† Assumed density of water is 1.0 g/cm^3

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

Water Retention Data Points

Sample Number: 0121-97-1326



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Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: LANL
Job Number: 7813
Sample Number: 0121-97-1327
Ring Number: 1327
Depth: 22.2-22.6

Dry wt. of sample (g): 737.65
Tare wt., screen & clamp (g): 2.58
Tare wt., ring (g): 331.41
Tare wt., epoxy (g): 0.00
Sample volume (cm^3): 588.71

Saturated weight at 0 cm tension* (g): 1327.29
Volume of water† in saturated sample (cm^3): 255.65
Saturated moisture content (% vol): 43.43

	Date/Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content† (% vol)
Hanging column:	03-Jun-97 / 15:00	1327.29	0.00	43.43
	06-Jun-97 / 16:45	1320.53	11.00	42.28
	09-Jun-97 / 10:00	1238.13	42.00	28.28
Pressure plate:	11-Jun-97 / 10:00	1220.43	81.58	25.27
	18-Jun-97 / 08:00	1199.01	254.95	21.64

Dry weight of thermocouple sample* (g): 1168.02
Tare weight, jar (g): 430.37
Sample bulk density (g/cm^3): 1.25

	Date/Time	Weight* (g)	Matric Potential (-cm water)	Moisture Content† (% vol)
Thermocouple:	17-Jul-97 / 11:00	1264.87	3263.4	16.45
	18-Jul-97 / 13:00	1236.91	11931.7	11.70

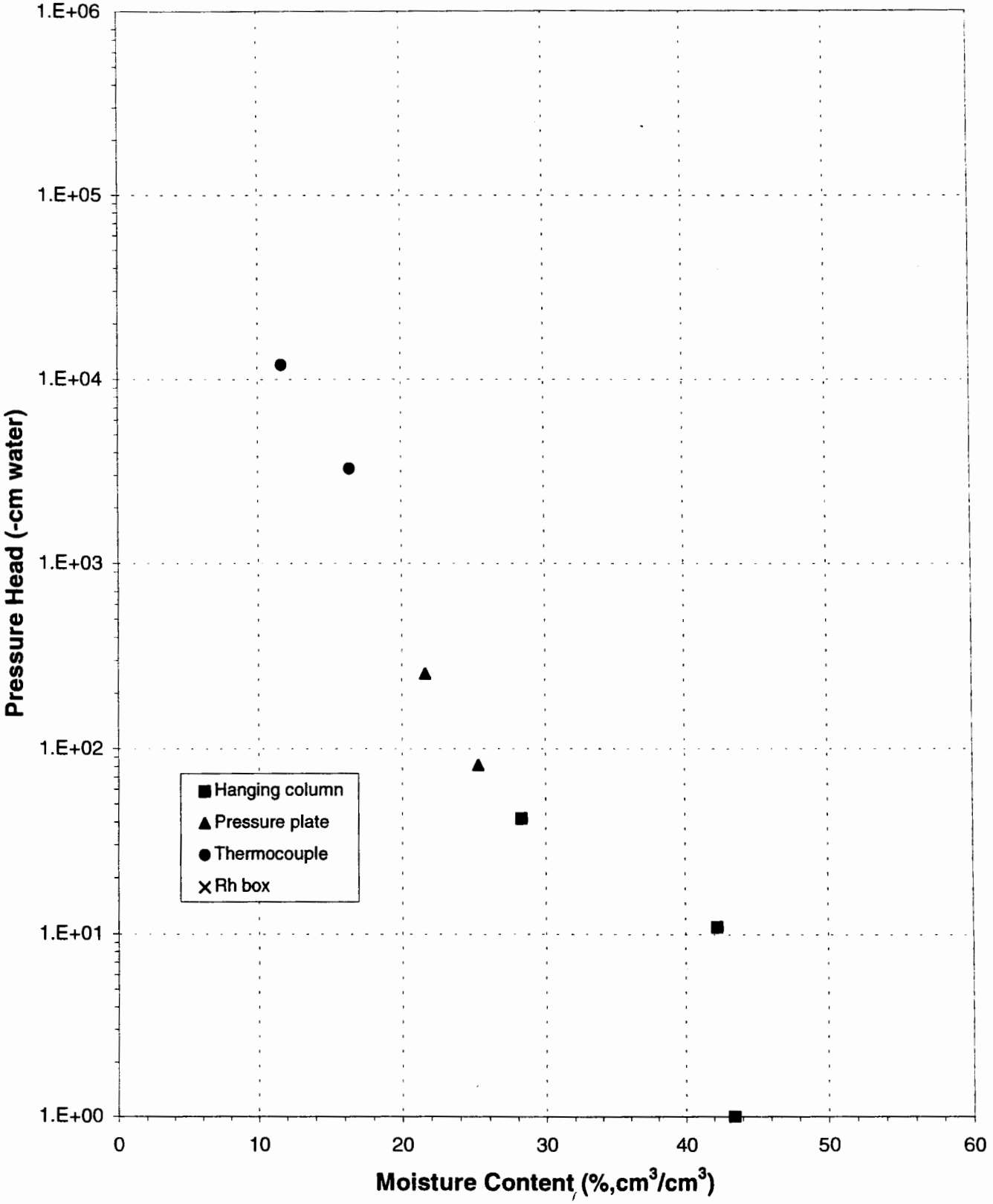
Comments:

* Weight including tares
† Assumed density of water is 1.0 g/cm^3

Laboratory analysis by: J. Locke
Data entered by: J. Locke
Checked by: M. Prieksat

Water Retention Data Points

Sample Number: 0121-97-1327



Appendix D

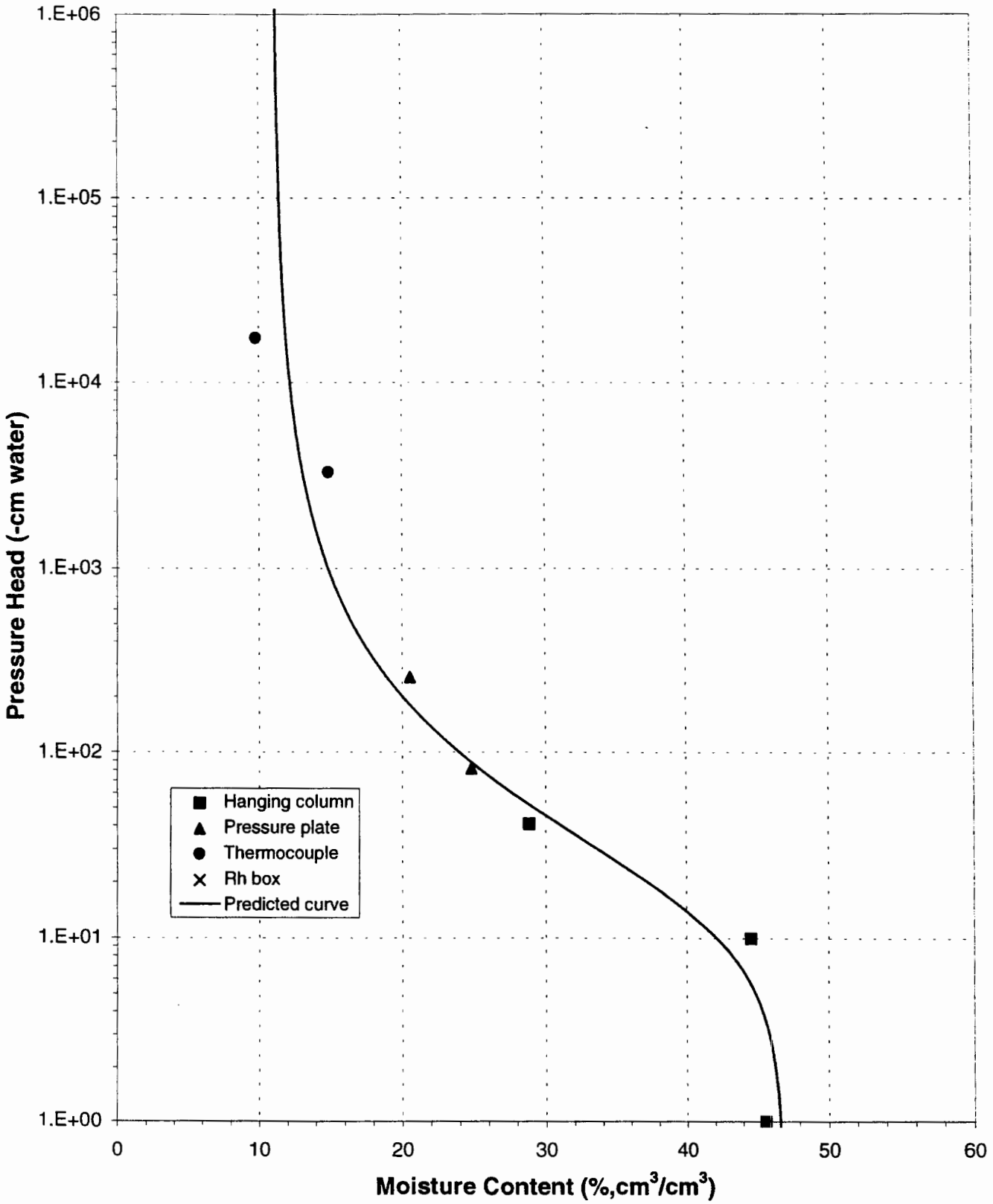
Unsaturated Hydraulic Properties

Summary of Calculated Unsaturated Hydraulic Properties

Sample Number	α (cm^{-1}) Calculated Value	α 95% Confidence Limits Lower	α 95% Confidence Limits Upper	N (dimensionless) Calculated Value	N 95% Confidence Limits Lower	N 95% Confidence Limits Upper	θ_r (%)	θ_s (%)
0121-97-1321	0.0630	-0.0580	0.1839	1.5452	0.7807	2.3097	0.1111	0.4680
0121-97-1322	0.0696	-0.0780	0.2172	1.2635	0.8088	1.7181	0.0587	0.4186
0121-97-1323	0.0648	-0.0559	0.1854	1.4773	0.8198	2.1348	0.0932	0.4179
0121-97-1324	0.0580	-0.0371	0.1530	1.5759	0.8311	2.3207	0.1440	0.4661
0121-97-1325	0.0537	-0.0605	0.1678	1.6415	0.5091	2.7738	0.1300	0.3950
0121-97-1326	0.1175	-0.1464	0.3814	1.2545	0.8356	1.6735	0.0431	0.4622
0121-97-1327	0.0618	-0.0689	0.1925	1.5432	0.6778	2.4087	0.1296	0.4448

Predicted Water Retention Curve and Data Points

Sample Number: 0121-97-1321



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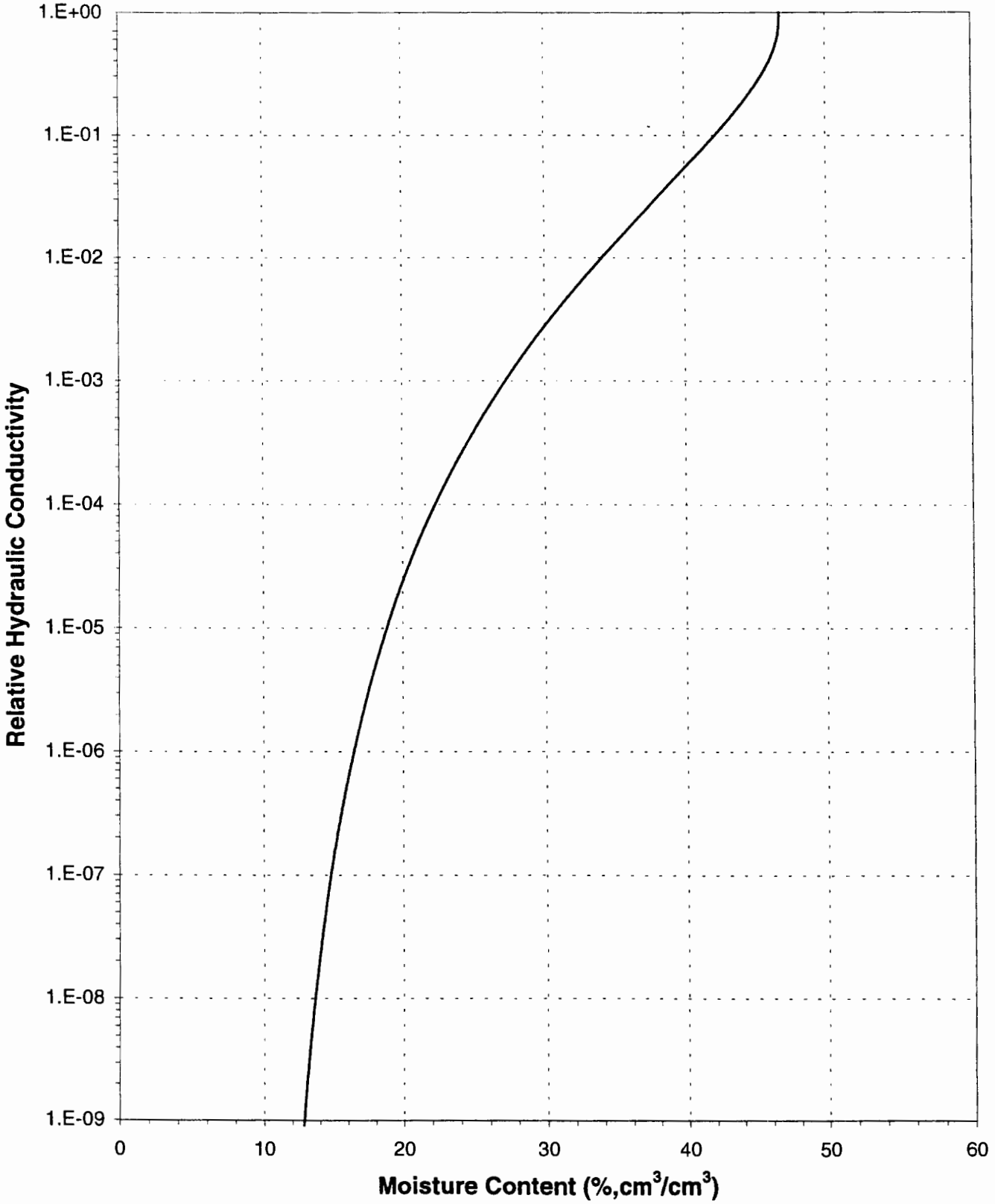
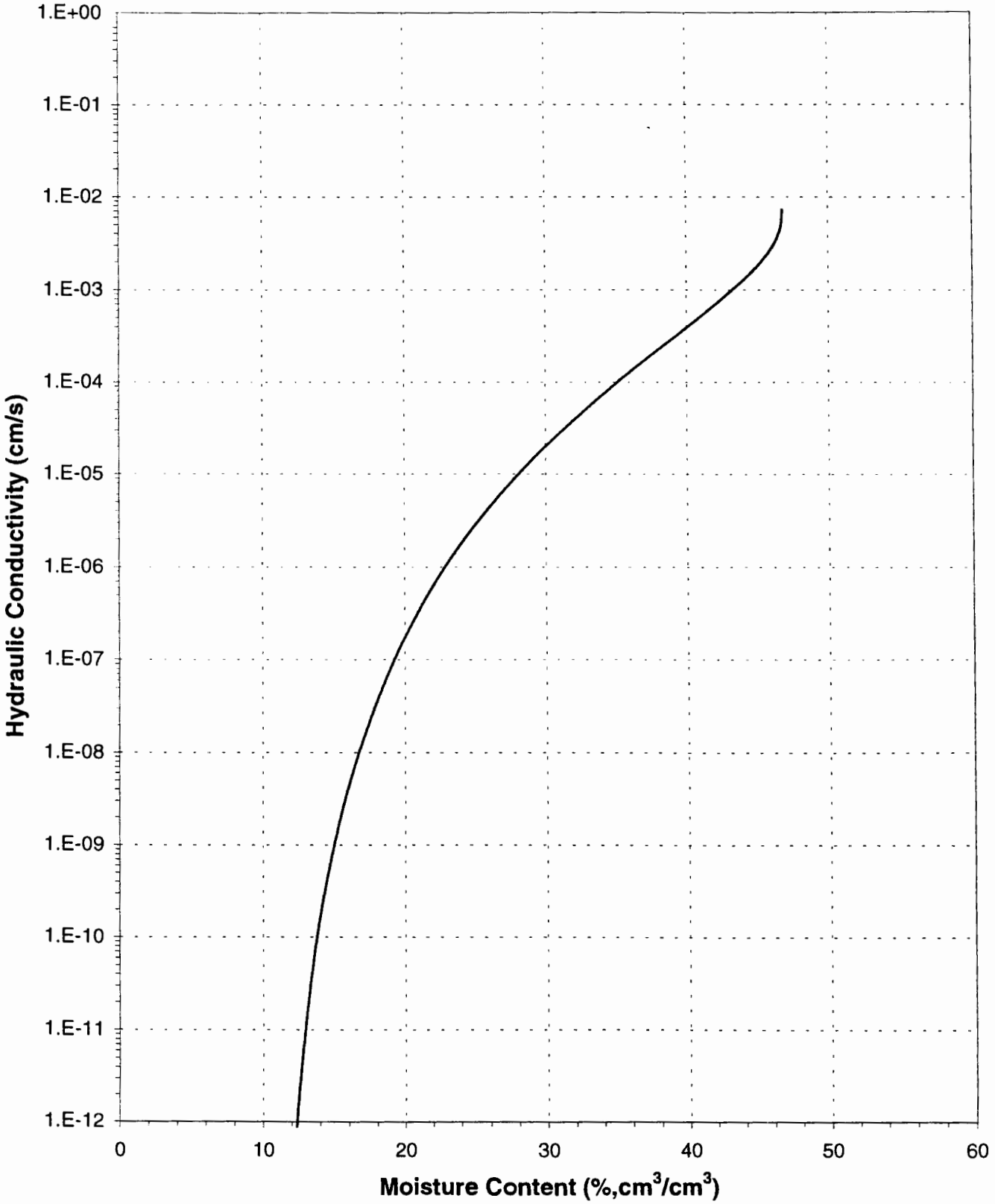
Plot of Relative Hydraulic Conductivity vs Moisture Content

Sample Number: 0121-97-1321



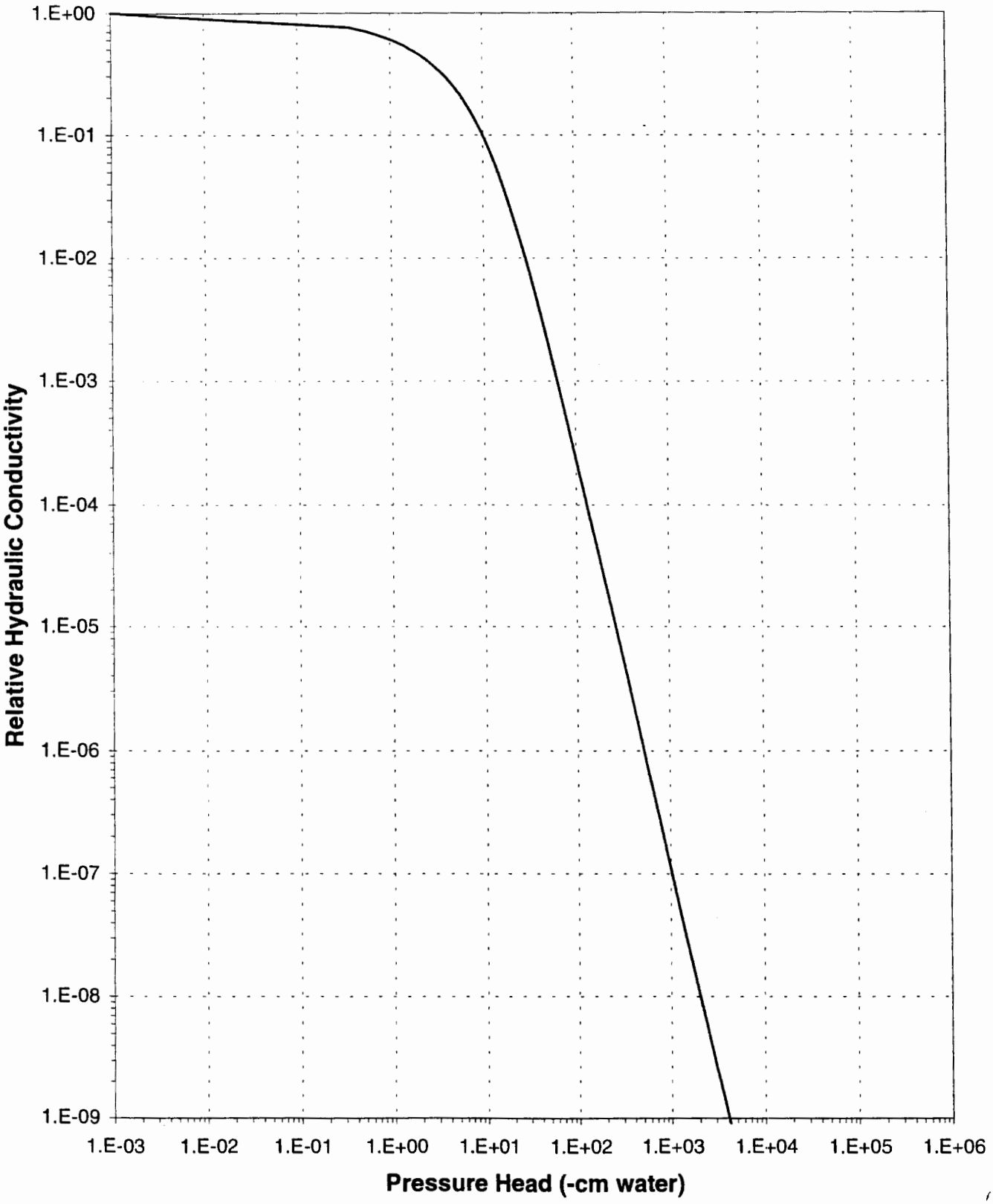
Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: 0121-97-1321



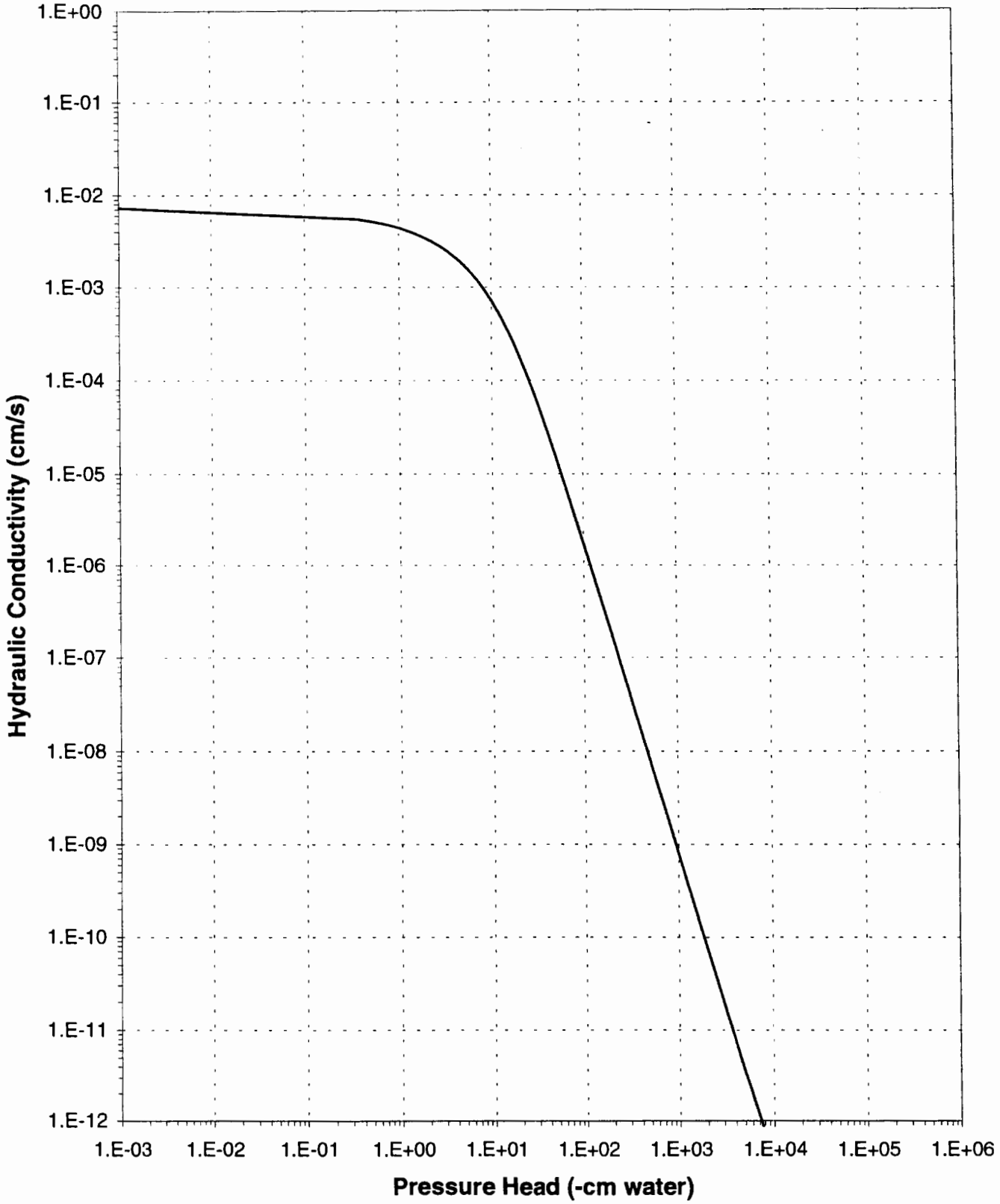
Plot of Relative Hydraulic Conductivity vs Pressure Head

Sample Number: 0121-97-1321



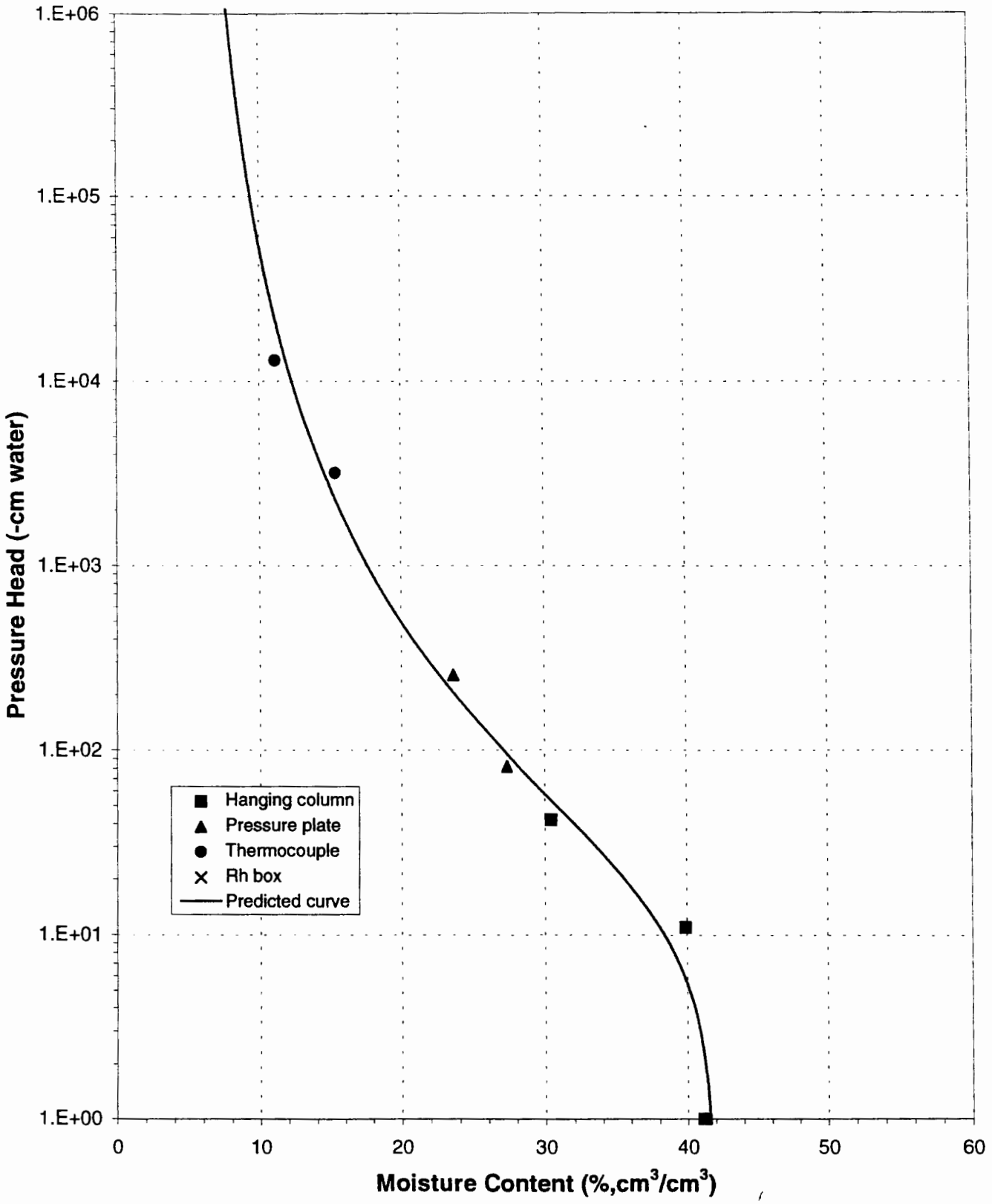
Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: 0121-97-1321



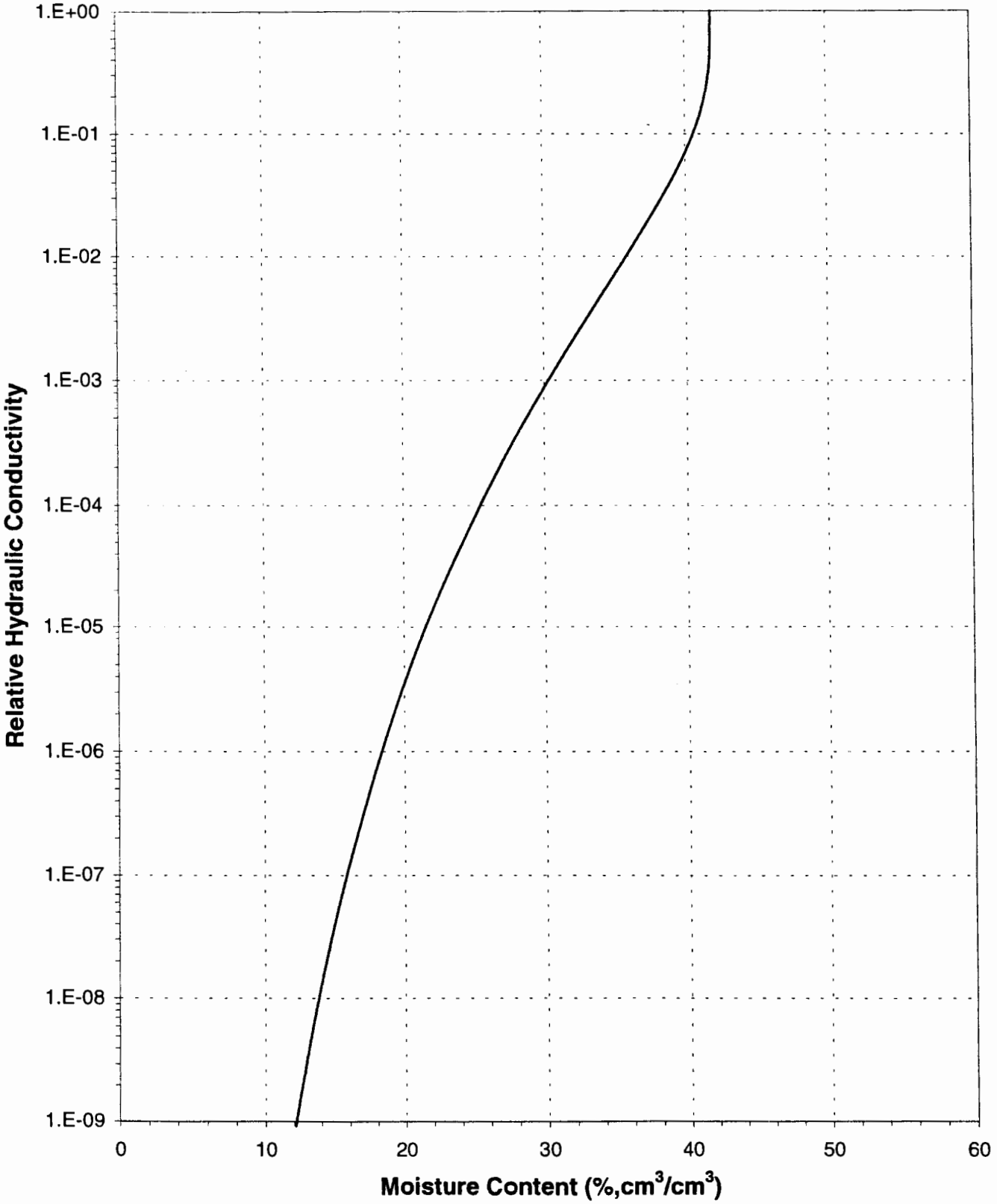
Predicted Water Retention Curve and Data Points

Sample Number: 0121-97-1322



Plot of Relative Hydraulic Conductivity vs Moisture Content

Sample Number: 0121-97-1322



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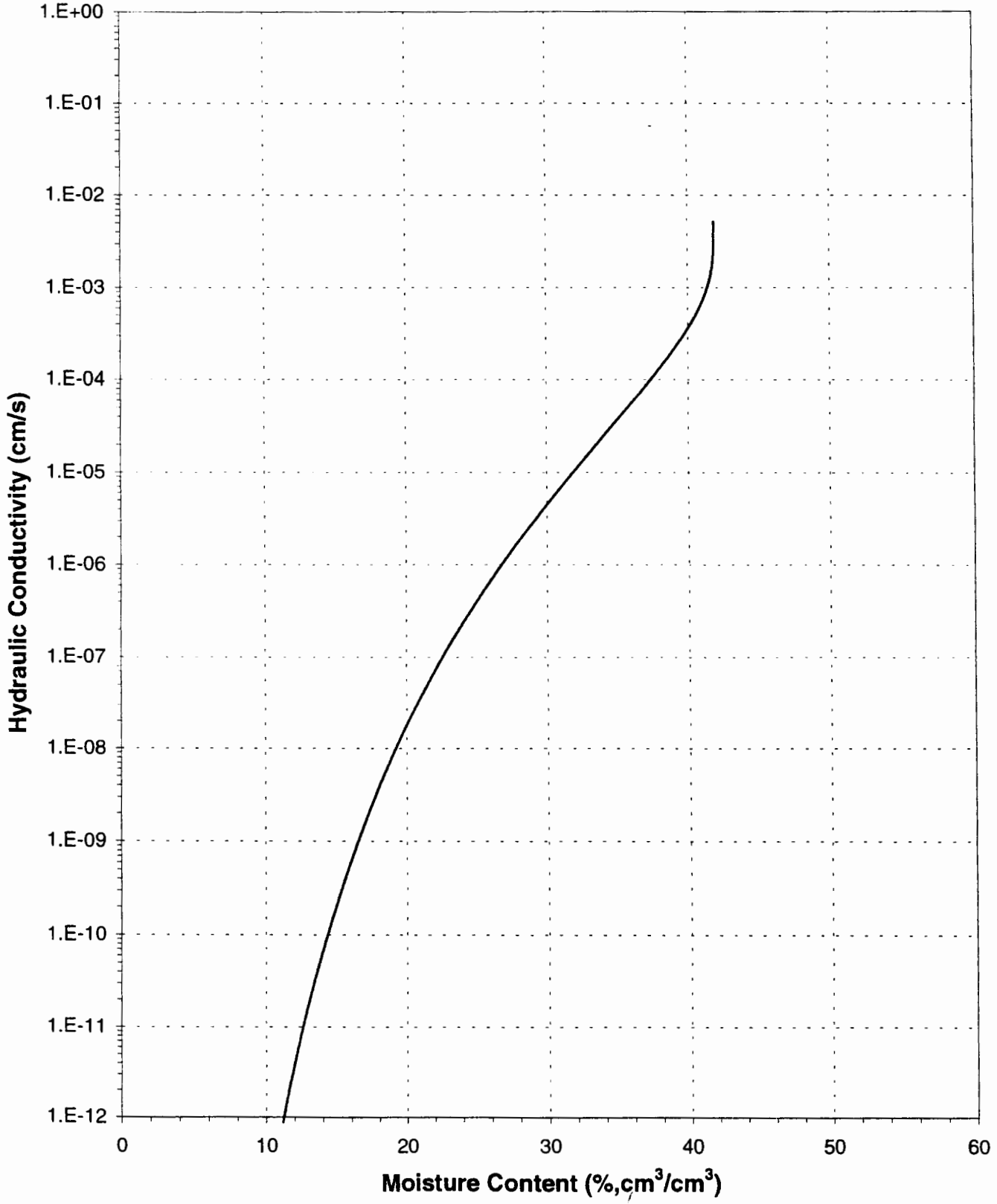
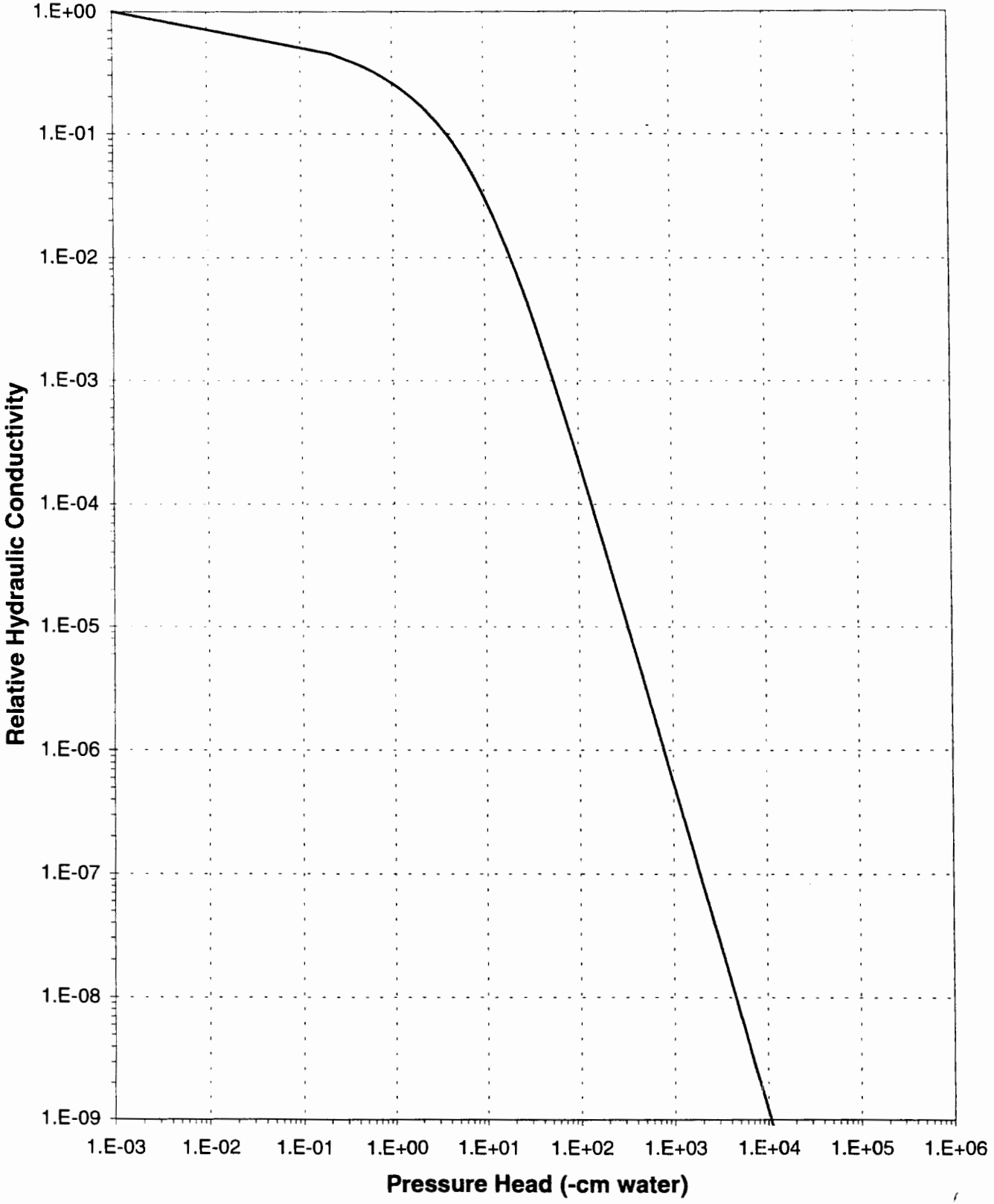
Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: 0121-97-1322



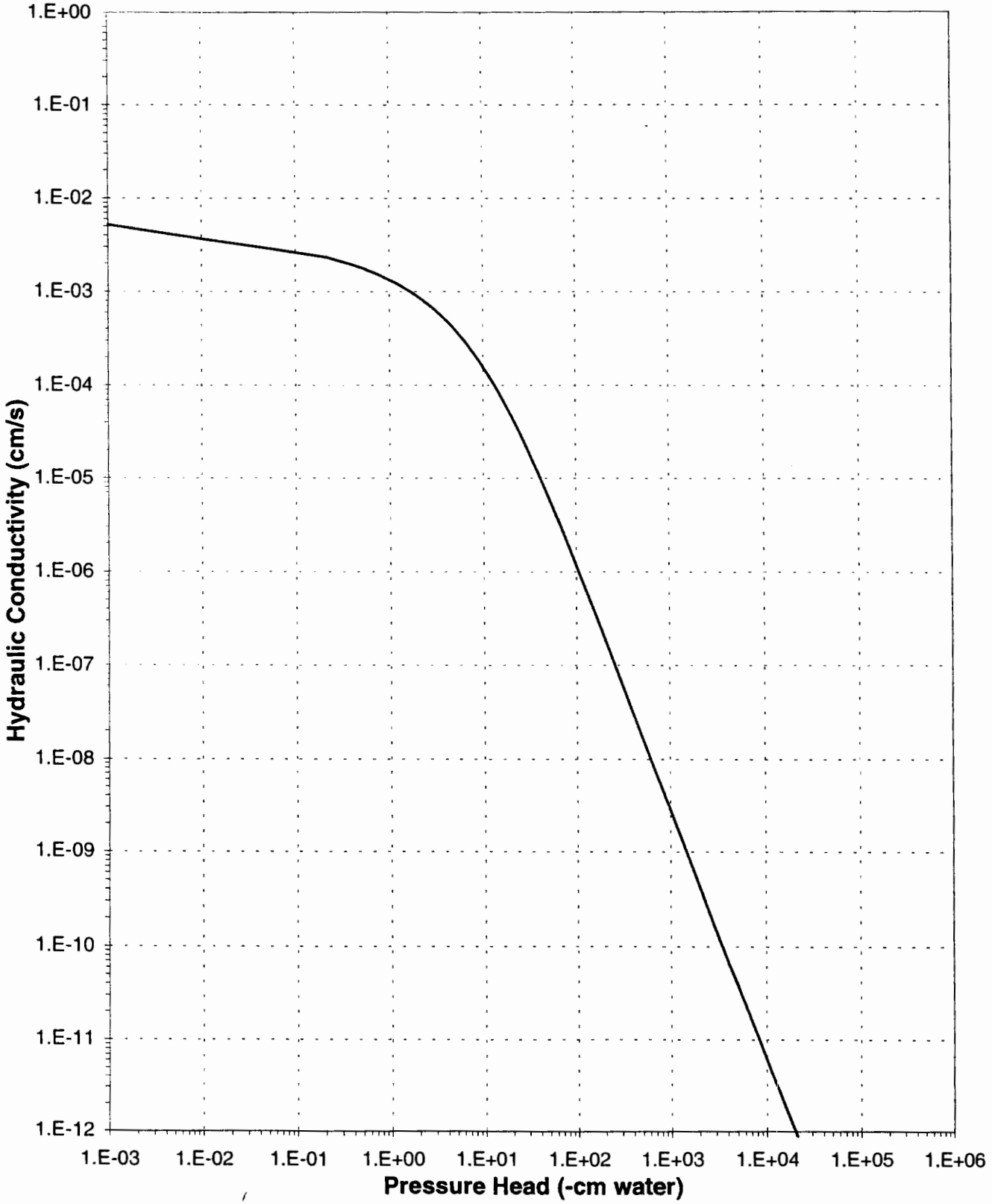
Plot of Relative Hydraulic Conductivity vs Pressure Head

Sample Number: 0121-97-1322



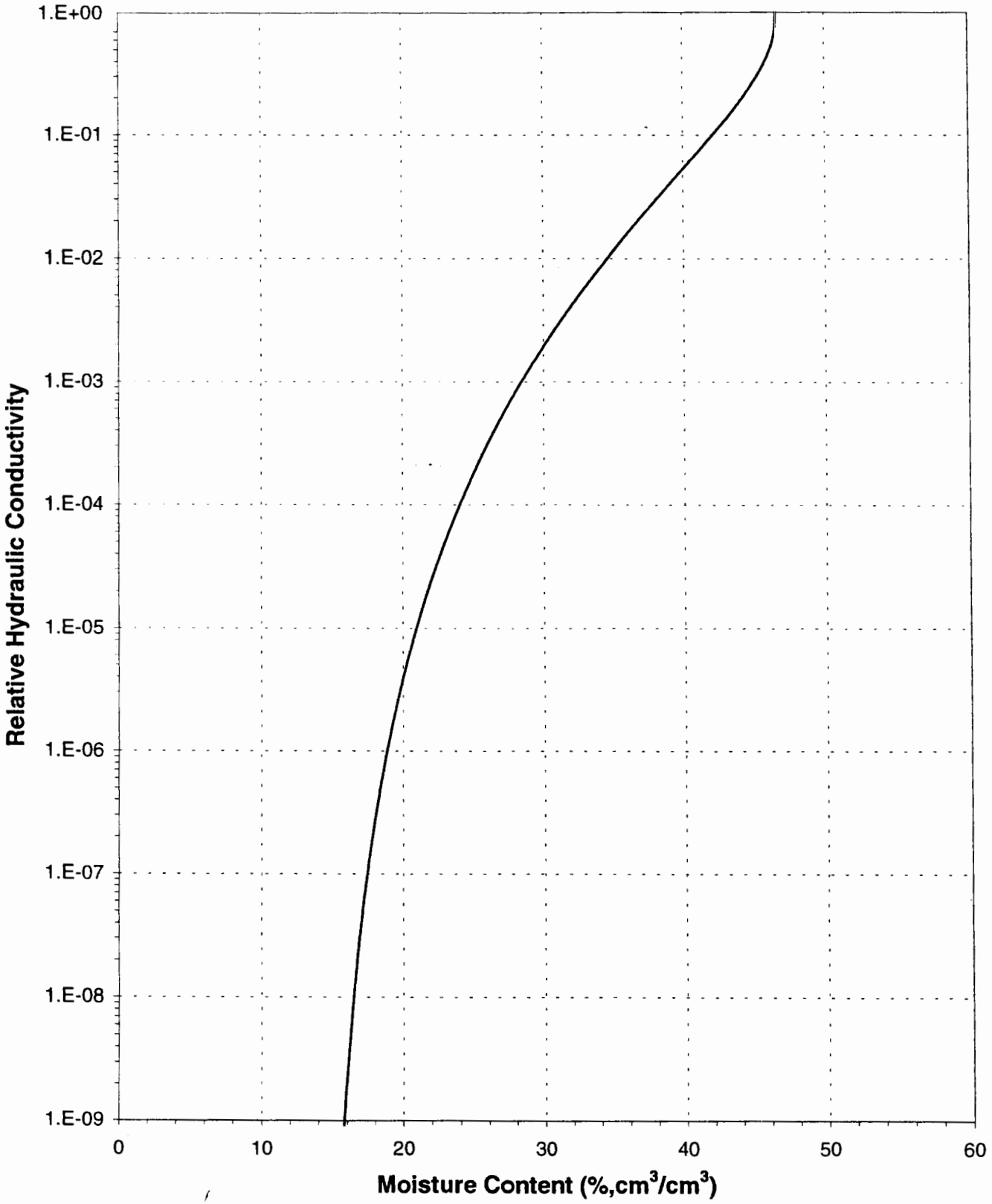
Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: 0121-97-1322



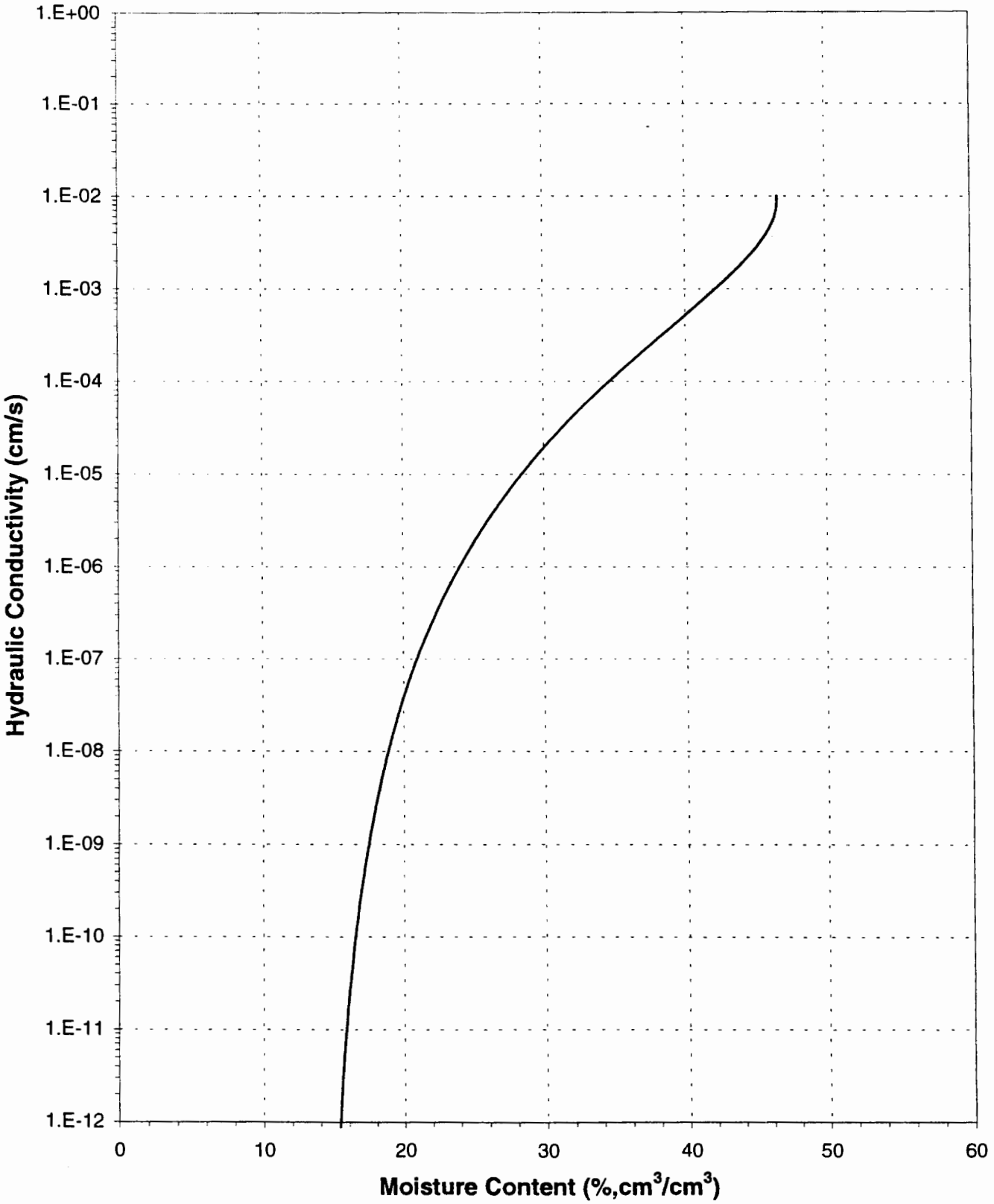
Plot of Relative Hydraulic Conductivity vs Moisture Content

Sample Number: 0121-97-1324



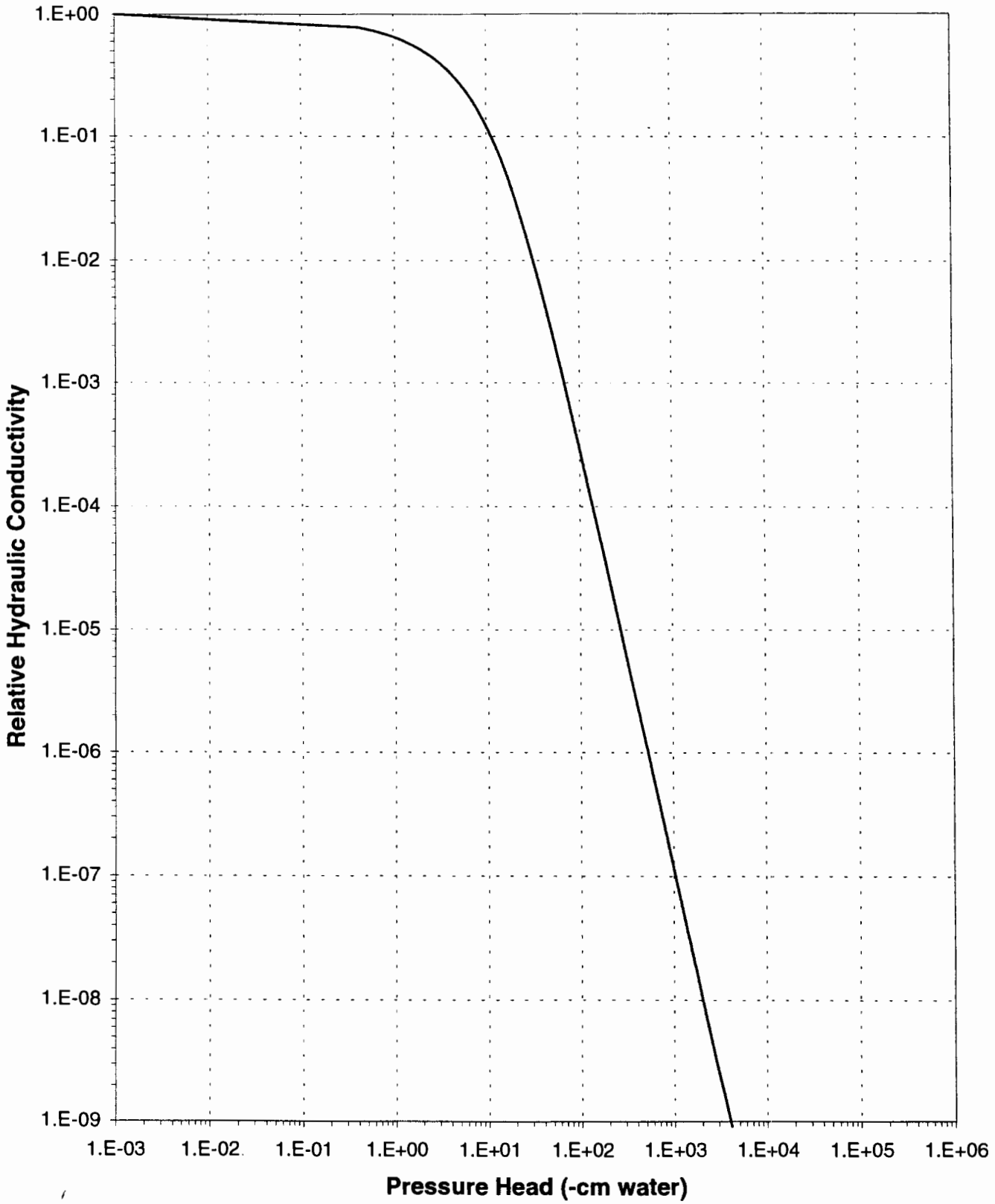
Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: 0121-97-1324



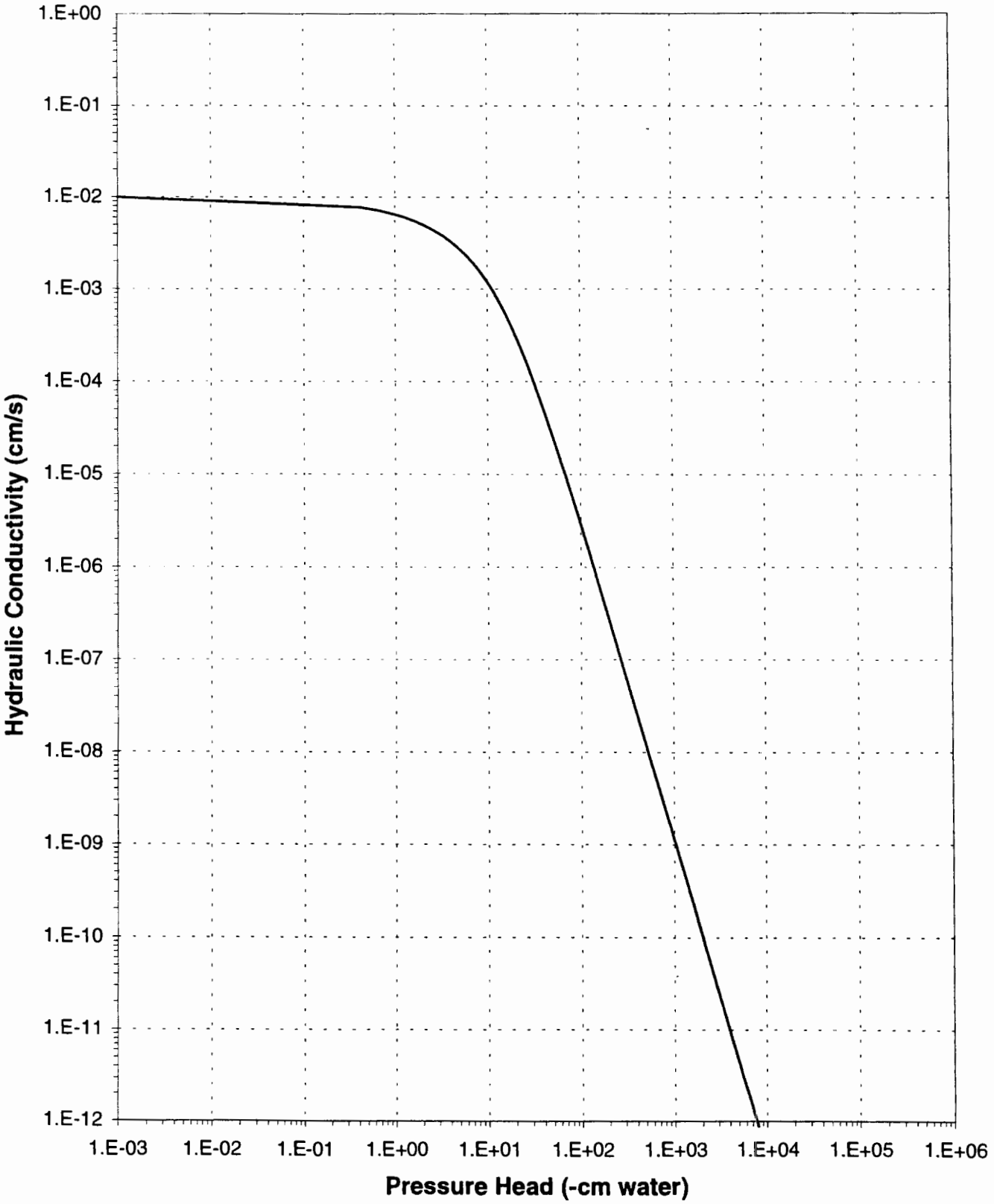
Plot of Relative Hydraulic Conductivity vs Pressure Head

Sample Number: 0121-97-1324



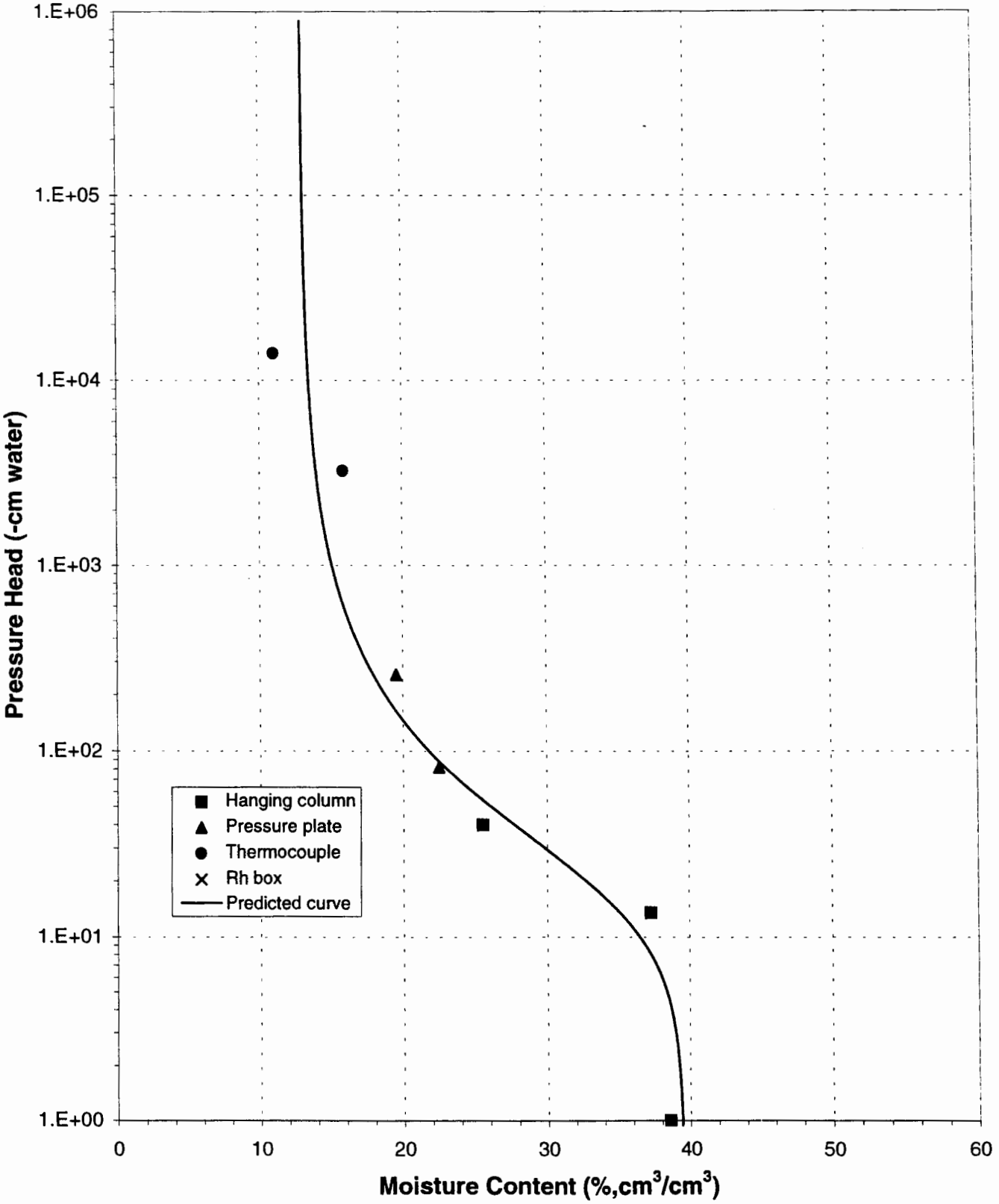
Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: 0121-97-1324



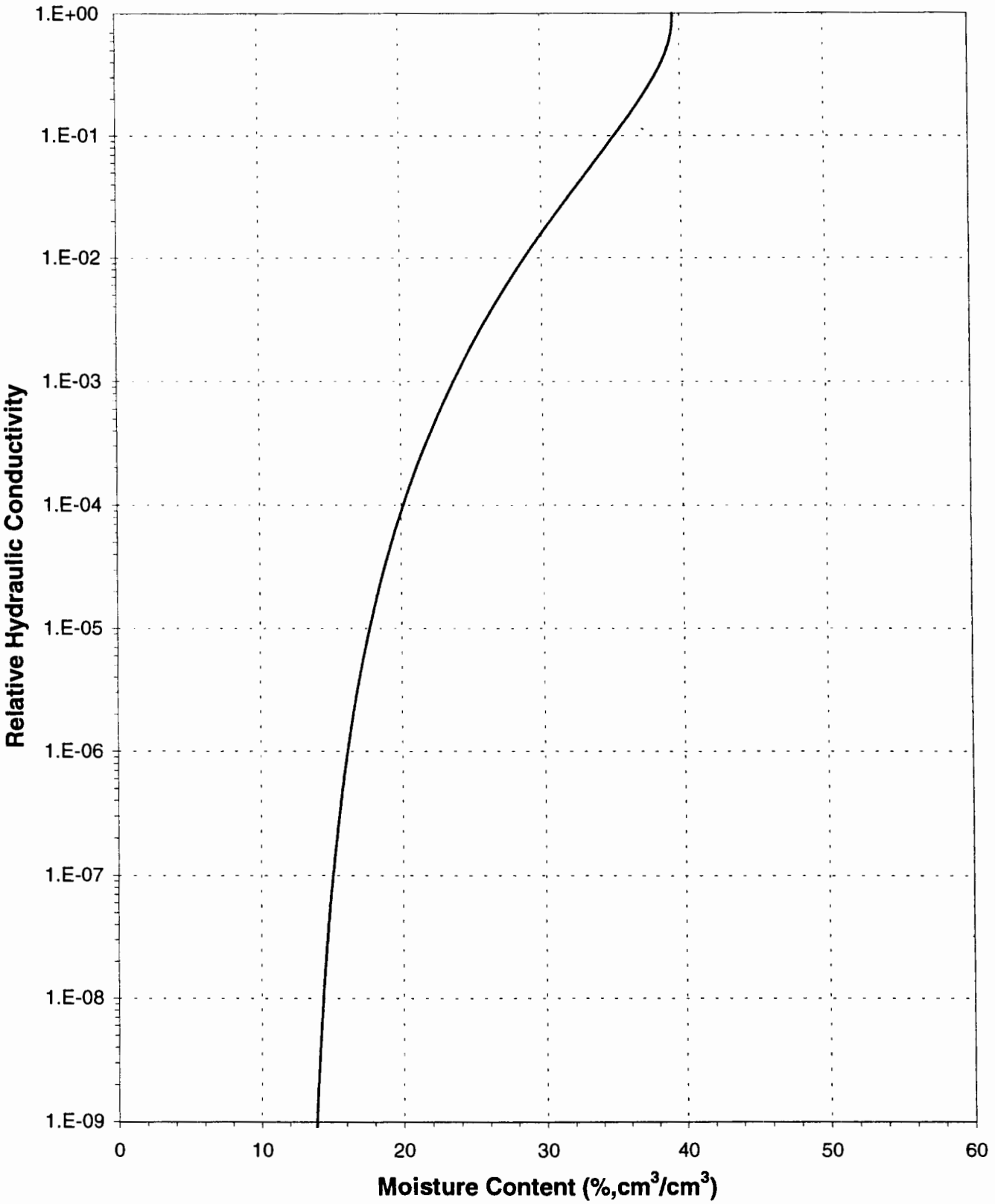
Predicted Water Retention Curve and Data Points

Sample Number: 0121-97-1325



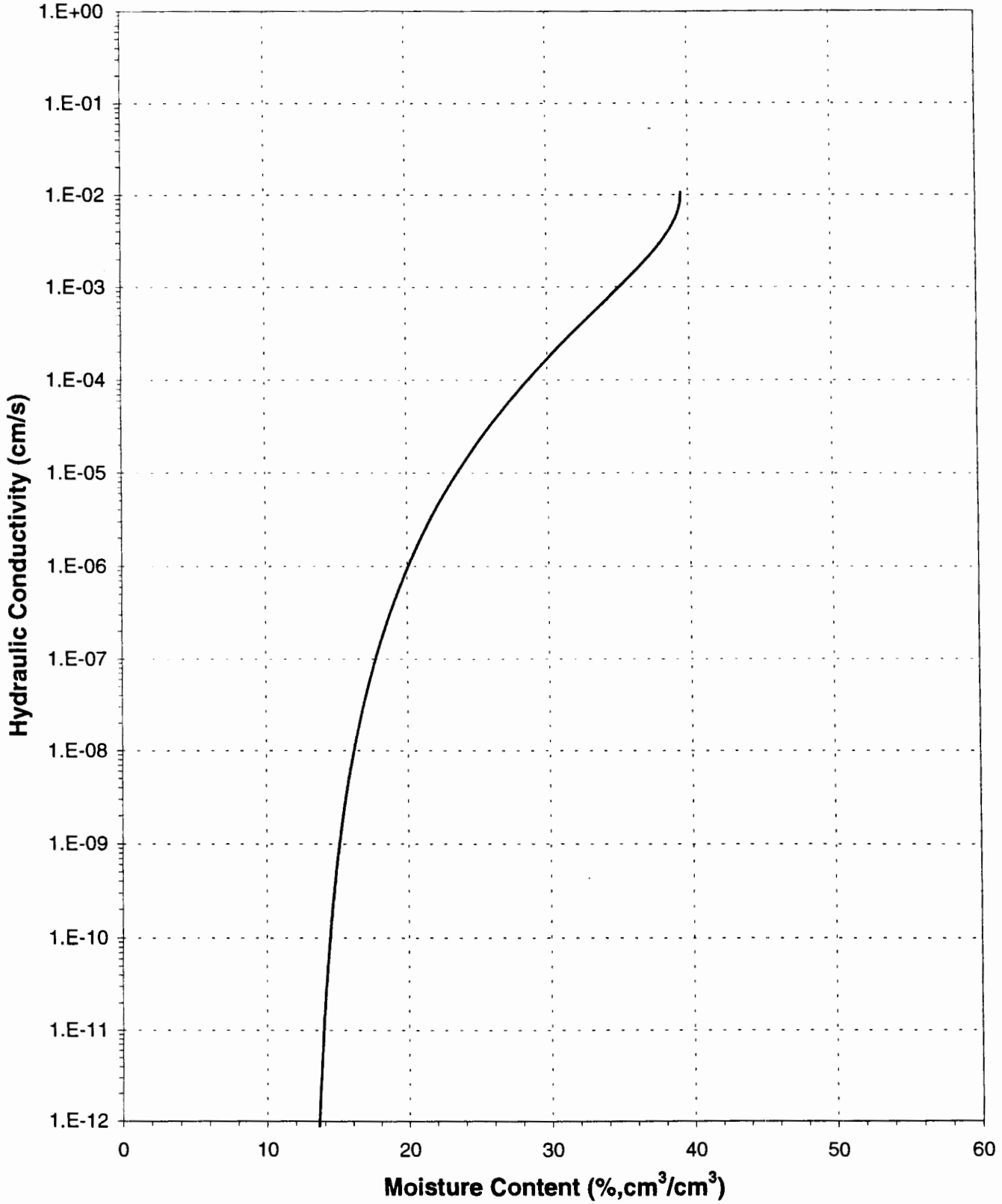
Plot of Relative Hydraulic Conductivity vs Moisture Content

Sample Number: 0121-97-1325



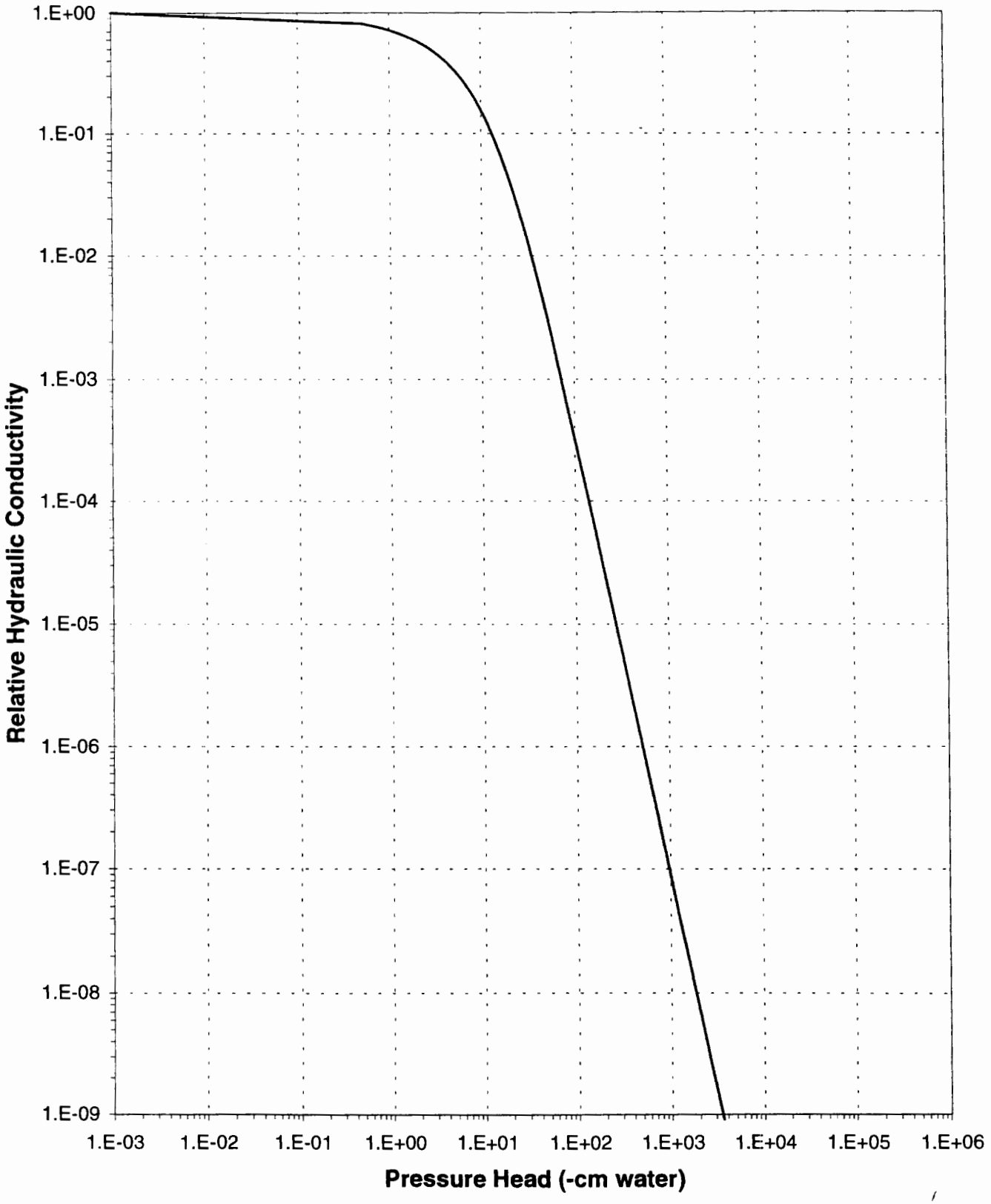
Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: 0121-97-1325



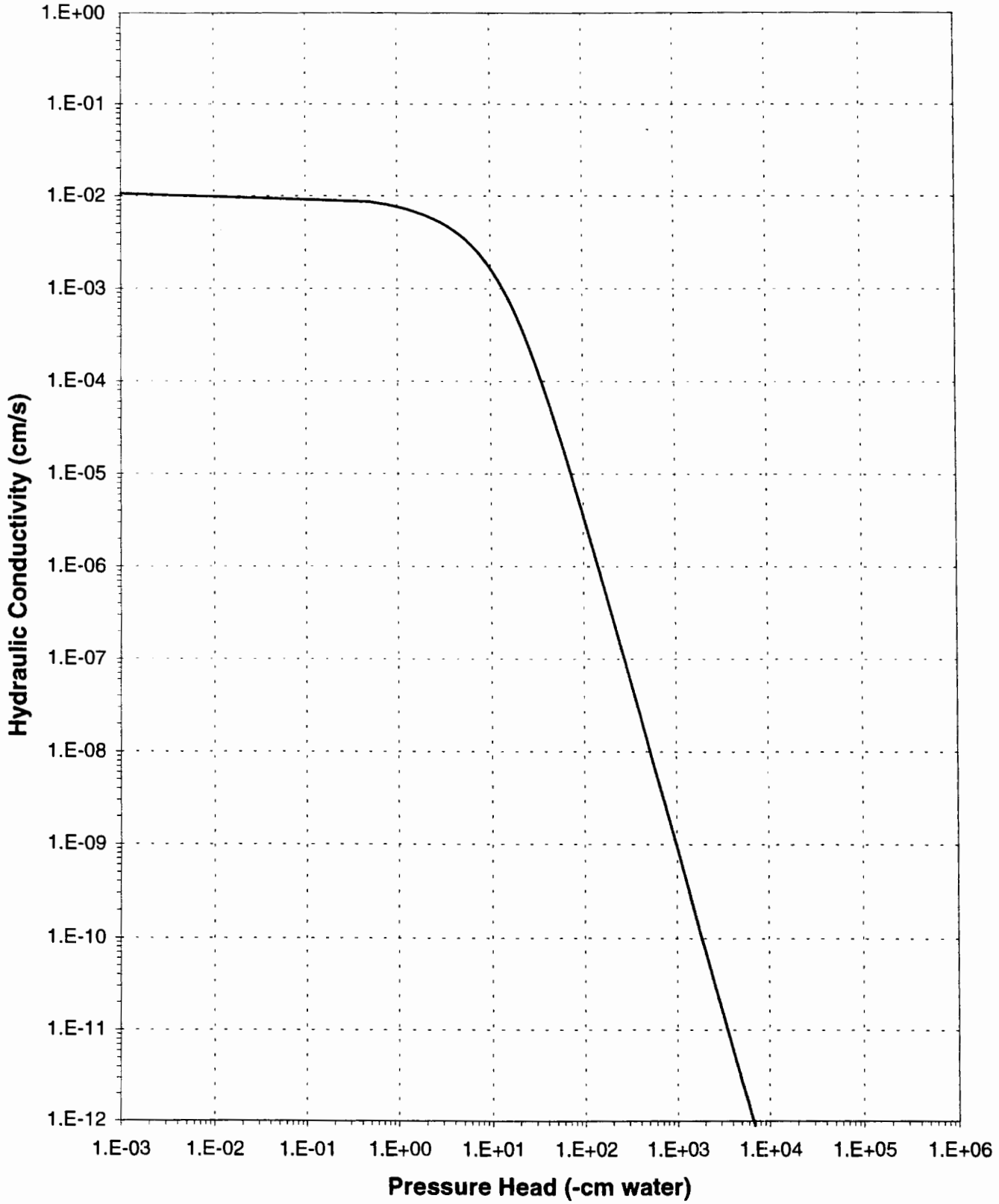
Plot of Relative Hydraulic Conductivity vs Pressure Head

Sample Number: 0121-97-1325



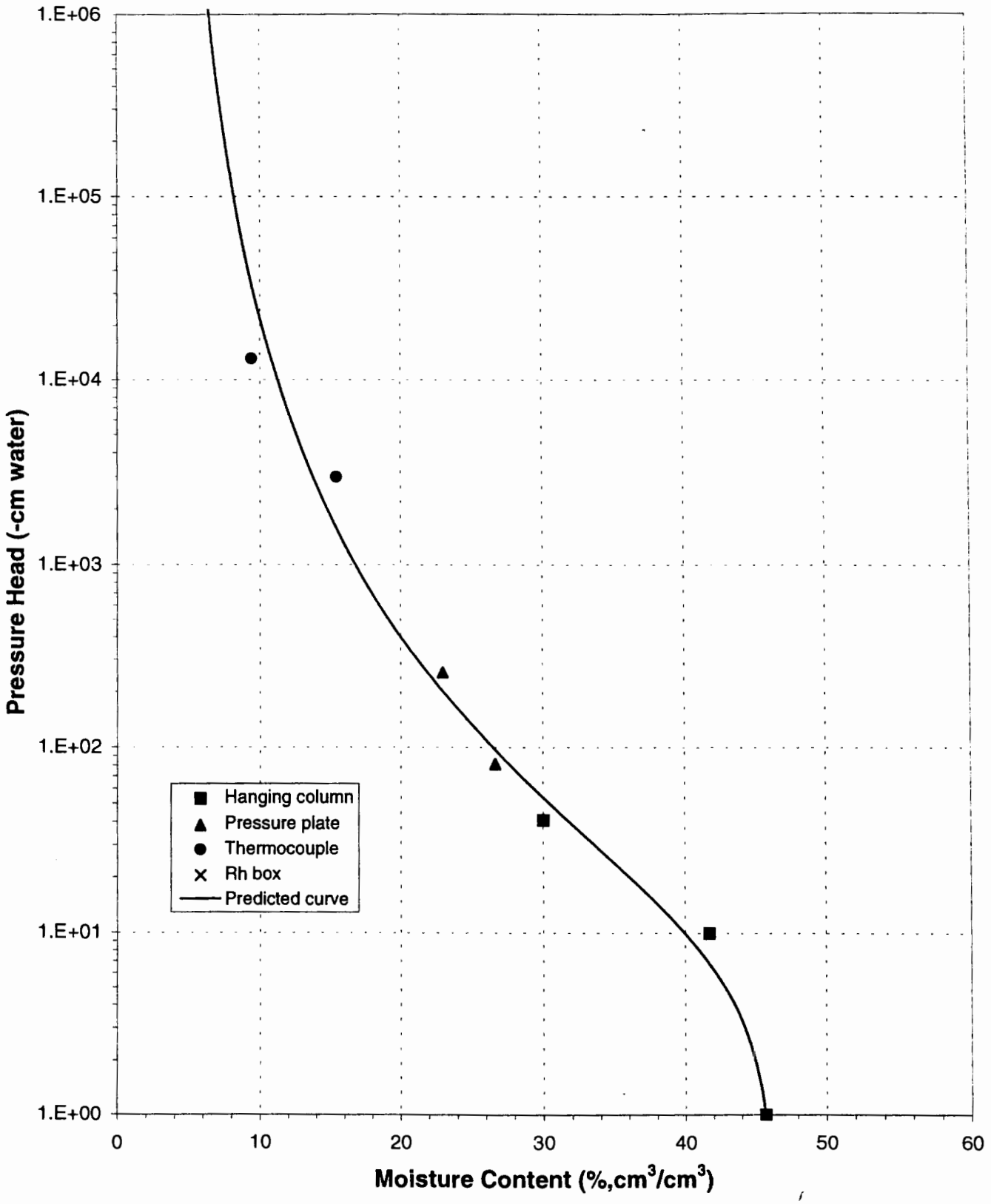
Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: 0121-97-1325



Predicted Water Retention Curve and Data Points

Sample Number: 0121-97-1326



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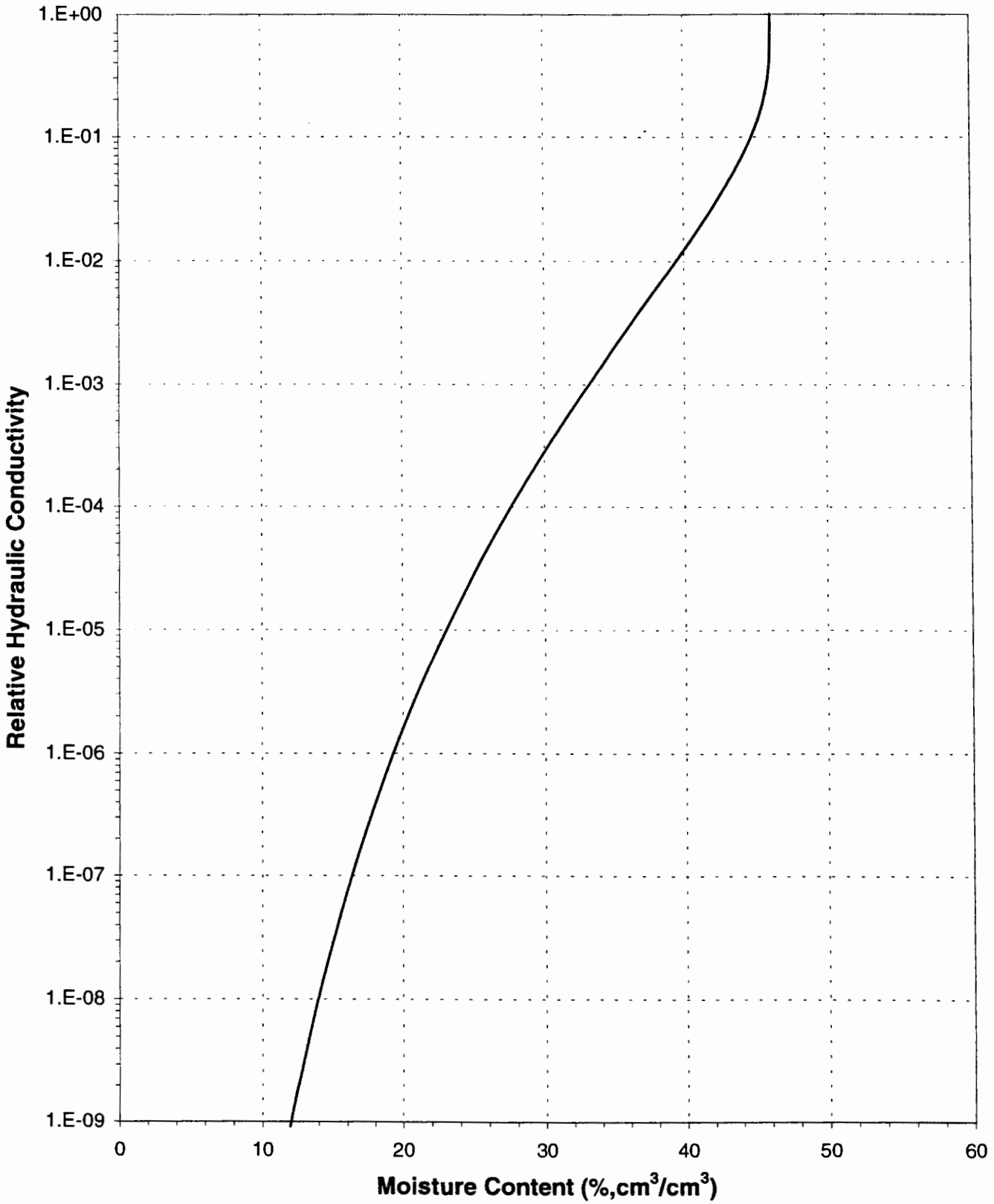
ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Plot of Relative Hydraulic Conductivity vs Moisture Content

Sample Number: 0121-97-1326

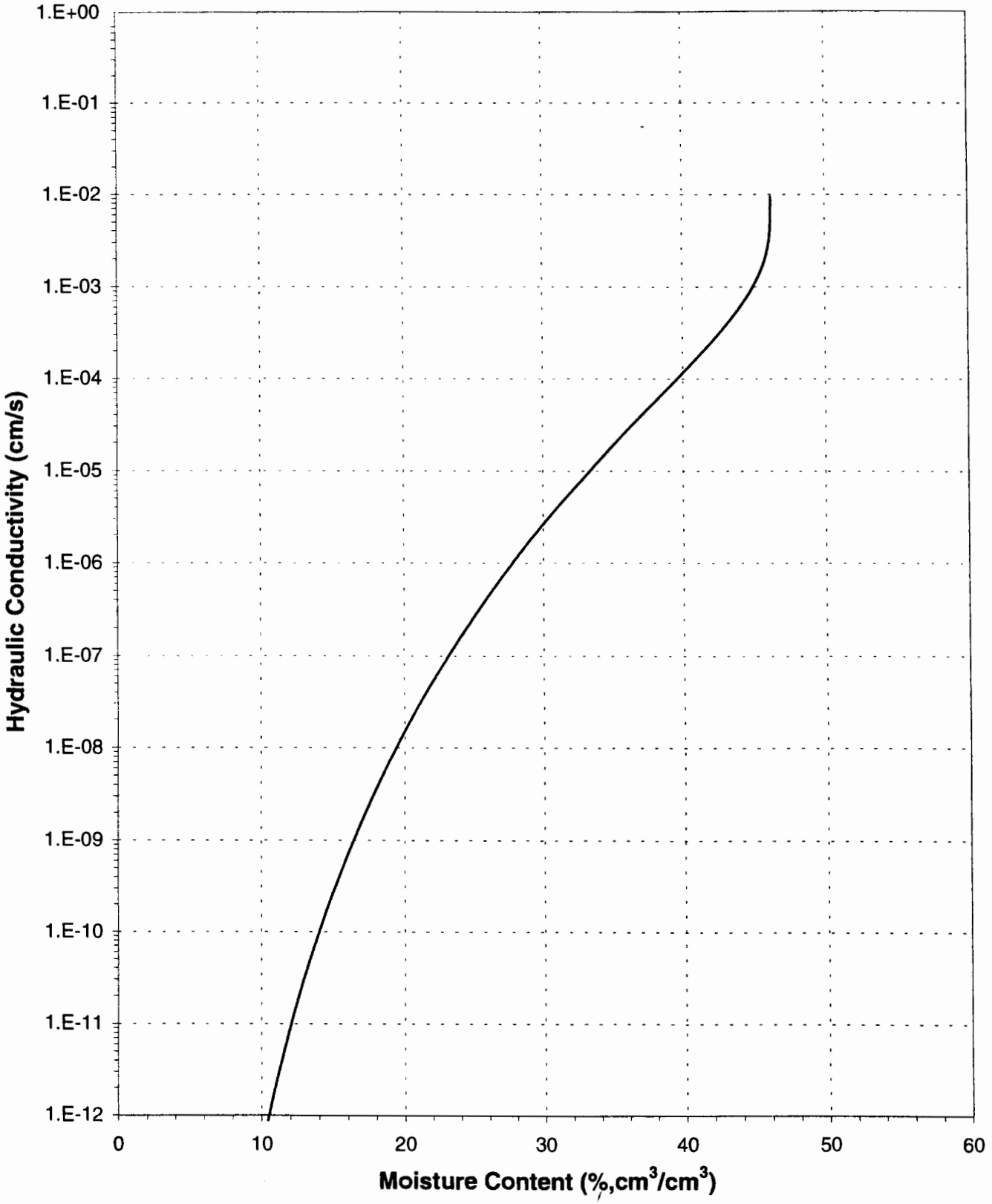


DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: 0121-97-1326



Plot of Relative Hydraulic Conductivity vs Pressure Head

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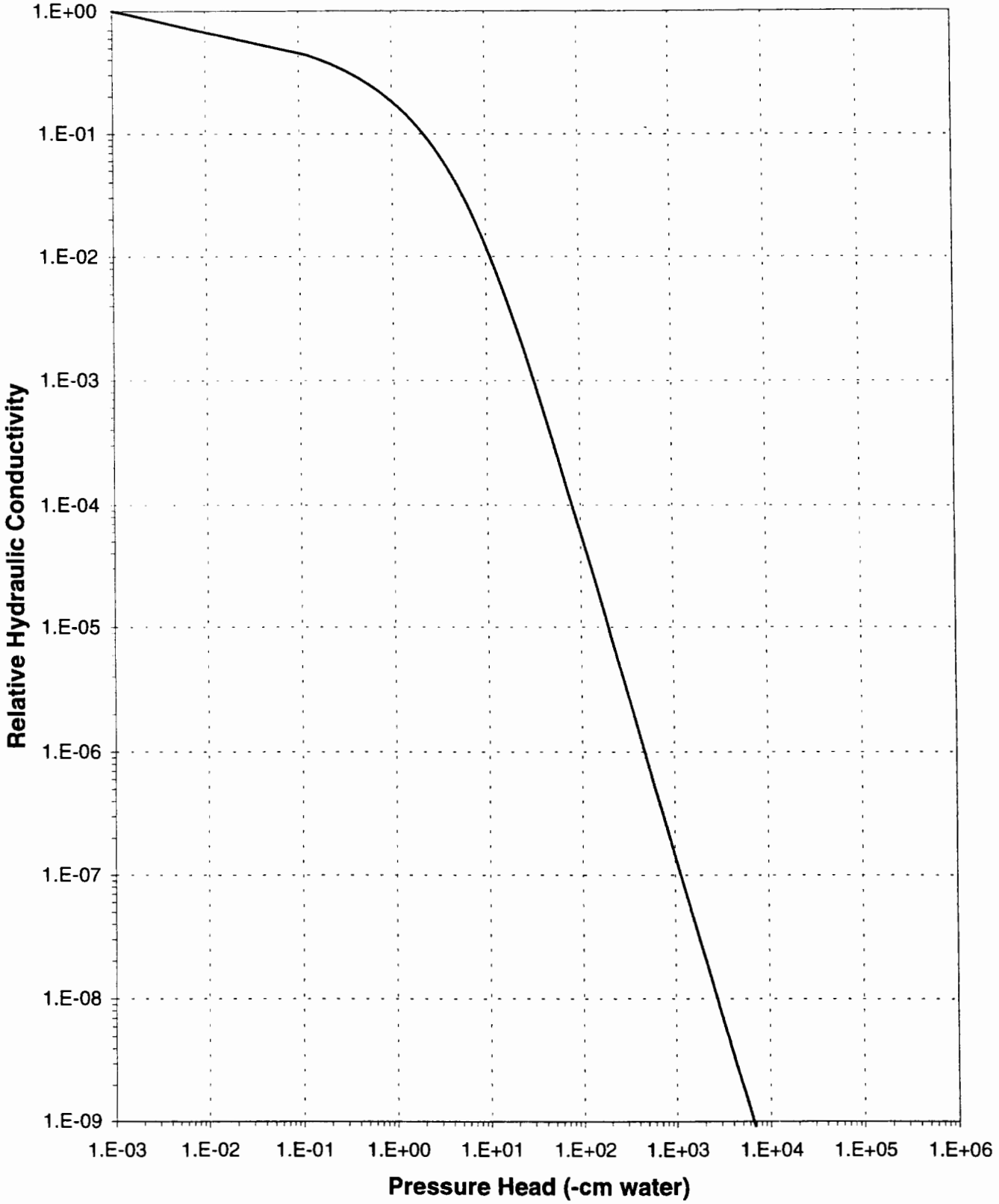
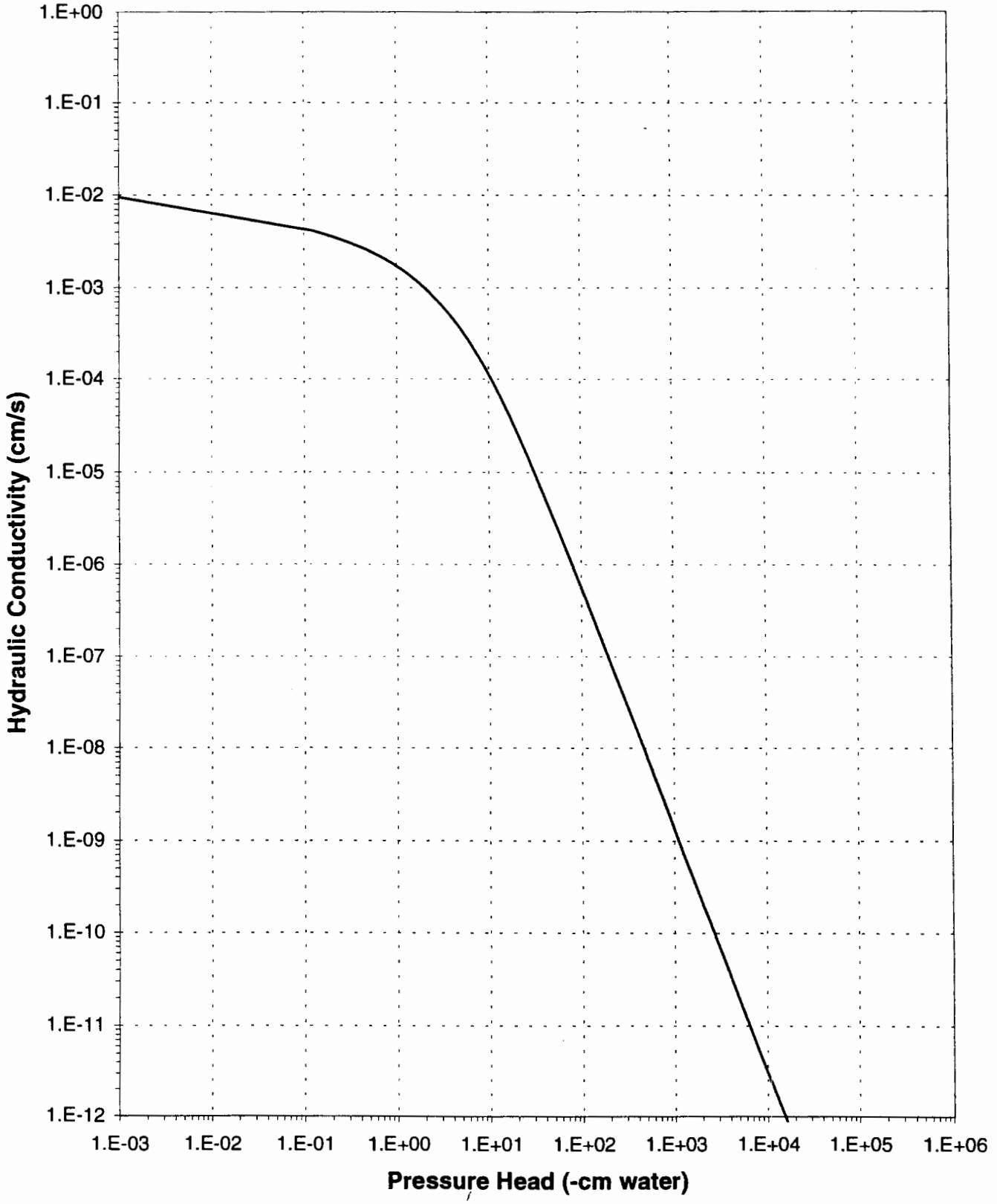


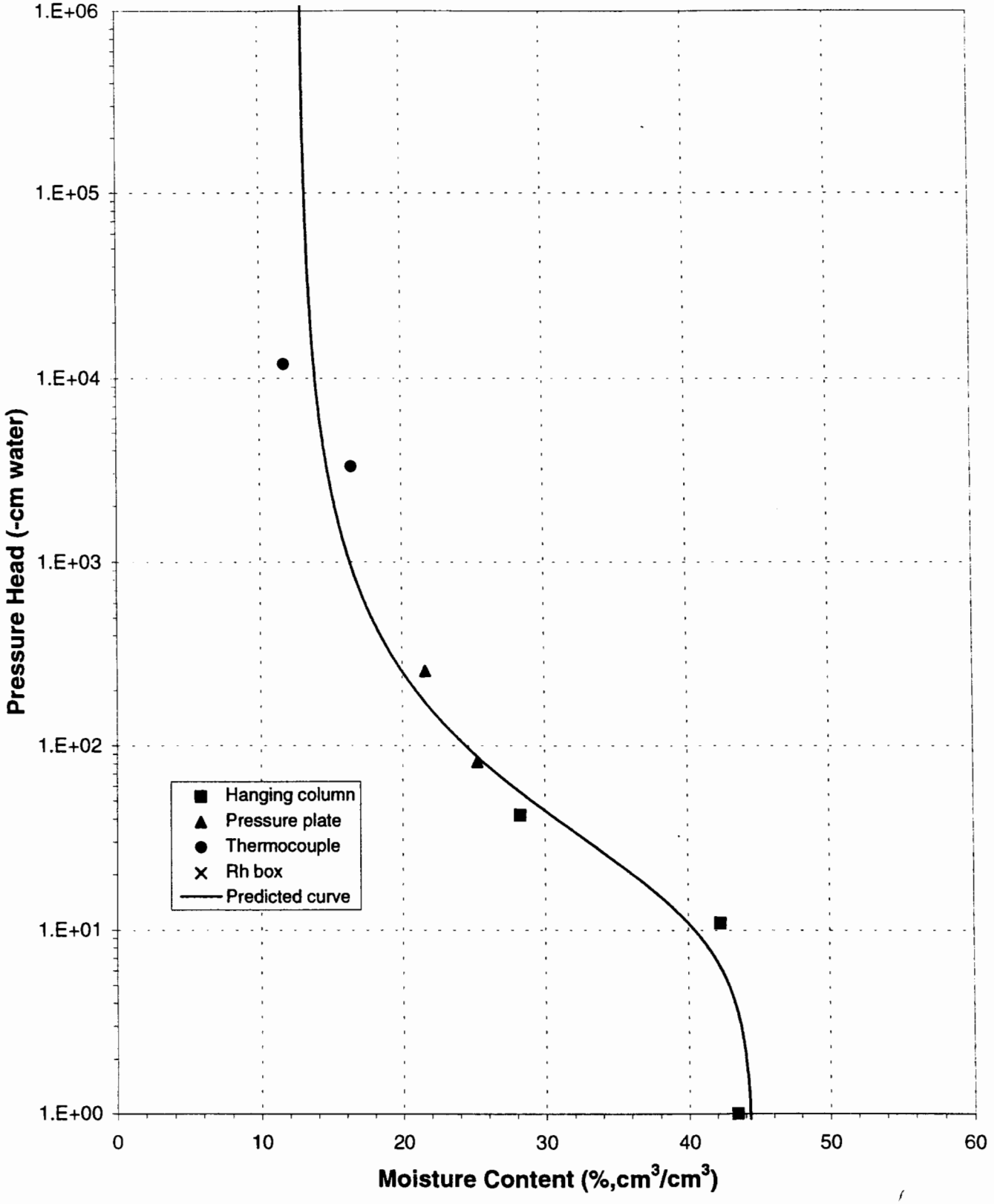
Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: 0121-97-1326



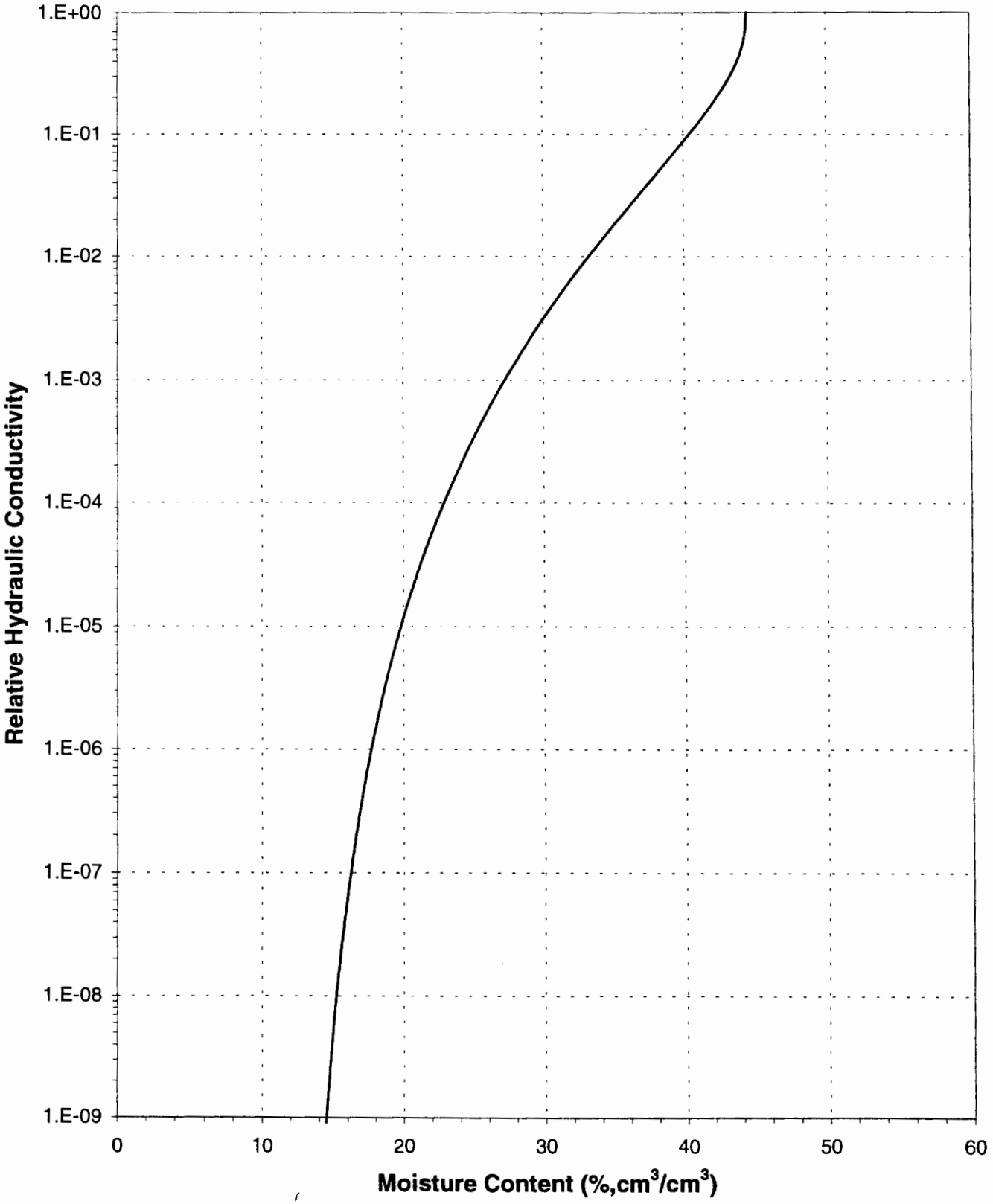
Predicted Water Retention Curve and Data Points

Sample Number: 0121-97-1327



Plot of Relative Hydraulic Conductivity vs Moisture Content

Sample Number: 0121-97-1327



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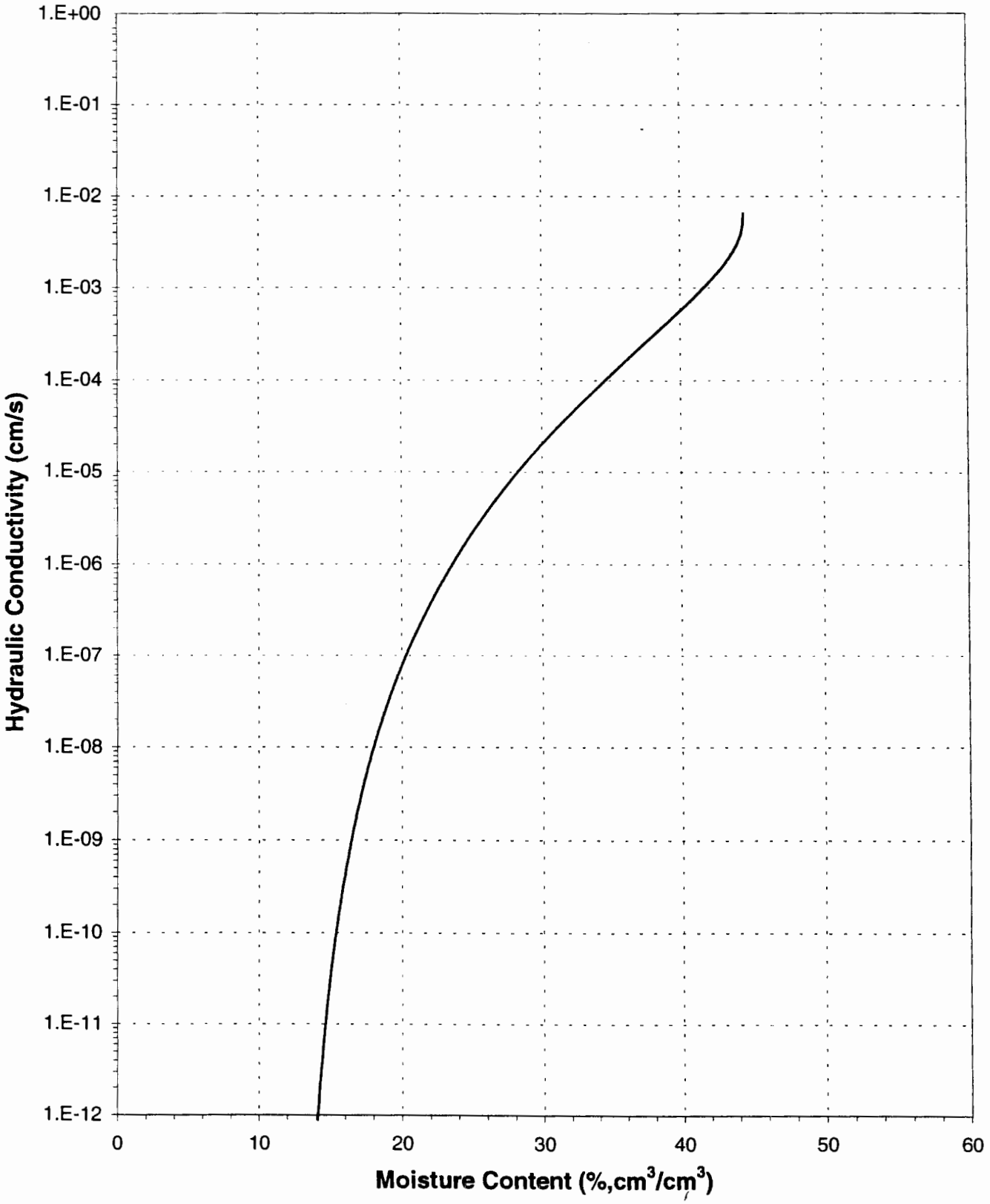
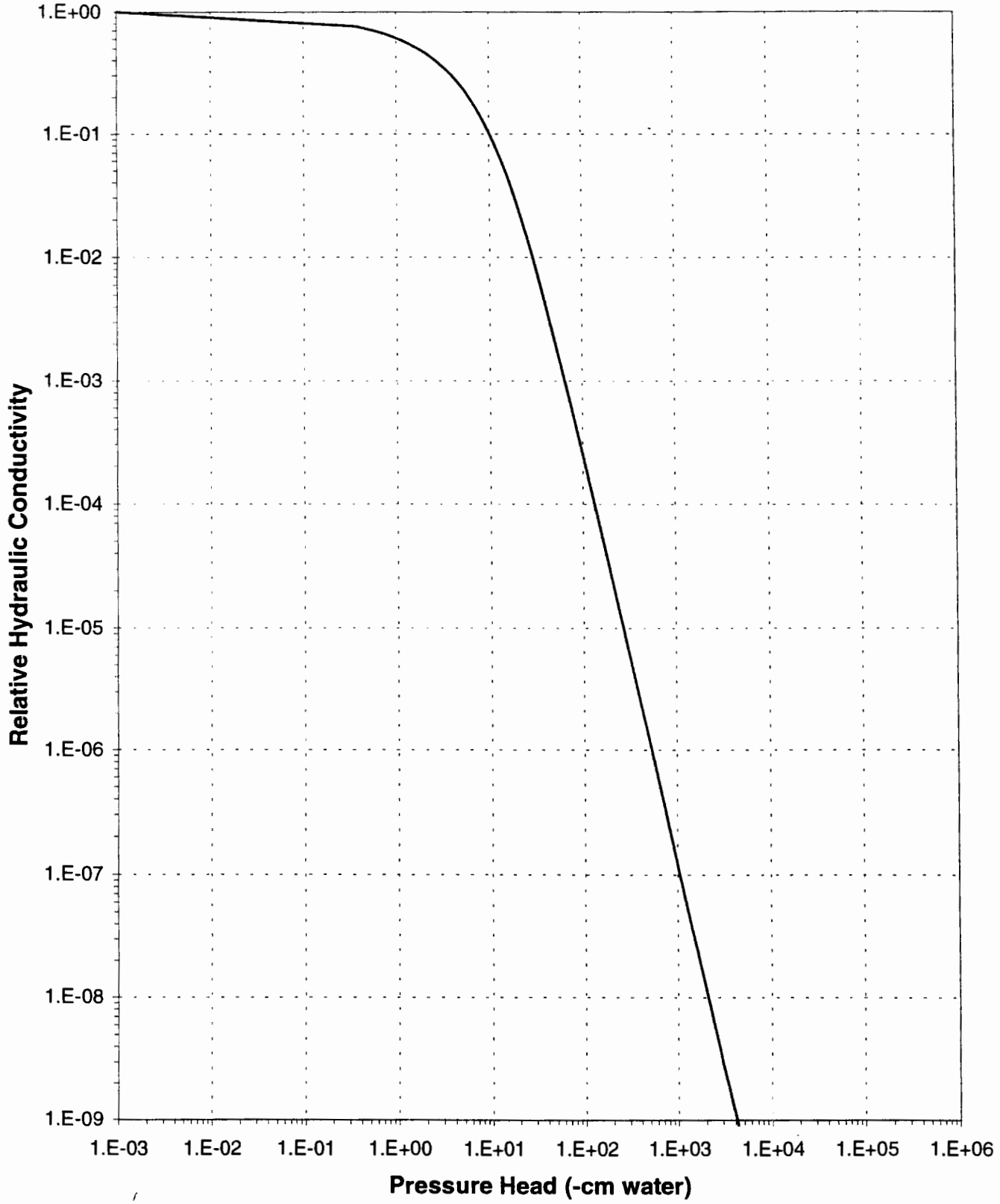
Plot of Hydraulic Conductivity vs Moisture Content

Sample Number: 0121-97-1327



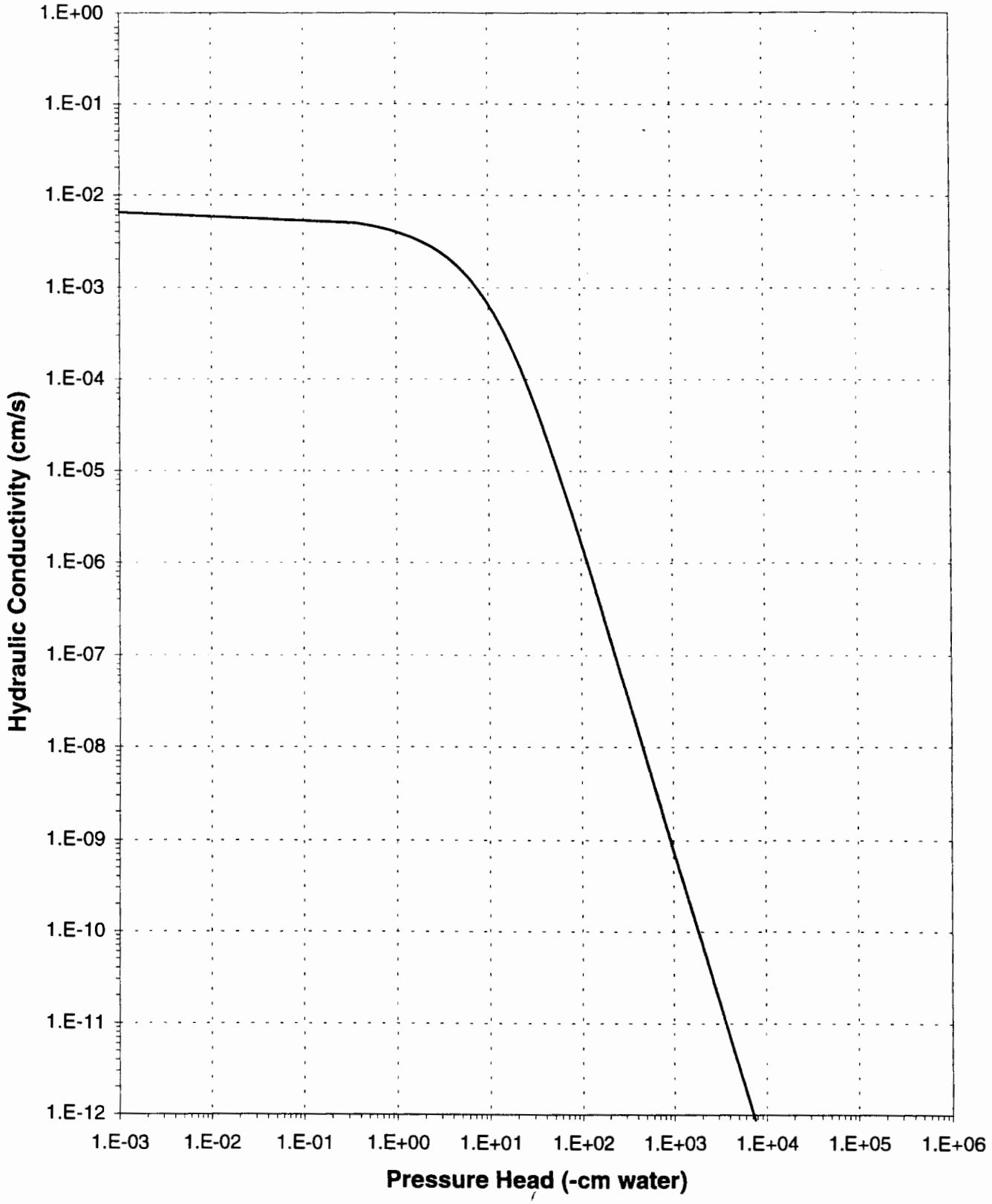
Plot of Relative Hydraulic Conductivity vs Pressure Head

Sample Number: 0121-97-1327



Plot of Hydraulic Conductivity vs Pressure Head

Sample Number: 0121-97-1327



Appendix E

Laboratory Methods

SUMMARY OF LABORATORY METHODS

Methods	Reference
Moisture Content	ASTM D 2216-92
Bulk Density	ASTM D 2937-94/Klute, 1986. Chp. 13, pp. 363-367
Porosity	Klute, 1986. Chp. 18, pp. 444-445
Saturated Hydraulic Conductivity	
Constant Head	ASTM D 2434-68(74)
Falling Head	Klute, 1986. Chp. 28, pp. 700-703
Moisture Retention Characteristics	
Hanging Column	Klute, 1986. Chp. 26, pp. 637-639
Pressure Plate Extractor	ASTM D 2325-68(94)
Thermocouple Psychrometer	Klute, 1986. Chp. 24, pp. 597-618 Operators Manual for the SC-10A Thermocouple Psychrometer Sample Chamber (manufactured by Decagon Devices, Inc., Pullman, WA)
Unsaturated Hydraulic Conductivity (Calculated from Moisture Retention Data)	Van Genuchten, M. 1980. A Closed Form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils. *Soil Sci. Soc. Am. J.* 44:892-898.

* Klute, A. (ed.) 1986. *Methods of Soil Analysis, Part 1*, 2nd ed. American Society of Agronomy. Madison, WI.