107087

Data Report:
Open Borehole Anemometry and In-Situ Gas Permeability Measurements in Boreholes 54-1001 through 54-1006, Los Alamos Technical Area 54

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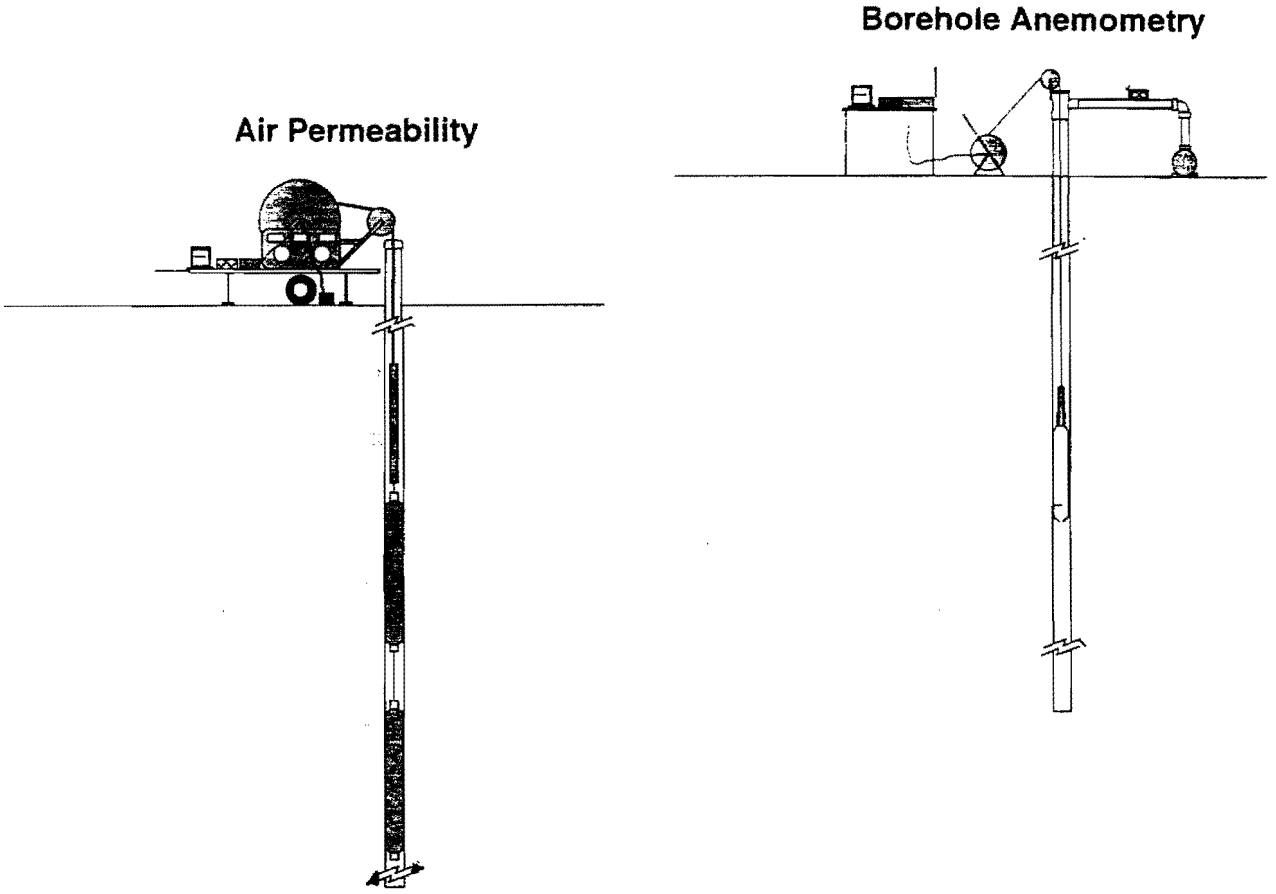
OU-1148
Contract Number: 9-XZ3-2348K-1



December 1994

Science & Engineering Associates, Inc.

1570 Pacheco, Suite D-1
Santa Fe, NM 87505
Phone: (505) 983-6698
Fax: (505) 983-5868

SEASF-TR-94-020

32185

Science & Engineering Associates, Inc.
1570 Pacheco, Suite D-1
Santa Fe, NM 87501
(505) 983-6698
FAX: (505) 983-5868

December 28, 1994

Don Krier
Los Alamos National Laboratories
MS J576, Group EES-1
Los Alamos, NM 87545

Reference: Los Alamos Contract #9-XZ3-2348K-1,
Eastman Cherrington Environmental Contract #1489-L0013-94

Dear Don,

Enclosed is the data report of the open borehole anemometry and gas permeability conducted by SEA in Technical Area 54, Area G boreholes 54-1001 through 54-1006.

Please contact me if you have questions.

Sincerely,

Bill

William E. Lowry, P.E.
Manager, Environmental Technologies Division

WEL/jj

xc: Bob Gilkeson
Carl Keller

Data Report:
Open Borehole Anemometry and In-Situ Gas Permeability Measurements in Boreholes 54-1001 through 54-1006, Los Alamos Technical Area 54

I. INTRODUCTION

In support of the Operable Unit 1148 site characterization, Science and Engineering Associates (SEA) performed a series of airflow characterization measurements in six boreholes drilled in Area G, TA-54.* The intent of these measurements was to characterize, on both the large and small scale, the airflow nature of the mesa . The tests included open borehole anemometry and discrete in-situ straddle packer gas permeability measurements.

The open borehole anemometry measurements were conducted shortly after the boreholes were drilled in the fall and winter of 1993. For these measurements an extraction blower was placed on top of the well, air was drawn out at a constant flow rate and a velocity probe was raised and lowered in the boreholes to determine the velocity profile in the well. These measurements indicated, on a large scale (tens to hundreds of cubic meters), the airflow production characteristics of the well, identifying contrasts in permeability in the boreholes. From this data and the geologic logs, locations for subsequent discrete gas permeability measurements were selected.

The straddle packer permeability measurements were performed at multiple depths in the holes to characterize, on a much smaller scale (cubic meters), the effective gas permeability of the media. Air was extracted from discrete zones isolated by pneumatic packers, and the resulting air flow rate and draw-down pressure were used to infer an effective gas permeability.

* This work was performed as a subcontract activity for the Eastman Cherrington Environmental Company, contract #1489-L0013-94.

II. METHODOLOGY

A. Open Borehole Anemometry

Open borehole anemometry measures air production zones in the borehole under a vacuum extraction condition. The six boreholes tested are nominally 8-inch-diameter, with actual diameters ranging from 7 to 9 inches. Each of the wells is cased in its top 30 feet with an 8-inch-diameter steel casing. After augering, the wells were measured with a 3-arm caliper, geophysical logs were run, and borehole camera runs were conducted.

To conduct the borehole anemometry measurements, the extraction blower was configured at the top of the well to apply approximately 6-inch water column (15 mbar) vacuum on the well. The extraction vacuum was measured with a digital transducer. During the extraction measurement, a velocity probe was lowered in the well (located within 2 inches of the borehole center) and stopped at discrete locations to collect velocity data. The physical configuration is indicated in Figure 1. The velocity sensor is a TSI hot film anemometry device with a measurement range of 10 ft/min. to 1000 ft/min standard velocity. Its stated accuracy is ±1.5 percent of the reading plus 0.5 percent of its full scale indication. At 10 ft/m this yields an uncertainty of ±5 ft/m, and at 100 ft/m the uncertainty is ±6.5 ft/min. At each location, pressure and temperature data were also acquired. The pressure transducer used was a SETRA Model 270 barometric pressure transducer with an accuracy of 0.1 millibar. Temperature measurements were accomplished by a thermocouple with an absolute accuracy of approximately 3°F.

Data was acquired and stored with a Campbell Scientific 21X datalogger located above ground. At each measurement location, the datalogger collected 10 samples (taken once per second), averaged them and performed standard deviation calculations. That data was then recorded and stored. The anemometer was moved to the next location and the sequence repeated. Typically, measurements were conducted every 20 feet as the anemometer was lowered in the hole; on the way out of the borehole, data was taken every 5 feet. Data at 5-foot spacing is reported.

B. Straddle Packer Permeability Measurements

Straddle packer permeability measurements have historically been performed to conduct air and water permeability measurements in porous media. For this application, a spherical extraction geometry model is used. If the air injection (or extraction) source can be approximated as a sphere, then the steady state air flow into the source, the source equivalent radius, the source pressure, and the ambient soil gas pressure can be used to infer the effective gas permeability k (References 1 and 2):

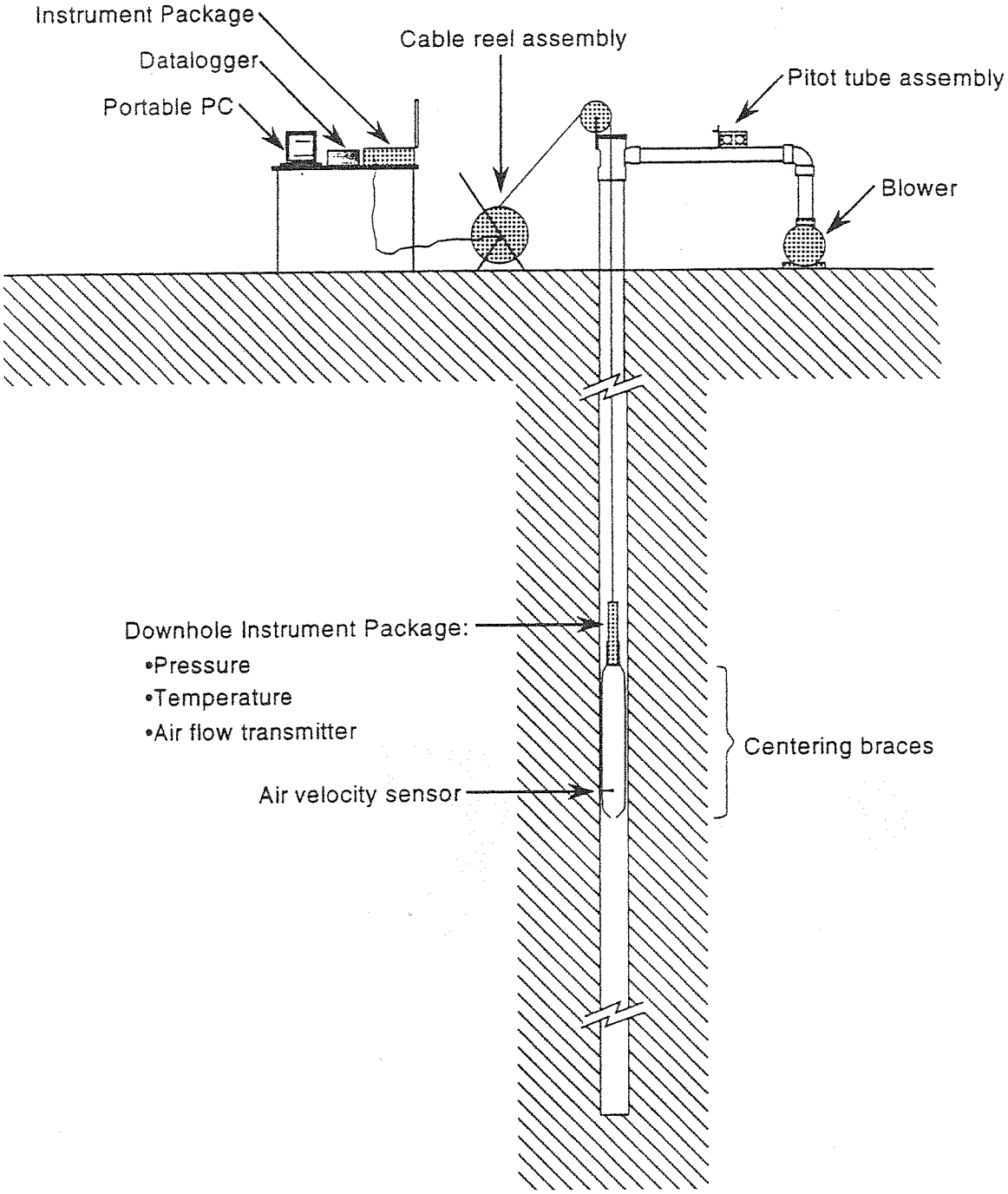


Figure 1. Los Alamos OU-1148 borehole anemometry system.

$$k = \frac{\mu R T \dot{m}}{2\pi M\left(P_o^2 - P^2\right)} \bullet \left(\frac{1}{r_o}\right)$$

where: μ = dynamic gas viscosity

R = universal gas constant

T = absolute temperature

$\dot{m}$ = gas mass flow into soil

M = gas molecular weight

P_o = absolute pressure of source

P = ambient absolute soil gas pressure

r_o = source radius

This model is applied in straddle packer measurements by setting r_o to be the radius of the sphere whose surface area is equal to the area of the exposed borehole wall (Figure 2).

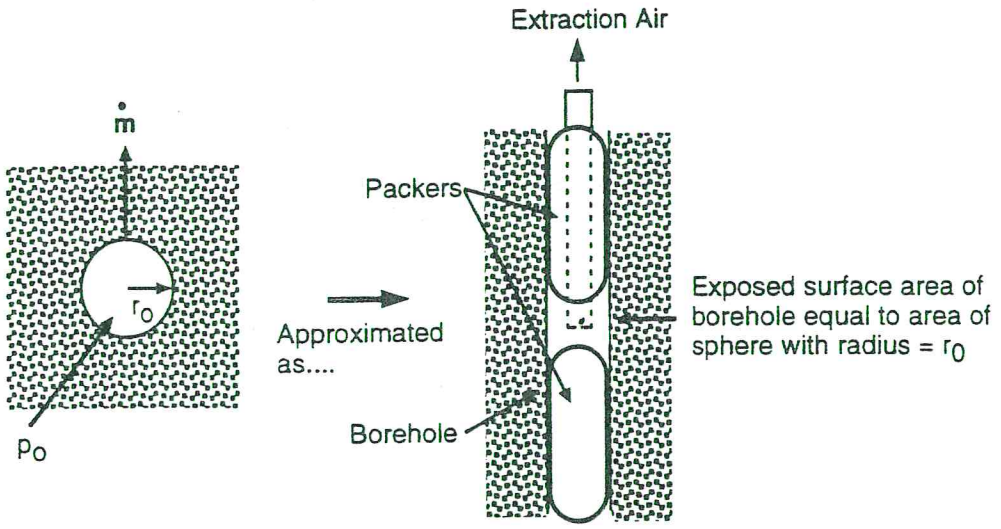


Figure 2. Approximation of a spherical air flow geometry with a conventional straddle packer design for in-situ soil gas permeability measurements.

The packer system applied in this field program is depicted in Figure 3 . Packers are located above and below the extraction zone, separated by 27 inches. This separation was selected to increase the possibility of intersecting fractures in the extraction zone. The packers are each 6 feet in length, fabricated of a lightweight packer material and operated at 5 psi internal pressure during the extraction measurements. The primary instrumentation used in these measurements was the absolute pressure in the extraction zone, the temperature of the air being extracted, and air flow rate during the extraction. All of the

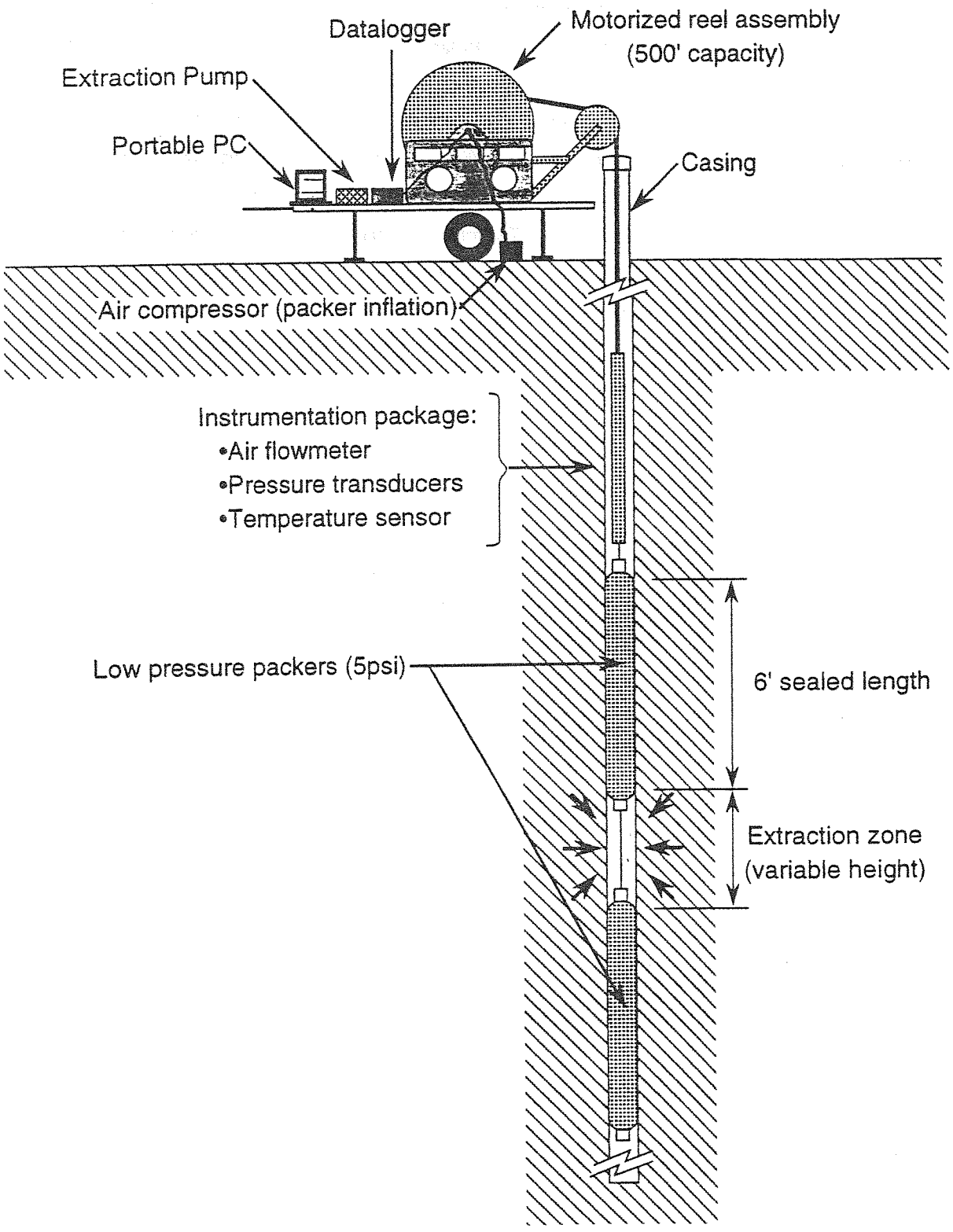


Figure 3. Los Alamos OU-1148 air permeability measurement system.

sensors were located in an electronics package situated above the packer system with the data transmitted uphole to a Campbell Scientific 21X datalogger for averaging and recording above ground.

A typical record of one of these measurements is shown in Figure 4. In that figure are plotted the extraction vacuum, flowrate, and resulting permeability. The instrument uncertainty in this measurement is dominated by the mass flow measurement. This was conducted using a hot film anemometer, which provides a point velocity measurement. The velocity sensor was located in a pipe section with flow straighteners, as recommended by the vendor. Flow calibrations were performed before (and sometimes after) emplacement in each borehole using a Dwyer variable area flowmeter. Given the accuracy of the Dwyer meter (±2 percent) we expect the mass flow determination to be within ±5 percent. This translates to an equivalent instrument uncertainty in the permeability determination of ±5 percent..

± error due to
Equation formula

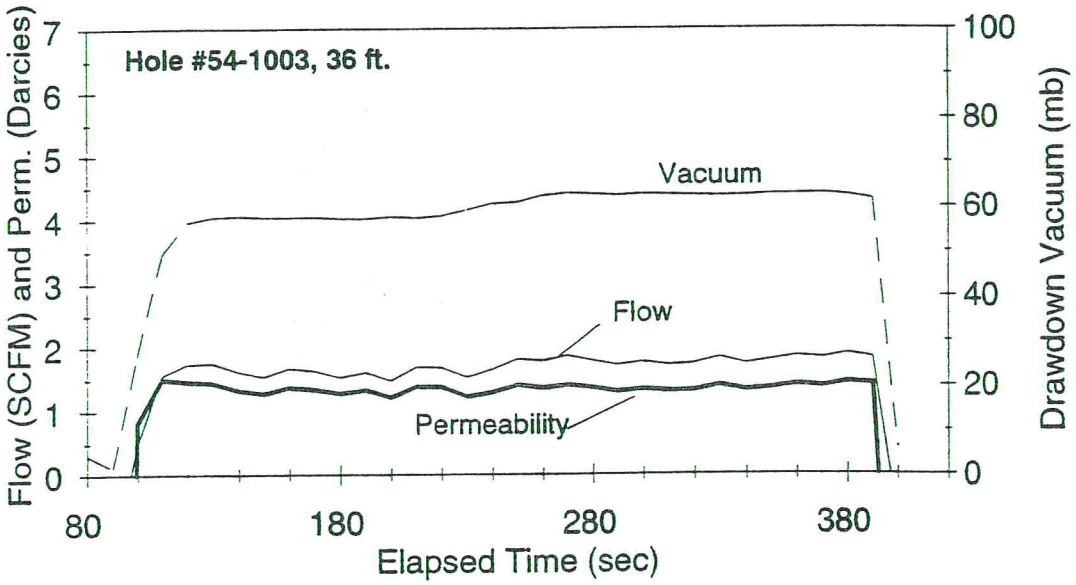


Figure 4. Drawdown pressure, air flow and resulting permeability during a typical measurement sequence.

III. DESCRIPTION OF PLOTTED RESULTS FROM TA-54 AIRFLOW MEASUREMENTS

For each of the six boreholes, four pages of plots are produced. At the end of each plot set is the table of permeability measurement data. Each plot page is described below:

First page: Gas Permeability Measurements

This is a single plot of the gas permeability data reflected in the permeability data table.

Second page: Anemometry Measurements

The first plot is velocity, which is the raw velocity data recorded with an approximately 6-inch water column vacuum on the well. Data was taken every 5 feet.

The second plot is the caliper log provided by Century Geophysics.

The third plot is borehole airflow, which is the air velocity times the cross-sectional area of the borehole (using caliper data). It has been smoothed with a 5 point moving average.

The fourth plot is of air production as a function of depth, which is a derivative the third plot with respect to depth. It represents the air flow production at different locations in the well.

Third Page: Air Velocity Measurements

This is a single plot of the smoothed volumetric flow data plotted on the second page, third plot.

Fourth page: Summary

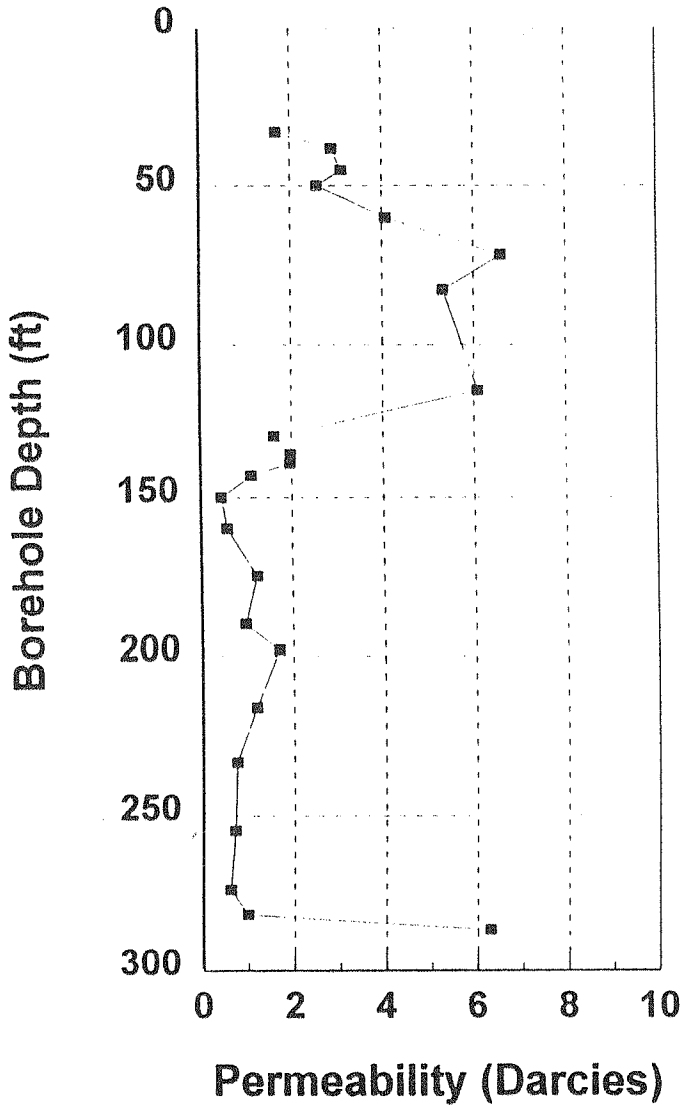
This is a summary page showing airflow production, measured permeability, borehole diameter, and moisture content. The moisture content data was provided by Vince Trujillo.

IV. REFERENCES

1. "In-Situ Permeability Measurements for the Event in U1-C," C. Keller, D. Engstrom, and F. West, Los Alamos Report LANL-5425-MS, 1973.

2. "High Resolution Gas Permeability Measurements with the SEAMIST™ System," with S. Narbutovskih, proceedings of the 5th National Outdoor Action Conference in Aquifer Restoration, Ground Water Monitoring, and Geophysical Methods, Las Vegas, NV, May 1991.

Borehole #54-1001
Gas Permeability Measurements



Validation sheet
Hole #1

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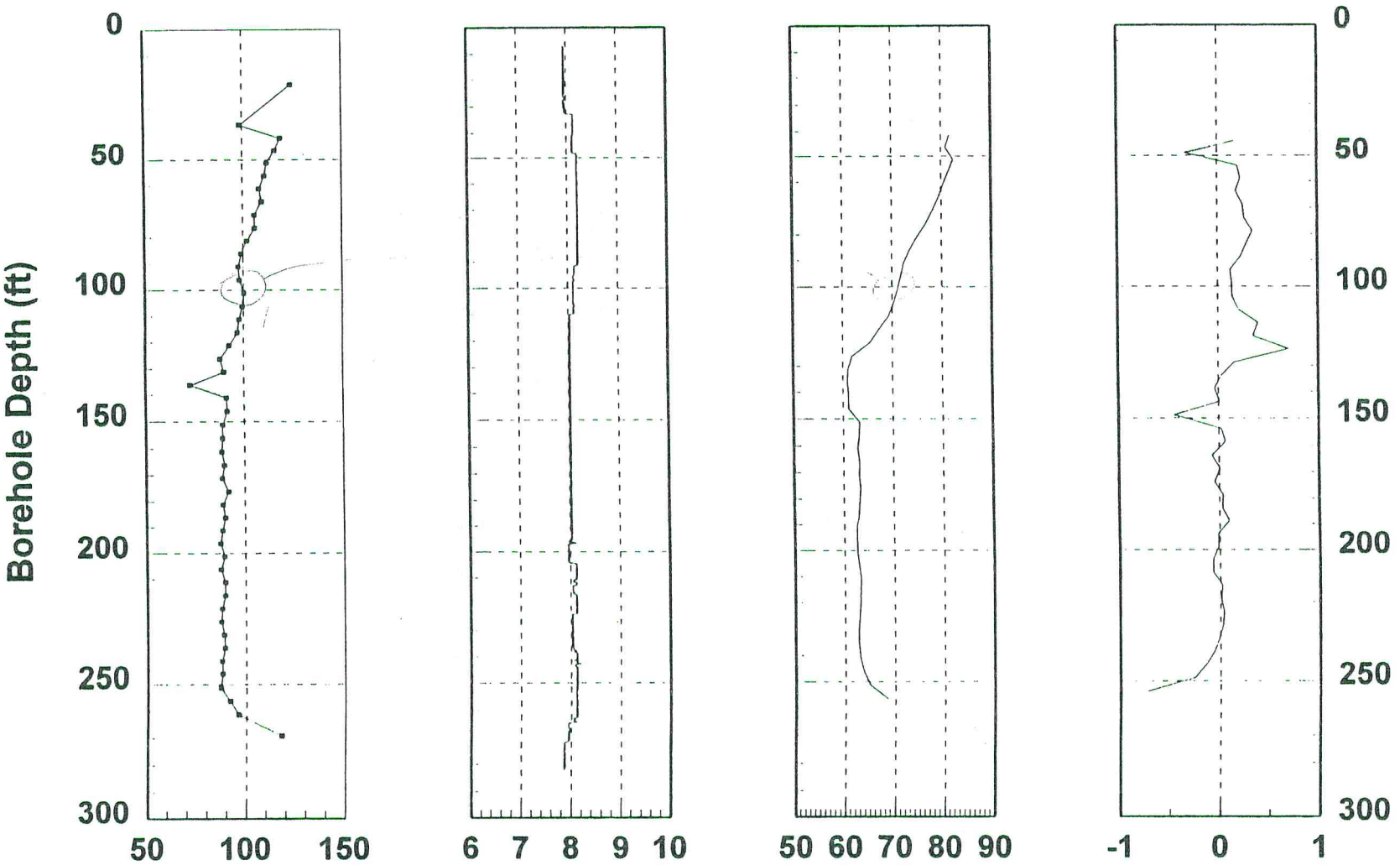
Borehole #54-1001
Anemometry Measurements



100 ft/minute, 6" dia ⇒ $\pi(\frac{1}{3})^2 \times 100$ ft³/min
≈ 35 cfm, not 70

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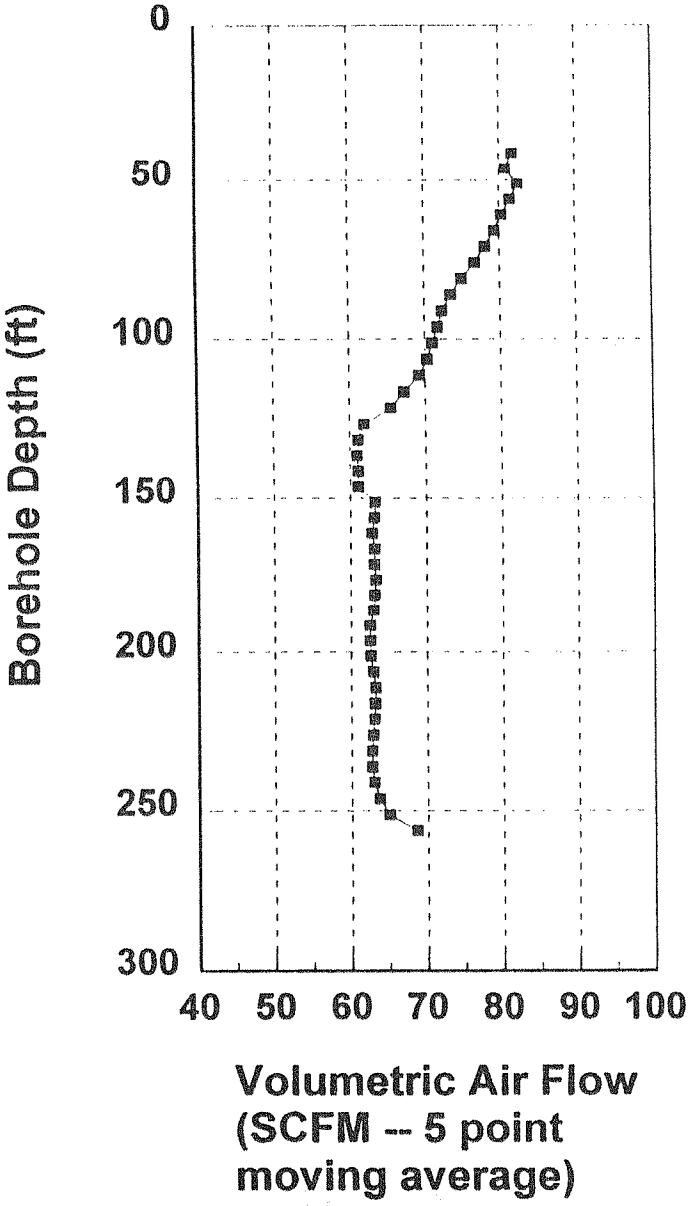
Borehole #54-1001
Air Velocity Measurements



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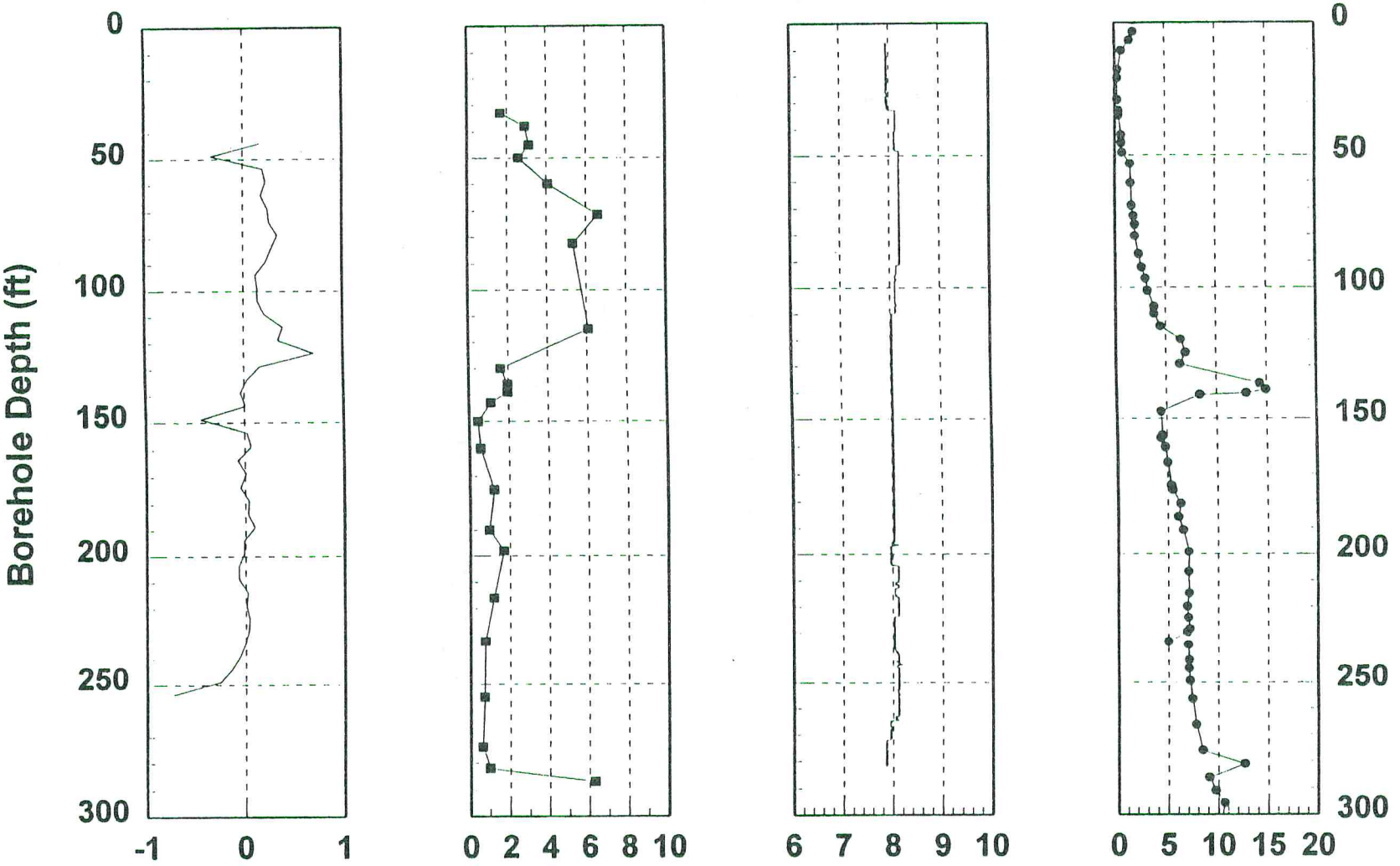
Borehole #54-1001
Summary



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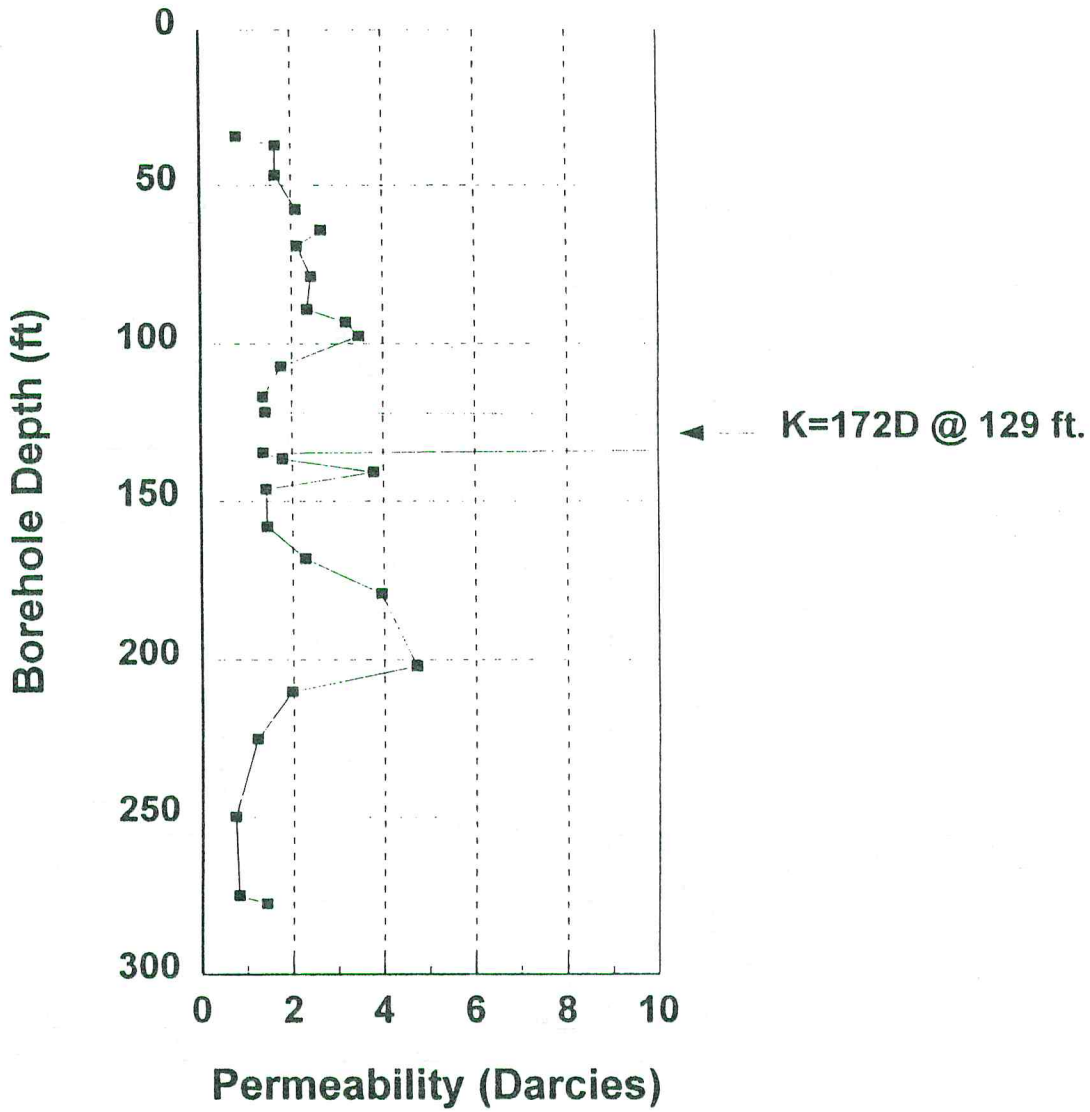
In-situ Soil Gas Permeability Data

Borehole 54-1001 **Slant (deg. off vert.)** **22**

Hole No.	Date	Time	Depth in Borehole (ft)	Hole Diameter (in.)	Extr. Zone Height (in.)	Packer Pressure (psi)	Ambient DH Pressure (mbar)	Extraction DP (mbar)	Air Temperature (C)	Air Flowrate (scfm)	Permeability (Darcies)	True Depth Below Ground (ft)
1	02-Mar	1058	33.0	8.10	27	5.20	800.15	28.47	17.88	1.01	1.70	30.6
1	02-Mar	1108	38.0	8.10	27	5.18	800.29	16.88	18.06	1.04	2.91	35.2
1	02-Mar	1117	45.0	8.10	27	5.31	799.61	15.13	18.07	1.00	3.12	41.7
1	02-Mar	1127	50.0	8.20	27	5.26	799.39	17.74	18.06	0.98	2.59	46.4
1	02-Mar	1137	60.0	8.20	27	5.22	799.59	12.04	17.87	1.05	4.08	55.6
1	02-Mar	1149	71.5	8.20	27	5.25	799.68	7.20	17.63	1.02	6.60	66.3
1	02-Mar	1157	82.5	8.20	27	5.30	799.98	8.99	17.49	1.03	5.33	76.5
1	02-Mar	1306	115.0	8.00	27	5.25	800.03	7.59	16.04	0.98	6.08	106.6
1	02-Mar	1323	130.0	8.00	27	5.26	801.15	30.88	16.53	1.05	1.62	120.5
1	02-Mar	1332	136.0	8.00	27	5.23	801.37	26.07	16.46	1.09	1.98	126.1
1	02-Mar	1341	139.0	8.00	27	5.20	801.36	26.76	16.52	1.11	1.97	128.9
1	02-Mar	1351	143.0	8.00	27	5.21	801.25	44.19	16.81	1.02	1.11	132.6
1	02-Mar	1401	150.0	8.00	27	5.16	800.84	115.13	17.30	1.03	0.45	139.1
1	02-Mar	1410	160.0	8.00	27	5.23	800.74	87.36	17.31	1.00	0.57	148.3
1	02-Mar	1420	175.0	8.00	27	5.26	801.00	38.46	17.15	0.98	1.23	162.3
1	02-Mar	1431	190.0	8.00	27	5.24	801.48	54.50	17.50	1.08	0.96	176.2
1	02-Mar	1440	198.0	8.00	27	5.23	800.91	28.95	17.35	1.03	1.70	183.6
1	02-Mar	1450	216.0	8.00	27	5.28	801.92	37.92	17.56	0.94	1.19	200.3
1	02-Mar	1505	233.0	8.00	27	4.86	802.31	72.33	18.02	1.11	0.75	216.0
1	02-Mar	1519	255.0	8.10	27	5.26	802.79	74.19	18.06	1.07	0.71	236.4
1	02-Mar	1528	274.0	8.10	27	5.18	803.16	74.35	18.19	0.92	0.61	254.0
1	02-Mar	1537	282.0	8.00	27	5.23	802.96	52.13	18.24	1.06	0.99	261.5
1	02-Mar	1545	287.0	8.00	27	5.22	802.83	7.65	18.08	1.02	6.28	266.1

Borehole #54-1002
Gas Permeability Measurements



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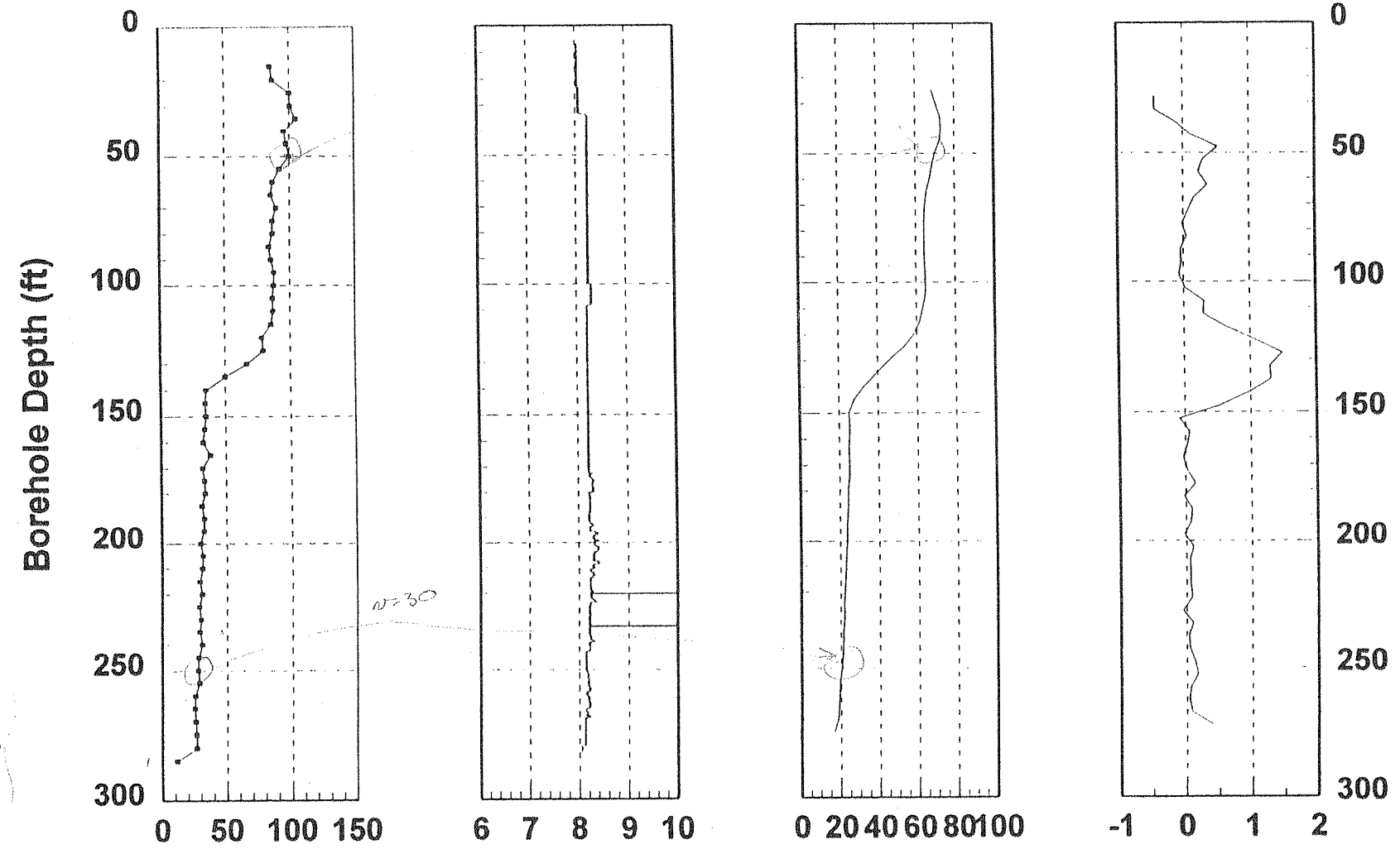
$\frac{\rho V d}{\mu} = \frac{1k_g/m^3 \times .5\,m/s \times .203\,m}{1.8\times10^{-5}\,\frac{kg}{s\,m}} = .057\times10^5 = 5700$. Turbulent

At v = 30 ft/min, laminar

Borehole #54-1002
Anemometry Measurements



8.2" dia

CFM = vel × area = 100 ft/m × $\pi \times \left(\frac{4.1}{12}\right)^2$ = 36.6, not 70. SCFM = 27.0

30 × π × ( )² = 10.9 not 20

SCFM = CFM × $\frac{790}{273}$ = CFM × 0.774

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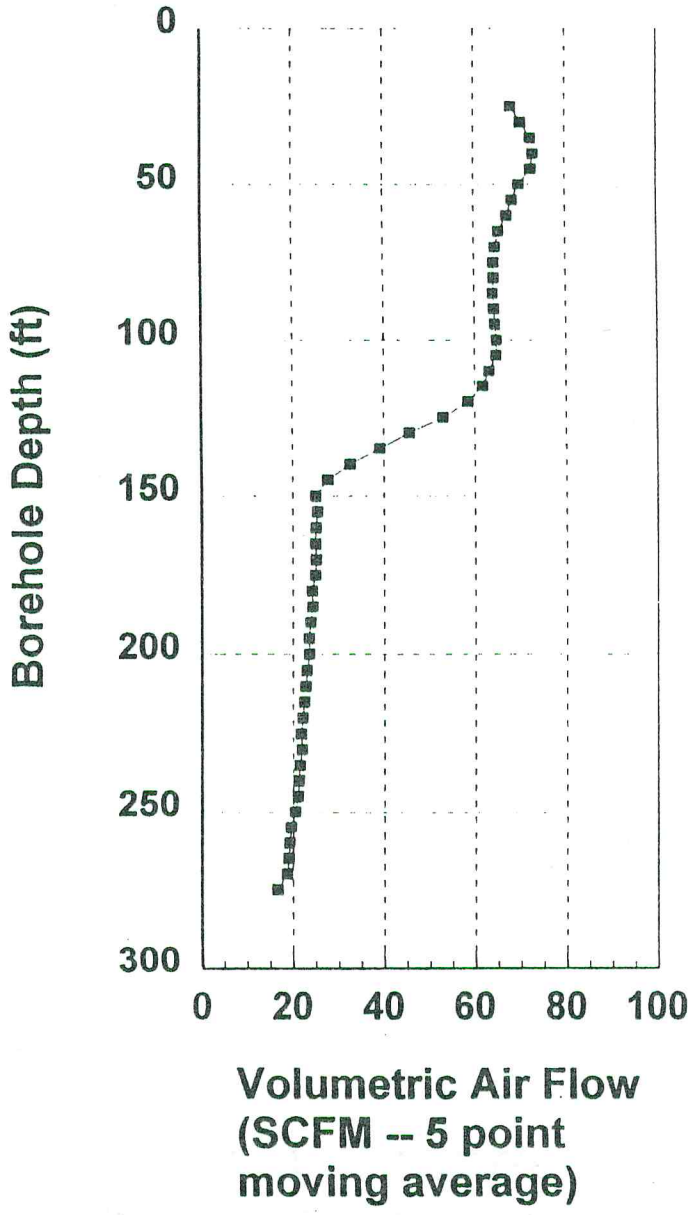
Borehole #54-1002
Air Velocity Measurements



same as 3rd plot of 2nd page

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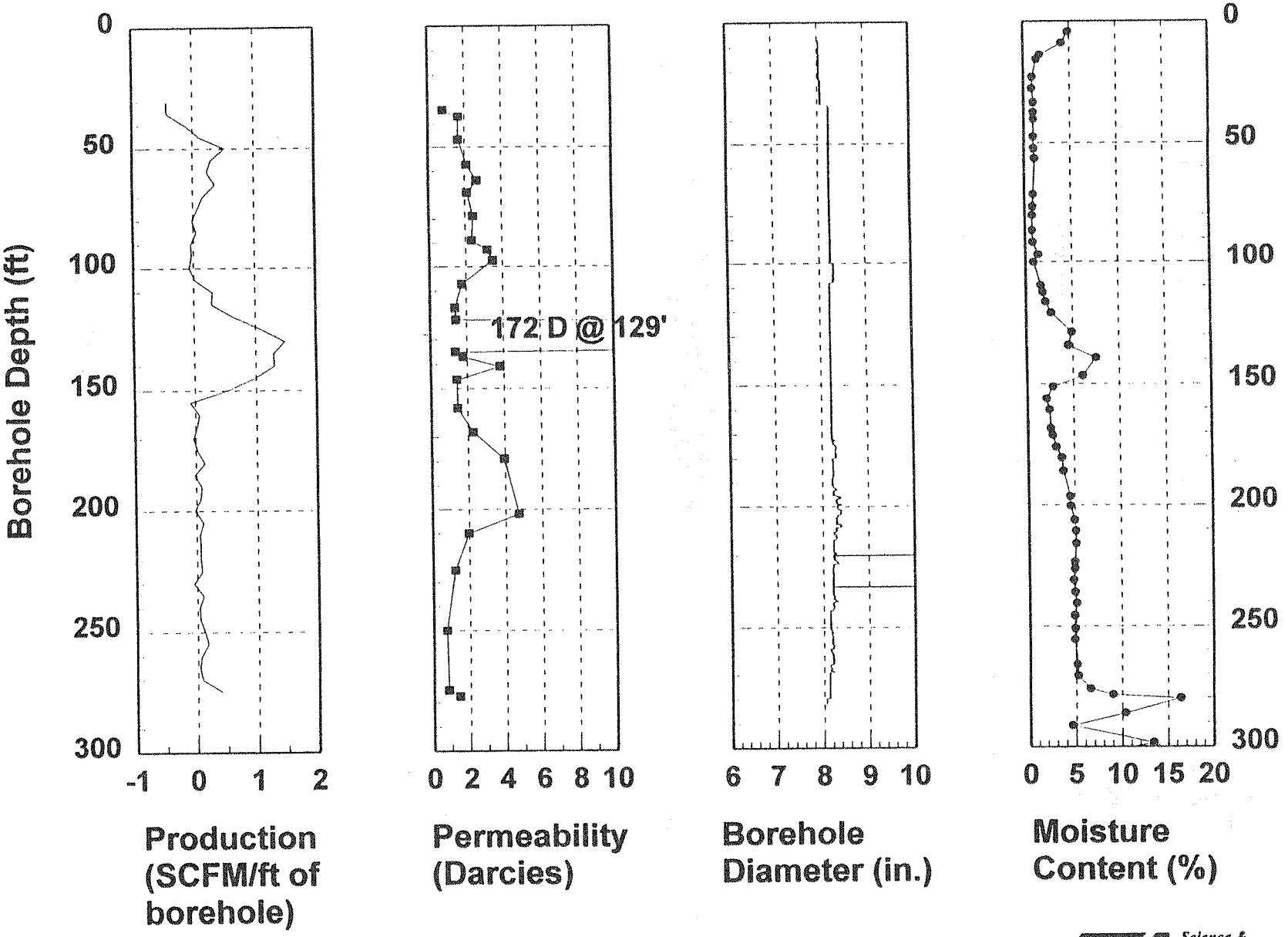
Borehole #54-1002
Summary

Depth Along Borehole, not below ground



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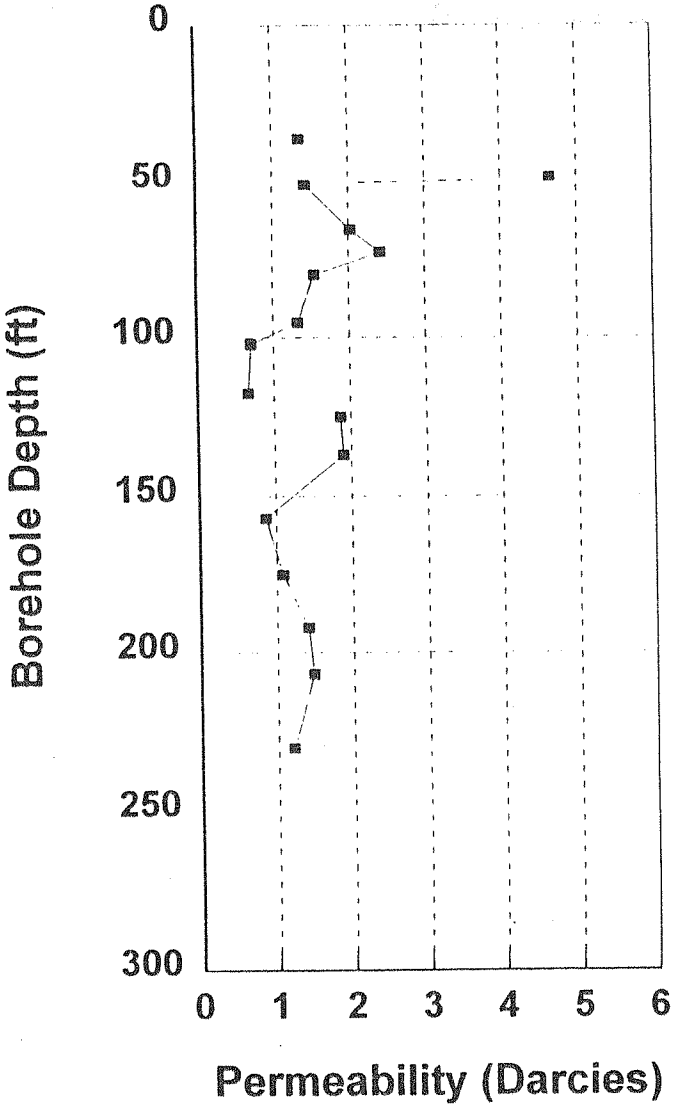
In-situ Soil Gas Permeability Data

Borehole 54-1002 **Slant (deg. off vert) 22**

Hole No.	Date	Time	Depth in Borehole (ft)	Hole Diameter (in.)	Extr. Zone Height (in.)	Packer Pressure (psi)	Ambient DH Pressure (mbar)	Extraction DP (mbar)	Air Temperature (C)	Air Flowrate (scfm)	Permeability (Darcies)	True Depth Below Ground (ft)
2	06-Mar	1121	34.2	8.20	27	5.01	794.66	56.05	15.84	0.94	0.81	31.7
2	06-Mar	1130	37.0	8.20	27	4.90	794.42	29.75	16.26	1.04	1.66	34.3
2	06-Mar	1140	46.7	8.20	27	5.11	794.69	30.66	16.72	1.07	1.65	43.3
2	06-Mar	1150	57.5	8.20	27	4.99	794.78	23.47	16.91	1.04	2.11	53.3
2	06-Mar	1243	64.0	8.20	27	4.83	794.48	20.43	15.93	1.14	2.65	59.3
2	06-Mar	1254	69.0	8.20	27	4.86	794.33	23.73	15.90	1.07	2.13	64.0
2	06-Mar	1311	78.8	8.20	27	5.15	794.88	19.57	16.23	1.01	2.43	73.1
2	06-Mar	1321	89.0	8.20	27	5.26	795.09	19.04	16.43	0.94	2.34	82.5
2	06-Mar	1329	93.0	8.20	27	5.22	794.94	14.27	16.59	0.97	3.19	86.2
2	06-Mar	1340	97.5	8.20	27	5.24	794.82	11.79	16.97	0.87	3.47	90.4
2	06-Mar	1349	107.3	8.30	27	5.26	794.97	25.13	17.23	0.94	1.77	99.5
2	06-Mar	1401	117.0	8.30	27	5.19	794.94	31.93	17.54	0.92	1.37	108.5
2	06-Mar	1409	122.0	8.20	27	5.21	795.17	30.25	17.66	0.90	1.42	113.1
2	06-Mar	1419	129.0	8.20	27	5.10	796.61	0.25	15.90	0.93	172.47	119.6
2	09-Mar	917	135.0	8.20	27	4.90	801.00	30.73	7.22	0.92	1.37	125.2
2	09-Mar	925	137.0	8.20	27	5.11	800.66	24.96	8.85	0.98	1.79	127.0
2	09-Mar	934	141.0	8.20	27	5.26	800.32	12.78	10.08	1.06	3.79	130.7
2	09-Mar	945	146.4	8.20	27	5.22	800.86	29.40	11.79	0.90	1.43	135.7
2	09-Mar	952	158.0	8.20	27	5.39	801.10	30.27	12.64	0.94	1.45	146.5
2	09-Mar	1001	168.0	8.20	27	5.47	800.68	18.23	13.33	0.90	2.28	155.8
2	09-Mar	1009	179.0	8.30	27	5.44	801.34	11.52	14.02	0.99	3.96	166.0
2	09-Mar	1021	202.0	8.30	27	5.42	802.74	10.09	14.88	1.04	4.72	187.3
2	09-Mar	1032	225.0	8.30	27	5.24	802.72	40.24	15.80	1.04	1.21	208.6
2	09-Mar	1041	250.0	8.30	27	5.48	803.57	63.20	16.50	0.96	0.73	231.8
2	09-Mar	1052	275.0	8.10	27	5.26	803.87	60.17	17.05	1.02	0.82	255.0
2	09-Mar	1110	277.5	8.10	27	5.07	803.18	37.28	17.58	1.11	1.42	257.3
2	09-Mar	1248	210.0	8.20	27	5.26	801.82	24.32	15.35	1.03	1.98	194.7

Borehole #54-1003
Gas Permeability Measurements



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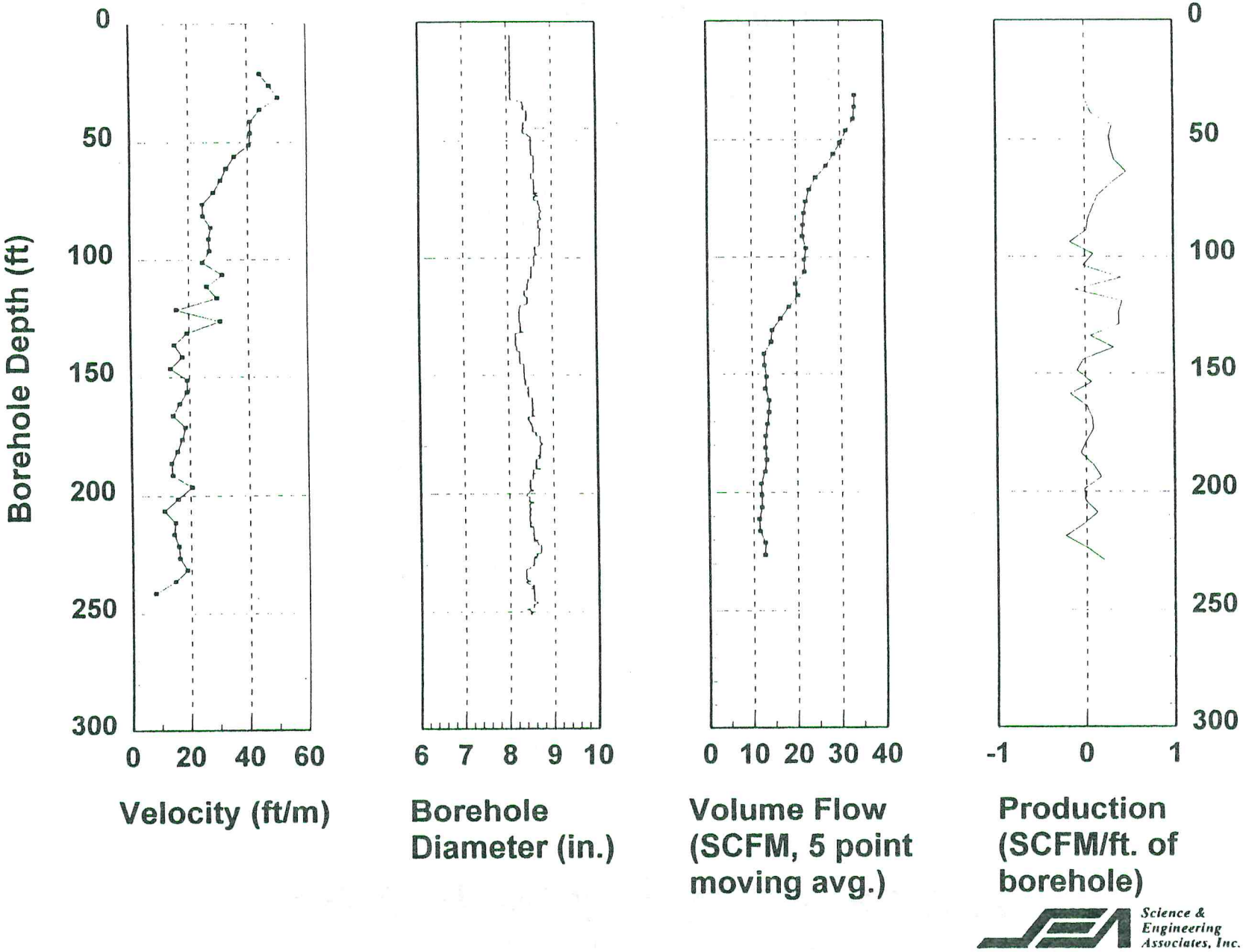
Borehole #54-1003
Anemometry Measurements



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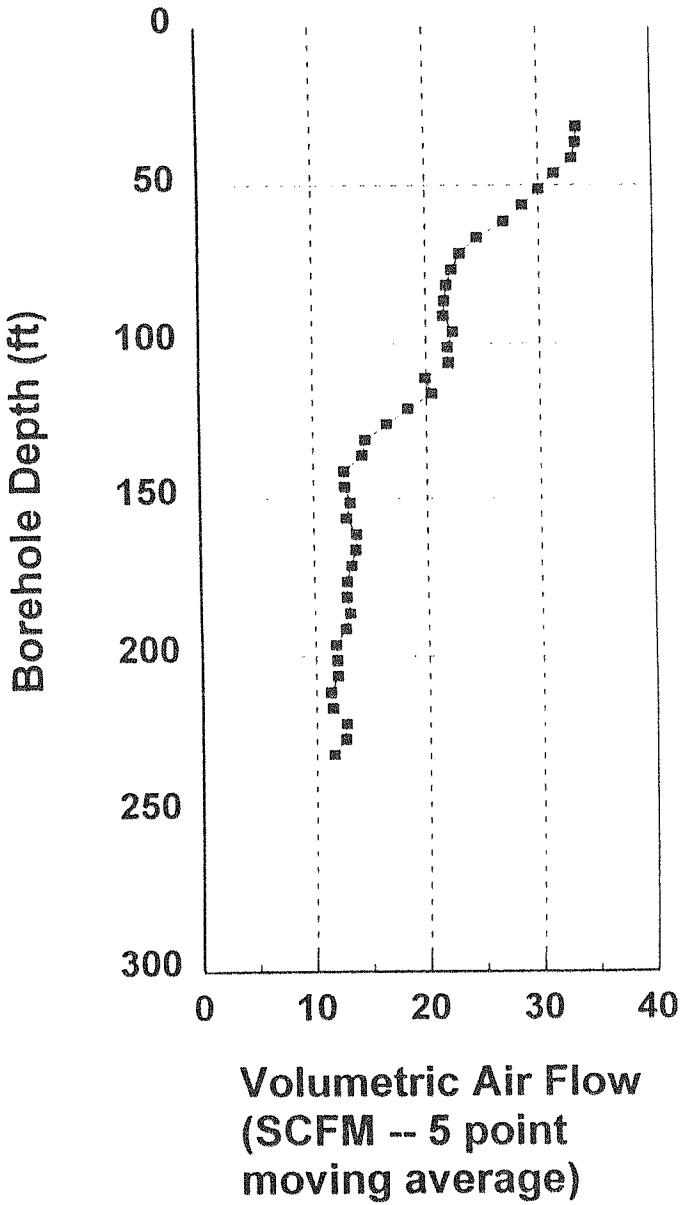
Borehole #54-1003
Air Velocity Measurements



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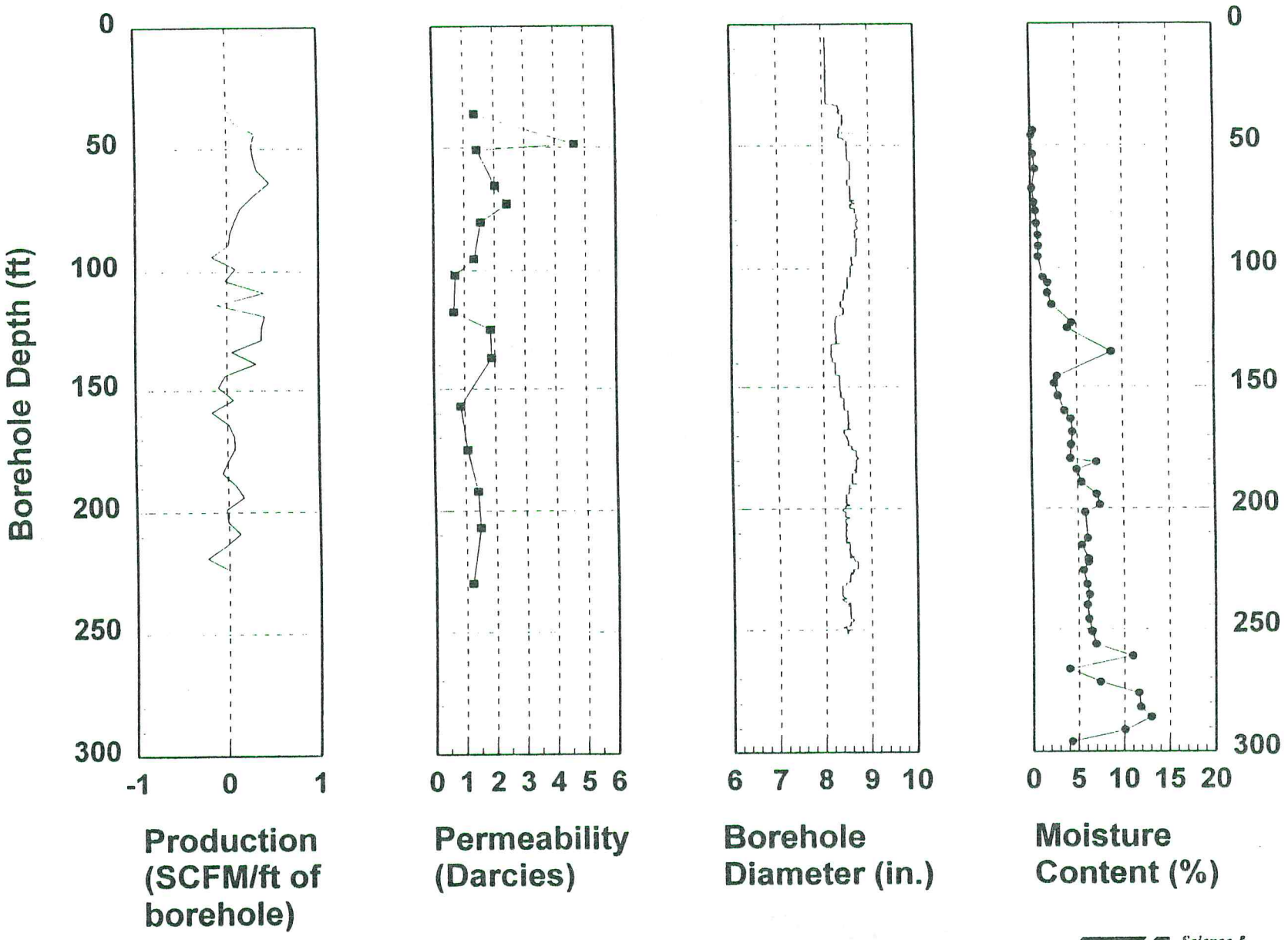
Borehole #54-1003
Summary



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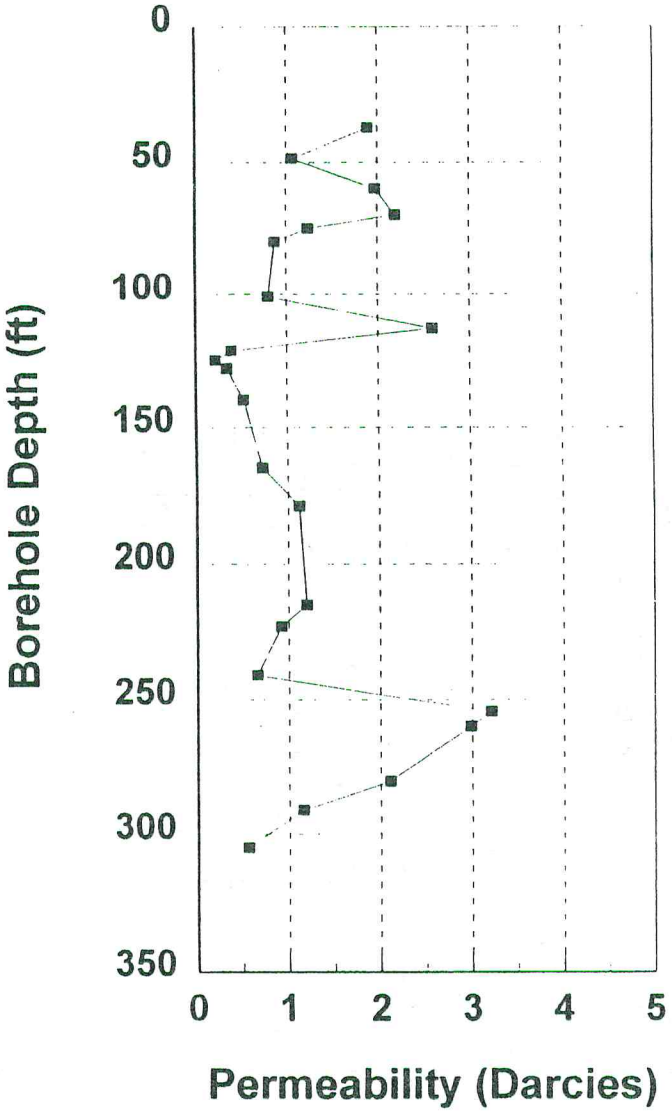
In-situ Soil Gas Permeability Data

Borehole 54-1003 **Slant (deg. off vert) 0**

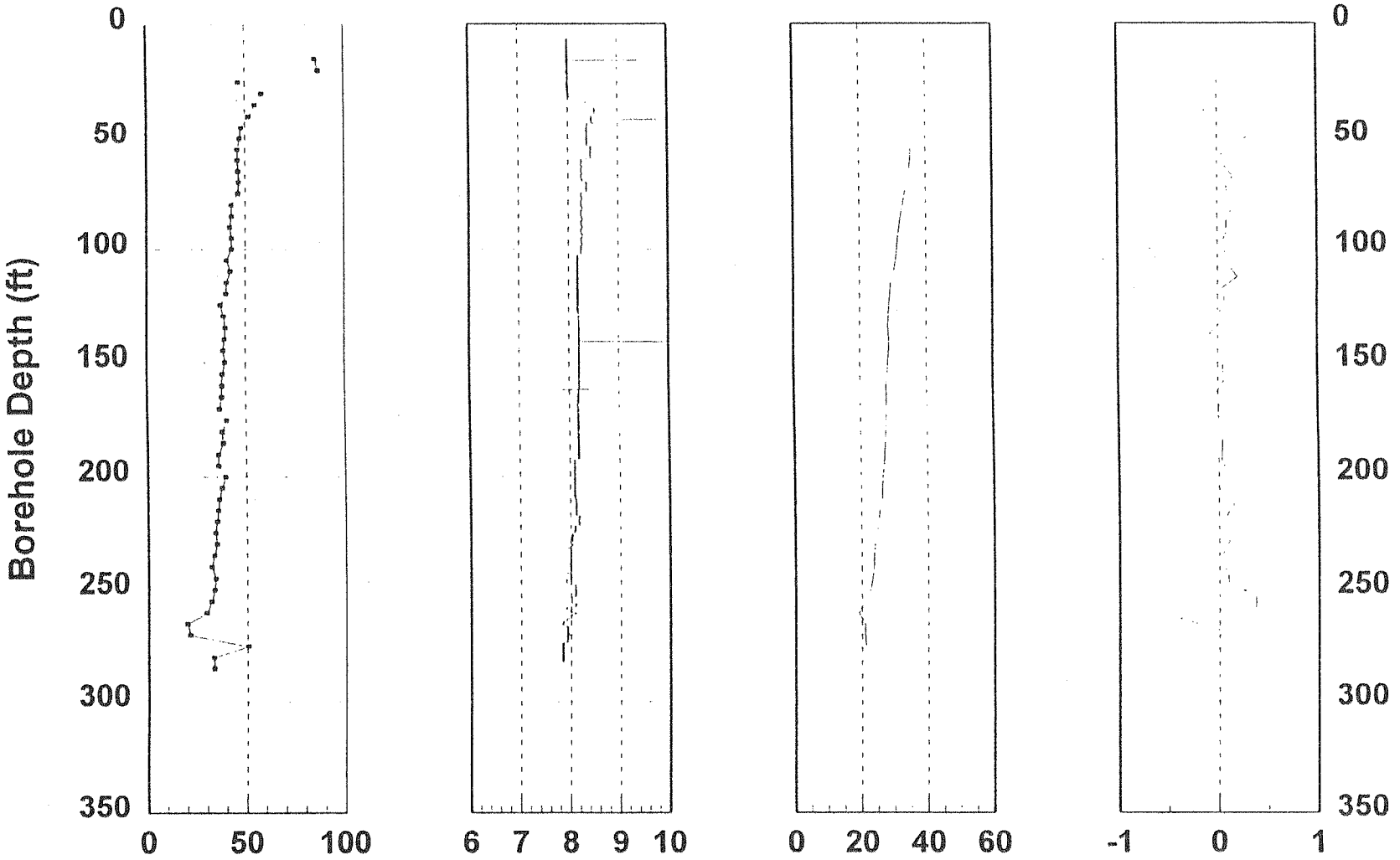
Hole No.	Date	Time	Depth in Borehole (ft)	Hole Diameter (in.)	Extr. Zone Height (in.)	Packer Pressure (psi)	Ambient DH Pressure (mbar)	Extraction DP (mbar)	Air Temperature (C)	Air Flowrate (scfm)	Permeability (Darcies)	True Depth Below Ground (ft)
3	02-Feb	1021	36.0	8.40	27	4.82	794.30	62.77	15.39	1.79	1.36	36.0
3	02-Feb	1037	48.6	8.50	27	4.85	794.58	30.97	15.95	3.09	4.65	48.6
3	02-Feb	1049	51.0	8.50	27	5.05	794.73	65.34	16.44	1.96	1.43	51.0
3	02-Feb	1103	65.5	8.50	27	4.82	795.02	56.34	16.84	2.40	2.03	65.5
3	02-Feb	1114	72.7	8.60	27	5.17	795.03	48.73	17.09	2.50	2.42	72.7
3	02-Feb	1135	80.0	8.70	27	5.02	795.04	63.36	17.77	2.07	1.55	80.0
3	02-Feb	1146	95.2	8.70	27	4.90	795.36	63.73	17.91	1.79	1.33	95.2
3	02-Feb	1297	102.0	8.60	27	5.01	795.04	78.79	16.67	1.17	0.71	102.0
3	02-Feb	1316	117.5	8.40	27	5.09	795.46	70.54	17.07	0.97	0.66	117.5
3	02-Feb	1329	125.0	8.30	27	5.14	796.25	58.52	17.30	2.27	1.87	125.0
3	02-Feb	1343	137.0	8.20	27	5.20	795.92	59.88	17.66	2.34	1.90	137.0
3	02-Feb	1356	157.0	8.40	27	5.23	796.29	66.03	18.06	1.19	0.87	157.0
3	02-Feb	1406	175.0	8.60	27	5.23	796.76	68.34	18.42	1.55	1.08	175.0
3	02-Feb	1418	192.0	8.50	27	5.22	797.20	68.16	18.66	2.00	1.41	192.0
3	02-Feb	1444	207.0	8.50	27	5.25	797.94	64.36	20.25	1.97	1.48	207.0
3	02-Feb	1456	230.0	8.50	27	5.25	798.65	66.72	20.38	1.67	1.21	230.0

Borehole #54-1004
Gas Permeability Measurements



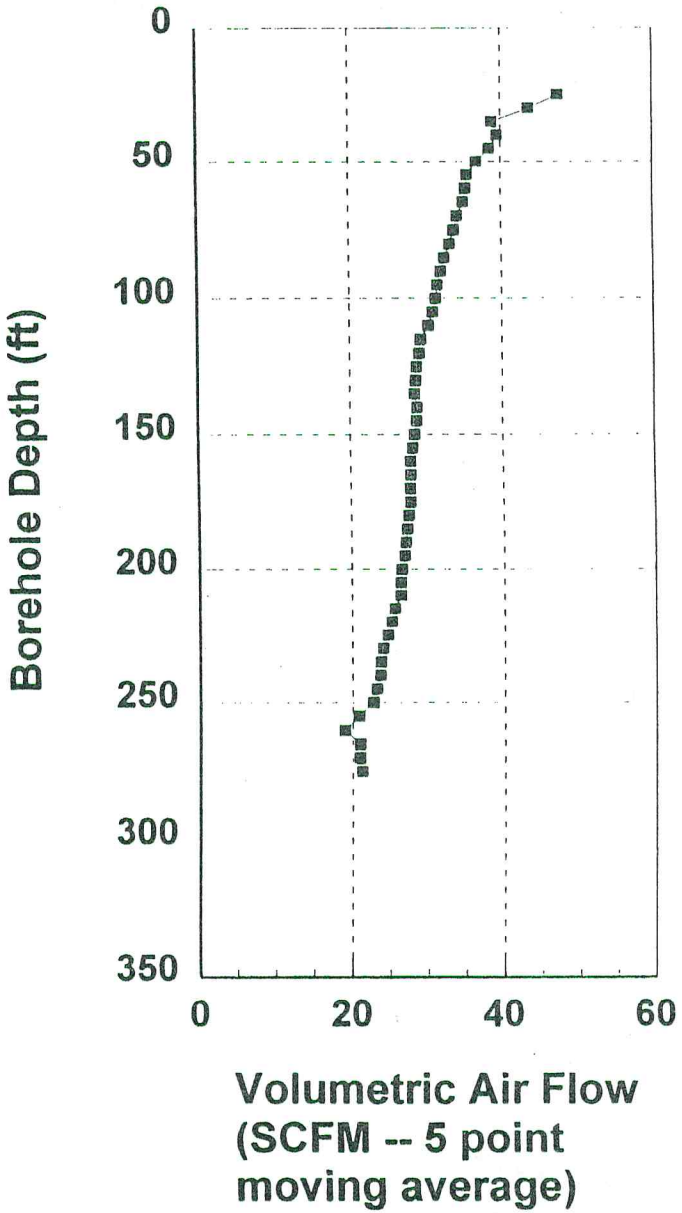
Science & Engineering Associates, Inc.

Borehole #54-1004
Anemometry Measurements



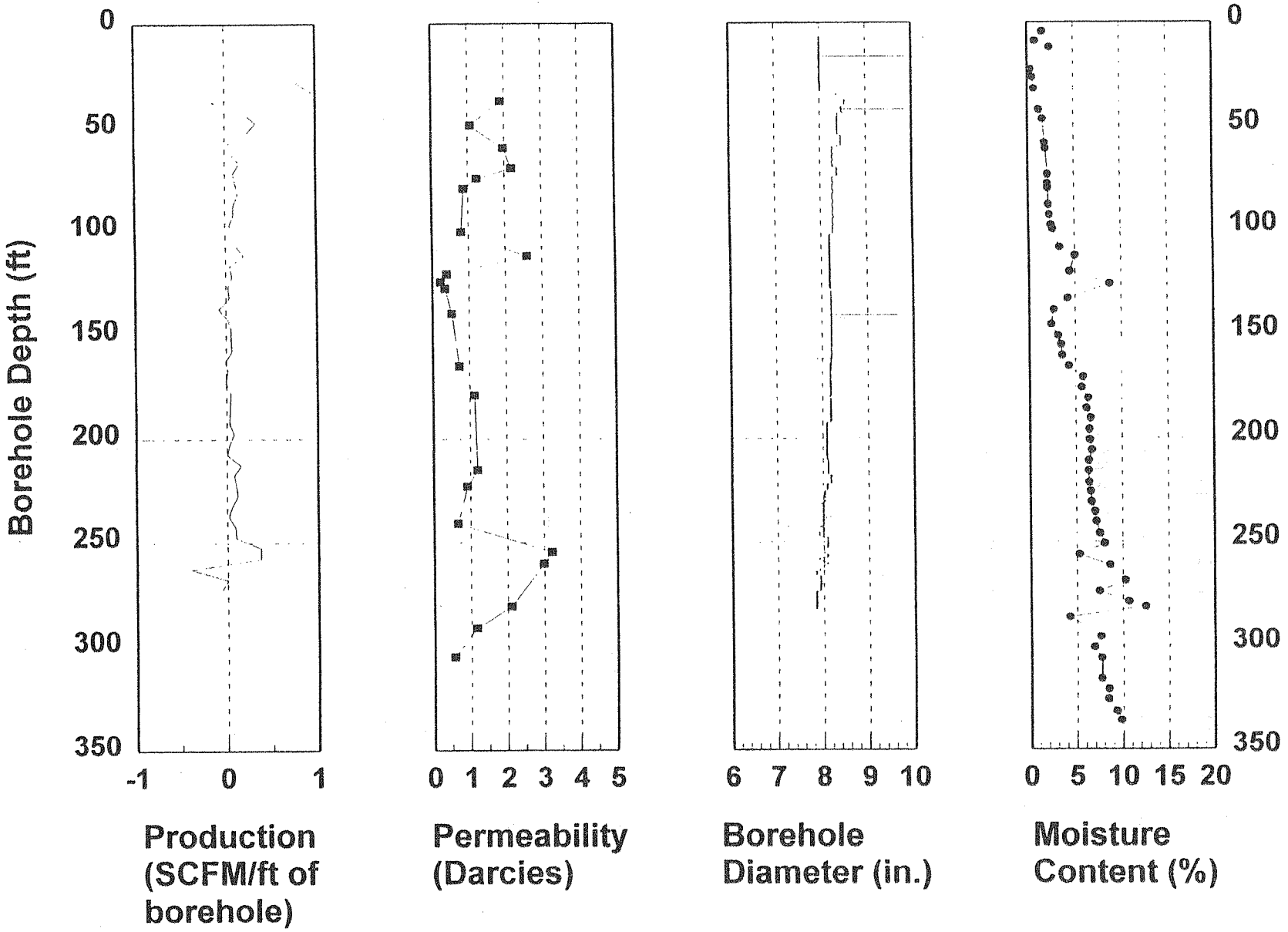
Science & Engineering Associates, Inc.

Borehole #54-1004
Air Velocity Measurements



Science & Engineering Associates, Inc.

Borehole #54-1004
Summary



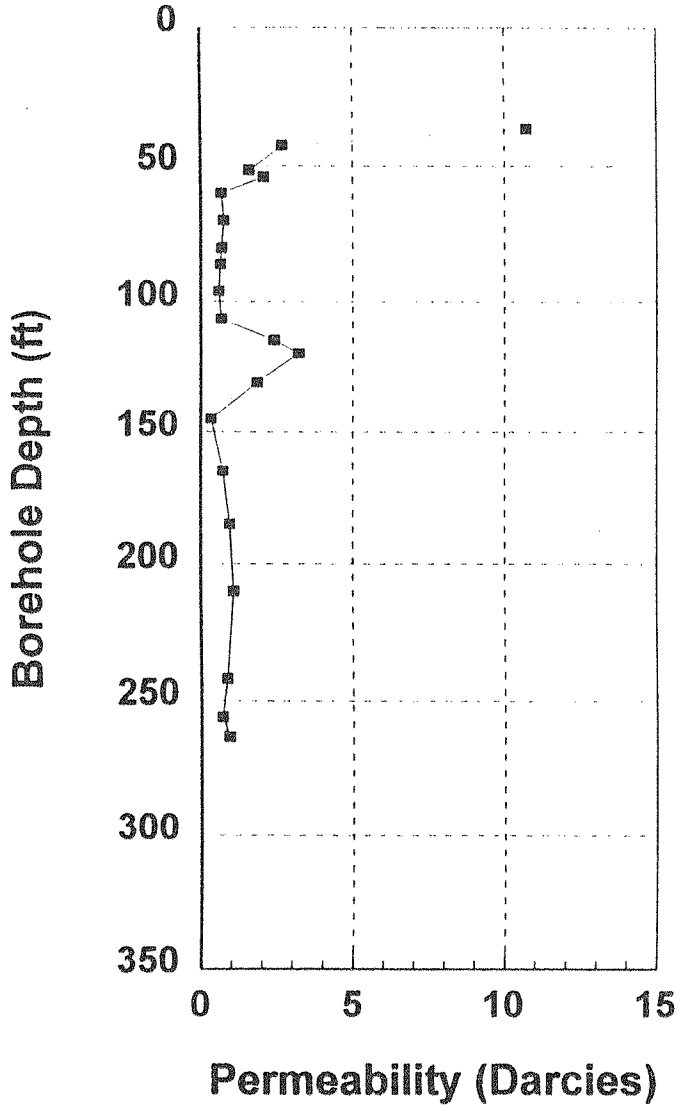
Science & Engineering Associates, Inc.

In-situ Soil Gas Permeability Data

Borehole 54-1004 **Slant (deg. off vert.) 0**

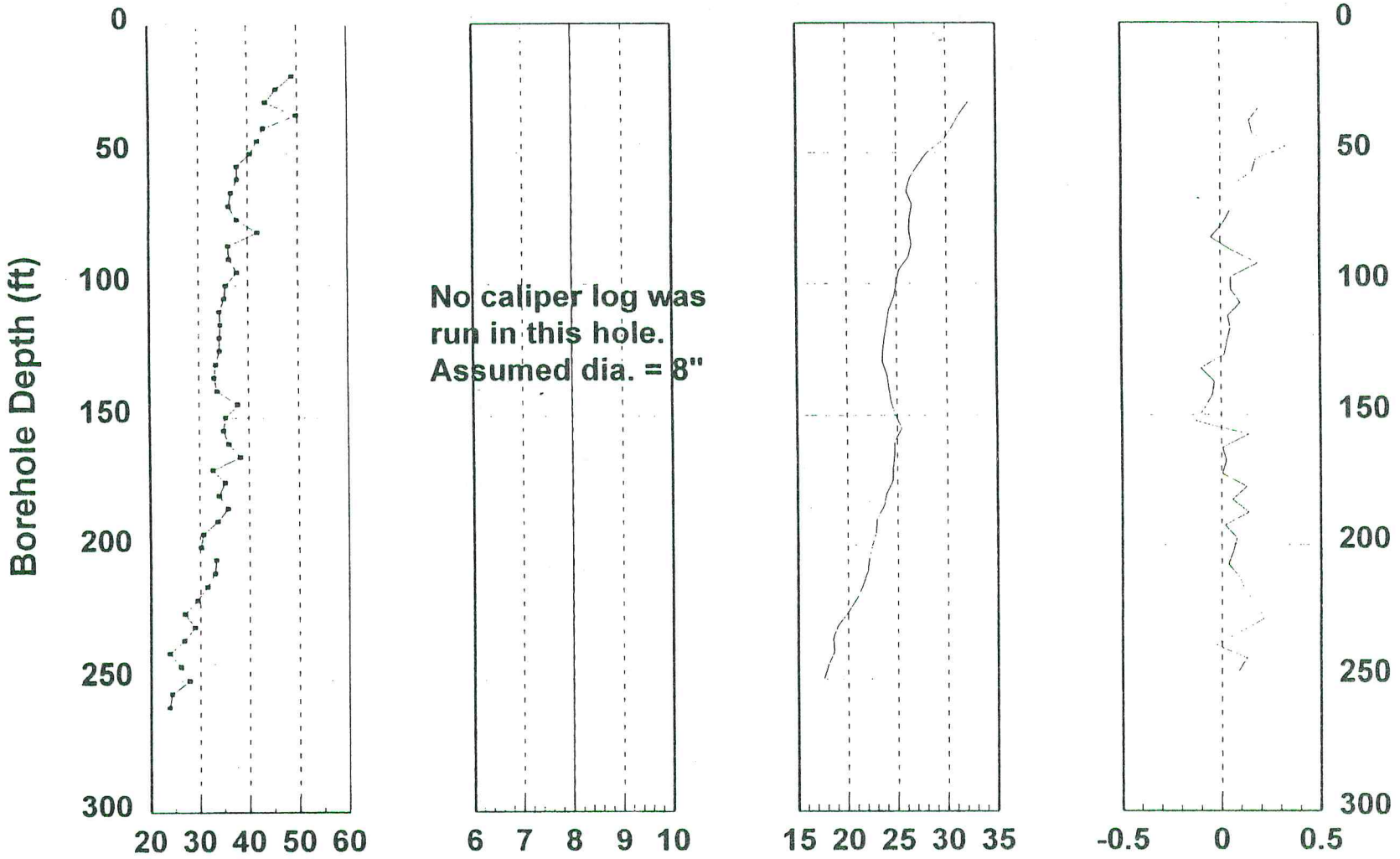
Hole No.	Date	Time	Depth in Borehole (ft)	Hole Diameter (in.)	Extr. Zone Height (in.)	Packer Pressure (psi)	Ambient DH Pressure (mbar)	Extraction DP (mbar)	Air Temperature (C)	Air Flowrate (scfm)	Permeability (Darcies)
4	09-Feb	1021	37.0	8.40	27	4.98	794.26	47.98	10.82	1.95	1.89
4	09-Feb	1039	48.6	8.40	27	5.07	794.60	78.51	12.64	1.75	1.07
4	09-Feb	1051	60.0	8.30	27	5.16	793.98	42.24	13.47	1.77	1.97
4	09-Feb	1103	70.0	8.30	27	5.08	794.94	40.52	14.19	1.88	2.19
4	09-Feb	1117	75.0	8.30	27	4.90	794.69	66.37	15.05	1.72	1.24
4	09-Feb	1133	80.0	8.30	27	4.97	794.85	91.74	16.03	1.64	0.88
4	09-Feb	1243	101.0	8.20	27	5.12	794.63	96.37	16.17	1.56	0.80
4	09-Feb	1255	113.0	8.20	27	5.16	794.94	32.14	15.99	1.75	2.59
4	09-Feb	1308	121.5	8.20	27	5.05	794.91	135.04	16.97	1.05	0.40
4	09-Feb	1320	125.2	8.20	27	5.13	794.74	148.63	17.60	0.63	0.22
4	09-Feb	1332	128.2	8.20	27	5.14	794.67	138.85	18.03	0.93	0.34
4	09-Feb	1350	140.0	8.20	27	5.07	794.77	120.31	18.55	1.25	0.53
4	09-Feb	1408	165.0	8.20	27	5.07	795.18	100.77	18.64	1.46	0.72
4	09-Feb	1418	179.0	8.20	27	5.23	795.52	76.96	18.54	1.75	1.12
4	09-Feb	1431	215.0	8.10	27	5.27	796.60	73.92	18.75	1.80	1.20
4	09-Feb	1445	223.0	8.10	27	4.99	796.61	87.96	18.89	1.62	0.92
4	09-Feb	1458	241.0	8.00	27	5.13	797.10	106.14	19.07	1.37	0.66
4	09-Feb	1513	254.5	8.00	27	5.17	793.48	29.05	18.97	1.92	3.21
4	09-Feb	1524	260.0	8.00	27	5.28	797.86	29.77	19.22	1.84	2.99
4	10-Feb	916	280.5	7.80	27	5.15	796.76	39.38	5.75	1.76	2.11
4	10-Feb	928	291.0	7.80	27	5.03	796.61	74.94	9.95	1.77	1.16
4	10-Feb	943	305.0	7.80	27	4.92	795.58	112.24	12.74	1.23	0.55

Borehole #54-1005
Gas Permeability Measurements



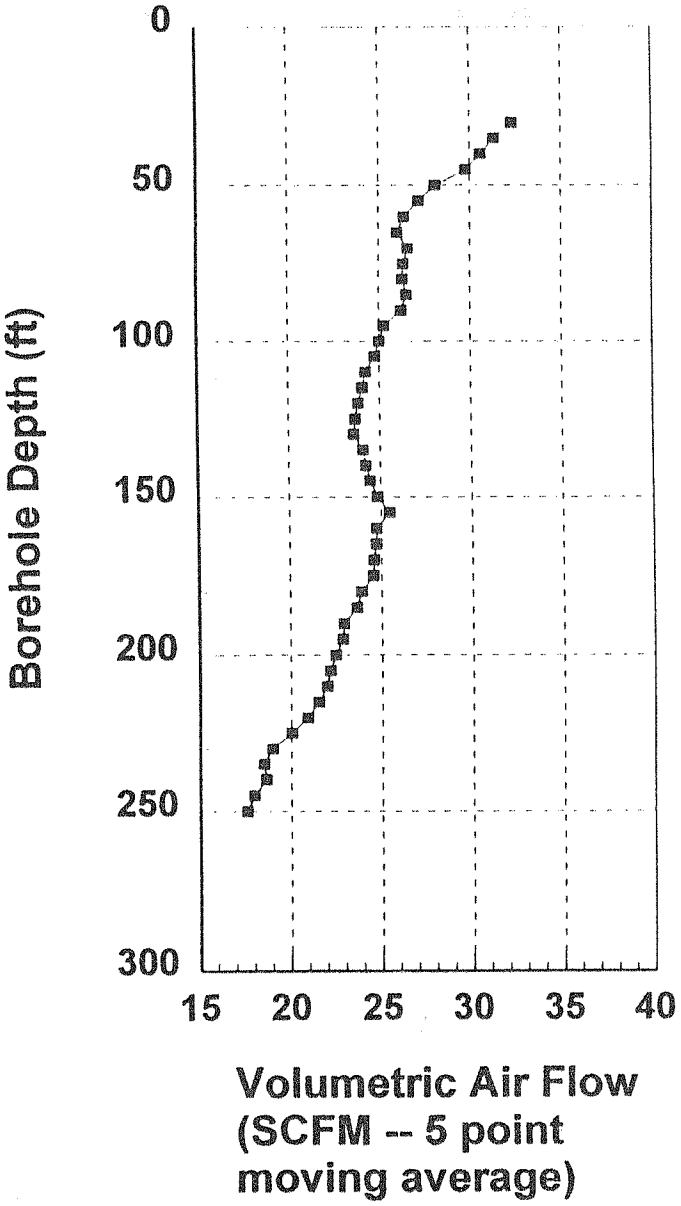
Science & Engineering Associates, Inc.

Borehole #54-1005
Anemometry Measurements



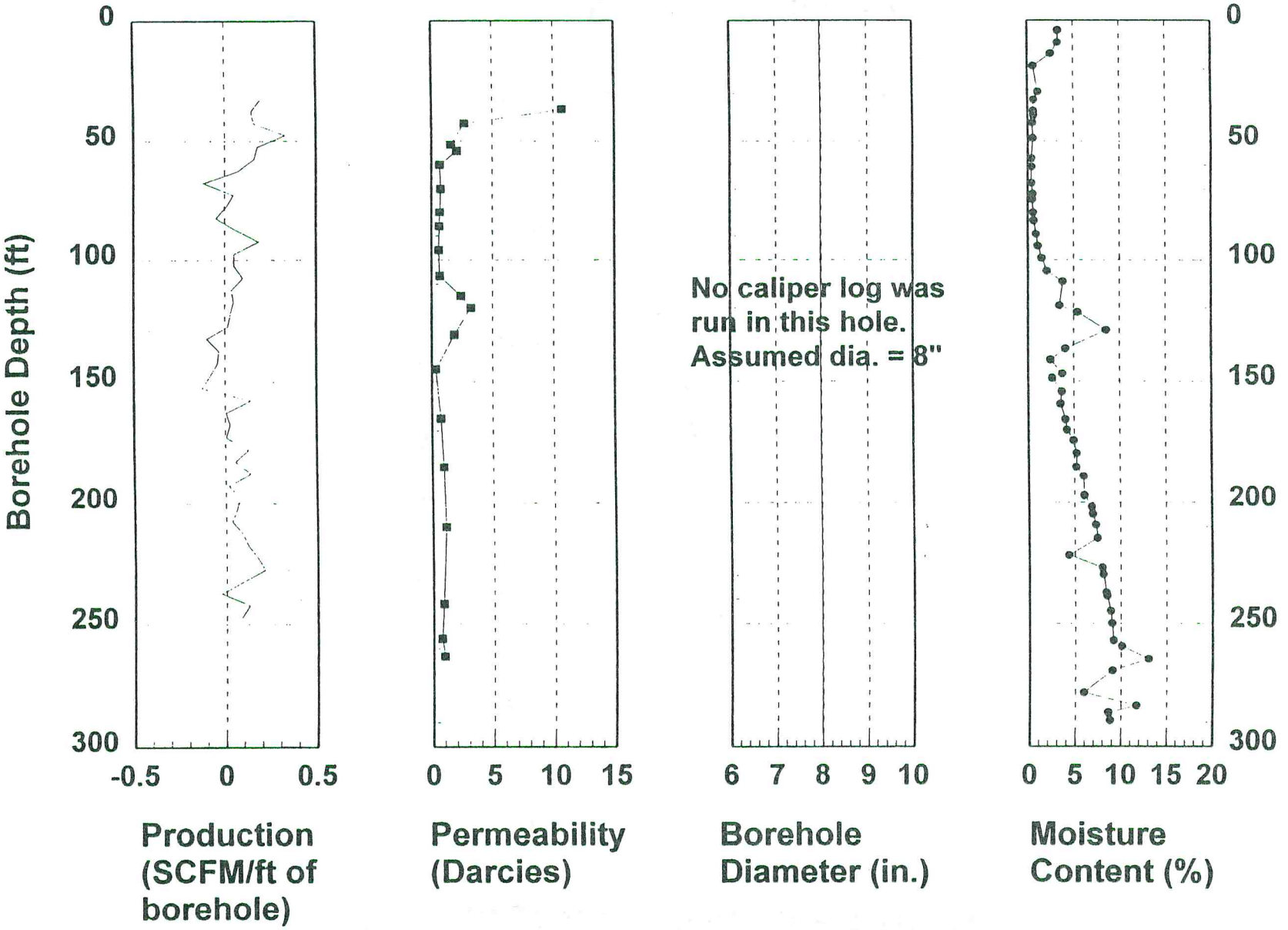
Science & Engineering Associates, Inc.

Borehole #54-1005
Air Velocity Measurements



Science & Engineering Associates, Inc.

Borehole #54-1005
Summary



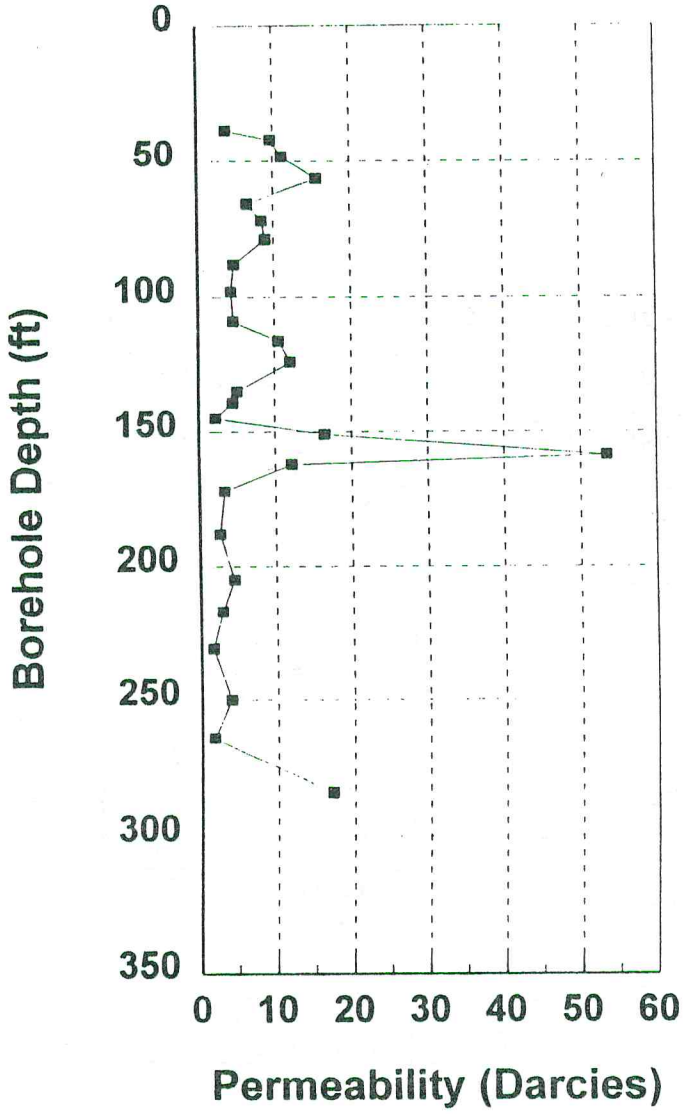
Science & Engineering Associates, Inc.

In-situ Soil Gas Permeability Data

Borehole 54-1005 **Slant (deg. off vert) 22**

Hole No.	Date	Time	Depth in Borehole (ft)	Hole Diameter (in.)	Extr. Zone Height (in.)	Packer Pressure (psi)	Ambient DH Pressure (mbar)	Extraction DP (mbar)	Air Temperature (C)	Air Flowrate (scfm)	Permeability (Darcies)	True Depth Below Ground (ft)
5	27-Feb	1452	36.5	8.00	27	4.98	791.19	4.38	13.46	1.00	10.74	33.8
5	27-Feb	1502	42.5	8.00	27	5.28	790.94	17.78	14.27	1.01	2.69	39.4
5	28-Feb	911	51.6	8.00	27	5.19	798.93	28.25	1.60	1.00	1.61	47.8
5	28-Feb	920	54.2	8.00	27	5.32	797.95	20.67	3.47	0.95	2.08	50.3
5	28-Feb	929	60.0	8.00	27	5.32	798.97	60.24	5.75	0.88	0.69	55.6
5	28-Feb	939	70.0	8.00	27	5.25	799.00	58.09	7.57	0.94	0.77	64.9
5	28-Feb	948	80.0	8.00	27	5.28	798.95	64.42	9.14	0.94	0.69	74.2
5	28-Feb	1001	86.0	8.00	27	5.19	799.20	77.98	10.95	1.05	0.65	79.7
5	28-Feb	1010	96.0	8.00	27	5.33	799.42	75.38	11.78	0.94	0.60	89.0
5	28-Feb	1019	106.7	8.00	27	5.31	798.38	72.11	12.62	1.01	0.68	98.9
5	28-Feb	1055	115.0	8.00	27	5.26	801.37	20.83	13.77	1.07	2.42	106.6
5	28-Feb	1104	120.0	8.00	27	5.34	800.66	14.85	13.96	1.02	3.23	111.3
5	28-Feb	1131	145.0	8.00	27	5.17	801.77	136.29	15.49	0.93	0.35	134.4
5	28-Feb	1140	165.0	8.00	27	5.32	801.25	66.81	15.53	1.01	0.74	153.0
5	28-Feb	1151	185.0	8.00	27	5.27	800.90	50.49	15.78	1.00	0.96	171.5
5	28-Feb	1242	210.0	8.00	27	5.29	801.69	43.82	15.78	0.99	1.09	194.7
5	28-Feb	1254	242.0	8.00	27	5.22	802.32	57.61	15.82	1.03	0.86	224.4
5	28-Feb	1304	256.0	8.00	27	5.31	802.59	65.61	16.14	0.95	0.71	237.4
5	28-Feb	1316	263.3	8.00	27	5.34	802.16	47.49	16.52	0.92	0.93	244.1
5	28-Feb	1330	131.0	8.00	27	5.36	800.39	23.84	16.84	0.93	1.86	121.5

Borehole #54-1006
Gas Permeability Measurements



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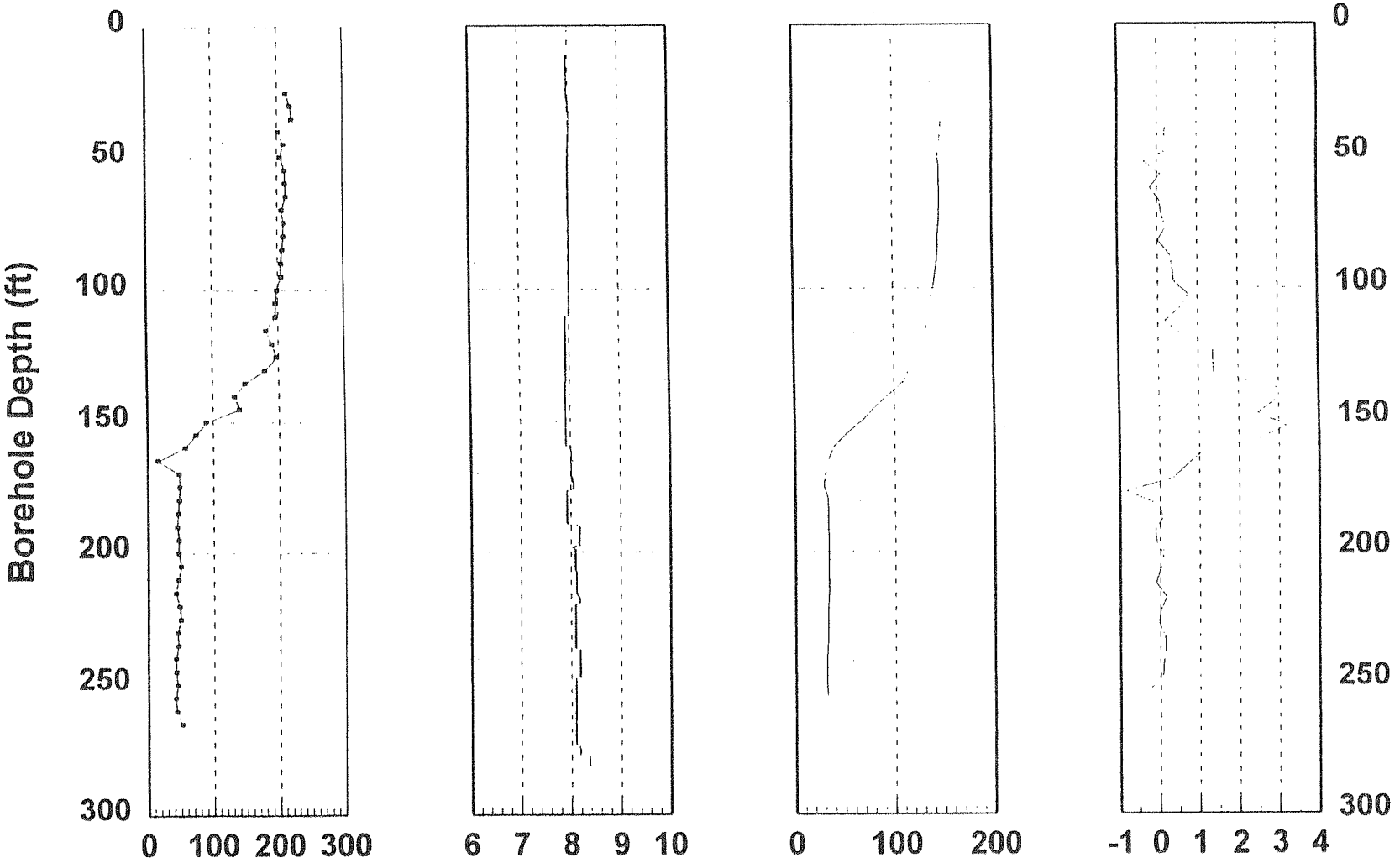
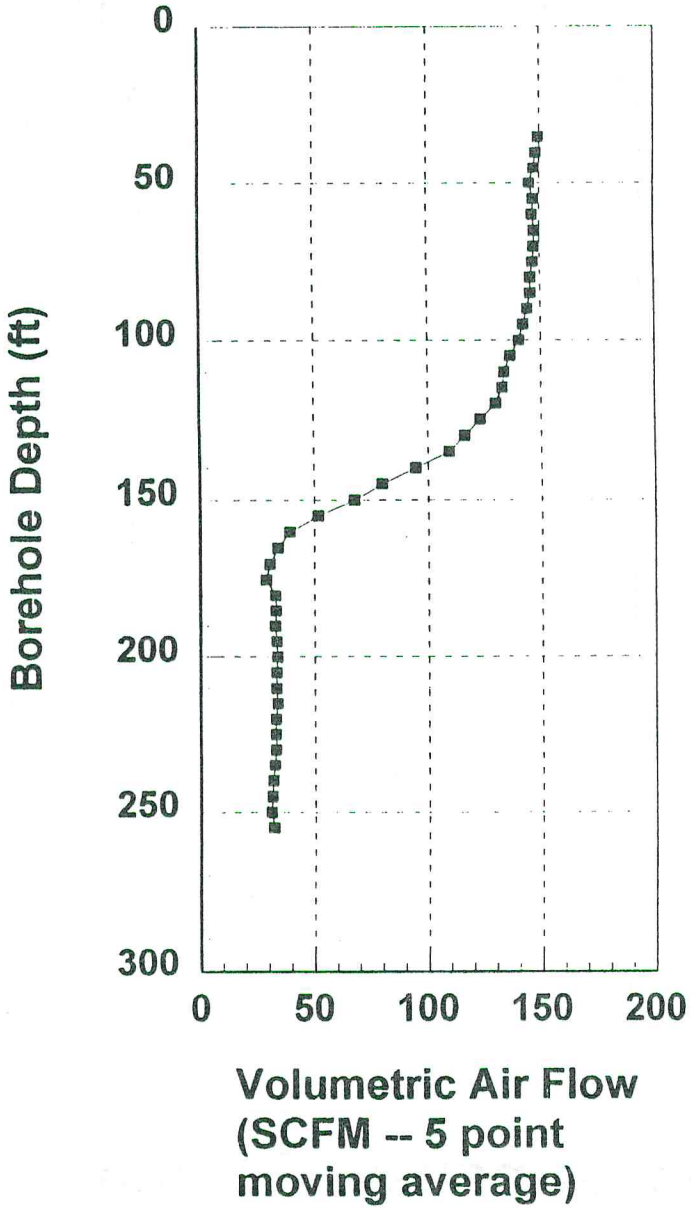
Borehole #54-1006
Anemometry Measurements



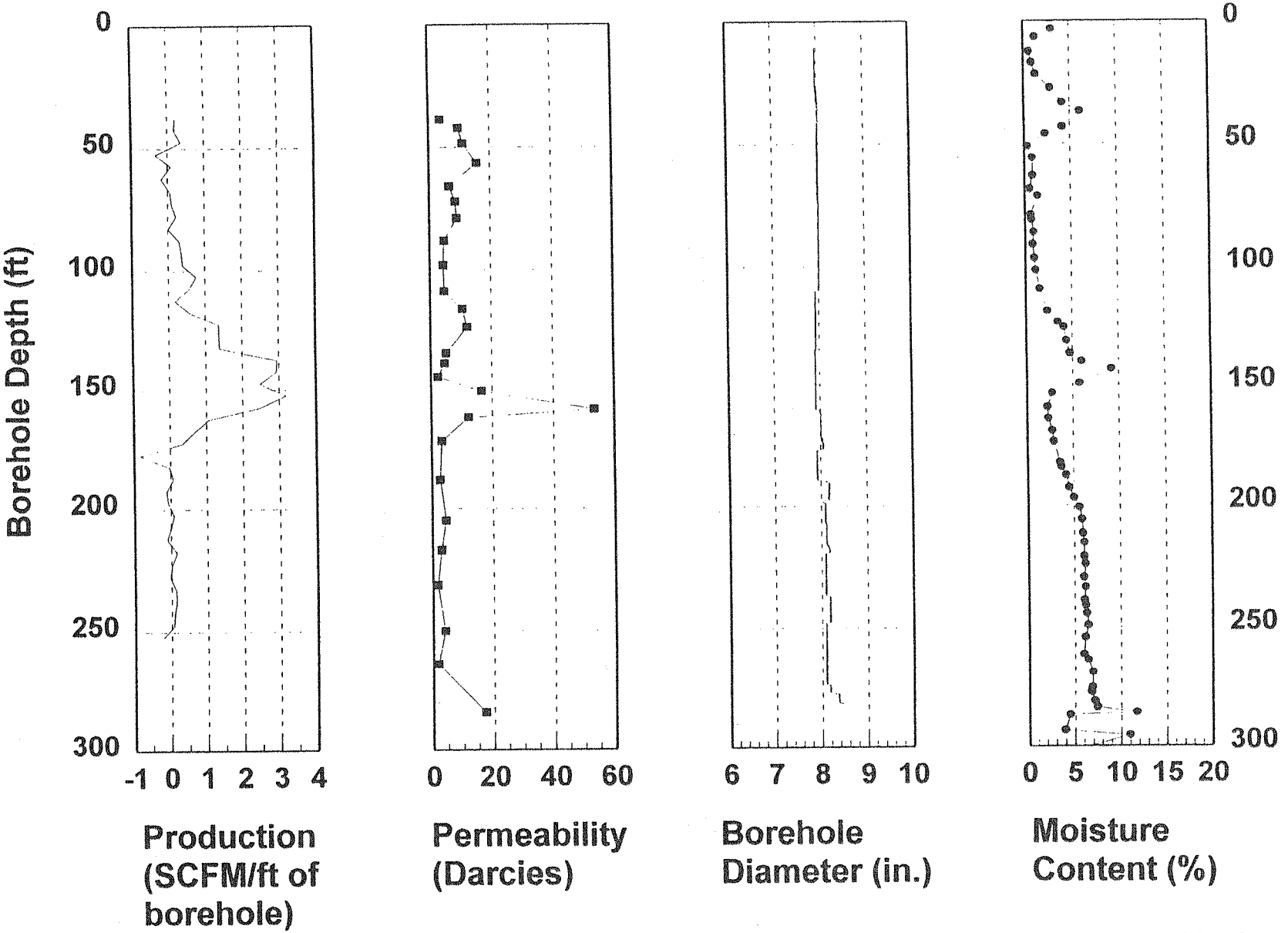
Science & Engineering Associates, Inc.

Borehole #54-1006
Air Velocity Measurements



Science & Engineering Associates, Inc.

Borehole #54-1006
Summary



Science & Engineering Associates, Inc.

In-situ Soil Gas Permeability Data

Borehole 54-1006 **Slant (deg. off vert) 27**

Hole No.	Date	Time	Depth in Borehole (ft)	Hole Diameter (in.)	Extr. Zone Height (in.)	Packer Pressure (psi)	Ambient DH Pressure (mbar)	Extraction DP (mbar)	Air Temperature (C)	Air Flowrate (scfm)	Permeability (Darcies)	True Depth Below Ground (ft)
6	01-Mar	1015	38.5	8.00	27	5.07	801.39	13.58	20.24	1.09	3.83	34.3
6	01-Mar	1025	42.0	8.00	27	5.23	799.42	5.50	19.74	1.12	9.73	37.4
6	01-Mar	1036	48.4	8.00	27	5.30	801.05	4.12	19.27	0.97	11.16	43.1
6	01-Mar	1048	56.7	8.00	27	5.19	801.32	3.11	18.66	1.03	15.69	50.5
6	01-Mar	1057	66.0	8.00	27	5.39	801.05	6.83	18.24	0.95	6.62	58.8
6	01-Mar	1109	72.0	8.00	27	5.36	801.52	6.05	17.89	1.09	8.50	64.2
6	01-Mar	1122	78.8	8.00	27	5.06	801.86	5.76	17.15	1.09	8.95	70.2
6	01-Mar	1130	88.0	8.00	27	5.40	801.52	10.34	16.94	1.05	4.79	78.4
6	01-Mar	1140	98.0	8.00	27	5.29	802.23	11.46	16.92	1.06	4.39	87.3
6	01-Mar	1149	109.0	8.00	27	5.33	802.11	10.93	16.88	1.08	4.65	97.1
6	01-Mar	1240	116.4	7.90	27	5.20	801.55	4.75	15.45	1.07	10.55	103.7
6	01-Mar	1251	124.0	7.90	27	5.19	802.29	4.41	14.95	1.13	12.07	110.5
6	01-Mar	1300	135.0	7.90	27	5.33	802.76	9.58	15.02	1.04	5.11	120.3
6	01-Mar	1312	139.2	7.90	27	5.18	802.19	11.87	15.15	1.14	4.54	124.0
6	01-Mar	1323	145.0	7.90	27	5.22	802.53	23.70	15.41	1.12	2.25	129.2
6	01-Mar	1336	151.0	7.90	27	5.97	802.06	3.11	15.67	1.09	16.53	134.5
6	01-Mar	1345	158.7	8.00	27	5.26	802.29	0.95	15.79	1.10	53.51	141.4
6	01-Mar	1355	162.0	8.00	27	5.25	802.71	4.14	16.20	1.08	12.18	144.3
6	01-Mar	1407	172.0	8.00	27	5.19	801.63	16.19	16.51	1.15	3.35	153.3
6	01-Mar	1416	188.0	7.90	27	5.36	802.14	19.67	16.78	1.10	2.68	167.5
6	01-Mar	1429	205.0	8.10	27	5.19	802.00	11.69	17.08	1.12	4.49	182.7
6	01-Mar	1440	217.0	8.10	27	5.29	803.37	17.69	17.21	1.10	2.93	193.3
6	01-Mar	1452	231.0	8.10	27	5.28	802.79	31.78	17.49	1.08	1.61	205.8
6	01-Mar	1502	250.0	8.10	27	5.35	801.75	12.38	17.61	1.04	3.95	222.8
6	01-Mar	1512	264.0	8.10	27	5.28	803.67	30.70	17.82	1.09	1.68	235.2
6	01-Mar	1525	284.2	8.20	27	5.25	801.38	2.98	18.04	1.10	17.19	253.2