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Federal Highway Administration

LTPP Seasonal Monitoring Program

Site Installation and Initial Data Collection

Section 161010
Idaho Falls, Idaho

Report No. FHWA-16-1010

February 1994

Notice

LTPP Seasonal Monitoring Program

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Section 161010, Idaho Falls, Idaho

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16. Abstract

This report contains a description of the instrumentation installation activities and initial data collection for test section 161010 which is a part of the LTPP Core Seasonal Monitoring program. This asphalt concrete surfaced pavement test section, which is located on Interstate Highway 15 (I-15) near Idaho Falls, Idaho, was instrumented on September 30, 1993. The instrumentation installed included time domain reflectometery probes for moisture content, electrical resistivity probes for frost location, thermistor probes for temperature, tipping bucket rain gage, piezometer to monitor the ground water table, and an on-site data logger. Initial data collection was performed on October 1, 1993 which consisted of deflection measurements with a Falling Weight Deflectometer, elevation measurements, temperature measurements, TDR measurements, and electrical resistance and resistivity measurements. The report contains a description of the test site and its location, the instruments installed at the site and their locations, characteristics of the installed instruments and probes, problems encountered during installation, specific site circumstances and deviations from the standard guidelines, and a summary of the initial data collection.

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I. Introduction

The installation of instrumentation on seasonal site 161010 near Idaho Falls, Idaho was performed on September 30, 1993. Initial data collection was performed on October 1, 1993.

The site is located in the southbound lanes of U.S. Interstate Highway 15 (I-15), approximately 1.5 mile south of the city of Roberts in western Idaho (Figure A-1 in Appendix A). The test section is located on a divided highway consisting a two travel lanes in each direction. The outside lane of the test section is striped 3.96m wide. The outside shoulder is approximately 2.7m wide. The test section is classified as a GPS-1 project (cell 1-130) and is assigned to Cell 15 of the Seasonal Monitoring Program (SMP) experiment design.

The pavement structure consists of 279mm asphalt concrete (AC) over an average of 137mm granular aggregate base. The subgrade is a gravelly-silty sand. Pavement structure information from the GPS material drilling log is presented in Figure A-2. Properties determined from the GPS laboratory material tests are presented Table 1.

Deflection profile and analysis results from FWDCHECK program are also given in Appendix A.

The climate at this site is classified as a dry-freeze zone. Summary data from the LTPP climate database indicates the following climatic conditions based on 11 years of data:

Freezing Index (C-Days)	688
Precipitation (mm)	305
No Freeze Thaw Cycles	136
Days Above 32° C	15
Days Below 0° C	185
Wet Days	114

The estimated annual average daily traffic (AADT) in 1989 was 3160 (two-way) of which 25% was truck traffic. The GPS lane carried approximately 46% of the total AADT. The truck AADT on the GPS lane was 365. The estimated annual ESAL applications on the GPS lane were 147,000.

Installation of the instrumentation was a cooperative effort between Idaho Transportation Department (ITD), Nichols Consulting Engineers (NCE) LTPP Western Region Coordination Office staff and staff from FHWA LTPP Division.

The following personnel participated in the instrumentation installation:

Gary E. Elkins	Nichols Consulting Engineers
Mark Potter	Nichols Consulting Engineers
Jason Dietz	Nichols Consulting Engineers
Doug Frith	Nichols Consulting Engineers
Brion Barnett	Nichols Consulting Engineers
Robert Szrot	Federal Highway Administration
Tom Cole	Idaho Transportation Department

Table 1. Material properties.

Description	Surface Layer	Base Layer	Subgrade
Material	AC	Aggregate	Silty Sand
Thickness (mm)	277	137	∞
In Situ Dry Density (kg/m^3)*	---	2047	1877
In Situ Moisture Content (%)	---	3.1	6.8
Lab Max Dry Density (kg/m^3)	---	2243 @ 5% MC	1826 @ 11% MC
Liquid Limit	---	NP	NP
Plastic Limit	---	NP	NP
Plastic Index	---	NP	NP
% Passing #200	---	8.0	10.7

* Measured at station 5+63 - 5+67 (test date: 5/19/89)
MC - Moisture Content
NP - Non Plastic

II. Instrumentation Installation

Meeting with Highway Agency and Site Visits

Planning arrangements with ITD were handled through telephone conversations and written correspondence. No direct planning meetings were held with ITD officials. All installation support was provided by ITD crews.

The test section is located on a slight vertical downgrade in what appears to be a shallow fill. The only distresses observed on the pavement were 4 low severity transverse cracks. A chip seal surface treatment was present on the test section. A small lake was present approximately .8 Km from the test section. No surface features indicated a preference of which end of the test section to instrument. Since the deflection profile was more uniform on the leave end of the test section, it was selected for instrumentation.

Equipment Installed

The equipment installed at the test site included instrumentation for measuring air and subsurface temperature, subsurface moisture content, frost depth, rainfall, and depth to water table. An equipment cabinet was installed to house cable leads from the instrumentation, the datalogger, and battery pack. The equipment installed are shown in Table 2.

Table 2. Equipment installed.

Equipment	Quantity	Serial Number
Instrument Hole		
MRC Thermistor Probe	1	196 (16BT)
ABF Resistivity Probe	1	16BR
TDR Sensors	10	16B01-16B10
Equipment Cabinet		
Campbell Scientific CR10 Datalogger	1	Check
Battery Package	1	5387
Weather Station		
TE525 MM Rain Gauge	1	Check
Air Temperature Probe (Model 107)	1	421316
Radiation Shield	1	41301
Observation Well/Bench Mark	1	None

Equipment Check/Calibration

Prior to field installation, all equipment were checked or calibrated. The air temperature probe, thermistor probe, and the tipping bucket rain gauge were connected to the CR10 datalogger for calibration and function checks. The tipping bucket rain gage was calibrated using 473ml of water placed in a plastic container with a tiny hole in the bottom. The hole size was adjusted so that 45 minutes were required to drain all of the water out of the container. For the 473ml of water, the tipping bucket was found to be within the range of 100 tips ± 3 tips. The air temperature and thermistor probes were checked for proper functioning by placing them in an ice bath and in direct sun light and comparing the measured temperatures. The results indicated that the air temperature and thermistor probes were functioning properly. The spacings between the thermistor sensors in the plastic tube were measured and recorded. These measurements are shown in Table 3.

The wiring of the resistivity probe was checked using continuity measurements between the each electrode and the pins in the connector. The distance between each electrode was measured and recorded. These spacing are shown in Table 4. Electrical resistance and resistivity measurements were performed with the probe immersed in a water bath. The results of these measurements are shown in Appendix B. The checks on the resistivity probe indicated all electrodes were functioning.

The functioning of the TDR sensors were checked by performing measurements in air, with the prongs shorted at beginning of the sensor and not shorted, and in water. The TDR measurements indicated that all sensors produced the expected traces and appeared to be functioning properly. Results of these TDR measurements are presented in Appendix B.

Equipment Installation

Installation of the instrumentation was performed on September 30, 1993. All details and responsibilities regarding the instrumentation installation were finalized with the ITD with a telephone call the day prior to in installation. ITD provided traffic control, pavement sawing and auguring of the instrumentation hole and Bench Mark/Observation Well, and pavement repair. The NCE and FHWA staff installed all measurement equipment, the observation well, and cabinet.

Installation of the instrumentation was completed in one day. Installation activities included the set-up of traffic control, site layout and marking, installation of piezometer, thermistor probe, resistivity probe, TDR sensors, air temperature probe, rain gauge, and cabinet, and site clean up. Wiring of all cables in the cabinet was also completed the first day.

The piezometer/bench mark was installed first. It was located next to the shoulder at test section station 4+00. The water table was encountered at approximately 2.43m which created problems with collapse of the hole. The piezometer assembly was inserted through the center of the hollow stem augur so that it could be placed at the proper depth. A geonor anchor point, typically used on Borros Type heave and settlement points, was used at the bottom of the piezometer assembly. This point consists of an outer metal sleeve which houses three extendable

Table 3. Description of MRC thermistor probe and sensor spacing.

Unit	Channel Number	Distance from Top of Unit (cm)	Remarks
1	1	1.3	This unit was installed in the surface layer.
	2	15.2	
	3	29.2	
2	4	1.8	This unit was installed in the base and subgrade.
	5	9.6	
	6	17.1	
	7	24.7	
	8	32.2	
	9	47.6	
	10	62.8	
	11	78.3	
	12	93.2	
	13	108.5	
	14	123.7	
	15	139.1	
	16	154.2	
	17	169.5	
	18	184.6	

anchors. The 25.4mm diameter outer sleeve is threaded and was connected to the inner piezometer pipe. A 12.7mm pipe was attached to the anchors inside the outer sleeve of the geonor point and was run through the inside of the inner piezometer pipe. The well assembly was placed approximately .61m above the desired final depth. The assembly was then driven to the desired depth by impacting the piezometer pipe. When the assembly reached the desired depth, the anchors were extended by driving the 12.7mm pipe an additional .31m. The inner 12.7mm pipe was then unscrewed from the anchors and removed. The augur was removed and the filter sand and bentonite layers were placed as normal. Pictures of the piezometer assembly and geonor anchor point are shown in Appendix E.

Table 4. Resistivity probe and sensor spacing.

Connector Pin Number	Electrode Number	Continuity ✓	Measurement	Spacing (cm)			Dist. from top (cm)
				Line 1	Line 2	Avg	
36	1	✓	Top-1	2.9	2.8	2.85	2.9
35	2	✓	1-2	5.0	4.9	4.95	7.8
34	3	✓	2-3	5.0	5.0	5.00	12.8
33	4	✓	3-4	5.0	5.0	5.00	17.8
32	5	✓	4-5	5.3	5.2	5.25	23.1
31	6	✓	5-6	4.9	5.0	4.95	28.0
30	7	✓	6-7	5.1	5.1	5.10	33.1
29	8	✓	7-8	5.0	5.0	5.00	38.1
28	9	✓	8-9	5.2	5.1	5.15	43.3
27	10	✓	9-10	5.0	5.0	5.00	48.3
26	11	✓	10-11	5.0	5.1	5.05	53.3
25	12	✓	11-12	5.1	5.1	5.10	58.4
24	13	✓	12-13	4.9	5.0	4.95	63.4
23	14	✓	13-14	5.1	5.1	5.10	68.5
22	15	✓	14-15	5.1	5.1	5.10	73.6
21	16	✓	15-16	4.8	5.0	4.90	78.5
20	17	✓	16-17	5.1	5.1	5.10	83.6
19	18	✓	17-18	5.0	5.0	5.00	88.6
18	19	✓	18-19	5.0	5.1	5.05	93.6
17	20	✓	19-20	5.2	5.1	5.15	98.8
16	21	✓	20-21	5.1	5.1	5.10	103.9
15	22	✓	21-22	5.1	5.1	5.10	109.0
14	23	✓	22-23	5.1	5.0	5.05	114.0
13	24	✓	23-24	5.0	5.0	5.00	119.0
12	25	✓	24-25	5.1	5.1	5.10	124.1
11	26	✓	25-26	5.0	5.0	5.00	129.1
10	27	✓	26-27	5.2	5.1	5.15	134.3
9	28	✓	27-28	5.0	5.1	5.05	139.3
8	29	✓	28-29	4.9	4.9	4.90	144.2
7	30	✓	29-30	5.2	5.1	5.15	149.4
6	31	✓	30-31	5.0	5.0	5.00	154.4
5	32	✓	31-32	5.0	5.1	5.05	159.4
4	33	✓	32-33	5.2	5.1	5.15	164.6
3	34	✓	33-34	4.9	5.0	4.95	169.5
2	35	✓	34-35	5.0	5.0	5.00	174.5
1	36	✓	35-36	5.2	5.2	5.20	179.7
			36-End	2.5	2.3	2.40	182.1

The instrumentation was installed on the leave end of the test section at approximate station 5+20. One 508mm square hole, located in the outside wheel path, 1.52m away from the pavement edge stripe, approximately 2.2m deep, was used to install the thermistor probe, TDR sensors, and resistivity probe. The hole layout was changed from the standard pattern. Instead of placing the trench in the center of the square cut out, it was aligned with the leave edge of the hole. The reduce the number of saw cuts and the number of required repositionings of the pavement saw. The pavement surface temperature probe was placed in the saw cut used to form the inside edge of the instrumentation hole. This was done since this was a thick pavement section and required significant over-cut and also to reduce the number of saw cuts and subsequent damage to the pavement. Anchor bolts were used to attach a lifting assembly to the cut out. The lifting assembly greatly aided in manipulation of the cut out during placement back into the hole.

Water was encountered in the very bottom of the instrumentation hole. As the installation proceeded, more water was drawn into the bottom of the hole. The hole had to be excavated a second time since too much soil was replaced in the hole prior to placement of the first TDR sensor (TDR #10). The temperature probe and electrical resistance probes were easily removed since the bottom of the hole had become muddy. The first two TDR probes (#9 and 10) were placed in near saturated conditions. The temperature and resistance probes were placed on opposites of the hole with the temperature probe on the leave side of the hole. The TDR sensors were placed in a fan arrangement with their connections next to the side of the hole closest to the shoulder. Wires from the instrumentation were placed in a 51mm diameter steel conduit and buried in a 76mm wide trench leading to the equipment cabinet located approximately 8.5m away from the instrument hole.

Table 5 presents the installed depths of the TDR probes, Table 6 the thermistor sensors, and Table 7 the electrodes of the resistivity probe. Table 8 presents the comparison between the computed moisture content from the TDR measurements and field measured moisture content during installation. The TDR traces obtained during installation are presented in Appendix C.

Upon completion of the installation, all wiring to the cabinet were carefully examined. Version 1.1 of the ONSITE computer program was downloaded to the onsite CR10 datalogger mounted in the cabinet. This version of the Onsite program was developed for use with the revised Onsite wiring configuration which uses a relay to actuate the MRC thermistor probe. The datalogger was left to collect data overnight so that the results could be evaluated the next day.

Site Repair

The instrumentation hole was repaired by reinstalling the asphalt concrete block originally cut from the pavement. The concrete block was positioned and secured into the pavement using PC-7 epoxy. Self-leveling 888 crack sealant was used in the pavement surface temperature grove and around the edges of the block. The conduit trench was repaired by placing and compacting a ITD supplied cold mix asphalt concrete patching material.

Table 5. Installed depths of TDR sensors.

Sensor #	Depth from Pavement Surface (m)	Layer
16B01	0.356	Base
16B02	0.508	Subgrade
16B03	0.660	
16B04	0.813	
16B05	0.965	
16B06	1.118	
16B07	1.270	
16B08	1.422	
16B09	1.727	
16B10	2.032	

Table 6. Installed location of MRC thermistor sensors.

Unit	Channel Number	Depth from Pavement Surface (m)	Remarks
1	1	0.023	AC layer
	2	0.138	
	3	0.254	
2	4	0.349	Base
	5	0.430	Subgrade
	6	0.504	
	7	0.581	
	8	0.654	
	9	0.809	
	10	0.958	
	11	1.114	
	12	1.264	
	13	1.418	
	14	1.568	
	15	1.721	
	16	1.874	
	17	2.027	
	18	2.176	

Table 7. Location of electrodes of the resistivity probe.

Connector Pin Number	Electrode Number	Depth from Pavement Surface (m)
36	1	0.359
35	2	0.408
34	3	0.458
33	4	0.508
32	5	0.561
31	6	0.610
30	7	0.661
29	8	0.711
28	9	0.763
27	10	0.813
26	11	0.863
25	12	0.914
24	13	0.964
23	14	1.015
22	15	1.066
21	16	1.115
20	17	1.166
19	18	1.216
18	19	1.266
17	20	1.318
16	21	1.369
15	22	1.420
14	23	1.470
13	24	1.520
12	25	1.571
11	26	1.621
10	27	1.673
9	28	1.723
8	29	1.772
7	30	1.824
6	31	1.874
5	32	1.924
4	33	1.976
3	34	2.025
2	35	2.075
1	36	2.127

Table 8. Field measured moisture content during installation.

Sensor Number	Sensor Depth (m)	Layer	TDR Moisture Content (% by wt)	Measured Moisture[3] Content (% by wt)
16B01	0.356	Base[1]	5.04	4.36
16B02	0.508	Subgrade[2]	7.10	5.28
16B03	0.660		6.17	3.92
16B04	0.813		6.17	4.70
16B05	0.965		7.10	7.02
16B06	1.118		16.72	8.93
16B07	1.270		16.72	7.91
16B08	1.422		17.98	6.46
16B09	1.727		17.32	9.40
16B10	2.032		17.65	5.63

[1] Conversion factor = 2.24, determined from laboratory maximum dry density.
[2] Conversion factor = 1.83, determined from laboratory maximum dry density.
[3] Raw data are given in Appendix C

III. Initial Data Collection

The second day activities included initial data collection on the site and checks on functioning of the installed equipment. The activities consisted of examination of the data collected over the previous night by the Onsite datalogger, collection of TDR and electrical resistance data with the Mobile data acquisition system, manual electrical resistance and resistivity measurements, deflection testing, and elevation survey.

Air Temperature, Subsurface Temperature, Rain-fall Measurements

The air temperature, pavement and subsurface temperature profile, and rainfall data monitored and stored by the onsite CR10 datalogger overnight were examined. It was found that at the end of installation on the first day, the data logger time was inadvertently set to 6:00 instead of 1800 Hrs. The datalogger interpreted this as 6:00 am instead of 6:00 pm and overnight its internal time did not pass 2400 hours when the average subsurface temperature for all 18 thermistor sensors are stored in secondary memory. Thus this data file did not contain the daily average temperatures for all 18 thermistors. Observations of the Onsite data logger in the monitoring mode indicated that measurements from all 18 channels on the thermistor probe were functioning. There was no precipitation that night. The equipment and datalogger appeared to be functioning properly. The battery voltages were checked and found to be acceptable. The overnight Onsite data file is presented in Appendix D.

Figure D-1 shows a plot of air temperature data collected from 6:00 p.m. (September 30) through 8:00 a.m. (October 1). Figure D-2 shows the hourly average subsurface temperature for the first 5 sensors. There was no precipitation that night as reflected by the datalogger data. The data collected indicated that the onsite CR10 datalogger and measurement equipment were working.

TDR Measurements

TDR measurements were performed using the Mobile data acquisition system. The mobile system contains a CR10 datalogger, a battery pack, two multiplexers, and a resistance multiplexer circuit board. Version 1.1 of the Mobile program was used to collect and record the TDR wave form traces for each sensor.

Figures D-3 to D-12 show the TDR wave form traces collected with the Mobile data acquisition system for all 10 sensors. These figures indicate that the multiplexers of the mobile systems and TDR sensors were working.

Resistance Measurements

Electrical resistance data were collected in two modes: automated and manual. The resistance measurement function on the Mobile data acquisition system was repaired prior to this installation. The Mobile data acquisition system automatically performs two point contact resistance measurements and stores the values in terms of millivolts between adjacent electrodes.

Figure D-13 shows the measured voltage between adjacent resistivity probe electrodes as measured with the Mobile data acquisition system.

Manual mode measurements were performed with a Simpson Model 420D function generator, manual switch board and two Beckman HD-110 digital multi-meters. The manually measured contact resistance data are plotted in Figure D-14 (contact resistance vs. electrode number) and in Figure D-15 (contact resistance vs. pavement depth). The 4-point resistivity results are plotted in Figure D-16. Raw data are given in Appendix D.

Figure D-17 shows a comparison between measured voltage from the Mobile system resistance measurement and manually measured contact resistance for each measurement on adjacent electrodes. The lack of any direct functional relationship between these two measurements is troublesome. It was expected that the manual and automated resistance measurements would result in similar profiles. These results may indicate that the automated and manual electrical resistance measurements are measuring different quantities, or that a problem may exist for one of the measurement methods. It may be that the lack of a controlled or measured current output from the automated system may be the source of the discrepancy between these measurements.

Deflection Measurements

Deflection measurement followed procedures described in the "LTPP Seasonal Monitoring Program: Instrumentation Installation and Data Collection Guidelines."

Elevation Surveys

One set of surface elevation surveys was performed following the guidelines. It was assumed the elevation of the well top was 1.000 meters. The survey results are presented in Appendix D.

IV. Summary

The SMP instrumentation was installed on test section 161010 was on September 30, 1993 and initial data collection was performed on October 1, 1993. The instrumentation installed included time domain reflectometery (TDR) probes for moisture content, electrical resistivity probes for frost location, thermistor probes for temperature, tipping bucket rain gage, piezometer to monitor the ground water table and serve as a bench mark, and an on-site datalogger.

The test section is located on southbound U.S. Interstate Highway 15 (I-15) near Idaho Falls, Idaho. The pavement structure on this test section consists of 277mm asphalt concrete over an average of 137mm granular aggregate base. The subgrade is a gravelly-silty sand.

The instrumentation installation generally followed the procedures described in the "LTPP Seasonal Monitoring Program: Instrumentation Installation and Data Collection Guidelines". Some the exceptions to the guidelines included:

- A geonor anchor point was used on the end of the piezometer/bench mark assembly. This device proved easy to install and promises to provide better anchoring than the floor flange. This type of anchor point is recommended for fine grain and active soil applications and in situations were the water table is likely to be encountered during installation.

- Water was encountered at the approximate mid-depth of the piezometer. The piezometer was placed through the center of the hollow stem augur used to excavate the hole.

- The access trench to the instrumentation hole was moved to the leave side of the square cut out. The reduces the number of cuts and damage to the pavement compared to the practice of placing the trench in the center of the square hole.

- The pavement temperature probe was placed in one of the saw cuts used to form the sides of the instrumentation cut out. This also reduces the number of saw cuts and subsequent pavement damage.

Due to the thickness of the pavement surface on this test section, a significant amount of over-cut was required around the edges of the instrumentation hole. The length of the over-cut is roughly equal to the depth of the layer being cut. In order to reduce this damage to the surrounding pavement from the over-cuts, coring of asphalt concrete surface pavements should be considered when its depth exceed 203mm.

The comparison between the automated and manual electrical resistance measurements performed on this site is troubling. The lack of any direct functional relationship between these two measurements may lead to problems with interpretation since the two profiles were not similar. These results may indicate that the automated and manual electrical resistance measurements are measuring different quantities, or that a problem may exist for one of the measurement methods. It may be that the lack of a controlled or measured current output from the automated system may be the source of the discrepancy between these measurements. Further investigation of the relationship between the electrical resistance measurements is warranted.

APPENDIX A

Test Section Background Information

Appendix A Includes the Following Supporting Information:

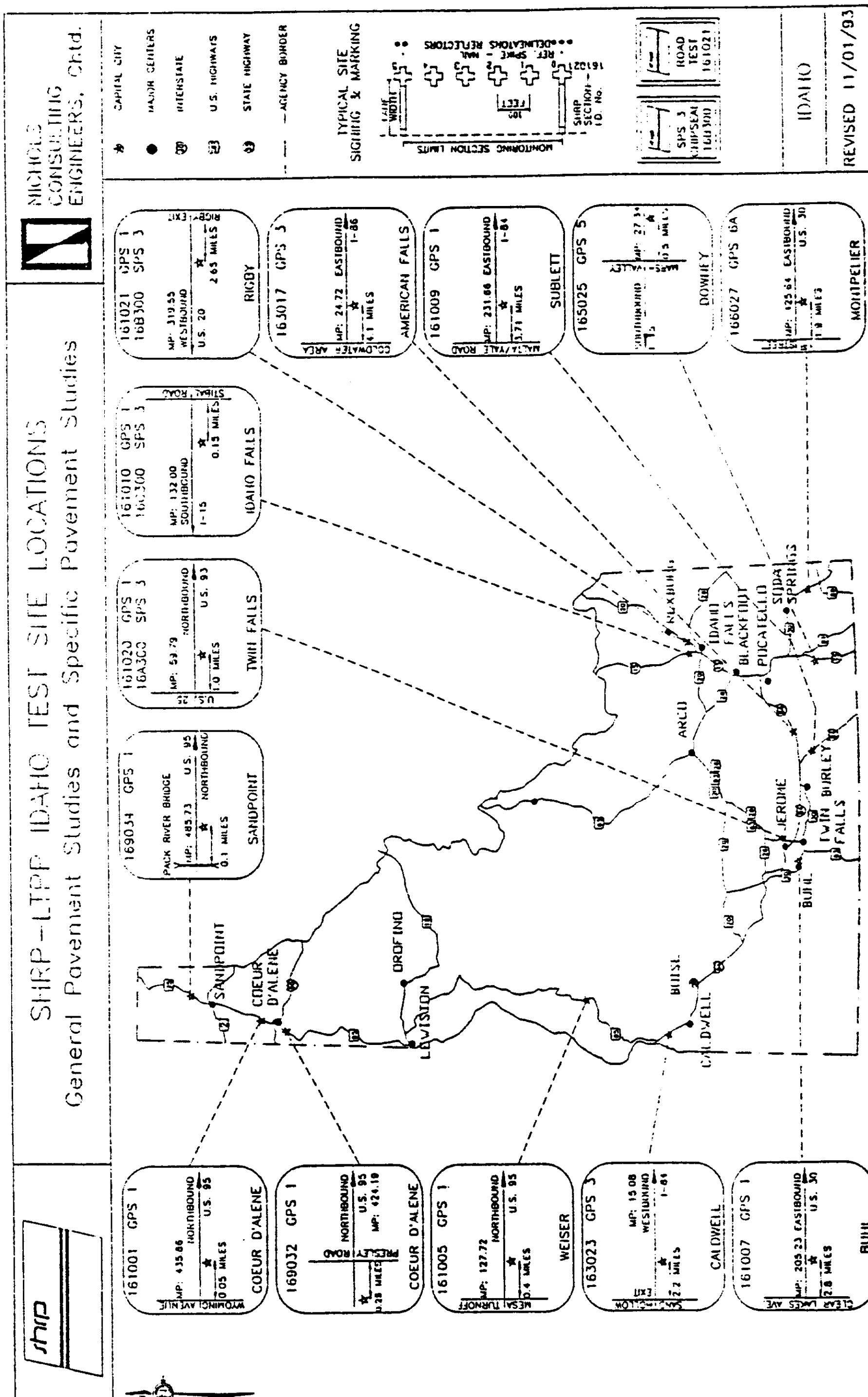


Figure A-1. Location of test site, GPS test section 161010.

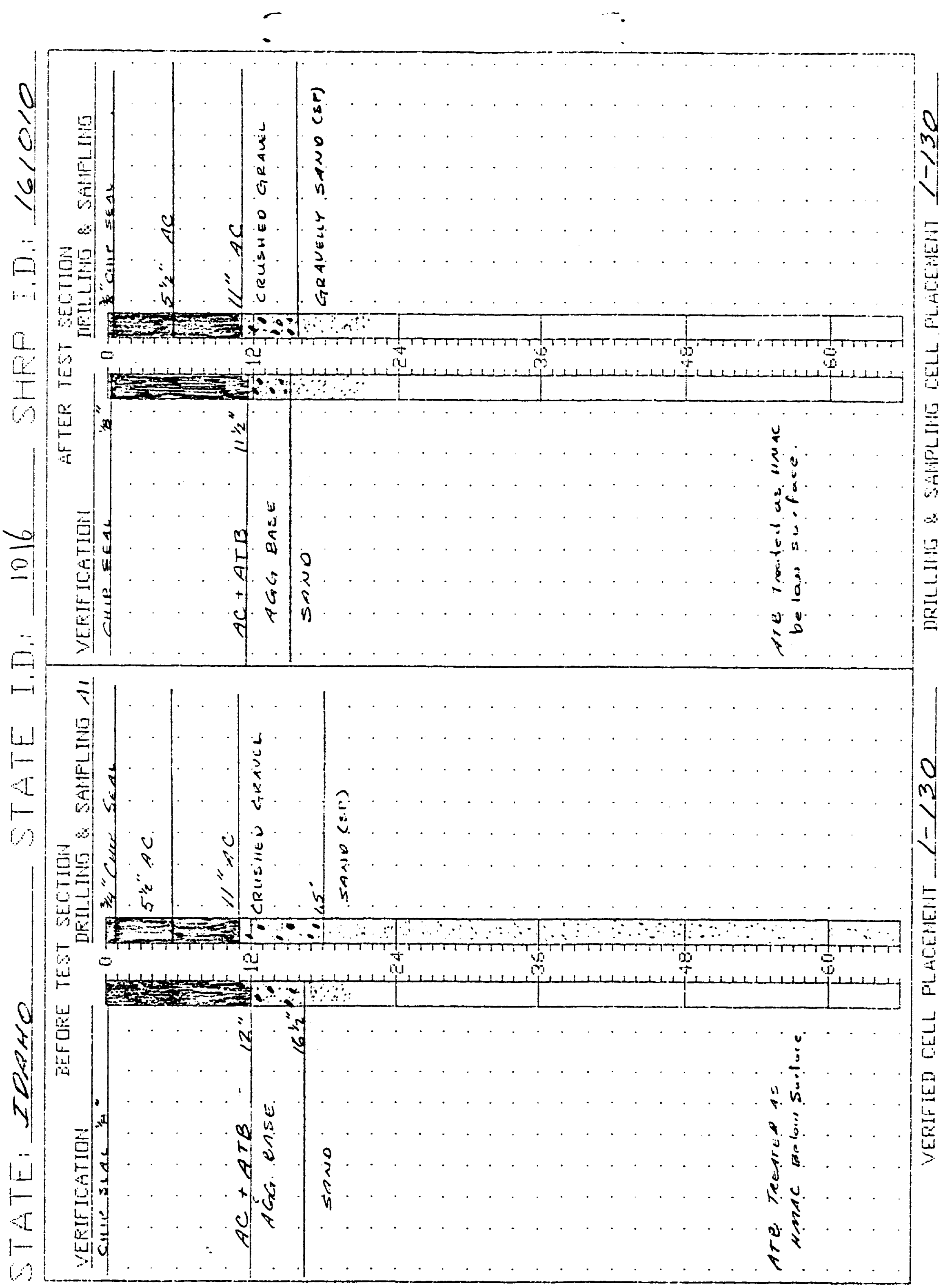


Figure A-2. Profile of test section.

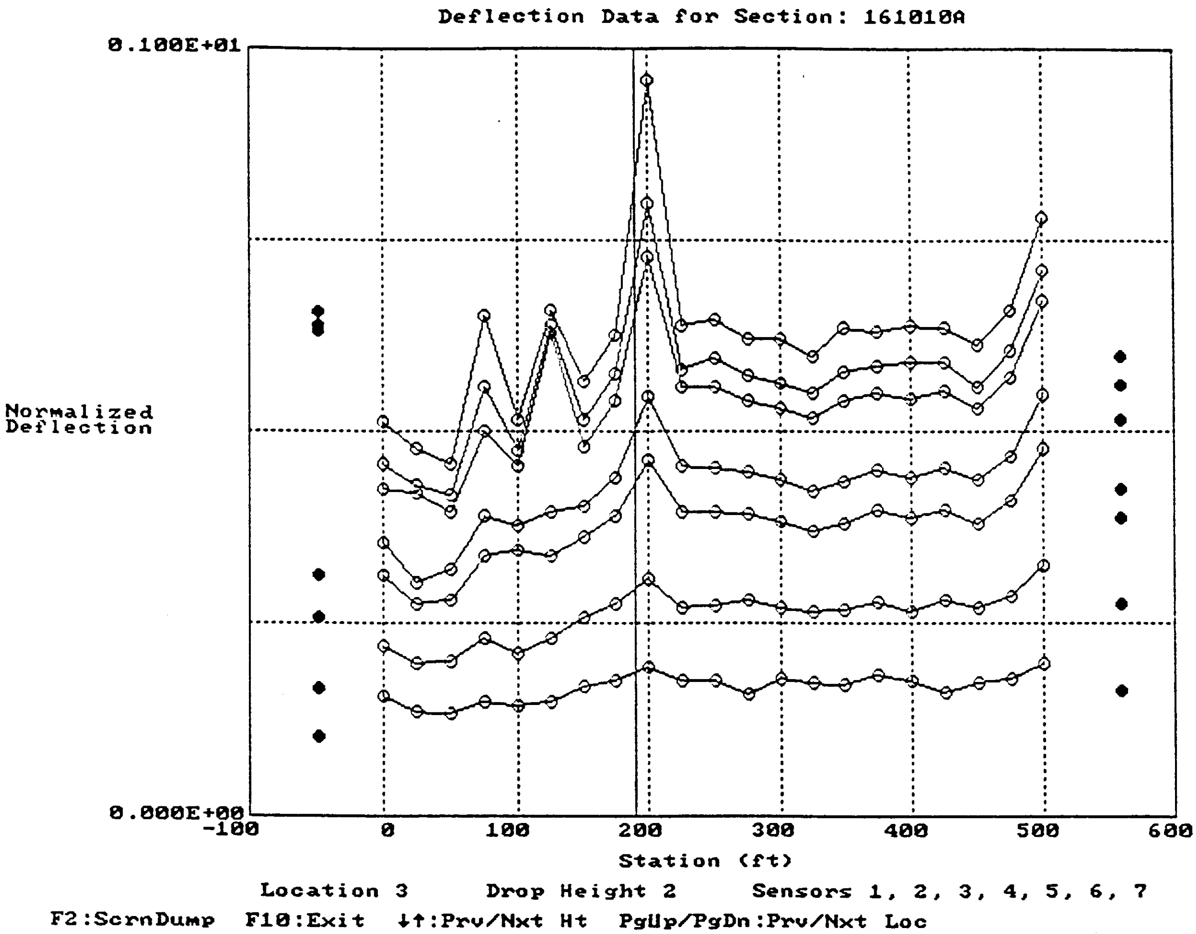


Figure A-3. Normalized deflection profile from FWDCHECK (test date 5/19/89).

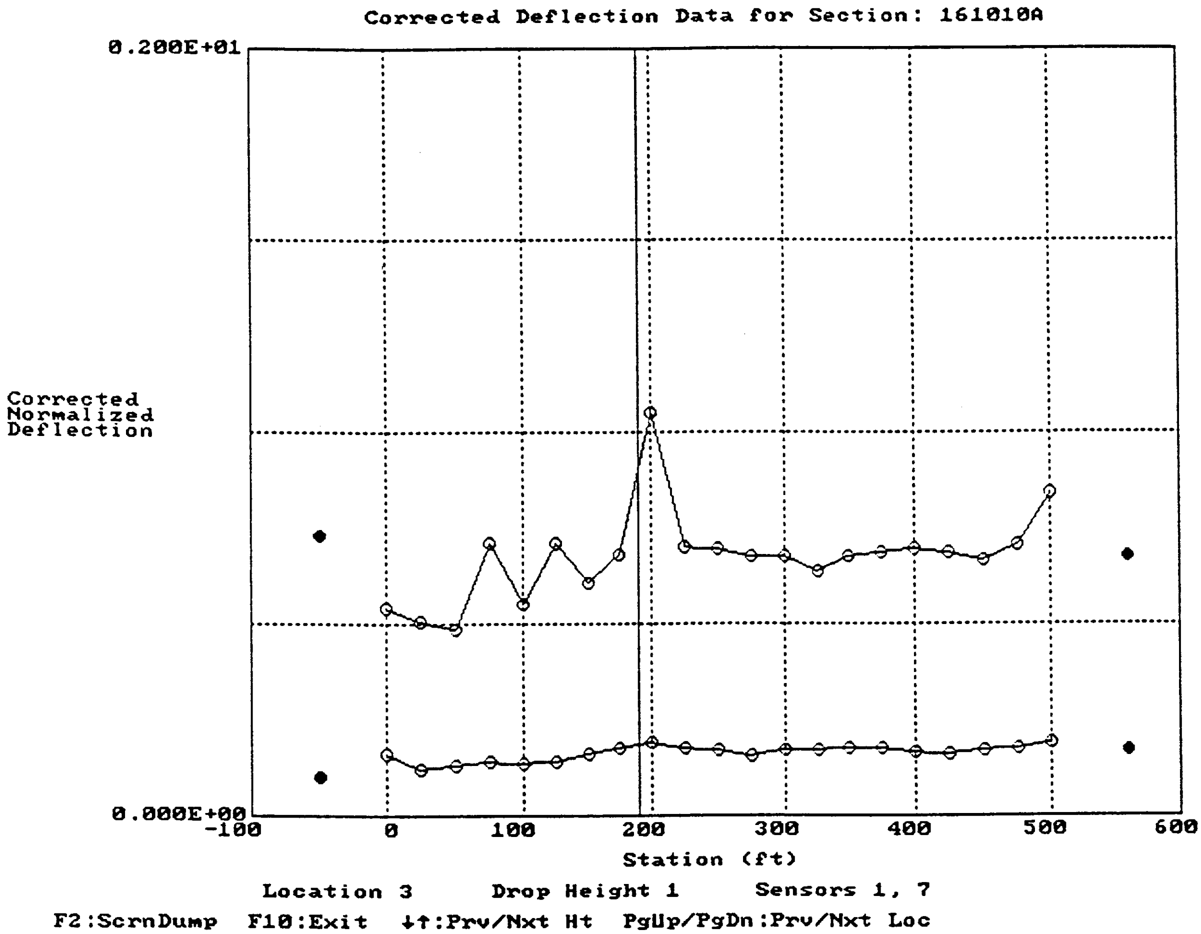


Figure A-4. Corrected normalized deflection profile from FWDCHECK.

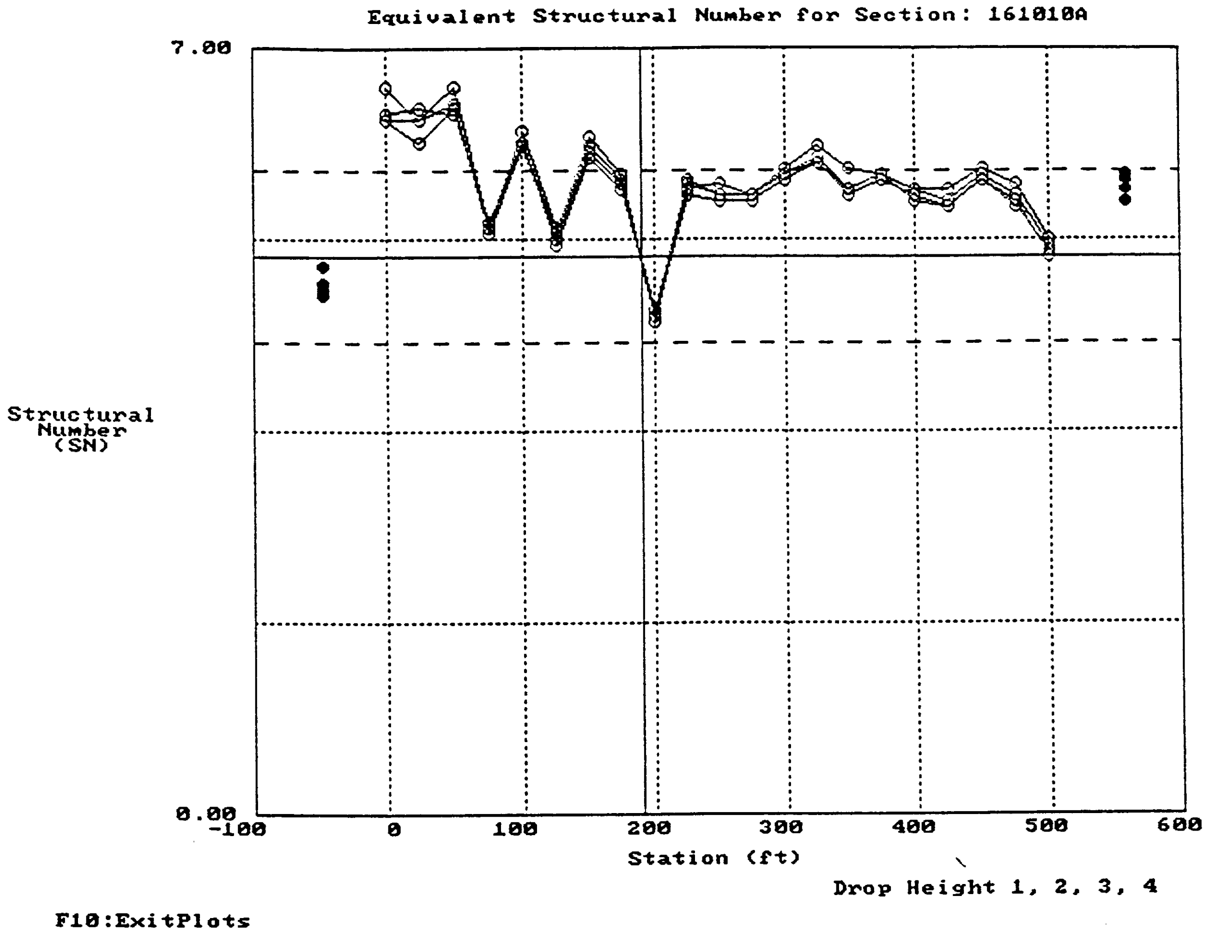


Figure A-5. Structural Number (SN) profile from FWDCHECK.

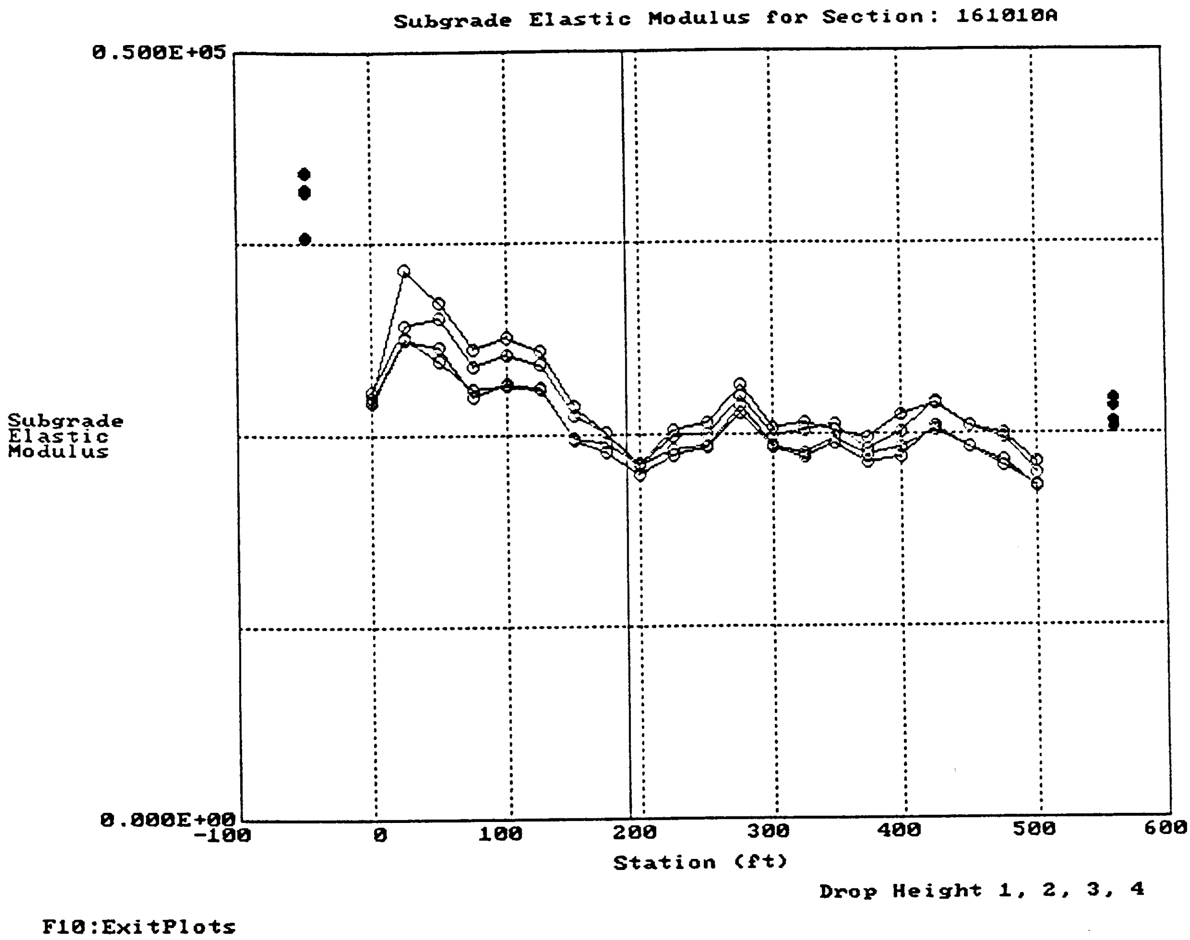


Figure A-6. Subgrade elastic modulus profile from FWDCHECK.

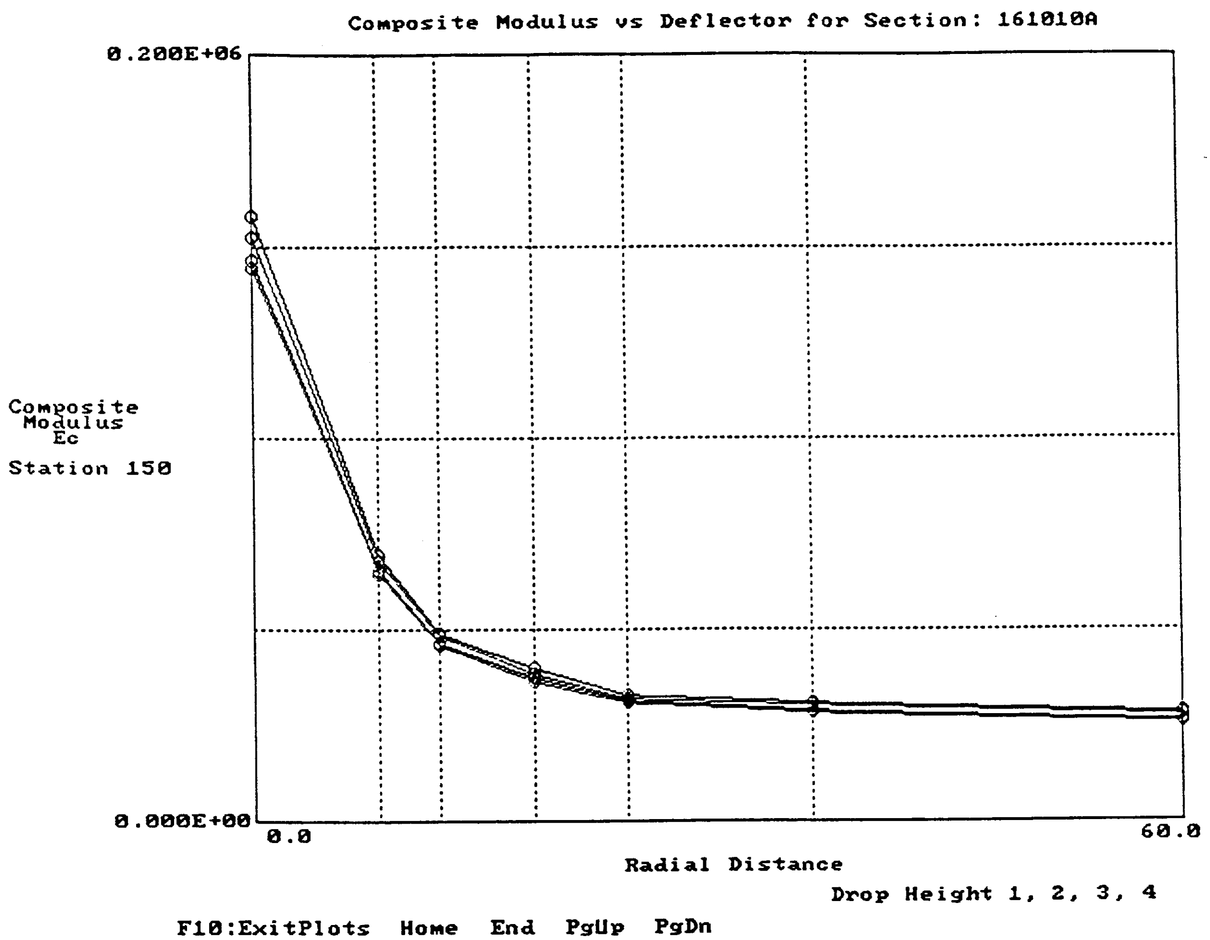


Figure A-7. Composite modulus Ec at station 150 from FWDCHECK.

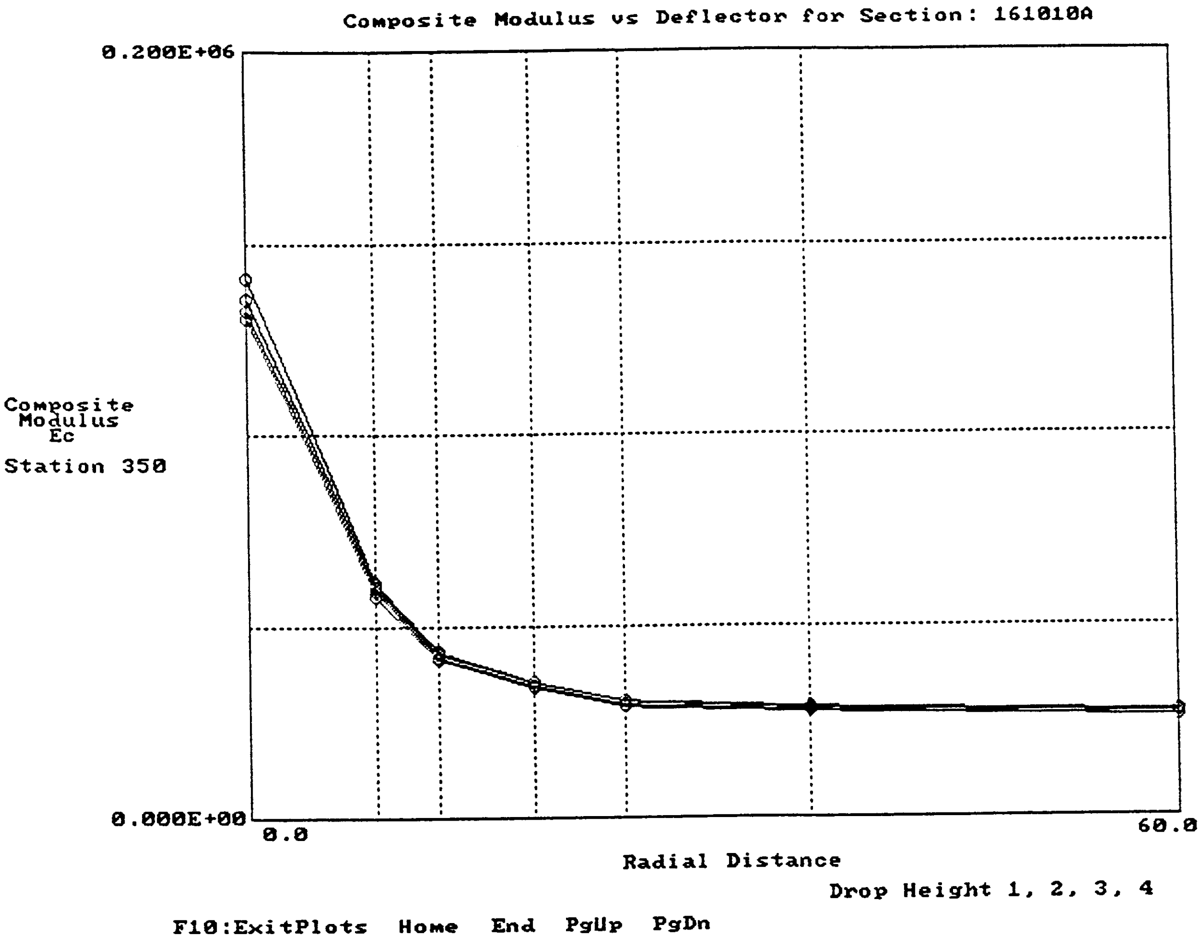


Figure A-8. Composite modulus Ec at station 350 from FWDCHECK.

APPENDIX B

Installed Instrument Information

Appendix B Includes the Following Supporting Information:

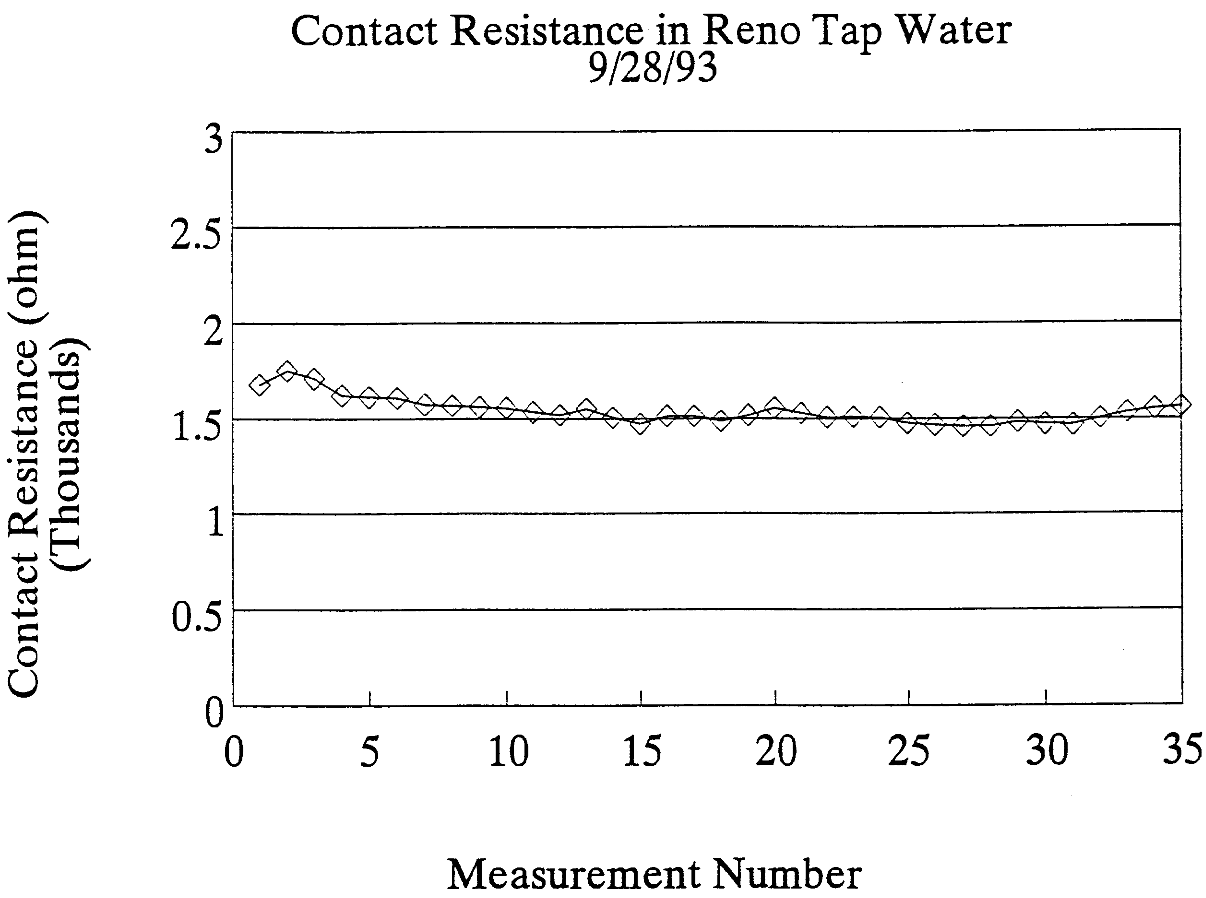


Figure B-1. Contact resistance measured in Reno tap water.

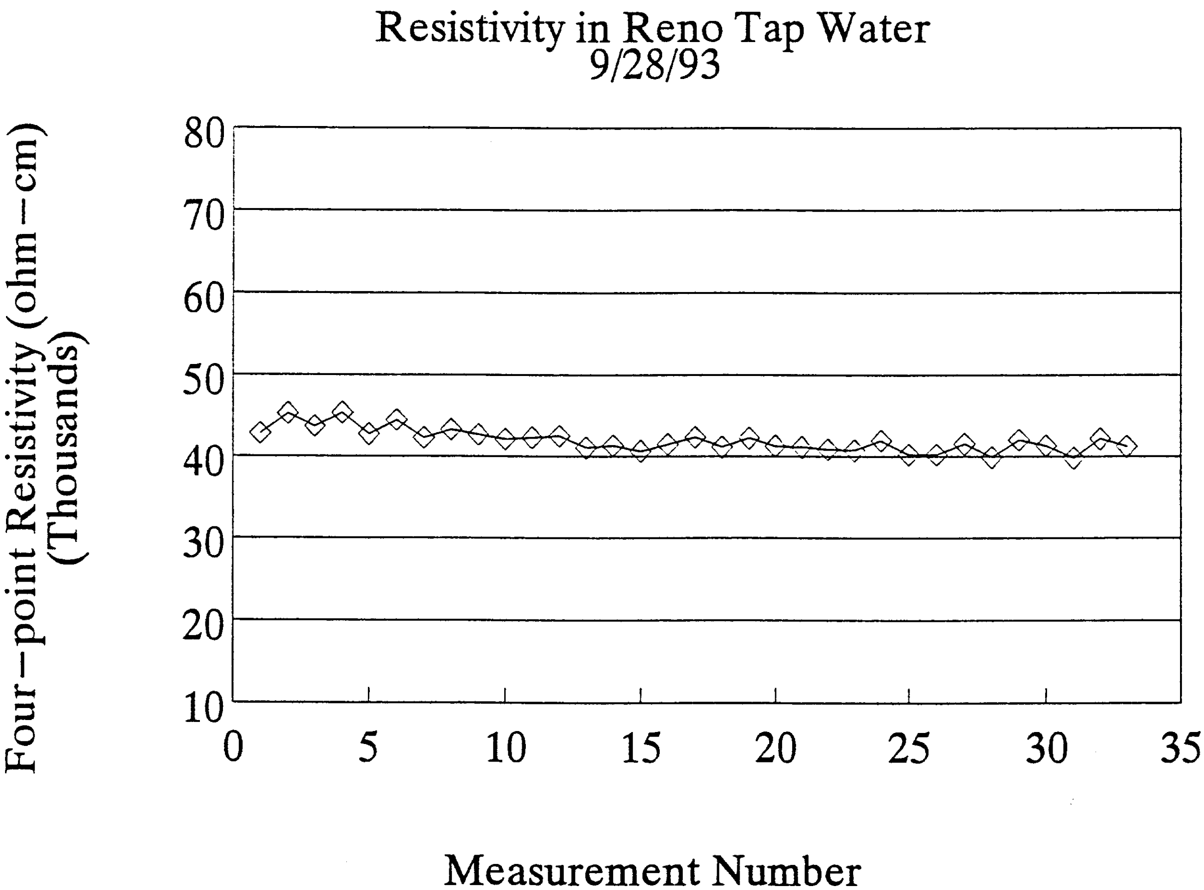
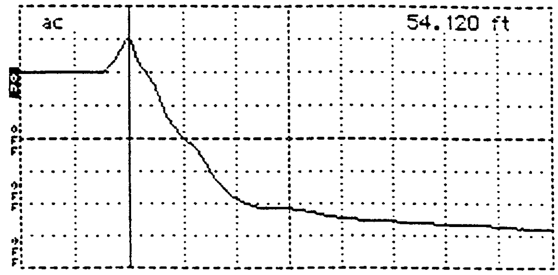


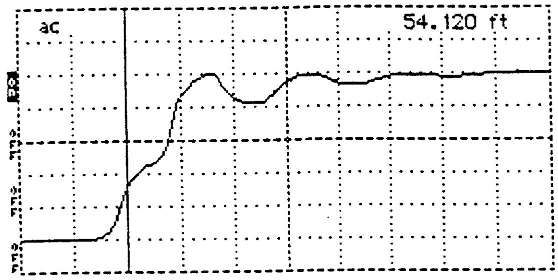
Figure B-2. Four-point resistivity measured in distilled water.

Cursor .... 54.120 ft
Distance/Div ..... 1 ft/div
Vertical Scale.... 177 mρ/div
VP 0.99
Noise Filter...... 1 avg
F r........... ac



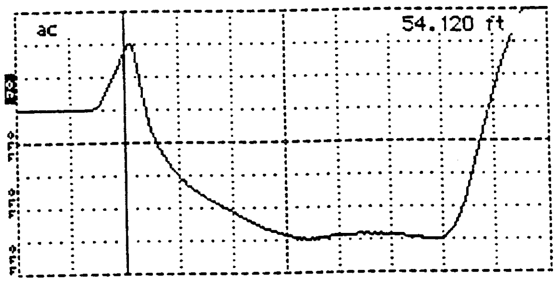
Tektronix 1502B TDR
Date 9/15/93
Cable 16 A01
Notes
Air 71°F
Input Trace
Stored Trace
Difference Trace

Cursor .... 54.120 ft
Distance/Div ..... 1 ft/div
Vertical Scale.... 177 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... ac



Tektronix 1502B TDR
Date
Cable A01
Notes
Input Trace
Stored Trace
Difference Trace

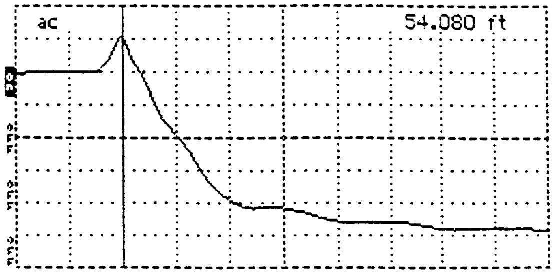
Cursor .... 54.120 ft
Distance/Div ..... 1 ft/div
Vertical Scale.... 72.7 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... ac



Tektronix 1502B TDR
Date
Cable A01
Notes
water 74°F
Input Trace
Stored Trace
Difference Trace

Figure B-3. TDR traces obtained during calibration.

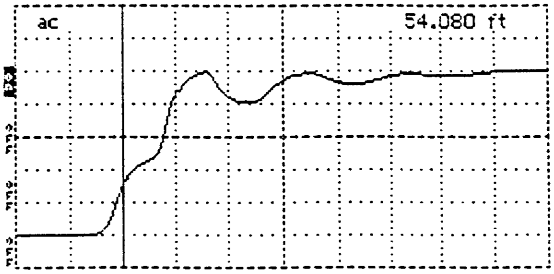
Cursor .... 54.080 ft
Distance/Div ..... 1 ft/div
Vertical Scale.... 177 mρ/div
VP 0.99
Noise Filter...... 1 avg
F[illegible]er .... ac



Tektronix 1502B TDR
Date ____
Cable ____ A02
Notes ____

Input Trace ____
Stored Trace ____
Difference Trace ____

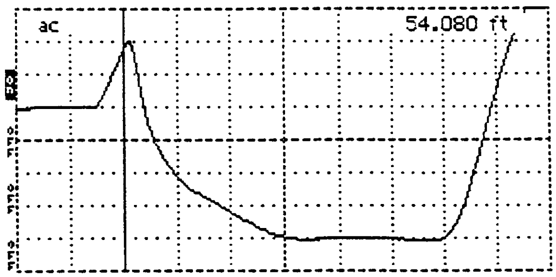
Cursor .... 54.080 ft
Distance/Div ..... 1 ft/div
Vertical Scale.... 177 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power .... ac



Tektronix 1502B TDR
Date ____
Cable ____ A02
Notes ____

Input Trace ____
Stored Trace ____
Difference Trace ____

Cursor .... 54.080 ft
Distance/Div ..... 1 ft/div
Vertical Scale.... 72.7 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power .... ac

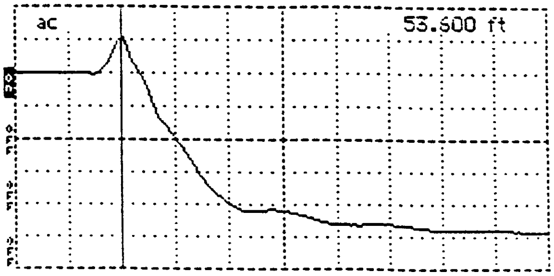


Tektronix 1502B TDR
Date ____
Cable ____ A02
Notes ____

Input Trace ____
Stored Trace ____
Difference Trace ____

Figure B-3. TDR traces obtained during calibration (cont.).

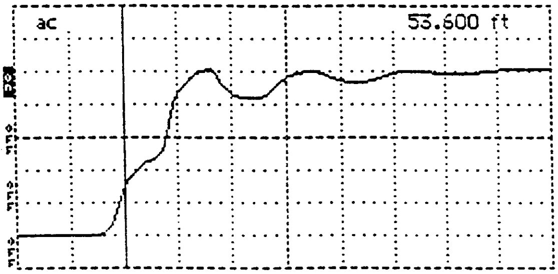
Cursor .... 53.600 ft
Distance/Div ..... 1 ft/div
Vertical Scale.... 177 mρ/div
VP 0.99
Noise Filter...... 1 avg
er........... ac



Tektronix 1502B TDR
Date
Cable
Notes

Input Trace
Stored Trace
Difference Trace

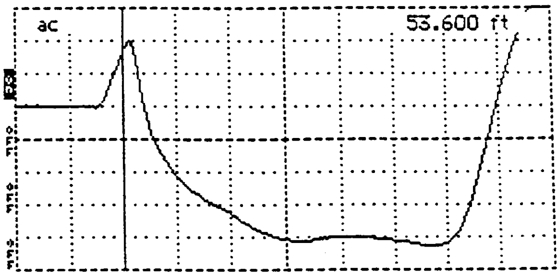
Cursor .... 53.600 ft
Distance/Div ..... 1 ft/div
Vertical Scale.... 177 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... ac



Tektronix 1502B TDR
Date
Cable
Notes

Input Trace
Stored Trace
Difference Trace

Cursor .... 53.600 ft
Distance/Div ..... 1 ft/div
Vertical Scale.... 72.7 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... ac



Tektronix 1502B TDR
Date
Cable
Notes

Input Trace
Stored Trace
Difference Trace

Figure B-3. TDR traces obtained during calibration (cont.).

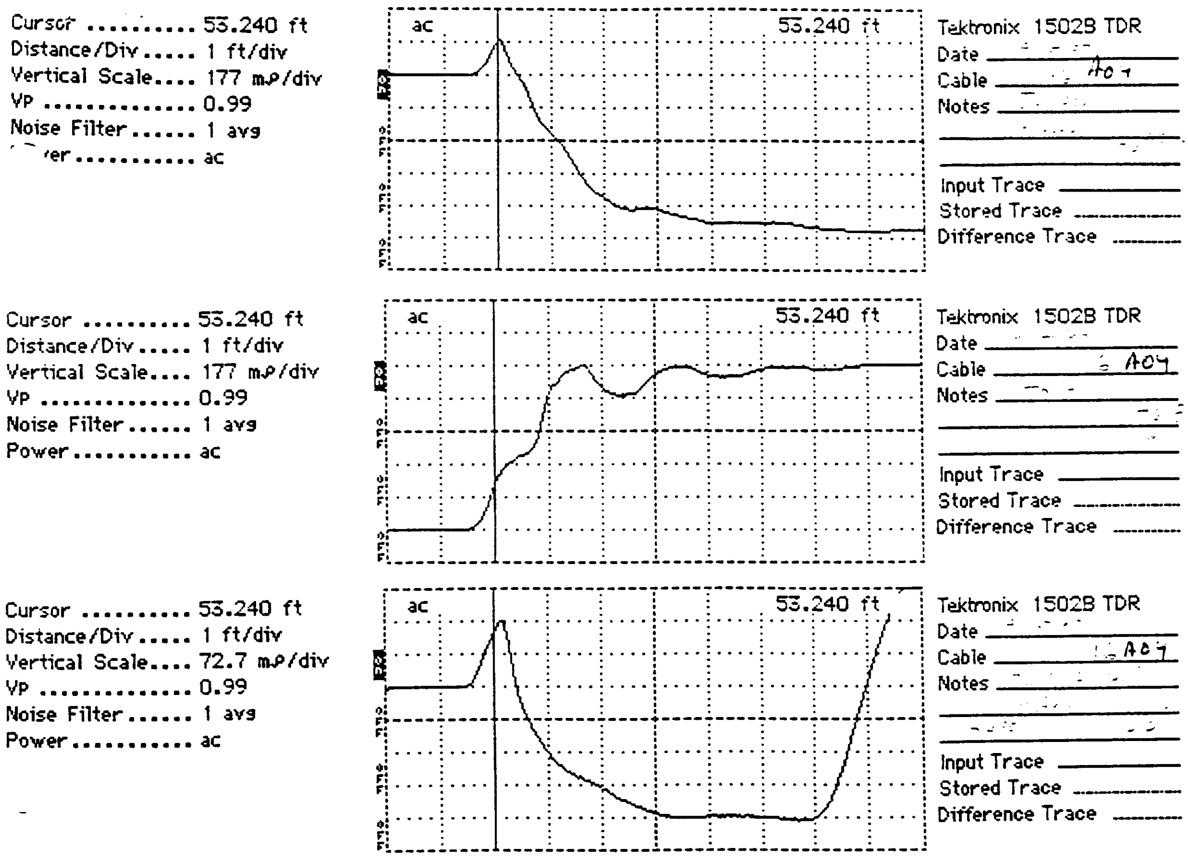


Figure B-3. TDR traces obtained during calibration (cont.).

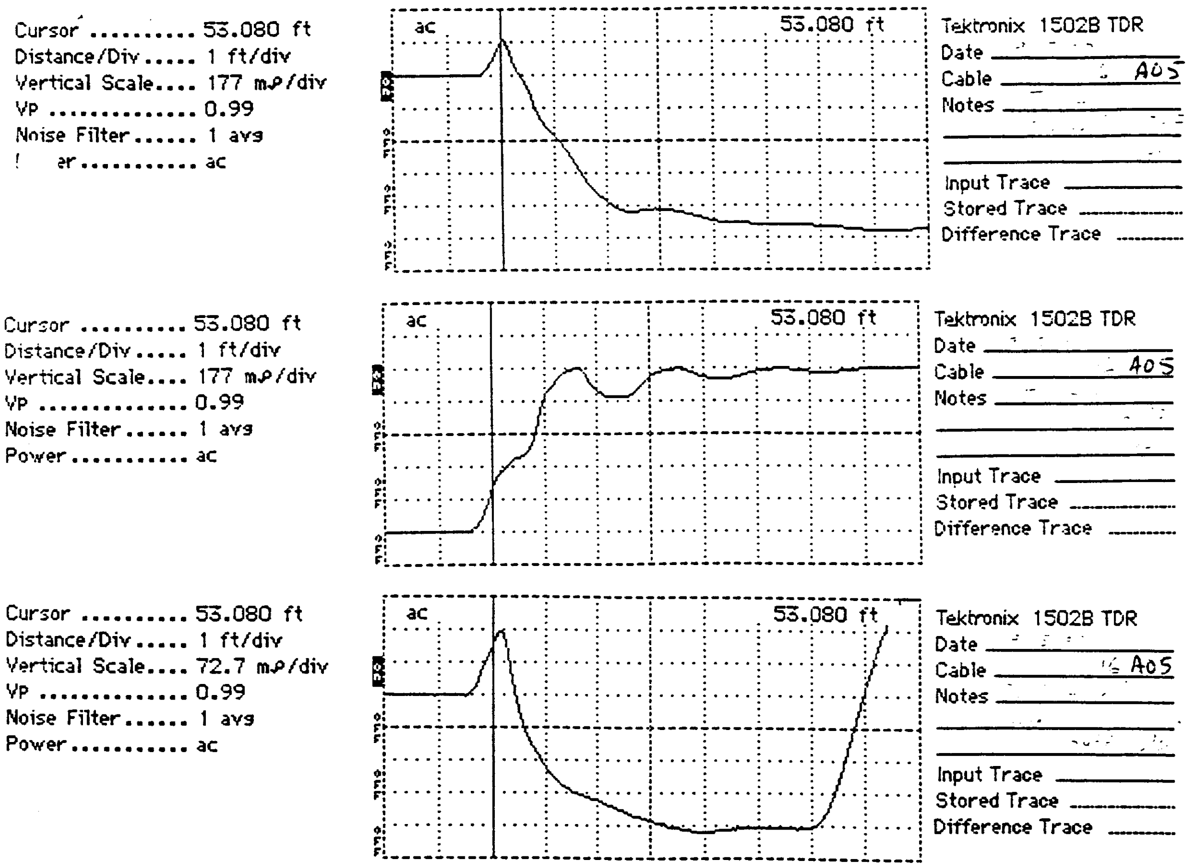
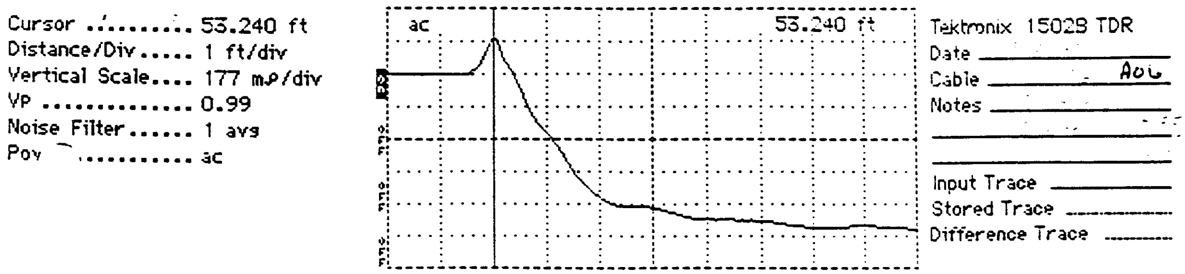
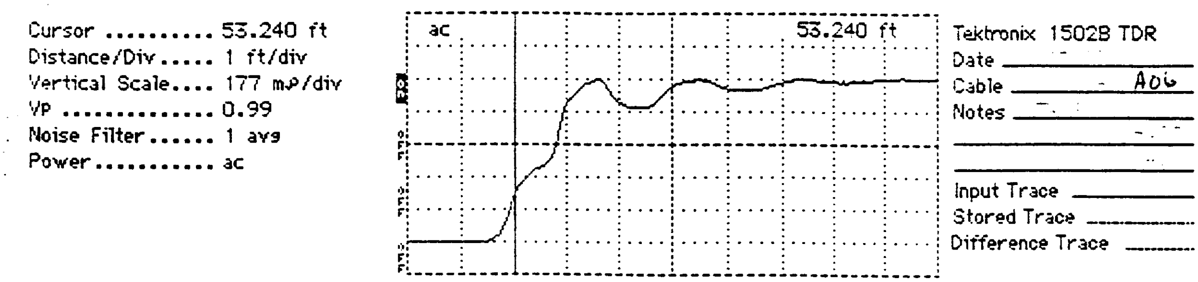


Figure B-3. TDR traces obtained during calibration (cont.).





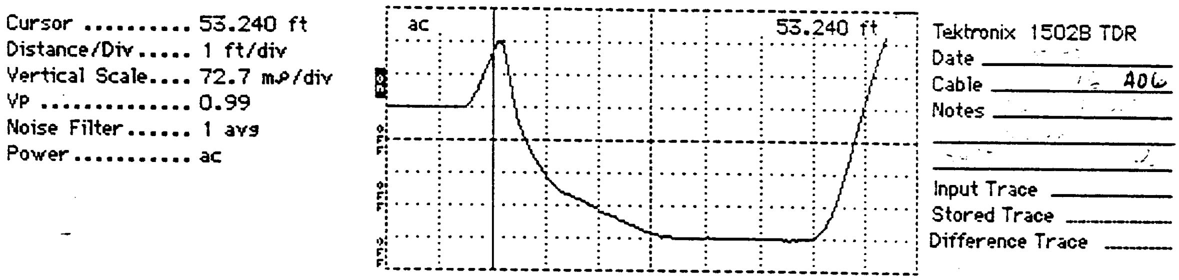


Figure B-3. TDR traces obtained during calibration (cont.).

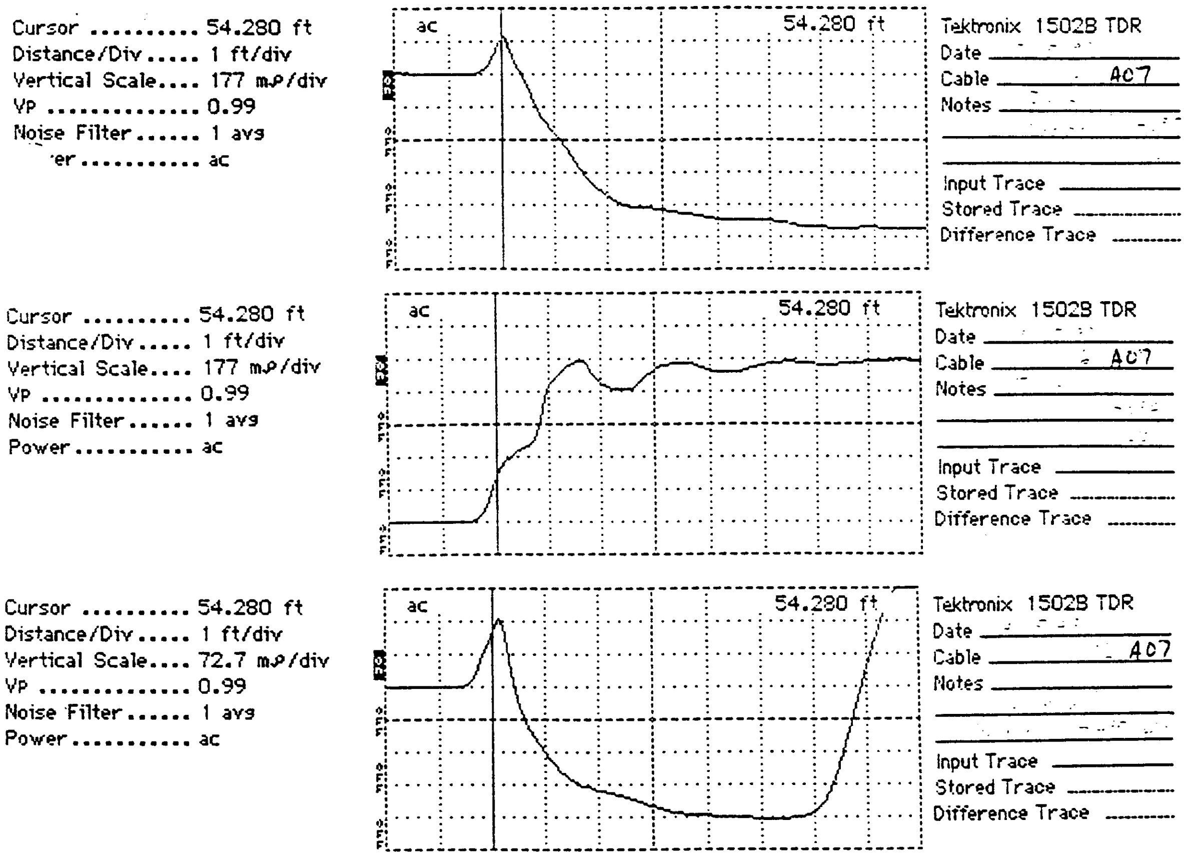
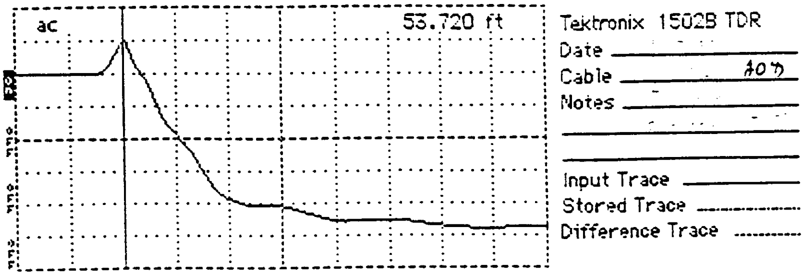
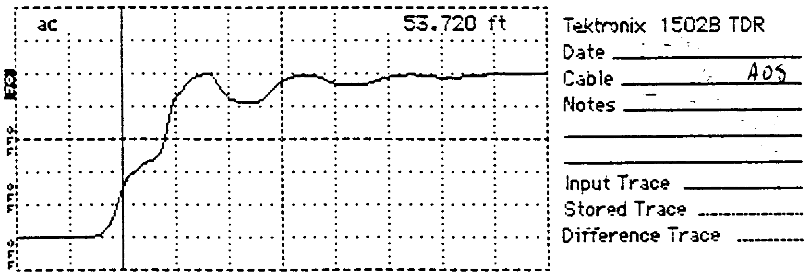


Figure B-3. TDR traces obtained during calibration (cont.).

Cursor .... 53.720 ft
Distance/Div ..... 1 ft/div
Vertical Scale.... 177 mρ/div
Vp 0.99
Noise Filter...... 1 avg
F[illegible]r........... ac



Cursor .... 53.720 ft
Distance/Div ..... 1 ft/div
Vertical Scale.... 177 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac



Cursor .... 53.720 ft
Distance/Div ..... 1 ft/div
Vertical Scale.... 72.7 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac

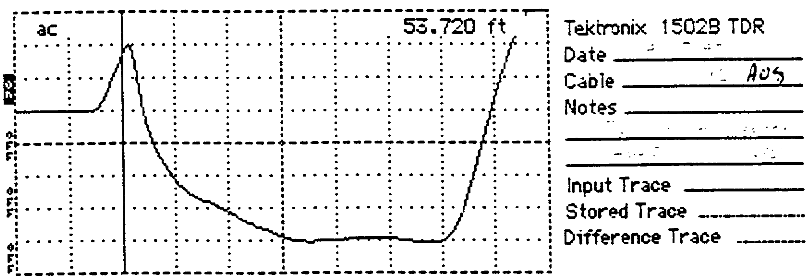
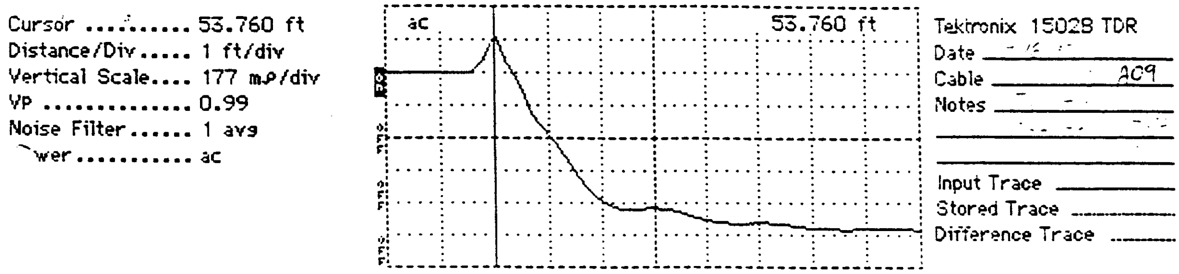
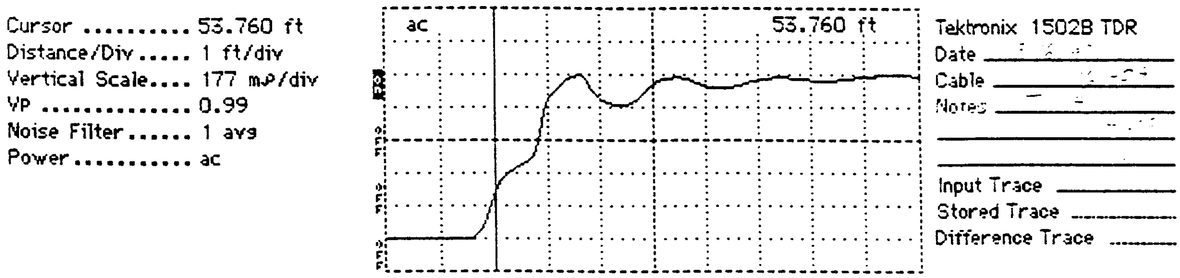


Figure B-3. TDR traces obtained during calibration (cont.).





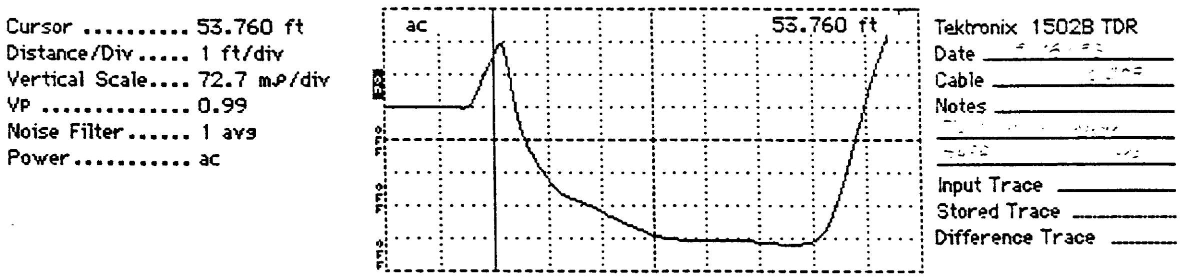


Figure B-3. TDR traces obtained during calibration (cont.).

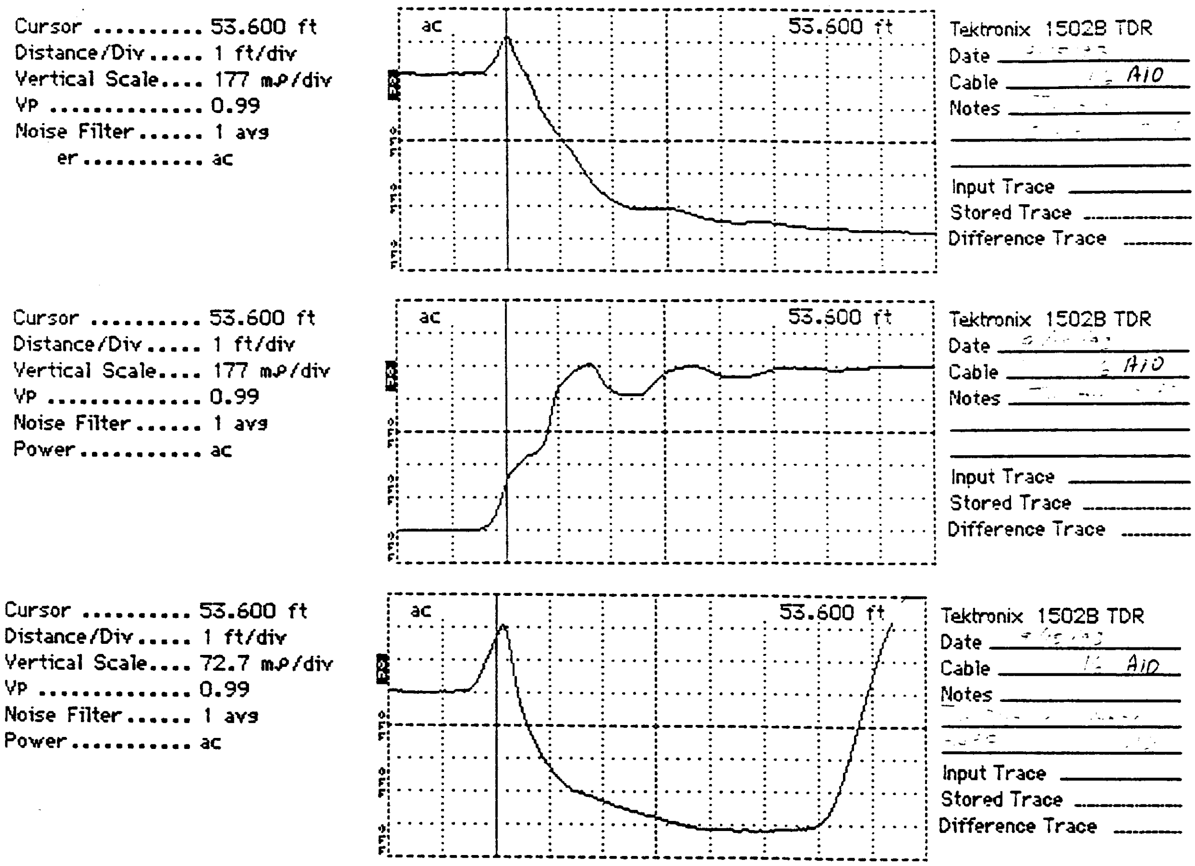


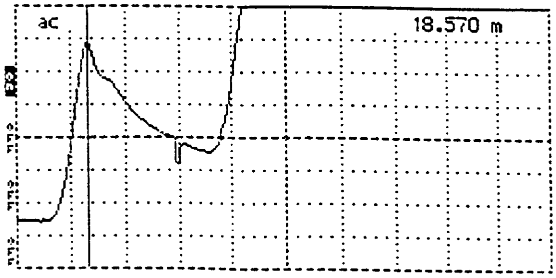
Figure B-3. TDR traces obtained during calibration (cont.).

APPENDIX C

Supporting Instrumentation Installation Information

Appendix C Includes the Following Supporting Information:

Cursor .... 18.570 m
Distance/Div ..... .25 m/div
Vertical Scale.... 39.7 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... ac

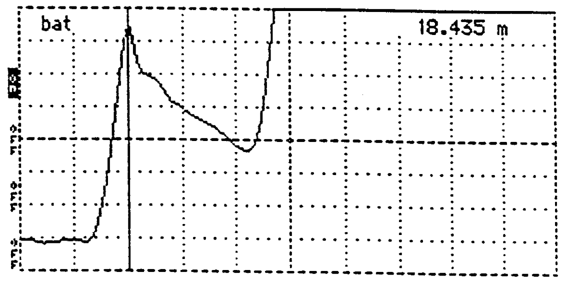


Tektronix 1502B TDR
Date 9/30/93
Cable 1 [illegible]
Notes went to A/C [illegible] operation [illegible]
Sect 161010
Input Trace
Stored Trace
Difference Trace

Cursor .... 18.545 m
Distance/Div ..... .25 m/div
Vertical Scale.... 39.7 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... bat/low

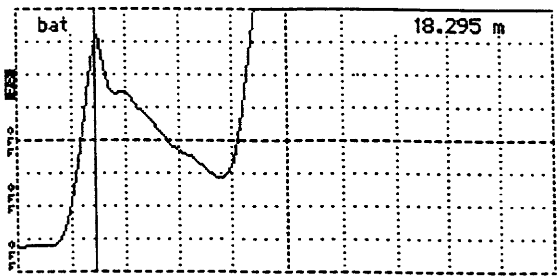
Tektronix 1502B TDR
Date 9/30/93
Cable 2 [illegible]
Notes Still [illegible] when this was [illegible]
Sect 161010
Input Trace
Stored Trace
Difference Trace

Cursor .... 18.435 m
Distance/Div ..... .25 m/div
Vertical Scale.... 31.5 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... bat/low



Tektronix 1502B TDR
Date 9/30/93 3:
Cable 3 [illegible]
Notes
Sect 161010
Input Trace
Stored Trace
Difference Trace

Cursor .... 18.295 m
Distance/Div ..... .25 m/div
Vertical Scale.... 31.5 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... bat/low



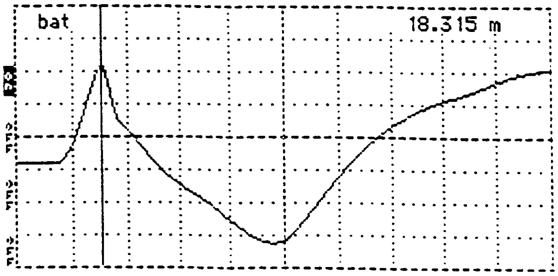
Tektronix 1502B TDR
Date 9/30/93 3:
Cable 4 3:40pm
Notes Probe Inspected dip - Appears Good
Sect 161010
Input Trace
Stored Trace
Difference Trace

Cursor .... 18.265 m
Distance/Div ..... .25 m/div
Vertical Scale.... 37.5 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... bat

Tektronix 1502B TDR
Date 9/30/93
Cable 5 3:35
Notes
Sect 161010
Input Trace
Stored Trace
Difference Trace

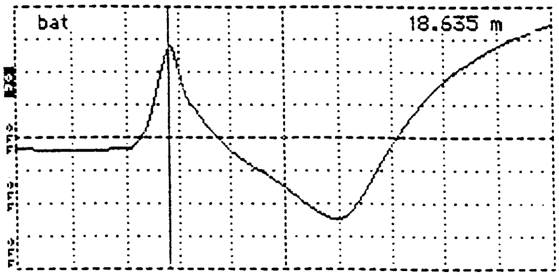
Figure C-1. TDR traces measured during installation.

Cursor .... 18.315 m
Distance/Div ..... .25 m/div
Vertical Scale.... 61.2 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... bat



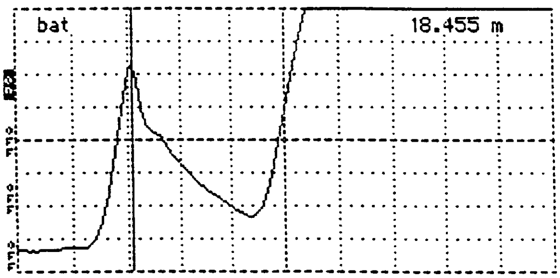
Tektronix 1502B TDR
Date 9/30/93
Cable 6
Notes
Sect 161010
Input Trace
Stored Trace
Difference Trace

Cursor .... 18.635 m
Distance/Div ..... .25 m/div
Vertical Scale.... 57.7 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... bat



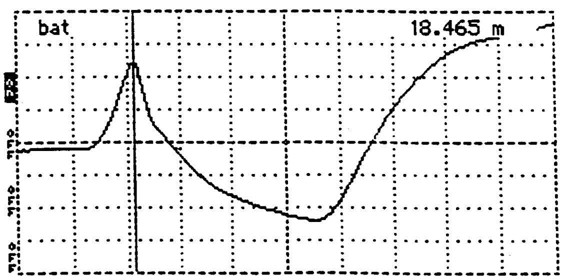
Tektronix 1502B TDR
Date 9/30/93
Cable 7
Notes
Sect 161010
Input Trace
Stored Trace
Difference Trace

Cursor .... 18.455 m
Distance/Div ..... .25 m/div
Vertical Scale.... 35.4 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... bat



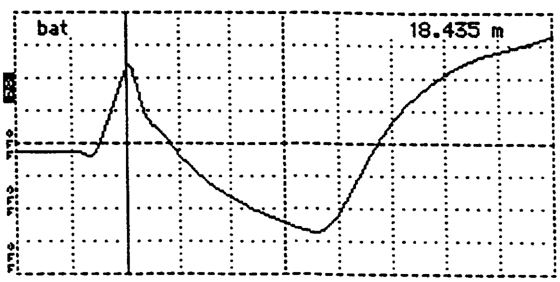
Tektronix 1502B TDR
Date 9/30/93
Cable 8
Notes DRY Soil
Sect 161010
Input Trace
Stored Trace
Difference Trace

Cursor .... 18.465 m
Distance/Div ..... .25 m/div
Vertical Scale.... 64.8 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... bat



Tektronix 1502B TDR
Date 9/30/93
Cable 9 2:55
Notes SATURATED with WATER
Sect 161010
Input Trace
Stored Trace
Difference Trace

Cursor .... 18.435 m
Distance/Div ..... .25 m/div
Vertical Scale.... 64.8 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... bat



Tektronix 1502B TDR
Date 9/30/93
Cable 10
Notes SATURATED with WATER
Sect 161010
Input Trace
Stored Trace
Difference Trace

Figure C-1. TDR traces measured during installation (cont.).

LTPP Seasonal Monitoring Study Moisture Contents	* State Code [16] * Test Section Number [1010]

Personnel : Jason M. Dietz
Date : 9/30/93
Start Time : 2:30 PM
Finish Time : 4:00 PM
Surface Type : Asphalt Concrete
Weather Conditions : Clear 23.9°C
Unusual Conditions : None

TDR Probe #	Field Moisture Content %
10*	5.63
9*	9.40
8	6.46
7	7.91
6	8.93
5	7.02
4	4.70
3	3.92
2	5.28
1	4.36

* Samples taken in saturated water level.

Figure C-2. Field measured moisture content.

APPENDIX D

Initial Data Collection

Appendix D Includes the Following Supporting Information:

Table D-1	Raw data from the onsite datalogger during initial data collection
Figure D-1	Measured air temperature during initial data collection
Figure D-2	Measured hourly average subsurface temperature for the first 5 sensors during initial data collection
Fig. D-3 - 12	TDR traces measured with the mobile system during initial data collection
Figure D-13	Measured voltage output vs. electrode number
Figure D-14	Manually measured contact resistance vs. electrode number
Figure D-15	Manually collected contact resistance
Figure D-16	Manually collected 4-point resistivity
Figure D-17	Comparison between voltage output vs. measured contact resistance
Table D-2	Contact resistance measurement data sheet
Table D-3	Four-point resistivity measurement data sheet
Table D-4	Surface elevation measurement data sheet

Table D-1 Data from the onsite datalogger during initial data collection, 9/30 - 10/1, 1993

```
4,273,600,23.74,0
5,273,600,20.91,19.36,18.32,16.99,16.81
4,273,700,21.05,0
5,273,700,20.16,19.49,18.5,17.48,17.1
4,273,800,17.3,0
5,273,800,18.05,19.16,18.7,18.02,17.53
4,273,900,12.79,0
5,273,900,16.35,18.34,18.65,18.32,17.87
4,273,1000,8,0
5,273,1000,14.84,17.42,18.37,18.45,18.09
4,273,1100,7.71,0
5,273,1100,13.74,16.49,17.97,18.46,18.22
4,273,1200,6.86,0
5,273,1200,12.93,15.7,17.51,18.35,18.24
4,273,1300,7.41,0
5,273,1300,12.51,15.08,17.05,18.17,18.2
4,273,1400,6.291,0
5,273,1400,12.09,14.6,16.62,17.93,18.09
4,273,1500,5.281,0
5,273,1500,11.44,14.11,16.23,17.68,17.94
4,273,1600,4.414,0
5,273,1600,10.63,13.56,15.84,17.42,17.77
4,273,1700,3.503,0
5,273,1700,10.01,12.98,15.42,17.14,17.57
4,273,1800,4.259,0
5,273,1800,9.49,12.45,15,16.85,17.36
4,273,1900,4.007,0
5,273,1900,9.04,11.98,14.58,16.55,17.14
4,273,2000,3.635,0
5,273,2000,8.65,11.54,14.18,16.24,16.9
```

Note: The time 600 was 1800 on Julian day 273.

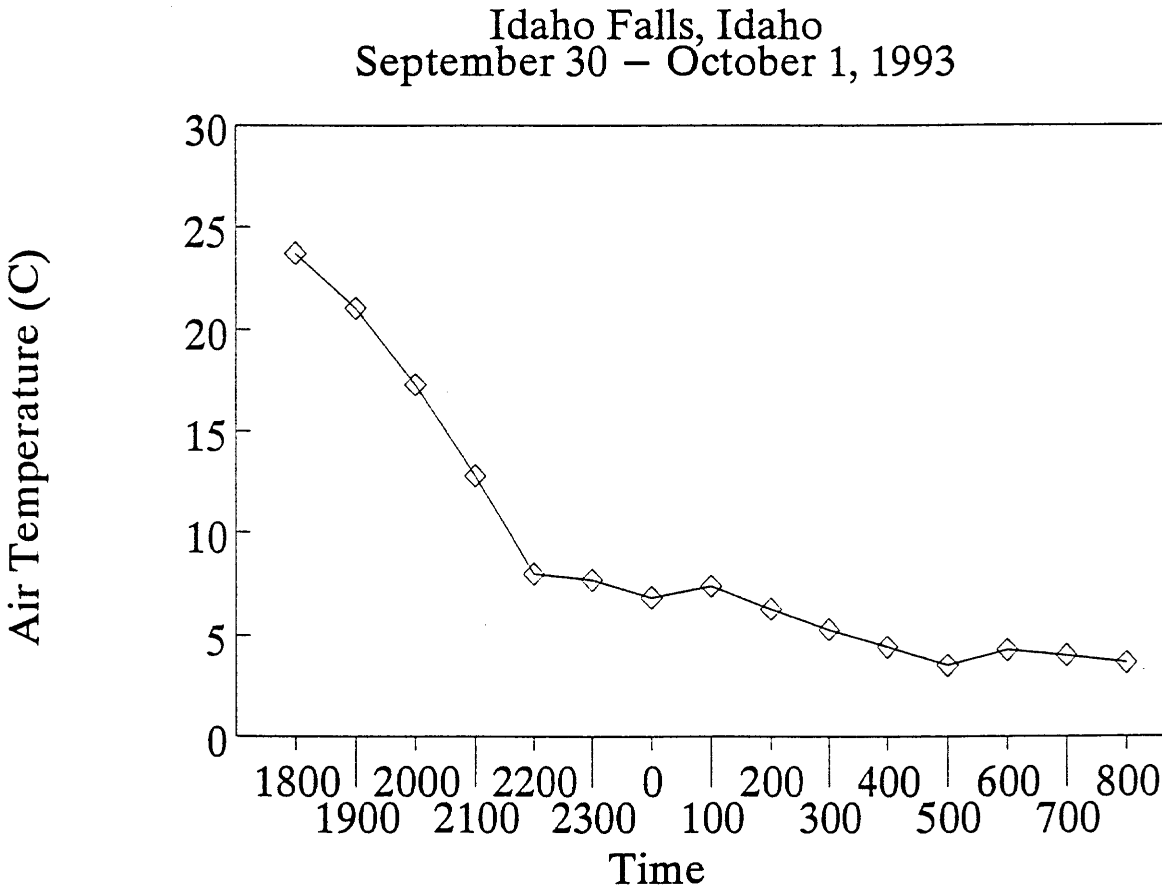


Figure D-1. Measured air temperature during initial data collection.

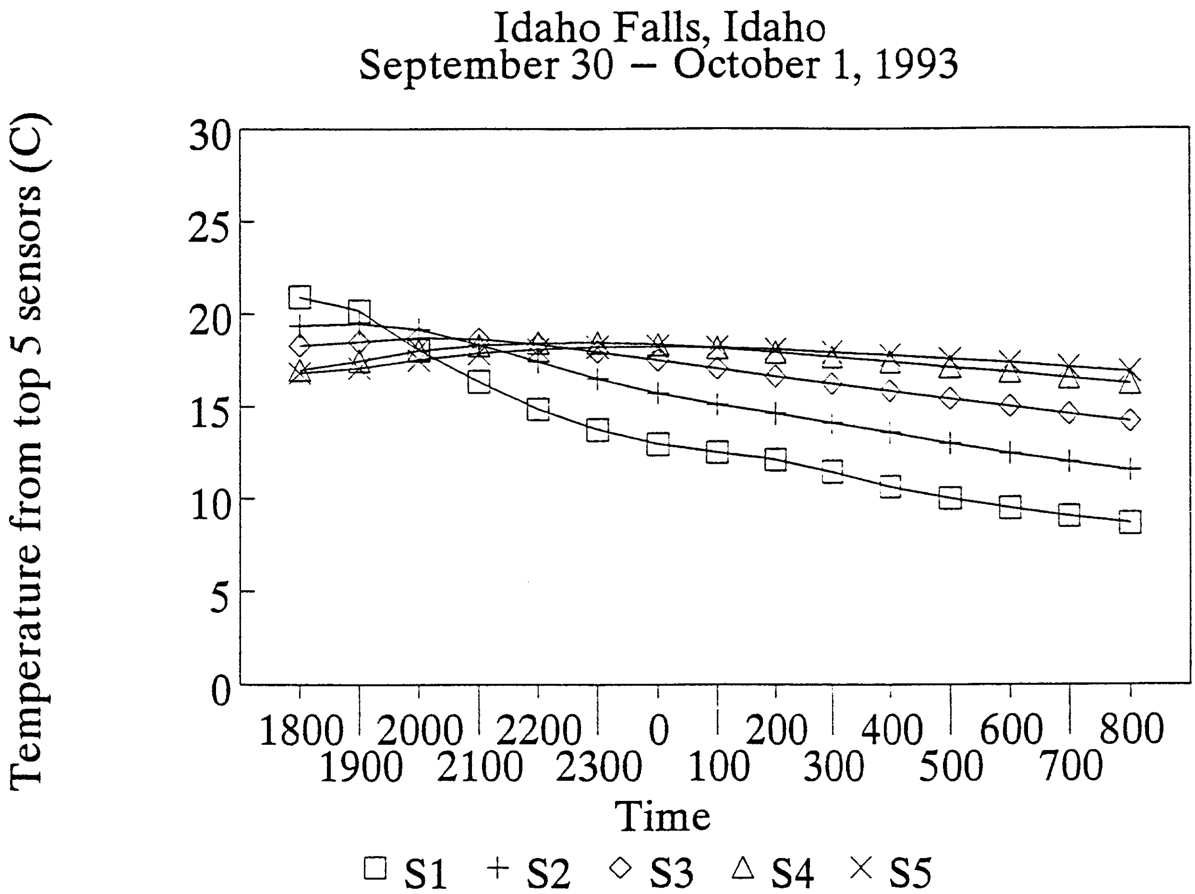


Figure D-2. Measured hourly average subsurface temperature for the first 5 sensors during initial data collection.

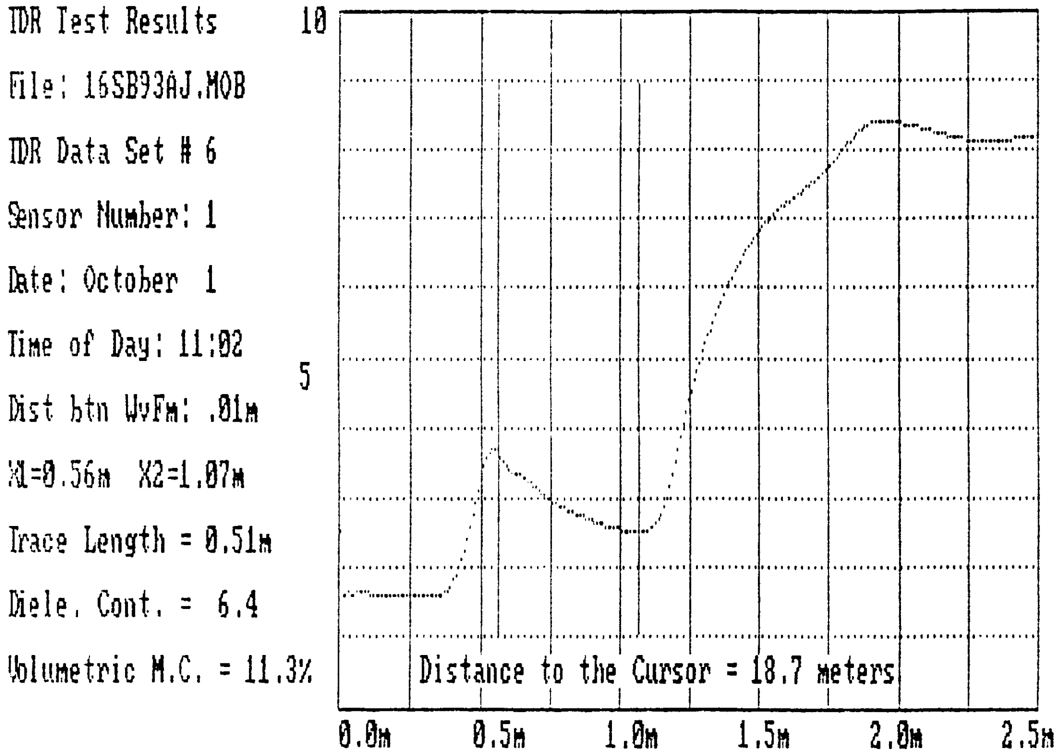


Figure D-3. Trace from TDR sensor 1.

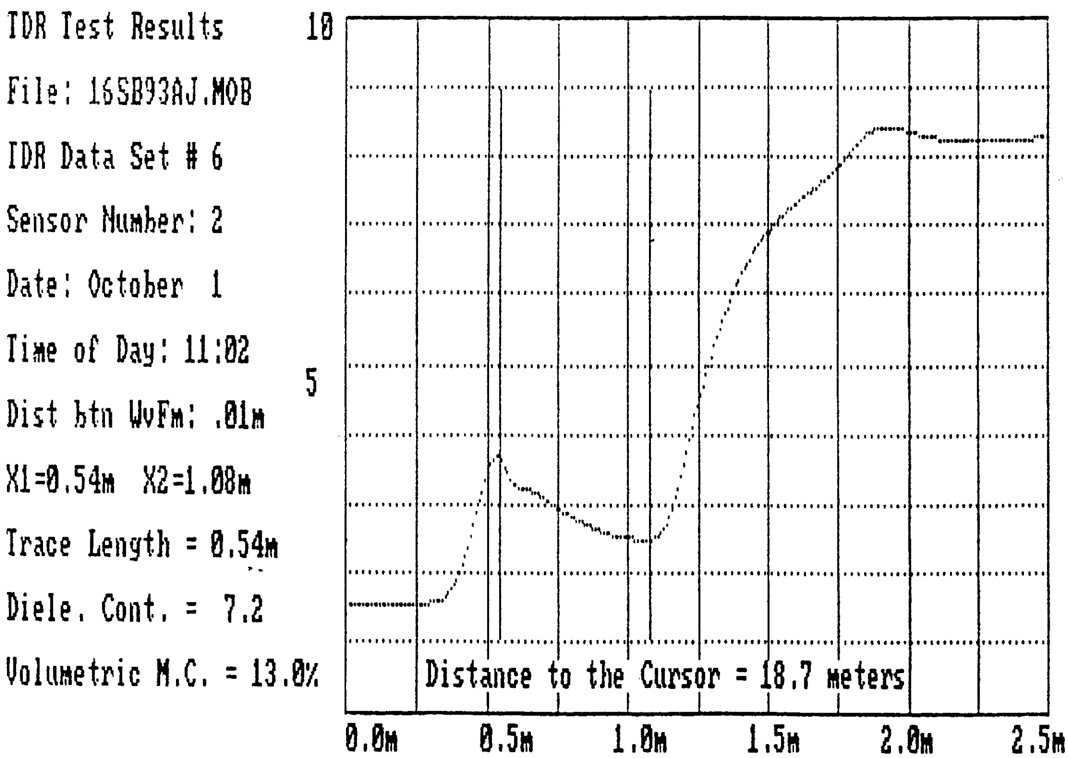


Figure D-4. Trace from TDR sensor 2.

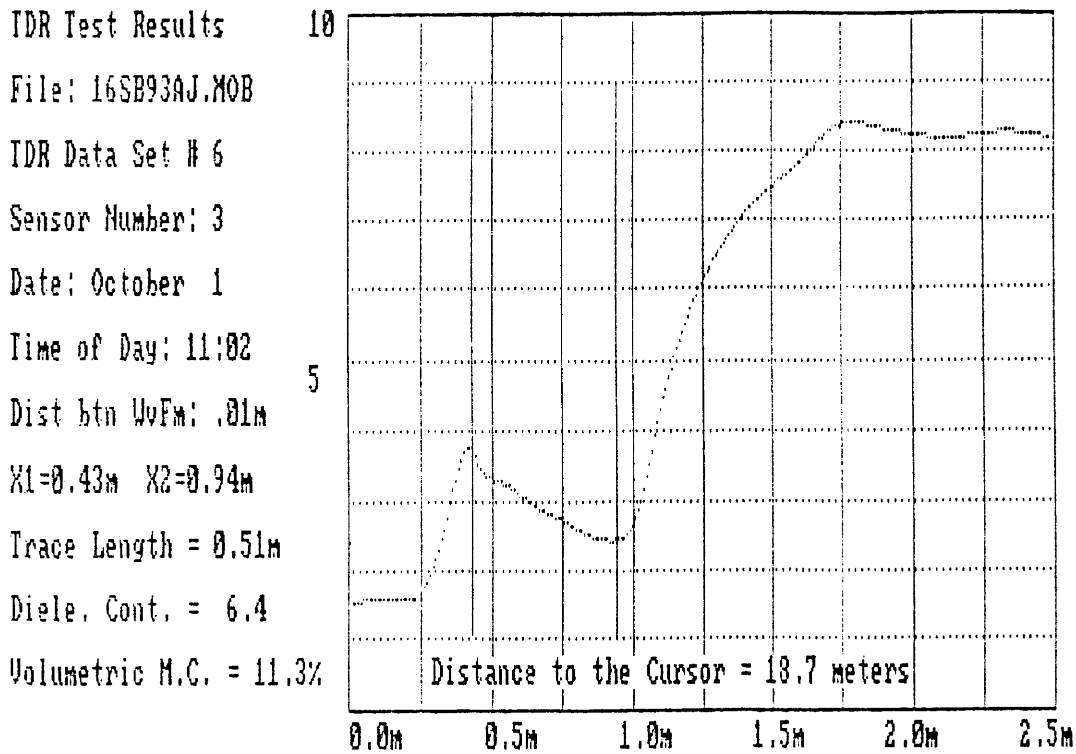


Figure D-5. Trace from TDR sensor 3.

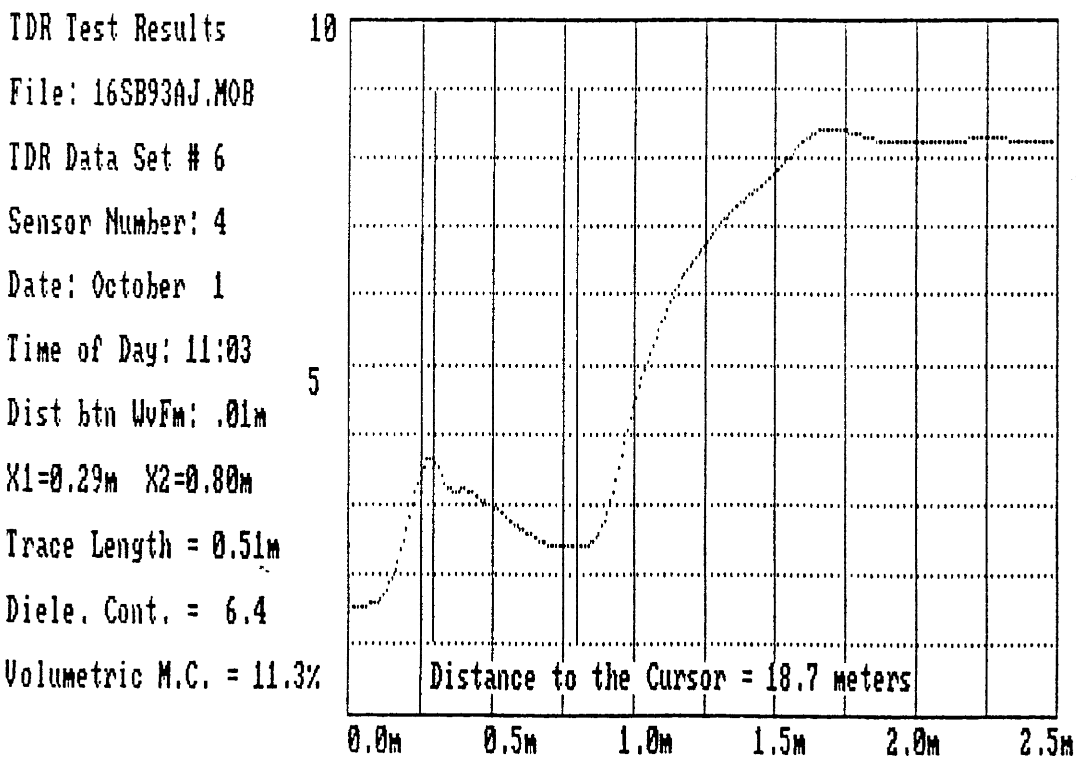


Figure D-6. Trace from TDR sensor 4.

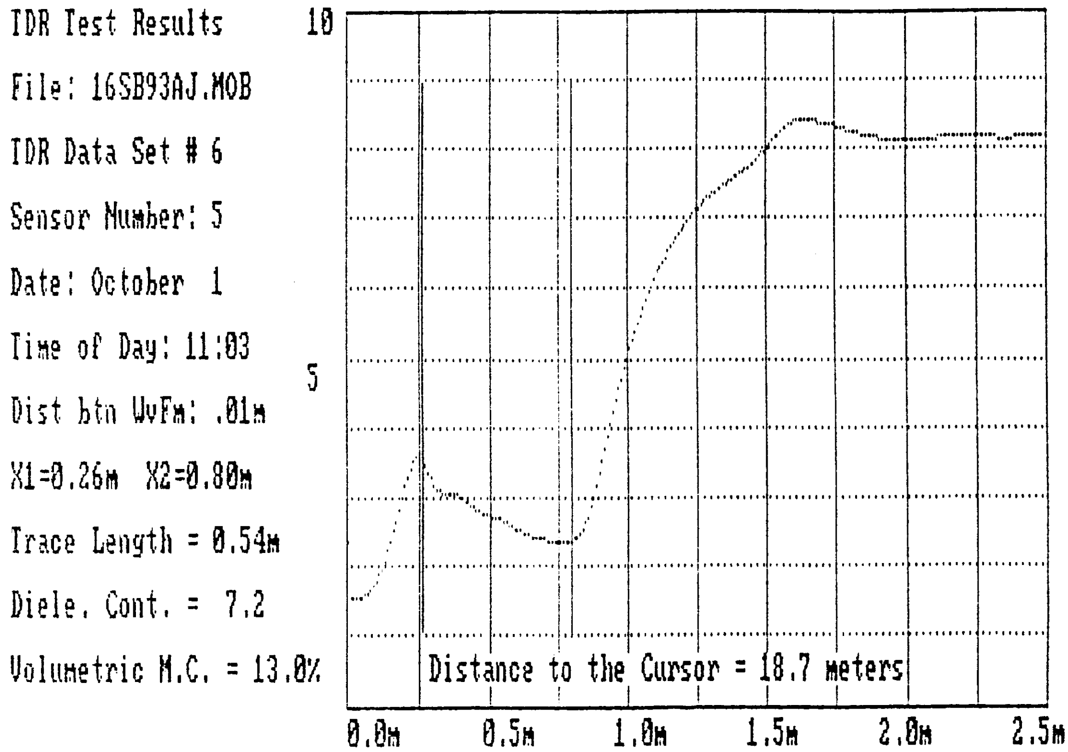


Figure D-7. Trace from TDR sensor 5.

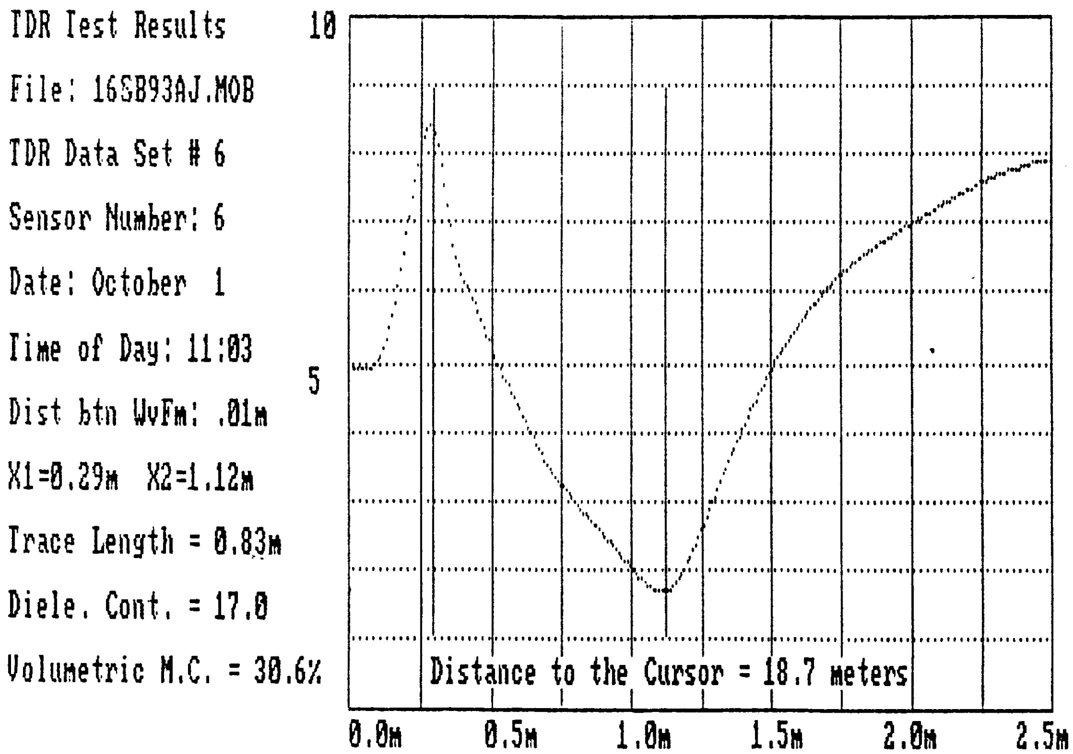


Figure D-8. Trace from TDR sensor 6.

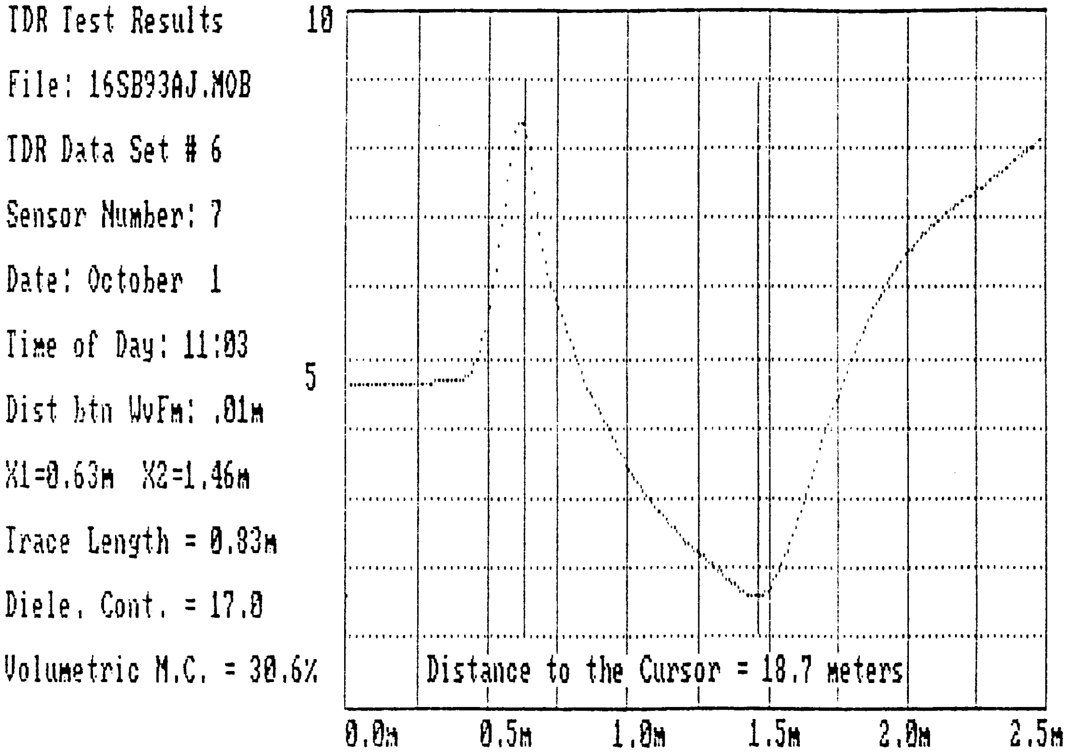


Figure D-9. Trace from TDR sensor 7.

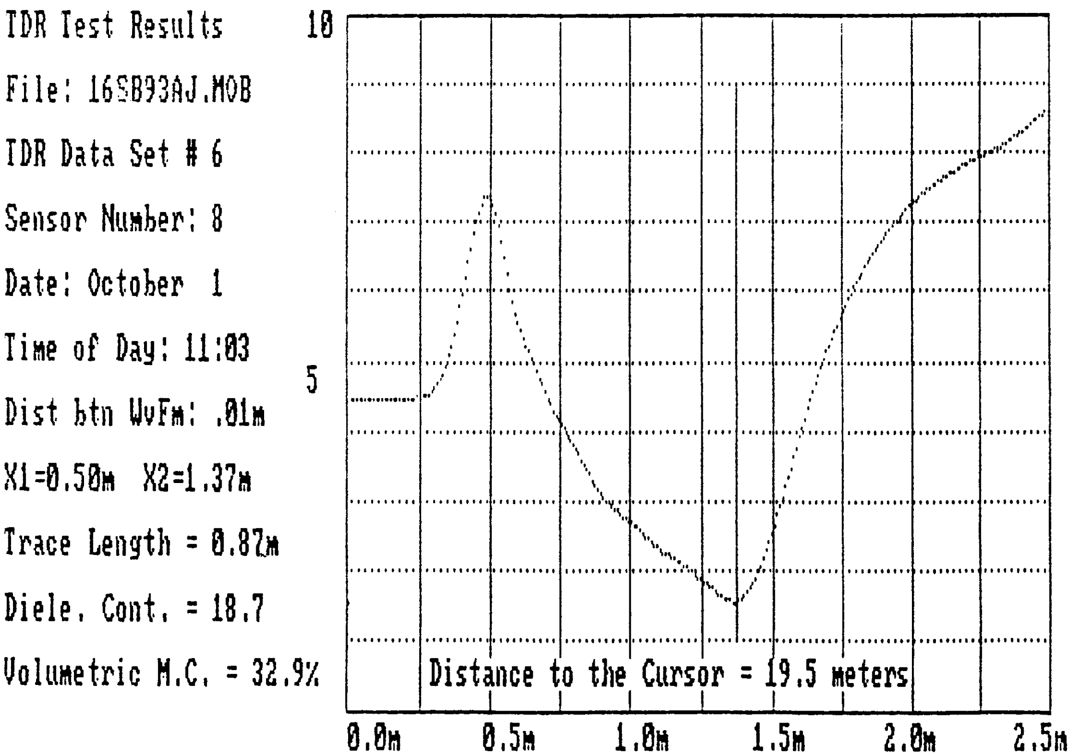


Figure D-10. Trace from TDR sensor 8.

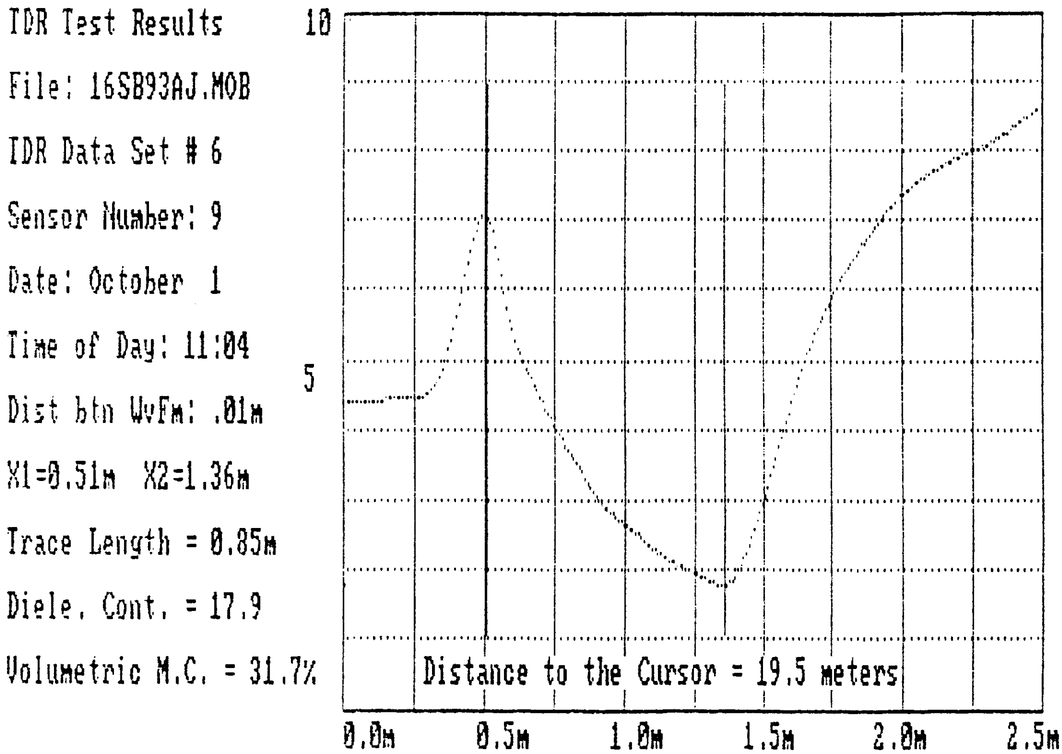


Figure D-11. Trace from TDR sensor 9.

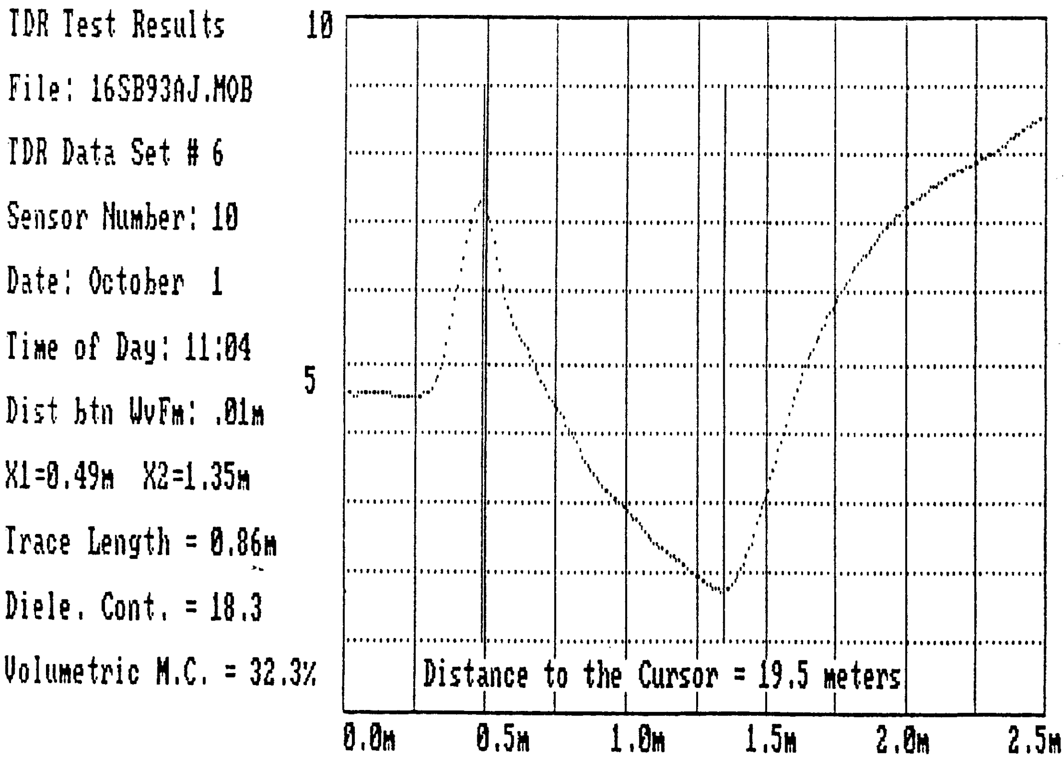


Figure D-12. Trace from TDR sensor 10.

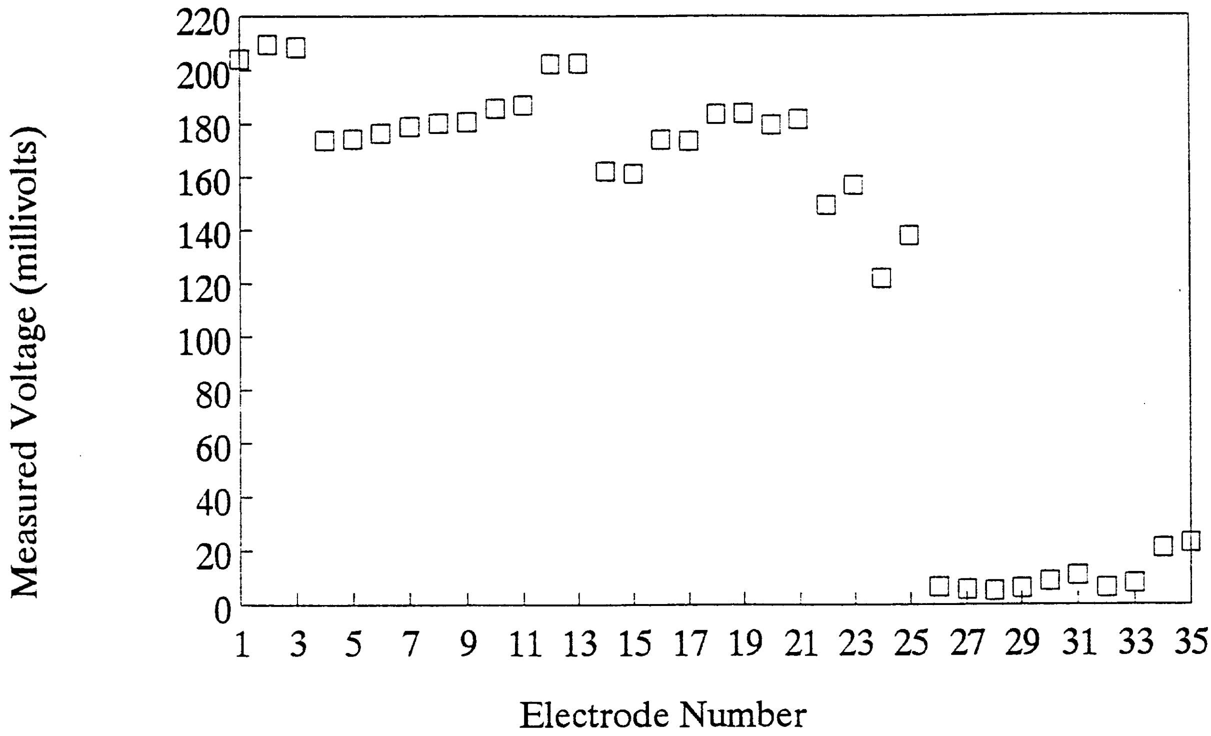


Figure D-13. Measured voltage output vs. electrode number.

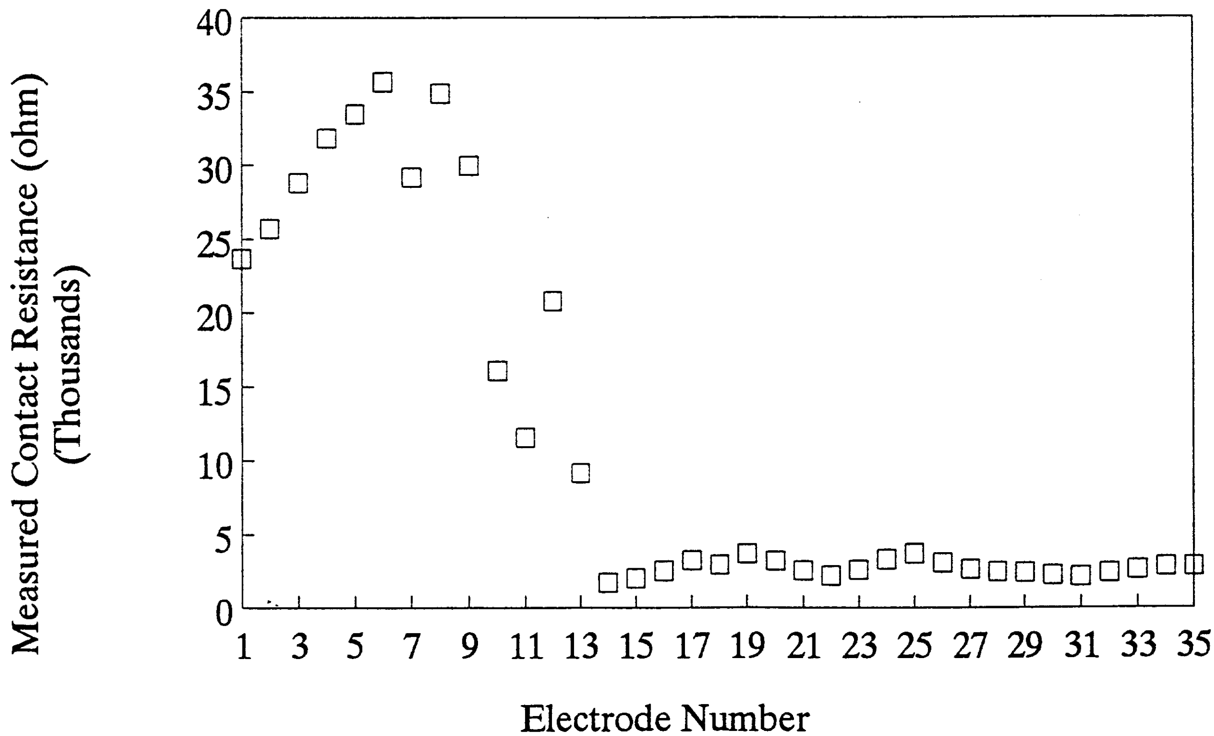


Figure D-14. Manually measured contact resistance vs. electrode number.

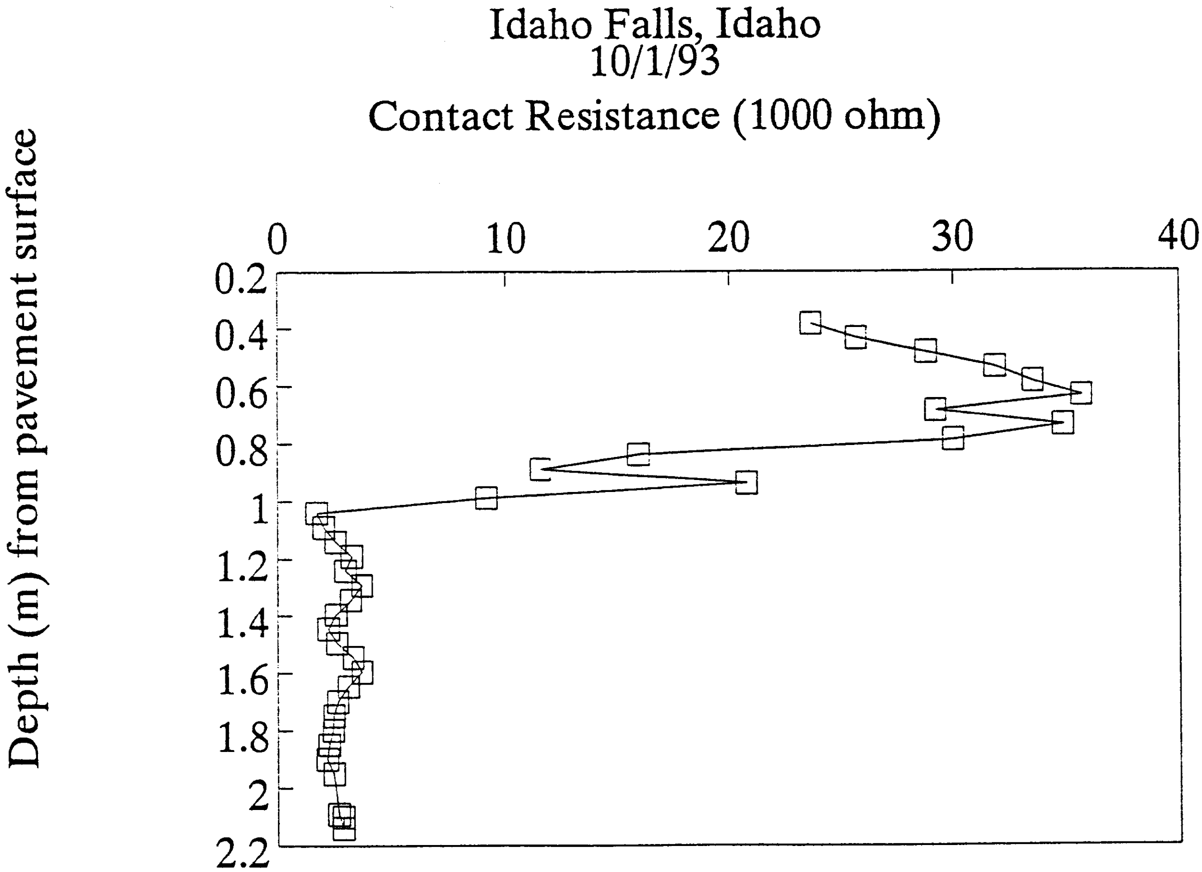


Figure D-15. Manually collected contact resistance.

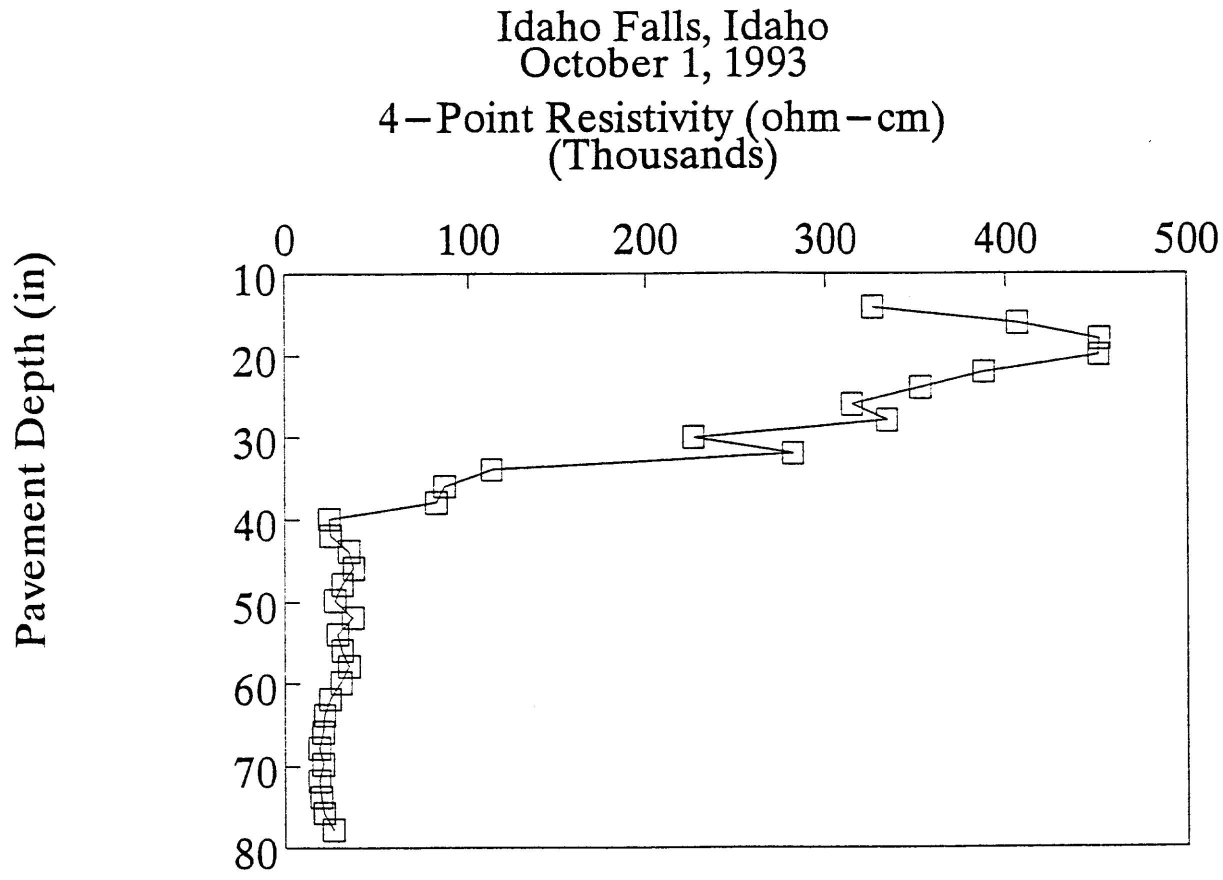


Figure D-16. Manually collected 4-point resistivity.

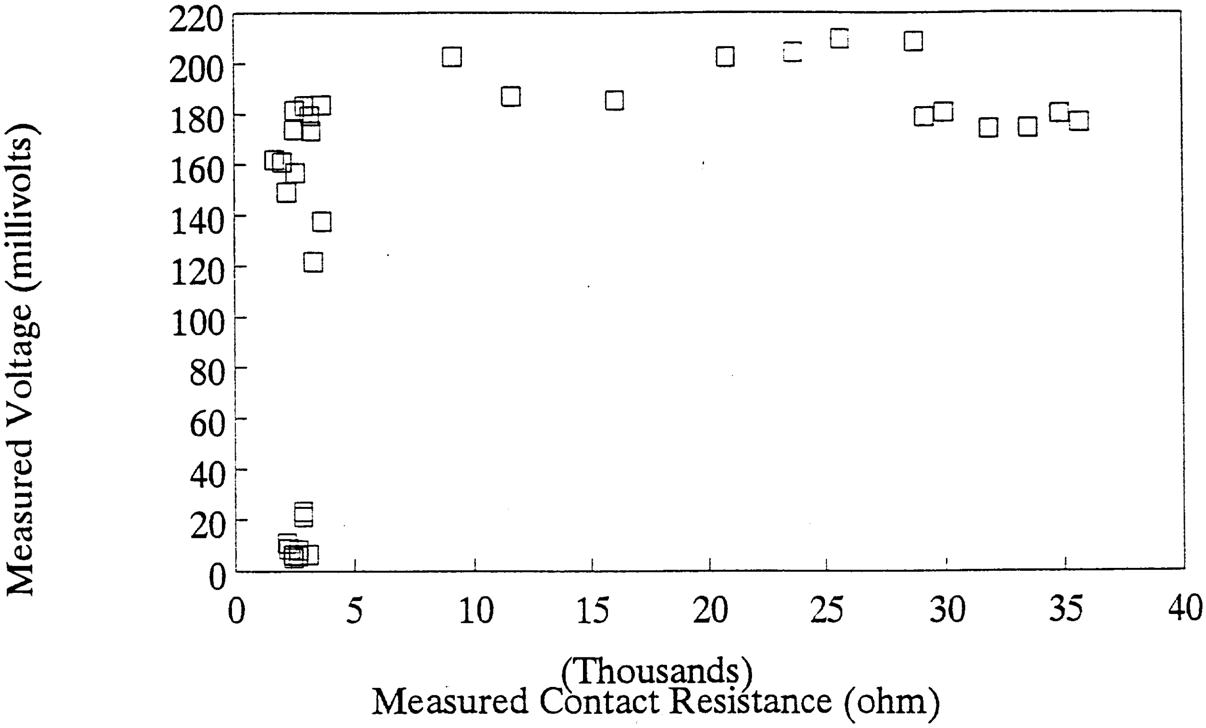


Figure D-17. Comparison between voltage output vs. measured contact resistance.

Table D-2 Contact Resistance Measurement Data Sheet

Seasonal Monitoring Program Guidelines: Version 1.1/June 1993

LTPP Seasonal Monitoring Study Data Sheet R1 Contact Resistance Measurements	* State Code [16] * Test Section Number [1010]

1. Date (Month - Day - Year) [10-01-93]

2. Time Measurements Began (Military) [09:41]

3. Comments ____________________

Test Position	Connections		Voltage (ACV)		Current (ACA)		Notes
	I_1 V_1	I_2 V_2	Range Setting	Reading	Range Setting	Reading	
1	1	2	20	9.09	2m	[illegible]	
2	3	2	20	9.10	2m	0.354	
3	3	4	20	9.42	2m	0.327	
4	5	4	20	9.43	2m	0.296	
5	5	6	20	9.52	2m	0.284	
6	7	6	20	9.53	2m	0.267	
7	7	8	20	9.23	2m	0.316	
8	9	8	20	9.24	2m	0.265	
9	9	10	20	9.00	2m	0.300	
10	11	10	20	7.72	2m	0.481	
11	11	12	20	7.84	2m	0.676	
12	13	12	20	7.88	2m	0.379	
13	13	14	20	4.85	2m	0.530	
14	15	14	20	4.44	20m	2.63	
15	15	16	20	4.61	20m	2.31	
16	17	16	20	4.63	20m	1.85	
17	17	18	20	5.05	20m	1.57	
18	19	18	20	5.02	20m	1.71	
19	19	20	20	5.42	20m	1.48	
20	21	20	20	5.42	20m	1.71	
21	21	22	20	4.46	20m	1.77	
22	23	22	20	4.40	20m	2.02	
23	23	24	20	4.80	20m	1.87	
24	25	24	20	4.80	20m	1.46	
25	25	26	20	4.81	20m	1.31	
26	27	26	20	4.80	20m	1.57	
27	27	28	20	3.92	20m	1.51	
28	29	28	20	3.91	20m	1.61	
29	29	30	20	3.91	20m	1.63	
30	31	30	20	3.88	20m	1.76	
31	31	32	20	3.86	20m	1.80	
32	33	32	20	3.87	20m	1.60	
33	33	34	20	4.21	20m	1.60	
34	35	34	20	4.22	20m	1.49	
35	35	36	20	4.56	20m	1.61	
36	37	38	20	11.48	200μ	16.4	1MΩ
37	38	39	20	7.07	20m	7.11	1kΩ
38	39	40	200m	19.7	20m	18.1	1Ω

Preparer Brian Barnett Employer NCE

Figure III-5 - Contact Resistant Measurements - Data Sheet R1

Table D-3 Four Point Resistivity Measurement Data Sheet

LTPP Seasonal Monitoring Study Data Sheet R2 Four-Point Resistivity Measurements	* State Code [16] * Test Section Number [1010]

1. Date (Month - Day - Year) [10-01-93]

2. Time Measurements Began (Military) [10:08]

3. Comments ____________________

Test Position	Connections				Voltage (ACV)		Current (ACA)		Notes
	I_1	V_1	V_2	I_2	Range Setting	Reading	Range Setting	Reading	
1	1	2	3	4	2	0.460	200u	87.1	
2	2	3	4	5	2	0.484	200u	78.1	
3	3	4	5	6	2	0.448	200u	59.6	
4	4	5	6	7	2	0.426	200u	63.5	
5	5	6	7	8	2	0.435	200u	68.4	
6	6	7	8	9	2	0.327	200u	60.8	
7	7	8	9	10	2	0.415	200u	81.2	
8	8	9	10	11	2	0.592	200u	114.5	
9	9	10	11	12	2	0.386	200u	108.9	
10	10	11	12	13	2	0.325	200u	71.9	
11	11	12	13	14	2	0.619	2m	0.554	
12	12	13	14	15	2	0.478	2m	0.347	
13	13	14	15	16	2	0.324	2m	0.244	
14	14	15	16	17	2	0.372	2m	1.019	
15	15	16	17	18	2	0.349	2m	0.871	
16	16	17	18	19	2	0.436	2m	0.805	
17	17	18	19	20	2	0.357	2m	0.620	
18	18	19	20	21	2	0.368	2m	0.744	
19	19	20	21	22	2	0.285	2m	0.684	
20	20	21	22	23	2	0.370	2m	0.636	
21	21	22	23	24	2	0.331	2m	0.741	
22	22	23	24	25	2	0.344	2m	0.708	
23	23	24	25	26	2	0.366	2m	0.658	
24	24	25	26	27	2	0.275	2m	0.598	
25	25	26	27	28	2	0.204	2m	0.517	
26	26	27	28	29	2	0.199	2m	0.599	
27	27	28	29	30	2	0.219	2m	0.698	
28	28	29	30	31	2	0.226	2m	0.747	
29	29	30	31	32	2	0.234	2m	0.736	
30	30	31	32	33	2	0.206	2m	0.731	
31	31	32	33	34	2	0.232	2m	0.727	
32	32	33	34	35	2	0.232	2m	0.727	
33	33	34	35	36	2	0.285	2m	0.696	

Preparer Brian Barnett Employer NCE

Figure III-6 - Four-Point Resistivity Measurements - Data Sheet R2

Table D-4 Surface Elevation Measurement Data Sheet

LTPP Seasonal Monitoring Study Surface Elevation Measurements	* State Code [16] * Test Section Number [1010]

Surveyed : Jason M. Dietz
Date : 10/1/93
Start Time : 8:30 AM
Finish Time : 10:30 AM
Surface Type : Asphalt Concrete
Weather Conditions : Cloudy 13.3°C
Unusual Conditions : None

Beginning Elevation of Frost Free Bench Mark : 1.000 meters
Ending Elevation of Frost Free Bench Mark : 1.000 meters

STATION		OLE 0.000 m	OWP 1.524 m	ML 2.438 m	IWP 3.353 m	ILE 4.267 m
0+00	3+00	1.332	1.366	1.382	1.387	1.387
0+25	3+25	1.317	1.351	1.367	1.375	1.375
0+50	3+50	1.316	1.347	1.362	1.364	1.364
0+75	3+75	1.311	1.341	1.357	1.361	1.359
1+00	4+00	1.313	1.346	1.362	1.367	1.370
1+25	4+25	1.313	1.347	1.365	1.368	1.372
1+50	4+50	1.300	1.338	1.350	1.354	1.359
1+75	4+75	1.302	1.332	1.343	1.343	1.351
2+00	5+00	1.306	1.338	1.346	1.350	1.355

OLE : Outside Lane Edge
OWP : Outer Wheel Path
ML : Mid Lane
IWP : Inner Wheel Path
ILE : Inside Lane Edge

→ Southbound Direction. I 15 North of Idaho Falls, ID

0+00 3+00 5+00

o

(Bench Mark)
Observation Well

APPENDIX E

Photographs

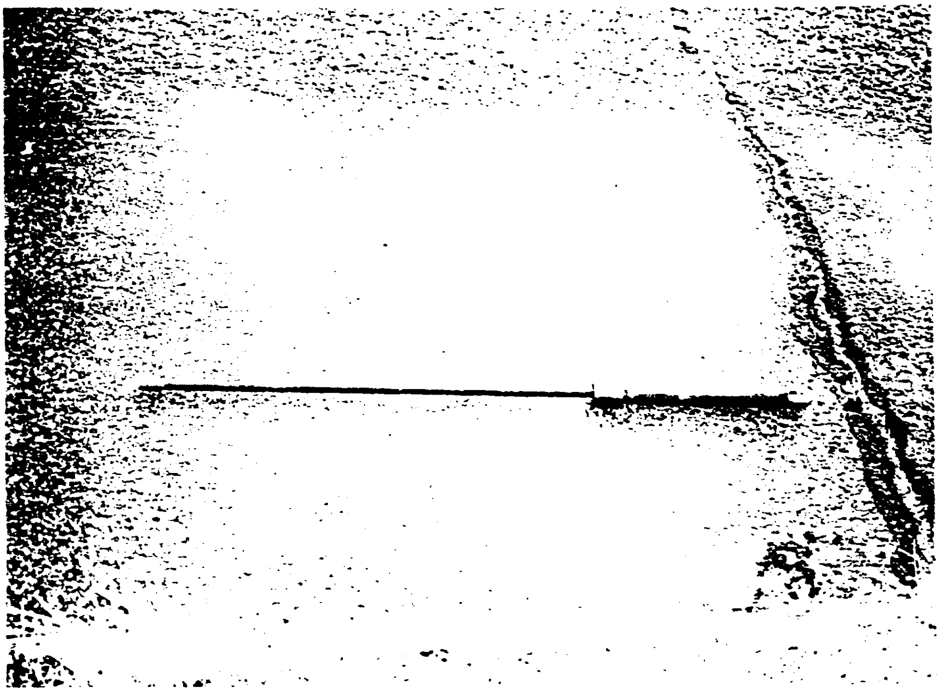


Figure E-1. Geonor anchor point used on piezometer/bench mark.

Figure E-2. Piezometer/bench mark assembly with geonor anchor point installed.

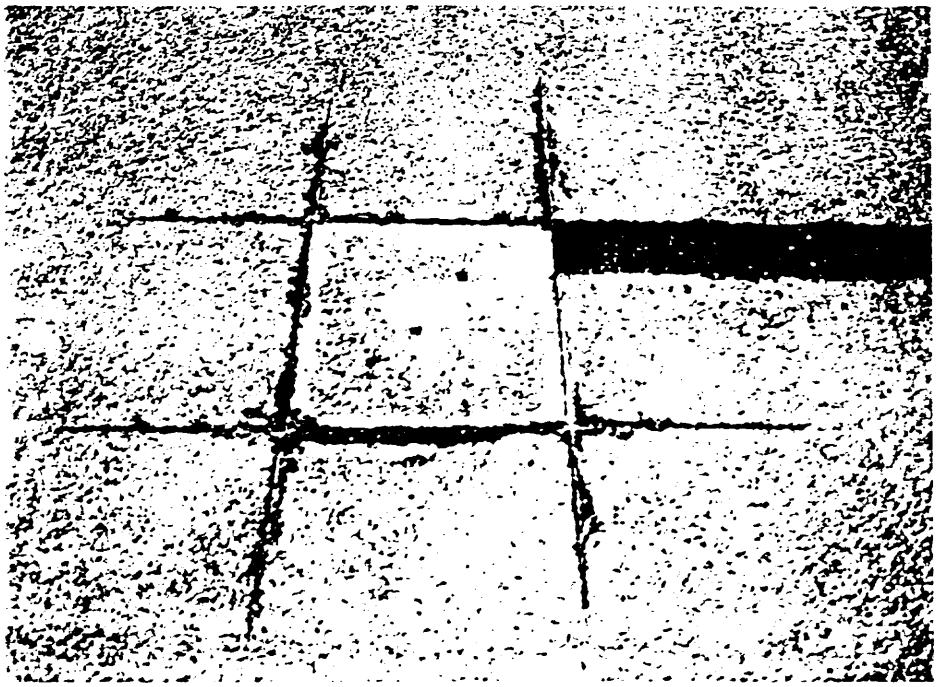


Figure E-3. Repaired instrumentation hole.

Figure E-4. Equipment cabinet and climatic sensors.