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MASSACHUSETTS

LTPP Seasonal Monitoring Program

Site Installation and Initial Data Collection
Section 251002, Chicopee
Massachusetts

Report No. FHWA-TS-94-25-01

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Notice

LTPP Seasonal Monitoring Program

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The report is a cooperative effort between Massachusetts Bureau of Transportation Planning and Development, Long Term Pavement Performance (LTPP) Division Federal Highway Administration, and Pavement Management Systems Limited LTPP North Atlantic Region Coordination Office.

16. Abstract

This report provides a description of the installation of seasonal monitoring instrumentation and initial data collection for the seasonal experimental study conducted as part of the Long Term Pavement Performance (LTPP) program at the General Pavement Study (GPS) section 251002 on I 391 in Chicopee Massachusetts. This asphalt concrete surface pavement test section was instrumented on August 31, 1993. The instrumentation installed included time domain reflectometry 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 September 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 251002 near Chicopee Massachusetts was performed on August 31 - September 1, 1993.

The test section is a GPS-1 experiment, located on northbound Interstate 391, approximately three miles north of Springfield city limits (Figure A-1 in Appendix A). The test section is located on a divided highway consisting of three 3.7m wide travel lanes in each direction with a concrete barrier in the center median. The outside shoulder is a paved 3.0m wide shoulder lipped at the edge. A catch basin exists in the shoulder just south of station 0+00 and in the median at station 5+40. A 500 volt power line exists on the east side treeline with a power transformer near station 8+00.

The site is in a fill area with a pavement structure consisting of 198mm of asphalt concrete over 102mm of crushed gravel base and 213mm of soil aggregate mixture subbase. The subgrade is classified as a coarse silty sand material. The depth to rock below road surface is more than 7.5m. Pavement structure information from the GPS material drilling logs is presented in Appendix A, Figure A-2. Properties determined from the laboratory material tests are shown in Table 1.

Table A-1 in Appendix A summarizes the distress, IRI values from the Profilometer longitudinal profile measurements, and Falling Weight Deflectometer deflection values as monitored since 1989. The uniformity survey results are summarizes in Table A-2 and the deflection values and analysis results from the FWDCHECK are also presented in Appendix A.

The site is in a wet-freeze zone and resides in cell 16 (thick AC on coarse subgrade) of the Seasonal Monitoring Program. The annual average frost depth is 0.6m and the maximum is 1.2m. Salt is frequently used for ice control at this location. Below is a summary from the LTPP climate database based on nine years of data:

Freezing Index (C-Days)	352
Precipitation (mm)	1168
No. of Freeze/Thaw Cycles	112
Days Above 32C	10
Days Below 0C	133
Wet Days	139

The road was opened in 1982. The estimated annual average daily traffic (AADT) in 1992 was 16083 (two way) of which 5.7% was truck traffic on the GPS lane. The traffic in the GPS direction carried approximately 59.2% and the GPS lane carried 24.0% of the total

AADT. The estimated annual kESALs on the GPS lane were 135 as measured by the IRD Weigh In Motion at station 5+60. These figures are based on 173 days of WIM/AVC coverage in 1992.

Installation of the instrumentation was a cooperative effort between Massachusetts Bureau of Transportation Planning and Development and Pavement Management Systems Limited (PMSL) LTPP North Atlantic Region Coordination Office staff.. The following personnel participated in the instrumentation installation:

Matthew Turo	MADOT
Michael Lonnergan	MADOT
Edmund J. Naras	MADOT
David Cole	MADOT
Don Lamontagne	MADOT
Michael J. Grabowski	MADOT
Robert Menard	MADOT
Edward Jendrysik	MADOT
Brian Haggerty	MADOT
Paul Fabian	Christman Associates
Jacob Harris	Warren George Inc.
Peter Gemeinhardt	Warren George Inc.
James McKenna	Massachusetts State Police
Brandt Henderson	Pavement Management Systems (NARO)
Perry Zabaldo	Pavement Management Systems (NARO)
Mike Zawisa	Pavement Management Systems (NARO)
Gabe Cimini	Pavement Management Systems (NARO)
Scott Comstock	Pavement Management Systems (NARO)
Bob Vogel	Pavement Management Systems (NARO)

Table 1. Material Properties

Description	Surface	Base	Subbase	Subgrade
Material (Code)	Dense Graded HMAC (01)	Crushed Gravel (304)	Soil Aggregate Mixture (308)	Sand (204)
Thickness (mm)	198	102	213	
Lab Max Dry Density (kg/m³)		2366	2093	1733
Lab Opt Moisture Content (%)		8.0	7.0	7.5
In-situ Wet Density (kg/m³) *		1999	2110	1861
In-situ Dry Density (kg/m³) *		1941	2033	1787
In-situ Moisture Content (%) *		3.0	3.8	4.0
Bulk Specific Gravity	2.43			
Max Specific Gravity	2.59			
Liquid Limit		0	0	0
Plastic Limit		0	0	0
Plasticity Index		NP	NP	NP
% Passing # 200		5.2	8.2	7.1

* Note: Test pit @ station 5+60

II. Instrumentation Installation

Site Inspection and Meeting with Highway Agency

A site inspection was done on September 15, 1992 in conjunction with the FWD uniformity survey. This review was conducted by Brandt Henderson (NARO) and Matt Turo (MADOT). The FWD uniformity survey indicated the section to be acceptable from a deflection standpoint but discussions with Matt Turo after the onsite review indicated some form of rehabilitation would occur in the 3-5 year period (1995-1997) due to the formation of fine alligator cracking over the length of the section.

From an experimental standpoint this was not the most desirable site as the section resides on a substantial fill material with catch basins and lateral drains to carry runoff from the pavement surface. A catch basin at the south end (station 0+00) would require installation of the instrumentation at the north end of the section (station 5+00). Pictures providing an overview of site conditions are presented in Appendix E.

From a state perspective, this site was more appealing in that traffic control would be available through state resources from the district maintenance facility. Additionally, the state was looking to coordinate this research effort, with similar research underway with the University of Massachusetts, to develop design parameters based on FWD deflection response.

A preliminary planning meeting was held at the Massachusetts Department of Public Works, Boston on July 20, 1993. The attendees at the meeting were

Philip Hughes	MADOT Highway Department
Matthew Turo	MADOT Pavement Management
Edmund J. Naras	MADOT Pavement Management
Dean Stratouly	MADOT Pavement Management
Ron West	MADOT Chief Engineer's Office
Leo Stevens	MADOT Research and Materials
Brian Haggerty	MADOT Research and Materials
Bill Highter	University of Massachusetts
Scott Michalak	University of Massachusetts
Bob Leet	University of Massachusetts
David Powell	Christman Associates
Bill Phang	Pavement Management Systems (NARO)
Brandt Henderson	Pavement Management Systems (NARO)

A presentation on the installation of seasonal monitoring instrumentation and monitoring requirements were provided by Bill Phang and Brandt Henderson of Pavement Management Systems. This was followed by a review and discussion on the potential seasonal site near Chicopee and if there were any potential alternatives to this site within the state. The state officials strongly endorsed the site for the reason previously mentioned. Plans for the installation on August 31 and September 1, 1993 were discussed; which covered tasks to be done by state resources and material requirements. Correspondence from the site inspection and planning meeting are in Appendix B.

A pre-installation meeting was held on August 30, 1993 at the district maintenance yard in the town of Northampton. Plans for the following day were discussed along with a verification check of the equipment to be used for coring the asphalt layer, augering the instrumentation hole, cutting the trench to the instrument cabinet and the various supplies necessary to complete the installation and patch the pavement. The only problem appeared to be with the saw provided by Christman Associates which was only capable of a 100mm depth cut. Efforts to acquire a larger blade were unsuccessful, with the alternative option being the use of an air powered jack hammer to remove the remaining 100mm of asphalt to the granular layer.

Equipment Installed

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

Table 2. Equipment Installed

Equipment	Quantity	Serial Number
Instrumentation Hole		
MRC Thermistor Probe	1	25AT
CRREL Resistivity Probe	1	25AR
TDR Probes	10	25A01-25A10
Equipment Cabinet		
Campbell Scientific CR10 Datalogger	1	16561
Campbell Scientific PS12 Power Supply	1	5619
Weather Station		
TE525MM Tipping Bucket Rain Gage	1	12086-693
Campbell Scientific 107-L Air Temperature Probe	1	25AAT
Observation Well/Bench Mark	1	none

Equipment Check/Calibration

Prior to installation, each measurement instrument was checked or calibrated. The tipping bucket rain gauge was connected to the CR10 datalogger for calibration. A plastic container with 473ml of water was placed in the tipping bucket. The container had a small hole in the bottom, which allowed all the water to be drained out in 45 minutes. For the 473ml of water, the tipping bucket should measure 100 tips ± 3 tips. The results showed 99 tips, which was in specification.

The air temperature and thermistor probes were connected to the CR10 datalogger simultaneously. They were checked by placing the probes in ice, room temperature, and boiling water. In order for the probes to pass this check, the temperatures for each probe should correspond to the water temperature. The check indicated that the air temperature and thermistor probes were working properly. A second check was done where the air temperature and thermistor probes were connected to the datalogger and run, in air, for 24 hours. The minimum, maximum, and mean temperature for each sensor were checked. All 18 thermistors were similar in their minimum, maximum, and mean readings respectfully, therefore the probes were considered functioning correctly. The results of the air temperature and thermistor probes along with the spacing between the thermistors are presented in Appendix B.

The wiring of the resistivity probe was checked using continuity measurements between each electrode and the corresponding pins on the connector. The distance between each electrode was measured and recorded as shown in Table B-4 in Appendix B. Contact resistance measurements were performed with the probe immersed in a salt water bath. The results of these measurements are also shown in Appendix B. Due to defects in the manufacturing, clear silicon sealant was used to cover exposed wires to the electrodes. The checks on the resistivity probe indicated all electrodes were functioning properly.

The functioning of the TDR probes were checked by performing measurements in air, water, methyl alcohol, and with the prongs shorted at the circuit board and the end of the probe. The traces were taken and the dielectric constant was calculated for the water, air, and methyl alcohol. These values were checked against expected dielectric constants for each medium. The test indicated that all probes were functioning properly. Results of the TDR measurements are presented in Appendix B.

Equipment Installation

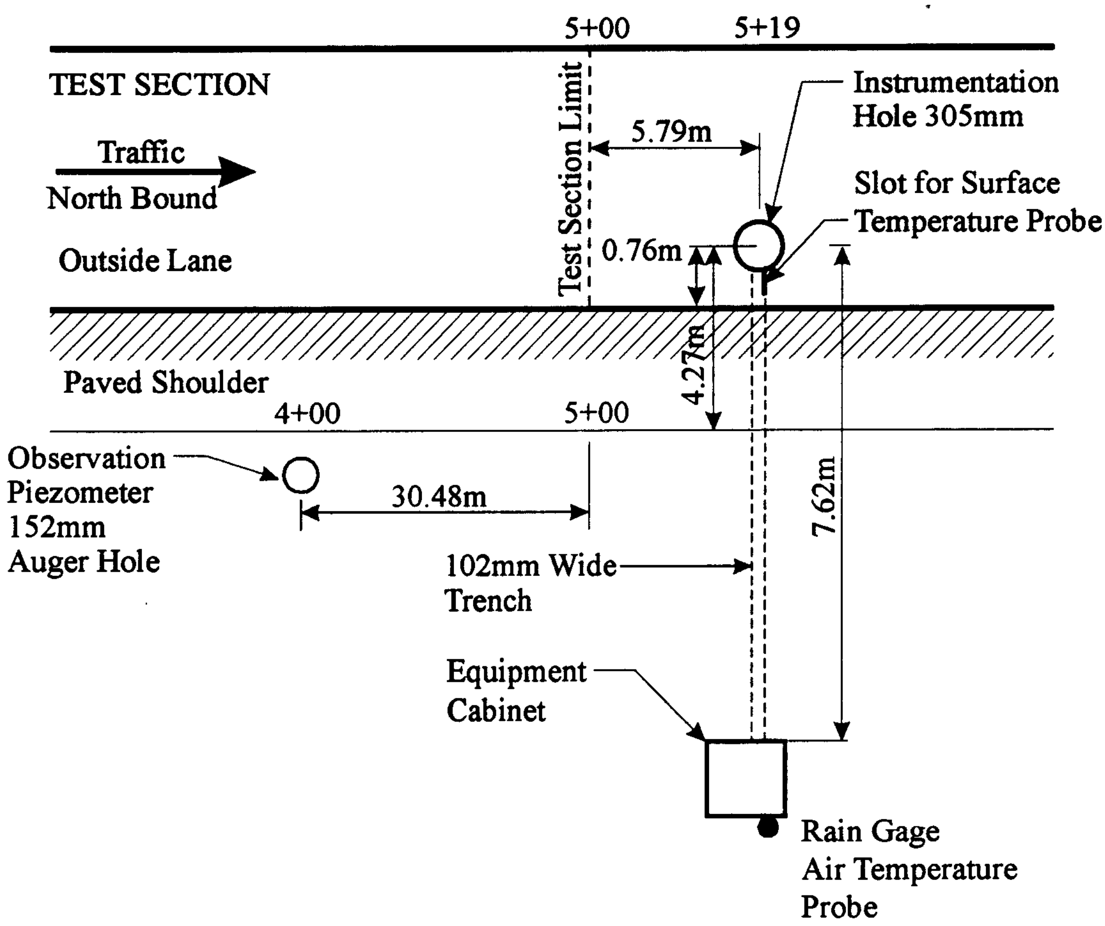
Final details for the installation and initial monitoring were discussed in a meeting on the afternoon of August 30, 1993. The installation was confirmed for 8:00 a.m. on August 31, 1993. Traffic control for the installation and monitoring was provided by the MADOT district office, Northampton. An off-duty state trooper (August 31) and Game Warden (September 1) provided additional traffic security. The pavement surface drilling and sawing were done by Christman Associates. The augering of the piezometer and instrumentation hole was done by Warren George Inc. of NJ under the supervision of Brian Haggerty, MADOT drilling supervisor. The installation of the measurement equipment, the observation piezometer, weather station pole, and cabinet was performed by PMSL staff. Assistance was provided by Matt Turo and Edmund Naras from the MADOT pavement management group and the local district personnel.

The instrumentation was installed on the north end of GPS 251002, in the outside lane of I-391 near Chicopee, Massachusetts. The combination benchmark/piezometer was placed in the shoulder at station 4+00. The in-pavement instrumentation was installed in the outer wheel path at station 5+19. The cabling from the instrumentation was placed in a 51mm flexible conduit and buried in a trench running from the instrument hole to an equipment cabinet installed on the slope of the roadway embankment, 7.62m from the instrumentation hole. The weather pole was installed immediately behind the equipment cabinet. Figure 1 provides the location and distances for the various instrumentation and equipment installed.

The installation generally followed the procedures described in the "LTPP Seasonal Monitoring Program: Instrumentation Installation and Data Collection Guidelines". The combination piezometer/benchmark was installed just off the edge of the paved shoulder to a depth of 4.48m. A 152mm flight auger was used for drilling the hole. A sample of the material was retained from approximately .5 to 1.5m below the surface. The hole was slightly over bored due to material collapsing into the hole. The 25.4mm galvanized pipe was firmly pressed into the hole, followed by .75m of filter sand, a .35m bentonite plug with the remainder of the hole filled with the native material removed. The final elevation for the pipe was 184mm below the natural ground level at the location of the installation. A Coleman gate box, held in location by approximately 25kg of concrete mix, was used to cover and protect the piezometer/benchmark.

A core hole was drilled in the pavement surface, located in the outside wheel path, 0.76m from the edge of the travel lane at station 5+19, using a portable electric drill and a 305mm thin wall diamond core barrel. A 102mm wide by 102mm deep saw cut was done between the core hole and the edge of the pavement, using a gas powered hand operated saw, to accommodate the instrumentation cabling. The remaining 91mm depth of asphalt and curb was removed with an air powered jack hammer. This added approximately two hours to the installation as this was a slow tedious strenuous task, especially on a hot muggy day.

A combination of methods were used to excavate the instrumentation hole. The crushed granular base was scooped out with a hand shovel. The driller used a 250mm hollow stem auger with the plug removed to loosen the base material, which again was removed by hand. The fill material below the subbase material was a very clean light brown dry sand which could not be removed with the power auger. A hand operated post hole digger was used to excavate the hole to a depth of 1.37m below the surface. The firmer darker brown sand with silt and stone encountered at this level was removed with the auger to a depth of 2.05m. The findings from the excavation of the instrumentation hole at station 5+19 are presented in Figure 2. All the material excavated from the instrument hole was placed and compacted in order of removal. No additional material was required or remained from the instrumentation hole. The equipment cabinet and pole for the rain gage and air temperature probe were installed as per manual guidelines. The excavation of the trench, aside from the need to jack hammer out the bottom 91mm of asphalt, went fairly smooth as the material was a generally clean sand without cobbles or boulders. The wiring of the instrumentation to the equipment cabinet was completed on the same day as installed.



- Height of Air Temperature Probe (center): 3.07m
- Height of Tipping Bucket Rain Gage (center): 3.00m
- Total Depth of Piezometer: 4.29m
- Distance of Piezometer Below Ground Level: 184mm

Figure 1. Location for Seasonal Monitoring Instrumentation Installed at GPS 251002

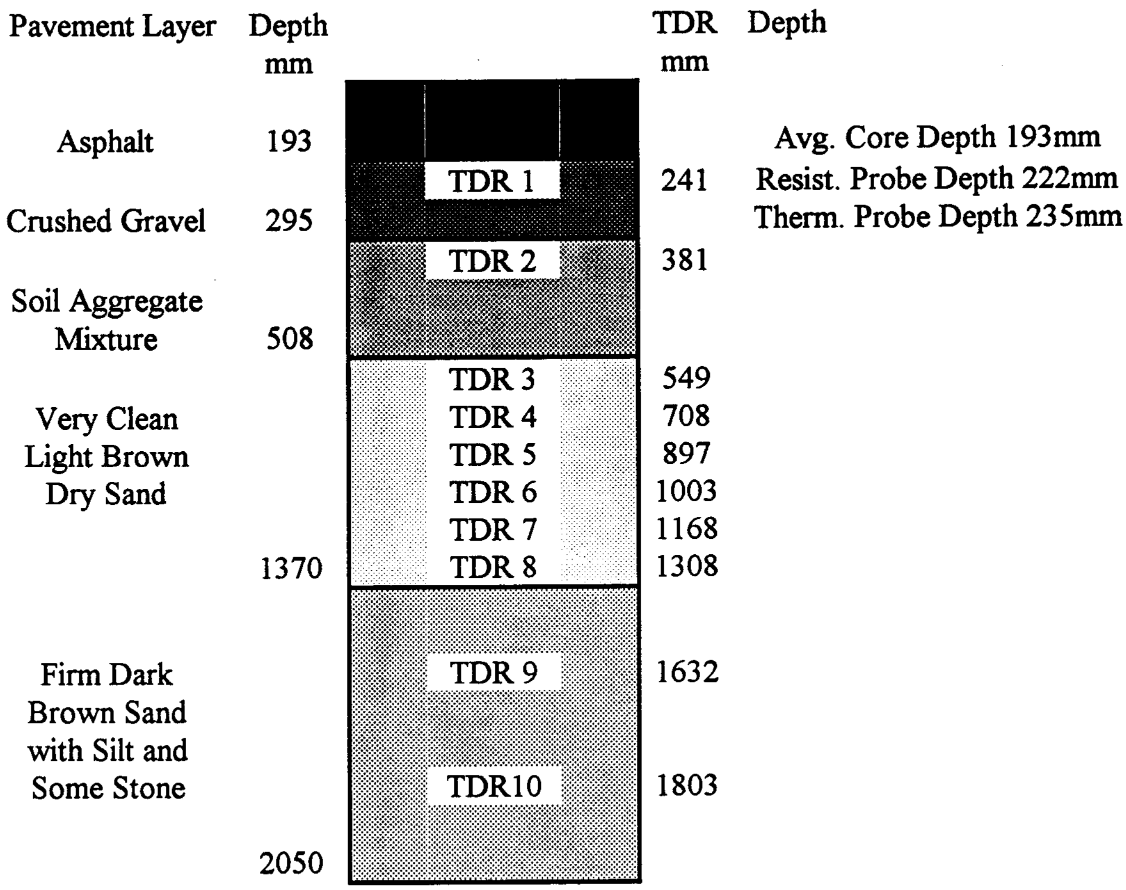


Figure 2. Profile of Pavement Structure and Probe Depths from Surface, Station 5+19

To check for breakage of the TDR probes during installation, each probe was connected to the cable tester and its wave form monitored during compaction of the material around it. The TDR traces are included in Appendix C. By alternating the TDR probes within the instrument hole we were able to keep the cables separate to avoid water from migrating along a bundle of cables attached to the probes placed at various depths. The thermistor and resistivity probes were installed at opposite sides of the instrumentation hole with the thermistor probe .235m and the resistivity probe .222m below the pavement surface. The cables were kept spaced as best as possible until they converged at the opening of the flexible conduit pipe, placed about 50mm from the edge of the core hole. The cables were then tie wrapped and passed through the conduit to the equipment cabinet. The ends of the conduit were plugged with a mastic pipe sealant.

Tables 3, 4, and 5 present the installed depths of the TDR probes, thermistor sensors, and the resistivity probe respectively. Table 6 gives TDR moisture content and field measured moisture content during installation. Moisture samples were also taken to Christman Associates Laboratories in Connecticut for laboratory moisture content but the results were never received.

Table 3. Installed Depths of TDR Sensors

Sensor #	Depth from Pavement Surface (m)	Layer
25A01	0.241	Base
25A02	0.381	Subbase
25A03	0.549	Subgrade
25A04	0.708	
25A05	0.897	
25A06	1.003	
25A07	1.168	
25A08	1.308	
25A09	1.632	
25A10	1.803	

Table 4. Installed Location of MRC Thermistor Sensor

Unit	Channel Number	Depth from Pavement Surface (m)	Remarks
1	1	0.025	This unit was installed in the AC layer.
	2	0.097	
	3	0.168	
2	4	0.257	This unit was installed below the AC layer into the subgrade.
	5	0.332	
	6	0.408	
	7	0.484	
	8	0.560	
	9	0.713	
	10	0.865	
	11	1.019	
	12	1.170	
	13	1.324	
	14	1.476	
	15	1.627	
	16	1.781	
	17	1.934	
	18	2.083	

Table 5. Location of Electrodes of the Resistivity Probe

Connector Pin Number	Electrode Number	Depth from Pavement Surface (m)
36	1	0.252
35	2	0.303
34	3	0.354
33	4	0.404
32	5	0.456
31	6	0.506
30	7	0.559
29	8	0.610
28	9	0.661
27	10	0.713
26	11	0.763
25	12	0.815
24	13	0.867
23	14	0.918
22	15	0.969
21	16	1.020
20	17	1.071
19	18	1.123
18	19	1.173
17	20	1.225
16	21	1.277
15	22	1.328
14	23	1.379
13	24	1.430
12	25	1.481
11	26	1.533
10	27	1.582
9	28	1.634
8	29	1.686
7	30	1.736
6	31	1.788
5	32	1.838
4	33	1.890
3	34	1.941
2	35	1.993
1	36	2.043

Table 6. TDR, Field, and Laboratory Moisture Content During Installation

Sensor Number	Sensor Depth (m)	Layer	TDR Moisture Content (by wt)*	Field Moisture Content (by wt)*	Lab Moisture Content (by wt)**
25A01	0.241	Base	4.16%	2.75%	
25A02	0.381	Subbase	3.97%	2.39%	
25A03	0.549	Subgrade	2.24%	2.27%	
25A04	0.708		2.78%	2.26%	
25A05	0.897		3.62%	3.06%	
25A06	1.003		3.62%	2.82%	
25A07	1.168		5.11%	3.85%	
25A08	1.308		4.21%	4.55%	
25A09	1.632		4.50%	4.95%	
25A10	1.803		4.21%	3.87%	

* Note: Raw data given in Appendix C

** Note: Moisture samples delivered to Lab but results never received

Site Repair and Cleanup

The instrumentation hole was repaired by reinstalling the 305mm asphalt core. Some juggling was required to get the core level with the existing pavement surface. Once the core was leveled it was removed from the hole and the bottom 100mm was heavily covered with a two part epoxy (PC-7) and reset into the hole forcing the epoxy against the side and up along the wall of the core hole. The weight of the state dump truck, which slowly moved back and forth over the core, was used to firmly seat the core into the hole.

The trench for the cabling from the instrumentation hole to the edge of pavement was leveled with crushed gravel to the existing bottom of the paved layer and a cold mix was compacted to the level of the existing surface. The remainder of the trench was filled with a combination of gravel and native material and compacted, followed by a cleanup of loose material from paved area. Traffic control was removed at 6:30 p.m. and the lane reopened to traffic. During the next day the instrument hole and edge of the trench were sealed using Corning self-leveling 888 crack sealing compound. Removal of the asphalt trench material and other disposable items were handled by the MADOT district.

Patch/Repair Area Assessment

When the site was visited on November 16 and December 23, 1993, two to three months after installation, the instrumentation hole patch was checked and photos were taken as shown in Appendix E. The pavement core was slightly below the existing pavement, as observed on day 2 of the installation and some settlement had taken place along the trench leading from the instrument hole to the edge of pavement. Additionally, the sealant failed to bond to the existing pavement and core.

III. Initial Data Collection

The second day activities included initial data collection on the site and checks on functioning of installed equipment. This consisted of examination of the data collected over the day by the onsite datalogger, data collection and check of the mobile CR10 datalogger, deflection testing, and elevation survey.

Air Temperature, Subsurface Temperature, Rain-fall Data

The air temperature, pavement subsurface temperature profile, and rainfall data, collected on September 1 by the CR10 datalogger, were examined. The equipment and datalogger appeared to be functioning properly. The battery voltages were checked and found to be acceptable. Raw data collected at the site are presented in Appendix D.

Figure D-1 shows the air temperature data collected from 16:18 (September 1) through 16:28 (September 1). Figure D-2 shows the first set of subsurface temperature for the first 5 sensors. Figure D-3 shows the first set of subsurface temperature for all 18 sensors. There was no precipitation that day. All these results indicated that the onsite CR10 datalogger and measurement equipment were working. Only 10 minutes of data were taken to check for the functioning of the sensors, not to be used at a later time.

The tipping bucket rain gauge was checked by determining the number of tips recorded from 473ml of water discharged into the gauge over a one hour time period. The rain gauge was found to be operating properly.

TDR Measurements

TDR data were collected using the mobile system provided by FHWA. The mobile system contains a CR10 datalogger, battery pack, two TDR multiplexers, and a resistance multiplexer circuit board. Version 1.0 of the MOBILE program was used to collect and record the TDR wave form traced for each sensor.

Figure D-4 shows the initial set of TDR wave form traces collected with the MOBILE data acquisition system for all 10 sensors. The figure indicates that the multiplexers of the mobile system and TDR sensors were working properly.

Resistance Measurement Data

Resistance data were collected in two modes, automated and manual. 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-5 shows pavement depth versus measured voltage produced by the MOBILE system. The data indicates the resistance multiplexer of the mobile system was functioning properly.

Manual contact resistance and resistivity measurements were performed using a Simpson Model 420d function generator, a Fluke and a Hewlett Packard digital multimeter and a manual circuit board. The measured contact resistance data are plotted in Figure D-6 and in Figure D-7 for the 4-point resistivity. Tables D-2 and D-3 in Appendix D show the raw data for the 2-point contact resistance and the 4-point resistance respectively.

Comparison between Figure D-5 (contact resistance results from automated mode) and Figure D-6 (contact resistance results from manual mode) indicates that the automated mode was functioning properly. Figure D-7 (4-point resistance results from manual mode) shows that the 4-point test setup was not working correctly. This was probably due to problem with the test circuit board or the multimeters.

Deflection Measurement Data

Deflection measurements followed procedures described in the "LTPP Seasonal Monitoring Program: Instrumentation Installation and Data Collection Guidelines". The analysis results from the FWDCHECK program from the day of installation and the following day are presented in Appendix D. Since then, eight more measurements have been collected with the FWD, the first on November 16, 1993, the second on December 23, 1993, the third on February 16, 1994, the fourth on March 9, 1994, the fifth on March 29, 1994, the sixth on April 20, 1994, the seventh on May 11, 1994, and the eighth on June 8, 1994.

Longitudinal Profile Data

According to the guidelines, since this is in a frost area, the survey should be performed on five different occasions; one survey during the middle of each season and one survey during the late winter period (fully frozen condition). Three surveys have already been performed on this site, the first in the winter season (January 20, 1994), the second during the fully frozen condition (February 22, 1994), and the third in the spring season (April 15, 1994).

Elevation Surveys

One set of the surface elevation survey was performed following the guidelines. It was assumed that the elevation at the top of the piezometer pipe was 1.000 meters. The survey was conducted on September 1, 1993 and the results are presented in Appendix D. Since then, two more sets of the surface elevation surveys have been performed, the first on February 16, 1994 and the second on April 20, 1994.

Water Depth

A check of the piezometer indicated that there was no water present. This was expected as the piezometer at a depth of 4.5m would reside within the fill material, approximately 3m above existing gound level.

IV. Summary

The installation of the seasonal monitoring instrumentation at the GPS site 251002 near Chicopee, MA was completed on August 31, 1993. A check of the equipment and initial data collection was completed on September 1, 1993. The instrumentation, permanently installed at the site, were:

- Time domain reflectometer probes for moisture measurements
- Electric resistivity probes for frost location
- Thermistor probes for soil gradient temperature measurements
- Air temperature thermistor probe and tipping bucket rain gage to record local climatic conditions, and
- Combination piezometer (well) and bench mark to determine changes in water level and pavement elevations.

The pavement gradient temperature and local climatic data are to have continuous data collection stored in an on-site datalogger. The moisture and electrical resistivity are to be collected during each site visit (14 times per year) using a mobile datalogger system. The water level and elevation data are to be collected manually during site visits.

The test section is on northbound Interstate 391, in Chicopee, MA. The section is on a divided highway consisting of three 3.7m wide travel lanes in each direction with a concrete barrier in the center median. This roadway mainly functions as a commuter route and is busiest in the early morning and late afternoon. The pavement structure consists of 193mm of asphalt concrete over 102mm of crushed gravel base and 213mm of soil aggregate mixture. This resides on a sandy fill material with the initial 850mm of material being a very light colored fine sand with silt over a medium brown sand containing silt and some stones. The embankment slopes to existing ground at about 7.5m below grade.

All instrumentation was checked prior to installation at the PMSL facility in Amherst, NY. These initial checks indicated that the instrumentation was within specifications, as required for the seasonal monitoring program. Operational checks during installation and the following day indicated that all instrumentation was functioning properly. The manual resistivity checks did not provide expected results; this could be due to a number of factors. The switching box was a proto type for which we were experiencing some switching problems, and the Hewlett Packard multimeter was questionable when set to read amperage. Improvements in equipment and procedures are required to ensure reliable results for this test.

Although the installation generally went as expected and all instrumentation was in working order at the completion, a few problems were encountered with the excavation of the trench, removal of material from instrumentation hole, and replacement of the asphalt core. The installation was delayed due to the additional time required to jack hammer 90mm of asphalt material from the 100mm wide trench from the instrumentation hole to the edge of the paved shoulder. This added an additional two hours to the expected time requirement for this activity extending the work day to 18:30. The 250mm hollow stem auger would not retain the dry sandy material encountered below the aggregate base/subbase material. It was necessary to remove this material to a depth 1.37m with a hand held post hole digger provided by the local district maintenance facility. The auger was used to move the hole to the required depth, but the progress was slow as the material became stiffer with depth; and the plug was removed from the barrel to ensure controlled removal of material.

The asphalt core when replaced was leveled to the existing pavement. When examined the following day, the core had slightly settled into the hole, probably due to compaction of the core by traffic action. We had purposely used a slow setting epoxy to allow for a little movement, but underestimated the amount of settlement. For future installation, the core should initially be set slightly above the existing surface (3-6mm) to allow for further compaction and settlement by traffic, especially for high volume facilities.

The ongoing monitoring of this section, except for the problems encountered due to weather and technical difficulties with the FWD, has gone fairly well. The state FWD, operated by the University of Massachusetts, has visited the site on a number of occasions in conjunction with the FHWA-LTPP FWD to collect data for comparison/evaluation purposes.

APPENDIX A

Test Section Background Information

Appendix A contains the following supporting information:

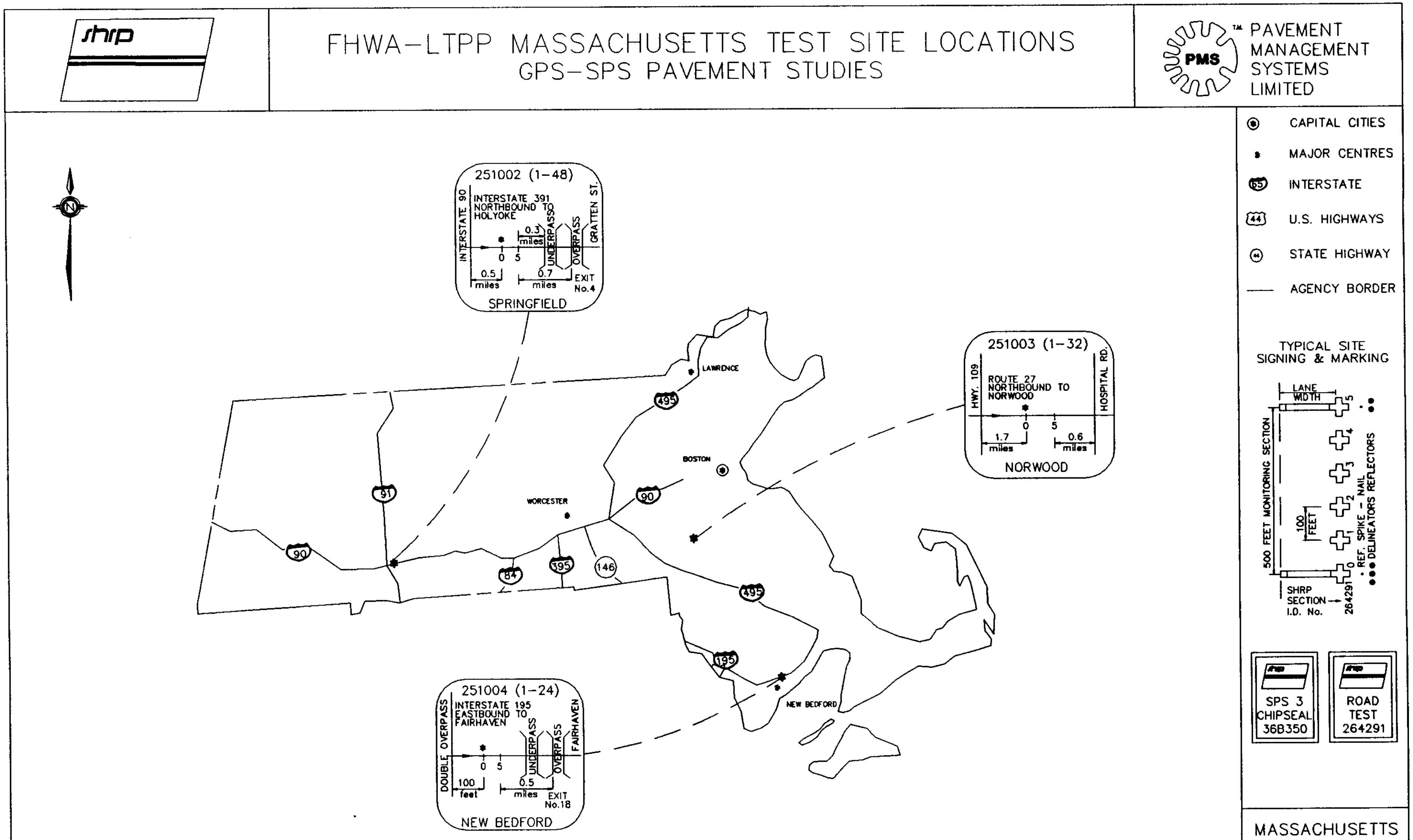


FIGURE A-1 SITE LOCATION MAP - SECTION 251002

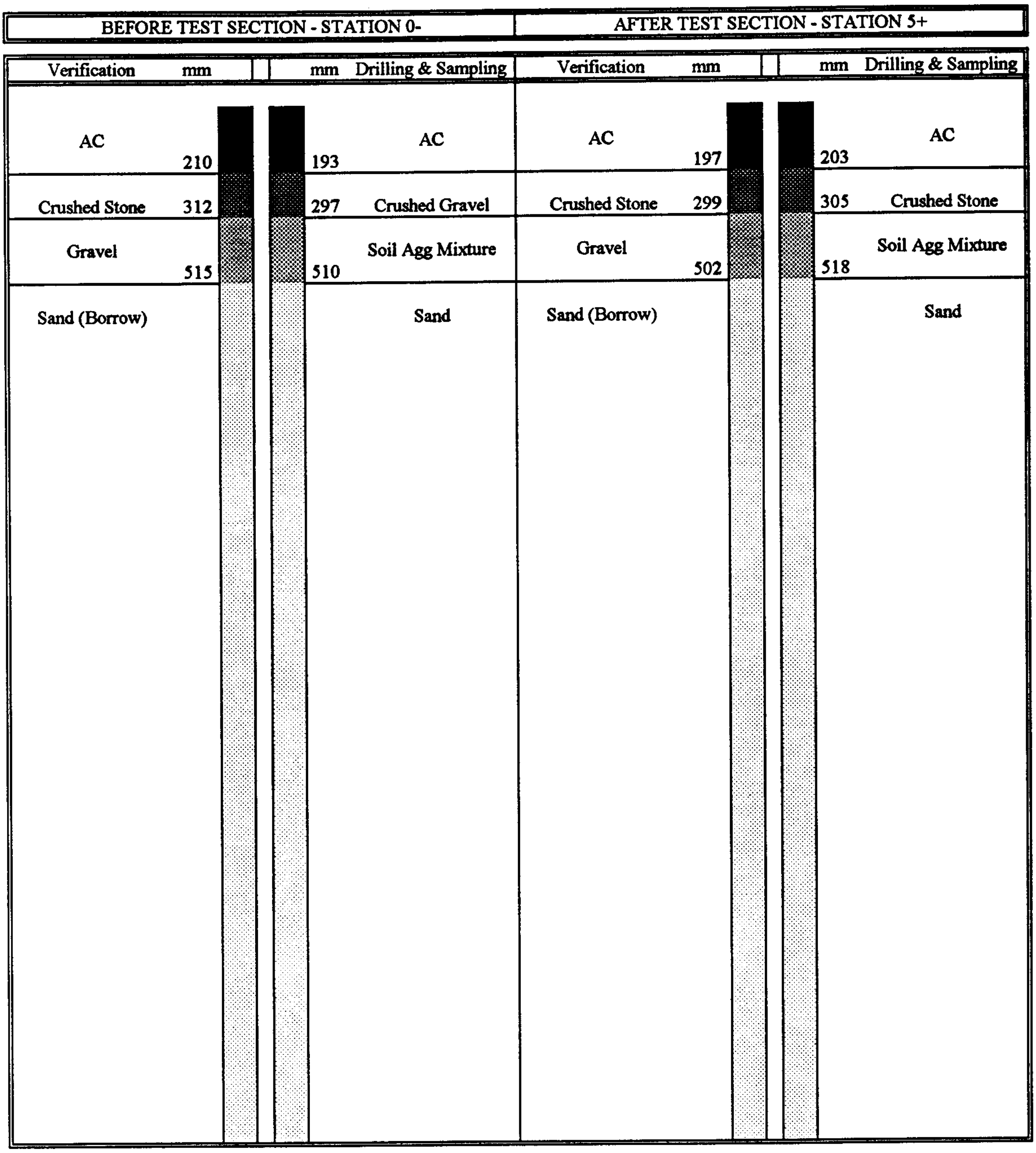


Figure A-2. Profile of Pavement Structure

Table A-1. Site Performance Summary

Distress and Profile Summary		
Distress Summary 1990	Profile Summary	
	Date (mm-dd-yy)	IRI (in/mi)
Low Sev. Allig. (Fat.) Cracks - 45.40 sq. ft.	10-26-89	73.88
Low Sev. Long. Cracks - 506.49 ft.	08-30-90	75.82
Low Sev. Trans. Cracks - 5 @ 24.21 ft.	07-28-91	75.32
Low Sev. Lane to Sh. Sep. - 25.22 ft.	09-02-92	71.74
	09-24-93	75.69

Falling Weight Deflectometer Data Summary

Date	Mean Value for Drop HT 2 (mils)					
	Sensor 1	Sensor 1 std. dev.	Sensor 7	Sensor 7 std. dev.	Mean Temp D1 (F)	Min/Max TempD1(F)
06-20-89	10.28	0.47	1.23	0.08	93	82/104
06-13-91	9.78	0.64	1.27	0.09	76	74/77
09-15-92	9.25	0.55	1.48	0.12	90	75/102

	Effective SN	SN std dev	Subgrade Modulus (psi)	Modulus std dev (psi)	Test Pit Mod. (psi)	
					1	2
06-20-89	5.43	0.15	25794	2183	23196	27442
06-13-91	5.35	0.23	25102	2353	-	-
09-15-92	5.69	0.21	23877	1958	-	-

Table A-2. Uniformity Survey Results

Seasonal Uniformity Survey Site Number: 251002 Date Surveyed: September 15, 1992					Falling Weight Deflectometer Data Collection and Processing Summary			
Section Interval (ft)	Mean Deflection Values for HT 2 (mils) - Corrected							
	Sensor 1	Sensor 1 std dev	Sensor 7	Sensor 7 std dev	Subg modulus (psi)	Subg modulus std dev	Effective SN	SN std dev
-100 to 0	9.79	0.97	1.65	0.05	21601	889	5.30	0.24
0 to 250	8.90	0.45	1.57	0.09	22454	1127	5.53	0.17
250 to 500	8.24	0.61	1.40	0.08	25171	1630	5.63	0.25
500 to 600	8.47	0.19	1.43	0.05	25190	1389	5.54	0.08

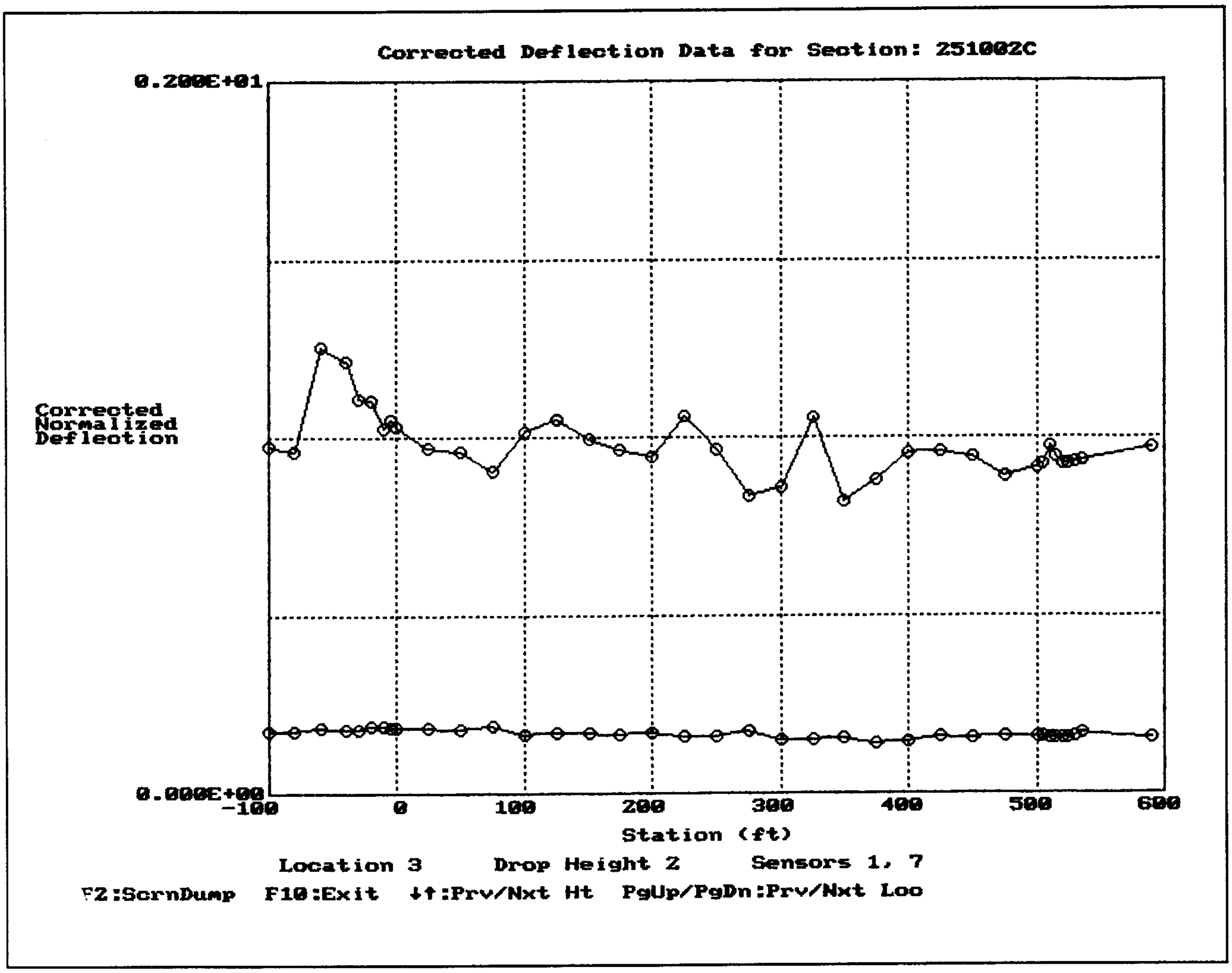


Figure A-3. Deflection Profile from FWDCHECK
(Test Date September 15, 1992)

Table A-3. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date September 15, 1992)

Flexible Pavement Thickness Statistics - 251002C - Drop Height 2			
Subsection	Station	Subgrade Modulus	Effective SN
1	0	21780	5.45
	25	21911	5.60
	50	21644	5.65
	75	21878	5.85
	100	20659	5.55
	125	22189	5.35
	150	22849	5.50
	175	24029	5.50
	200	24070	5.60
	225	23526	5.25
2	250	22355	5.60
	275	22735	6.05
	300	24459	5.85
	325	24374	5.25
	350	25211	6.00
	375	27973	5.60
	400	26625	5.40
	425	25543	5.45
	450	25849	5.50
	475	25957	5.65
	500	25799	5.60
Subsection 1	Overall Mean	22454	5.53
	Standard Deviation	1127	0.17
	Coeff of Variation	5.02%	2.99%
Subsection 2	Overall Mean	25171	5.63
	Standard Deviation	1630	0.25
	Coeff of Variation	6.48%	4.39%

Note: No test pit data found, therefore no results exist...

APPENDIX B

Supporting Site Visit and Installed Instrument Information

Appendix B contains the following supporting information:

Correspondence from the Site Inspection and the Planning Meeting

Table B-1. Air Temperature Thermistor Calibration

Table B-2. MRC Probe Calibration

Table B-3. Description of MRC Thermistor Probe and Sensor Spacing

Table B-4. Resistivity Probe and Sensor Spacing

Table B-5. Contact Resistance Calibration

Table B-6. TDR Probes Calibration

Figure B-1. TDR Traces Obtained During Calibration

PAVEMENT
MANAGEMENT
SYSTEMS

MEMORANDUM

TO:	C. Dougan, CT T. Karasopolous, ME L. Kenison, NH R. Cauley, VT G. Jones, ON G. Dore, QE P. Hughes, MA	**DATE:**	May 07, 1992
		PROJECT:	50450732
		FILE:	6.01
FROM:	Bill Phang		
SUBJECT:	SHRP Seasonal Monitoring Reconfirming Participation	**COPIES TO:**	See Below

Planning for the SHRP Seasonal Monitoring program has now progressed to the stage where preliminary schedules for installation of temperature, moisture, and frost depth penetration need to be determined.

The results of the measurements made at the pilot seasonal testing site at Syracuse, N.Y., and at Boise, ID, are to be examined and recommendations made regarding the instrumentation which will be used at other seasonal testing sites by the end of May 1992. These recommendations will be discussed and the instrumentation finalized by the Instrumentation ETG in June 1992. Acquisition of equipment and plans for installation over the next few months imply that field installation will begin in September 1992.

In the meantime, in order to develop and test the schedules for FWD testing, a trial run of the testing circuit will be made in July. At this juncture the eight (8) first round GPS seasonal testing sites include:

Cell No.	Agency	SHRP ID	SHRP Expt.	Subgrade	AC Thickness	Traffic
4 *	ON **	871620	1	Fine	4.5	High
12	NY **	361011	1	Fine	10.7	Low
12	VT	510002	1	Fine	8.1	Low
16	CT **	091803	1	Coarse	7.0	Low
16	MA	251003	1	Coarse	8.5	High
16	NH	331001	1	Coarse	8.3	High
20	QE	893015	3	Fine	8.5	High
24	ME	233014	3	Coarse	10.0	Low

* To be rehabilitated in May 1992 ** 1992 Confirmation

415 LAWRENCE BELL DRIVE
UNIT #3
AMHERST, N.Y. 14221
TEL. (716) 632-0804
FAX (716) 632-4808

PAVEMENT
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July 7, 1993

Mr. Matt Turo
Massachusetts Department of Public Works
10 Park Plaza, Room 4150
BOSTON, MA 02116

Dear Matt:

Please find enclosed a copy of the "LTPP Seasonal Monitoring Program: Instrumentation Installation and Data Collection Guidelines". This is a pre-distribution "draft" copy. An updated version is to be distributed in early August which will form the basis for the installation and data collection for the seasonal monitoring program.

In preparation for the preliminary planning meeting scheduled for July 20, 1993, the installation guidelines (pages II 23 - 39, 44 - 54) will provide an idea of the requirements/activities involved in the installation of the seasonal monitoring program test sites.

A summary of the information available for GPS 251002 should be forwarded to you early next week. Because this site is in a fill area it is not ideal for the seasonal program. We would like to review the potential of the other GPS sites within the State of Massachusetts to see if we can come up with a candidate more in line with the program requirements, that can be supported by the state (ie, traffic control). In the meantime, if you have any questions or require additional information, please do not hesitate to call the undersigned or Bill Phang at your convenience.

Yours truly,

PAVEMENT MANAGEMENT SYSTEMS LIMITED

Brandt Henderson
Manager, Field and Data Operations

BH/lh
Encl.

Copies: Bill Phang
Ivan Pecnik

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PAVEMENT
MANAGEMENT
SYSTEMS

July 23, 1993
50450925-16.00

Mr. Matt Turo
Massachusetts Department of Public Works
10 Park Plaza, Room 4150
Boston, Massachusetts 02116

RE: Seasonal Monitoring Program - Installation of Instrumentation

Dear Phillip,

Thank you for making arrangements for the meeting held in your Boston office, Tuesday, July 20, 1993, to plan for the installation of instrumentation at a GPS site.

The participation requirements of traffic control during installation and for monitoring activities with the FWD, levels, etc., fourteen times per year every other year, supply of drill rig and crew for a day during installation, backfill for the piezometer, patching for the pavement and shoulder, and a yearly check of the temporary bench mark (the piezometer) were discussed and agreed on for GPS # 251002.

Installation is scheduled to begin on August 30, 1993 with an on-site (nearby hotel) briefing meeting of all the participants, to check on readiness and completeness of equipment, and availability of needed materials. Actual installation will be on August 31, while completion of hook-up and testing will be completed on September 01, 1993.

The schedule for subsequent monthly monitoring beginning in November 1993 will be determined in October.

Yours Sincerely,
PAVEMENT MANAGEMENT SYSTEMS LIMITED

W.A. Phang, D. Eng.
Program Manager, FHWA-LTPP

BP/tf

c.c. I.J. Pecnik
A. Lopez
G. Rada
B. Henderson

415 LAWRENCE BELL DRIVE
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Table B-1. Air Temperature Thermistor Calibration

LTPP Seasonal Monitoring Study	State Code	[2 5]
Air Temperature Thermistor Calibration	Test Section Number	[1 0 0 2]

Before Operation Checks	Calibration Date mm-dd-yy	08-29-93
	Probe S/N	25AAT
	Operator	Perry Zabaldo

Mobile Datalogger (24 hour)			Water Room Temperature		Ice Bath 0 C (+/- 1 C)		Hot Water 50 C (+/-)		ok
Mean	Min.	Max.	Reading	Time	Reading	Time	Reading	Time	y/n
27.77	27.69	27.89	27.70	16:14	5.48	17:42	46.10	18:18	y

Probe Accepted	P.Z.	(Initial)

Table B-2. MRC Probe Calibration

LTPP Seasonal Monitoring Study	State Code	[25]
MRC Probe Calibration	Test Section Number	[1002]

Before Operation Checks	Calibration Date mm-dd-yy	08-29-93
	Probe S/N	25AT
	Operator	Perry Zabaldo

	Mobile Datalogger (24 hour)			Water Room Temp Time 16:14	Ice Bath 0 C(+/- 1 C) Time 17:42	Hot Water 50 C (+/-) Time 18:17	ok
No.	Mean	Min.	Max.	Reading	Reading	Reading	y/n
1	28.2	28.1	28.3	28.2	6.40	47.8	y
2	28.0	27.9	28.1	28.0	5.65	47.9	y
3	27.9	27.8	27.9	27.8	5.91	47.0	y
4	28.2	28.1	28.2	28.1	6.69	48.2	y
5	28.3	28.2	28.4	28.2	4.17	48.2	y
6	28.4	28.2	28.5	28.3	4.10	47.6	y
7	28.2	28.1	28.3	28.1	4.17	47.4	y
8	28.1	28.0	28.1	28.0	4.10	47.1	y
9	28.2	28.0	28.3	28.0	4.48	46.7	y
10	28.3	28.2	28.3	28.2	4.85	46.2	y
11	28.5	28.4	28.5	28.5	4.98	46.3	y
12	28.6	28.5	28.7	28.5	5.51	45.8	y
13	28.5	28.5	28.6	28.5	4.14	46.6	y
14	28.6	28.5	28.7	28.5	3.86	46.2	y
15	28.7	28.7	28.8	28.7	2.82	47.2	y
16	28.7	28.6	28.8	28.6	2.89	47.0	y
17	28.6	28.5	28.6	28.5	3.97	47.9	y
18	28.6	28.5	28.6	28.5	5.05	48.2	y

Probe Accepted:	P.Z.	(Initials)
Probe Length:	1.856	(meters)

Thermistor distance from top of probe:					(meters)				
4	.0222	7	.2492	10	.6302	13	1.0890	16	1.5462
5	.0968	8	.3254	11	.7842	14	1.2414	17	1.6986
6	.1730	9	.4778	12	.9350	15	1.3922	18	1.8479

Table B-3. Description of MRC Thermistor Probe and Sensor Spacing

Unit	Channel No.	Distance from Top of Unit(m)	Remarks
1	1	.0127	0.3302m long by 63.5mm stainless steel probe installed in the AC layer.
	2	.1651	
	3	.3175	
2	4	.0222	1.854m long by 25.4mm PVC tube installed in the base and subgrade.
	5	.0968	
	6	.1730	
	7	.2492	
	8	.3254	
	9	.4778	
	10	.6302	
	11	.7842	
	12	.9350	
	13	1.0890	
	14	1.2414	
	15	1.3922	
	16	1.5462	
	17	1.6986	
	18	1.8479	

Table B-4. Resistivity Probe and Sensor Spacing

Connector Pin No.	Electrode Number	Continuity x	Measure-ment	Spacing (mm)			Dist. from Top (m)
				Line 1	Line 2	Avg.	
36	1	x	Top-1	29	30	29.5	.030
35	2	x	1-2	50	51	50.5	.081
34	3	x	2-3	51	52	51.5	.132
33	4	x	3-4	50	50	50.0	.182
32	5	x	4-5	51	52	51.5	.234
31	6	x	5-6	51	49	50.0	.284
30	7	x	6-7	52	53	52.5	.336
29	8	x	7-8	51	51	51.0	.387
28	9	x	8-9	51	51	51.0	.438
27	10	x	9-10	52	51	51.5	.490
26	11	x	10-11	50	50	50.0	.540
25	12	x	11-12	52	51	51.5	.591
24	13	x	12-13	52	52	52.0	.643
23	14	x	13-14	51	51	51.0	.694
22	15	x	14-15	51	50	50.5	.745
21	16	x	15-16	50	51	50.5	.795
20	17	x	16-17	51	50	50.5	.846
19	18	x	17-18	52	51	51.5	.897
18	19	x	18-19	50	50	50.0	.947
17	20	x	19-20	52	52	52.0	.999
16	21	x	20-21	52	52	52.0	1.051
15	22	x	21-22	51	51	51.0	1.102
14	23	x	22-23	51	51	51.0	1.153
13	24	x	23-24	50	51	50.5	1.204
12	25	x	24-25	51	50	50.5	1.254
11	26	x	25-26	51	52	51.5	1.306
10	27	x	26-27	52	50	51.0	1.357
9	28	x	27-28	51	52	51.5	1.408
8	29	x	28-29	52	52	52.0	1.460
7	30	x	29-30	50	50	50.0	1.510
6	31	x	30-31	51	52	51.5	1.562
5	32	x	31-32	51	49	50.0	1.612
4	33	x	32-33	51	52	51.5	1.663
3	34	x	33-34	51	50	50.5	1.714
2	35	x	34-35	52	52	52.0	1.766
1	36	x	35-36	50	50	50.0	1.816
			36-End	23	24	23.5	1.839

Table B-5. Contact Resistance Calibration

LTPP Seasonal Monitoring Study					State Code		[25]
Data Sheet R1							
Contact Resistance Measurements					Test Section Number		[1002]
1. Date (Month - Day - Year)							[08-31-93]
2. Time Measurements Began (Military)							[13:24]
3. Comments							In Salt Water Prior to Installation
Test Position	Connections		Voltage (ACV)		Current (ACA)		Notes
	I V	I V	Range Setting	Reading	Range Setting	Reading	
1	1	2	mV	65.6	uA	892	
2	3	2	mV	55.3	uA	896	
3	3	4	mV	53.2	uA	898	
4	5	4	mV	52.0	uA	900	
5	5	6	mV	53.0	uA	899	
6	7	6	mV	60.1	uA	891	
7	7	8	mV	61.0	uA	892	
8	9	8	mV	62.0	uA	894	
9	9	10	mV	61.5	uA	891	
10	11	10	mV	57.3	uA	896	
11	11	12	mV	57.4	uA	899	
12	13	12	mV	54.2	uA	899	
13	13	14	mV	53.7	uA	902	
14	15	14	mV	54.5	uA	902	
15	15	16	mV	54.9	uA	902	
16	17	16	mV	54.8	uA	899	
17	17	18	mV	52.8	uA	903	
18	19	18	mV	53.3	uA	903	
19	19	20	mV	54.3	uA	901	
20	21	20	mV	53.7	uA	896	
21	21	22	mV	53.9	uA	901	
22	23	22	mV	51.8	uA	903	
23	23	24	mV	51.0	uA	900	
24	25	24	mV	56.9	uA	897	
25	25	26	mV	67.1	uA	894	Electrodes 25 - 33 are
26	27	26	mV	74.0	uA	895	high due to a possible
27	27	28	mV	76.9	uA	890	greater concentration
28	29	28	mV	71.7	uA	892	of salt in that area.
29	29	30	mV	81.9	uA	884	
30	31	30	mV	96.5	uA	873	
31	31	32	mV	97.7	uA	874	
32	33	32	mV	139.3	uA	839	
33	33	34	mV	120.4	uA	858	
34	35	34	mV	59.4	uA	896	
35	35	36	mV	66.6	uA	892	
36	37	38	mV	358.4	uA	689	
37	38	39	mV	227.3	uA	732	
38	39	40	mV	2.3	uA	951	
Preparer :		Perry Zabaldo			Employer :		PMSL

Table B-6. TDR Probes Calibration

LTPP Seasonal Monitoring Study	State Code		[25]
TDR Probes	Test Section Number		[1002]

Before Operation Checks	P.Z.	Initial	Calibration Date (mm-dd-yy)	08-25-93
			Seasonal Site	25SA

No.	Probe (S/N)	Resistance (ohms) Core	Resistance (ohms) Shield	Probe Shorted Begin Length	Probe Shorted End Length	Air Begin Length	Alcohol Begin Length	Water Begin Length
1	25A01	0.675	0.533	16.381	16.551	16.381	16.411	16.411
2	25A02	0.675	0.468	16.371	16.541	16.371	16.411	16.411
3	25A03	0.878	0.468	16.381	16.551	16.381	16.421	16.421
4	25A04	0.665	0.455	16.391	16.561	16.391	16.421	16.421
5	25A05	0.656	0.460	16.381	16.551	16.381	16.411	16.411
6	25A06	0.672	0.466	16.361	16.541	16.361	16.401	16.401
7	25A07	0.666	0.482	16.361	16.531	16.361	16.391	16.391
8	25A08	0.673	0.471	16.361	16.521	16.361	16.401	16.401
9	25A09	0.671	0.489	16.401	16.561	16.401	16.431	16.431
10	25A10	0.562	0.371	16.401	16.561	16.401	16.431	16.431

NOTE: Record lengths from TDR

Calculation of Dielectric Constant

Probe Length .203 m

V_p Setting .99 V_p

$$\varepsilon = \left[\frac{TDRL}{(PL)(V_p)} \right]^2$$

No.	Air TDR Length	Air Dielectric Constant	Air In Spec. (?)	Alcohol TDR Length	Alcohol Dielectric Constant	Alcohol In Spec. (?)	Water TDR Length	Water Dielectric Constant	Water In Spec. (?)
1	.17	.70	y	1.16	32.67	y	1.82	80.42	y
2	.17	.70	y	1.15	32.11	y	1.82	80.42	y
3	.18	.78	y	1.16	32.67	y	1.83	81.31	y
4	.18	.78	y	1.16	32.67	y	1.83	81.31	y
5	.18	.78	y	1.16	32.67	y	1.82	80.42	y
6	.18	.78	y	1.15	32.10	y	1.82	80.42	y
7	.17	.70	y	1.15	32.10	y	1.83	81.30	y
8	.17	.70	y	1.17	33.23	y	1.82	80.42	y
9	.20	.97	y	1.15	32.10	y	1.82	80.42	y
10	.16	.62	y	1.15	32.10	y	1.78	76.92	y

LTPP Seasonal Monitoring Study	State Code	[23]
TDR Probe Calibration	Test Section Number	[1003]

fore Operation Checks

- Calibration Date 8/25/93
- Probe S/N 25A01

Probe Number 1

R Trace 1 - Beginning Probe Shorted

ırsor .... 16.381 m
stance/Div..... .25 m/div
ertical Scale.... 163 mρ/div
P 0.99
oise Filter...... 1 avg
ower........... ac

Tektronix 1502B TDR
Date 8/25/93
Cable #1
Notes shorted at C.B.

Input Trace
Stored Trace
Difference Trace

ıce Number 2 - Ending Probe Shorted

ursor .... 16.551 m
istance/Div..... .25 m/div
ertical Scale.... 163 mρ/div
P 0.99
oise Filter...... 1 avg
ower........... ac

Tektronix 1502B TDR
Date 8/25/93
Cable #1
Notes Shorted at far end

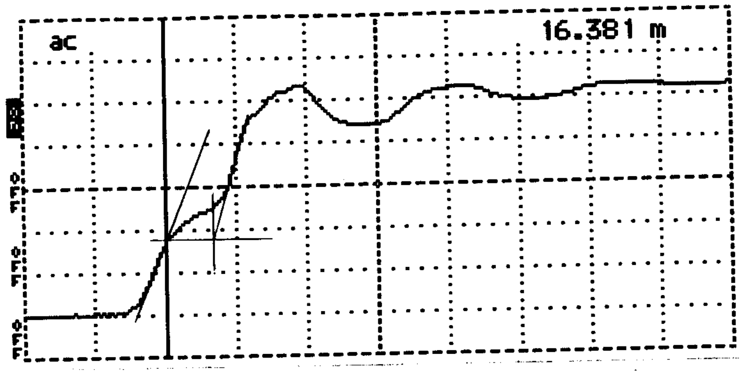
Input Trace
Stored Trace
Difference Trace

Figure B-1. TDR Traces Obtained During Calibration

Probe Number 1 (cont.)

ce Number 3 - Probe in Air

ursor .... 16.381 m
istance/Div..... .25 m/div
ertical Scale.... 163 mρ/div
/P 0.99
oise Filter...... 1 avg
ower........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #1
Notes in air @ 26.8°C

Input Trace
Stored Trace
Difference Trace

ce Number 4 - Probe in Alcohol

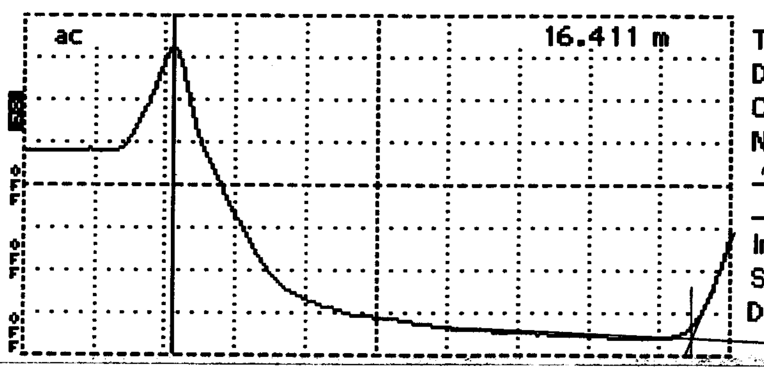
ursor .... 16.411 m
istance/Div..... .25 m/div
ertical Scale.... 50.0 mρ/div
P 0.99
oise Filter...... 1 avg
ower........... ac

Tektronix 1502B TDR
Date 8/25/93
Cable #1
Notes in methyl alcohol @ 24.0°C

Input Trace
Stored Trace
Difference Trace

ace Number 5 - Probe in Water

ursor .... 16.411 m
istance/Div..... .25 m/div
ertical Scale.... 66.7 mρ/div
P 0.99
oise Filter...... 1 avg
ver........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #1
Notes in water @ 22.5°C

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

LTPP Seasonal Monitoring Study	State Code	[2 5]
TDR Probe Calibration	Test Section Number	[1 0 0 2]

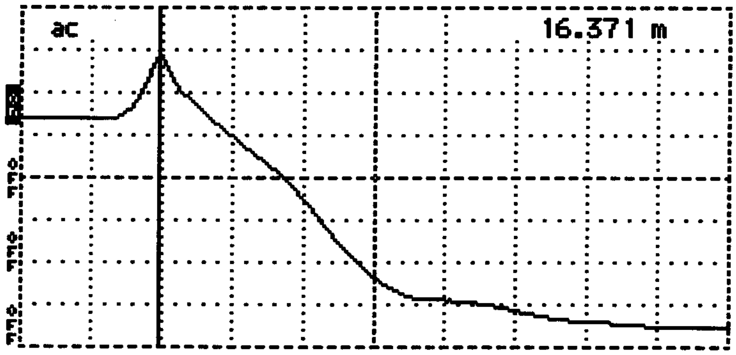
ore Operation Checks - Calibration Date 8/25/93

- Probe S/N 25A02

Probe Number 2

R Trace 1 - Beginning Probe Shorted

ursor .... 16.371 m
istance/Div..... .25 m/div
ertical Scale.... 163 mρ/div
P 0.99
oise Filter...... 1 avg
ower .... ac

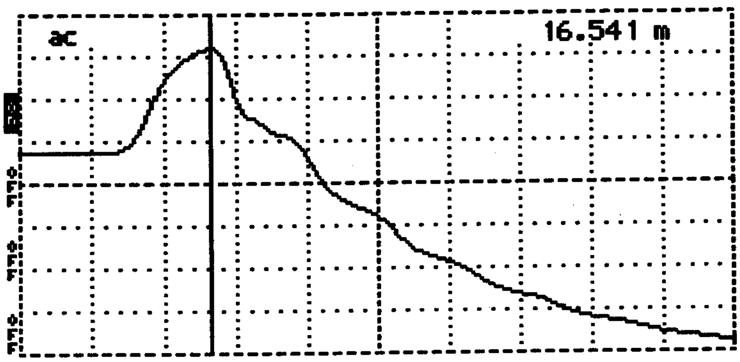


Tektronix 1502B TDR
Date 8/25/93
Cable #2
Notes Shorted at C.B.

Input Trace ______
Stored Trace ------
Difference Trace ......

ce Number 2 - Ending Probe Shorted

sor .... 16.541 m
tance/Div..... .25 m/div
tical Scale.... 163 mρ/div
.... 0.99
se Filter...... 1 avg
er .... ac



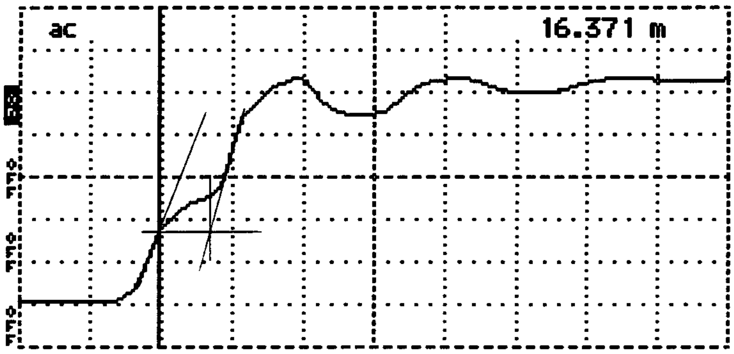
Tektronix 1502B TDR
Date 8/25/93
Cable #2
Notes Shorted at far end

Input Trace ______
Stored Trace ------
Difference Trace ......

Figure B-1(cont.). TDR Traces Obtained During Calibration

ace Number 3 - Probe in Air

Cursor .... 16.371 m
Distance/Div..... .25 m/div
Vertical Scale.... 163 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... ac

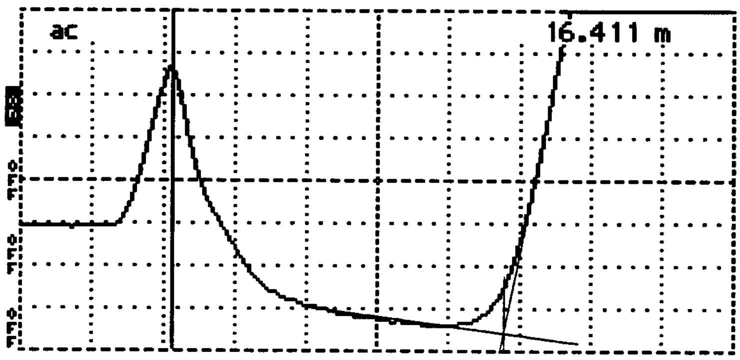


Tektronix 1502B TDR
Date 8/25/93
Cable #2
Notes in air @ 26.8

Input Trace
Stored Trace
Difference Trace

ace Number 4 - Probe In Alcohol

rsor .... 16.411 m
tance/Div..... .25 m/div
rtical Scale.... 50.0 mρ/div
.... 0.99
se Filter...... 1 avg
wer........... ac

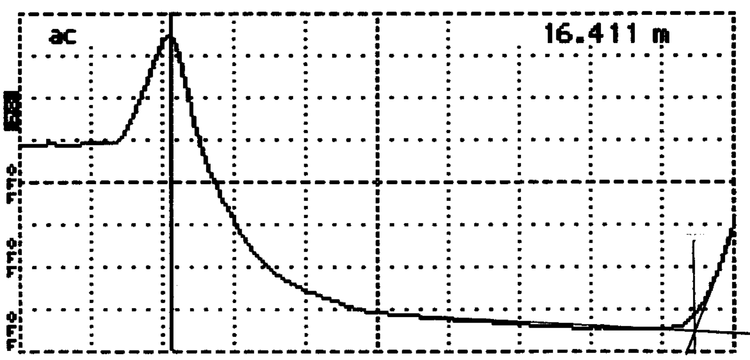


Tektronix 1502B TDR
Date 8/25/93
Cable #2
Notes in methyl alcohol @ 24.0°C

Input Trace
Stored Trace
Difference Trace

ace Number 5 - Probe in Water

rsor .... 16.411 m
tance/Div..... .25 m/div
rtical Scale.... 66.7 mρ/div
.... 0.99
se Filter...... 1 avg
wer........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #2
Notes in water @ 22.5°C

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

LTPP Seasonal Monitoring Study	State Code	[25]
TDR Probe Calibration	Test Section Number	[1002]

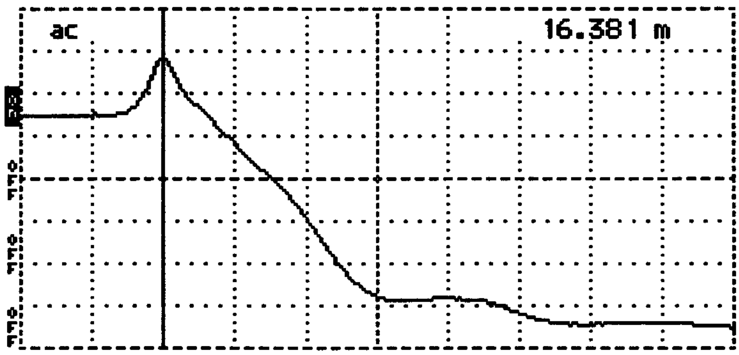
ore Operation Checks

- Calibration Date 8/25/93
- Probe S/N 25A03

Probe Number 3

R Trace 1 - Beginning Probe Shorted

sor .... 16.381 m
tance/Div..... .25 m/div
tical Scale.... 163 mρ/div
.... 0.99
se Filter...... 1 avg
ver........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #3
Notes shorted at C.B.

Input Trace
Stored Trace
Difference Trace

ce Number 2 - Ending Probe Shorted

sor .... 16.551 m
tance/Div..... .25 m/div
tical Scale.... 163 mρ/div
.... 0.99
se Filter...... 1 avg
ver........... ac

Tektronix 1502B TDR
Date 8/25/93
Cable #3
Notes Shorted at far end

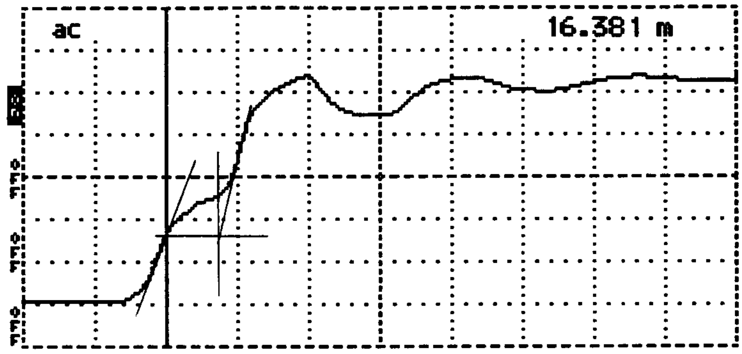
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

Probe Number 3 (cont.)

ce Number 3 - Probe In Air

rsor .... 16.381 m
stance/Div..... .25 m/div
rtical Scale.... 163 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac

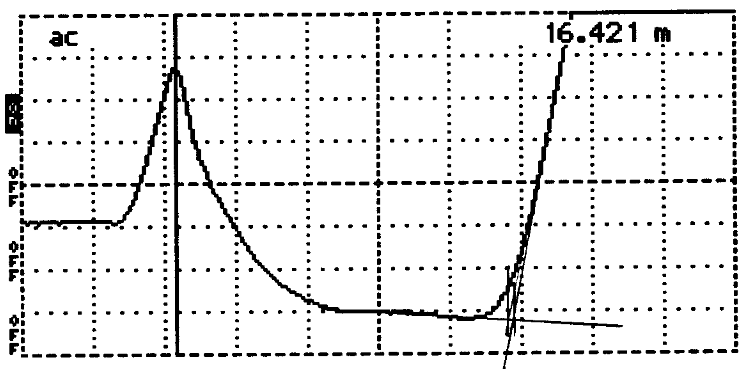


Tektronix 1502B TDR
Date 8/25/93
Cable #3
Notes in air @ 26.8°C

Input Trace
Stored Trace
Difference Trace

ce Number 4 - Probe In Alcohol

ɹr .... 16.421 m
tance/Div..... .25 m/div
rtical Scale.... 50.0 mρ/div
.... 0.99
se Filter...... 1 avg
wer........... ac

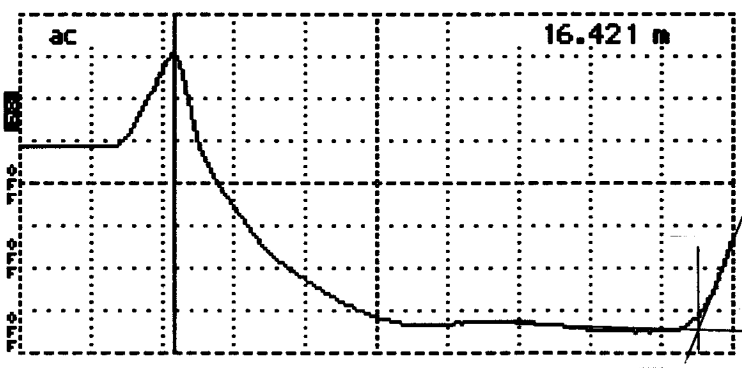


Tektronix 1502B TDR
Date 8/25/93
Cable #3
Notes in methyl alcohol @ 24.0°C

Input Trace
Stored Trace
Difference Trace

ce Number 5 - Probe In Water

rsor .... 16.421 m
stance/Div..... .25 m/div
rtical Scale.... 66.7 mρ/div
.... 0.99
ise Filter...... 1 avg
ꞌer........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #3
Notes in water @ 22.5°C

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

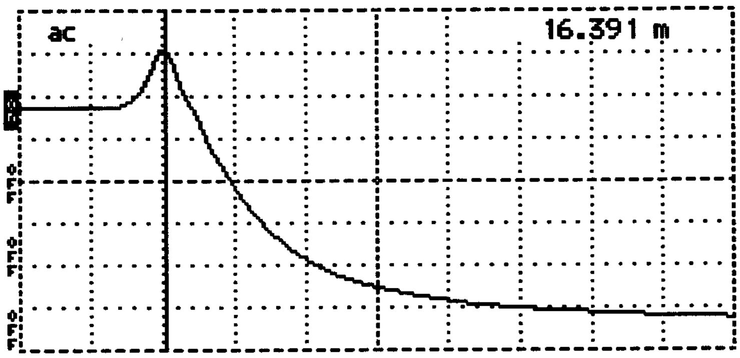
LTPP Seasonal Monitoring Study	State Code	25
TDR Probe Calibration	Test Section Number	0022

fore Operation Checks - Calibration Date 8/25/97
- Probe S/N 25 A04

Probe Number 4

R Trace 1 - Beginning Probe Shorted

rsor .... 16.391 m
stance/Div..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac

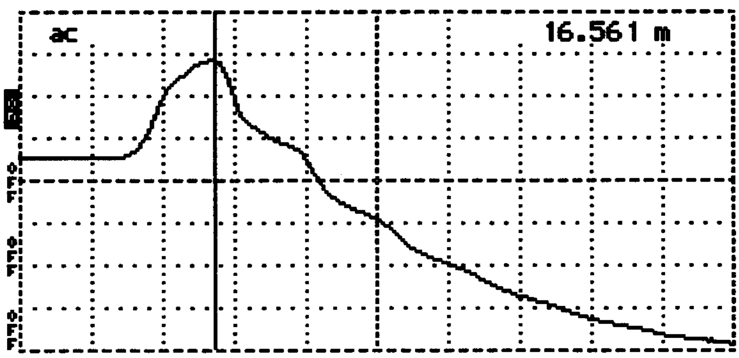


Tektronix 1502B TDR
Date 8/25/03
Cable #4
Notes Shorted at C.B.

Input Trace
Stored Trace
Difference Trace

ce Number 2 - Ending Probe Shorted

rsor .... 16.561 m
stance/Div..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac



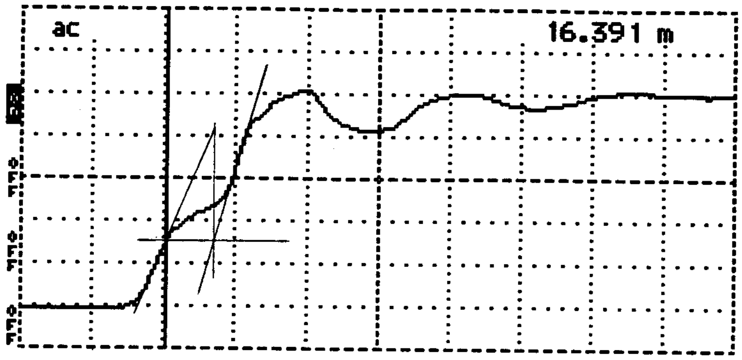
Tektronix 1502B TDR
Date 8/25/03
Cable #4
Notes Shorted at far end

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

ce Number 3 - Probe in Air

ursor .... 16.391 m
stance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter...... 1 avg
ower........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #4
Notes in air @ 26.8°

Input Trace
Stored Trace
Difference Trace

ce Number 4 - Probe in Alcohol

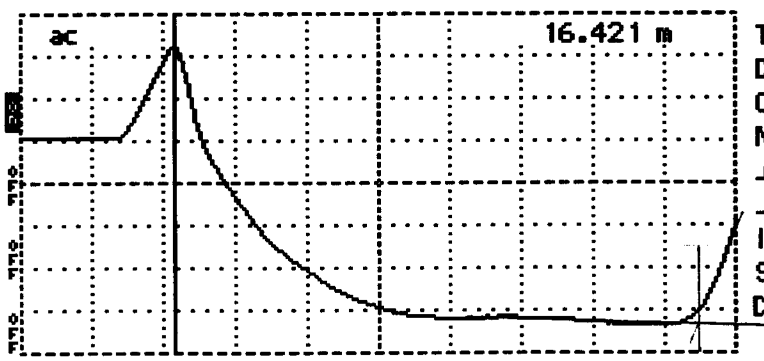
sor .... 16.421 m
stance/Div..... .25 m/div
rtical Scale.... 50.0 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac

Tektronix 1502B TDR
Date 8/25/93
Cable #4
Notes in alcohol (meth
@ 24.0 °C

Input Trace
Stored Trace
Difference Trace

ce Number 5 - Probe in Water

sor .... 16.421 m
tance/Div..... .25 m/div
tical Scale.... 66.7 mρ/div
.... 0.99
se Filter...... 1 avg
er........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #4
Notes in water
@ 22.5 °C

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

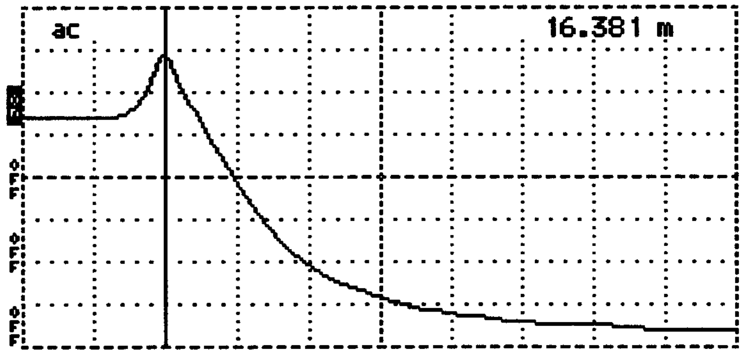
LTPP Seasonal Monitoring Study	State Code	[25]
TDR Probe Calibration	Test Section Number	[1 0 0 2]

fore Operation Checks
- Calibration Date 8/25/93
- Probe S/N 25A05

Probe Number 5

R Trace 1 - Beginning Probe Shorted

ursor .... 16.381 m
istance/Div..... .25 m/div
ertical Scale.... 163 mρ/div
P 0.99
oise Filter...... 1 avg
ower............ ac



Tektronix 1502B TDR
Date 8/25/93
Cable #5
Notes shorted at C.B.

Input Trace
Stored Trace
Difference Trace

ce Number 2 - Ending Probe Shorted

ursor .... 16.551 m
istance/Div..... .25 m/div
ertical Scale.... 163 mρ/div
P 0.99
oise Filter...... 1 avg
ower............ ac

Tektronix 1502B TDR
Date 8/25/93
Cable #5
Notes Shorted at far end

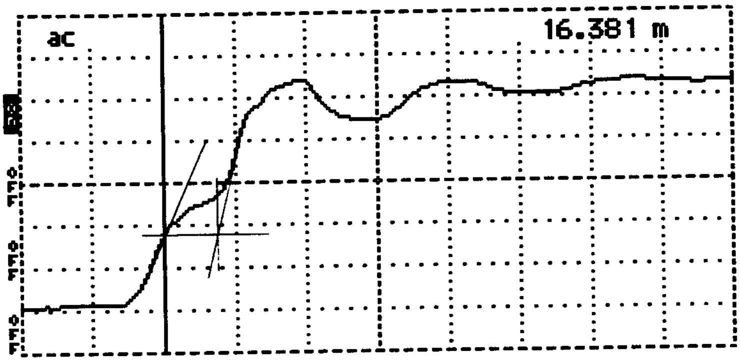
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

Probe Number 5 (cont.)

Trace Number 3 - Probe in Air

Cursor .... 16.381 m
Distance/Div..... .25 m/div
Vertical Scale.... 163 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac

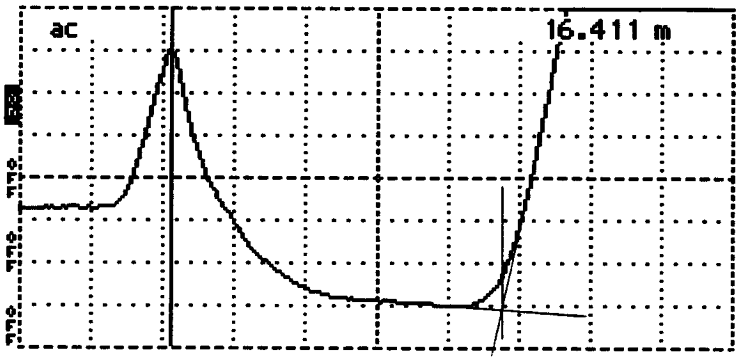


Tektronix 1502B TDR
Date 8/25/93
Cable #5
Notes in air @ 26.8°C

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

ursor .... 16.411 m
'ance/Div..... .25 m/div
.. tical Scale.... 50.0 mρ/div
P 0.99
oise Filter...... 1 avg
ower........... ac

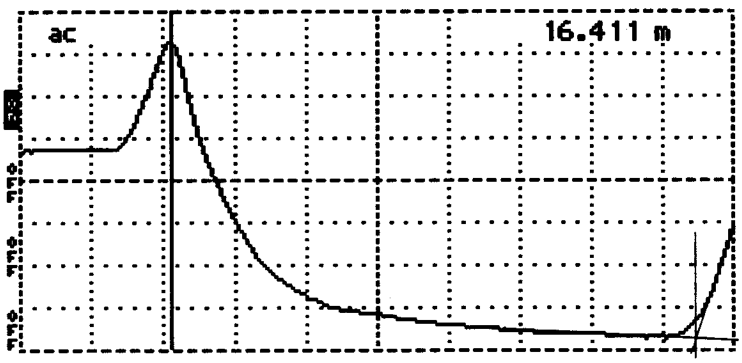


Tektronix 1502B TDR
Date 8/25/93
Cable #5
Notes in methyl alcohol @ 24.0°C

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

Cursor .... 16.411 m
Distance/Div..... .25 m/div
Vertical Scale.... 66.7 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #5
Notes in water @ 22.5°C

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

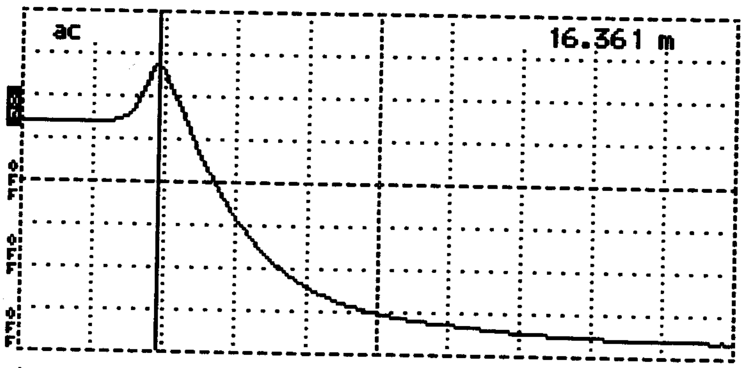
LTPP Seasonal Monitoring Study	State Code	[25]
TDR Probe Calibration	Test Section Number	[1002]

efore Operation Checks - Calibration Date 8/25/93
- Probe S/N 25A06

Probe Number 6

DR Trace 1 - Beginning Probe Shorted

rsor .... 16.361 m
tance/Div..... .25 m/div
tical Scale.... 163 mρ/div
.... 0.99
se Filter...... 1 avg
ver........... ac

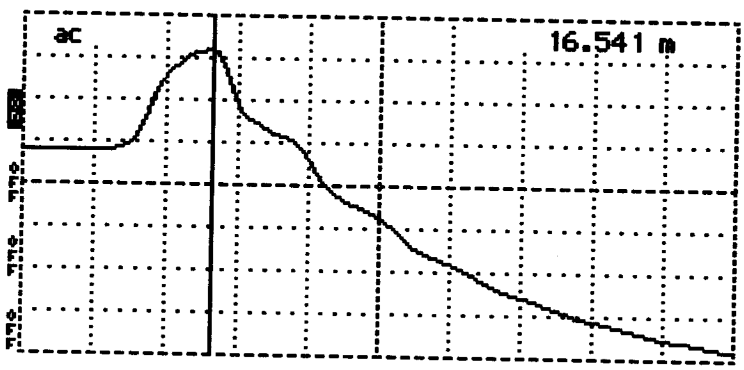


Tektronix 1502B TDR
Date 8/25/93
Cable #6
Notes shorted at C.B.

Input Trace
Stored Trace
Difference Trace

race Number 2 - Ending Probe Shorted

rsor .... 16.541 m
stance/Div..... .25 m/div
rtical Scale.... 163 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac



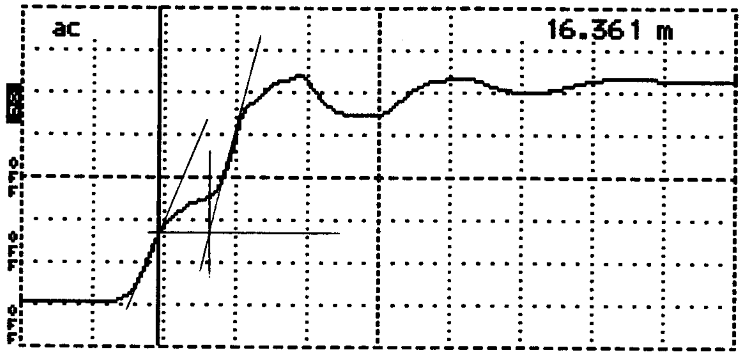
Tektronix 1502B TDR
Date 8/25/93
Cable #6
Notes Shorted at far end

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

rrace Number 3 - Probe in Air

ursor .... 16.361 m
stance/Div ..... .25 m/div
ertical Scale.... 163 mρ/div
P 0.99
oise Filter ...... 1 avg
ower .... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #6
Notes in air @ 26.8°C

Input Trace
Stored Trace
Difference Trace

race Number 4 - Probe in Alcohol

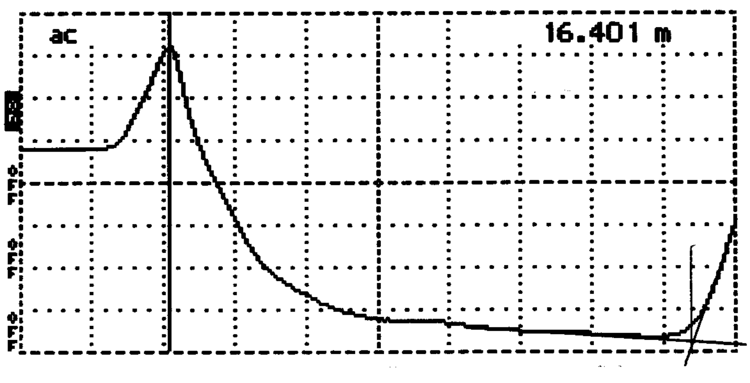
..sor .... 16.401 m
stance/Div ..... .25 m/div
rtical Scale.... 50.0 mρ/div
 .... 0.99
ise Filter ...... 1 avg
wer .... ac

Tektronix 1502B TDR
Date 8/25/93
Cable #6
Notes in alcohol (meth
@ 24.0°C

Input Trace
Stored Trace
Difference Trace

ace Number 5 - Probe in Water

ursor .... 16.401 m
istance/Div ..... .25 m/div
ertical Scale.... 66.7 mρ/div
P 0.99
oise Filter ...... 1 avg
ower .... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #6
Notes in water @ 22.5°C

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

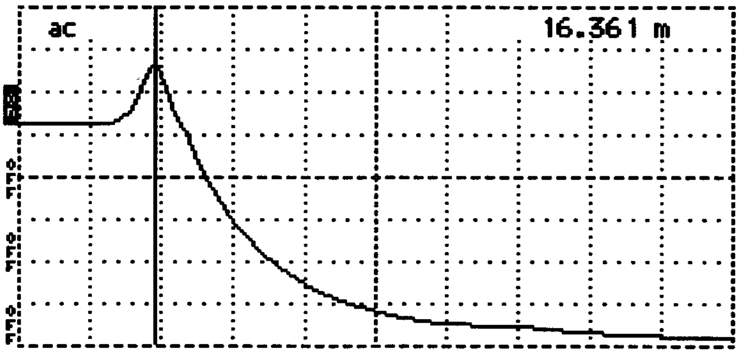
LTPP Seasonal Monitoring Study	State Code	[25]
TDR Probe Calibration	Test Section Number	[1002]

ore Operation Checks
- Calibration Date 8/25/93
- Probe S/N 25A07

Probe Number 7

R Trace 1 - Beginning Probe Shorted

sor .... 16.361 m
tance/Div..... .25 m/div
tical Scale.... 163 mρ/div
.... 0.99
se Filter...... 1 avg
ver........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #7
Notes Shorted at C.B

Input Trace
Stored Trace
Difference Trace

ce Number 2 - Ending Probe Shorted

rsor .... 16.531 m
stance/Div..... .25 m/div
rtical Scale.... 163 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac

Tektronix 1502B TDR
Date 8/25/93
Cable #7
Notes Shorted at far end

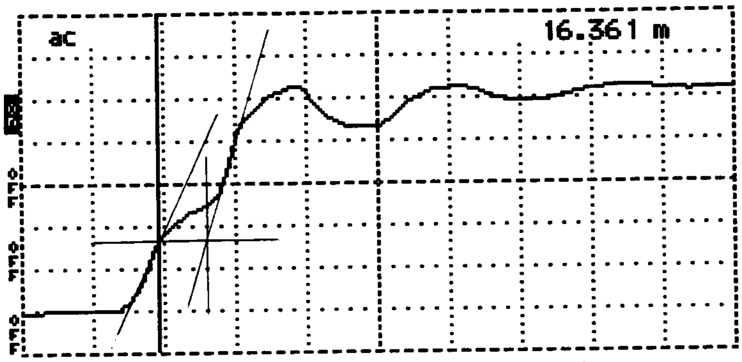
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

Probe Number 7 (cont.)

ce Number 3 - Probe in Air

Cursor .... 16.361 m
Distance/Div..... .25 m/div
Vertical Scale.... 163 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac

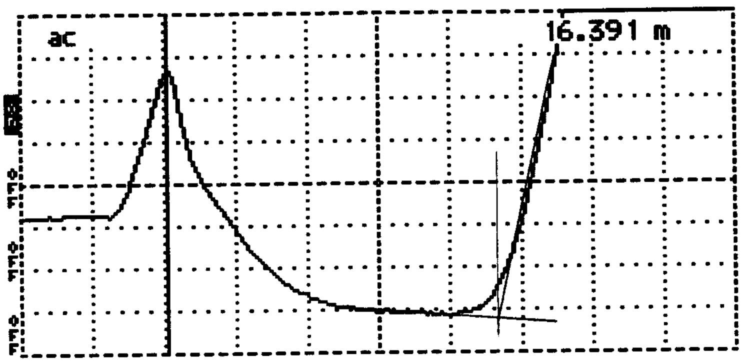


Tektronix 1502B TDR
Date 8/25/93
Cable #7
Notes in air @ 26.8

Input Trace
Stored Trace
Difference Trace

ce Number 4 - Probe in Alcohol

ursor .... 16.391 m
istance/Div..... .25 m/div
ertical Scale.... 50.0 mρ/div
'p 0.99
loise Filter...... 1 avg
'ower........... ac

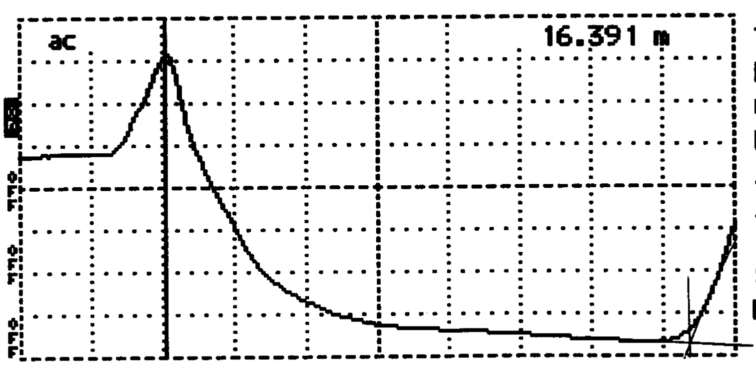


Tektronix 1502B TDR
Date 8/25/93
Cable #7
Notes in methyl alcohol @ 24.0°C

Input Trace
Stored Trace
Difference Trace

ace Number 5 - Probe in Water

rsor .... 16.391 m
stance/Div..... .25 m/div
rtical Scale.... 66.7 mρ/div
.... 0.99
ise Filter...... 1 avg
er........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #7
Notes in water @ 22.5°C

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

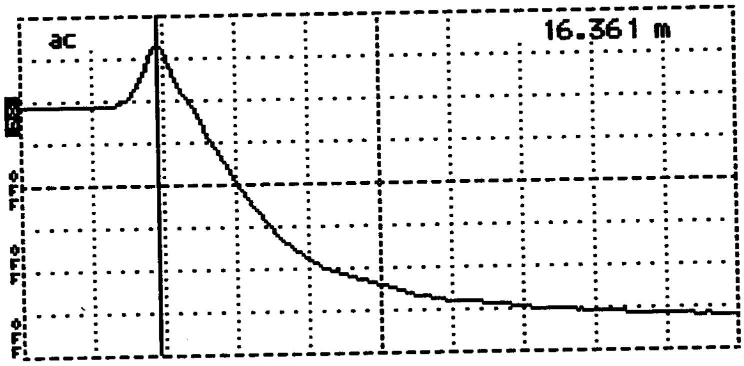
LTPP Seasonal Monitoring Study	State Code	[25]
TDR Probe Calibration	Test Section Number	[1002]

fore Operation Checks
- Calibration Date 8/25/93
- Probe S/N 25A08

Probe Number 8

R Trace 1 - Beginning Probe Shorted

ırsor .... 16.361 m
stance/Div ..... .25 m/div
ertical Scale.... 163 mρ/div
) 0.99
oise Filter ...... 1 avg
ower .... ac

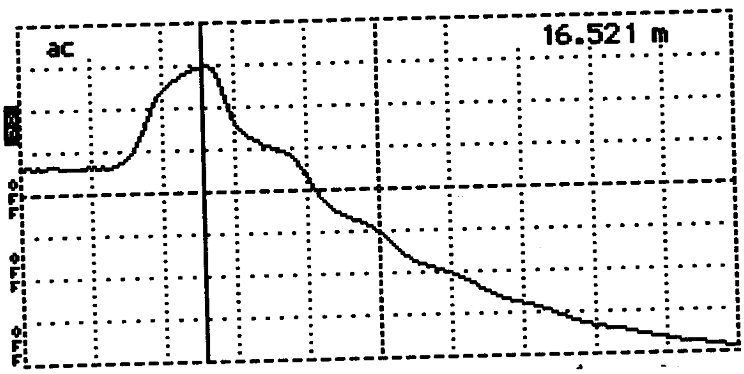


Tektronix 1502B TDR
Date 8/25/93
Cable #8
Notes Shorted at C.B.

Input Trace
Stored Trace
Difference Trace

ace Number 2 - Ending Probe Shorted

Cursor .... 16.521 m
Distance/Div ..... .25 m/div
Vertical Scale.... 163 mρ/div
/P 0.99
Noise Filter ...... 1 avg
Power .... ac



Tektronix 1502B TDR
Date 8/25/93
Cable # 8
Notes Shorted at far end

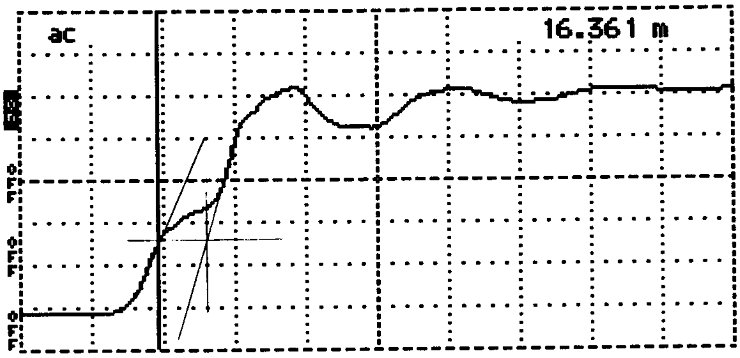
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

Probe Number 8 (cont.)

ce Number 3 - Probe in Air

rsor .... 16.361 m
stance/Div ..... .25 m/div
rtical Scale.... 163 mρ/div
.... 0.99
ise Filter ...... 1 avg
wer .... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #8
Notes in air @ 26.8°C

Input Trace
Stored Trace
Difference Trace

ce Number 4 - Probe in Alcohol

sor .... 16.401 m
stance/Div ..... .25 m/div
rtical Scale.... 50.0 mρ/div
.... 0.99
oise Filter ...... 1 avg
ower .... ac

Tektronix 1502B TDR
Date 8/25/93
Cable #8
Notes in methyl alcohol @ 24.0°C

Input Trace
Stored Trace
Difference Trace

ce Number 5 - Probe in Water

sor .... 16.401 m
tance/Div ..... .25 m/div
rtical Scale.... 66.7 mρ/div
.... 0.99
se Filter ...... 1 avg
er .... ac

Tektronix 1502B TDR
Date 8/28/93
Cable #8
Notes in water @ 22.5°C

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

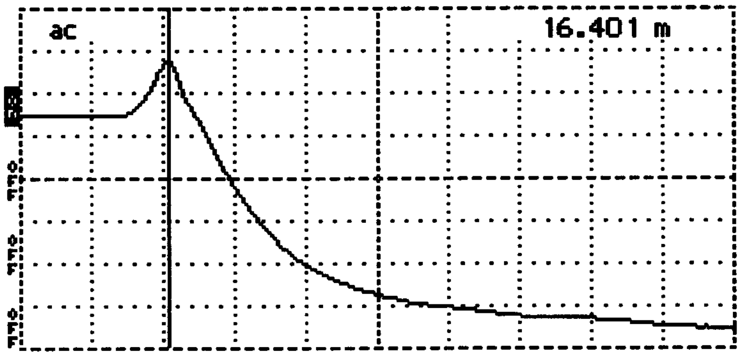
LTPP Seasonal Monitoring Study	State Code	25
TDR Probe Calibration	Test Section Number	1002

fore Operation Checks - Calibration Date 8/25/93
- Probe S/N 25A09

Probe Number 9

R Trace 1 - Beginning Probe Shorted

ursor .... 16.401 m
stance/Div..... .25 m/div
ertical Scale.... 163 mρ/div
ρ 0.99
oise Filter...... 1 avg
ower........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #9
Notes Shorted at C.B.

Input Trace
Stored Trace
Difference Trace

ace Number 2 - Ending Probe Shorted

rsor .... 16.561 m
tance/Div..... .25 m/div
rtical Scale.... 163 mρ/div
 .... 0.99
se Filter...... 1 avg
wer........... ac

Tektronix 1502B TDR
Date 8/25/93
Cable #9
Notes shorted at far end

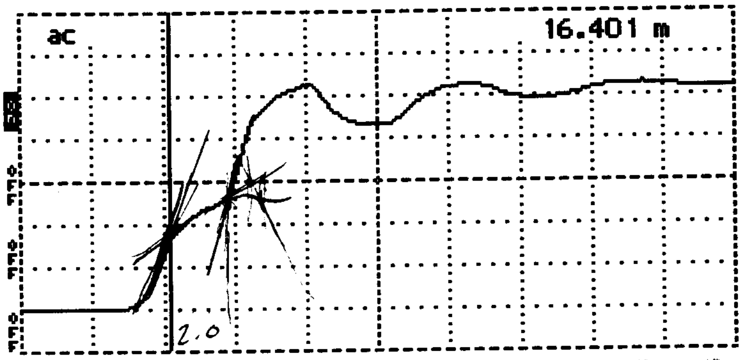
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

Probe Number 9 (cont.)

ce Number 3 - Probe in Air

sor .... 16.401 m
tance/Div..... .25 m/div
rtical Scale.... 163 mρ/div
.... 0.99
se Filter...... 1 avg
ver........... ac

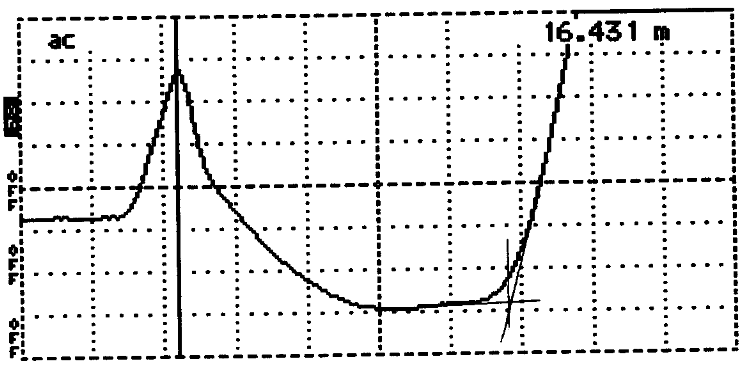


Tektronix 1502B TDR
Date 8/25/93
Cable #9
Notes in air @ 22.5°C

Input Trace
Stored Trace
Difference Trace

ce Number 4 - Probe in Alcohol

ursor .... 16.431 m
istance/Div..... .25 m/div
ertical Scale.... 50.0 mρ/div
P 0.99
oise Filter...... 1 avg
ower........... ac

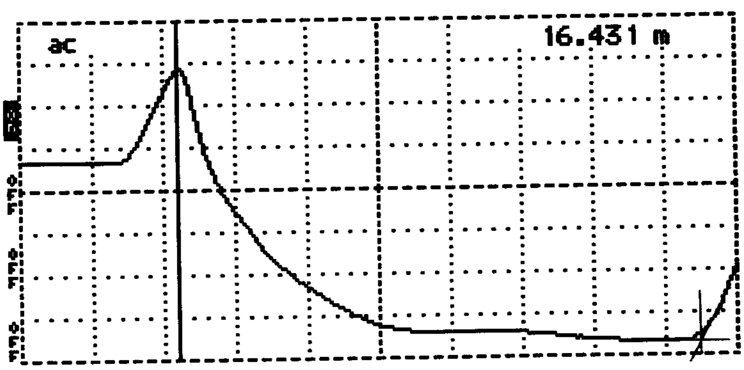


Tektronix 1502B TDR
Date 8/25/93
Cable #9
Notes in methyl alcohol @ 24.0°C

Input Trace
Stored Trace
Difference Trace

ce Number 5 - Probe in Water

sor .... 16.431 m
tance/Div..... .25 m/div
tical Scale.... 66.7 mρ/div
.... 0.99
se Filter...... 1 avg
`........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #9
Notes in water @ 22.5°C

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

LTPP Seasonal Monitoring Study	State Code	[25]
TDR Probe Calibration	Test Section Number	[1002]

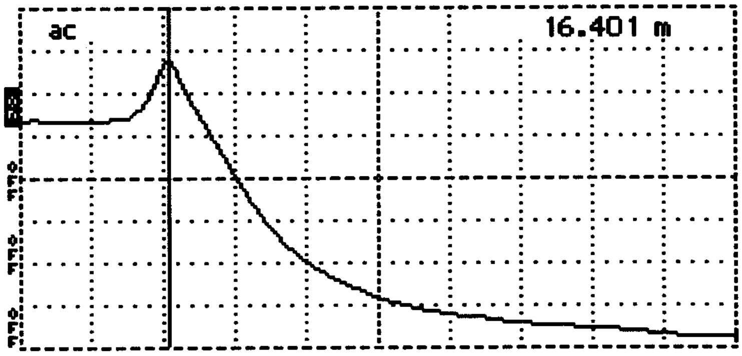
efore Operation Checks

- Calibration Date 8/25/93
- Probe S/N 25A10

Probe Number 10

DR Trace 1 - Beginning Probe Shorted

Cursor .... 16.401 m
Distance/Div ..... .25 m/div
Vertical Scale.... 163 mρ/div
Vp 0.99
Noise Filter ...... 1 avg
Power .... ac

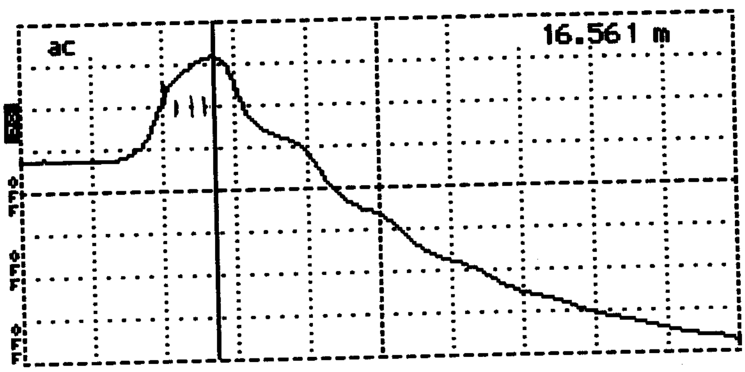


Tektronix 1502B TDR
Date 8/25/93
Cable #10
Notes shorted at C.B.

Input Trace
Stored Trace
Difference Trace

ace Number 2 - Ending Probe Shorted

ursor .... 16.561 m
istance/Div ..... .25 m/div
ertical Scale.... 163 mρ/div
/p 0.99
loise Filter ...... 1 avg
ower .... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #10
Notes shorted at far end

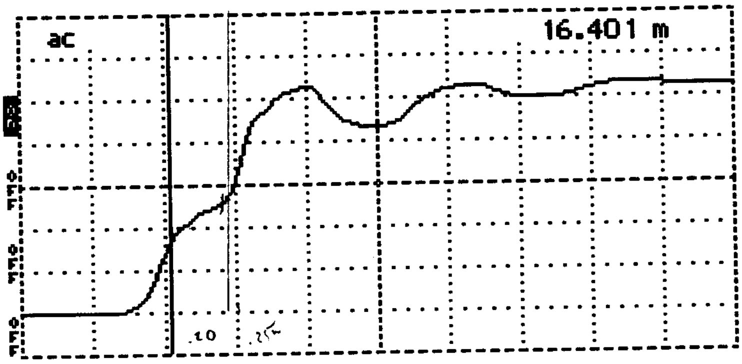
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

Probe Number 10 (cont.)

ce Number 3 - Probe in Air

ursor .... 16.401 m
istance/Div..... .25 m/div
ertical Scale.... 163 mρ/div
P 0.99
oise Filter...... 1 avg
ower........... ac

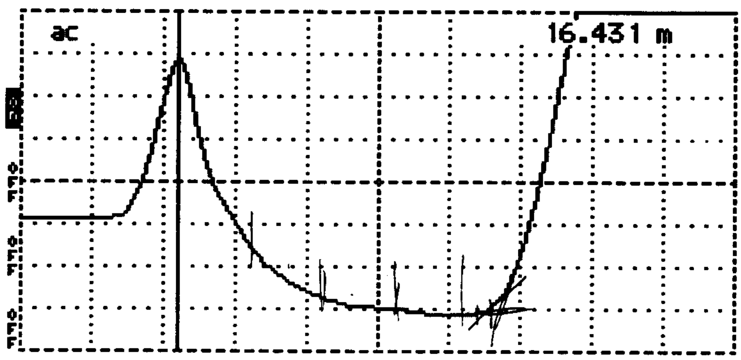


Tektronix 1502B TDR
Date 8/25/93
Cable #10
Notes in air @ 26.8

Input Trace
Stored Trace
Difference Trace

ce Number 4 - Probe in Alcohol

or .... 16.431 m
stance/Div..... .25 m/div
rtical Scale.... 50.0 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac

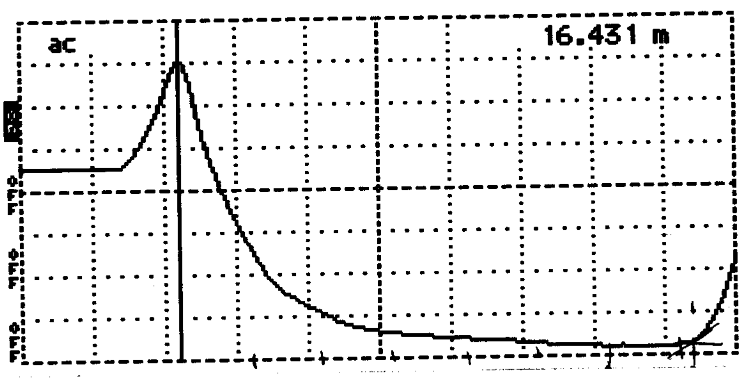


Tektronix 1502B TDR
Date 8/25/93
Cable #10
Notes in methyl alcoh
@ 24.0°C

Input Trace
Stored Trace
Difference Trace

ce Number 5 - Probe in Water

ursor .... 16.431 m
istance/Div..... .25 m/div
ertical Scale.... 66.7 mρ/div
P 0.99
loise Filter...... 1 avg
er........... ac



Tektronix 1502B TDR
Date 8/25/93
Cable #10
Notes in water @
22.5°C
1.8m

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

APPENDIX C

Supporting Instrumentation Installation Information

Appendix C contains the following supporting information:

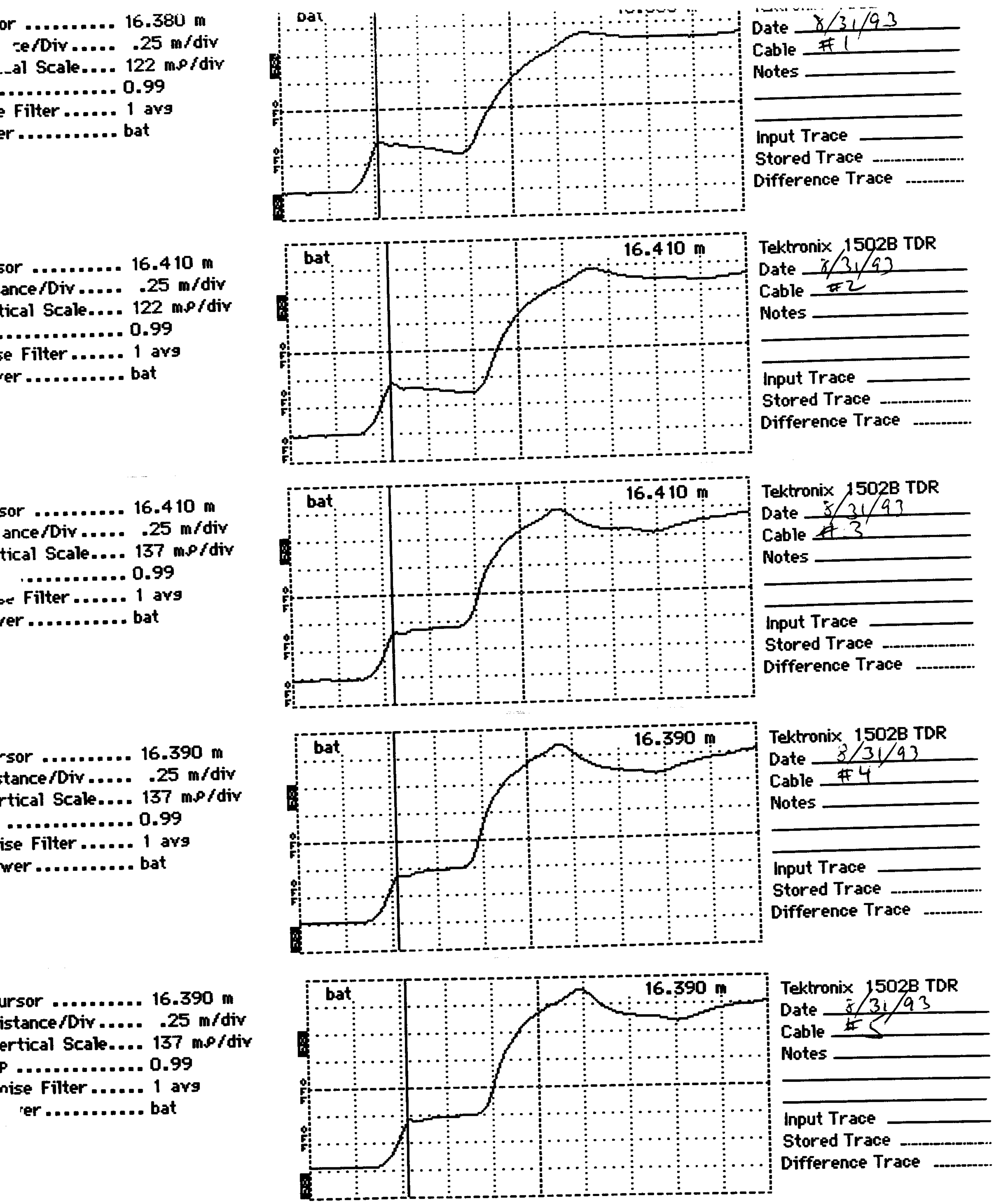
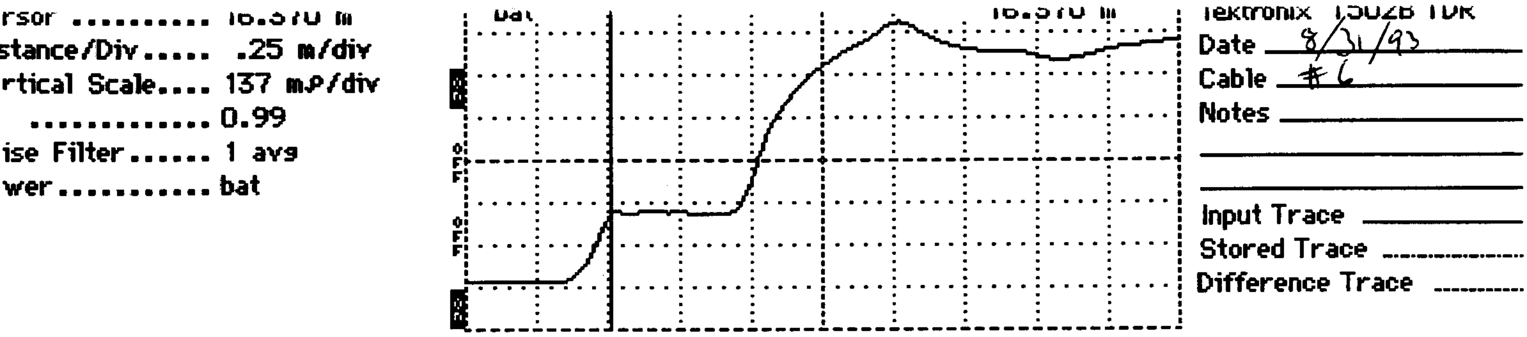
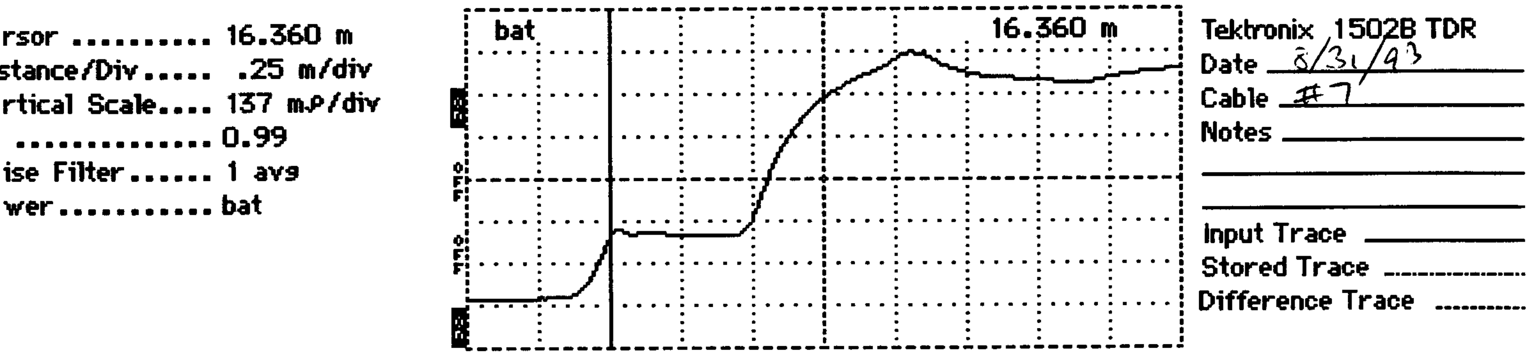
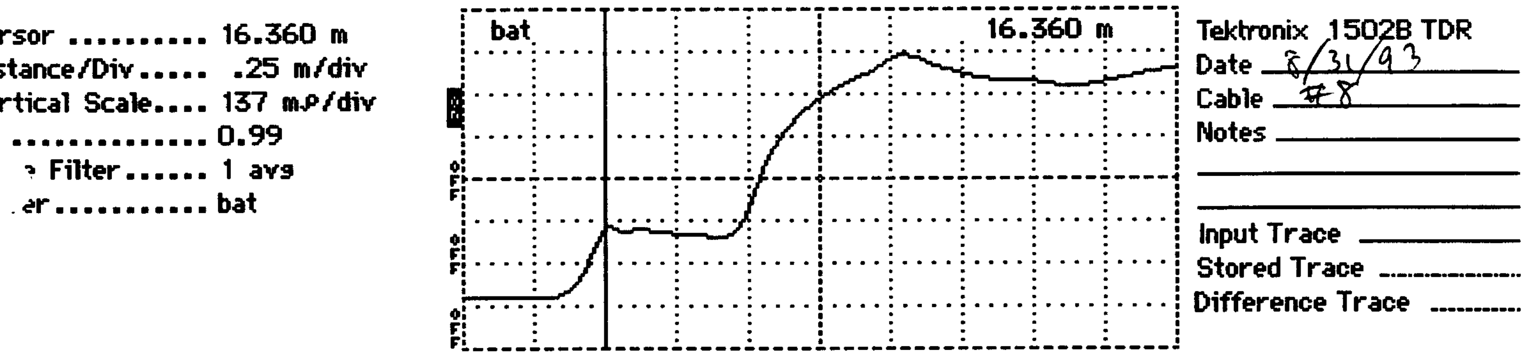
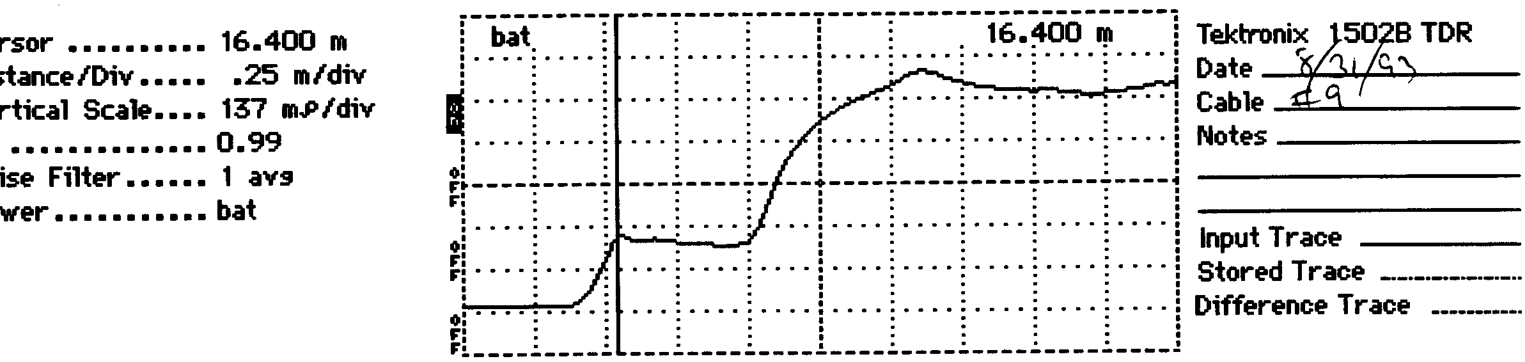


Figure C-1. TDR Traces Measured Manually During Installation









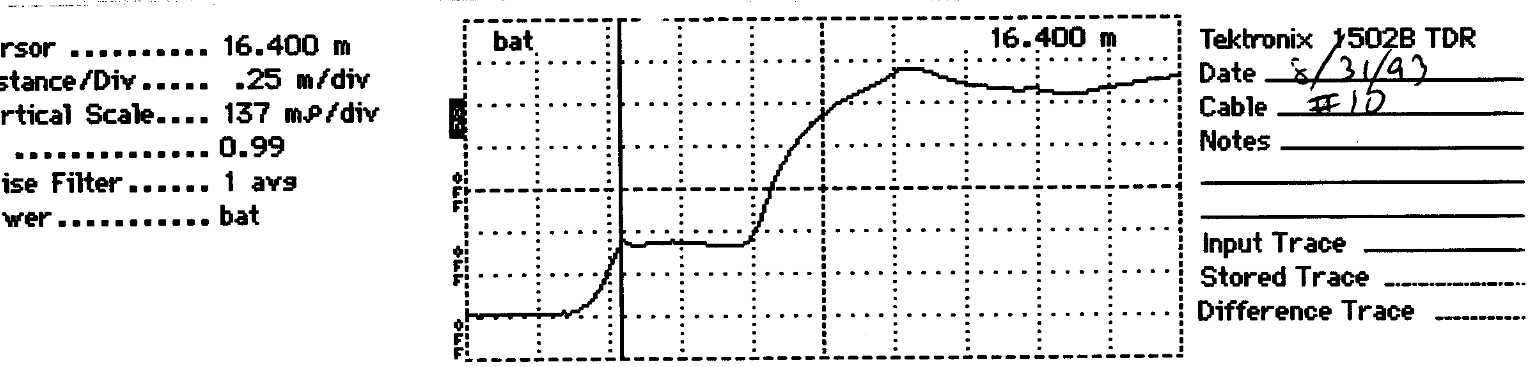


Figure C-1(cont.). TDR Traces Measured Manually During Installation

Table C-1. TDR Moisture Content

TDR No.	TDR Length (m)	Dielectric Constant (ε)	Volumetric Moisture Content (%)	In-Situ Dry Density (kg/m³)	Gravimetric Moisture Content (%)
25A01	0.450	5.01	8.06	1.94	4.16
25A02	0.450	5.01	8.06	2.03	3.97
25A03	0.370	3.39	4.02	1.79	2.24
25A04	0.390	3.77	4.98	1.79	2.78
25A05	0.420	4.37	6.48	1.79	3.62
25A06	0.420	4.37	6.48	1.79	3.62
25A07	0.470	5.47	9.15	1.79	5.11
25A08	0.440	4.79	7.53	1.79	4.21
25A09	0.450	5.01	8.06	1.79	4.50
25A10	0.440	4.79	7.53	1.79	4.21

Table C-2. Field Measured Moisture Content

LTPP Seasonal Monitoring Study	State Code	[25]
In-Situ Moisture Tests	Test Section Number	[1002]

Weight (gms)	Probe 1	Probe 2	Probe 3	Probe 4	Probe 5
Weight of Pan + Wet Soil	270.1	249.5	315.0	216.1	265.4
Weight of Pan + Dry Soil	266.1	246.5	310.7	214.0	261.1
Weight of Pan	120.9	120.9	120.9	121.0	120.5
Weight of Dry Soil	145.2	125.6	189.8	93.0	140.6
Weight of Wet Soil	149.2	128.6	194.1	95.1	144.9
Weight of Moisture	4.0	3.0	4.3	2.1	4.3
Wt of Moisture/Dry Wt x 100	2.75	2.39	2.27	2.26	3.06

Weight (gms)	Probe 6	Probe 7	Probe 8	Probe 9	Probe 10
Weight of Pan + Wet Soil	405.4	342.2	167.1	428.2	289.8
Weight of Pan + Dry Soil	397.6	334.0	165.1	413.7	283.5
Weight of Pan	120.8	120.8	121.1	120.8	120.7
Weight of Dry Soil	276.8	213.2	44.0	292.9	162.8
Weight of Wet Soil	284.6	221.4	46.0	307.4	169.1
Weight of Moisture	7.8	8.2	2.0	14.5	6.3
Wt of Moisture/Dry Wt x 100	2.82	3.85	4.55	4.95	3.87

APPENDIX D

Initial Data Collection

Appendix D contains the following supporting information:

Table D-1. Data from the Onsite Datalogger During Initial Data Collection, September 1, 1993

4,244,1618,23.05,0
5,244,1618,34.23,33.84,31.37,29.6,29.09
4,244,1619,23.13,.4
5,244,1619,34.19,33.82,31.37,29.59,29.08
4,244,1620,23.04,1.9
5,244,1620,34.15,33.81,31.38,29.6,29.08
4,244,1621,22.93,1.7
5,244,1621,34.06,33.79,31.4,29.58,29.09
6,244,1621,-345.2,-584.4,-815,-1038,-1253,-1446,-1601,-1711,-1782,-1826,-1851,-1867,-1875,-1879,-1882,-1883,-1884,-1884,-1884,-1837,-1858,-1870,-1878,-1881,-1884,-1885,-1886,-1886,-1839,-1860,-1825,-1853,-1868,-1877,-1882
4,244,1622,22.87,1.4
5,244,1622,34.02,33.76,31.38,29.62,29.09
4,244,1623,22.95,1.3
5,244,1623,33.96,33.74,31.38,29.61,29.08
1,1993,244,23.02,23.22,1623,22.83,1621,7.7,-6999,-6999,1618,-6999,1618,34.04,33.77,31.38,29.61,29.08,28.88,28.79,28.7,28.29,27.7,27.01,26.3,25.63,25.06,24.47,23.8,23.18,22.6
2,1993,244,34.23,1618,33.84,1618,31.4,1619,29.63,1621,29.09,1618,28.91,1623,28.81,1618,28.71,1618,28.3,1618,27.71,1618,27.02,1618,26.33,1618,25.63,1618,25.07,1618,24.47,1618,23.8,1618,23.18,1618,22.61,1618
3,1993,244,33.87,1623,33.69,1623,31.37,1618,29.58,1619,29.07,1618,28.86,1618,28.76,1621,28.68,1623,28.27,1618,27.66,1622,26.99,1619,26.27,1621,25.61,1619,25.04,1618,24.45,1618,23.78,1621,23.15,1623,22.58,1618
4,244,1624,23.19,1
5,244,1624,33.89,33.71,31.39,29.62,29.08
6,244,1625,-1110,-1321,-1507,-1649,-1743,-1803,-1839,-1811,-1844,-1863,-1873,-1879,-1882,-1884,-1838,-1860,-1870,-1877,-1880,-1883,-1884,-1886,-1886,-1886,-1887,-1887,-1888,-1886,-1886,-1886,-1886,-1886,-1886,-1886,-1886
4,244,1625,23.14,.7
5,244,1625,33.82,33.69,31.39,29.62,29.11
4,244,1626,23.14,.6
5,244,1626,33.74,33.67,31.4,29.63,29.1
4,244,1627,23.1,0
5,244,1627,33.71,33.65,31.41,29.63,29.11
4,244,1628,23.14,0
5,244,1628,33.64,33.62,31.42,29.65,29.1

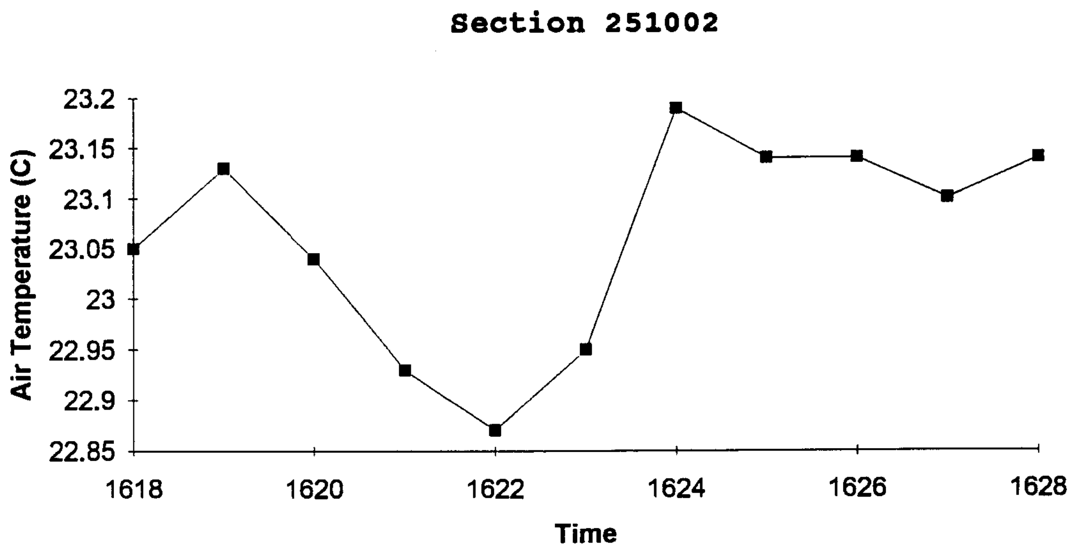


Figure D-1. Measured Air Temperature
During Initial Data Collection, September 1, 1993

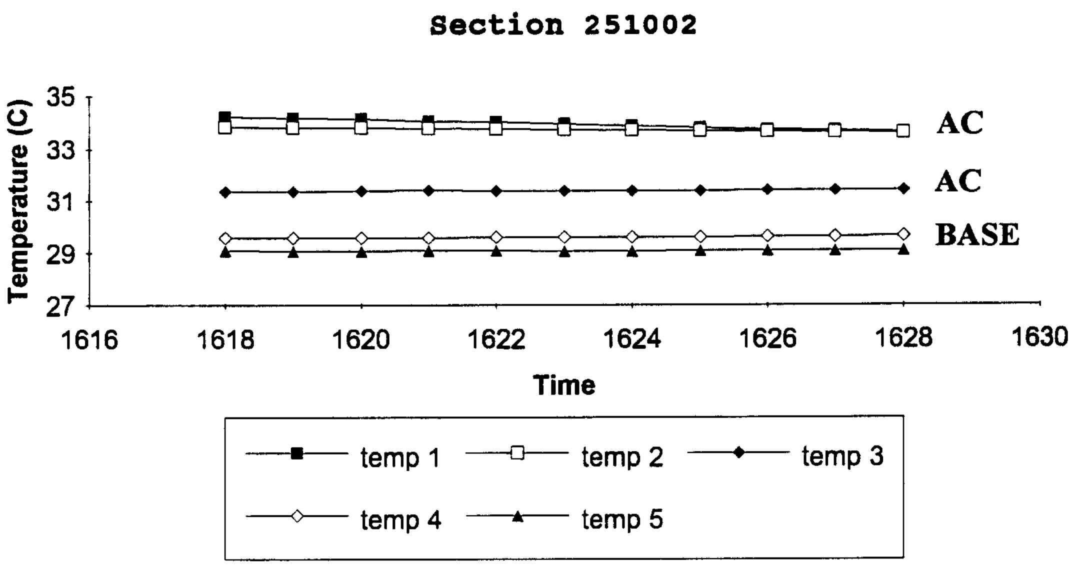


Figure D-2. Measured Subsurface Temperature for the First 5 Sensors During Initial Data Collection, September 1, 1993

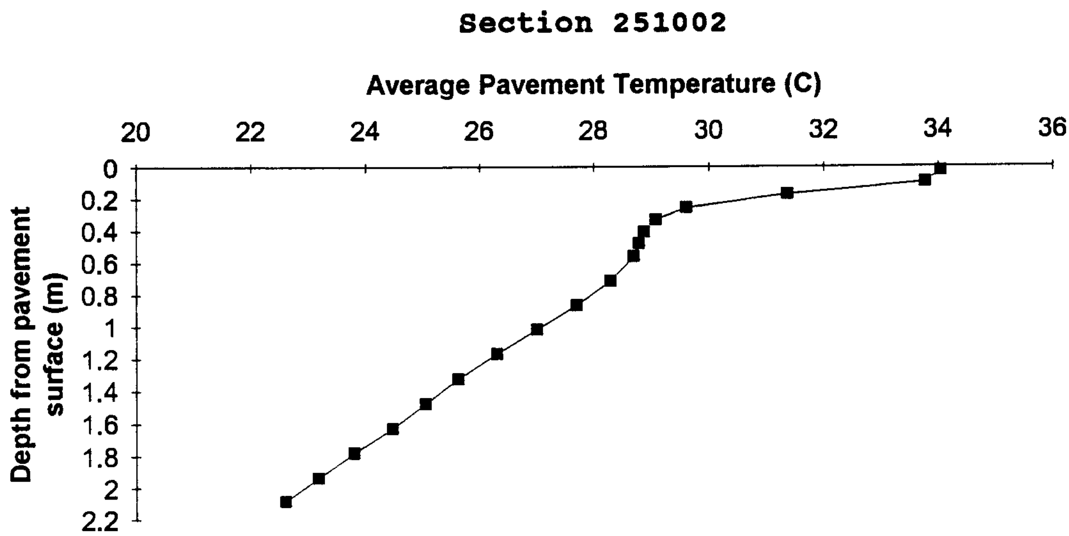


Figure D-3. Measured Subsurface Temperature for All 18 Sensors During Initial Data Collection, September 1, 1993

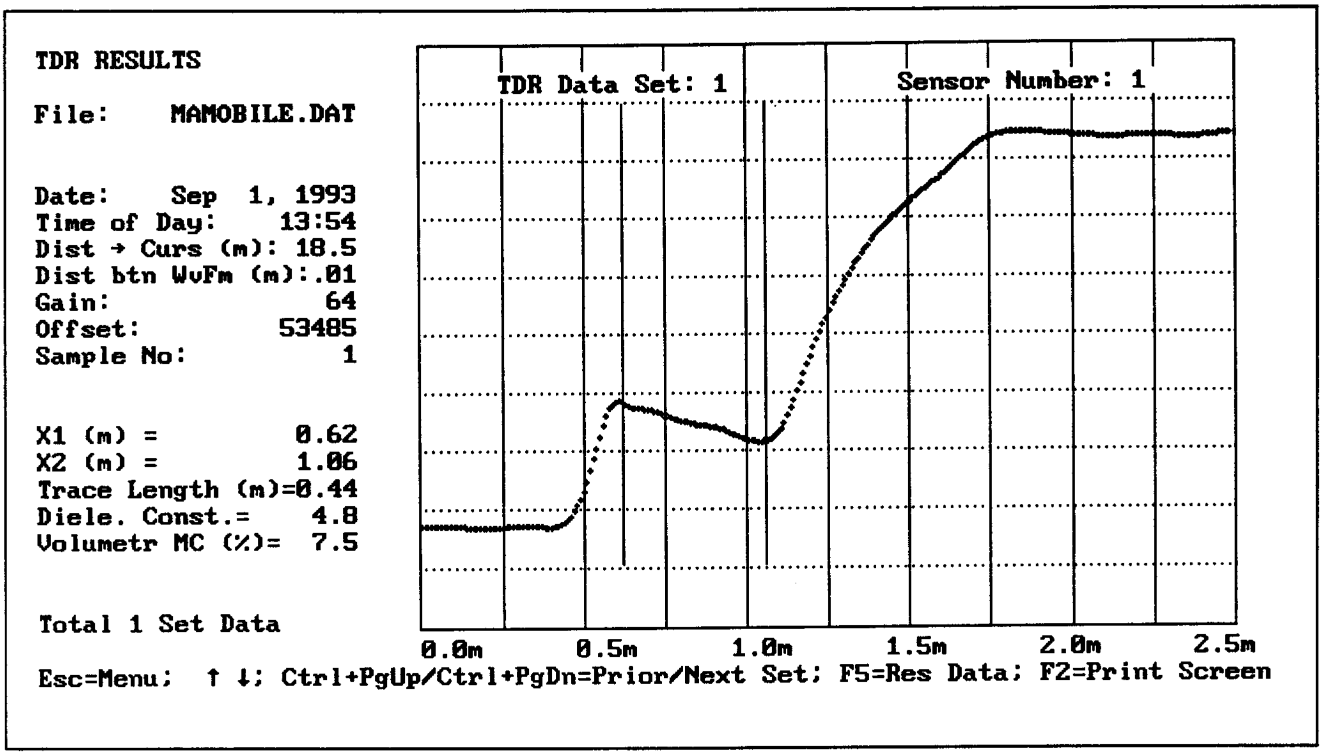


Figure D-4. Initial Set of TDR Traces Measured with the Mobile Unit

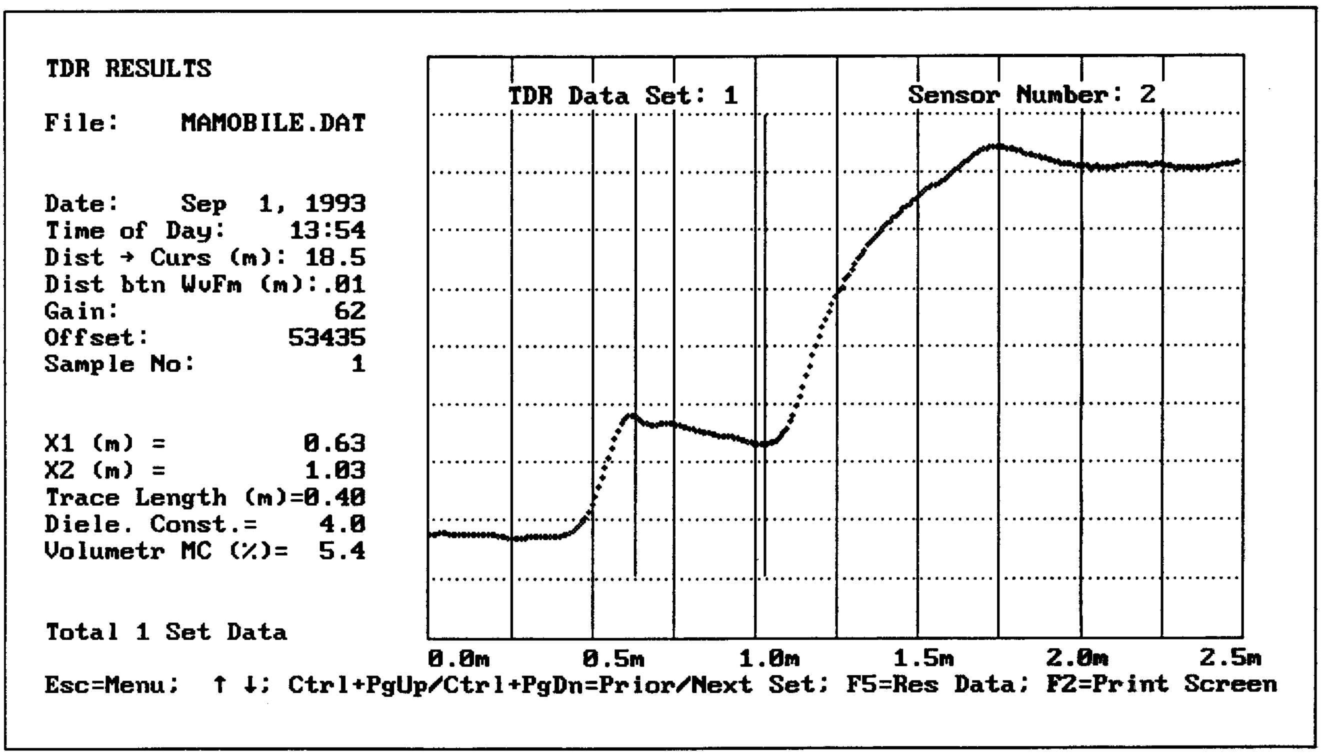


Figure D-4(cont.). Initial Set of TDR Traces Measured with the Mobile Unit

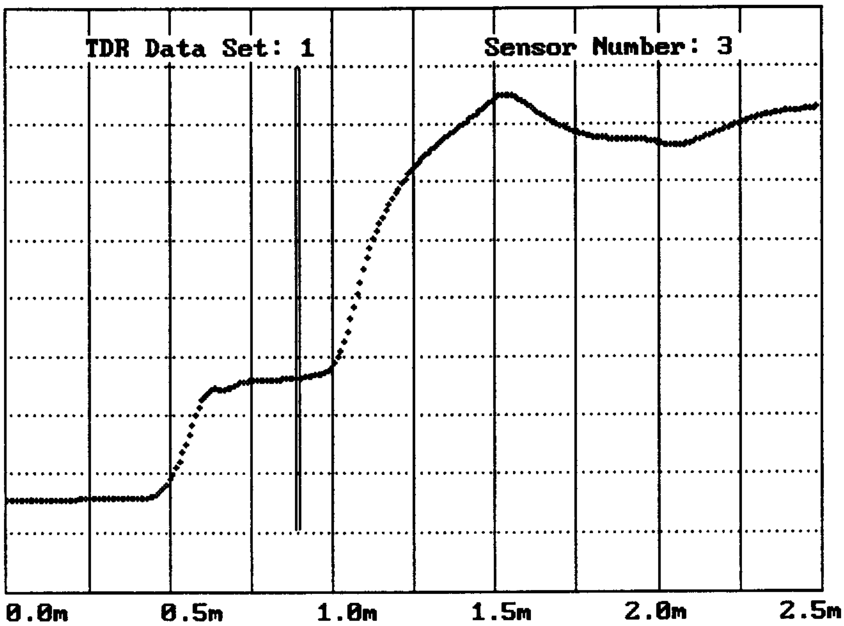
TDR RESULTS

File: MAMOBILE.DAT

Date: Sep 1, 1993
Time of Day: 13:55
Dist → Curs (m): 18.5
Dist btn WvFm (m):.01
Gain: 57
Offset: 53243
Sample No: 1

X1 (m) = 0.89
X2 (m) = 0.90
Trace Length (m)=0.01
Diele. Const.= 0.0
Volumetr MC (%)= -5.3

Total 1 Set Data



Esc=Menu; ↑ ↓; Ctrl+PgUp/Ctrl+PgDn=Prior/Next Set; F5=Res Data; F2=Print Screen

Figure D-4(cont.). Initial Set of TDR Traces Measured with the Mobile Unit

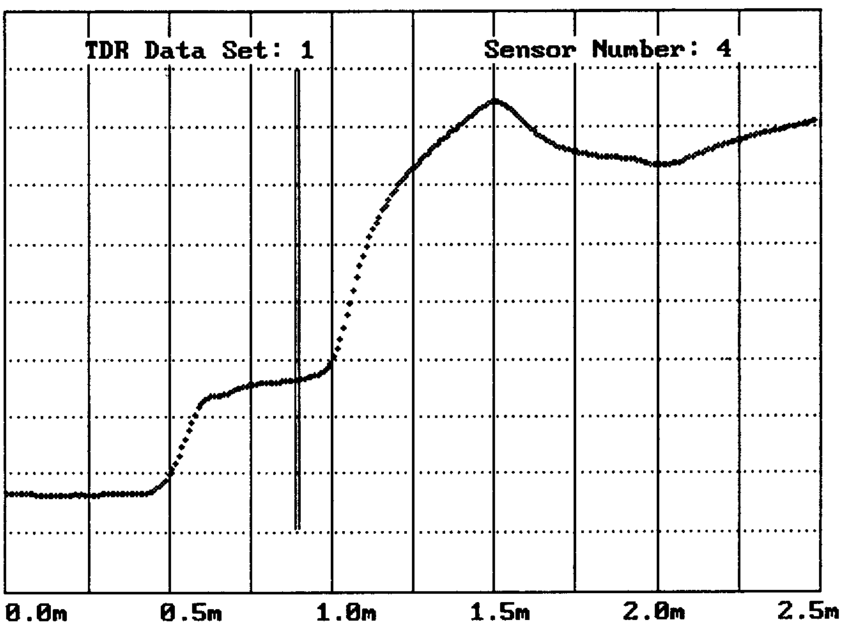
TDR RESULTS

File: MAMOBILE.DAT

Date: Sep 1, 1993
Time of Day: 13:56
Dist → Curs (m): 18.5
Dist btn WvFm (m):.01
Gain: 54
Offset: 53178
Sample No: 1

X1 (m) = 0.89
X2 (m) = 0.90
Trace Length (m)=0.01
Diele. Const.= 0.0
Volumetr MC (%)= -5.3

Total 1 Set Data



Esc=Menu; ↑ ↓; Ctrl+PgUp/Ctrl+PgDn=Prior/Next Set; F5=Res Data; F2=Print Screen

Figure D-4(cont.). Initial Set of TDR Traces Measured with the Mobile Unit

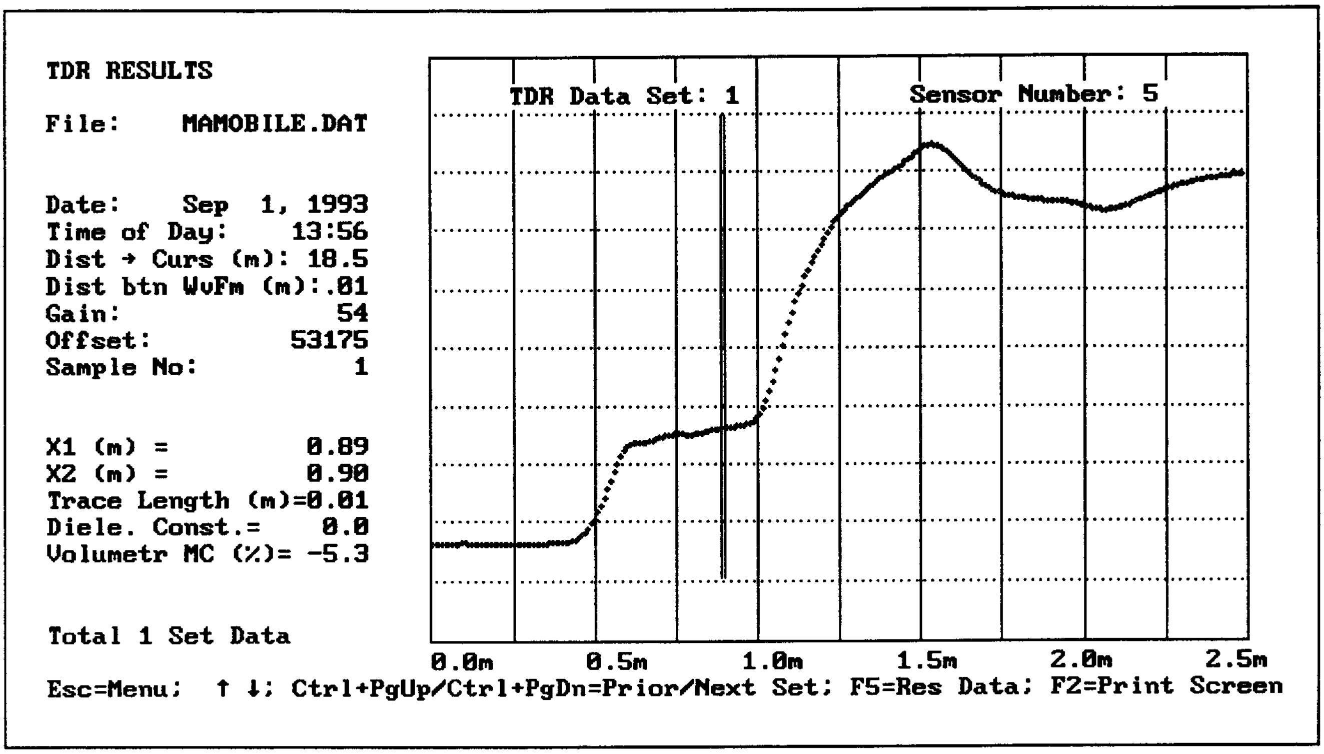


Figure D-4(cont.). Initial Set of TDR Traces Measured with the Mobile Unit

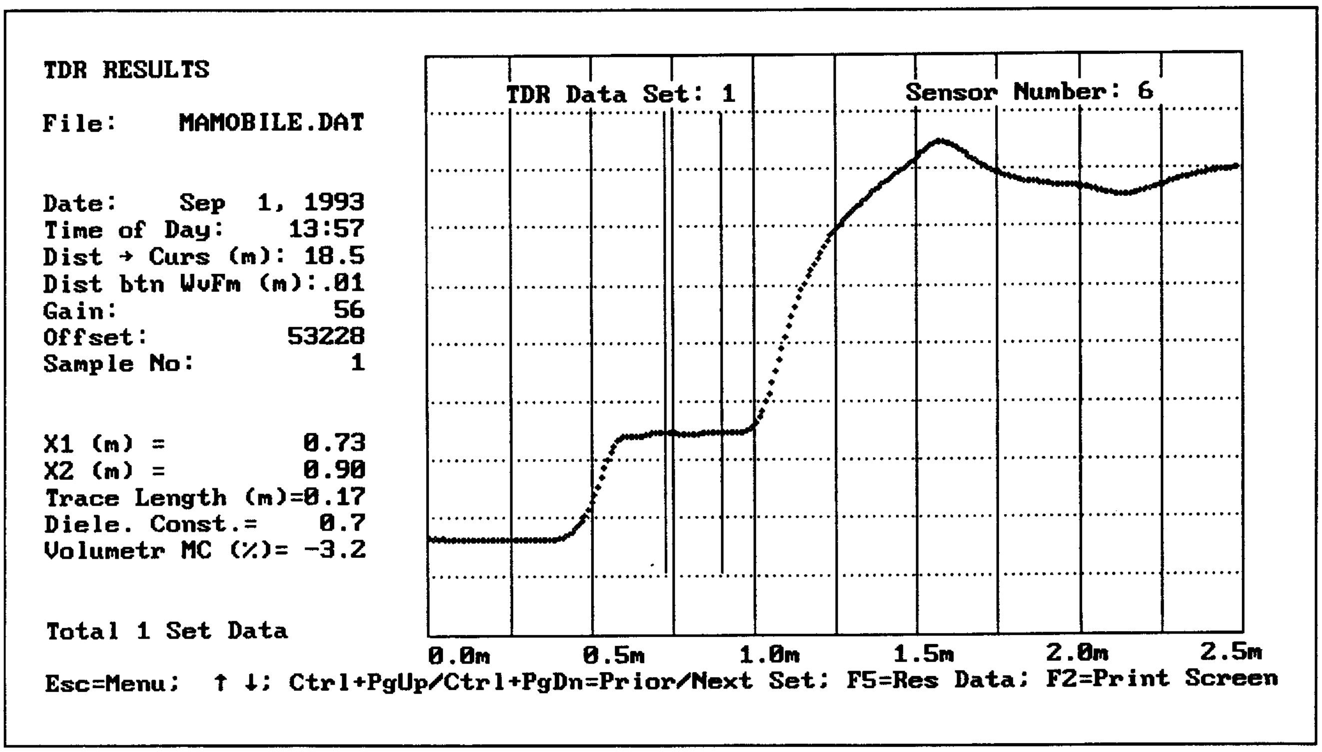


Figure D-4(cont.). Initial Set of TDR Traces Measured with the Mobile Unit

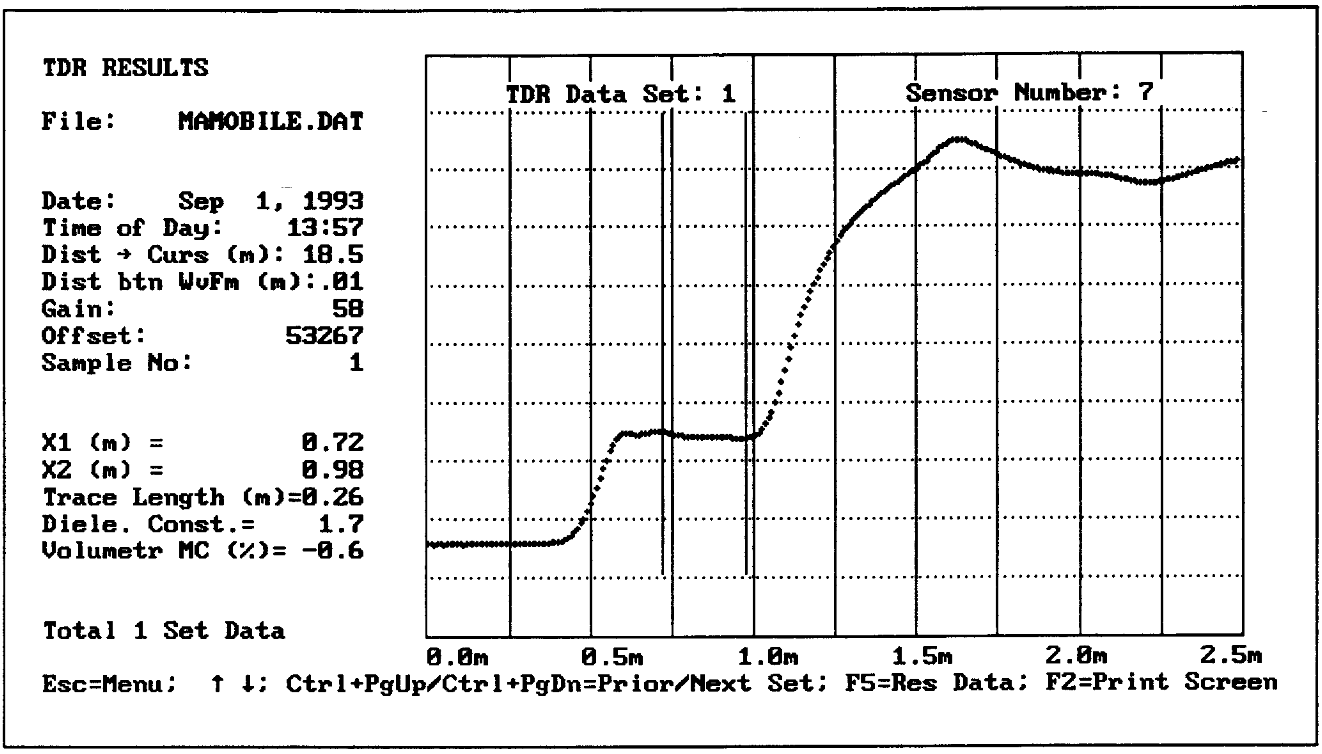


Figure D-4(cont.). Initial Set of TDR Traces Measured with the Mobile Unit

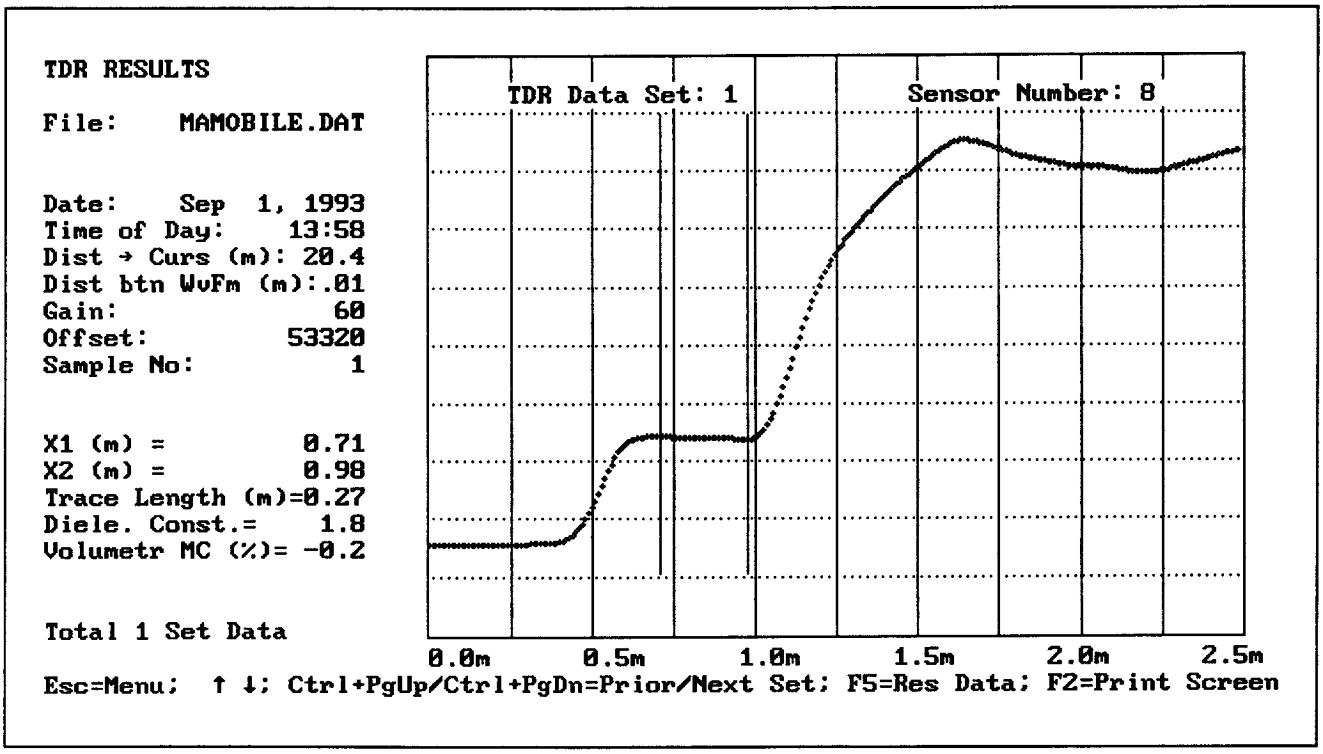


Figure D-4(cont.). Initial Set of TDR Traces Measured with the Mobile Unit

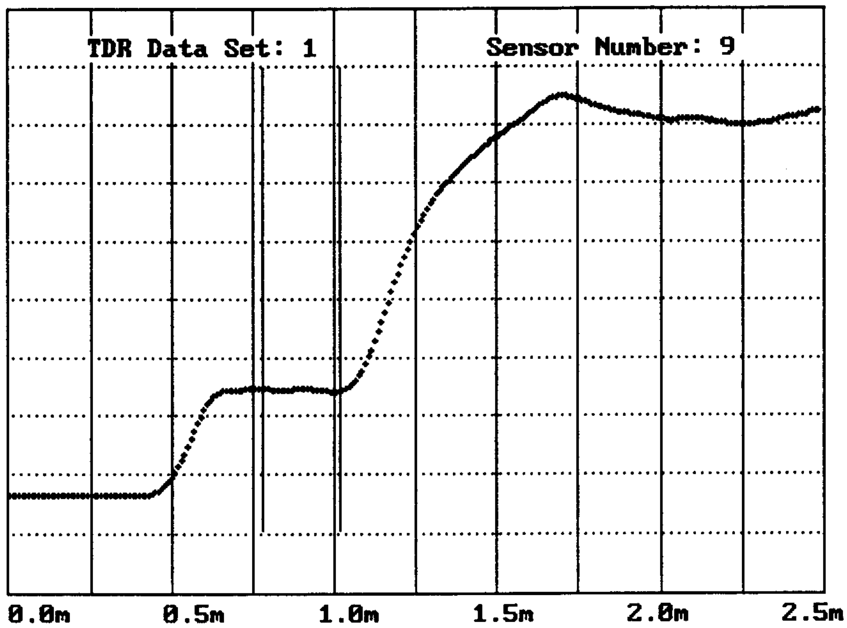
TDR RESULTS

File: MAMOBILE.DAT

Date: Sep 1, 1993
Time of Day: 13:58
Dist → Curs (m): 20.4
Dist btn WvFm (m): .01
Gain: 60
Offset: 53361
Sample No: 1

X1 (m) = 0.78
X2 (m) = 1.02
Trace Length (m)=0.24
Diele. Const.= 1.4
Volumetr MC (%)= -1.3

Total 1 Set Data



Esc=Menu; ↑ ↓; Ctrl+PgUp/Ctrl+PgDn=Prior/Next Set; F5=Res Data; F2=Print Screen

Figure D-4(cont.). Initial Set of TDR Traces Measured with the Mobile Unit

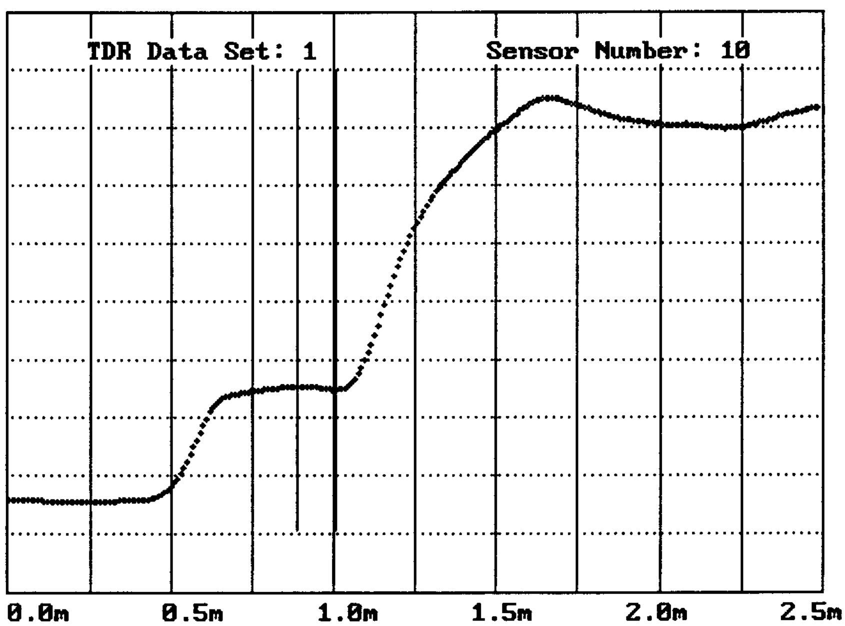
TDR RESULTS

File: MAMOBILE.DAT

Date: Sep 1, 1993
Time of Day: 13:59
Dist → Curs (m): 20.4
Dist btn WvFm (m): .01
Gain: 60
Offset: 53334
Sample No: 1

X1 (m) = 0.89
X2 (m) = 1.01
Trace Length (m)=0.12
Diele. Const.= 0.4
Volumetr MC (%)= -4.3

Total 1 Set Data



Esc=Menu; ↑ ↓; Ctrl+PgUp/Ctrl+PgDn=Prior/Next Set; F5=Res Data; F2=Print Screen

Figure D-4(cont.). Initial Set of TDR Traces Measured with the Mobile Unit

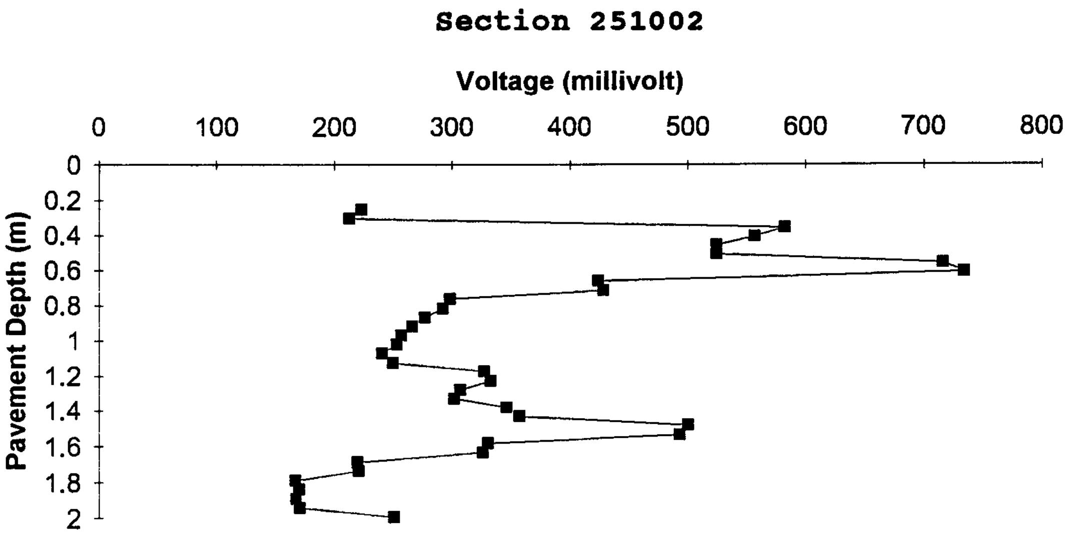


Figure D-5. Voltages Measured Using the Mobile System
During Initial Data Collection, September 1, 1993

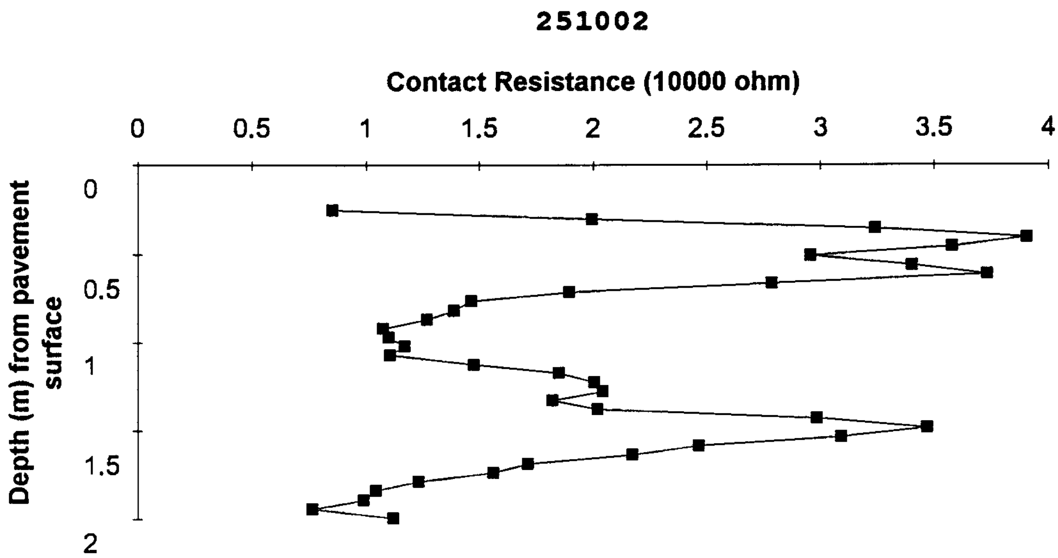


Figure D-6. Manually Collected Contact Resistance
During Initial Data Collection, September 1, 1993

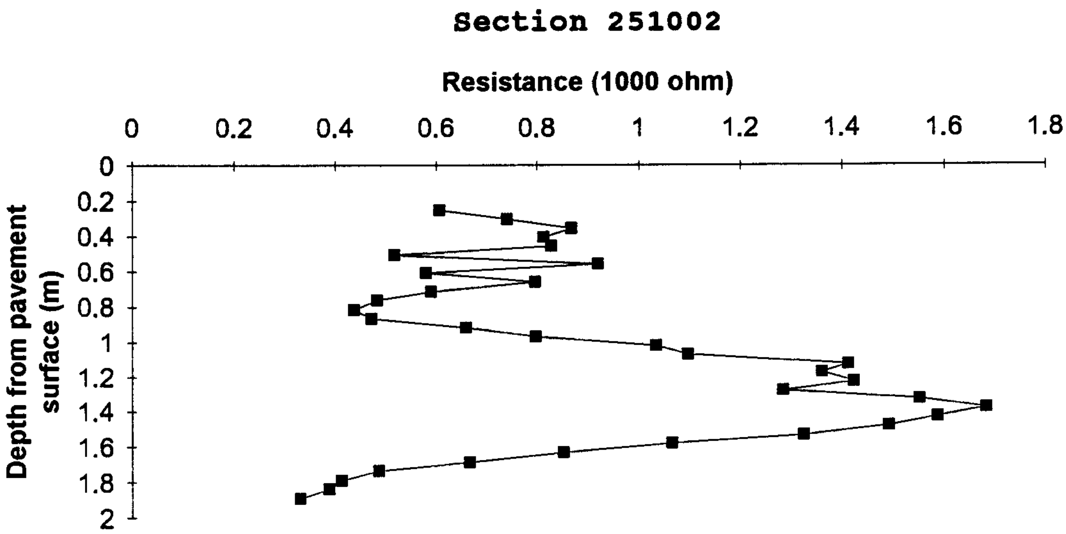


Figure D-7. Manually Collected Four Point Resistivity During Initial Data Collection, September 1, 1993

Table D-2. Contact Resistance After Installation

LTPP Seasonal Monitoring Study	State Code	[25]
Data Sheet R1		
Contact Resistance Measurements	Test Section Number	[1002]

1. Date (Month-Day-Year)	[09-01-93]
2. Time Measurements Began (Military)	[17:30]
3. Comments	After Installation * Note: Known Resistors

Test Position	Connections		Voltage (ACV)		Current (ACA)		notes
	I V	I V	Range Setting	Reading	Range Setting	Reading	
1	1	2	mV	330.4	uA	38.7	
2	3	2	mV	345.0	uA	17.3	
3	3	4	mV	349.9	uA	10.8	
4	5	4	mV	351.2	uA	9.0	
5	5	6	mV	350.7	uA	9.8	
6	7	6	mV	349.1	uA	11.8	
7	7	8	mV	350.4	uA	10.3	
8	9	8	mV	350.7	uA	9.4	
9	9	10	mV	348.6	uA	12.5	
10	11	10	mV	344.8	uA	18.2	
11	11	12	mV	341.3	uA	23.3	
12	13	12	mV	340.4	uA	24.5	
13	13	14	mV	338.9	uA	26.7	
14	15	14	mV	335.6	uA	31.2	
15	15	16	mV	336.2	uA	30.6	
16	17	16	mV	337.4	uA	28.8	
17	17	18	mV	336.3	uA	30.4	
18	19	18	mV	341.3	uA	23.1	
19	19	20	mV	344.4	uA	18.6	
20	21	20	mV	345.3	uA	17.2	
21	21	22	mV	345.4	uA	16.9	
22	23	22	mV	344.2	uA	18.9	
23	23	24	mV	345.5	uA	17.1	
24	25	24	mV	349.3	uA	11.7	
25	25	26	mV	350.6	uA	10.1	
26	27	26	mV	349.5	uA	11.3	
27	27	28	mV	347.5	uA	14.1	
28	29	28	mV	350.0	uA	16.1	
29	29	30	mV	343.2	uA	20.0	
30	31	30	mV	341.8	uA	21.9	
31	31	32	mV	338.0	uA	27.4	
32	33	32	mV	334.9	uA	32.1	
33	33	34	mV	333.9	uA	33.7	
34	35	34	mV	327.6	uA	42.8	
35	35	36	mV	336.3	uA	30.0	
36 *	37	38	mV	355.1	uA	0.8	
37 *	38	39	mV	212.0	uA	213.2	
38 *	39	40	mV	0.831	uA	531.0	

Preparer:	Perry Zabaldo	Employer:	PMSL

Table D-3. Four-Point Resistivity After Installation

LTPP Seasonal Monitoring Study	State Code	[2 5]
Data Sheet R2		
Four-Point Resistivity Measurements	Test Section Number	[1 0 0 2]

1. Date (Month-Day-Year)	[09-01-93]
2. Time measurements Began (Military)	[18:15]
3. Comments	After Installation

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	mV	8.37	uA	13.8	
2	2	3	4	5	mV	8.37	uA	11.3	
3	3	4	5	6	mV	9.63	uA	11.1	
4	4	5	6	7	mV	7.88	uA	9.7	
5	5	6	7	8	mV	6.54	uA	7.9	
6	6	7	8	9	mV	5.22	uA	10.1	
7	7	8	9	10	mV	11.30	uA	12.3	
8	8	9	10	11	mV	6.56	uA	11.3	
9	9	10	11	12	mV	10.43	uA	13.1	
10	10	11	12	13	mV	10.40	uA	17.6	
11	11	12	13	14	mV	11.44	uA	23.7	
12	12	13	14	15	mV	11.48	uA	26.3	
13	13	14	15	16	mV	13.70	uA	29.1	
14	14	15	16	17	mV	17.73	uA	26.9	
15	15	16	17	18	mV	23.22	uA	29.1	
16	16	17	18	19	mV	20.36	uA	19.7	
17	17	18	19	20	mV	22.36	uA	20.4	
18	18	19	20	21	mV	25.84	uA	18.3	
19	19	20	21	22	mV	22.17	uA	16.3	
20	20	21	22	23	mV	23.78	uA	16.7	
21	21	22	23	24	mV	17.98	uA	14.0	
22	22	23	24	25	mV	17.08	uA	11.0	
23	23	24	25	26	mV	19.19	uA	11.4	
24	24	25	26	27	mV	20.00	uA	12.6	
25	25	26	27	28	mV	15.67	uA	10.5	
26	26	27	28	29	mV	14.71	uA	11.1	
27	27	28	29	30	mV	15.98	uA	15.0	
28	28	29	30	31	mV	13.37	uA	15.7	
29	29	30	31	32	mV	14.79	uA	22.2	
30	30	31	32	33	mV	11.19	uA	23.0	
31	31	32	33	34	mV	10.94	uA	26.5	
32	32	33	34	35	mV	14.38	uA	37.0	
33	33	34	35	36	mV	7.84	uA	23.8	

Preparer	MZ & PZ	Employer	PMSL

Table D-4. Uniformity Survey Results Before and After Installation

Seasonal Uniformity Survey	Falling Weight Deflectometer
Site Number: 251002	Data Collection and
Date Surveyed: August 31-September 1, 1993	Processing Summary

Section Interval (ft)	Mean Deflection Values for HT 2 (mils) Corrected								Mean Temp D1 (F)
	Sensor 1	Sensor 1 std dev	Sensor 7	Sensor 7 std dev	Subg modulus (psi)	Subg modulus std dev	Effective SN	SN std dev	
300 to 550 **August 31** @ 09:01 *	9.57	0.81	1.08	0.05	27670	2413	5.05	0.19	93.5
300 to 524 **Sept. 1** @ 09:02	9.51	0.63	1.08	0.04	27257	1647	5.08	0.17	83.0
300 to 524 **Sept. 1** @ 11:39	10.21	0.65	1.06	0.05	27397	1580	4.88	0.17	99.0
300 to 524 **Sept. 1** @ 13:48	10.88	0.75	1.05	0.05	28102	1744	4.69	0.16	105.4

* Note: station 500 not tested.

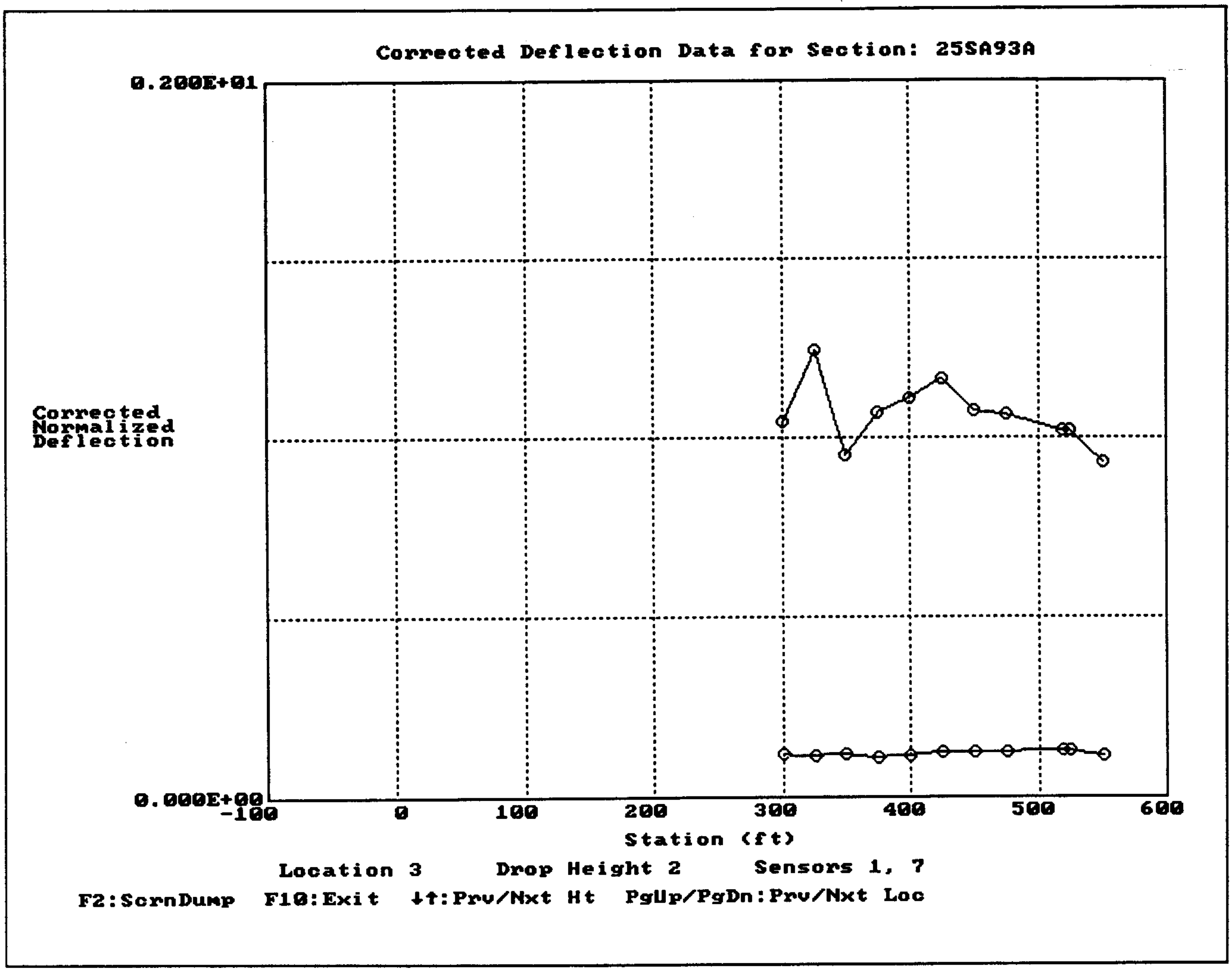


Figure D-8. Deflection Profile from FWDCHECK
(Test Date and Time August 31, 1993 @ 09:01)

Table D-5. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date and Time August 31, 1993 @ 09:01)

Flexible Pavement Thickness Statistics - 25SA93A - Drop Height 2			
Subsection	Station	Subgrade Modulus	Effective SN
1	300	24291	5.20
	325	25815	4.70
	350	26490	5.40
	375	28449	5.00
	400	27868	4.90
	425	26458	4.85
	450	27121	5.00
	475	28316	5.00
	519	28596	5.10
	524	27137	5.15
	550	33834	5.20
Subsection 1	Overall Mean	27670	5.05
	Standard Deviation	2413	0.19
	Coeff of Variation	8.72%	3.82%

Note: No test pit data found, therefore no results exist...
Note: Station 500 not tested.

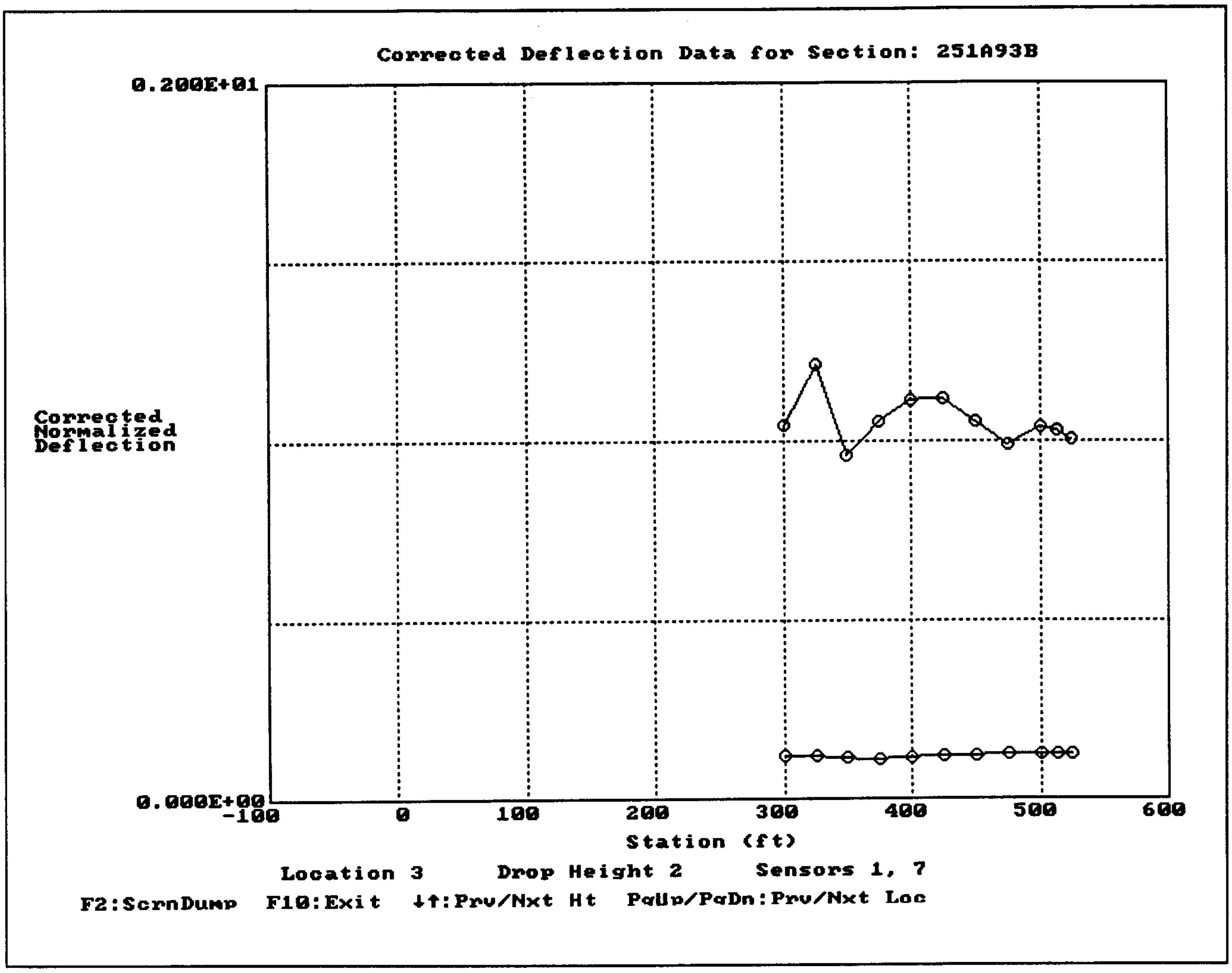


Figure D-9. Deflection Profile from FWDCHECK
(Test Date and Time September 1, 1993 @ 09:02)

Table D-6. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date and Time September 1, 1993 @ 09:02)

Flexible Pavement Thickness Statistics - 251A93B - Drop Height 2			
Subsection	Station	Subgrade Modulus	Effective SN
1	300	24893	5.20
	325	25228	4.80
	350	25667	5.40
	375	29188	5.00
	400	26700	4.95
	425	26895	4.90
	450	26437	5.10
	475	28863	5.20
	500	28479	5.05
	513	29625	5.05
	524	27854	5.20
Subsection 1	Overall Mean	27257	5.08
	Standard Deviation	1647	0.17
	Coeff of Variation	6.04%	3.31%

Note: No test pit data found, therefore no results exist...

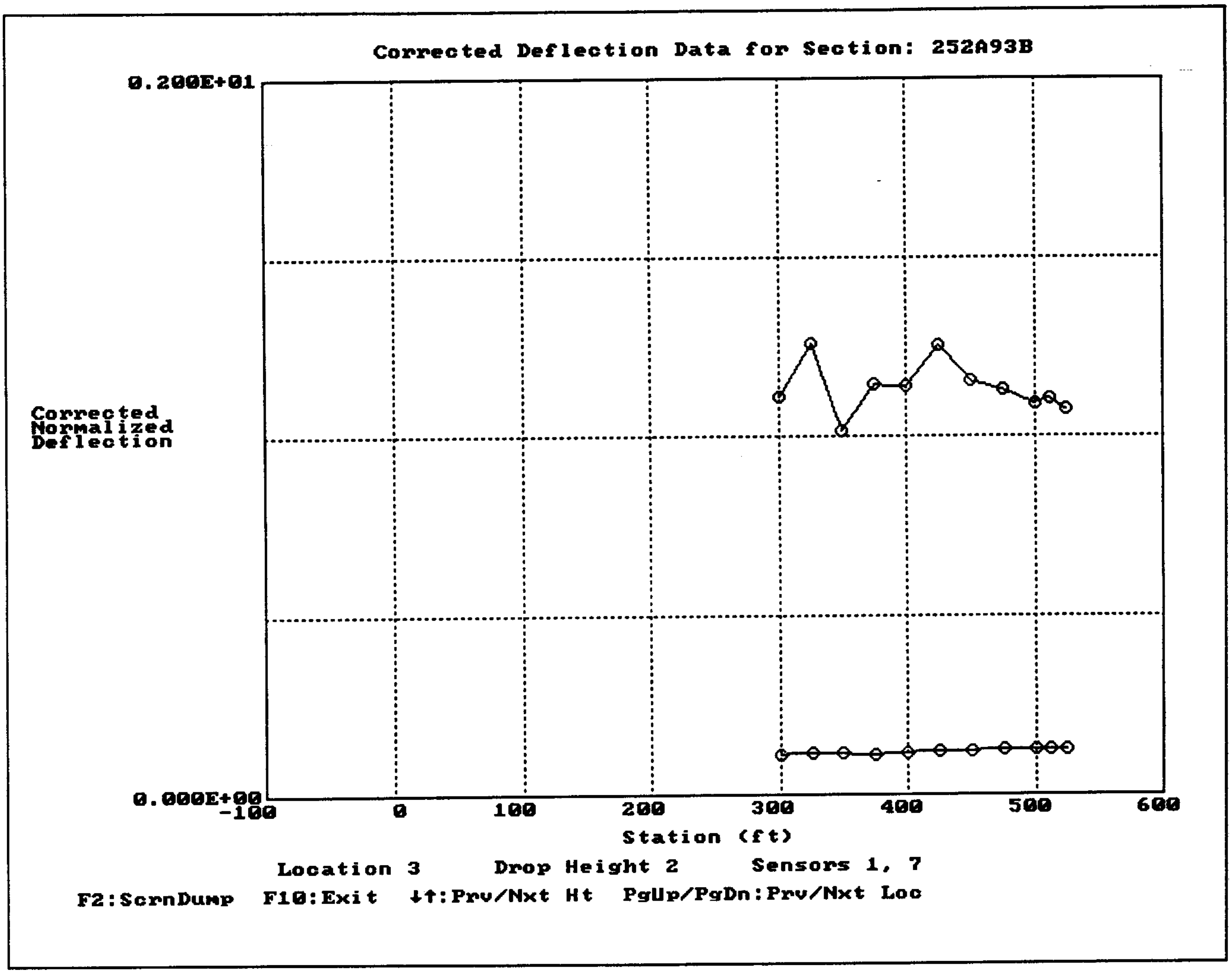


Figure D-10. Deflection Profile from FWDCHECK
(Test Date and Time September 1, 1993 @ 11:39)

Table D-7. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date and Time September 1, 1993 @ 11:39)

Flexible Pavement Thickness Statistics - 252A93B - Drop Height 2			
Subsection	Station	Subgrade Modulus	Effective SN
1	300	25235	5.00
	325	26417	4.65
	350	25752	5.25
	375	28736	4.80
	400	27809	4.85
	425	26312	4.65
	450	26475	4.85
	475	29051	4.85
	500	29002	4.90
	513	29982	4.85
	524	26601	5.05
Subsection 1	Overall Mean	27397	4.88
	Standard Deviation	1580	0.17
	Coeff of Variation	5.77%	3.53%

Note: No test pit data found, therefore no results exist...

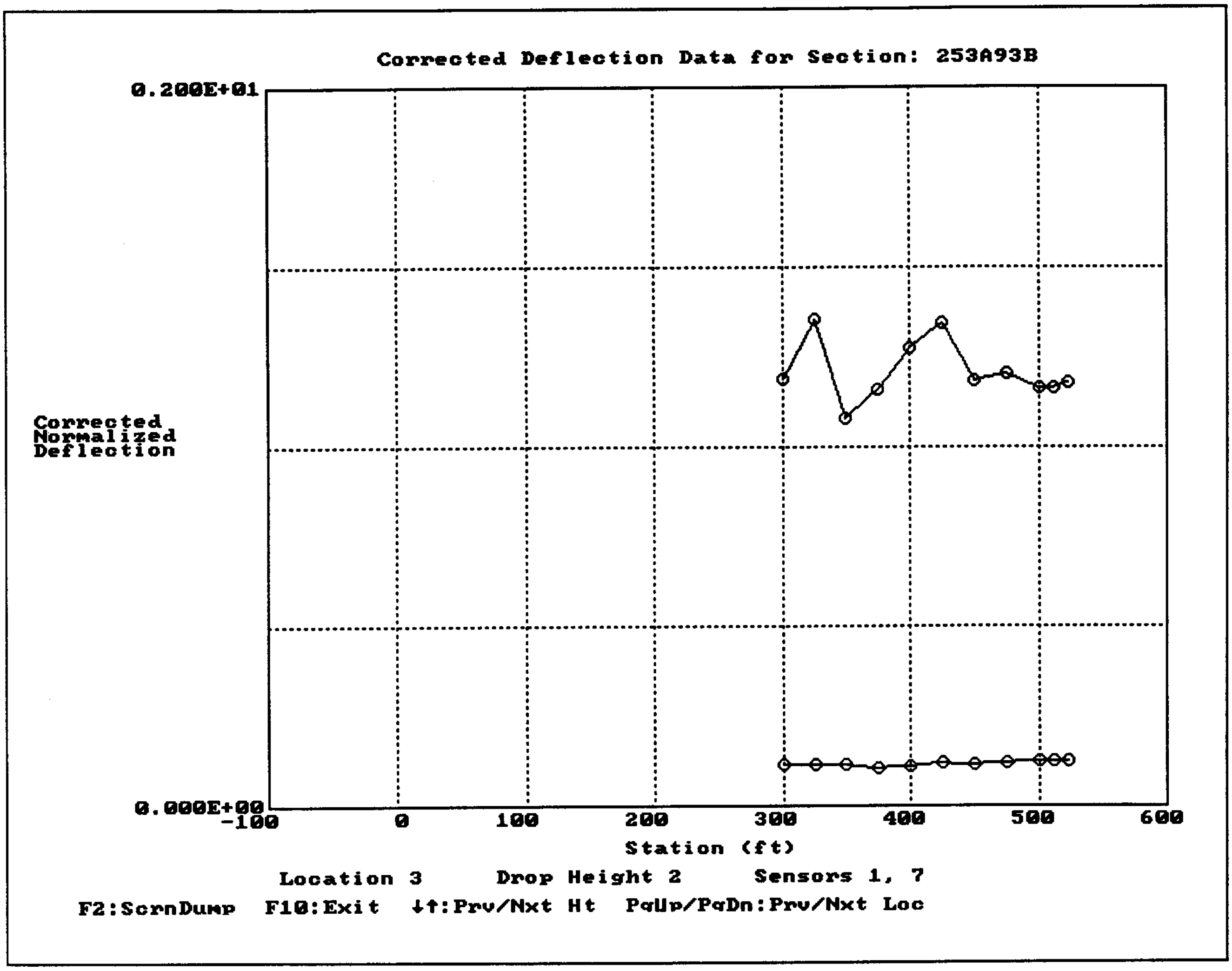


Figure D-11. Deflection Profile from FWDCHECK
(Test Date and Time September 1, 1993 @ 13:48)

Table D-8. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date and Time September 1, 1993 @ 13:48)

Flexible Pavement Thickness Statistics - 253A93B - Drop Height 2			
Subsection	Station	Subgrade Modulus	Effective SN
1	300	25491	4.80
	325	26186	4.45
	350	26901	5.00
	375	30210	4.75
	400	28243	4.55
	425	26784	4.45
	450	27218	4.75
	475	28610	4.70
	500	30561	4.70
	513	30334	4.70
	524	28581	4.75
Subsection 1	Overall Mean	28102	4.69
	Standard Deviation	1744	0.16
	Coeff of Variation	6.21%	3.40%

Note: No test pit data found, therefore no results exist...

Table D-9. Surface Elevation Measurements

LTPP Seasonal Monitoring Study	State Code	[25]
Surface Elevation Measurements	Test Section Number	[1002]

Survey Date	September 1, 1993
Surveyed By	MZ & PZ
Surface Type	A/C
Benchmark	Observation Piezometer - 1.000 meters - assumed

STATION		PE m offset 0.15m	OWP m offset 0.76m	ML m offset 1.68m	IWP m offset 2.59m	ILE m offset 3.20m
0+00	3+00	1.085	1.098	1.122	1.137	1.165
0+25	3+25	1.125	1.131	1.152	1.168	1.192
0+50	3+50	1.143	1.155	1.177	1.192	1.216
0+75	3+75	1.168	1.183	1.207	1.226	1.247
1+00	4+00	1.213	1.229	1.259	1.271	1.293
1+25	4+25	1.280	1.290	1.314	1.332	1.357
1+50	4+50	1.335	1.347	1.375	1.390	1.415
1+75	4+75	1.402	1.408	1.439	1.451	1.475
2+00	5+00	1.479	1.491	1.518	1.533	1.558
2+25	5+25	1.573	1.585	1.610	1.625	1.649
2+50	5+50	1.671	1.683	1.704	1.725	1.750

PE	Pavement Edge
OWP	Outer Wheel Path
ML	Mid Lane
IWP	Inner Wheel Path
ILE	Inner Lane Edge

APPENDIX E

Photographs

Figure E-1. Site Overview - Preliminary Visit

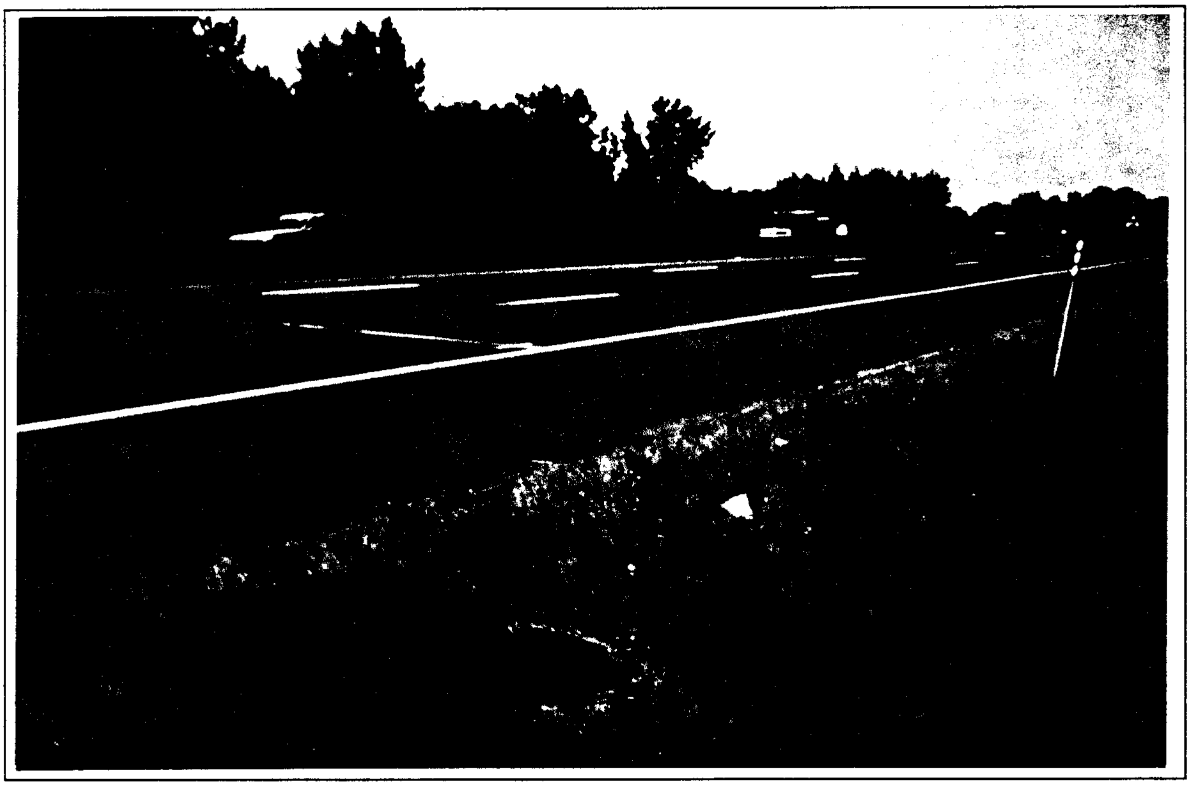


Figure E-2. Site Overview - Preliminary Visit

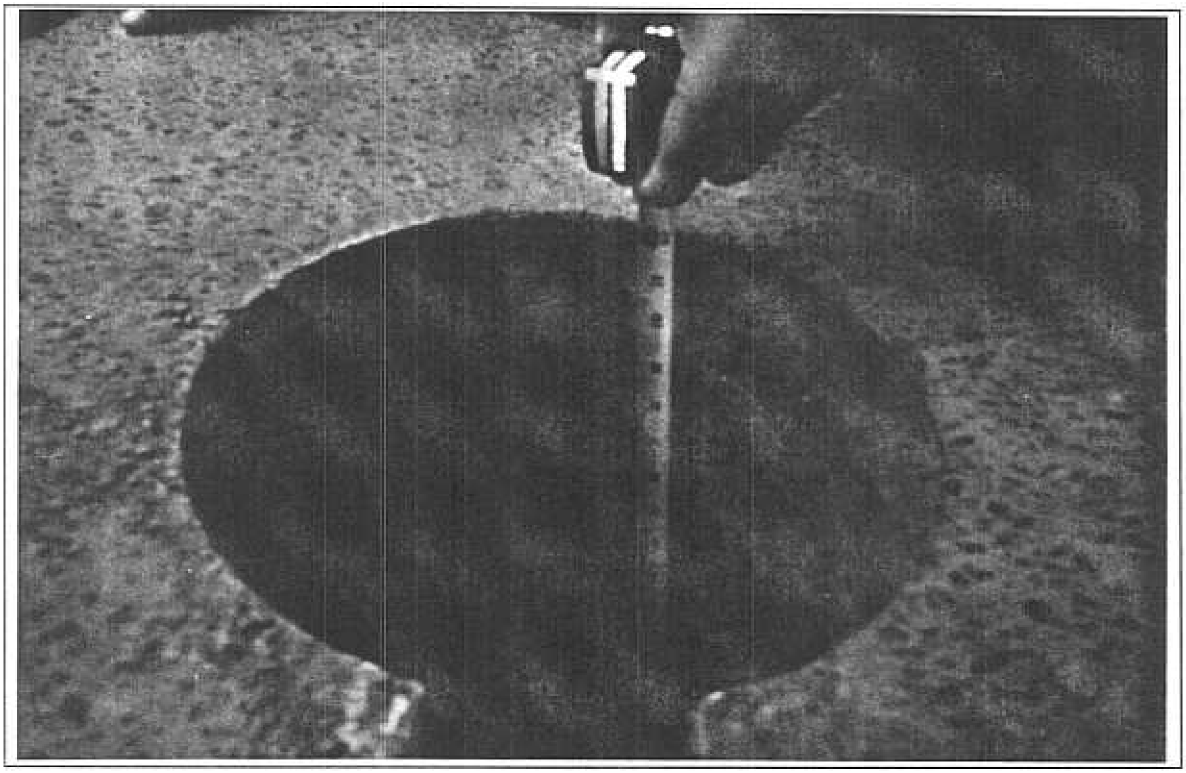


Figure E-3. Instrument Hole

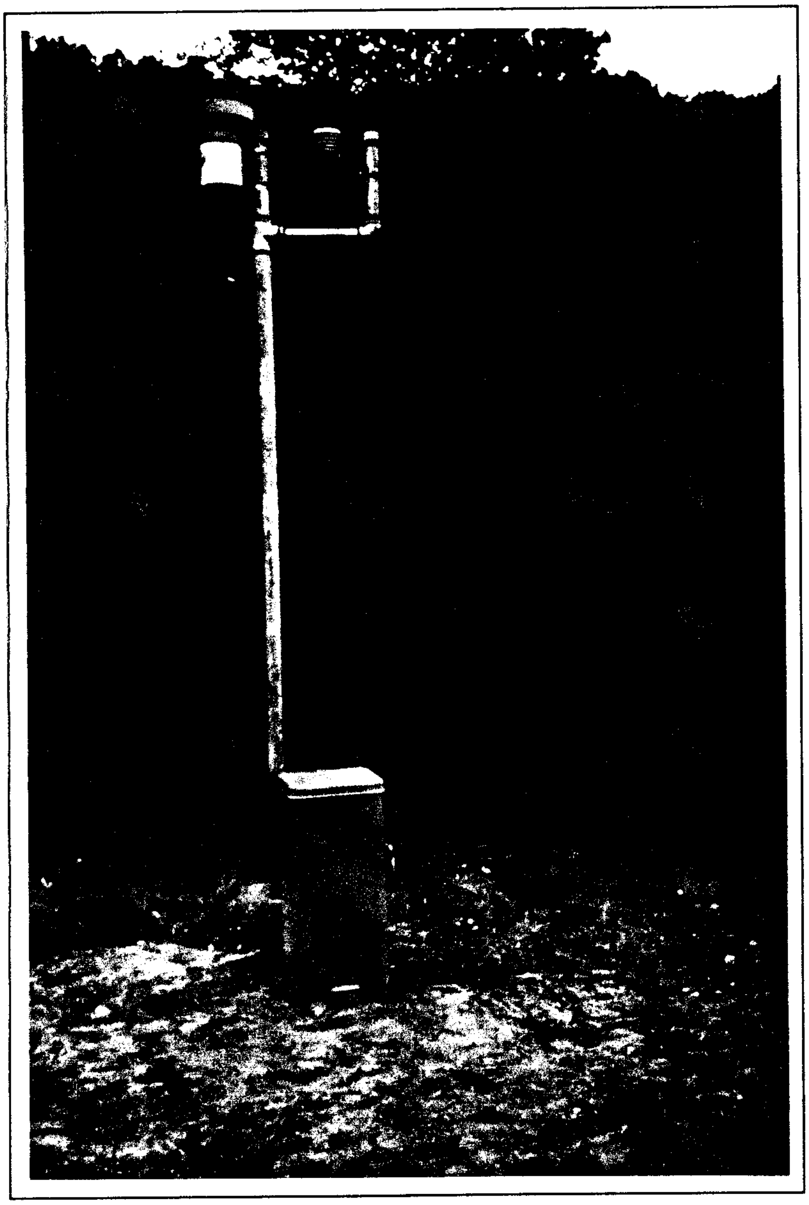


Figure E-4. Equipment Cabinet, Air Temperature Probe, and Rain Gage

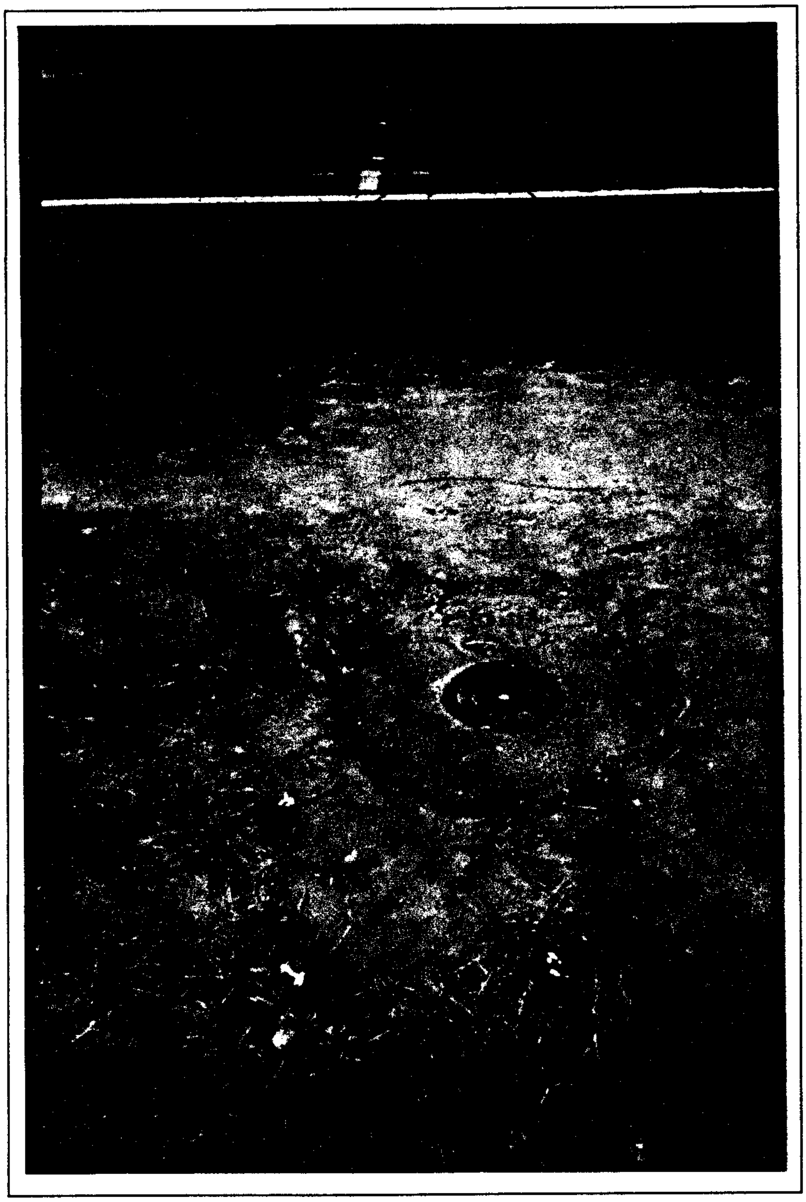


Figure E-5. Observation Well

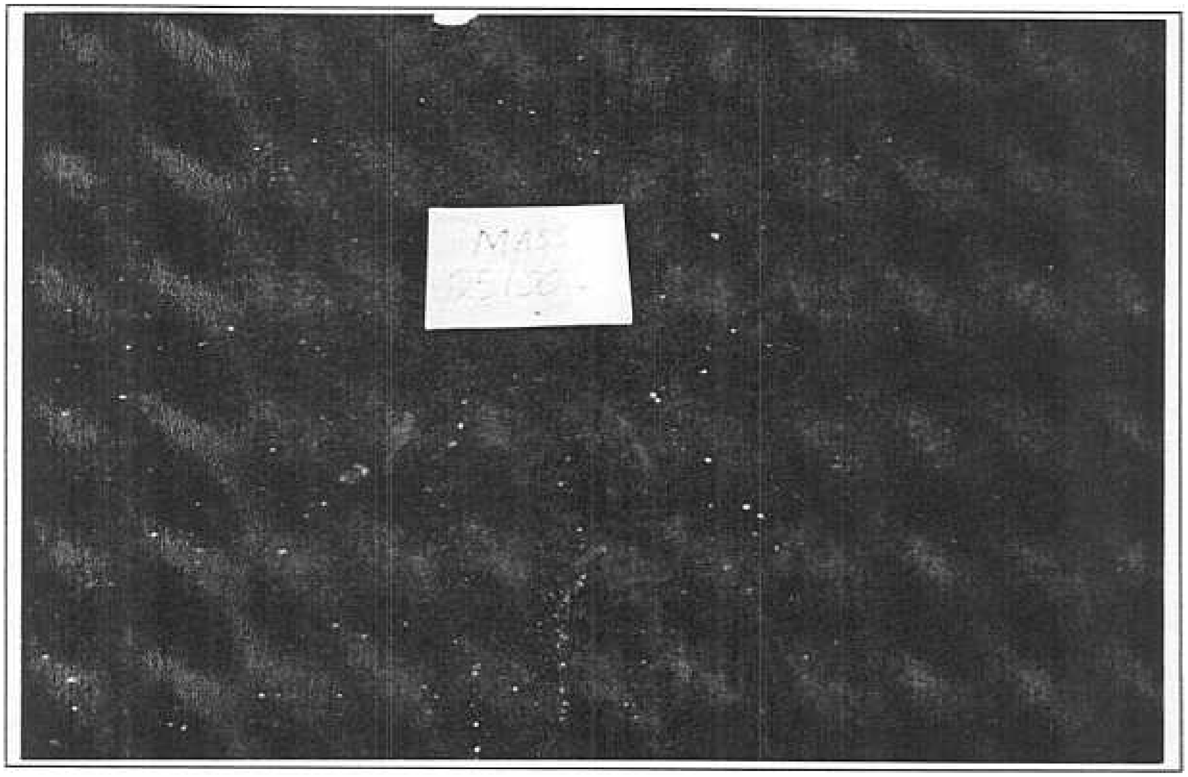


Figure E-6. Patch Area, Two to Three Months After Installation

Figure E-7. Patch Area, Two to Three Months After Installation