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VERMONT

# LTPP Seasonal Monitoring Program

Site Installation and Initial
Data Collection
Section 501002, New Haven
Vermont

**Report No. FHWA-TS-94-50-01** **December 1994**

## Notice

# LTPP Seasonal Monitoring Program

## Site Installation and Initial Data Collection
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| 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 501002 on RT 7 in New Haven, Vermont. This asphalt concrete surface pavement test section was instrumented on October 6, 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 October 7, 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

### Background (State Experiment)

The state of Vermont in conjunction with the Army Corps of Engineers, Cold Region Research and Engineering Laboratory (CRREL), Hanover, NH, initiated a Seasonal Monitoring Program on four SHRP sites in the fall of 1989. These sites were instrumented in conjunction with the initial FWD testing and material sampling at the SHRP sites. Watermark sensors (moisture) and thermistor sensors (temperature) were installed in the test pit locations at each site. A monitoring well to determine the water table level was also installed at each site. The initial findings were reported by Wendy L. Allen, US Army Corps of Engineers, Cold Region Research and Engineering Laboratory, Hanover, NH (Internal Report 1053, January 1990).

In the spring of 1991, datalogger/storage modules were installed at sites 501002 - New Haven, 501004 - South Hero, and 501681 - Charlotte for continuous data collection from the watermark sensors and thermistor strings. In addition to the SHRP sites, instrumentation was also installed at two locations on route 62 in Berlin and adjacent to the Materials and Research Facility parking lot on town highway 27 in Berlin. In conjunction with the installation of the equipment cabinet and data logger/storage module at site 501002 in New Haven on April 3, 1991, the SHRP FWD collected four sets of data as a trial test procedure for the planned LTPP seasonal data collection. Appendix A provides plots of deflection and temperature variations with time as recorded during FWD testing for 501002 on April 3, 1991 and for town highway 27 on April 4, 1991. Pictures documenting the installation of the data logger/storage module and FWD testing are provided in Appendix E.

In the fall of 1992, new sets of instrumentation were installed at the three SHRP sites and the two sites in Berlin. This instrumentation included:

- MRC thermistor probe (3.05m)
- TDR moisture probes (2 prong)
- Watermark moisture sensors
- Air temperature probe
- Wind speed/direction recorder
- TI tipping bucket rain gage

The installation at site 501004 - South Hero was visited by Aramis Lopez (LTPP) and Brandt Henderson (NARO). The sites instrumented by Vermont Agency of Transportation (VAOT) were to be included in the LTPP seasonal program as supplemental sites. Details outlining the scope of the project and installation plans are provided in Dick Haupt's letter of October 5, 1992 (Appendix B).

**Site Specifics (LTPP Experiment)**

The installation of the LTPP instrumentation on seasonal site 501002 near New Haven, Vermont was performed on October 6 - October 7, 1993. The test section is a GPS-1 experiment, located on northbound Route 7, approximately 0.16 kilometers south of New Haven, Junction RT 17, 2.08 kilometers north of Middlebury, and 9.6 kilometers west of Bristol city limits (Figure A-1 in Appendix A). The highway consists of one 3.7 m wide lane in each direction with a 2.44 m wide paved outside shoulder.

The pavement structure, which elevates the roadway in a wet low lying plain between two hills, consists of 216 mm of asphalt concrete on 655 mm of crushed gravel base over a coarse grained poorly graded gravel with silt and sand. The depth to rock below road surface is more than 7.5 m. 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. The materials and layers encountered during the installation differ from what was encountered during the drilling and sampling done in 1989.

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 12 (thick AC on fine subgrade) of the Seasonal Monitoring Program. The annual average frost depth is 1.40 m and the maximum is 1.65 m. Salt is frequently used for ice control at this location. Below is a summary from the LTPP climate database based on seven years of data:

- Freezing Index (C-Days) 766
- Precipitation (mm) 1041
- No. of Freeze/Thaw Cycles 99
- Days Above 32C 1
- Days Below 0C 157
- Wet Days 192

This portion of route 7 was reconstructed and opened to traffic in 1984. The WIM location is on route US 7, 0.6 km South of route 17. The estimated annual average daily traffic (AADT) in 1992 was 6116 (two way) of which 49.9% was on the GPS direction. The truck traffic in the GPS direction carried approximately 7.9% of the total AADT. The estimate of annual ESALS in the GPS diection using vehicle ESALS is 52.3. These figures are based on 357 days of AVC coverage and 359 days of WIM data in 1992.

Installation of the instrumentation was a cooperative effort between Vermont Agency of Transportation (VAOT) Materials and Research Division, Federal Highway Administration Long Term Pavement Performance Division, and Pavement Management Systems Limited (PMSL) LTPP North Atlantic Region Coordination Office staff.. The following personnel participated in the instrumentation installation:

| | |
|---|---|
| Robert Cauley (LTPP Coordinator) | VAOT - Materials and Research |
| Sven Coenye | VAOT - Materials and Research |
| Chris Benda | VAOT - Materials and Research |
| Reg Holt | VAOT - Materials and Research |
| Dale Warren | VAOT - Materials and Research |
| Robert McGlynn | VAOT - Materials and Research |
| Alan McBean | VAOT - Materials and Research |
| Roger Lyon-Surrey | VAOT - FWD Testing |
| Martin Kelley | VAOT - FWD Testing |
| Dave Blackmore | VAOT - District 5 |
| Jim Mobbs | VAOT - District 5 |
| Bruce Carter | VAOT - District 5 |
| Chuck Booska | VAOT - District 5 |
| Bruce King | VAOT - District 5 |
| Martin Dukter | E.F. Wall Assoc. - Barre, VT |
| John Klemunes | FHWA-LTPP Division |
| Brandt Henderson | Pavement Management Systems (NARO) |
| Perry Zabaldo | Pavement Management Systems (NARO) |
| Mike Zawisa | Pavement Management Systems (NARO) |
| Doug Marshall | Pavement Management Systems (NARO) |

Table 1. Material Properties

| Description | Surface | Base | Subgrade |
|---|---|---|---|
| Material (Code) | Dense Graded HMAC (01) | Crushed Gravel (304) | Silty Sand Gravel (255) |
| Thickness (mm) | 216 | 655 | |
| Lab Max Dry Density (kg/m$^3$) | | 2302 | 2198 |
| Lab Opt Moisture Content (%) | | 7.00 | 6.50 |
| In-situ Wet Density (kg/m$^3$) * | | 2073 | 2004 |
| In-situ Dry Density (kg/m$^3$) * | | 2092 | 1761 |
| In-situ Moisture Content (%) * | | 2.10 | 13.98 |
| Bulk Specific Gravity | 2.42 | | |
| Max Specific Gravity | 2.51 | | |
| Liquid Limit | | 0 | 0 |
| Plastic Limit | | 0 | 0 |
| Plasticity Index | | NP | NP |
| % Passing # 200 | | 3.05 | 6.90 |

* Note: Test pit @ station 5+60

## II. Instrumentation Installation

### Site Inspection and Meeting with Highway Agency

The site initially nominated for inclusion in the seasonal monitoring program by Vermont was 501683, on state route 7 southbound in North Charlotte. This site was rehabilitated (mill and overlay 10/21/91) but was considered on the basis that the existing available LTPP sites were already instrumented and would be supplemental sites. Prior to finalizing plans for the installation, we were notified by FHWA (June 93) that this site could not be included in the core experiment as it would introduce another factor (rehabilitation) into the experiment. As it was desirable to have a site in Vermont, the decision was to instrument one of the existing supplemental seasonal monitoring sites for inclusion in the core experiment. The New Haven LTPP 501002 site was to be instrumented at the 0+00 end, which would allow for a comparison of the environmental results from the LTPP and state installed instrumentation along with any potential local differences over the length of the site.

As time was limited, a pre survey of this section was not undertaken. Previous surveys did not indicate the section was very uniform, but there were no indication that any major problem may exist. A preliminary planning meeting was held at the Materials and Research Division in Berlin, Vermont on September 8, 1993. The attendees at the meeting were:

| | |
|---|---|
| • Richard Haupt | VAOT Research and Technology Engineer |
| • Sven Coenye | VAOT Instrumentation Technician |
| • Chris Benda | VAOT Soils and Foundations Engineer |
| • Larry Willoy | VAOT Materials Engineer |
| • Reg Holt | VAOT Soils Drilling Supervisor |
| • Vincent Janoo | CRREL |
| • Erik Simonsen | CRREL (Visiting Ph.D. Student) |
| • 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 seasonal site near New Haven. Plans for the installation on October 6 and October 7, 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.

Due to the familiarity of the Vermont VAOT personnel with the requirements for installation of the seasonal instrumentation, a pre installation meeting was not necessary. Arrangements were made to meet on site at 0800 hours with traffic control to be in place by 0830 hours.

### 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 | 50AT |
| CRREL Resistivity Probe | 1 | 50AR |
| TDR Probes | 10 | 50A01-50A10 |
| Equipment Cabinet | | |
| Campbell Scientific CR10 Datalogger | 1 | 16556 |
| Campbell Scientific PS12 Power Supply | 1 | 5620 |
| Weather Station | | |
| TE525MM Tipping Bucket Rain Gage | 1 | 12080-693 |
| Campbell Scientific 107-L Air Temperature Probe | 1 | 50AAT |
| Observation Well/Bench Mark | 1 | N/A |

### 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 473 ml 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 473 ml of water, the tipping bucket should measure 100 tips $\pm$ 3 tips. The results showed 100 tips, which was within 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 respectively, 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**

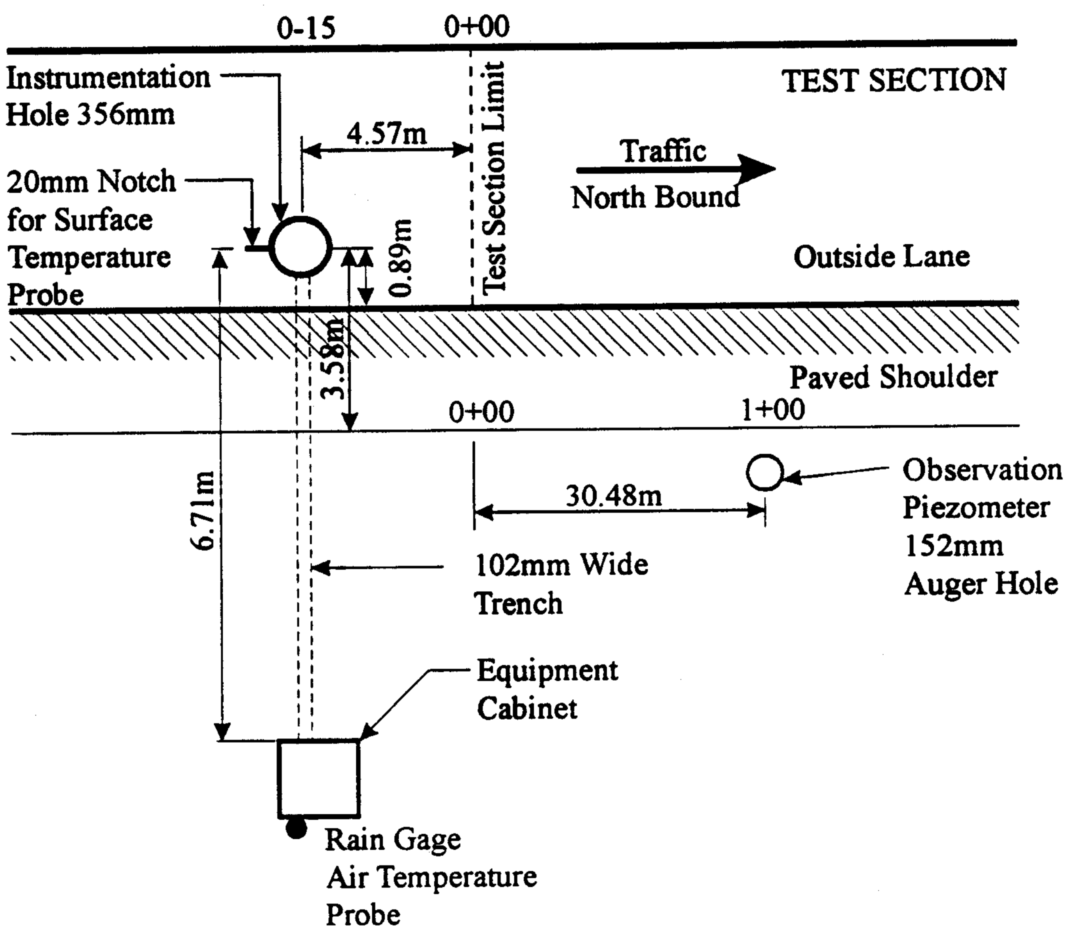
Final details for the installation and initial monitoring were discussed with Sven Coenye on the afternoon of October 5, 1993. The installation was confirmed for 0830 hours on October 6, 1993. Traffic control for the installation and monitoring was provided by Vermont Agency of Transportation district 5 maintenance facility in Burlington. The pavement surface drilling and augering of the piezometer and instrumentation hole were done by agency equipment and drilling crew under the supervision of Chris Benda, P.E., Soils and Foundations Engineer. The sawing of the trench and cut for the pavement surface temperature probe were done by Martin Dukter, E.F. Wall and Associates, Barre, VT. The installation of the measurement equipment, the observation piezometer, weather station pole, and cabinet was performed by PMSL staff. Assistance was provided by VAOT Materials and Research Division and the local district personnel.

The instrumentation was installed on the south end of GPS 501002, in the northbound lane of route 7, 0.16 km south of junction with route 17 in New Haven, Vermont. The combination benchmark/piezometer was placed in the shoulder at station 1+00. The in-pavement instrumentation was installed in the outer wheel path at station 0-15. The cabling from the instrumentation was placed in a 51 mm flexible conduit and buried in a trench running from the instrument hole to an equipment cabinet installed on the slope of the roadway embankment, 6.71 m from the instrumentation hole. To support the cabinet, approximately 0.5 cubic meter of crushed gravel was spread around the cabinet base, which resided on the inside slope of the ditch line. This material would only provide a minor restriction to the water flow in the ditch. This also provides a level surface for access to the cabinet. 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 4.88 m. A 152 mm flight auger was used for drilling the hole. A sample of the material was retained from approximately 1.0 to 2.0 m below the surface. No water was encountered during the drilling exercise. The piezometer/benchmark was to reside in a soft clay material. To ensure the stability of the pipe assembly, a 300 mm Rocktest borris point was attached to the 25.4 mm galvanized pipe prior to installation. When the pipe was firmly seated in the hole, the borris points were expanded into the clay material to form a firm grip at the base of the pipe. At the completion of the installation of the pipe, 2.75 m of Ottawa sand was compacted at the base of the pipe to provide a filter medium for the water, followed by a 0.35 m of bentonite plug with the remainder of the hole filled with native material. The final elevation for the pipe was 102 mm below the natural ground level at the location of the installation. A CT type cover, held in location by approximately 25 kg 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, 0.89 m from the edge of the travel lane at station 0-15, using a 356 mm thin wall diamond core barrel, attached to the truck mounted drilling unit. A 102 mm wide by 220 mm deep saw cut was done between the core hole and the edge of the pavement, using a heavy duty pavement sawing machine. The blade of the pavement saw was used to notch a location for the pavement surface temperature probe at the south edge of the core hole. The remainder of the material from the trench was removed with a pick and shovel.

A combination of methods were used to excavate the instrumentation hole. The crushed dolomite base was scraped out with a hand shovel. The driller used a 280 mm flight auger with a 300 mm cutting tip to loosen the subbase material, which again was removed by hand. The subbase material appeared to be an old road bed that was scarified and blended, as chunks of asphalt concrete were evident throughout the material layer. The underlying clay material was removed in 0.3 to 0.4 m lifts. Care was taken to ensure material removed was consistently representative of material at the location from the bore hole. The findings from the excavation of the instrumentation hole at station 0-15 are presented in Figure 2. All the material excavated from the instrument hole was placed and compacted in order of removal. Samples of the material placed around the TDR probes were retrieved to determine the gravimetric moisture at these locations. A field moisture determination was done at the site with sample material retained for laboratory moisture determination by the VAOT Materials Laboratory. No additional material remained from the instrumentation hole with some material from the trench area required to top up and level the instrumentation hole. The equipment cabinet and pole for the rain gage and air temperature probe were installed as per manual guidelines with the following two exceptions, first the cabinet was installed on the inside ledge of the ditch and a crushed granular fill was used to support the cabinet and provided a platform for access, and second the pole for the rain gage and air temperature probe was installed to a depth of 0.66 m supported in the granular base for the cabinet. The excavation of the trench 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): 2.77m
- Height of Tipping Bucket Rain Gage (center): 2.67m
- Total Depth of Piezometer: 4.88m
- Distance of Piezometer Below Ground Level: 102mm

Figure 1. Location for Seasonal Monitoring Instrumentation Installed at GPS 501002

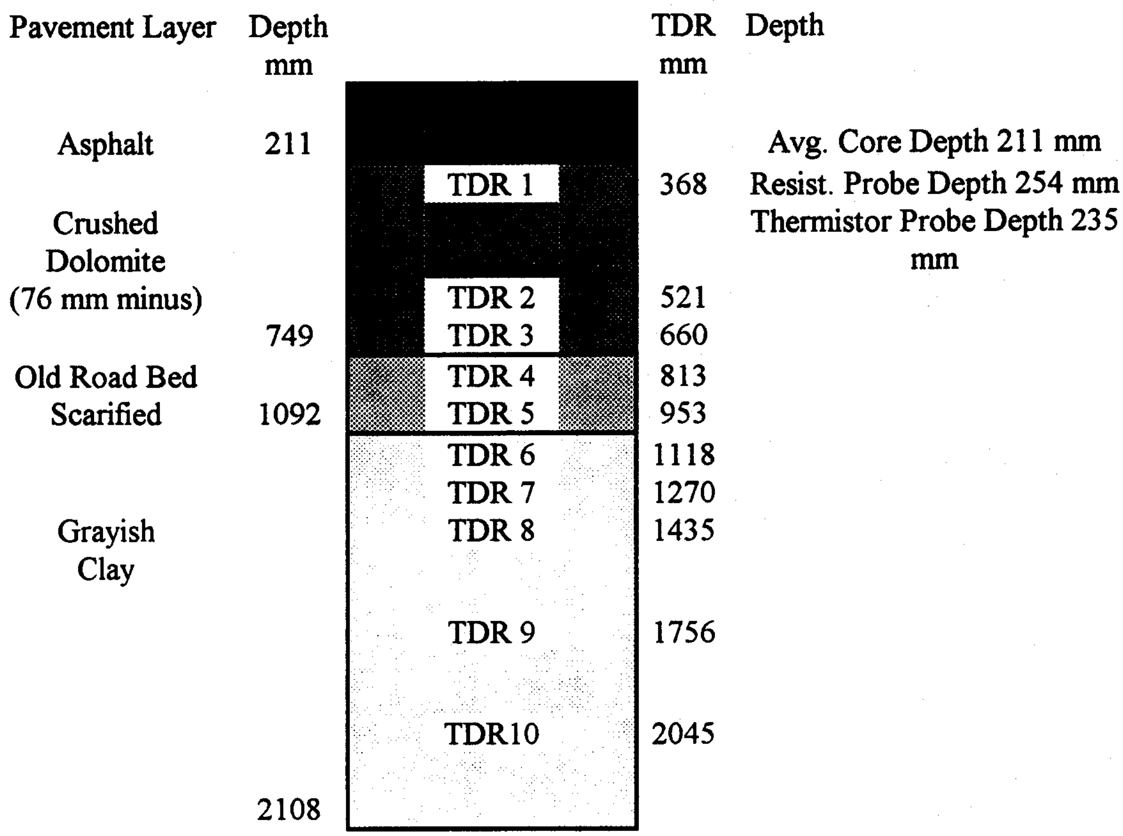



Figure 2. Profile of Pavement Structure and Probe Depths from Surface, Station 0-15

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 0.235 m and the resistivity probe 0.254 m 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 50 mm 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, field, and laboratory measured moisture content during installation. A comparison of the moisture content from the TDR traces, field, and laboratory determination indicate some discrepancies. The field and laboratory moisture contents generally compare more favorably. The TDR method indicates higher moisture content for the dolomite base material, lower moisture content for the granular subbase, with generally similar values for the clay subgrade with the exception being sensor 10 at a depth of 2.045 m which is roughly half the moisture content of the field and laboratory results. Given the method under which the material was sampled and the variability in the material, the results can be considered reasonable. It should be noted that the calculation of moisture is dependent on the calibration inputs to the TDR model. Differences of moisture content in the range of 1 to 2% are not uncommon.

Table 3. Installed Depths of TDR Sensors

| Sensor # | Depth from Pavement Surface (m) | Layer |
|---|---|---|
| 50A01 | 0.368 | Base |
| 50A02 | 0.521 | |
| 50A03 | 0.660 | |
| 50A04 | 0.813 | Subbase |
| 50A05 | 0.953 | |
| 50A06 | 1.118 | Subgrade |
| 50A07 | 1.270 | |
| 50A08 | 1.435 | |
| 50A09 | 1.756 | |
| 50A10 | 2.045 | |

Table 4. Installed Location of MRC Thermistor Sensor

| Unit | Channel Number | Depth from Pavement Surface (m) | Remarks |
|---|---|---|---|
| 1 | 1 | 0.032 | This unit was installed in the AC layer. |
| | 2 | 0.106 | |
| | 3 | 0.186 | |
| 2 | 4 | 0.252 | This unit was installed below the AC layer into the subgrade. |
| | 5 | 0.328 | |
| | 6 | 0.404 | |
| | 7 | 0.481 | |
| | 8 | 0.557 | |
| | 9 | 0.710 | |
| | 10 | 0.859 | |
| | 11 | 1.013 | |
| | 12 | 1.163 | |
| | 13 | 1.315 | |
| | 14 | 1.474 | |
| | 15 | 1.621 | |
| | 16 | 1.780 | |
| | 17 | 1.926 | |
| | 18 | 2.076 | |

Table 5. Location of Electrodes of the Resistivity Probe

| Connector Pin Number | Electrode Number | Depth from Pavement Surface (m) |
|---|---|---|
| 36 | 1 | 0.283 |
| 35 | 2 | 0.335 |
| 34 | 3 | 0.385 |
| 33 | 4 | 0.435 |
| 32 | 5 | 0.487 |
| 31 | 6 | 0.536 |
| 30 | 7 | 0.588 |
| 29 | 8 | 0.637 |
| 28 | 9 | 0.687 |
| 27 | 10 | 0.741 |
| 26 | 11 | 0.791 |
| 25 | 12 | 0.841 |
| 24 | 13 | 0.890 |
| 23 | 14 | 0.941 |
| 22 | 15 | 0.992 |
| 21 | 16 | 1.042 |
| 20 | 17 | 1.095 |
| 19 | 18 | 1.145 |
| 18 | 19 | 1.197 |
| 17 | 20 | 1.248 |
| 16 | 21 | 1.298 |
| 15 | 22 | 1.349 |
| 14 | 23 | 1.399 |
| 13 | 24 | 1.448 |
| 12 | 25 | 1.499 |
| 11 | 26 | 1.550 |
| 10 | 27 | 1.602 |
| 9 | 28 | 1.651 |
| 8 | 29 | 1.701 |
| 7 | 30 | 1.751 |
| 6 | 31 | 1.803 |
| 5 | 32 | 1.853 |
| 4 | 33 | 1.904 |
| 3 | 34 | 1.954 |
| 2 | 35 | 2.004 |
| 1 | 36 | 2.053 |

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)* |
|---|---|---|---|---|---|
| 50A01 | 0.368 | Base | 3.91% | 1.31% | 2.20% |
| 50A02 | 0.521 | | 5.73% | 2.03% | 1.63% |
| 50A03 | 0.660 | | 5.73% | 2.94% | 1.48% |
| 50A04 | 0.813 | Subbase | 7.81% | ** | ** |
| 50A05 | 0.953 | | 9.78% | 12.03% | 11.53% |
| 50A06 | 1.118 | Subgrade | 10.08% | 12.99% | 13.79% |
| 50A07 | 1.270 | | 17.95% | 19.27% | 22.31% |
| 50A08 | 1.435 | | 16.12% | 13.56% | 19.70% |
| 50A09 | 1.756 | | 20.74% | 25.39% | 25.45% |
| 50A10 | 2.045 | | 12.73% | 24.88% | 23.67% |

* Note: Raw data given in Appendix C
**Note: No field and lab moisture for probe #4

### Site Repair and Cleanup

The instrumentation hole was repaired by reinstalling the 356 mm 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 100 mm 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 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 1730 hours 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 VAOT district 5 maintenance crew.

### Patch/Repair Area Assessment

When the site was visited on December 20, 1993, two and a half months after installation, the instrumentation hole patch was checked and a photo was taken as shown in Appendix E. The pavement core was slightly below the existing pavement and some settlement had taken place along the trench leading from the instrument hole to the edge of pavement. Additionally, the sealant failed to fully 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 October 7 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.

The data collected for October 7, 1993 was not sufficient to show change in temperatures. This was due to the fact that the onsite.dld program, that was downloaded to the datalogger, only records hourly averages (only field 5 data collected). The d_onsite.dld, which stores data every minute, should have been used to collect the data.

The tipping bucket rain gauge was checked by determining the number of tips recorded from 473 ml of water discharged into the gauge over a 1 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.

Figures D-1 and D-2 show the initial TDR wave form traces collected with the MOBILE data acquisition system for all 10 sensors. The figures indicate 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-3 shows pavement depth versus measured voltage produced by the MOBILE system.

Manual contact resistance and resistivity measurements were performed using a Simpson Model 420d function generator, two Fluke 87 digital multimeters, to measure voltage and amperage, and a manual electrode switching board. The measured contact resistance data are plotted in Figure D-4 and in Figure D-5 for the 4-point resistivity. Tables D-1 and D-2 in Appendix D show the raw data for the 2-point and the 4-point resistance respectively.

Comparison between Figure D-3 (contact resistance results from automated mode) and Figure D-4 (contact resistance results from manual mode) indicate similar results with the electrodes in the base material indicating differences in resistance from the subbase/subgrade material. Figure D-5 (4-point resistance results from manual mode) indicates that the 4-point test setup has similar results. If the reading equipment is working correctly, all the resistance/resistivity outputs will have similar shapes, although the values will be somewhat different based on the energy applied and distance between sampled electrodes.

**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, fifteen more measurements have been collected with the FWD, the first and second on November 8 and December 20, 1993, then on January 12, March 2, March 22, April 13, May 4, May 25, June 22, July 20, August 17, September 21, October 19, November 16, and the fifteenth on December 14, 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). Four surveys have already been performed on this site, the first during the fully frozen condition (February 18, 1994), the second in the spring season (April 12, 1994), the third in the summer season (July 25, 1994), and the fourth during the fall season (October 23, 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 October 7, 1993 and the results are presented in Appendix D. Since then, five more sets of the surface elevation surveys have been performed, the first on January 12, then on April 13, July 20, August 17, and the fifth on October 19, 1994.

**Water Depth**

A check of the piezometer indicated that there was no water present. This was odd as water was present in the existing monitoring well at approximately 1.2 m below surface. This would be somewhat consistent with the water evident in the ditch line. Also during our visit of December 20, 1993, water was detected at approximately 1.0 m below surface.

## IV. Summary

The installation of the seasonal monitoring instrumentation at the GPS site 501002 near New Haven, VT was completed on October 6, 1993. A check of the equipment and initial data collection was completed on October 7, 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 north end of the site has been instrumented by the VAOT Materials and Research Division. The instrumentation installed were:

- TDR and Watermark moisture sensors
- MRC temperature thermistor probe
- Pavement temperature thermistors
- Ground water level monitoring well with pressure transducer to monitor water table levels
- Air temperature thermistor probe
- Tipping bucket rain gage, and
- Wind speed and direction recorder.

These instruments are connected to a Campbell Scientific datalogger/storage module for continuous data collection, storage, and retrieval. This module is tied into a telephone line for dial-up retrieval of data. Plans are to compare the data from the two sets of instrumentation installed at either end of the site for efficiency of instrumentations and variability/similarity in site data.

The test section is on northbound route 7, 0.16 km south of the intersection of route 17, New Haven. The site is located in a low lying area between two hills. Open fields exist on either side of the pavement structure. The pavement resides in a slightly elevated platform and consists of two 3.7 m wide lanes with 2.44 m paved shoulder. The ditch line is very wet and contains cattails, reeds, and other vegetation. The pavement structure consists of 211 mm of asphalt concrete over 538 mm of 76 mm minus crushed dolomite rock and 343 mm soil aggregate mixture, which appears to comprise part of the old road bed as there were chunks of asphalt concrete mixed in with the aggregate material. This resides on a grayish clay (A-7 clay). The results are inconsistent with the drilling and sampling logs from 1989, although they are consistent with the findings from the installation of the instrumentation at the north end by VAOT.

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 air temperature and gradient temperatures measured in the pavement surface compared favorably with the hand held Omega temperature gage. The temperature profile for the pavement soils appeared reasonable with no outlying sensors. A check of the tipping bucket indicated it was functioning correctly with tips corresponding to amount of water supplied.

The resistance/resistivity measurements appeared reasonable with results being typical of traces for similar materials. Moisture content of the soil was determined by TDR method, field moisture determination at time of installation by soil drying, and laboratory results provided by Chris Benda, VAOT Materials and Research Division. There were differences between the moisture content determined by the TDR method and gravimetric moisture content determined from the samples taken, although there was nothing that may indicate the TDR probes were not functioning correctly. Some of the differences may be attributed to the estimated in-situ dry density of the material.

The installation generally went as expected with only a few minor problems. The installation was completed and the section was opened to traffic by 1730 hours. The removal/replacement of the material from the instrumentation hole went very well, with the material being well consolidated around the instrumentation and the core level with the existing pavement surface at completion. It was a surprise that no water was encountered in the piezometer hole although the material was quite saturated.

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 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:

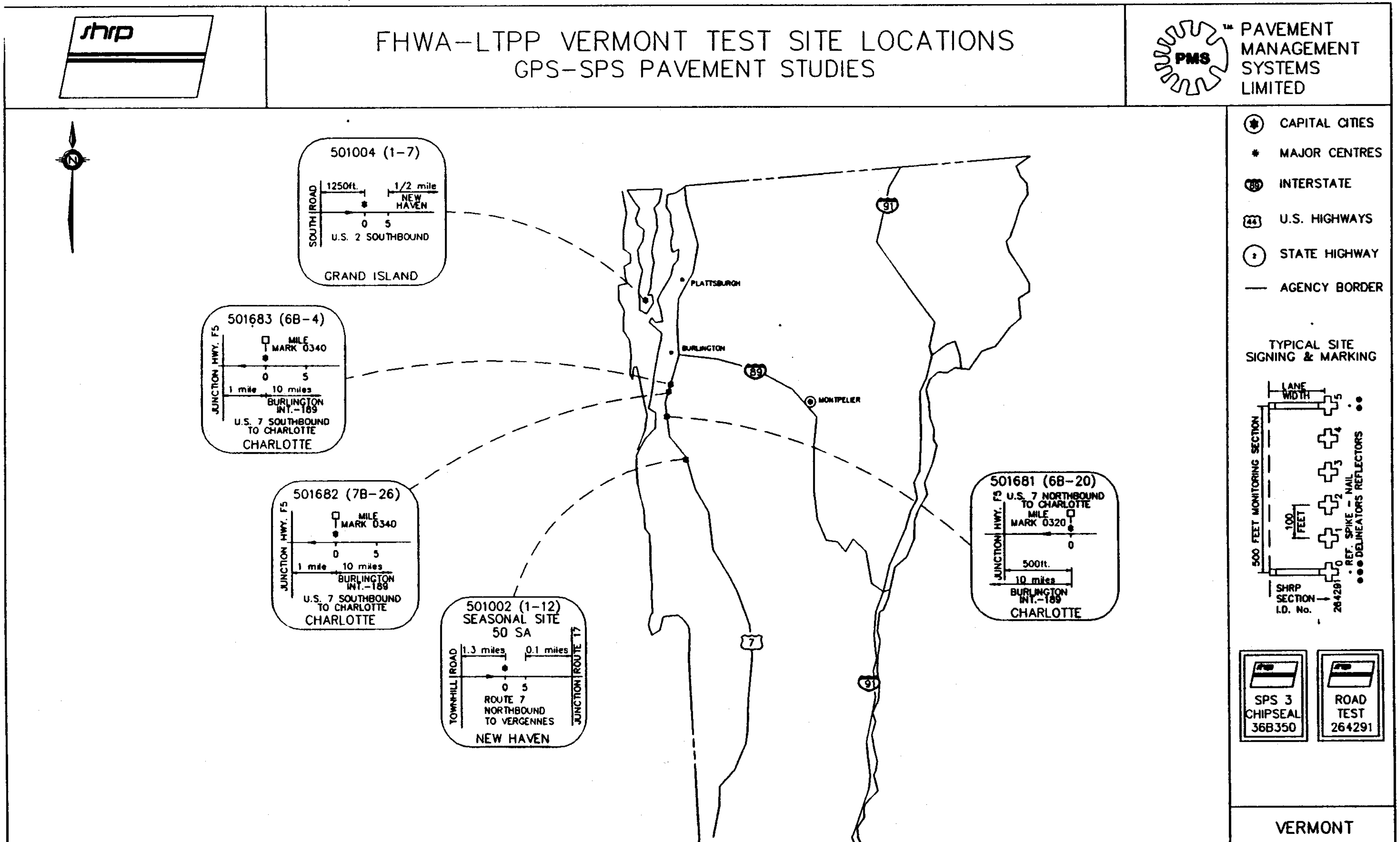



**FIGURE A-1 SITE LOCATION MAP - SECTION 501002**

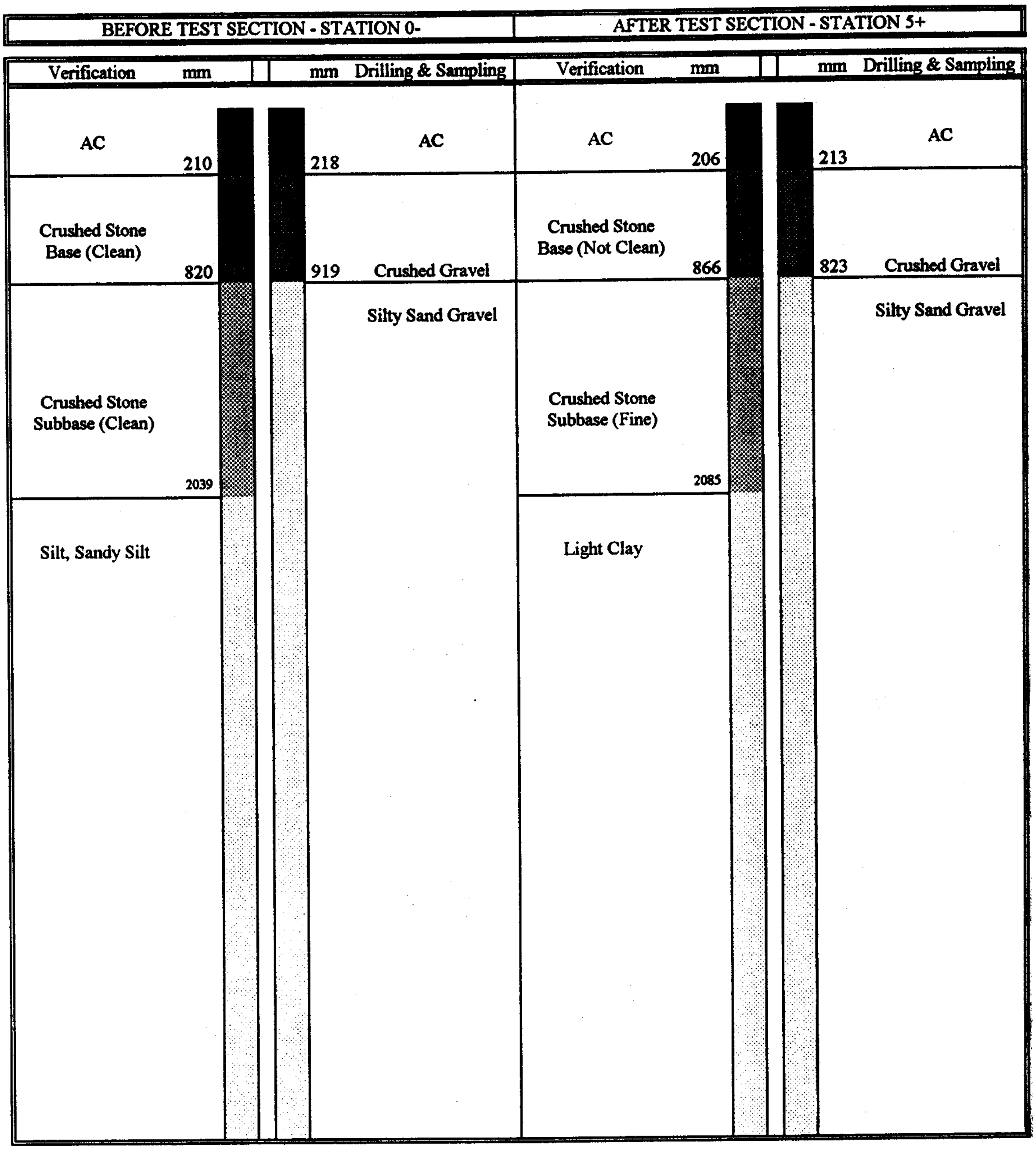



Figure A-2. Profile of Pavement Structure

Table A-1. Site Performance Summary

| Distress and Profile Summary | | |
|---|---|---|
| **Distress Summary 1990** | **Profile Summary Date (mm-dd-yy)** | **IRI (in/mi)** |
| Low Sev. Long. Cracks - 9.31 ft. | 10-22-89 | 77.98 |
| | 06-07-90 | 77.44 |
| | 05-09-91 | 68.05 |
| | 07-23-92 | 70.72 |
| | 08-09-93 | 83.12 |

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) |
| 09-07-89 | 10.65 | 2.05 | 1.81 | 0.21 | 82 | 71/91 |

| | Effective SN | SN std dev | Subgrade Modulus (psi) | Modulus std dev (psi) | Test Pit Mod. (psi) 1 | 2 |
|---|---|---|---|---|---|---|
| 09-07-89 | 8.32<br>7.99<br>7.41 | 0.20<br>0.24<br>0.10 | 23444<br>14958<br>13738 | 1825<br>3046<br>817 | 26468 | 15282 |

Note: FWD subsection boundaries at 210 ft and 335 ft as entered into RIMS.

Table A-2. Uniformity Survey Results

| Seasonal Uniformity Survey<br>Site Number: 501002<br>Date Surveyed: September 7, 1989 | Falling Weight Deflectometer<br>Data Collection and<br>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 |
| -50 | | | | | 26239 | | 9.45 | |
| 0 -310 | 8.77 | 0.91 | 1.71 | 0.21 | 22057 | 3009 | 8.41 | 0.26 |
| 310 -500 | 12.24 | 0.34 | 1.95 | 0.08 | 16231 | 1215 | 7.48 | 0.10 |
| 562 | | | | | 18514 | | 8.00 | |

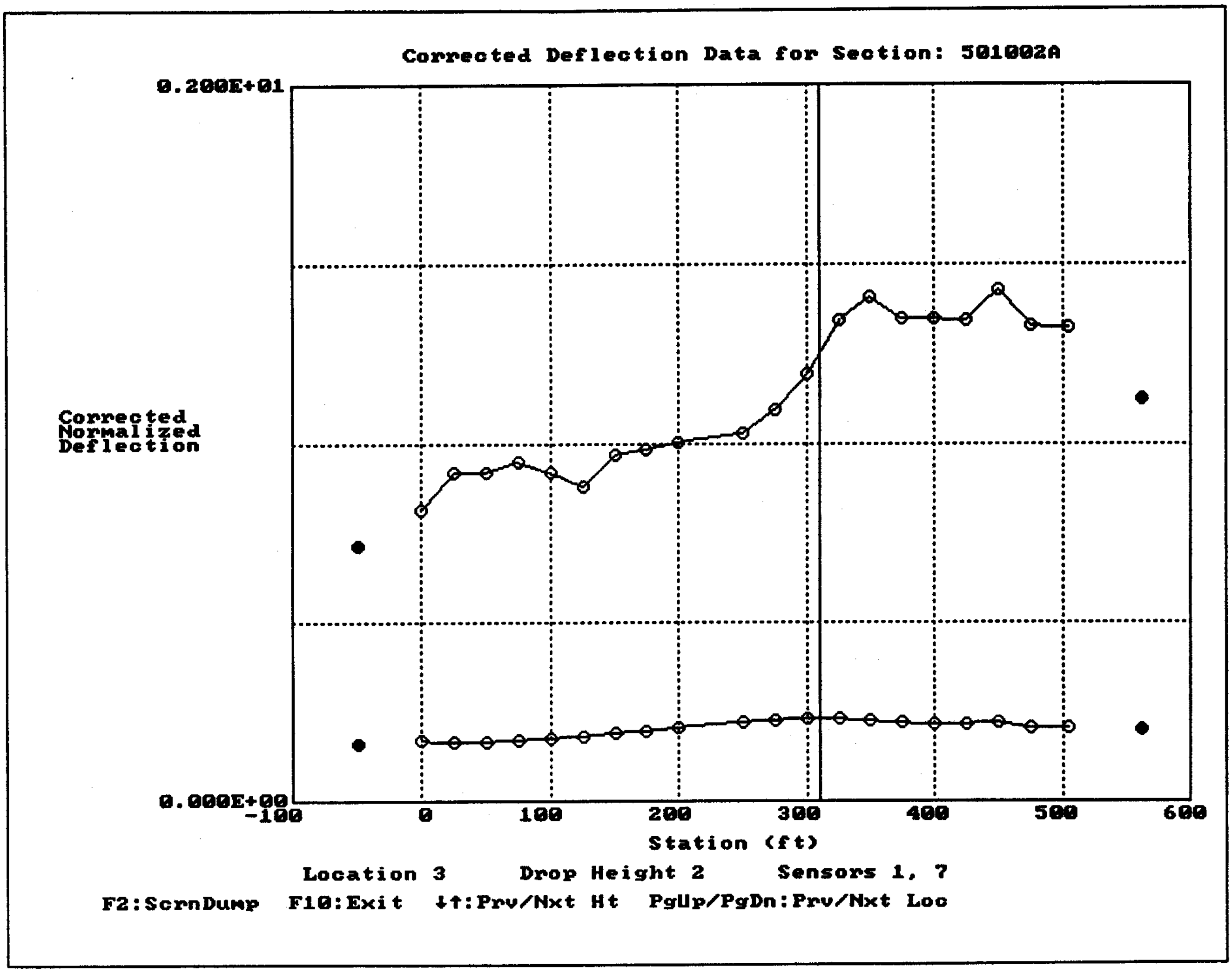



Figure A-3. Deflection Profile from FWDCHECK
(Test Date September 7, 1989)

Table A-3. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date September 7, 1989)

| Flexible Pavement Thickness Statistics - 501002A - Drop Height 2 | | | |
|---|---|---|---|
| Subsection | Station | Subgrade Modulus | Effective SN |
| Test Pit | -50 | 26239 | 9.45 |
| 1 | 0 | 24756 | 8.95 |
| | 25 | 25205 | 8.45 |
| | 50 | 25051 | 8.45 |
| | 75 | 24672 | 8.35 |
| | 100 | 24034 | 8.50 |
| | 125 | 23341 | 8.75 |
| | 150 | 22095 | 8.40 |
| | 175 | 21534 | 8.35 |
| | 200 | 20240 | 8.35 |
| | 250 | 19289 | 8.30 |
| | 275 | 18510 | 8.10 |
| | 300 | 15955 | 7.95 |
| 2 | 325 | 14386 | 7.65 |
| | 350 | 14593 | 7.45 |
| | 375 | 15791 | 7.55 |
| | 400 | 17290 | 7.45 |
| | 425 | 16287 | 7.50 |
| | 450 | 16774 | 7.30 |
| | 475 | 17540 | 7.45 |
| | 500 | 17189 | 7.50 |
| Test Pit | 562 | 18514 | 8.00 |
| Subsection 1 | Overall Mean | 22057 | 8.41 |
| | Standard Deviation | 3009 | 0.26 |
| | Coeff of Variation | 13.64% | 3.10% |
| Subsection 2 | Overall Mean | 16231 | 7.48 |
| | Standard Deviation | 1215 | 0.10 |
| | Coeff of Variation | 7.48% | 1.33% |

Note: Station 225 not tested

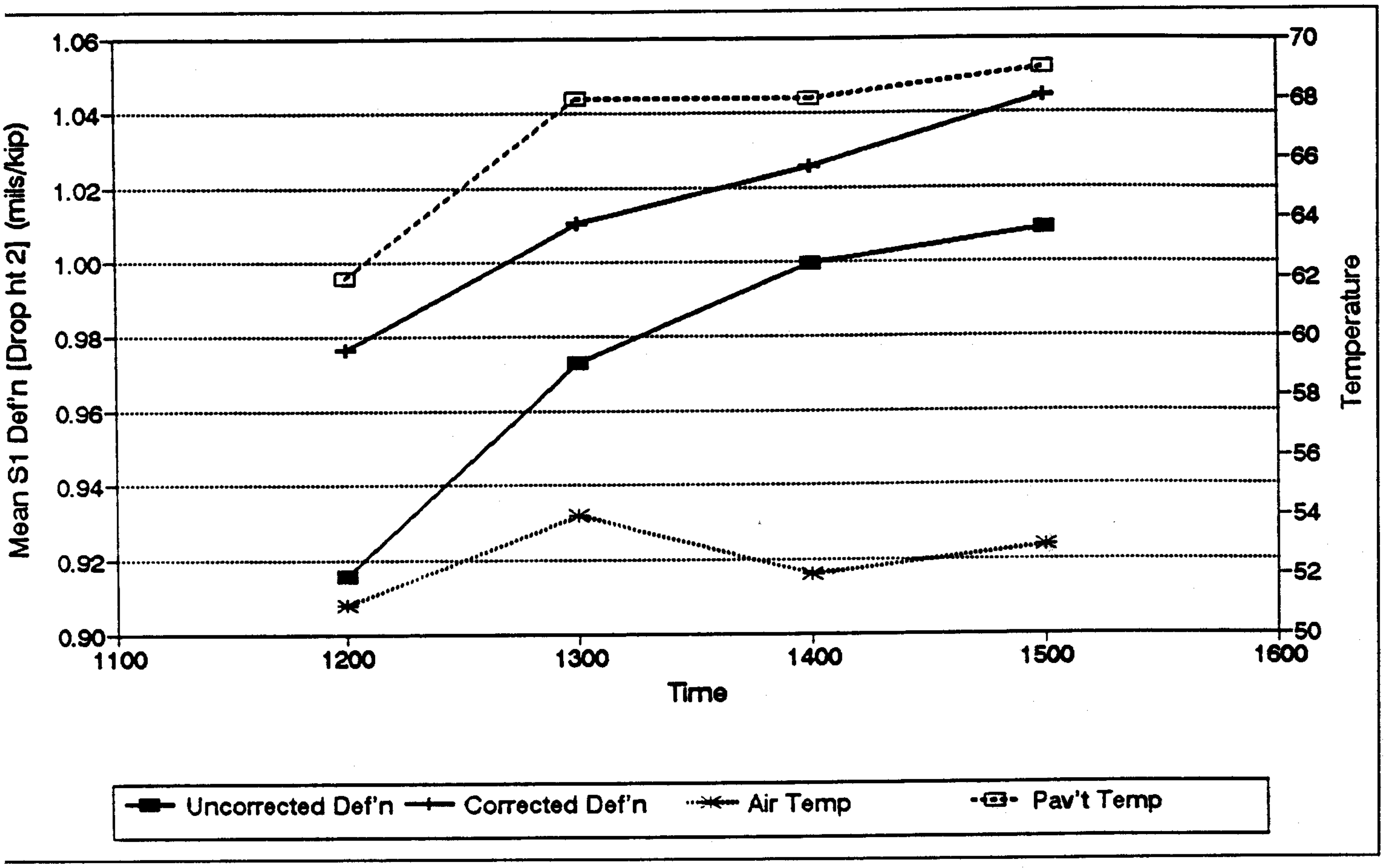



Figure A-4. Deflection and Temperature Variations with Time, on Site 501002, as Recorded During FWD Testing on April 3, 1991 (State Experiment)

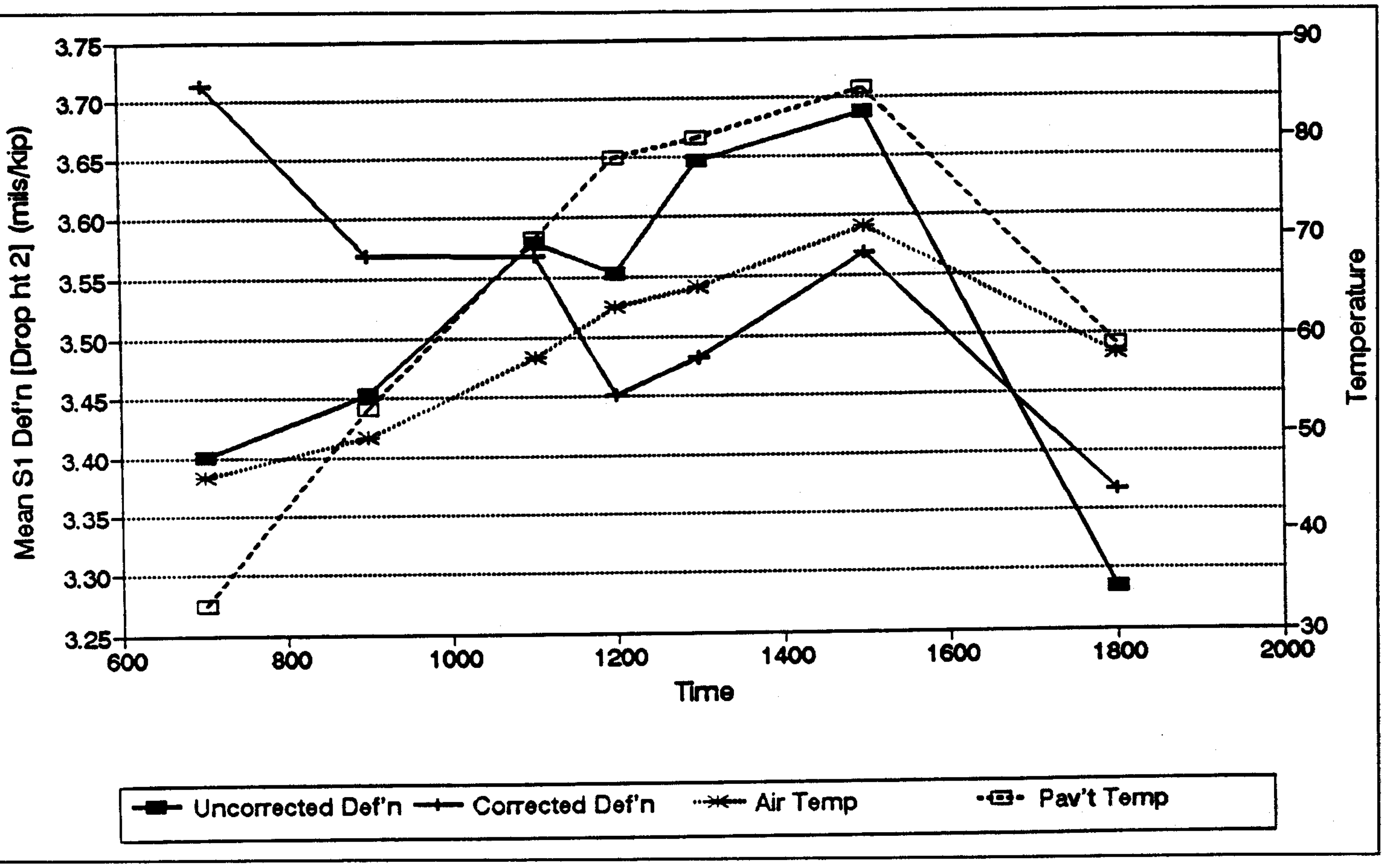



Figure A-5. Deflection and Temperature Variations with Time, on Town Highway 27, as Recorded During FWD Testing on April 4, 1991 (State Experiment)

# 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:** | Dick Haupt | **DATE:** | February 14, 1991 |
| **FROM:** | Bill Phang Bill Phang | **FILE REF:** | 12.16.1 |
| **SUBJECT:** | FWD Seasonal Testing, NARCO Year 1 | **COPIES TO:** | I. Pecnik<br>B. Henderson |

NARCO is developing plans for their Year 1 core experiment. For easy reference enclosed are copies of a NARCO newsletter describing the FWD seasonal testing concept, and a SHRP State participation Synopsis inviting nominations.

As you are aware through discussions with Brandt Henderson, NARCO expects to include three (3) Vermont GPS-1 sites which were instrumented by CRREL in the Year 1 plan. These are GPS 501002, 501004, and 501994. A list of GPS sites in Vermont is attached.

The SHRP seasonal testing plan is not yet finalized, but at present the agency would be responsible for traffic control during FWD testing. The test frequency during the spring thaw period is about once weekly, but reduces during fall and winter to twice per season. A total of from 12-16 test per year per GPS site is expected.

NARCO proposes to initiate a pilot Year 1 program this spring, so would appreciate confirmation of your participation.

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

BH

PAVEMENT
MANAGEMENT
SYSTEMS

**MEMORANDUM**

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

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FAX (716) 632-4808

PAVEMENT
MANAGEMENT
SYSTEMS

# MEMORANDUM

| | | | |
|---|---|---|---|
| **TO:** | Guy Dore, QE<br>Dick Haupt, VT<br>Warren Foster, ME<br>Alan Rawson,. NH<br>Charles Dougan, CT | **DATE:** | June 29, 1992 |
| | | **PROJECT:** | 50450732 |
| **FROM:** | Bill Phang Bill Phang | **FILE:** | 6.01 |
| **SUBJECT:** | Seasonal Testing<br>Preliminary FWD Investigation | **COPIES TO:** | See Below |

One of the findings of the seasonal testing pilot at Syracuse, NY was that the FWD results near the points where the sensors were installed outside of the test section were somewhat different to results within the GPS test section.

It was subsequently decided that for future seasonal testing installations, a preliminary FWD test series would be conducted in the areas adjacent to the test sections. This would help to fix on a location for sensor installation that more closely represents the part of the test section being monitored for seasonal effects.

The FWD has been scheduled to carry out these preliminary tests beginning July 21 at GPS 893015 in Trois Riviere, QE. Other sites are 501683 in Charlotte, VT, on July 24, 237028 in Bethel, ME on July 28, 331001 in Concord, NH on July 29 and 091803 in Groton, CT July 30.

A copy of the FWD schedule is attached. Would you please make necessary arrangements for traffic control. Please call Brandt Henderson of you have any questions.

Distribution to:
I.J. Pecnik
B. Henderson

415 LAWRENCE BELL DRIVE
UNIT #3
AMHERST, N.Y. 14221
TEL. (716) 632-0804
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AGENCY OF TRANSPORTATION                OFFICE MEMORANDUM

TO: Christopher C. Benda, P.E., Soils & Foundations Eng.

FROM: Richard S. Haupt, P.E., Research & Testing Engineer RH

DATE: July 15, 1992

SUBJECT: Installation of Seasonal Instrumentation @ SHRP Sites

Please schedule the following dates for performing the necessary borings for installation of below ground instrumentation sensors, monitoring wells and posts for instrumentation:

| | |
|---|---|
| July 30 | Thursday |
| July 31 | Friday |
| August 3 | Monday |
| August 4 | Tuesday |
| August 5 | Wednesday |
| August 6 | Thursday |
| August 7 | Friday |

All work will be weather dependent. The scheduled work will proceed as follows:

(1) Three sites on VT 62 (Dist. 6)

(2) New Haven SHRP site 501002 (Dist. 5)

(3) Charlotte SHRP site 501681 (Dist. 5)

(4) South Hero SHRP site 501004 (Dist. 8)

Each site will need traffic control. The work at each location will involve the following:

(1) Core drilling thru the shoulder pavement at the edge of the traffic pavement with a 15" core bit. Remove pavement core.

(2) Saw cut a 3 to 4 inch width strip from the hole to the edge of the shoulder. Remove pavement and enough gravel to insert a 2" ID PVC conduit sleeve below the surface of the shoulder pavement.

(3) With a 14" dia. Auger, carefully remove each layer of subbase materials to the Subgrade. Representative samples of each material to be taken. Moisture samples of representative material to be taken.

(4) Install a 10 foot long (one on VT 62 to be 5 feet) temperature probe in each core hole plus five moisture sensors at designated depths (75", 51", 39", 27" & 15" depths below surface as the hole is backfilled). Two temperature sensors will also be installed in the pavement in each core hole.

(5) The 15" diameter core will be replaced and sealed. Hot mix will be needed to fill the slotted hole.

(6) New monitoring wells will need to be installed at New Haven & Charlotte. I expect that a depth between 10 and 15 feet will be adequate.

(7) Charge Numbers:

(a) Vt. 62 - Berlin-Barre F026-1(33)
SF 03
Project 3457
FF 50
Task Code 2662

(b) New Haven & South Hero - Statewide F SHRP (1)
SF 03
Project 3414
FF 50
Task Code 2605

(c) Charlotte - Charlotte F019-4(21)
SF 03
Project 3626
FF 50
Task Code 2662

I will keep the District personnel informed of the progress as the work proceeds.

RSH:sls

cc: David Blackmore - Dist. 5
Ray Cyr - Dist. 6
Jim Smith - Dist. 8
Vincent Janoo - CRREL
Dale Bull, CRREL
Bill Phang - PMS
Brant Henderson - PMS
Aramis Lopez, FHWA LTPP Div.
R. Cauley
Sven Coenye
RFC/Lab File - Read. File - RSH File - Central Files

COPY

STATE OF VERMONT
AGENCY OF TRANSPORTATION
133 State Street, Administration Building
Montpelier, Vermont 05633
FAX # (802) 828-2792

DATE REC. JUL 27 1992
JOB #
FILE #

July 23, 1992

Mr. Bill Phang
Pavement Management Systems
415 Lawrence Bell Drive - Unit #3
Amherst, New York 14221

Dear Mr. Phang:

Subject: GPS Seasonal Monitoring Sites

Your questionnaire on seasonal monitoring installations, SHRP GPS seasonal study site number 501683, has been completed and is being returned.

Along with this questionnaire, you will find a copy of a report on soil sample, laboratory number E88721.

Sincerely,

Robert F. Cauley

Robert F. Cauley, P.E.
Materials and Research Engineer

RFC:RSH:etn

Enclosures

c RFC/Lab File - Read. File - CF

COPY


STATE OF VERMONT
AGENCY OF TRANSPORTATION
133 State Street, Administration Building
Montpelier, Vermont 05633

FAX # (802) 828-2792


October 5, 1992

Mr. Aramis Lopez, Jr.
Highway Research Engineer
U.S. Department of Transp. - FHWA
6300 Georgetown Pike, HNR-40
McLean, Virginia 22101-2296

Dear Mr. Lopez:

I would like to thank you and Brant for your assistance in our installation of the South Hero sensors that will become part of the data collection program for seasonal testing. We appreciated the opportunity to discuss this project with both of you and learn your perspectives for the overall program.

As discussed during your visit, we are in the process of developing a project outline that will describe its overall scope, objectives, and evaluations and what we expect to derive from performing a seasonal testing program. Attached is a draft copy of this project. We would appreciate any input and comments that you or any of your staff would like to contribute.

When you have developed a protocol and process for evaluation of seasonal test data, we would be interested in a copy. In the meantime, if we can be of any assistance in its development, please let me know. Until a unified protocol has been established, we will do our best to derive what is occurring from the collected data.

As we are able to derive results from the data collected, I will provide you with copies of the information. If there is anything that I can provide for the regional meeting at Hartford on November 5th, please let me know. If there are pictures that need to be made into slides, I would need to know by October 19, 1992.

I look forward to seeing you again on November 5, 1992, and the opportunity for an update on the status of SHRP related activities.

Sincerely,

Richard S. Haupt

Richard S. Haupt, P.E.
Vermont SHRP Contact Engineer



RSH:etn
cc:B. Henderson, V. Janoo - Dir. Merchant

# VERMONT AGENCY OF TRANSPORTATION SHRP-LTPP SITE TESTING

## Background

One of the primary goals of the Strategic Highway Research Program (SHRP), now under the jurisdiction of the Federal Highway Administration (FHWA), is to collect and evaluate data that will influence revisions to the AASHTO Design Guide. To help achieve this goal, the Long Term Pavement Performance (LTPP) Program was established. This 20-year program involves testing almost 1,000 in-service sections of pavement representing common types of pavement design currently in use, and sections which highlight certain factors or conditions calling for special design consideration. Among these conditions are severe soil, drainage, or environmental conditions, any of which often result in less than predicted performance.

LTPP sites that highlight these conditions have been identified in Vermont: one on U. S. Route 7 in New Haven, four on U.S. Route 7 in Charlotte, and one on U. S. Route 2 in South Hero. The Materials and Research Division of the Vermont Agency of Transportation (VAOT) is assisting the SHRP study in the evaluation of these sites by monitoring seasonal soil moisture and temperature variations, pavement temperature, loading, and deflections, atmospheric and ground water conditions, and pavement performance.

This monitoring program is an extension and modification of a program initiated in 1989 in conjunction with the U.S. Army Corps of Engineers Cold Regions Research Engineering Laboratory (CRREL) in Hanover, New Hampshire, to evaluate the effects of moisture in and near sections of a highway facility constructed over ledge. A location on Vt. Route 62 in Berlin was initially selected for this study, and this site has been included in the testing program being performed for the SHRP locations. Another test site adjacent to the Materials and Research Division on Town Highway 27 has also been included to evaluate the performance of a thin (weak) pavement section.

The five test locations all differ in traffic loading, pavement structure, and subgrade conditions (both soil type and moisture). The site locations are shown in Figure 1, and the site conditions are shown in Table 1.

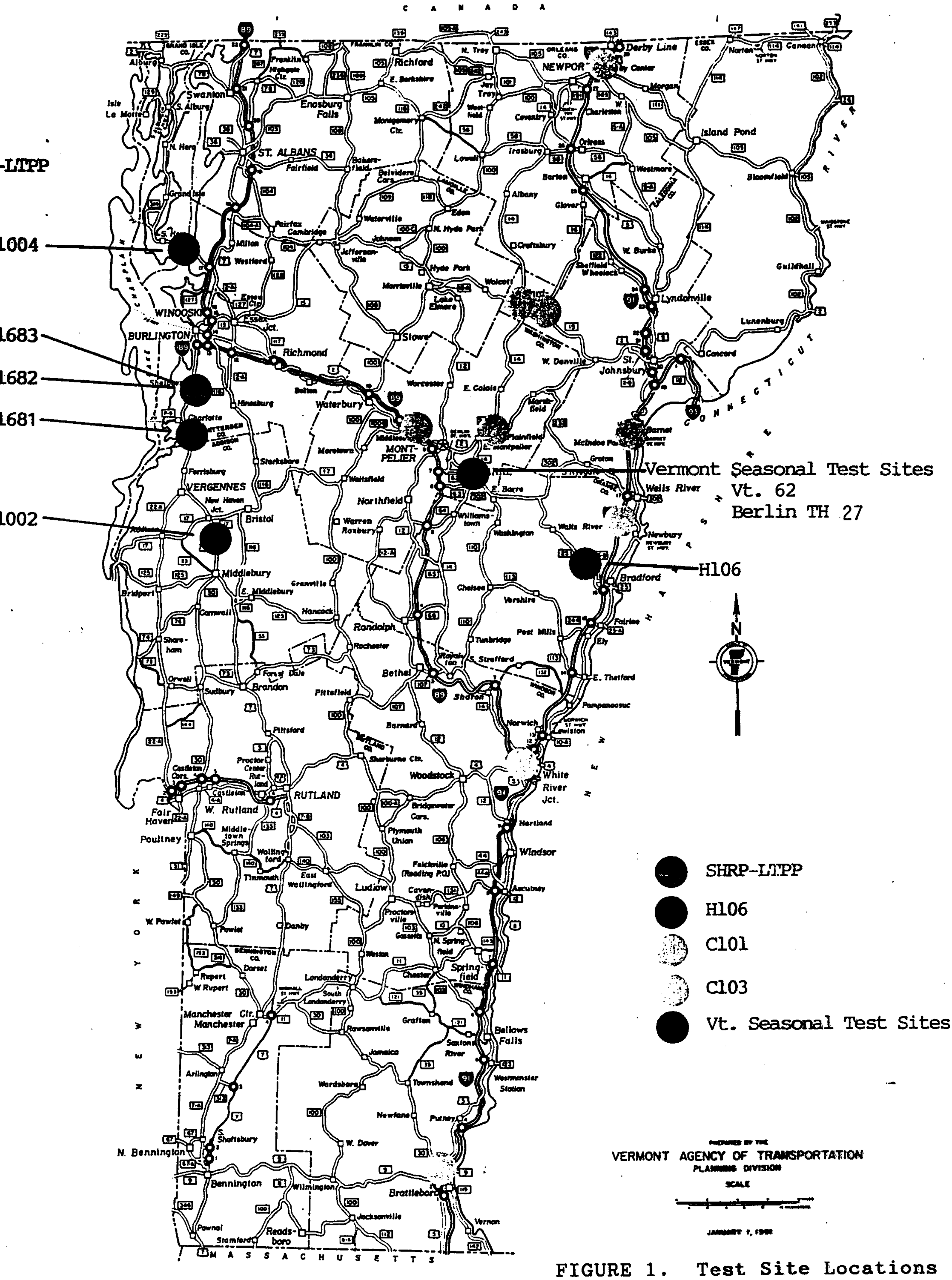



FIGURE 1. Test Site Locations

Table 1. Test Site Profiles

| Site | Pavement Structure | Subgrade | Traffic |
| --- | --- | --- | --- |
| VT 62 (Berlin) | 9.5" pavement<br>24" subbase<br>18" - 24" sand | silt | 4,800 ADT |
| TH 27 (Berlin) | 2.5" pavement<br>18" gravel | silt | Low |
| SHRP SITE 501002<br>New Haven | 8" pavement<br>24" crushed rock | A-7 clay | 6,500 ADT |
| SHRP SITE 501681<br>Charlotte | 10" pavement<br>20" gravel<br>12" granular borrow | 3'-9" A-1-a Granular<br>silt | 11,000 ADT |
| SHRP SITE 501004<br>South Hero | 8" pavement<br>24" crushed gravel<br>24" sand | hard pan silt | 7,800 ADT |
| *SHRP SITE 1683<br>Charlotte | 10" pavement<br>20" gravel<br>12" granular borrow | A-6 clay | 11,000 ADT |

*Seasonal Test Site to be Installed in 1993 by SHRP

## Objective

The specific objectives of the seasonal testing program are to monitor soil temperatures to a depth below the frost level, monitor moisture of each subbase and subgrade layer,and measure rainfall, air temperature, wind speed and direction, and water table fluctuations at the site year-round. This data will then be combined with traffic data from Weigh-in-Motion (WIM) installations located at each site, pavement deflections measured by FWD testing, and distress surveys to evaluate the effects of the conditions on different pavement structures.

From this testing, the following will be evaluated:

- Effect of freeze/thaw on pavement performance
- Effectiveness of sand layers for drainage
- Length and severity of freeze/thaw seasons
- Sources of moisture in pavement structures, time of retention, and soil permeability
- Relative performance of structural layers (layer coefficients)
- Seasonal effects on the structural capacity of structural layers (layer coefficients)
- Effects of traffic loading on pavement performance under severe moisture and temperature conditions (spring thaw).

All data and information will be used to evaluate and improve pavement design, pavement specifications, and maintenance management criteria. The whole concept of this program is integrated with the SHRP-LTPP program and will become part of their worldwide databases.

## Site Installation And Testing

Each location has received essentially the same format for installation of instrumentation, with variations tailored to the differences in pavement structure at that location. This treatment involves the placement of moisture and temperature sensors in the pavement structure and subgrade, soil property characterization, installation of a ground water level monitoring well, and installation of a weather monitoring station. Each site has a Weigh-in-Motion (WIM) installation, except TH 27 where a counter classifier was used due to its low traffic volume.

INSTALLATION: A 15" diameter core was cut through the pavement and removed. An auger was used to remove the material below the pavement, keeping each removed layer separate for replacement. Samples of each material were taken for analysis and testing. Removal of material continued to a depth of 75". At that depth, a four inch diameter hole was drilled through the subgrade to a depth of 11'. A 10' long MRC temperature probe was installed in the 11' hole and backfilled. This probe measures temperature at 3 inch intervals to a 15 inch depth, and then at one foot intervals to ten feet. TDR and Watermark moisture sensors were placed at depths of 75", 51", 39", 27" and 15" (the New Haven site,due to its reduced pavement section, received sensors at 39", 27", and 15" depths only). Backfilling and compaction was performed using the same material removed from the pavement structure. Thermistor temperature sensors were placed in the pavement at 2" and 6" depths below the surface. All wires were run through a 2" I.D. PVC pipe placed in a trench under the shoulder pavement. The roadway pavement plug and shoulder cut sections were replaced and sealed. Figure 2. depicts a typical site installation.

FIGURE 2. Typical Sensor Installation

| Top of Pavement | Sensor Depths | | Shoulder 2 1/2" AC |
|---|---|---|---|
| Pavement 8 - 10" AC | + 2" | | |
| | + 6" | | |
| Subbase | - 12" | | |
| | - 15" | * | |
| | - 18" | | |
| | - 21" | | |
| | - 24" | | |
| | - 27" | * | |
| Sand | - 39" | * | |
| | - 51" | * | |
| Subgrade | - 63" | | |
| | - 75" | * | |
| | - 87" | | |
| | - 99" | | |
| | - 111" | | |
| | - 123" | | |
| | - 132" | | |

* TDR and Watermark moisture sensors at each depth indicated.

\- MRC Temperature thermistor probe is from 12" to 132" below top of pavement with a thermistor at each depth indicated.

\+ Pavement temperature thermistors at each indicated depth.

A ground water level monitoring well wàs drilled approxi-amately 15' from the data collection recorder and equipped with a pressure transducer to monitor water table levels. A weather monitoring station, including a rain gauge, wind speed and direction gauge, and temperature sensor, was also installed adjacent to the recorder. The temperature sensors, moisture sensors, ground-water elevation, wind speed, wind direction, rainfall, and pavement temperature sensors are connected to a Campbell Scientific control module for continuous data collection, storage and retrieval. This module is tied in to a telephone line for dial-up retrieval of data. The TH 27 site has a continuous recorder for the TDR soil moisture probes. Due to equipment costs, all other sites are scheduled to be manually recorded on at least a monthly basis.

Deflection data from the FWD will be obtained at each site on a scheduled basis throughout the year. Deflections will be measured monthly during the Winter, twice a month during Summer, and at least weekly during the critical Fall (freeze) and Spring (thaw) seasons. WIM information is part of the required data for indicating traffic classification, loadings, Equivalent Single Axle Loads (ESAL's), and Average Daily Traffic (ADT) counts at each site.

Throughout the year, data will be retrieved and analyzed for each site. The sensors will indicate temperature and moisture conditions at various depths of the pavement structure. This can be correlated to rainfall and/or water table levels and air temperatures. Additionally, pavement performance under various conditions of moisture and temperature (freeze/thaw) can be evaluated through FWD deflections, distress surveys and traffic loading data.

<u>Applications of the Testing</u>

VAOT and SHRP will use the test results to address the following issues:

- Evaluation of the effectiveness of sand layers for drainage
- Identification of length and severity of spring thaw periods (including frost depths, role of thaw and moisture levels)
- Pavement performance during spring thaw periods under different loading conditions
- Identification of sources of moisture in pavement structures and retention times
- Permeability of soil layers and drainage characteristics for use in pavement design equations
- Effectiveness of pavement layers and correlation with structural layer coefficients used in pavement design

- Verification of effective roadbed resilient modulus used in pavement design calculations
- Evaluation of severe climate and moisture conditions on pavement design
- Some of these issues are currently being proposed for inclusion on the FY '93 Highway Planning Research (HPR) work plan. The SHRP testing will support the new initiatives.

Table B-1. Air Temperature Thermistor Calibration

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

| | | |
|---|---|---|
| Before Operation Checks | Calibration Date mm-dd-yy | 10-04-93 |
| | Probe S/N | 50AAT |
| | Operator | PZ & MZ |

| 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 |
| 8.71 | 3.90 | 14.85 | 22.20 | 1201 | 0.156 | 1112 | 52.80 | 1243 | y |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| | | |
|---|---|---|
| Probe Accepted | P.Z. & M.Z. | (Initials) |

Table B-2. MRC Probe Calibration

| LTPP Seasonal Monitoring Study | State Code | [50] |
|---|---|---|
| MRC Probe Calibration | Test Section Number | [1002] |

| Before Operation Checks | Calibration Date mm-dd-yy | 10-04-93 |
|---|---|---|
| | Probe S/N | 50AT |
| | Operator | PZ & MZ |

| | Mobile Datalogger (24 hour) | | | Water Room Temp Time 1201 | Ice Bath 0 C(+/- 1 C) Time 1112 | Hot Water 50 C (+/-) Time 1243 | ok |
|---|---|---|---|---|---|---|---|
| No. | Mean | Min. | Max. | Reading | Reading | Reading | y/n |
| 1 | 8.70 | 3.91 | 14.71 | 22.4 | 0.81 | 53.6 | y |
| 2 | 8.71 | 3.92 | 14.68 | 22.3 | 0.63 | 53.7 | y |
| 3 | 8.80 | 3.99 | 14.73 | 22.4 | 0.99 | 53.4 | y |
| 4 | 8.76 | 4.11 | 15.01 | 22.7 | 0.88 | 50.8 | y |
| 5 | 8.78 | 4.08 | 14.96 | 23.0 | 0.45 | 53.5 | y |
| 6 | 8.66 | 3.94 | 14.87 | 23.0 | 0.26 | 53.4 | y |
| 7 | 8.61 | 3.87 | 14.94 | 23.0 | 0.33 | 52.9 | y |
| 8 | 8.53 | 3.84 | 14.87 | 22.9 | 0.40 | 53.5 | y |
| 9 | 8.54 | 3.87 | 14.90 | 23.0 | 0.88 | 54.2 | y |
| 10 | 8.56 | 3.85 | 14.82 | 22.8 | 0.99 | 54.2 | y |
| 11 | 8.56 | 3.84 | 14.84 | 22.8 | 0.74 | 54.4 | y |
| 12 | 8.47 | 3.77 | 14.73 | 22.6 | 0.70 | 54.2 | y |
| 13 | 8.52 | 3.77 | 14.80 | 22.8 | 0.59 | 54.6 | y |
| 14 | 8.52 | | 14.73 | 22.7 | 0.73 | 53.9 | y |
| 15 | 8.52 | | 14.68 | 22.7 | 0.70 | 53.7 | y |
| 16 | 8.54 | | 14.79 | 22.8 | 0.56 | 53.5 | y |
| 17 | 8.14 | | 14.87 | 22.9 | 0.56 | 52.6 | y |
| 18 | 8.02 | | 14.90 | 22.8 | 0.25 | 53.1 | y |

| Probe Accepted: | M.Z. | (Initials) |
|---|---|---|
| Probe Length: | 1.854 | (meters) |

| Thermistor distance from top of probe: | | | | (meters) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4 | 0.017 | 7 | 0.246 | 10 | 0.624 | 13 | 1.080 | 16 | 1.545 |
| 5 | 0.093 | 8 | 0.322 | 11 | 0.778 | 14 | 1.239 | 17 | 1.691 |
| 6 | 0.169 | 9 | 0.475 | 12 | 0.928 | 15 | 1.386 | 18 | 1.841 |

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

| Unit | Channel No. | Distance from Top of Unit(m) | Remarks |
|---|---|---|---|
| 1 | 1 | 0.013 | 0.3302 m long by 63.5 mm stainless steel probe installed in the AC layer. |
| | 2 | 0.165 | |
| | 3 | 0.318 | |
| 2 | 4 | 0.017 | 1.854 m long by 25.4 mm PVC tube installed in the base and subgrade. |
| | 5 | 0.093 | |
| | 6 | 0.169 | |
| | 7 | 0.246 | |
| | 8 | 0.322 | |
| | 9 | 0.475 | |
| | 10 | 0.624 | |
| | 11 | 0.778 | |
| | 12 | 0.928 | |
| | 13 | 1.080 | |
| | 14 | 1.239 | |
| | 15 | 1.386 | |
| | 16 | 1.545 | |
| | 17 | 1.691 | |
| | 18 | 1.841 | |

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 | 0.029 |
| 35 | 2 | x | 1-2 | 52 | 51 | 51.5 | 0.081 |
| 34 | 3 | x | 2-3 | 50 | 51 | 50.5 | 0.131 |
| 33 | 4 | x | 3-4 | 50 | 49 | 49.5 | 0.181 |
| 32 | 5 | x | 4-5 | 52 | 53 | 52.5 | 0.233 |
| 31 | 6 | x | 5-6 | 49 | 50 | 49.5 | 0.282 |
| 30 | 7 | x | 6-7 | 52 | 51 | 51.5 | 0.334 |
| 29 | 8 | x | 7-8 | 49 | 48 | 48.5 | 0.383 |
| 28 | 9 | x | 8-9 | 50 | 51 | 50.5 | 0.433 |
| 27 | 10 | x | 9-10 | 54 | 55 | 54.5 | 0.487 |
| 26 | 11 | x | 10-11 | 50 | 50 | 50.0 | 0.537 |
| 25 | 12 | x | 11-12 | 50 | 51 | 50.5 | 0.587 |
| 24 | 13 | x | 12-13 | 49 | 48 | 48.5 | 0.636 |
| 23 | 14 | x | 13-14 | 51 | 52 | 51.5 | 0.687 |
| 22 | 15 | x | 14-15 | 51 | 50 | 50.5 | 0.738 |
| 21 | 16 | x | 15-16 | 50 | 51 | 50.5 | 0.788 |
| 20 | 17 | x | 16-17 | 53 | 52 | 52.5 | 0.841 |
| 19 | 18 | x | 17-18 | 50 | 49 | 49.5 | 0.991 |
| 18 | 19 | x | 18-19 | 52 | 51 | 51.5 | 0.943 |
| 17 | 20 | x | 19-20 | 51 | 52 | 51.5 | 0.994 |
| 16 | 21 | x | 20-21 | 50 | 50 | 50.0 | 1.044 |
| 15 | 22 | x | 21-22 | 51 | 50 | 50.5 | 1.095 |
| 14 | 23 | x | 22-23 | 50 | 50 | 50.0 | 1.145 |
| 13 | 24 | x | 23-24 | 49 | 49 | 49.0 | 1.194 |
| 12 | 25 | x | 24-25 | 51 | 51 | 51.0 | 1.245 |
| 11 | 26 | x | 25-26 | 51 | 52 | 51.5 | 1.296 |
| 10 | 27 | x | 26-27 | 52 | 50 | 51.0 | 1.348 |
| 9 | 28 | x | 27-28 | 49 | 50 | 49.5 | 1.397 |
| 8 | 29 | x | 28-29 | 50 | 50 | 50.0 | 1.447 |
| 7 | 30 | x | 29-30 | 50 | 50 | 50.0 | 1.497 |
| 6 | 31 | x | 30-31 | 52 | 52 | 52.0 | 1.549 |
| 5 | 32 | x | 31-32 | 50 | 51 | 50.5 | 1.599 |
| 4 | 33 | x | 32-33 | 51 | 49 | 50.0 | 1.650 |
| 3 | 34 | x | 33-34 | 50 | 51 | 50.5 | 1.700 |
| 2 | 35 | x | 34-35 | 50 | 51 | 50.5 | 1.750 |
| 1 | 36 | x | 35-36 | 49 | 50 | 49.5 | 1.799 |
| | | | 36-End | 25 | 25 | 25.0 | 1.824 |

Table B-5. Contact Resistance Calibration

| LTPP Seasonal Monitoring Study | | | | | State Code | | [50] |
|---|---|---|---|---|---|---|---|
| Data Sheet R1 | | | | | | | |
| Contact Resistance Measurements | | | | | Test Section Number | | [1002] |
| 1. Date (Month - Day - Year) | | | | | | | [10-04-93] |
| 2. Time Measurements Began (Military) | | | | | | | [1330] |
| 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 | 159.4 | uA | 116.3 | |
| 2 | 3 | 2 | mV | 159.1 | uA | 115.9 | |
| 3 | 3 | 4 | mV | 158.2 | uA | 114.8 | |
| 4 | 5 | 4 | mV | 159.2 | uA | 112.6 | |
| 5 | 5 | 6 | mV | 154.5 | uA | 119.0 | |
| 6 | 7 | 6 | mV | 152.2 | uA | 122.1 | |
| 7 | 7 | 8 | mV | 148.1 | uA | 126.5 | |
| 8 | 9 | 8 | mV | 149.9 | uA | 123.7 | |
| 9 | 9 | 10 | mV | 153.0 | uA | 119.0 | |
| 10 | 11 | 10 | mV | 148.7 | uA | 124.4 | |
| 11 | 11 | 12 | mV | 153.2 | uA | 117.8 | |
| 12 | 13 | 12 | mV | 153.6 | uA | 116.9 | |
| 13 | 13 | 14 | mV | 153.9 | uA | 116.4 | |
| 14 | 15 | 14 | mV | 151.9 | uA | 118.8 | |
| 15 | 15 | 16 | mV | 149.8 | uA | 121.4 | |
| 16 | 17 | 16 | mV | 149.3 | uA | 121.5 | |
| 17 | 17 | 18 | mV | 146.6 | uA | 125.1 | |
| 18 | 19 | 18 | mV | 148.5 | uA | 121.9 | |
| 19 | 19 | 20 | mV | 146.5 | uA | 123.8 | |
| 20 | 21 | 20 | mV | 144.5 | uA | 125.8 | |
| 21 | 21 | 22 | mV | 144.5 | uA | 125.4 | |
| 22 | 23 | 22 | mV | 145.9 | uA | 123.9 | |
| 23 | 23 | 24 | mV | 144.6 | uA | 124.8 | |
| 24 | 25 | 24 | mV | 144.7 | uA | 124.2 | |
| 25 | 25 | 26 | mV | 145.2 | uA | 122.5 | |
| 26 | 27 | 26 | mV | 146.5 | uA | 120.9 | |
| 27 | 27 | 28 | mV | 145.7 | uA | 121.4 | |
| 28 | 29 | 28 | mV | 144.7 | uA | 122.4 | |
| 29 | 29 | 30 | mV | 142.9 | uA | 124.6 | |
| 30 | 31 | 30 | mV | 143.1 | uA | 123.9 | |
| 31 | 31 | 32 | mV | 142.5 | uA | 124.1 | |
| 32 | 33 | 32 | mV | 141.4 | uA | 124.9 | |
| 33 | 33 | 34 | mV | 140.7 | uA | 125.6 | |
| 34 | 35 | 34 | mV | 140.0 | uA | 126.4 | |
| 35 | 35 | 36 | mV | 138.1 | uA | 128.8 | |
| 36 | 37 | 38 | mV | | uA | | |
| 37 | 38 | 39 | mV | | uA | | |
| 38 | 39 | 40 | mV | | uA | | |
| Preparer : | | Michael Zawisa | | | Employer : | | PMSL |

## Table B-6. TDR Probes Calibration

| LTPP Seasonal Monitoring Study | State Code | [50] |
|---|---|---|
| | | |
| TDR Probes | Test Section Number | [1002] |

| Before Operation Checks | P.Z. | Initial | Calibration Date (mm-dd-yy) | 10-02-93 |
|---|---|---|---|---|
| | | | Seasonal Site | 50SA |

| 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 | 50A01 | 0.700 | 1.100 | 16.331 | 16.451 | 16.351 | 16.361 | 16.361 |
| 2 | 50A02 | 0.800 | 0.700 | 16.331 | 16.501 | 16.341 | 16.361 | 16.361 |
| 3 | 50A03 | 0.700 | 0.600 | 16.311 | 16.451 | 16.331 | 16.351 | 16.351 |
| 4 | 50A04 | 0.800 | 0.700 | 16.341 | 16.501 | 16.361 | 16.361 | 16.371 |
| 5 | 50A05 | 0.900 | 0.800 | 16.381 | 16.501 | 16.351 | 16.411 | 16.431 |
| 6 | 50A06 | 0.600 | 1.200 | 16.321 | 16.351 | 16.341 | 16.361 | 16.361 |
| 7 | 50A07 | 0.800 | 0.700 | 16.391 | 16.501 | 16.391 | 16.431 | 16.461 |
| 8 | 50A08 | 0.800 | 0.600 | 16.331 | 16.501 | 16.351 | 16.361 | 16.361 |
| 9 | 50A09 | 0.600 | 0.500 | 16.351 | 16.481 | 16.351 | 16.361 | 16.481 |
| 10 | 50A10 | 1.000 | 0.800 | 16.421 | 16.491 | 16.401 | 16.411 | 16.461 |

NOTE: Record lengths from TDR

Calculation of Dielectric Constant

Probe Length 0.203 m

$V_p$ Setting 0.99 $V_p$

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

| 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 | 0.19 | 0.88 | y | 1.20 | 35.0 | y | 1.86 | 84.0 | y |
| 2 | 0.20 | 0.97 | y | 1.21 | 35.5 | y | 1.86 | 84.0 | y |
| 3 | 0.20 | 0.97 | y | 1.21 | 35.5 | y | 1.86 | 84.0 | y |
| 4 | 0.20 | 0.97 | y | 1.19 | 34.4 | y | 1.87 | 84.9 | y |
| 5 | 0.21 | 1.07 | y | 1.22 | 36.1 | y | 1.86 | 84.0 | y |
| 6 | 0.20 | 0.97 | y | 1.20 | 35.0 | y | 1.85 | 83.1 | y |
| 7 | 0.18 | 0.78 | y | 1.21 | 35.5 | y | 1.86 | 84.0 | y |
| 8 | 0.19 | 0.88 | y | 1.24 | 37.3 | y | 1.87 | 84.9 | y |
| 9 | 0.21 | 1.07 | y | 1.20 | 35.0 | y | 1.86 | 84.0 | y |
| 10 | 0.18 | 0.78 | y | 1.20 | 35.0 | y | 1.85 | 83.1 | y |

| LTPP Seasonal Monitoring Study | State Code | [_ _] |
|---|---|---|
| TDR Probe Calibration | Test Section Number | [_ _ _ _] |

Before Operation Checks - Calibration Date ____________
- Probe S/N ____________

Probe Number 1

TDR Trace 1 - Beginning Probe Shorted

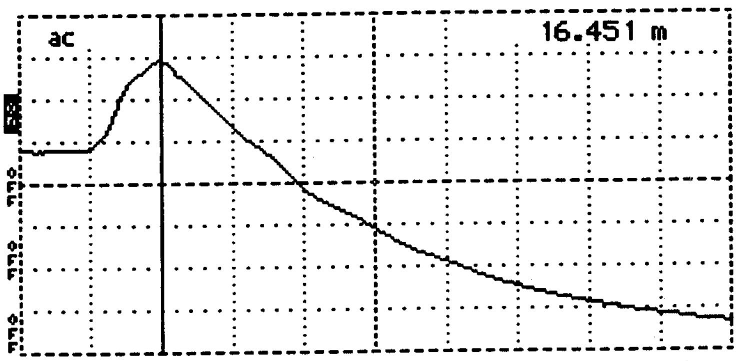
Cursor .......... 16.331 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp ............. 0.99
Noise Filter...... 1 avg
Power........... ac


Tektronix 1502B TDR
Date 10/02/93
Cable 1
Notes Short CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

rsor .......... 16.451 m
stance/Div..... .25 m/div
rtical Scale.... 182 mρ/div
............. 0.99
ise Filter...... 1 avg
wer........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 1
Notes Shortend

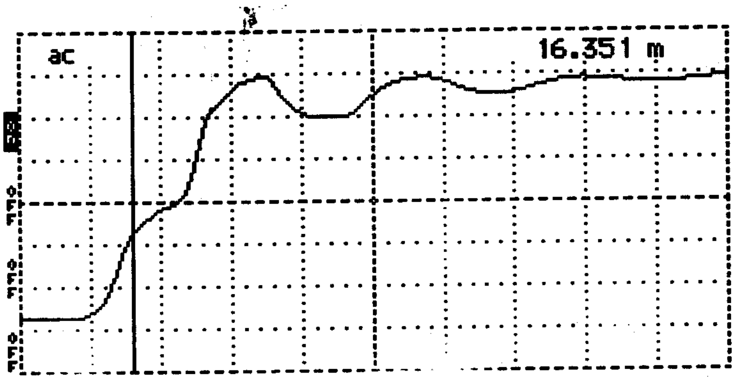
Input Trace
Stored Trace
Difference Trace

Figure B-1. TDR Traces Obtained During Calibration

Probe Number 1 (cont.)

Trace Number 3 - Probe in Air

ursor .......... 16.351 m
stance/Div..... .25 m/div
ertical Scale.... 158 mρ/div
P ............. 0.99
oise Filter...... 1 avg
ower........... ac

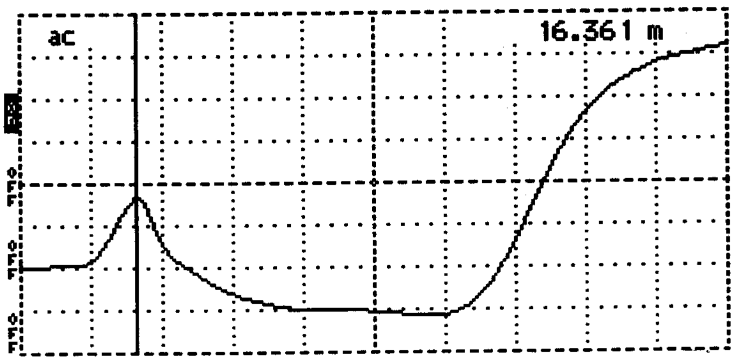



Tektronix 1502B TDR
Date 10/02/93
Cable 1
Notes Air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

rsor .......... 16.361 m
Distance/Div..... .25 m/div
Vertical Scale.... 115 mρ/div
VP ............. 0.99
Noise Filter...... 1 avg
Power........... ac

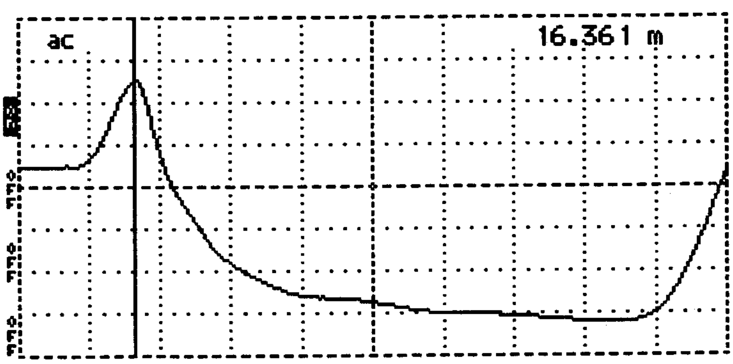



Tektronix 1502B TDR
Date 10/02/93
Cable 1
Notes Alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

ursor .......... 16.361 m
stance/Div..... .25 m/div
ertical Scale.... 86.4 mρ/div
P ............. 0.99
oise Filter...... 1 avg
ower........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 1
Notes H2O

Input Trace
Stored Trace
Difference Trace

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

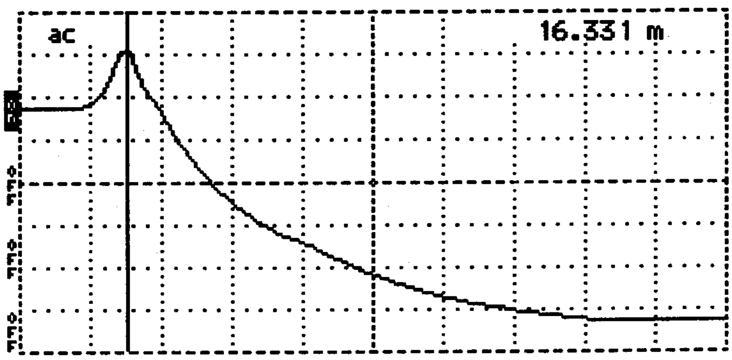
| | | |
|---|---|---|
| LTPP Seasonal Monitoring Study | State Code | [__ __] |
| TDR Probe Calibration | Test Section Number | [__ __ __ __] |

Before Operation Checks - Calibration Date ______________
- Probe S/N ______________

Probe Number 2

TDR Trace 1 - Beginning Probe Shorted

rsor .......... 16.331 m
stance/Div ..... .25 m/div
rtical Scale.... 167 mρ/div
.............. 0.99
ise Filter...... 1 avg
wer........... ac

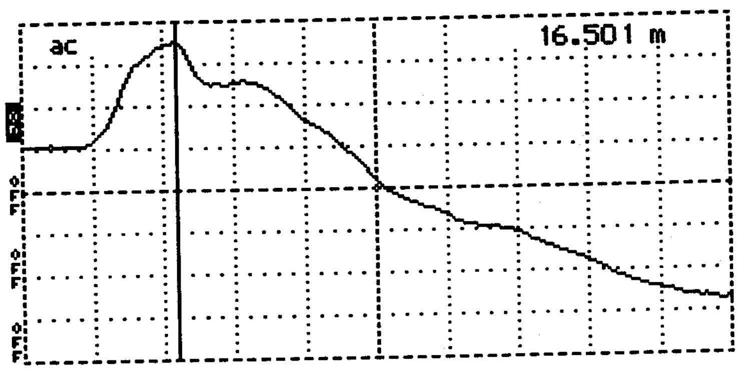



Tektronix 1502B TDR
Date 10/02/93
Cable 2
Notes Short CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

rsor .......... 16.501 m
stance/Div ..... .25 m/div
rtical Scale.... 167 mρ/div
.............. 0.99
ise Filter...... 1 avg
wer........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 2
Notes Short end

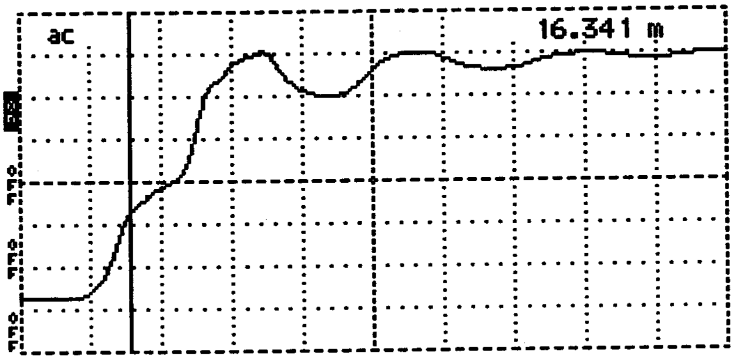
Input Trace
Stored Trace
Difference Trace

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

Probe Number 2 (cont.)

Trace Number 3 - Probe in Air

sor .......... 16.341 m
tance/Div..... .25 m/div
rtical Scale.... 154 mρ/div
............... 0.99
se Filter...... 1 avg
ver........... ac

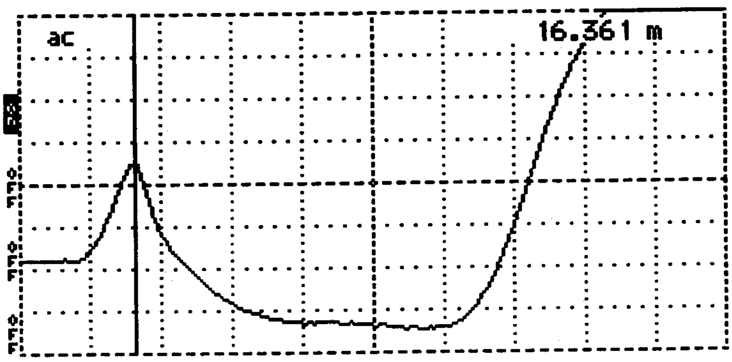



Tektronix 1502B TDR
Date 10/02/93
Cable 2
Notes Air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

or .......... 16.361 m
tance/Div..... .25 m/div
tical Scale.... 81.6 mρ/div
............... 0.99
se Filter...... 1 avg
ver........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 2
Notes Alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

sor .......... 16.361 m
tance/Div..... .25 m/div
tical Scale.... 81.6 mρ/div
............... 0.99
se Filter...... 1 avg
ver........... ac


Tektronix 1502B TDR
Date 10/02/93
Cable 2
Notes $H_2O$

Input Trace
Stored Trace
Difference Trace

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

| LTPP Seasonal Monitoring Study | State Code | [___] |
|---|---|---|
| TDR Probe Calibration | Test Section Number | [______] |

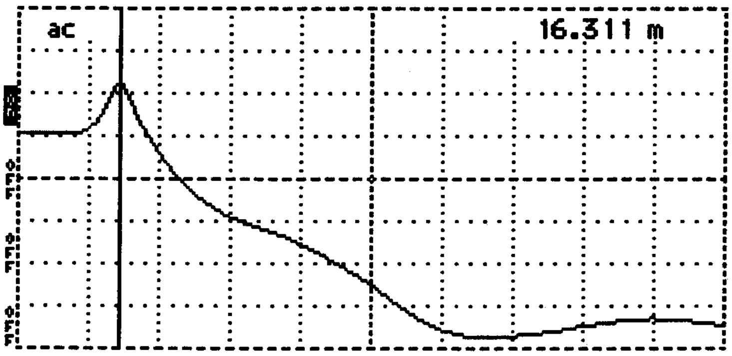
3efore Operation Checks - Calibration Date ________________

- Probe S/N ________________

Probe Number 3

TDR Trace 1 - Beginning Probe Shorted

Cursor ........... 16.311 m
)istance/Div ..... .25 m/div
/ertical Scale.... 182 mρ/div
/P .............. 0.99
Noise Filter...... 1 avg
Power........... ac

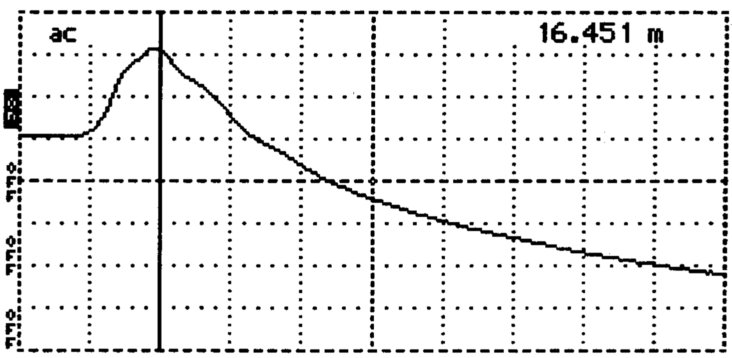



Tektronix 1502B TDR
Date 10/02/93
Cable 3
Notes Short CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

rsor ........... 16.451 m
tance/Div ..... .25 m/div
rtical Scale.... 182 mρ/div
.............. 0.99
se Filter...... 1 avg
wer........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 3
Notes Short end

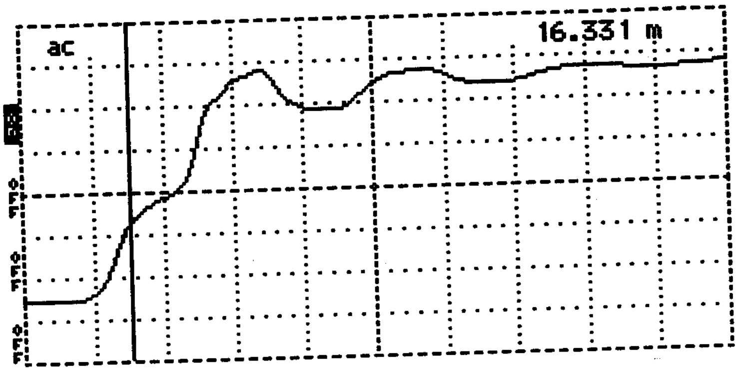
Input Trace
Stored Trace
Difference Trace

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

Probe Number 3 (cont.)

race Number 3 - Probe in Air

rsor .......... 16.331 m
stance/Div..... .25 m/div
rtical Scale.... 167 mρ/div
 ............. 0.99
ise Filter...... 1 avg
wer........... ac

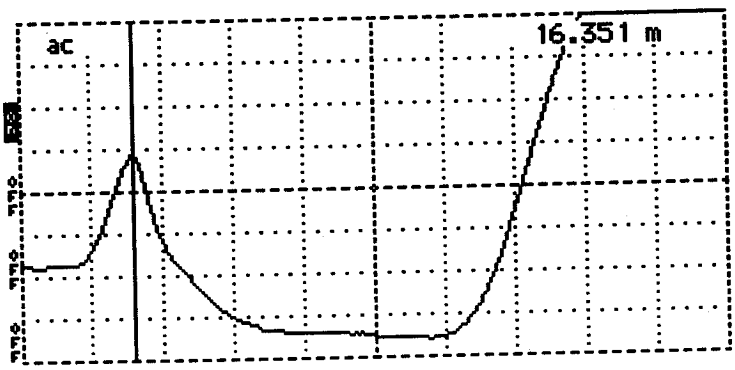



Tektronix 1502B TDR
Date 10/02/93
Cable 3
Notes Air

Input Trace
Stored Trace
Difference Trace

race Number 4 - Probe in Alcohol

.or .......... 16.351 m
ance/Div..... .25 m/div
tical Scale.... 72.7 mρ/div
 ............. 0.99
se Filter...... 1 avg
ver........... ac

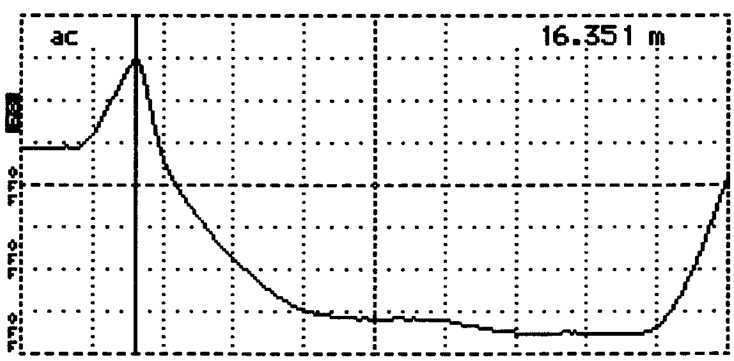



Tektronix 1502B TDR
Date 10/02/93
Cable 3
Notes Alcohol

Input Trace
Stored Trace
Difference Trace

race Number 5 - Probe in Water

r .......... 16.351 m
nce/Div..... .25 m/div
cal Scale.... 72.7 mρ/div
 ............ 0.99
 Filter...... 1 avg
 ........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 3
Notes $H_2O$

Input Trace
Stored Trace
Difference Trace

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

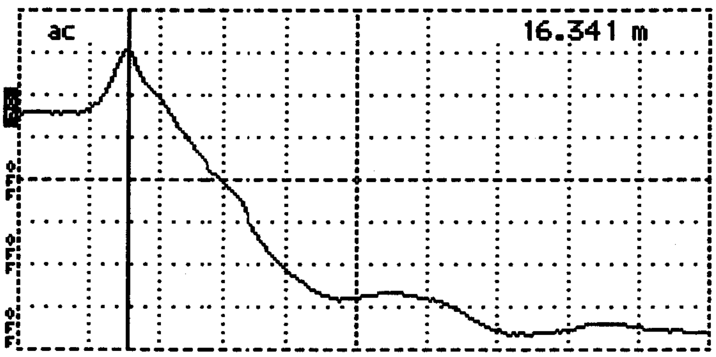
| LTPP Seasonal Monitoring Study | State Code | [_ _] |
|---|---|---|
| TDR Probe Calibration | Test Section Number | [_ _ _ _ _] |

efore Operation Checks - Calibration Date ______
- Probe S/N ______

Probe Number 4

DR Trace 1 - Beginning Probe Shorted

rsor .......... 16.341 m
tance/Div ..... .25 m/di
tical Scale.... 163 mρ/dv
............... 0.99
se Filter ...... 1 avg
ver ........... ac

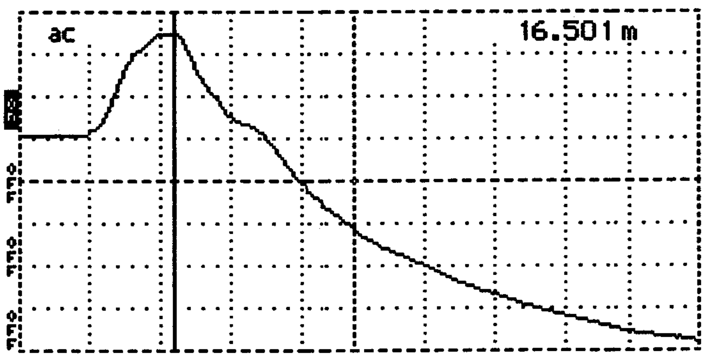



Tektronix 1502B TDR
Date 10/02/93
Cable 4
Notes Short CB

Input Trace
Stored Trace
Difference Trace

race Number 2 - Ending Probe Shorted

Cursor .......... 16.501 m
Distance/Div ..... .25 m/div
Vertical Scale.... 163 mρ/div
/P .............. 0.99
Noise Filter ...... 1 avg
Power ........... ac



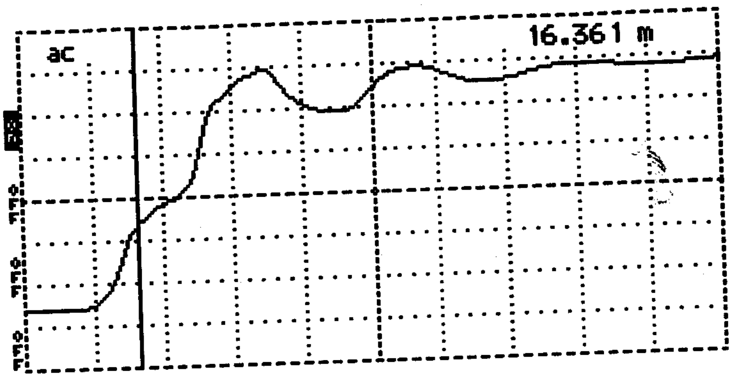

Tektronix 1502B TDR
Date 10/02/93
Cable 4
Notes Short End

Input Trace
Stored Trace
Difference Trace

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

race Number 3 - Probe in Air

ursor .......... 16.361 m
istance/Div..... .25 m/div
ertical Scale.... 163 mρ/div
'p ............. 0.99
loise Filter...... 1 avg
'ower.......... ac

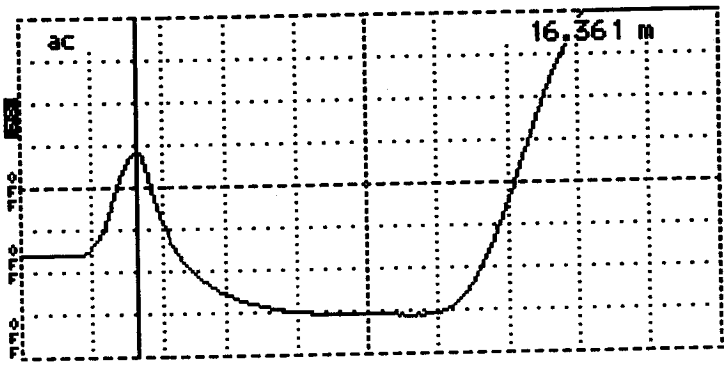



Tektronix 1502B TDR
Date 10/02/93
Cable 4
Notes Air

Input Trace
Stored Trace
Difference Trace

race Number 4 - Probe in Alcohol

:ursor .......... 16.361 m
Distance/Div..... .25 m/div
Vertical Scale.... 81.6 mρ/div
VP ............. 0.99
Noise Filter...... 1 avg
Power.......... ac

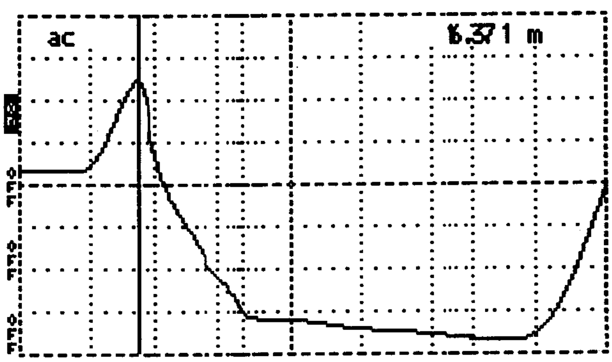



Tektronix 1502B TDR
Date 10/02/93
Cable 4
Notes Alcohol

Input Trace
Stored Trace
Difference Trace

race Number 5 - Probe in Water

Cursor ..........16.371 m
Distance/Div..... .25 m/div
Vertical Scale....81.6 mρ/div
VP .............0.99
Noise Filter......1 avg
Power..........ac




Tektronix 1502B TDR
Date 10/02/93
Cable 4
Notes $H_2O$

Input Trace
Stored Trace
Difference Trace

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

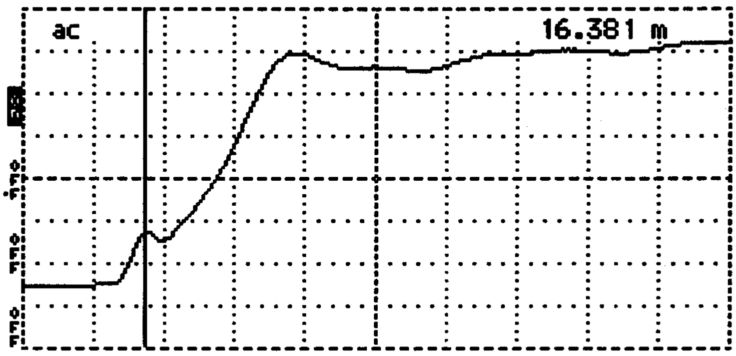
| LTPP Seasonal Monitoring Study | State Code | [__] |
|---|---|---|
| TDR Probe Calibration | Test Section Number | [____] |

efore Operation Checks - Calibration Date __________
- Probe S/N __________

Probe Number 5

DR Trace 1 - Beginning Probe Shorted

rsor ........... 16.381 m
tance/Div..... .25 m/div
rtical Scale.... 154 mρ/div
.............. 0.99
se Filter...... 1 avg
wer........... ac

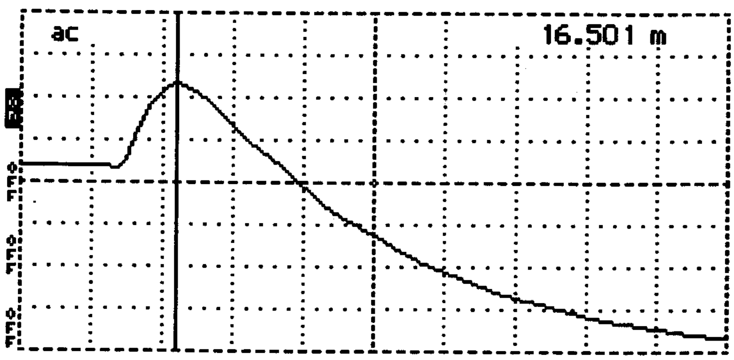



Tektronix 1502B TDR
Date 10/02/93
Cable 5
Notes Short CB

Input Trace
Stored Trace
Difference Trace

ace Number 2 - Ending Probe Shorted

rsor ........... 16.501 m
tance/Div..... .25 m/div
rtical Scale.... 188 mρ/div
.............. 0.99
se Filter...... 1 avg
wer........... ac



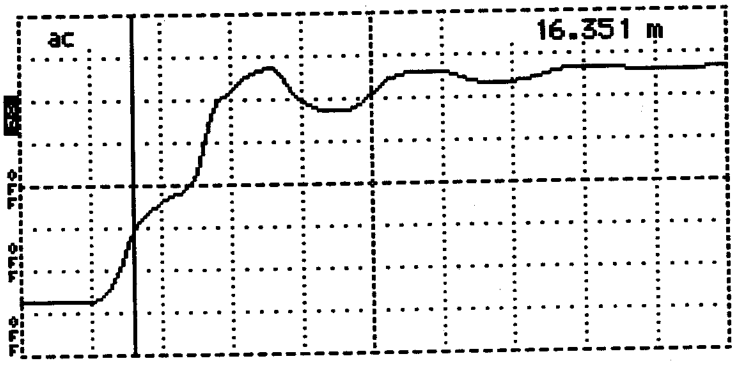

Tektronix 1502B TDR
Date 10/02/93
Cable 5
Notes Shorted End

Input Trace
Stored Trace
Difference Trace

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

Trace Number 3 - Probe in Air

ursor .......... 16.351 m
stance/Div..... .25 m/div
ertical Scale.... 163 mρ/div
ρ ............. 0.99
oise Filter...... 1 avg
ower........... ac

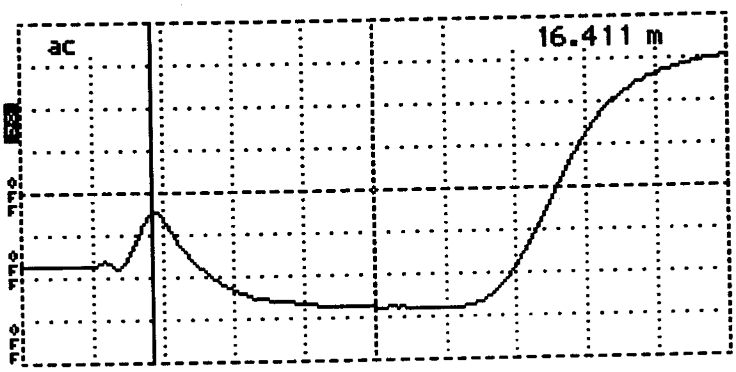



Tektronix 1502B TDR
Date 10/02/93
Cable 5
Notes In Air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

or .......... 16.411 m
stance/Div..... .25 m/div
rtical Scale.... 122 mρ/div
............. 0.99
ise Filter...... 1 avg
wer........... ac

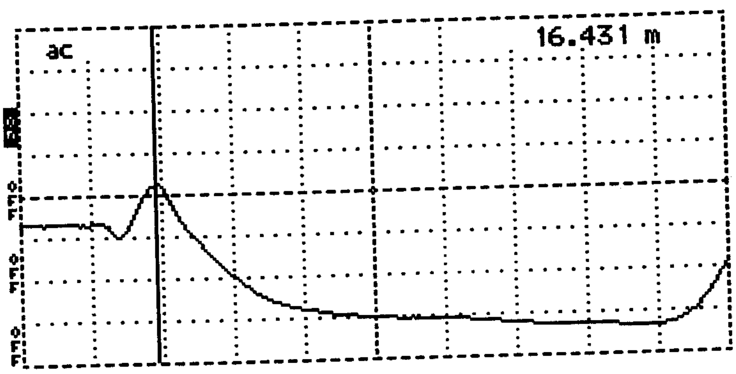



Tektronix 1502B TDR
Date 10/02/93
Cable 5
Notes In Alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

ursor .......... 16.431 m
istance/Div..... .25 m/div
ertical Scale.... 122 mρ/div
P ............. 0.99
oise Filter...... 1 avg
ower........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 5
Notes $H_2O$

Input Trace
Stored Trace
Difference Trace

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

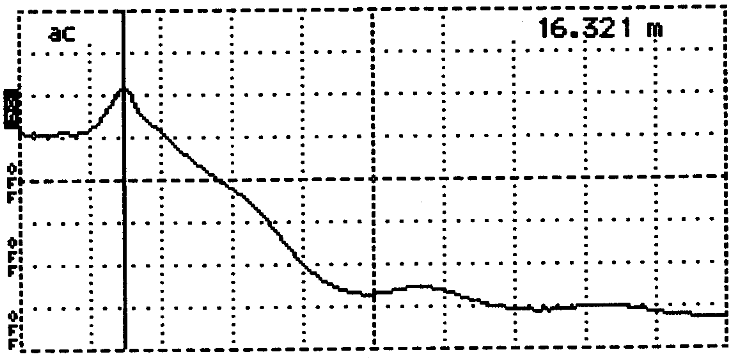
| LTPP Seasonal Monitoring Study | State Code | [_ _] |
|---|---|---|
| TDR Probe Calibration | Test Section Number | [_ _ _ _] |

Before Operation Checks - Calibration Date ____________
- Probe S/N ____________

Probe Number 6

TDR Trace 1 - Beginning Probe Shorted

sor .......... 16.321 m
tance/Div..... .25 m/div
tical Scale.... 200 mρ/div
.............. 0.99
se Filter...... 1 avg
ver........... ac

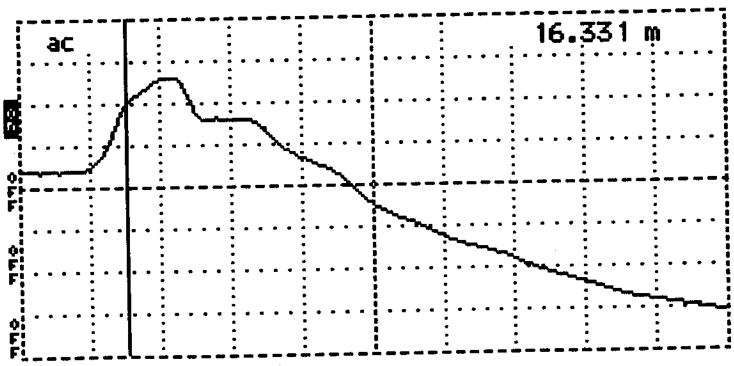



Tektronix 1502B TDR
Date 10/02/93
Cable 6
Notes Shorted @ CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

rsor .......... 16.331 m
tance/Div..... .25 m/div
rtical Scale.... 182 mρ/div
.............. 0.99
ise Filter...... 1 avg
wer........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 6
Notes Shorted@end

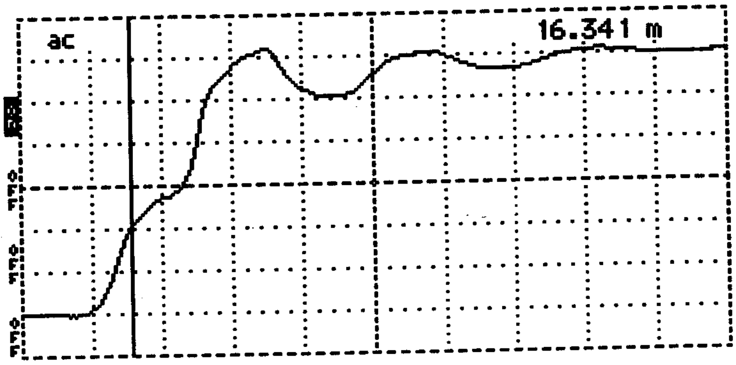
Input Trace
Stored Trace
Difference Trace

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

Probe Number 6 (cont.)

Trace Number 3 - Probe in Air

rsor .......... 16.341 m
stance/Div..... .25 m/div
rtical Scale.... 145 mρ/div
.............. 0.99
ise Filter...... 1 avg
wer........... ac

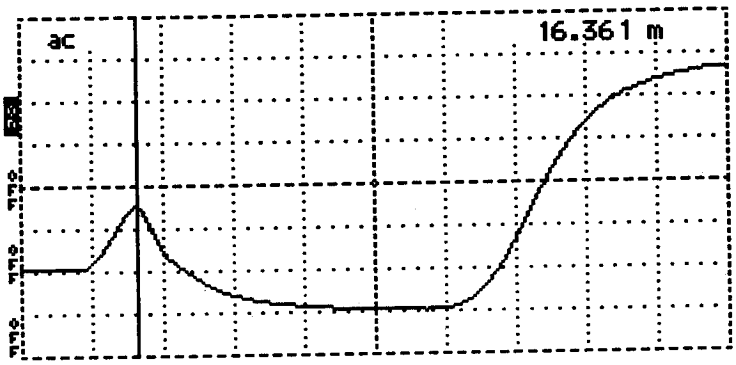



Tektronix 1502B TDR
Date 10/02/93
Cable 6
Notes In Air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

'or .......... 16.361 m
..ance/Div..... .25 m/div
rtical Scale.... 129 mρ/div
ρ .............. 0.99
ise Filter...... 1 avg
wer........... ac

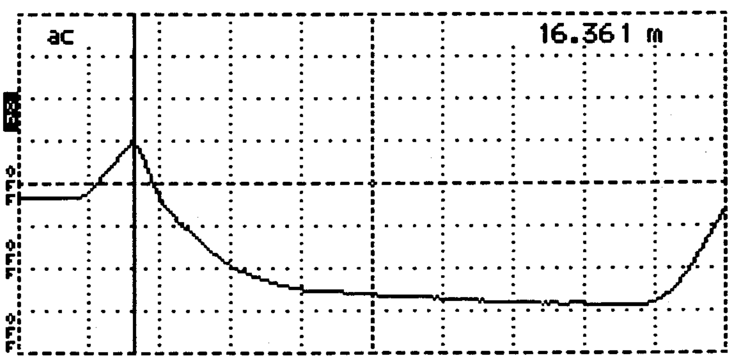



Tektronix 1502B TDR
Date 10/02/93
Cable 6
Notes In Alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

ursor .......... 16.361 m
istance/Div..... .25 m/div
ertical Scale.... 126 mρ/div
ρ .............. 0.99
oise Filter...... 1 avg
ower........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 6
Notes In $H_2O$

Input Trace
Stored Trace
Difference Trace

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

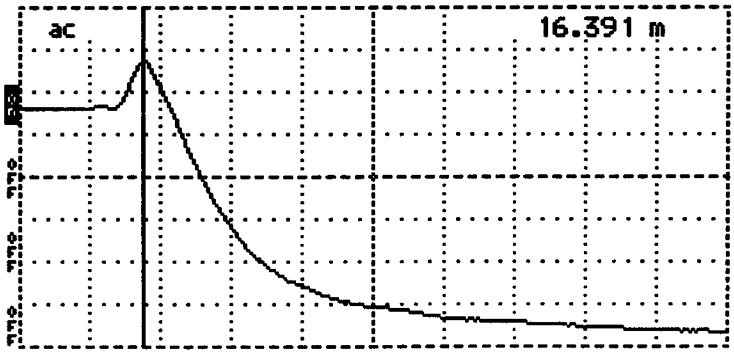
| LTPP Seasonal Monitoring Study | State Code | [_ _] |
|---|---|---|
| TDR Probe Calibration | Test Section Number | [_ _ _ _] |

Before Operation Checks - Calibration Date ______________
- Probe S/N ______________

Probe Number 7

TDR Trace 1 - Beginning Probe Shorted

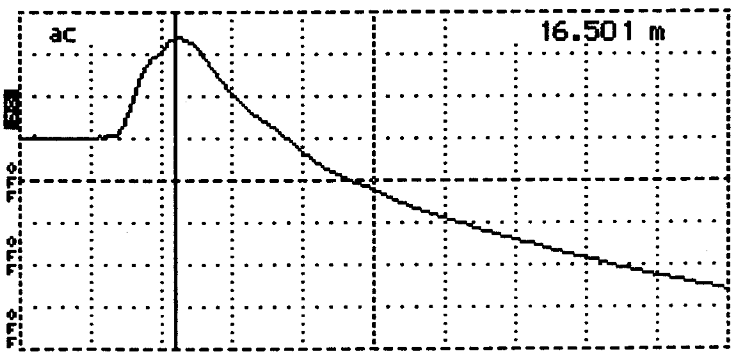
rsor ........... 16.391 m
stance/Div..... .25 m/div
rtical Scale.... 163 mρ/div
 .............. 0.99
ise Filter...... 1 avg
wer........... ac




Tektronix 1502B TDR
Date ______________
Cable ______________
Notes Short CB
______________
______________
Input Trace ______
Stored Trace ......
Difference Trace ......

Trace Number 2 - Ending Probe Shorted

ursor ........... 16.501 m
istance/Div..... .25 m/div
ertical Scale.... 163 mρ/div
P .............. 0.99
oise Filter...... 1 avg
ower........... ac

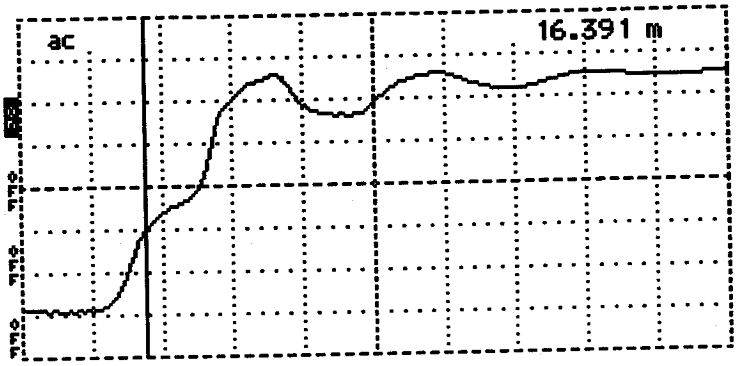



Tektronix 1502B TDR
Date 1010293
Cable 7
Notes Shortend
______________
______________
Input Trace ______
Stored Trace ......
Difference Trace ......

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

Trace Number 3 - Probe in Air

rsor .......... 16.391 m
stance/Div..... .25 m/div
rtical Scale.... 163 mρ/div
............. 0.99
ise Filter...... 1 avg
wer........... ac

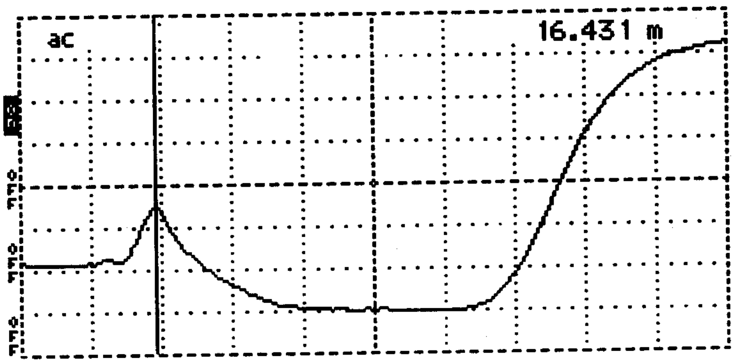



Tektronix 1502B TDR
Date 10/02/93
Cable 7
Notes Air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

ursor .......... 16.431 m
istance/Div..... .25 m/div
ertical Scale.... 115 mρ/div
p ............. 0.99
loise Filter...... 1 avg
ower........... ac

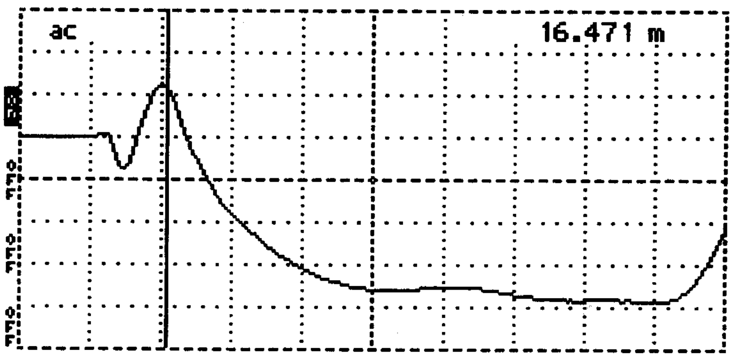



Tektronix 1502B TDR
Date 10/02/93
Cable 7
Notes Alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

rsor .......... 16.471 m
stance/Div..... .25 m/div
rtical Scale.... 83.9 mρ/div
............. 0.99
ise Filter...... 1 avg
wer........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 7
Notes $H_2O$

Input Trace
Stored Trace
Difference Trace

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

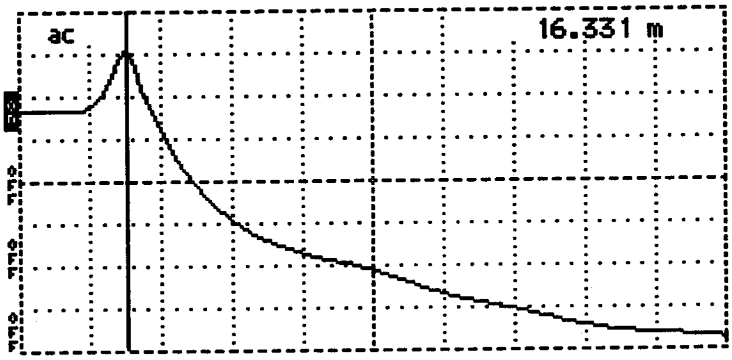
| LTPP Seasonal Monitoring Study | State Code | [_ _] |
|---|---|---|
| TDR Probe Calibration | Test Section Number | [_ _ _ _] |

Before Operation Checks - Calibration Date ________
- Probe S/N ________

Probe Number 8

TDR Trace 1 - Beginning Probe Shorted

rsor .......... 16.331 m
stance/Div..... .25 m/div
rtical Scale.... 163 mρ/div
.............. 0.99
ise Filter...... 1 avg
wer........... ac

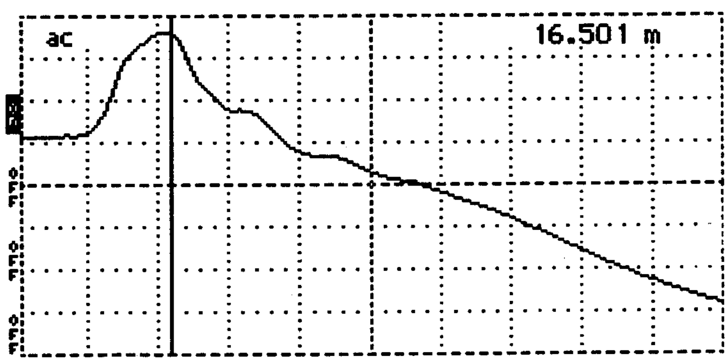



Tektronix 1502B TDR
Date 10/02/93
Cable 8
Notes Short CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

ırsor .......... 16.501 m
stance/Div..... .25 m/div
ertical Scale.... 163 mρ/div
.............. 0.99
oise Filter...... 1 avg
ower........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 8
Notes Short end

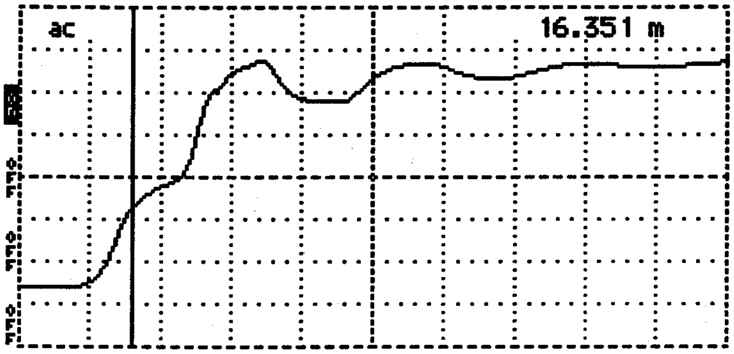
Input Trace
Stored Trace
Difference Trace

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

Probe Number 8 (cont.)

Trace Number 3 - Probe in Air

ursor .......... 16.351 m
istance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P ..............0.99
oise Filter...... 1 avg
ower...........ac

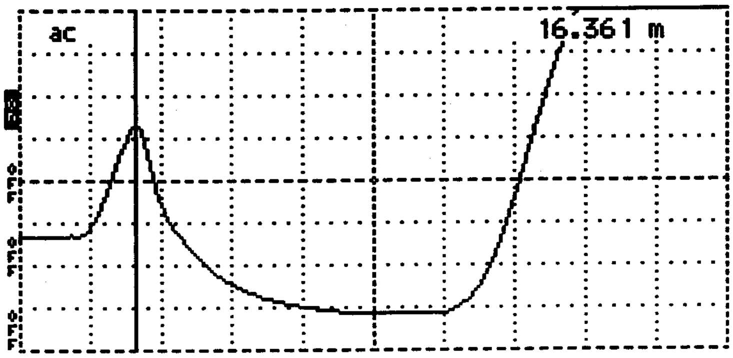



Tektronix 1502B TDR
Date 10/18 2/93
Cable 8
Notes Air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

or .......... 16.361 m
tance/Div..... .25 m/div
rtical Scale.... 72.7 mρ/div
.............. 0.99
se Filter...... 1 avg
wer........... ac

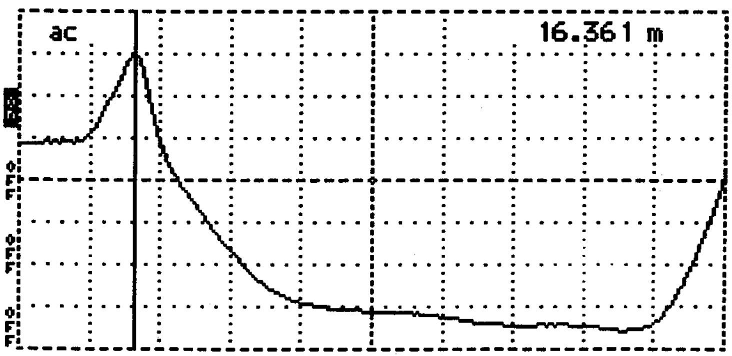



Tektronix 1502B TDR
Date 10/02/93
Cable 8
Notes Alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

or .......... 16.361 m
nce/Div..... .25 m/div
cal Scale.... 72.7 mρ/div
.............. 0.99
Filter...... 1 avg
........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 8
Notes $H_2O$

Input Trace
Stored Trace
Difference Trace

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

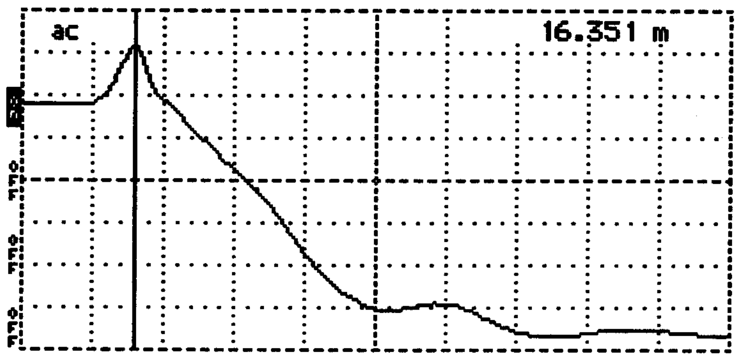
| LTPP Seasonal Monitoring Study | State Code | [__] |
|---|---|---|
| TDR Probe Calibration | Test Section Number | [____] |

Before Operation Checks - Calibration Date ______
- Probe S/N ______

Probe Number 9

TDR Trace 1 - Beginning Probe Shorted

rsor .......... 16.351 m
stance/Div..... .25 m/div
rtical Scale.... 154 mρ/div
.............. 0.99
ise Filter...... 1 avg
wer........... ac

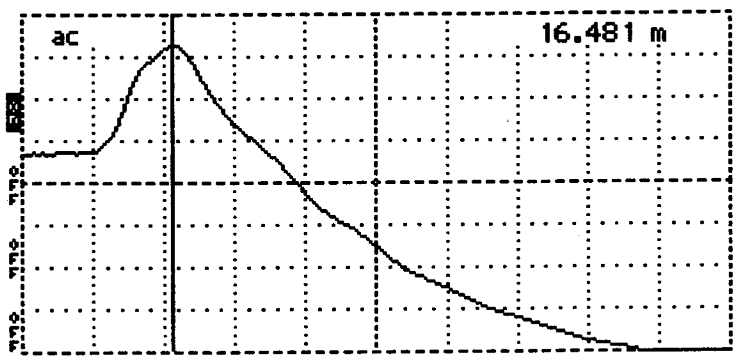



Tektronix 1502B TDR
Date 10/12/93
Cable 9
Notes Short CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

sor .......... 16.481 m
ance/Div..... .25 m/div
tical Scale.... 154 mρ/div
.............. 0.99
e Filter...... 1 avg
er........... ac



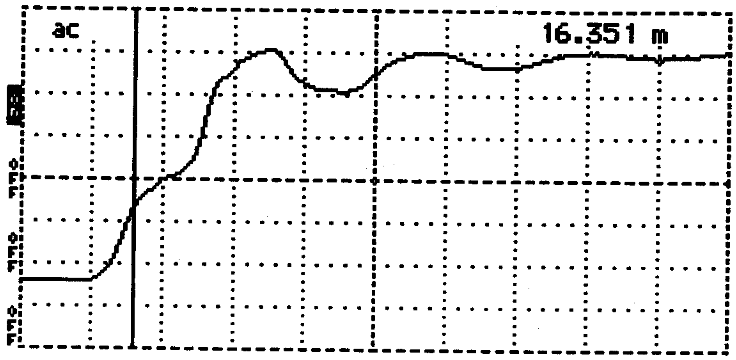

Tektronix 1502B TDR
Date 10/02/93
Cable 9
Notes Shorted

Input Trace
Stored Trace
Difference Trace

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

ace Number 3 - Probe in Air

rsor .......... 16.351 m
tance/Div ..... .25 m/div
tical Scale.... 163 mρ/div
.............. 0.99
se Filter...... 1 avg
ver........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 9
Notes Air

Input Trace
Stored Trace
Difference Trace

race Number 4 - Probe in Alcohol

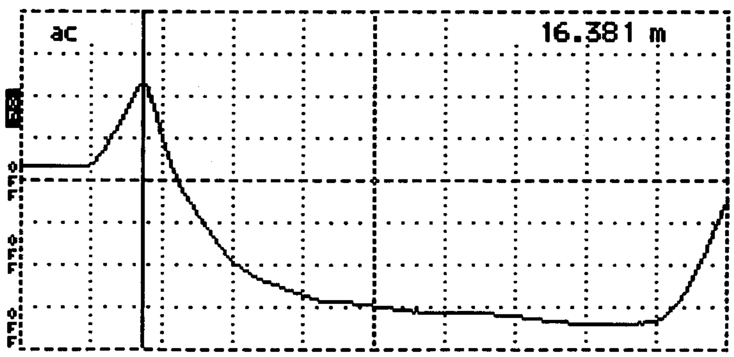
.r .......... 16.361 m
nce/Div ..... .25 m/div
ical Scale.... 86.4 mρ/div
.............. 0.99
Filter...... 1 avg
r........... ac


Tektronix 1502B TDR
Date 10/02/93
Cable 9
Notes Alcohol

Input Trace
Stored Trace
Difference Trace

race Number 5 - Probe in Water

rsor .......... 16.381 m
tance/Div ..... .25 m/div
rtical Scale.... 86.4 mρ/div
.............. 0.99
se Filter...... 1 avg
'er........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 9
Notes $H_2O$

Input Trace
Stored Trace
Difference Trace

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

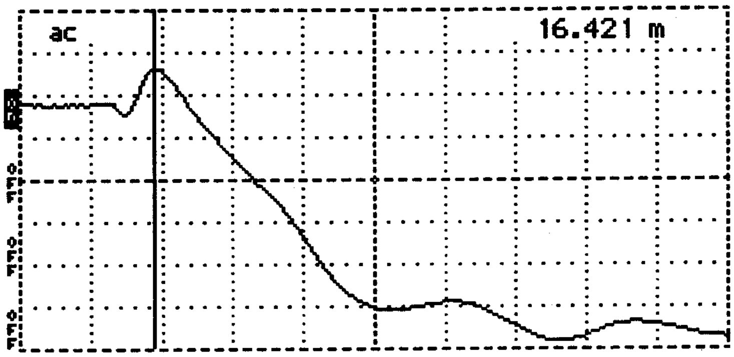
| LTPP Seasonal Monitoring Study | State Code | [_ _] |
|---|---|---|
| TDR Probe Calibration | Test Section Number | [_ _ _ _] |

efore Operation Checks
- Calibration Date ________
- Probe S/N ________

Probe Number 10

DR Trace 1 - Beginning Probe Shorted

sor .......... 16.421 m
tance/Div..... .25 m/div
tical Scale.... 158 mρ/div
.............. 0.99
se Filter...... 1 avg
ver........... ac

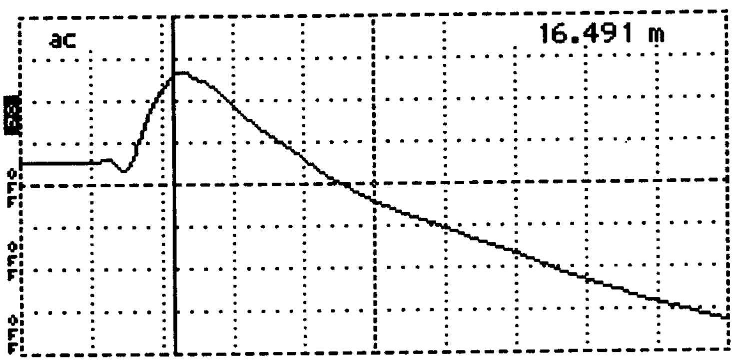



Tektronix 1502B TDR
Date 10/02/93
Cable 10
Notes Short CB

Input Trace ________
Stored Trace ........
Difference Trace ........

race Number 2 - Ending Probe Shorted

sor .......... 16.491 m
tance/Div..... .25 m/div
tical Scale.... 158 mρ/div
.............. 0.99
se Filter...... 1 avg
ver........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 10
Notes Short end

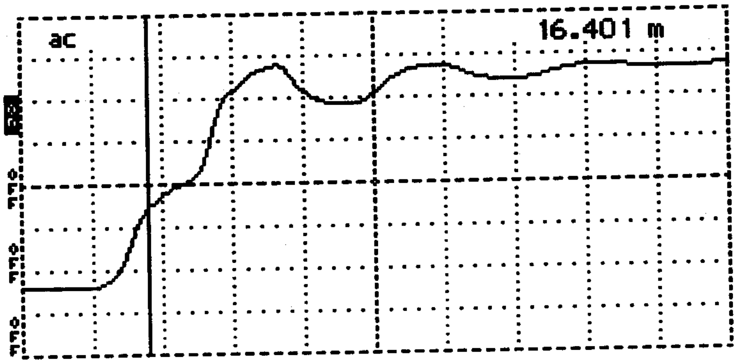
Input Trace ________
Stored Trace ........
Difference Trace ........

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

Probe Number 10 (cont.)

Trace Number 3 - Probe in Air

or .......... 16.401 m
nce/Div..... .25 m/div
ical Scale.... 172 mρ/div
............. 0.99
e Filter...... 1 avg
er........... ac

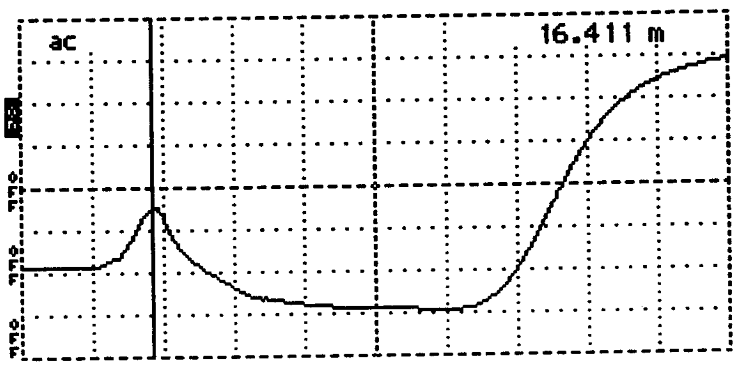



Tektronix 1502B TDR
Date 10/02/93
Cable 10
Notes Air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

sor .......... 16.411 m
stance/Div..... .25 m/div
rtical Scale.... 126 mρ/div
............. 0.99
ise Filter...... 1 avg
wer........... ac

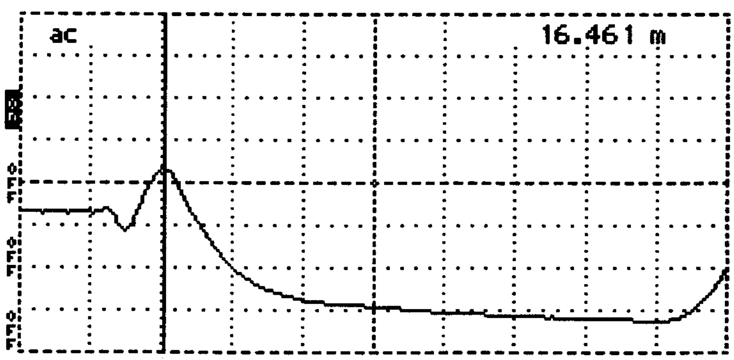



Tektronix 1502B TDR
Date 10/02/93
Cable 10
Notes Alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

sor .......... 16.461 m
tance/Div..... .25 m/div
tical Scale.... 126 mρ/div
.............. 0.99
se Filter...... 1 avg
ver........... ac




Tektronix 1502B TDR
Date 10/02/93
Cable 10
Notes $H_2O$

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 |
| Table C-1 | TDR Moisture Content During Installation |
| Table C-2 | Field Measured Moisture Content During Installation |

Laboratory Moisture Samples' Results as Received from the State

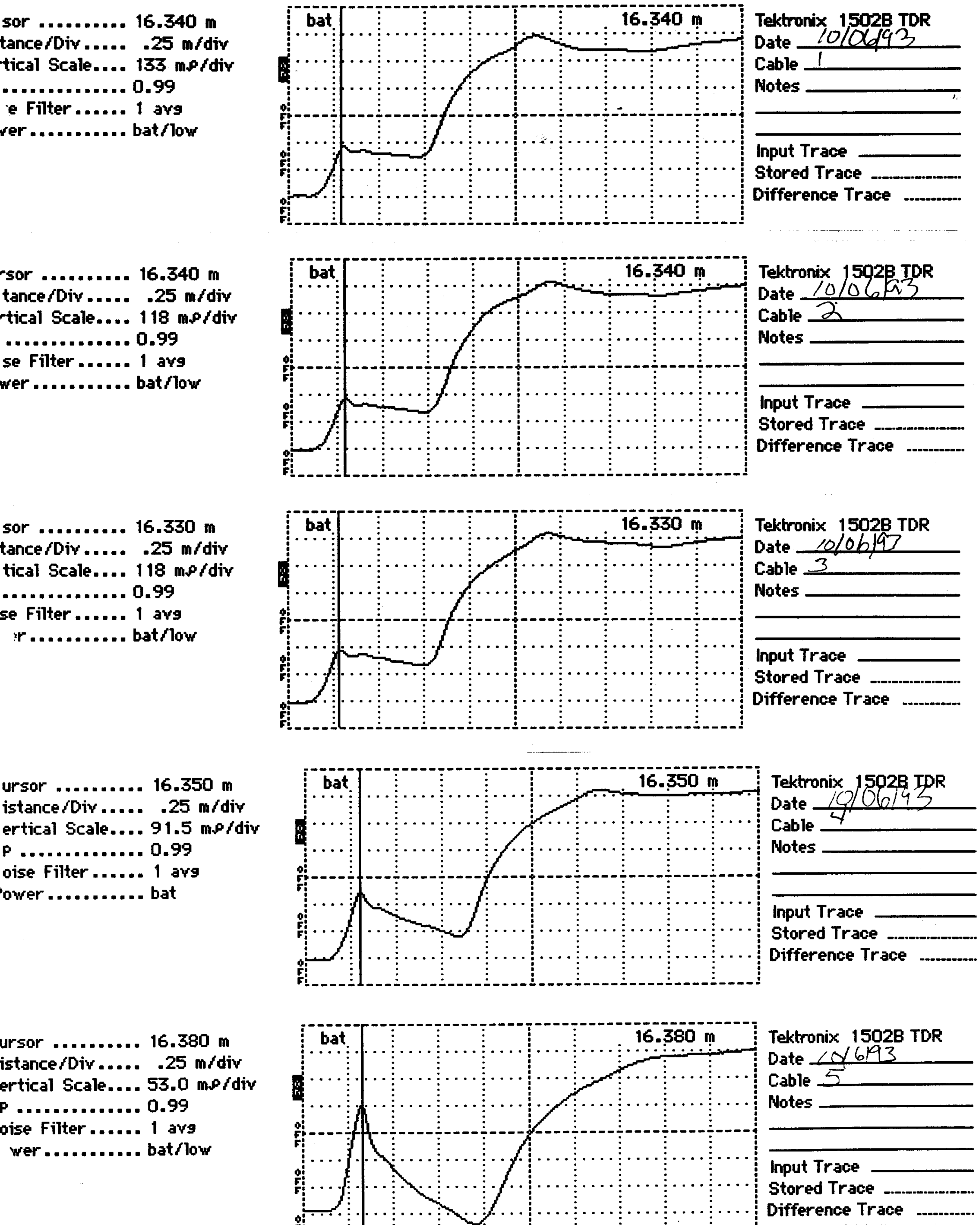
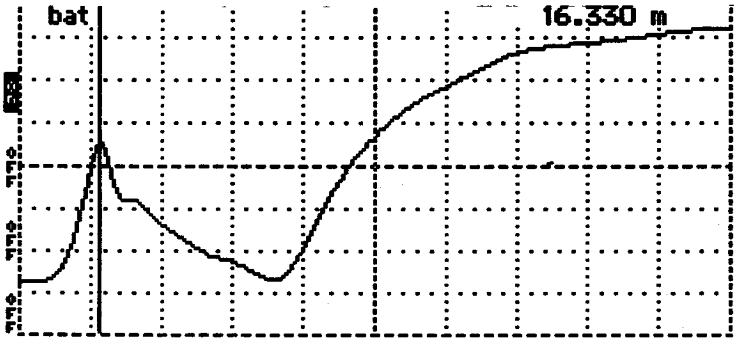



Figure C-1. TDR Traces Measured Manually During Installation

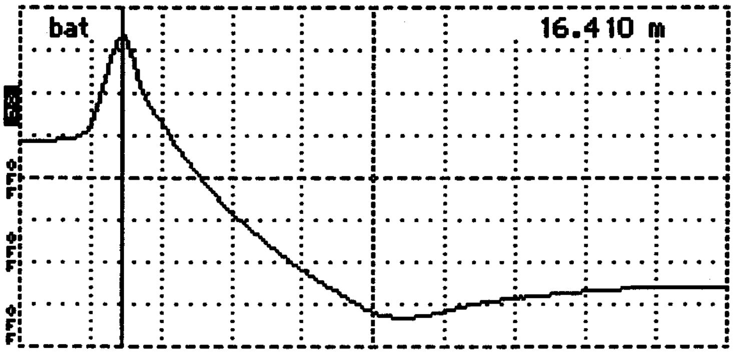
sor .......... 16.330 m
ance/Div..... .25 m/div
tical Scale.... 64.8 mρ/div
 ............. 0.99
 Filter...... 1 avg
er........... bat




Tektronix 1502B TDR
Date 10/06/93
Cable 6
Notes

Input Trace
Stored Trace
Difference Trace

sor .......... 16.410 m
tance/Div..... .25 m/div
tical Scale.... 77.0 mρ/div
 ............. 0.99
se Filter...... 1 avg
ver........... bat




Tektronix 1502B TDR
Date 10/06/93
Cable 7
Notes

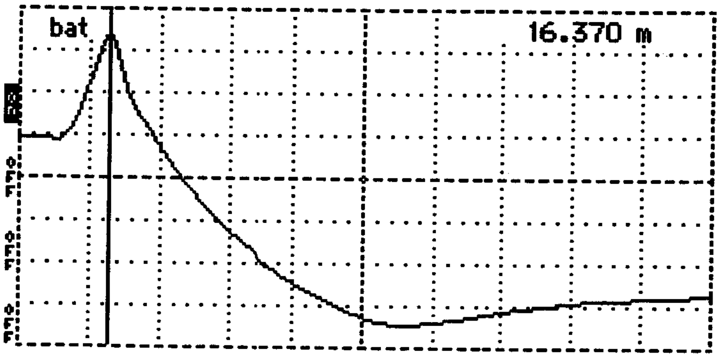
Input Trace
Stored Trace
Difference Trace

Cursor ....... 16.350 m
Distance/Div .25 m/div
Vertical Scale 72.7 mρ/div
VP .......... 0.99
Noise Filter 1 avg
ower....... bat


Tektronix 1502B TDR
Date 10/6/93
Cable 8
Notes

Input Trace
Stored Trace
Difference Trace

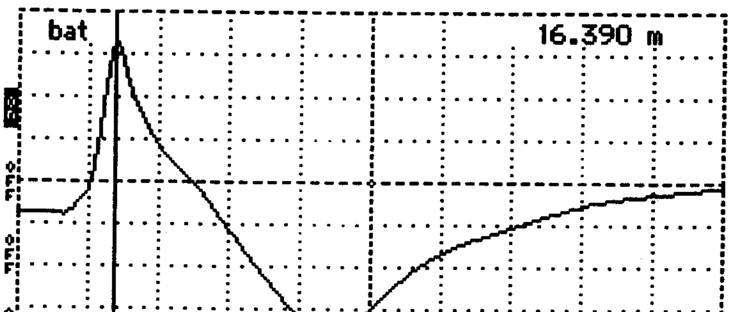
Cursor ..........16.370 m
Distance/Div..... .25 m/div
Vertical Scale....79.2 mρ/div
VP .............0.99
Noise Filter......1 avg
Power..........bat




Tektronix 1502I TDR
Date 10/6/93
Cable 9
Notes

Input Trace
Stored Trace
Difference Trace

ursor .......... 16.390 m
stance/Div..... .25 m/div
ertical Scale.... 54.5 mρ/div
 ............. 0.99
se Filter...... 1 avg
wer........... bat




Tektronix 1502B TDR
Date 10/6/93
Cable 10
Notes

Input Trace
Stored Trace
Difference Trace

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 ($kg/m^3$) | Gravimetric Moisture Content (%) |
|---|---|---|---|---|---|
| 50A01 | 0.450 | 5.01 | 8.06 | 2.06 | 3.91 |
| 50A02 | 0.510 | 6.44 | 11.40 | 1.99 | 5.73 |
| 50A03 | 0.510 | 6.44 | 11.40 | 1.99 | 5.73 |
| 50A04 | 0.580 | 8.33 | 15.54 | 1.99 | 7.81 |
| 50A05 | 0.660 | 10.79 | 20.44 | 2.09 | 9.78 |
| 50A06 | 0.670 | 11.11 | 21.06 | 2.09 | 10.08 |
| 50A07 | 0.950 | 22.35 | 37.51 | 2.09 | 17.95 |
| 50A08 | 0.880 | 19.17 | 33.69 | 2.09 | 16.12 |
| 50A09 | 1.070 | 28.35 | 43.36 | 2.09 | 20.74 |
| 50A10 | 0.760 | 14.30 | 26.61 | 2.09 | 12.73 |

Table C-2. Field Measured Moisture Content

| LTPP Seasonal Monitoring Study | State Code | [50] |
|---|---|---|
| In-Situ Moisture Tests | Test Section Number | [1002] |

| Weight (gm) | Probe 1 | Probe 2 | Probe 3 | Probe 4 | Probe 5 |
|---|---|---|---|---|---|
| Weight of Pan + Wet Soil | 367.4 | 271.2 | 218.5 | * | 241.0 |
| Weight of Pan + Dry Soil | 364.2 | 268.2 | 215.7 | * | 228.1 |
| Weight of Pan | 120.6 | 120.6 | 120.6 | * | 120.9 |
| Weight of Dry Soil | 243.6 | 147.6 | 95.1 | * | 107.2 |
| Weight of Wet Soil | 246.8 | 150.6 | 97.9 | * | 120.1 |
| Weight of Moisture | 3.2 | 3.0 | 2.8 | * | 12.9 |
| Wt of Moisture/Dry Wt x 100 | 1.31 | 2.03 | 2.94 | * | 12.03 |

| Weight (gm) | Probe 6 | Probe 7 | Probe 8 | Probe 9 | Probe 10 |
|---|---|---|---|---|---|
| Weight of Pan + Wet Soil | 229.3 | 208.1 | 218.6 | 233.0 | 227.5 |
| Weight of Pan + Dry Soil | 216.8 | 193.9 | 206.9 | 210.4 | 206.2 |
| Weight of Pan | 120.6 | 120.2 | 120.6 | 121.4 | 120.6 |
| Weight of Dry Soil | 96.2 | 73.7 | 86.3 | 89.0 | 85.6 |
| Weight of Wet Soil | 108.7 | 87.9 | 98.0 | 111.6 | 106.9 |
| Weight of Moisture | 12.5 | 14.2 | 11.7 | 22.6 | 21.3 |
| Wt of Moisture/Dry Wt x 100 | 12.99 | 19.27 | 13.56 | 25.39 | 24.88 |

* Note: No field moisture for probe #4

STATE OF VERMONT
AGENCY OF TRANSPORTATION
133 State Street, Administration Building
Montpelier, Vermont 05633

OCT 29 1993

COPY

FILE #

October 27, 1993

Mr. Brandt Henderson
Pavement Management Systems
415 Lawrence Bell Drive
Amherst, NY 15221

**RE: Seasonal testing - Sample moisture content**

Dear Mr. Henderson,

The following are the results of the moisture content analysis run on the soil samples taken from the New Haven seasonal test installation on 10/06/1993.

| Sample | % moisture | Sample | % moisture |
|---|---|---|---|
| 1 | 2.20% | 6 | 13.79% |
| 2 | 1.63% | 7 | 22.31% |
| 3 | 1.48% | 8 | 19.70% |
| 4 | N/A | 9 | 25.45% |
| 5 | 11.53% | 10 | 23.67% |

Sincerely yours,

Christopher C Benda

Chris Benda

# APPENDIX D

## Initial Data Collection

Appendix D contains the following supporting information:

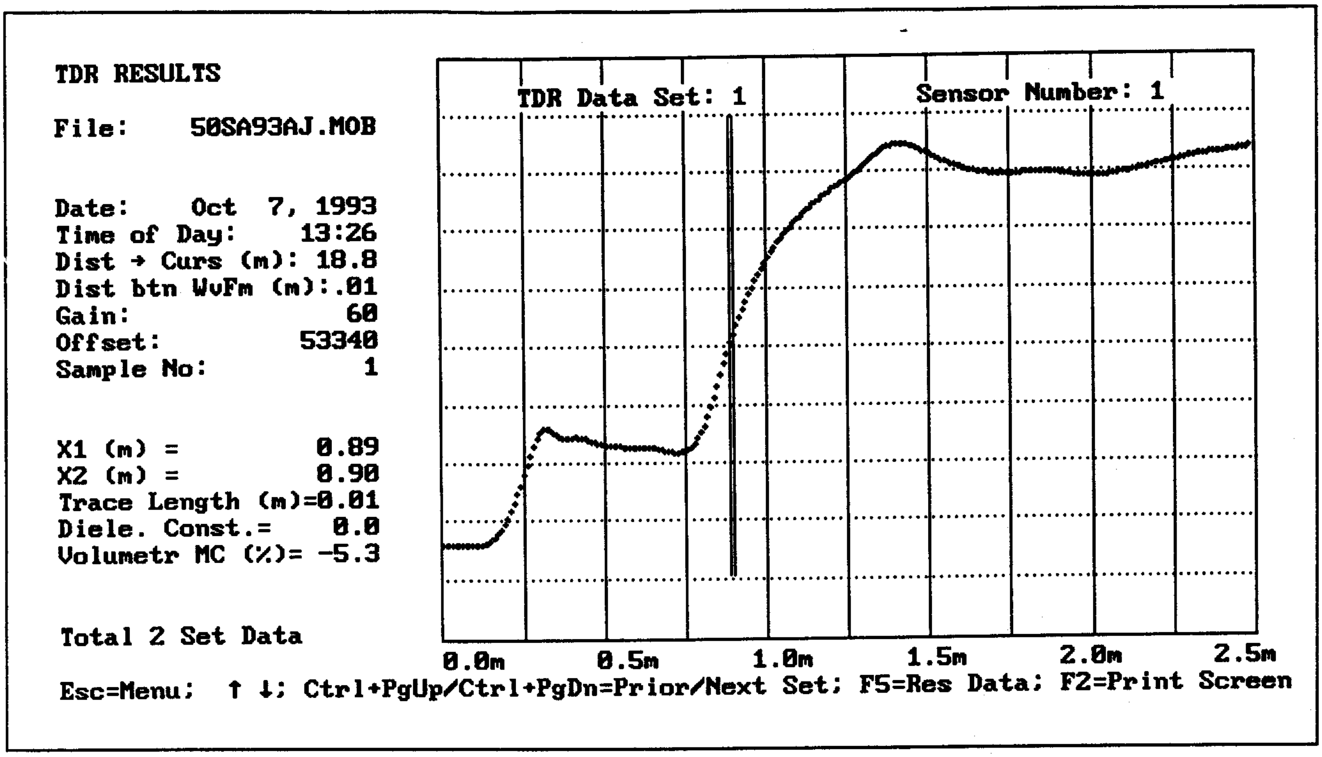



Figure D-1. Initial First Set of TDR Traces Measured with the Mobile Unit

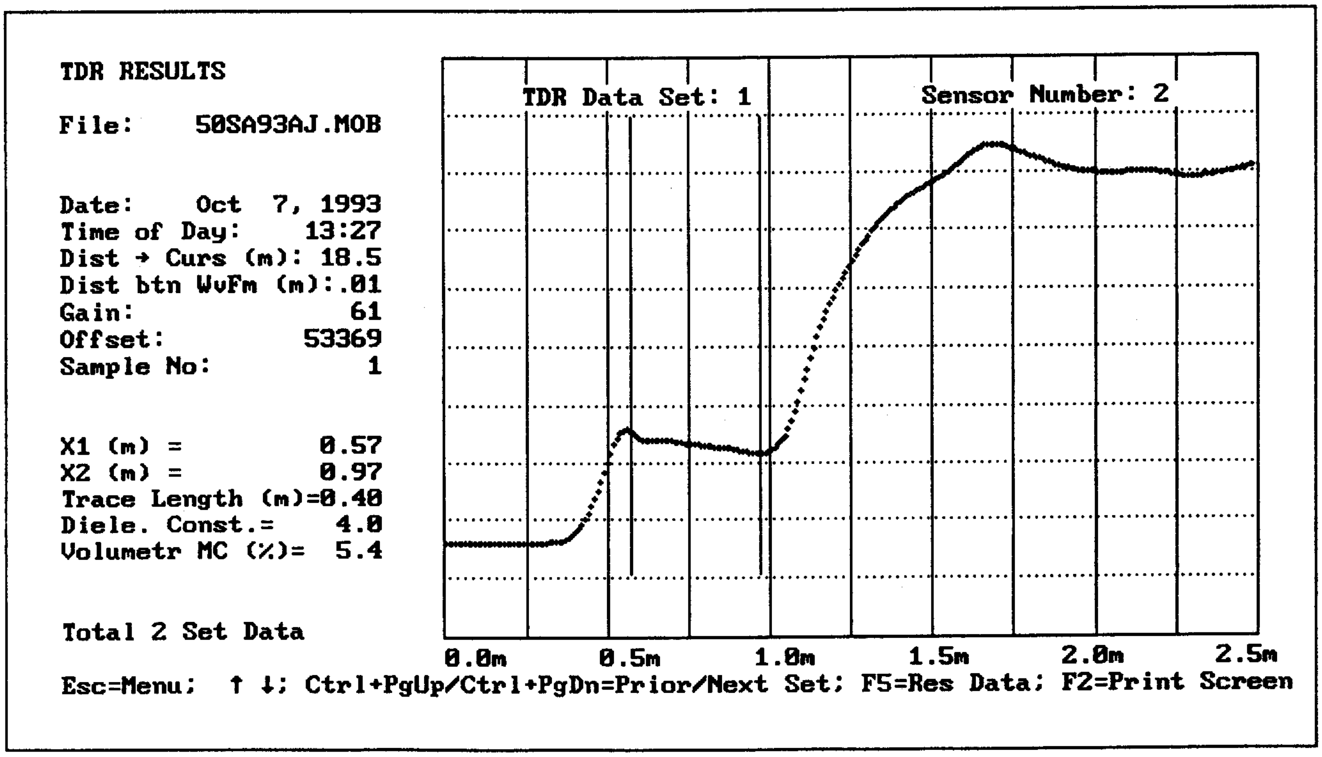



Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

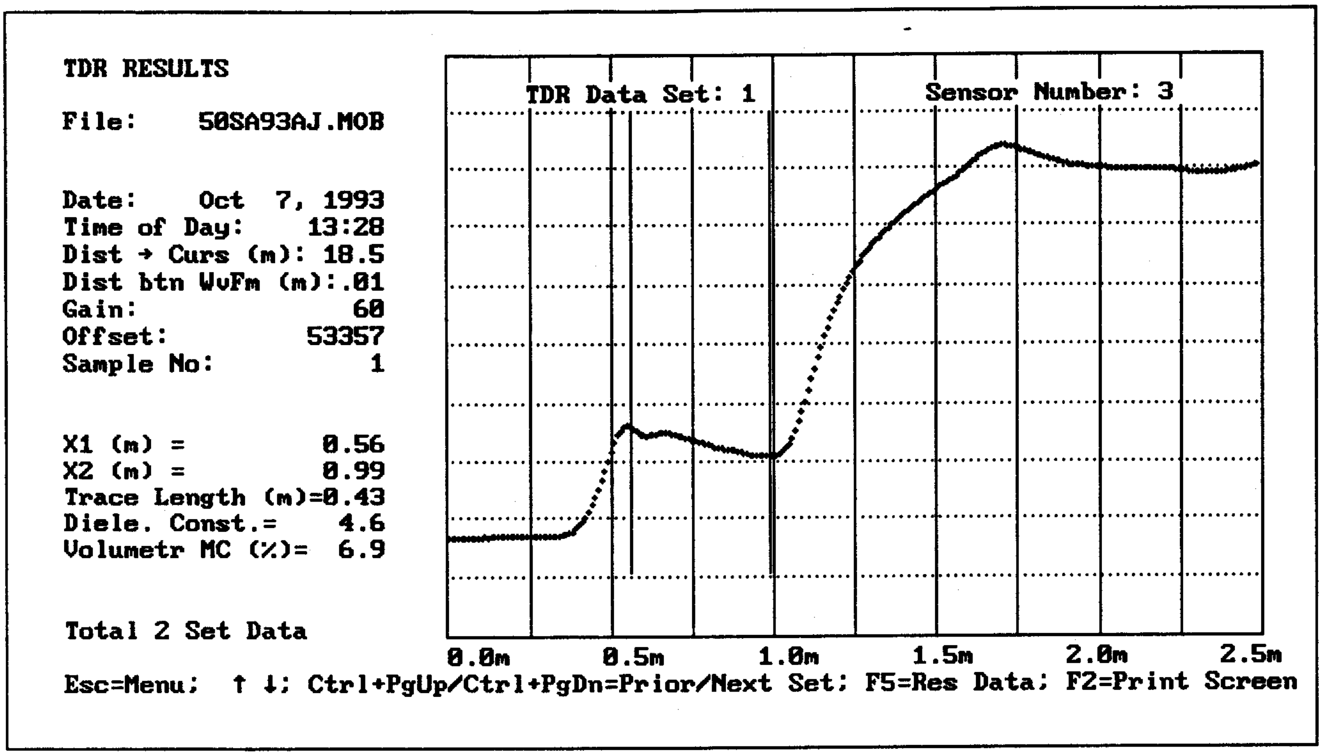



Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

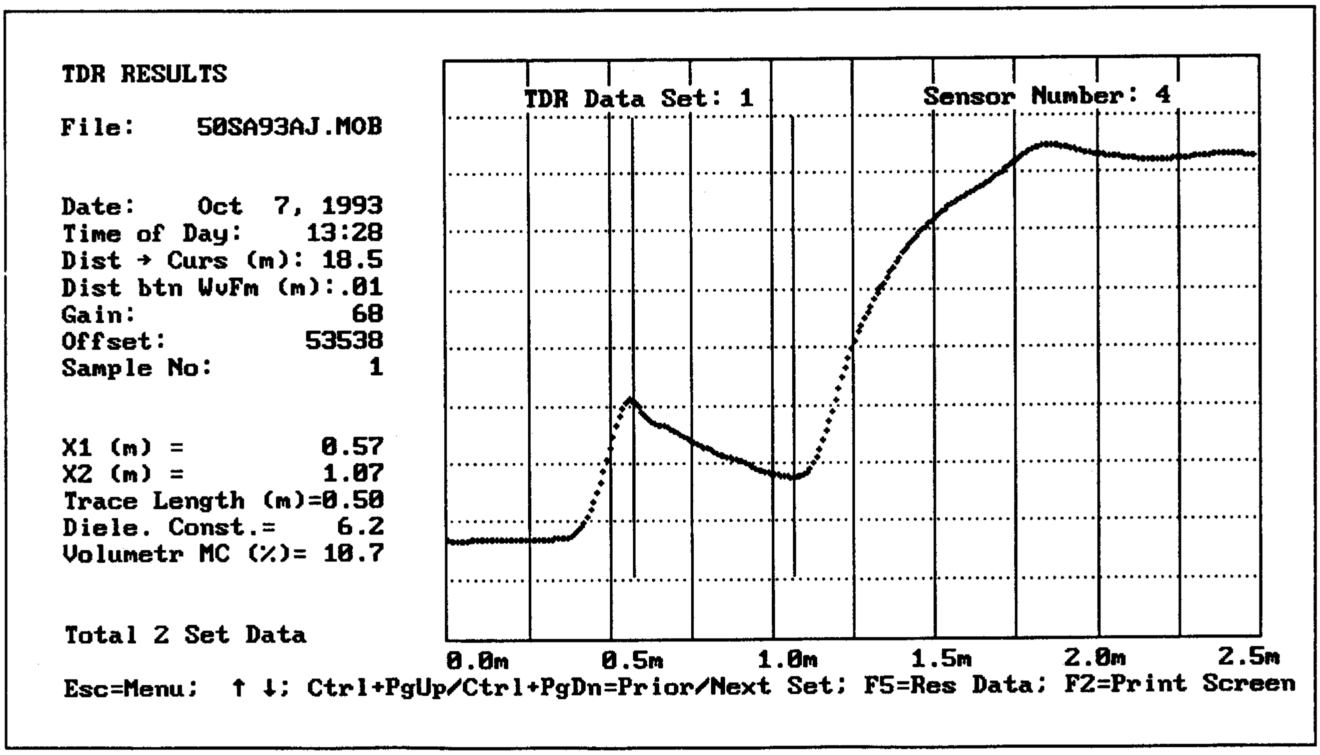



Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

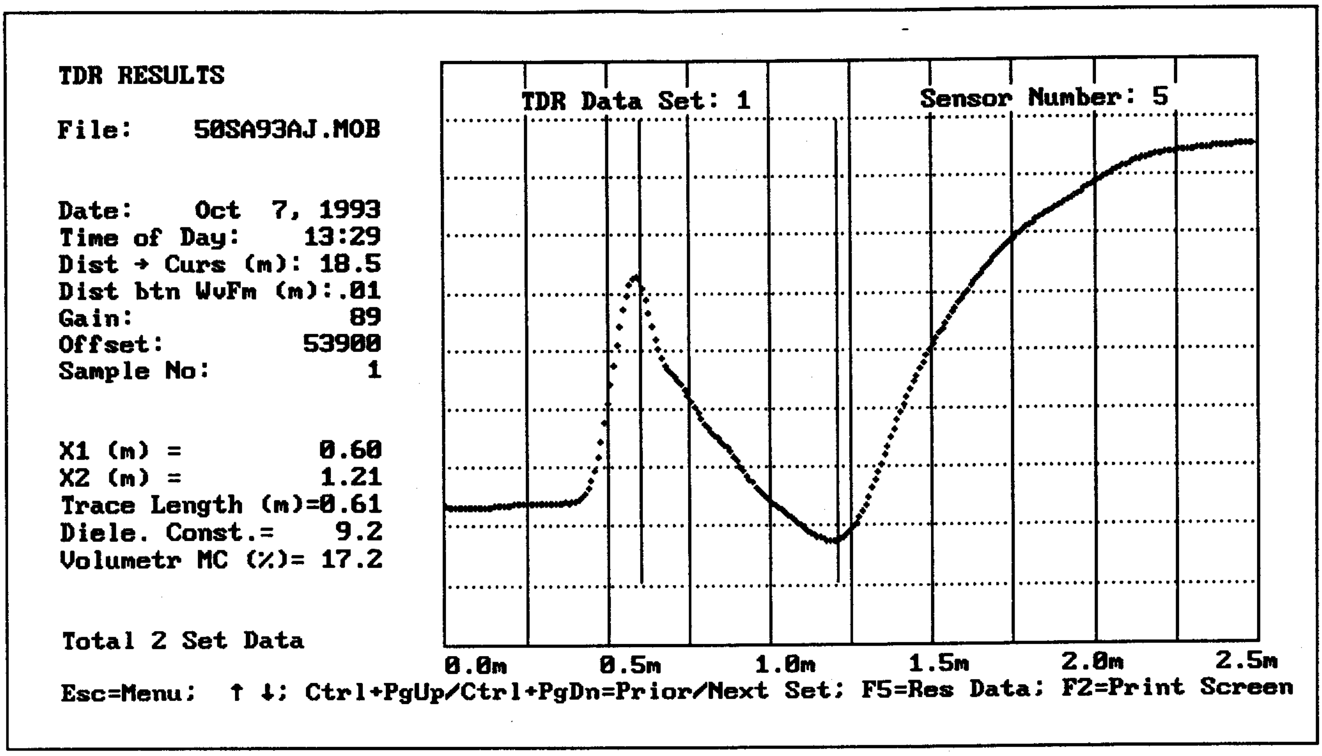



Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

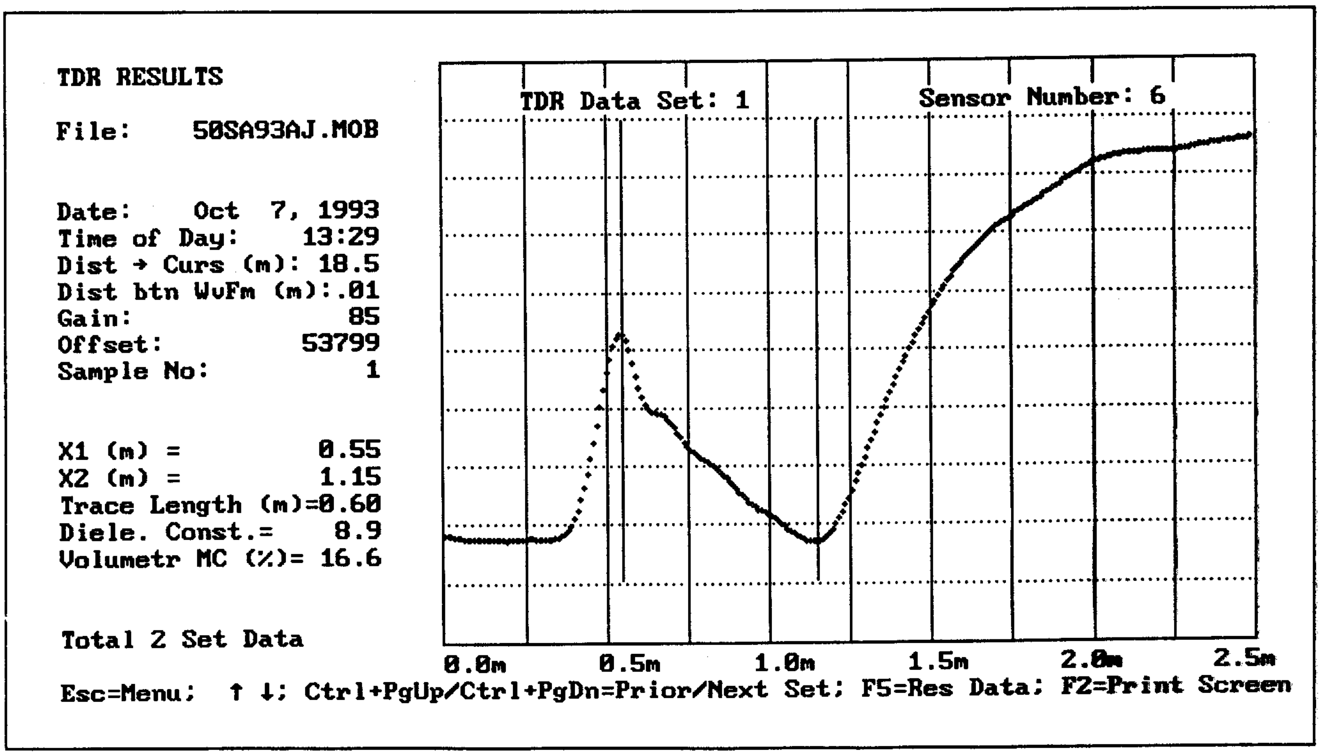



Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

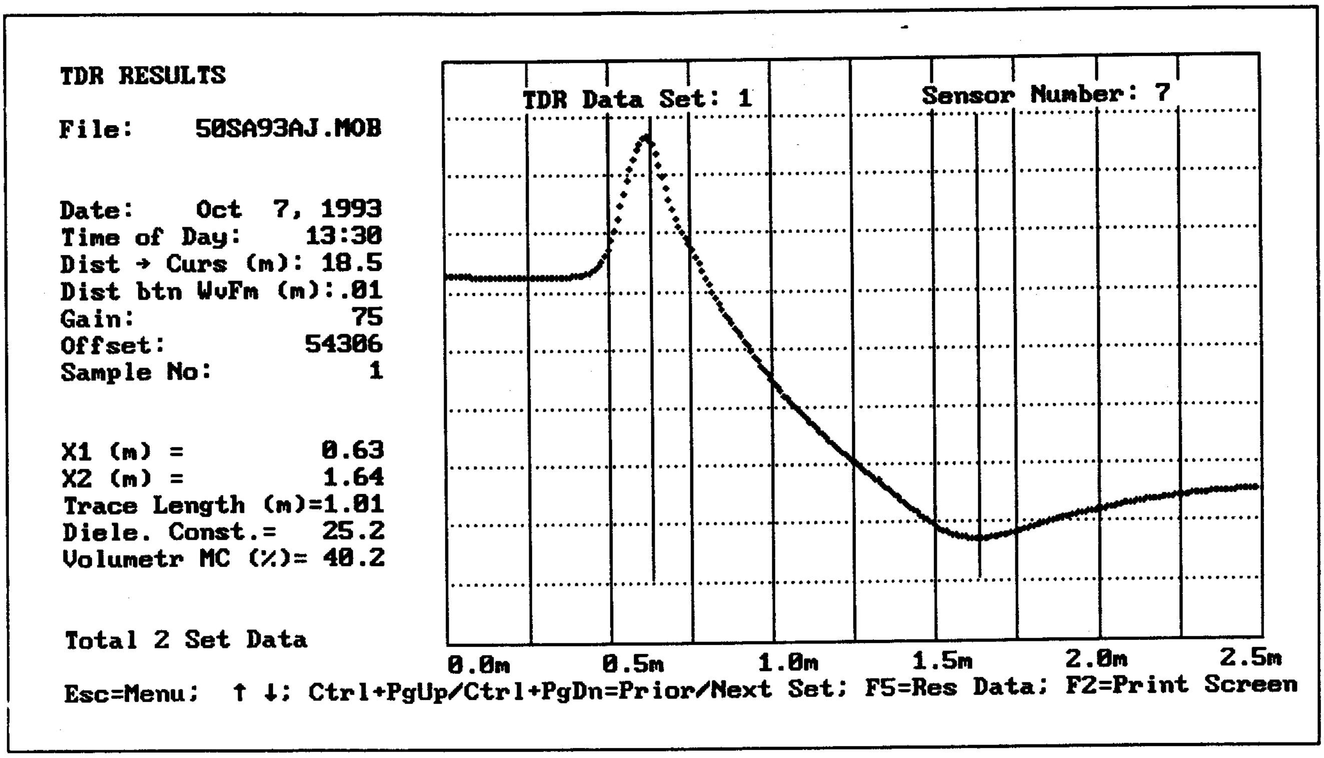



Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

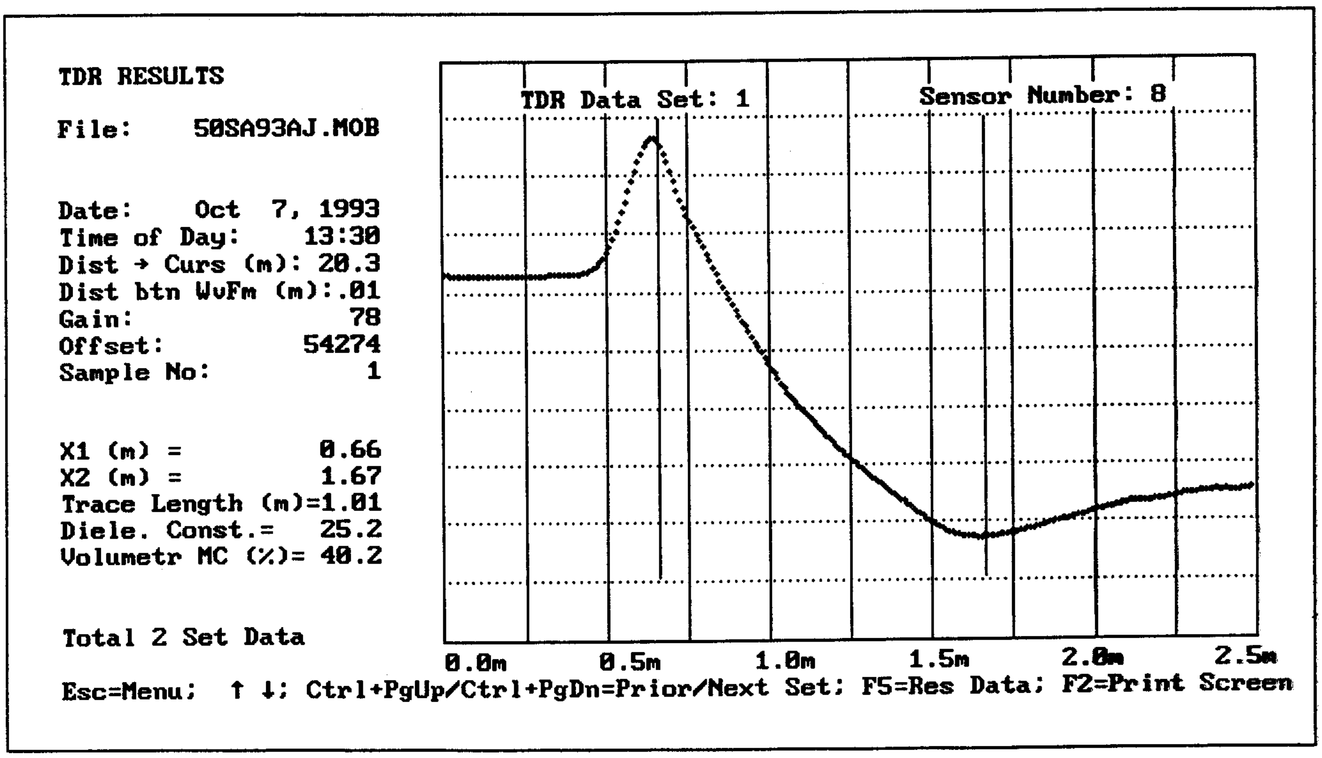



Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

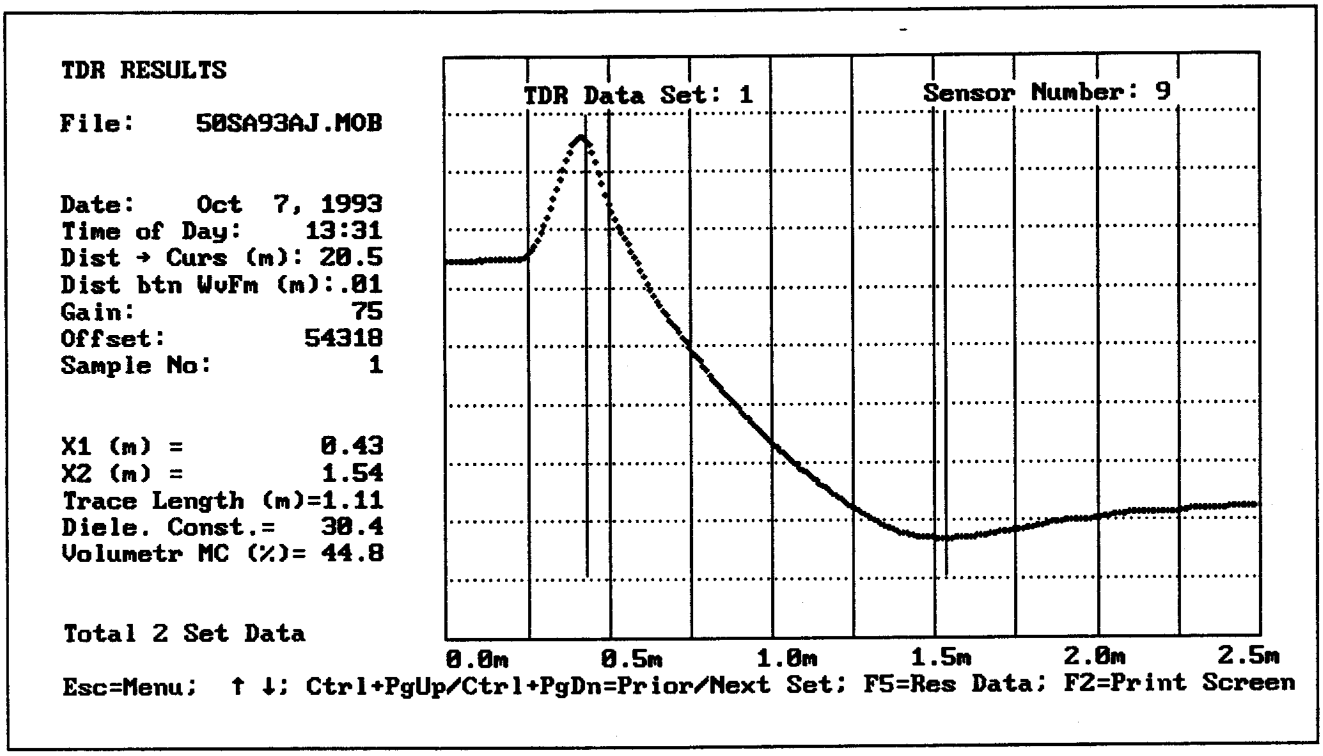



Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

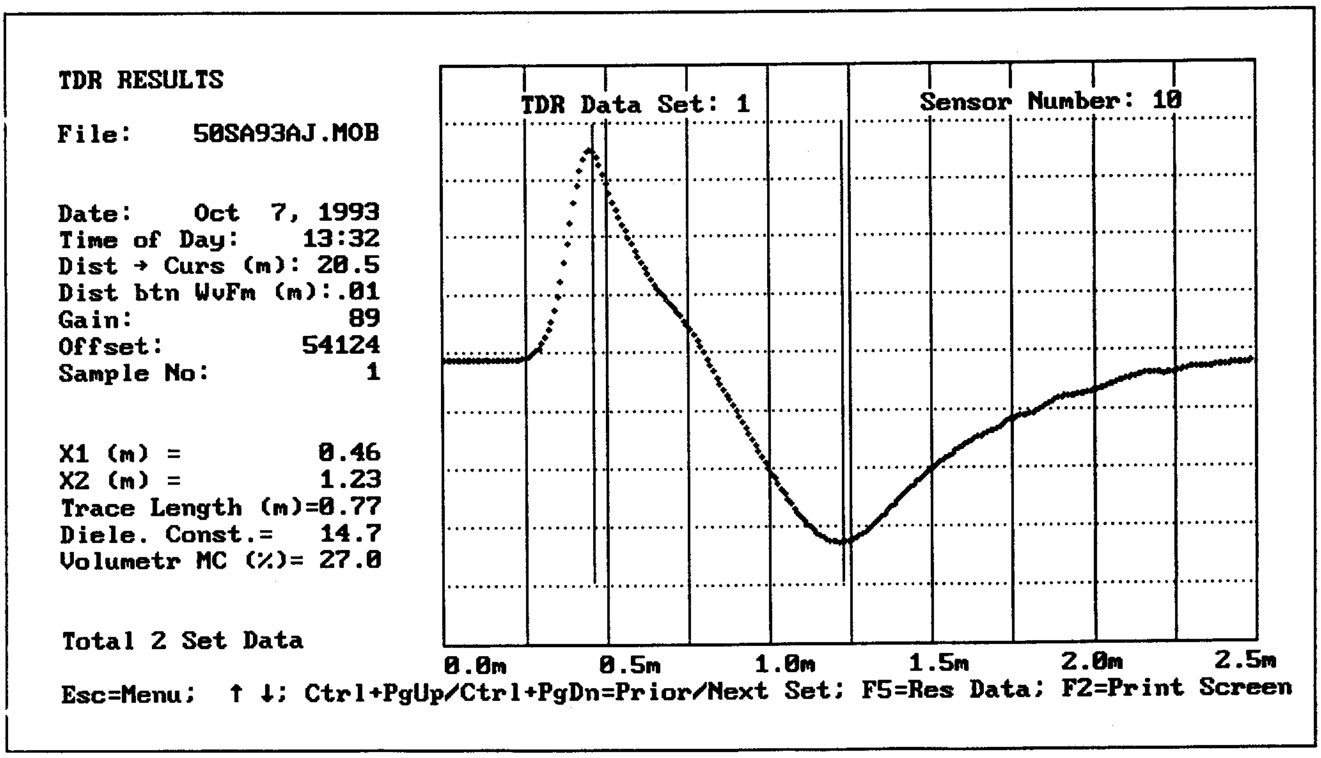



Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

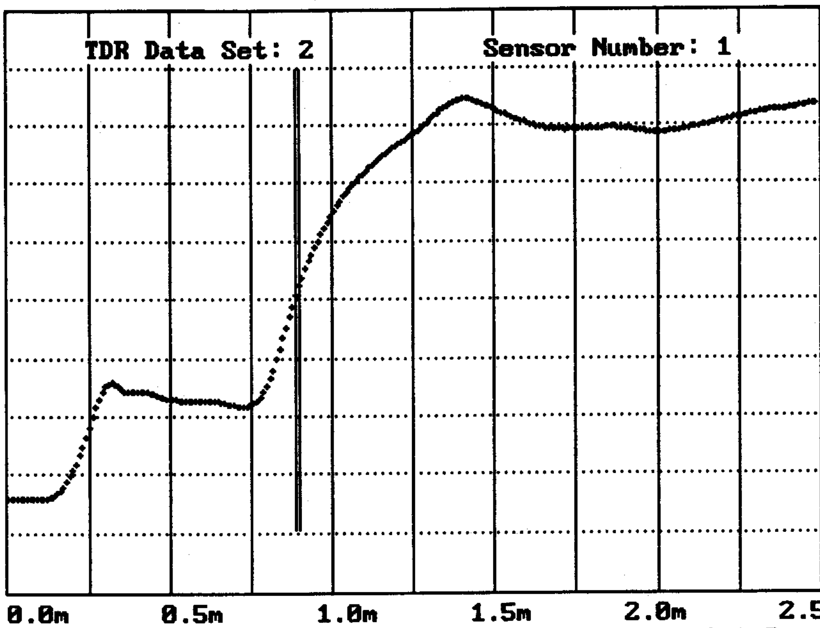
TDR RESULTS

File: 50SA93AJ.MOB

Date: Oct 7, 1993
Time of Day: 13:41
Dist → Curs (m): 10.8
Dist btn WvFm (m):.01
Gain: 60
Offset: 53340
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 2 Set Data




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

Figure D-2. Initial Second Set of TDR Traces Measured with the Mobile Unit

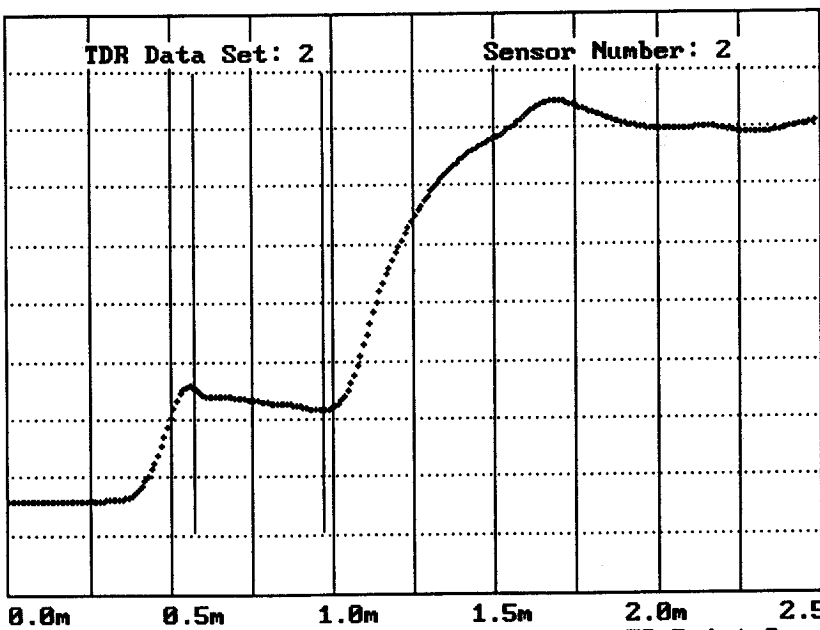
TDR RESULTS

File: 50SA93AJ.MOB

Date: Oct 7, 1993
Time of Day: 13:41
Dist → Curs (m): 10.5
Dist btn WvFm (m):.01
Gain: 61
Offset: 53369
Sample No: 1

X1 (m) = 0.57
X2 (m) = 0.97
Trace Length (m)=0.40
Diele. Const.= 4.0
Volumetr MC (%)= 5.4

Total 2 Set Data




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

Figure D-2(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

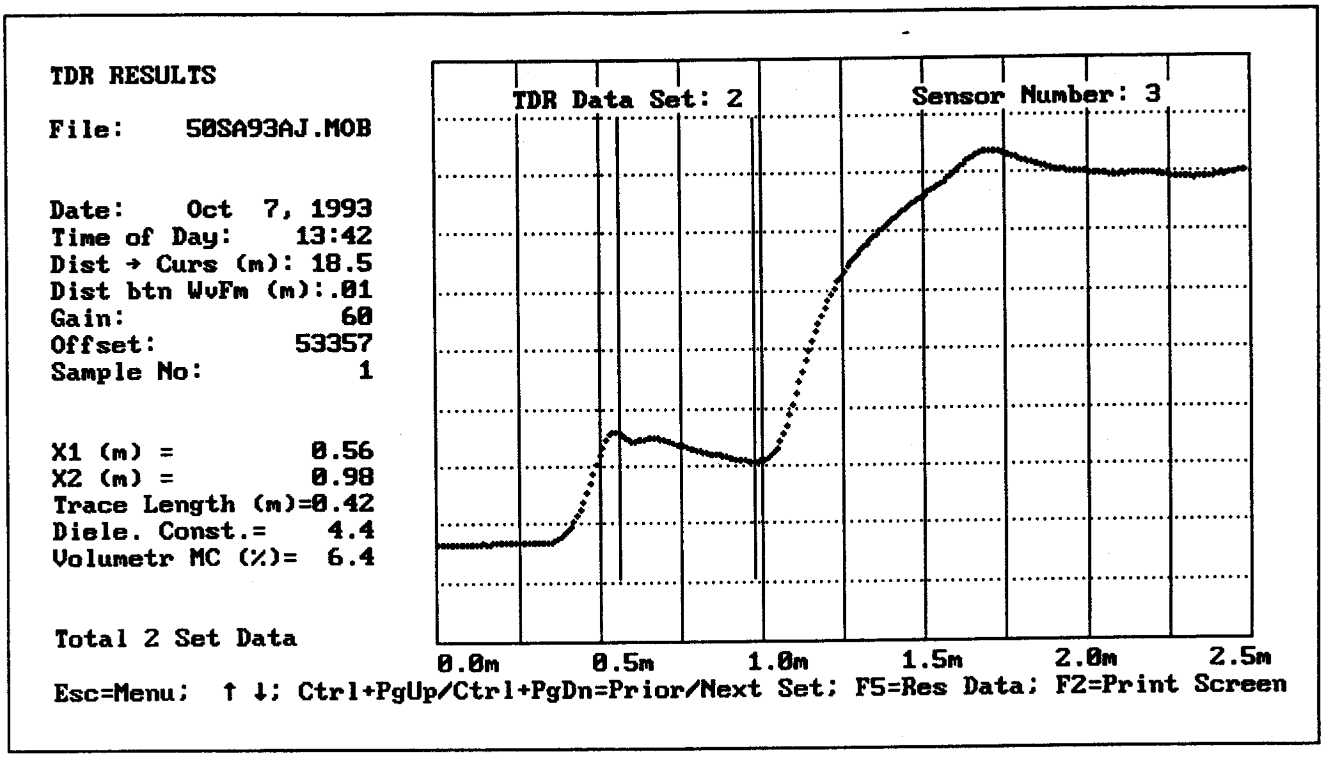



Figure D-2(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

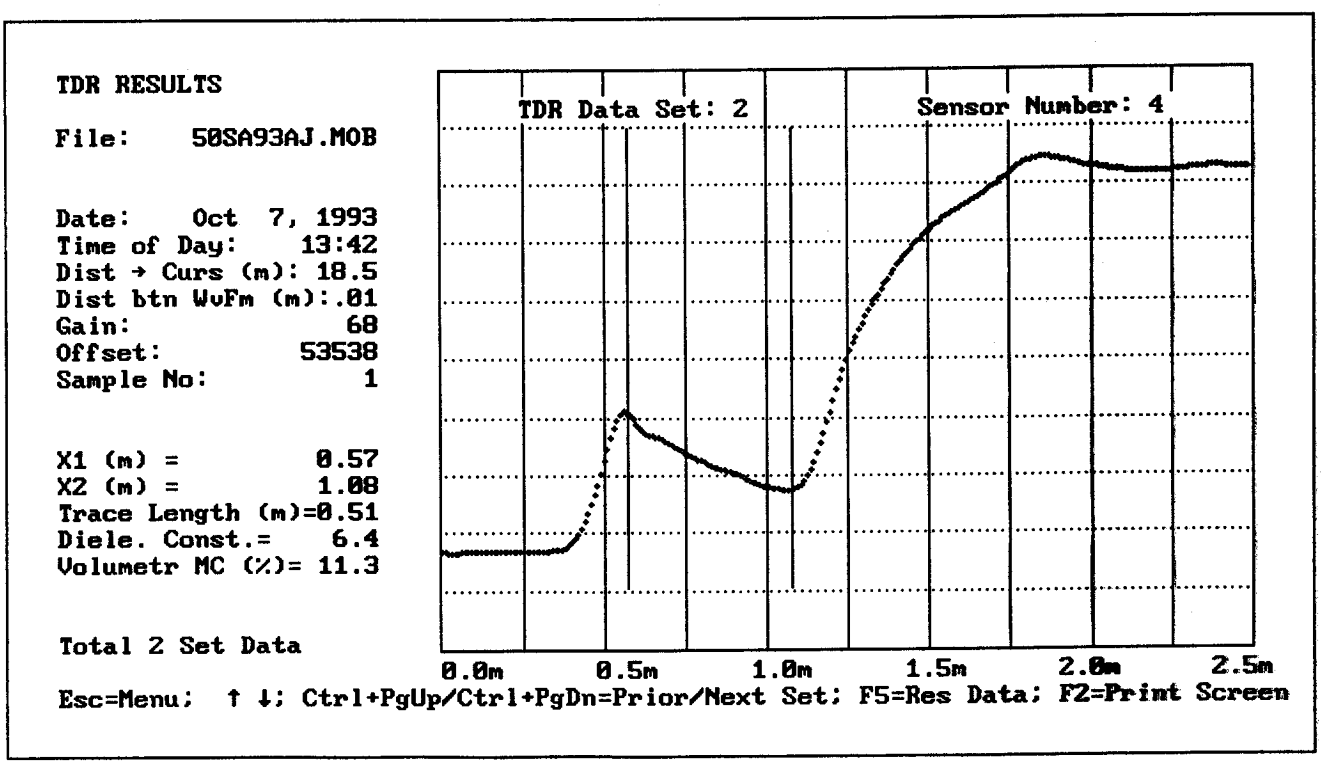



Figure D-2(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

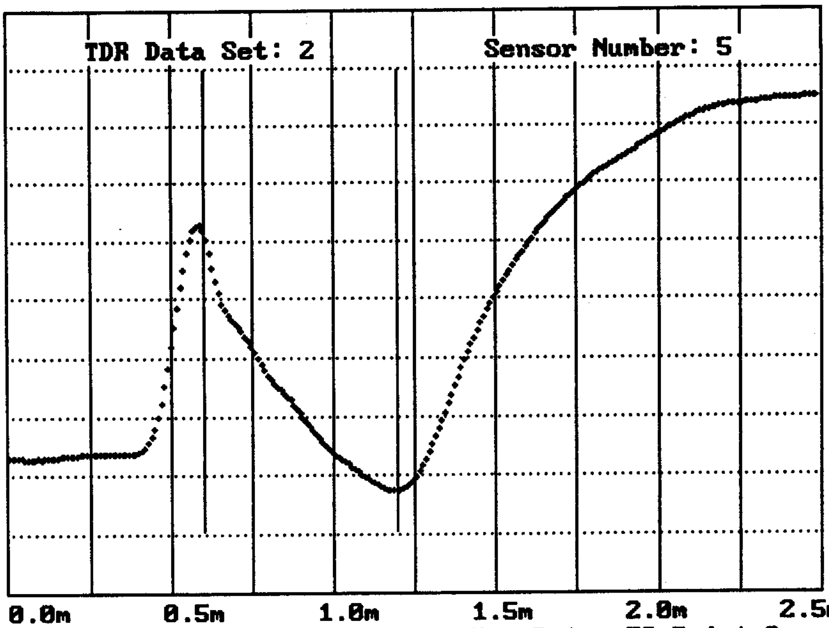
TDR RESULTS

File: 50SA93AJ.MOB

Date: Oct 7, 1993
Time of Day: 13:42
Dist → Curs (m): 18.5
Dist btn WvFm (m):.01
Gain: 89
Offset: 53900
Sample No: 1

X1 (m) = 0.60
X2 (m) = 1.20
Trace Length (m)=0.60
Diele. Const.= 8.9
Volumetr MC (%)= 16.6

Total 2 Set Data




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

Figure D-2(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

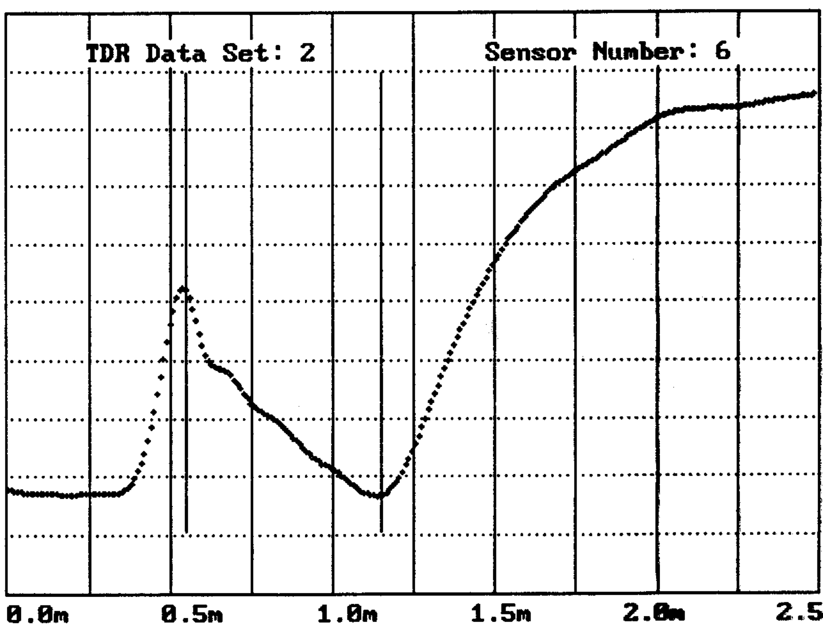
TDR RESULTS

File: 50SA93AJ.MOB

Date: Oct 7, 1993
Time of Day: 13:42
Dist → Curs (m): 18.5
Dist btn WvFm (m):.01
Gain: 85
Offset: 53799
Sample No: 1

X1 (m) = 0.55
X2 (m) = 1.15
Trace Length (m)=0.60
Diele. Const.= 8.9
Volumetr MC (%)= 16.6

Total 2 Set Data




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

Figure D-2(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

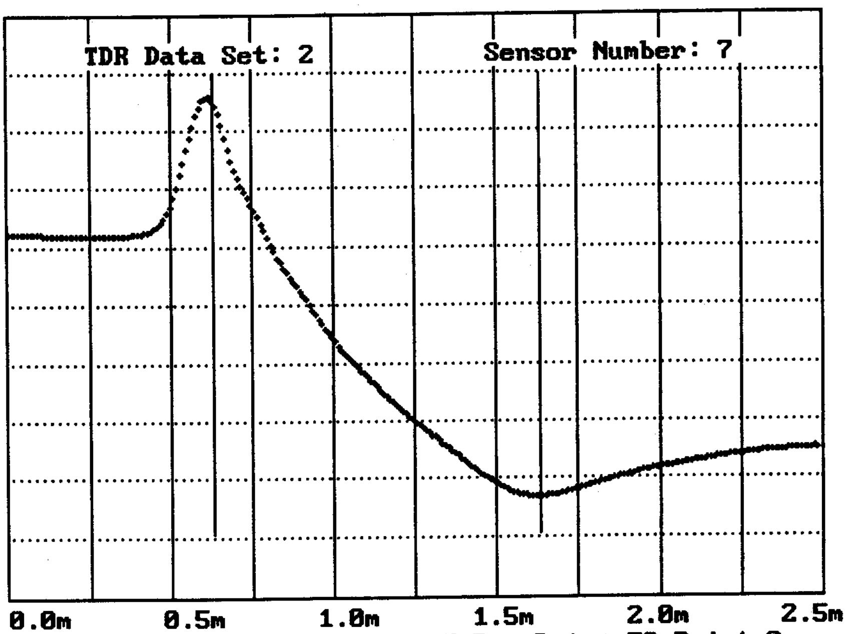
TDR RESULTS

File: 50SA93AJ.MOB

Date: Oct 7, 1993
Time of Day: 13:42
Dist → Curs (m): 18.5
Dist btn WvFm (m):.01
Gain: 75
Offset: 54306
Sample No: 1

X1 (m) = 0.63
X2 (m) = 1.64
Trace Length (m)=1.01
Diele. Const.= 25.2
Volumetr MC (%)= 40.2

Total 2 Set Data




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

Figure D-2(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

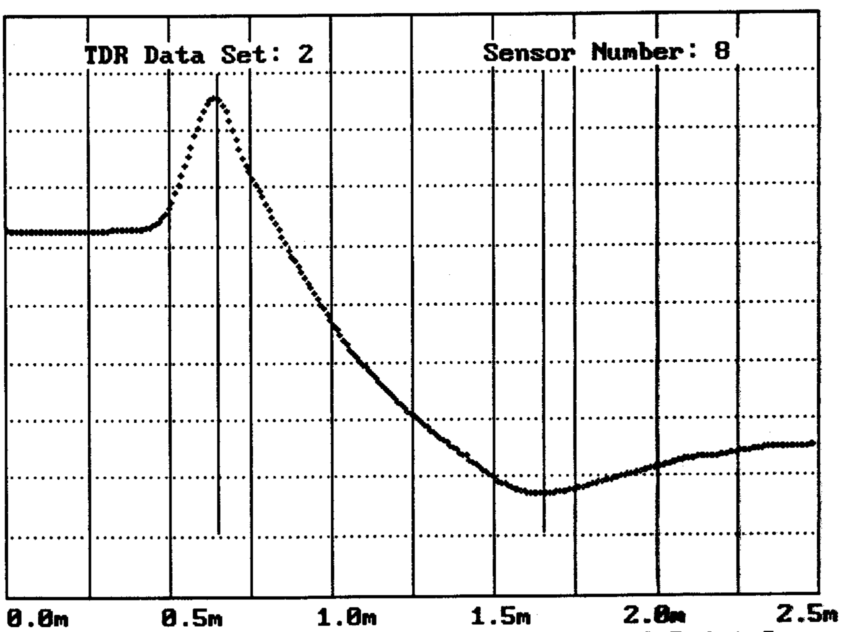
TDR RESULTS

File: 50SA93AJ.MOB

Date: Oct 7, 1993
Time of Day: 13:43
Dist → Curs (m): 20.3
Dist btn WvFm (m):.01
Gain: 78
Offset: 54274
Sample No: 1

X1 (m) = 0.65
X2 (m) = 1.66
Trace Length (m)=1.01
Diele. Const.= 25.2
Volumetr MC (%)= 40.2

Total 2 Set Data




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

Figure D-2(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

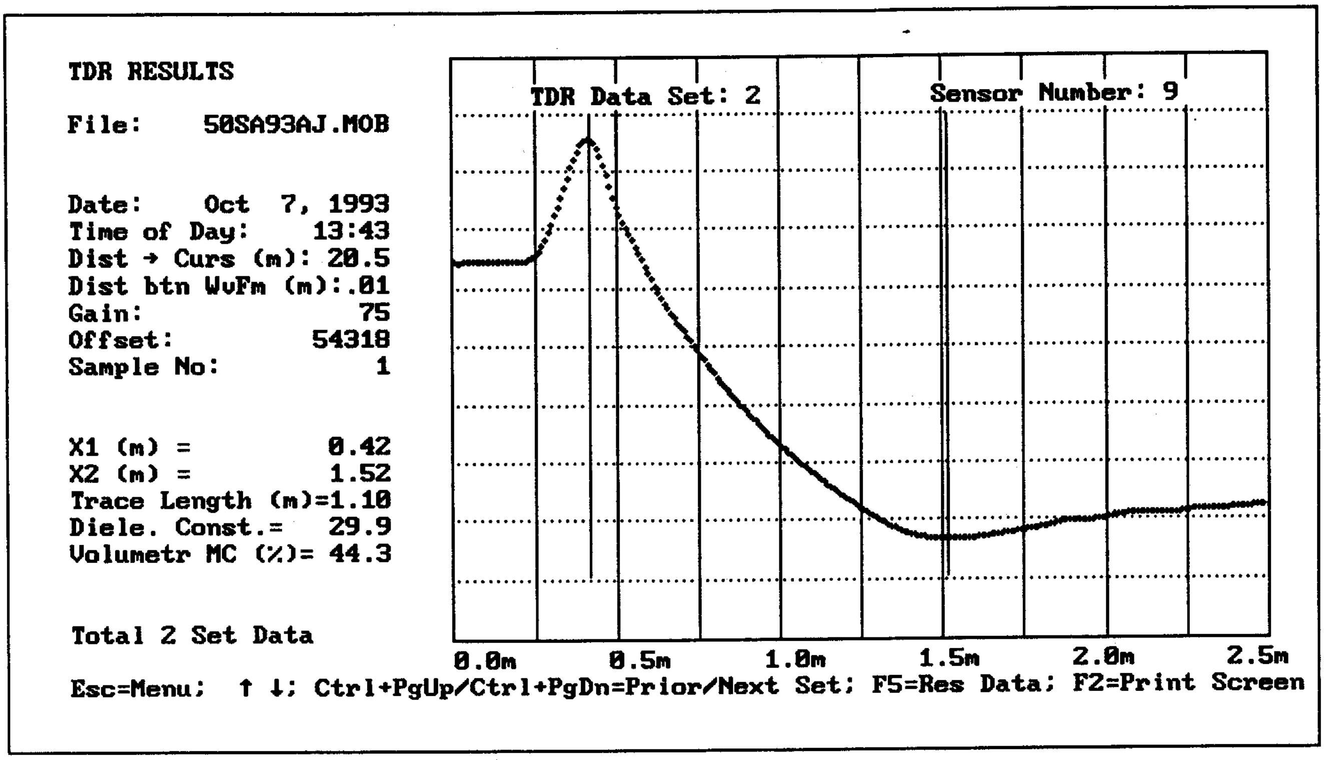



Figure D-2(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

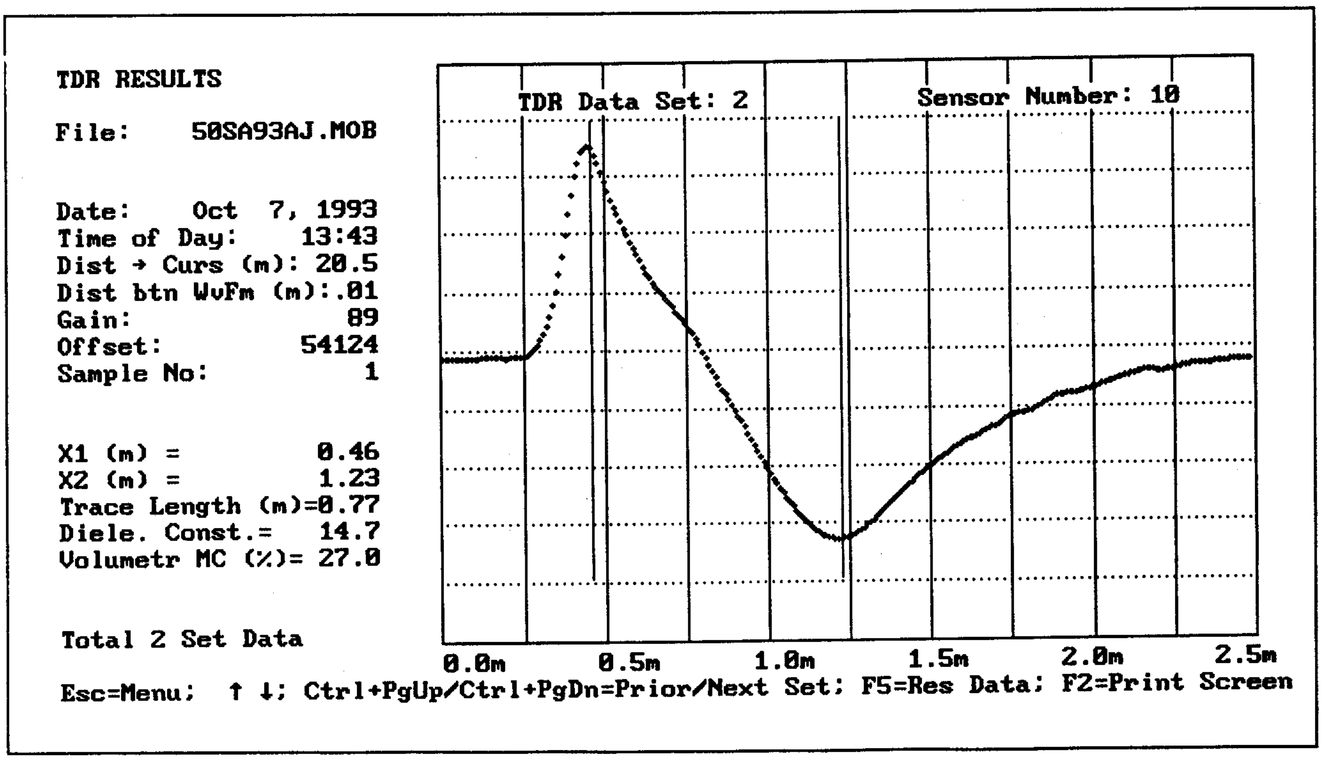



Figure D-2(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

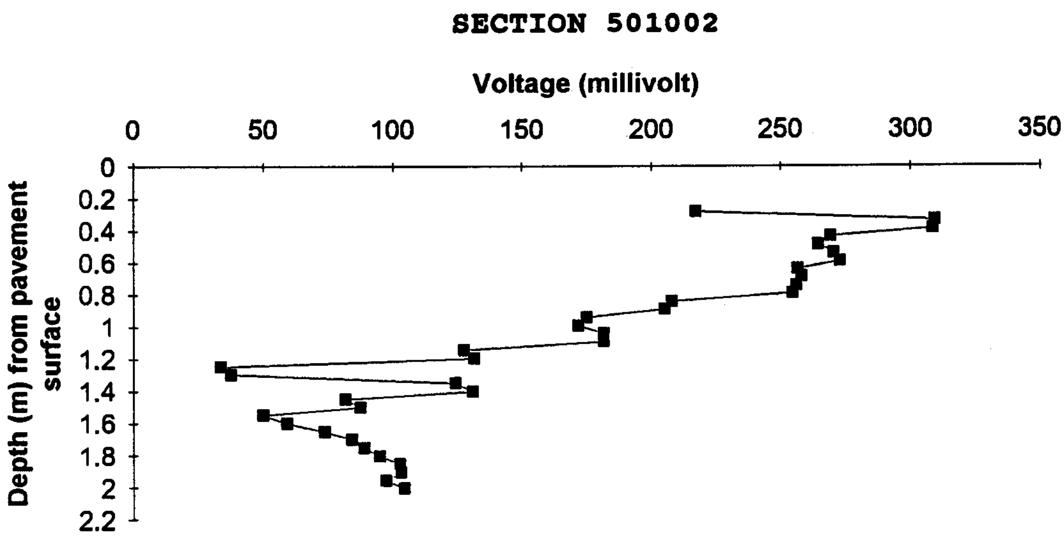



Figure D-3. Voltages Measured Using the Mobile System
During Initial Data Collection, October 7, 1993

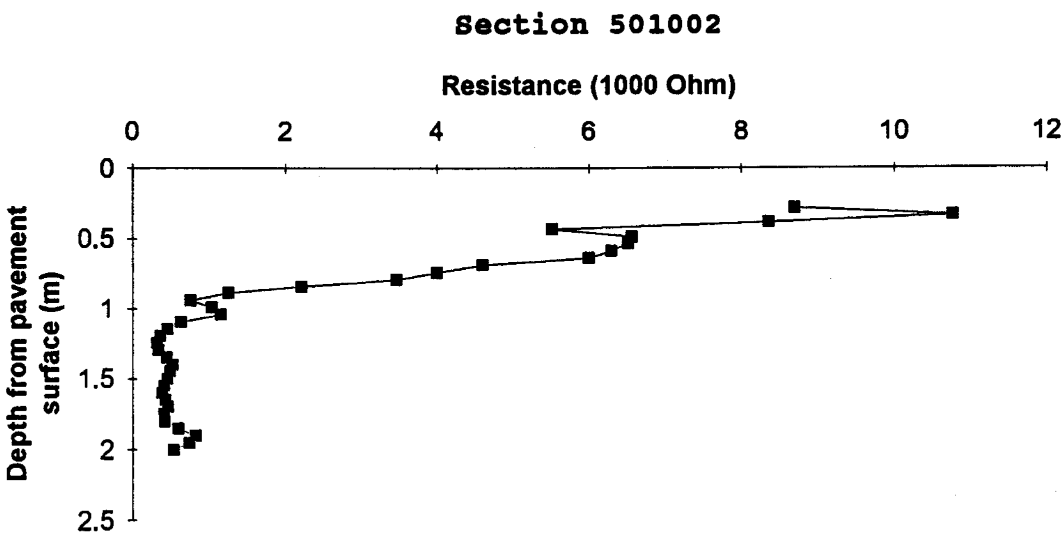



Figure D-4. Manually Collected Contact Resistance
During Initial Data Collection, October 7, 1993

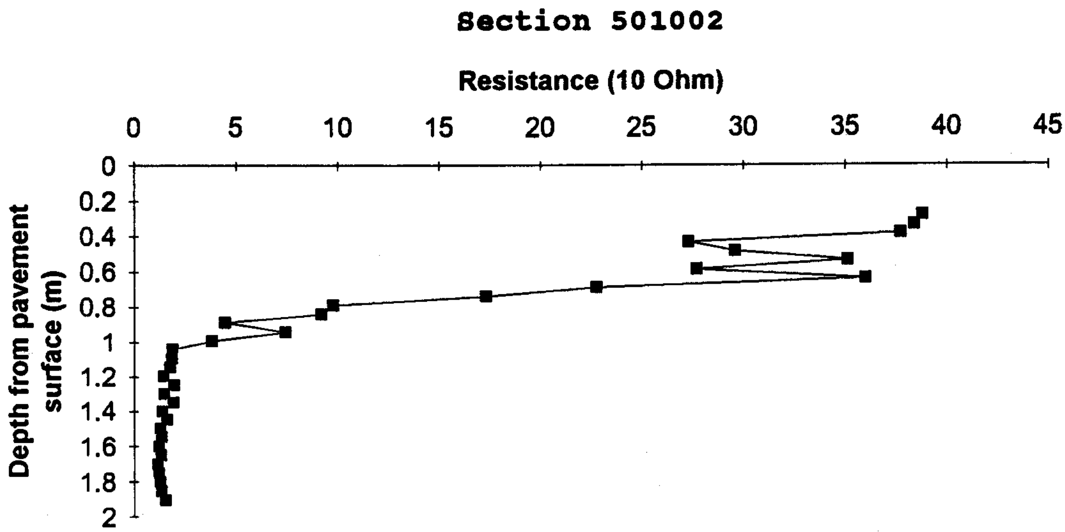



Figure D-5. Manually Collected Four Point Resistivity
During Initial Data Collection, October 7, 1993

Table D-1. Contact Resistance After Installation

| LTPP Seasonal Monitoring Study | State Code | [50] |
|---|---|---|
| Data Sheet R1 | | |
| Contact Resistance Measurements | Test Section Number | [1002] |

| | | |
|---|---|---|
| 1. Date (Month-Day-Year) | | [10-07-93] |
| 2. Time Measurements Began (Military) | | [1125] |
| 3. Comments | After Installation | * Note: Known Resistors |

| Test Position | Connections | | Voltage (ACV) | | Current (ACA) | | notes |
|---|---|---|---|---|---|---|---|
| | I<br>V | I<br>V | Range Setting | Reading | Range Setting | Reading | |
| 1 | 1 | 2 | mV | 215.0 | uA | 24.7 | |
| 2 | 3 | 2 | mV | 203.5 | uA | 18.9 | |
| 3 | 3 | 4 | mV | 201.6 | uA | 24.1 | |
| 4 | 5 | 4 | mV | 193.9 | uA | 35.1 | |
| 5 | 5 | 6 | mV | 196.4 | uA | 29.9 | |
| 6 | 7 | 6 | mV | 194.8 | uA | 29.9 | |
| 7 | 7 | 8 | mV | 168.1 | uA | 26.7 | |
| 8 | 9 | 8 | mV | 167.5 | uA | 27.9 | |
| 9 | 9 | 10 | mV | 163.3 | uA | 35.5 | |
| 10 | 11 | 10 | mV | 160.9 | uA | 40.2 | |
| 11 | 11 | 12 | mV | 157.6 | uA | 45.5 | |
| 12 | 13 | 12 | mV | 144.6 | uA | 65.4 | |
| 13 | 13 | 14 | mV | 123.6 | uA | 97.9 | |
| 14 | 15 | 14 | mV | 100.7 | uA | 131.9 | |
| 15 | 15 | 16 | mV | 115.6 | uA | 110.8 | |
| 16 | 17 | 16 | mV | 119.6 | uA | 102.9 | |
| 17 | 17 | 18 | mV | 92.1 | uA | 144.3 | |
| 18 | 19 | 18 | mV | 76.7 | uA | 166.3 | |
| 19 | 19 | 20 | mV | 66.2 | uA | 181.3 | |
| 20 | 21 | 20 | mV | 60.4 | uA | 188.5 | |
| 21 | 21 | 22 | mV | 62.9 | uA | 185.2 | |
| 22 | 23 | 22 | mV | 76.0 | uA | 167.7 | |
| 23 | 23 | 24 | mV | 81.9 | uA | 156.8 | |
| 24 | 25 | 24 | mV | 78.9 | uA | 161.0 | |
| 25 | 25 | 26 | mV | 77.0 | uA | 166.9 | |
| 26 | 27 | 26 | mV | 72.3 | uA | 172.6 | |
| 27 | 27 | 28 | mV | 70.5 | uA | 180.9 | |
| 28 | 29 | 28 | mV | 75.3 | uA | 174.2 | |
| 29 | 29 | 30 | mV | 79.3 | uA | 170.0 | |
| 30 | 31 | 30 | mV | 73.9 | uA | 176.0 | |
| 31 | 31 | 32 | mV | 73.9 | uA | 173.2 | |
| 32 | 33 | 32 | mV | 89.9 | uA | 148.8 | |
| 33 | 33 | 34 | mV | 104.6 | uA | 126.0 | |
| 34 | 35 | 34 | mV | 99.1 | uA | 133.1 | |
| 35 | 35 | 36 | mV | 83.2 | uA | 154.1 | |
| 36 * | 37 | 38 | mV | | uA | | |
| 37 * | 38 | 39 | mV | | uA | | |
| 38 * | 39 | 40 | mV | | uA | | |

| Preparer: | Michael Zawisa | Employer: | PMSL |
|---|---|---|---|

Table D-2. Four-Point Resistivity After Installation

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

| | |
|---|---|
| 1. Date (Month-Day-Year) | [10-07-93] |
| 2. Time measurements Began (Military) | [1145] |
| 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 | 10.4 | uA | 26.8 | |
| 2 | 2 | 3 | 4 | 5 | mV | 7.1 | uA | 18.5 | |
| 3 | 3 | 4 | 5 | 6 | mV | 6.3 | uA | 16.7 | |
| 4 | 4 | 5 | 6 | 7 | mV | 7.5 | uA | 27.5 | |
| 5 | 5 | 6 | 7 | 8 | mV | 7.1 | uA | 24.0 | |
| 6 | 6 | 7 | 8 | 9 | mV | 8.5 | uA | 24.2 | |
| 7 | 7 | 8 | 9 | 10 | mV | 8.5 | uA | 30.7 | |
| 8 | 8 | 9 | 10 | 11 | mV | 9.8 | uA | 27.2 | |
| 9 | 9 | 10 | 11 | 12 | mV | 8.1 | uA | 35.6 | |
| 10 | 10 | 11 | 12 | 13 | mV | 8.5 | uA | 49.1 | |
| 11 | 11 | 12 | 13 | 14 | mV | 5.3 | uA | 54.2 | |
| 12 | 12 | 13 | 14 | 15 | mV | 6.6 | uA | 71.6 | |
| 13 | 13 | 14 | 15 | 16 | mV | 3.5 | uA | 80.6 | |
| 14 | 14 | 15 | 16 | 17 | mV | 8.5 | uA | 114.2 | |
| 15 | 15 | 16 | 17 | 18 | mV | 5.6 | uA | 146.0 | |
| 16 | 16 | 17 | 18 | 19 | mV | 2.1 | uA | 109.0 | |
| 17 | 17 | 18 | 19 | 20 | mV | 2.8 | uA | 148.4 | |
| 18 | 18 | 19 | 20 | 21 | mV | 2.9 | uA | 163.5 | |
| 19 | 19 | 20 | 21 | 22 | mV | 2.5 | uA | 170.0 | |
| 20 | 20 | 21 | 22 | 23 | mV | 3.2 | uA | 162.1 | |
| 21 | 21 | 22 | 23 | 24 | mV | 2.5 | uA | 165.8 | |
| 22 | 22 | 23 | 24 | 25 | mV | 3.2 | uA | 163.8 | |
| 23 | 23 | 24 | 25 | 26 | mV | 2.2 | uA | 156.6 | |
| 24 | 24 | 25 | 26 | 27 | mV | 2.6 | uA | 160.8 | |
| 25 | 25 | 26 | 27 | 28 | mV | 2.2 | uA | 166.2 | |
| 26 | 26 | 27 | 28 | 29 | mV | 2.2 | uA | 160.7 | |
| 27 | 27 | 28 | 29 | 30 | mV | 2.1 | uA | 168.9 | |
| 28 | 28 | 29 | 30 | 31 | mV | 2.3 | uA | 172.1 | |
| 29 | 29 | 30 | 31 | 32 | mV | 1.9 | uA | 160.5 | |
| 30 | 30 | 31 | 32 | 33 | mV | 1.8 | uA | 144.8 | |
| 31 | 31 | 32 | 33 | 34 | mV | 1.8 | uA | 138.0 | |
| 32 | 32 | 33 | 34 | 35 | mV | 2.1 | uA | 152.8 | |
| 33 | 33 | 34 | 35 | 36 | mV | 2.2 | uA | 139.6 | |

| Preparer | MZ | Employer | PMSL |
|---|---|---|---|

Table D-3. Uniformity Survey Results Before and After Installation

| Seasonal Uniformity Survey | Falling Weight Deflectometer Data Collection and Processing Summary |
|---|---|
| Site Number: 331001 | |
| Date Surveyed: October 06-October 07, 1993 | |

| 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 | |
| -20 to 200 **Oct 06** @ 0943 | 6.19 | 0.53 | 1.52 | 0.15 | 24934 | 2282 | 9.75 | 0.32 | ** |
| -20 to 175* **Oct 07** @ 0952 | 6.69 | 0.52 | 1.46 | 0.15 | 25547 | 1943 | 9.36 | 0.35 | 57.9 |
| -20 to 200 **Oct 07** @ 1144 | 7.42 | 0.66 | 1.49 | 0.17 | 24830 | 2077 | 8.95 | 0.33 | 67.9 |
| -20 to 200 **Oct 07** @ 1347 | 7.87 | 0.68 | 1.56 | 0.11 | 24094 | 1480 | 8.74 | 0.35 | 75.4 |

* Note: Station 200 not tested

** Note: No temperatures recorded on October 06, 1993

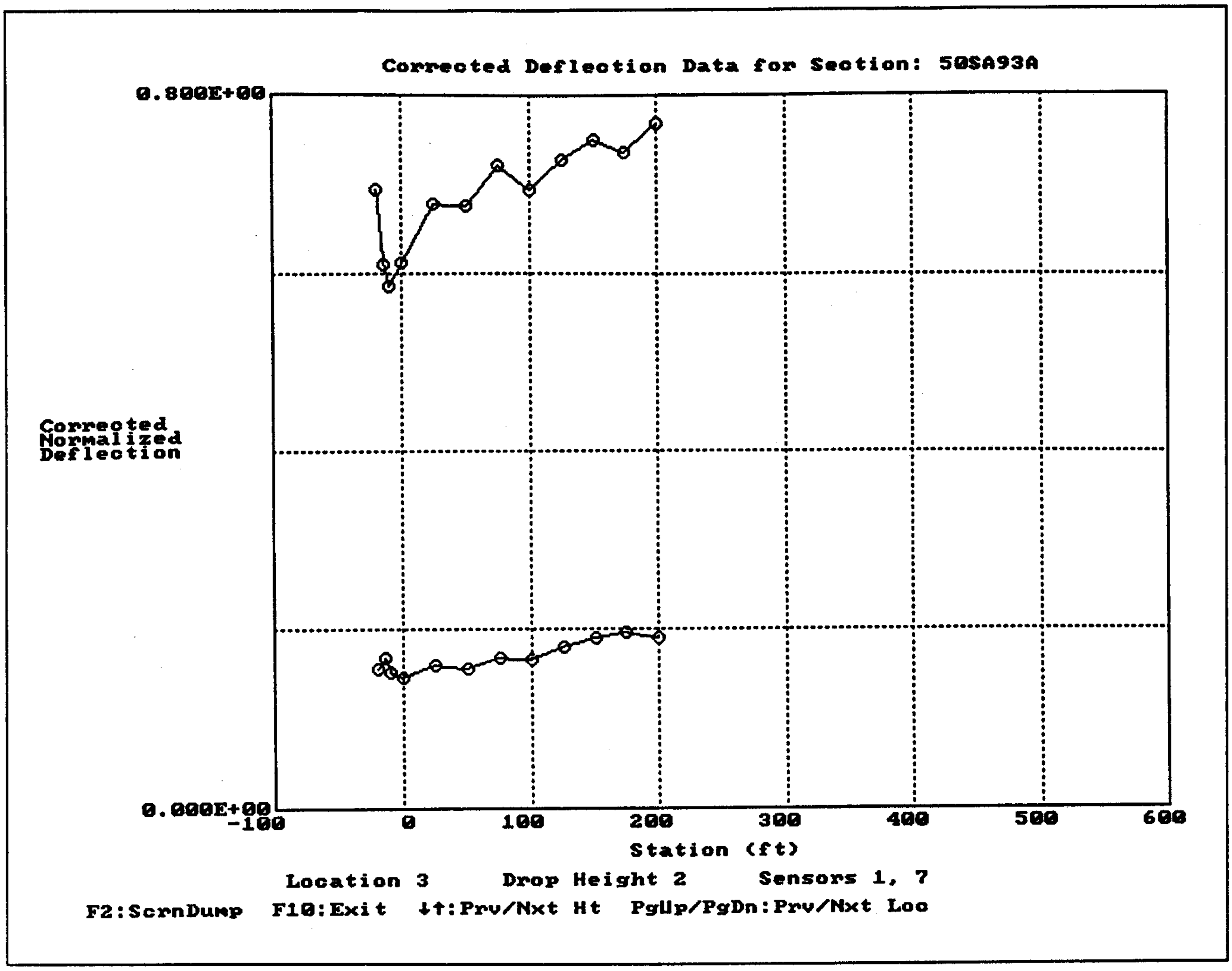



Figure D-6. Deflection Profiles from FWDCHECK
(Test Date and Time October 06, 1993 @ 0943)

Table D-4. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date and Time October 06, 1993 @ 0943)

| Flexible Pavement Thickness Statistics - 50SA93A - Drop Height 2 | | | |
|---|---|---|---|
| Subsection | Station | Subgrade Modulus | Effective SN |
| 1 | -20 | 26632 | 9.60 |
| | -15 | 24975 | 10.30 |
| | -10 | 27301 | 10.35 |
| | 0 | 28345 | 10.10 |
| | 25 | 26215 | 9.70 |
| | 50 | 26816 | 9.70 |
| | 75 | 24949 | 9.50 |
| | 100 | 25219 | 9.65 |
| | 125 | 23278 | 9.55 |
| | 150 | 21926 | 9.50 |
| | 175 | 21472 | 9.60 |
| | 200 | 22084 | 9.40 |
| Subsection 1 | Overall Mean | 24934 | 9.75 |
| | Standard Deviation | 2282 | 0.32 |
| | Coeff of Variation | 9.15% | 3.29% |

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

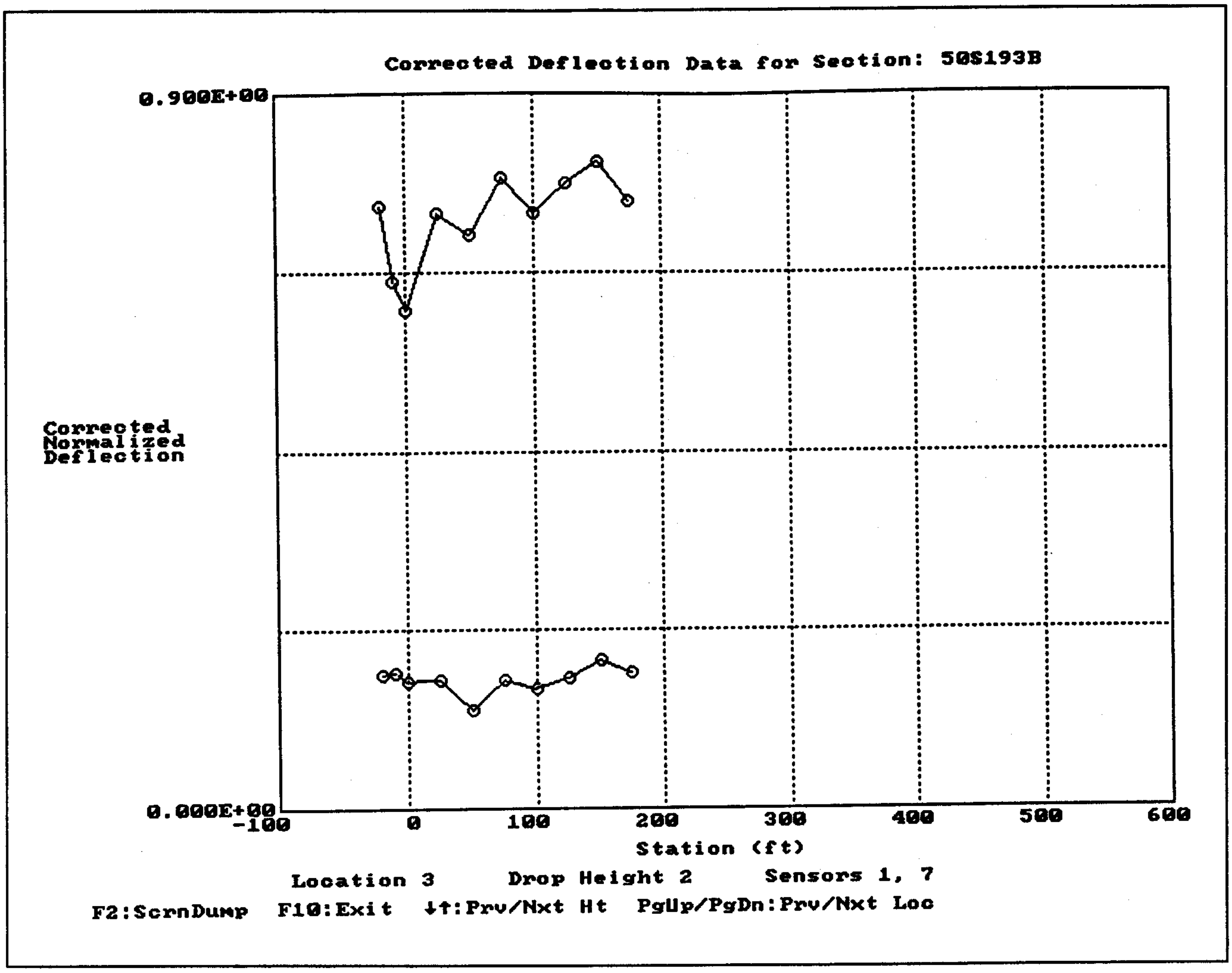



Figure D-7. Deflection Profiles from FWDCHECK
(Test Date and Time October 07, 1993 @ 0952)

Table D-5. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date and Time October 07, 1993 @ 0952)

| Flexible Pavement Thickness Statistics - 50S193B - Drop Height 2 | | | |
|---|---|---|---|
| Subsection | Station | Subgrade Modulus | Effective SN |
| 1 | -20 | 24768 | 9.30 |
| | -10 | 24389 | 9.90 |
| | 0 | 26199 | 10.10 |
| | 25 | 25686 | 9.30 |
| | 50 | 30061 | 9.25 |
| | 75 | 25817 | 9.05 |
| | 100 | 26240 | 9.25 |
| | 125 | 25473 | 9.10 |
| | 150 | 22521 | 9.10 |
| | 175 | 24319 | 9.25 |
| | 200* | | |
| Subsection 1 | Overall Mean | 25547 | 9.36 |
| | Standard Deviation | 1943 | 0.35 |
| | Coeff of Variation | 7.61% | 3.76% |

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

* Note: Station 200 not tested

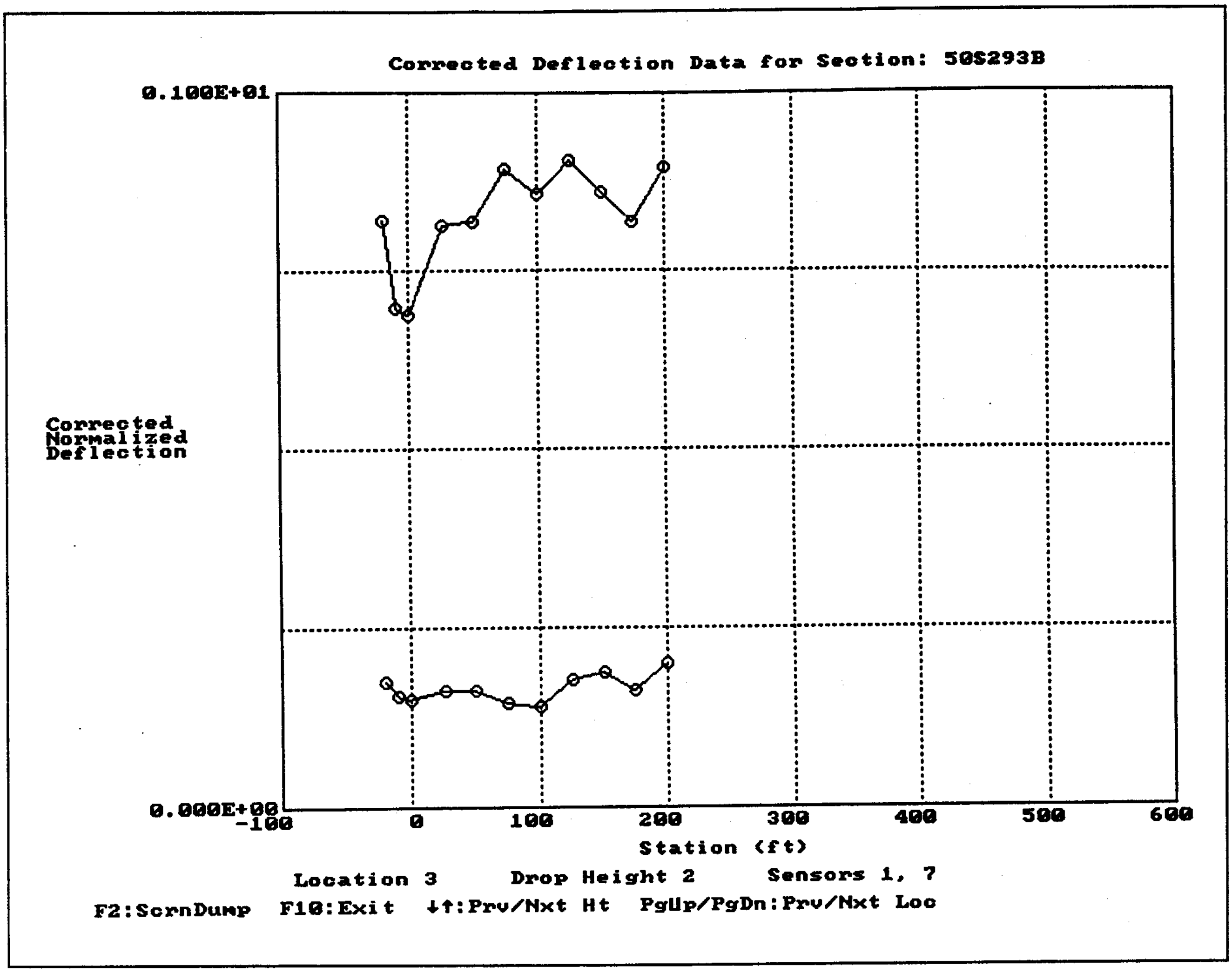



Figure D-8. Deflection Profiles from FWDCHECK
(Test Date and Time October 07, 1993 @ 1144)

Table D-6. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date and Time October 07, 1993 @ 1144)

| Flexible Pavement Thickness Statistics - 50S293B - Drop Height 2 | | | |
|---|---|---|---|
| Subsection | Station | Subgrade Modulus | Effective SN |
| 1 | -20 | 23968 | 9.00 |
| | -10 | 27014 | 9.55 |
| | 0 | 27720 | 9.55 |
| | 25 | 25790 | 8.95 |
| | 50 | 25636 | 8.90 |
| | 75 | 24770 | 8.60 |
| | 100 | 26542 | 8.70 |
| | 125 | 23414 | 8.60 |
| | 150 | 22232 | 8.85 |
| | 175 | 25195 | 8.95 |
| | 200 | 20846 | 8.80 |
| Subsection 1 | Overall Mean | 24830 | 8.95 |
| | Standard Deviation | 2077 | 0.33 |
| | Coeff of Variation | 8.36% | 3.65% |

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

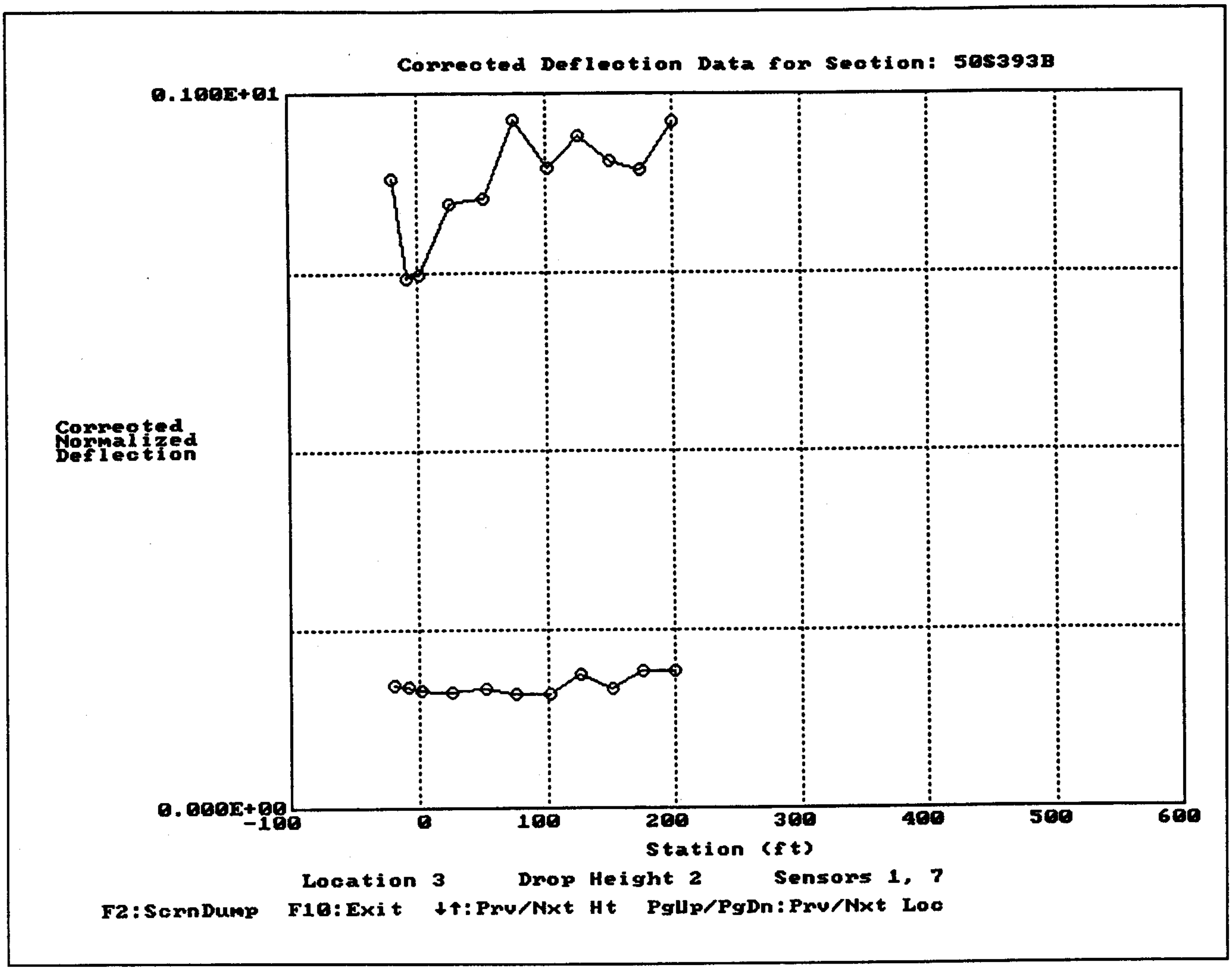



Figure D-9. Deflection Profiles from FWDCHECK
(Test Date and Time October 07, 1993 @ 1347)

Table D-7. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date and Time October 07, 1993 @ 1347)

| Flexible Pavement Thickness Statistics - 50S393B - Drop Height 2 | | | |
|---|---|---|---|
| Subsection | Station | Subgrade Modulus | Effective SN |
| 1 | -20 | 24279 | 8.65 |
| | -10 | 24403 | 9.40 |
| | 0 | 25129 | 9.35 |
| | 25 | 25587 | 8.80 |
| | 50 | 24875 | 8.80 |
| | 75 | 24500 | 8.30 |
| | 100 | 25911 | 8.55 |
| | 125 | 22382 | 8.50 |
| | 150 | 24527 | 8.55 |
| | 175 | 21667 | 8.75 |
| | 200 | 21772 | 8.45 |
| Subsection 1 | Overall Mean | 24094 | 8.74 |
| | Standard Deviation | 1480 | 0.35 |
| | Coeff of Variation | 6.14% | 4.02% |

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

Table D-8. Surface Elevation Measurements

| | | |
|---|---|---|
| LTPP Seasonal Monitoring Study | State Code | [50] |
| Surface Elevation Measurements | Test Section Number | [1002] |

| | |
|---|---|
| Survey Date | October 07, 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 0.91m | ML m offset 1.83m | IWP m offset 2.59m | ILE m offset 3.51m |
|---|---|---|---|---|---|---|
| 0-25 | 3+00 | 1.469 | 1.485 | 1.512 | 1.512 | 1.524 |
| 0-15 | 3+25 | 1.472 | 1.485 | 1.509 | 1.512 | 1.527 |
| 0-10 | 3+50 | 1.469 | 1.482 | 1.509 | 1.512 | 1.527 |
| 0+00 | 3+75 | 1.463 | 1.475 | 1.509 | 1.506 | 1.524 |
| 0+25 | 4+00 | 1.448 | 1.466 | 1.491 | 1.494 | 1.512 |
| 0+50 | 4+25 | 1.430 | 1.448 | 1.472 | 1.482 | 1.500 |
| 0+75 | 4+50 | 1.408 | 1.421 | 1.454 | 1.451 | 1.475 |
| 1+00 | 4+75 | 1.393 | 1.405 | 1.436 | 1.439 | 1.457 |
| 1+25 | 5+00 | 1.366 | 1.375 | 1.405 | 1.408 | 1.430 |
| 1+50 | 5+10 | 1.338 | 1.354 | 1.384 | 1.384 | 1.408 |
| 1+75 | 5+20 | 1.317 | 1.335 | 1.366 | 1.366 | 1.418 |
| 2+00 | 5+30 | 1.290 | 1.335 | 1.338 | 1.341 | 1.360 |

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

# APPENDIX E

## Photographs

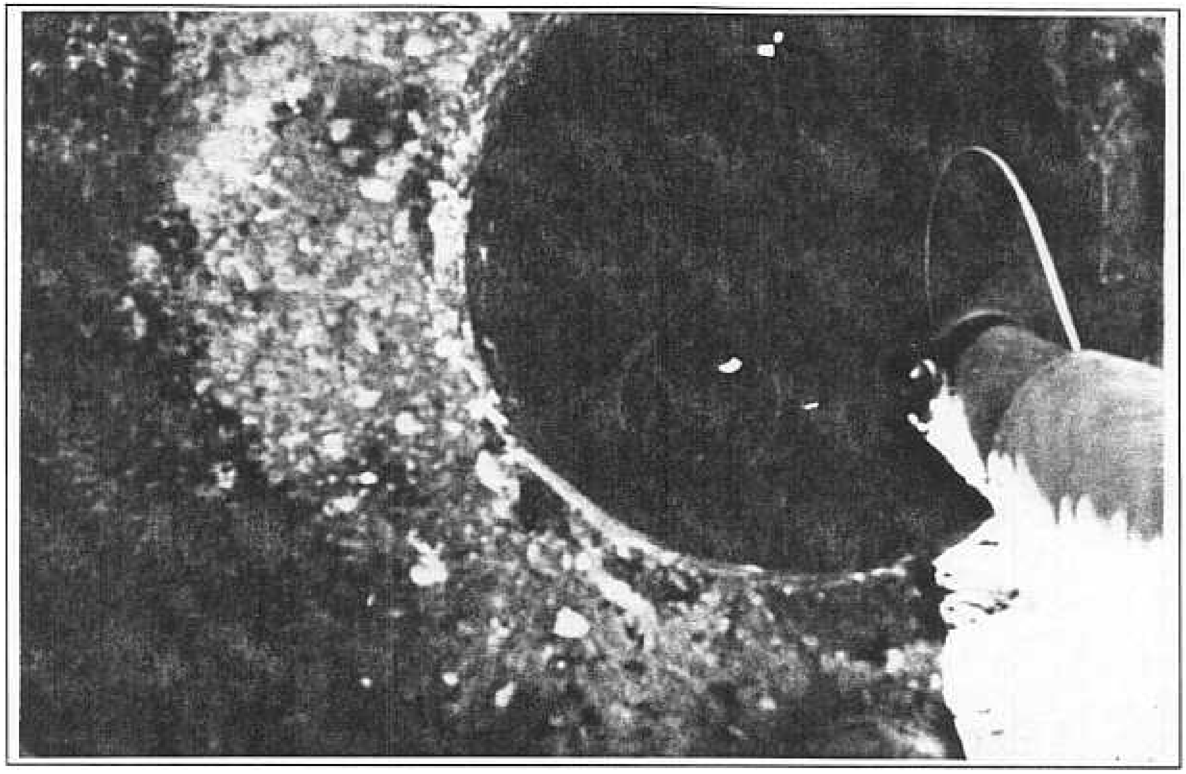


Figure E-1. Instrumentation Hole

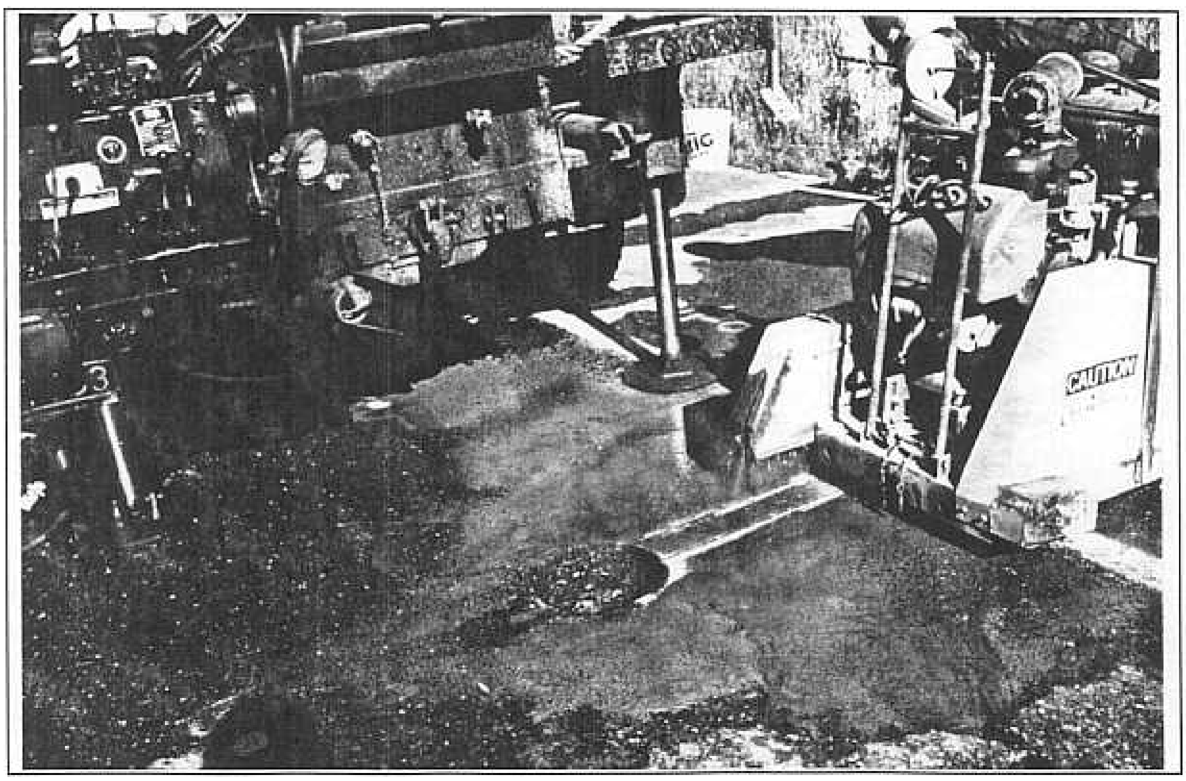



Figure E-2. Instrumentation Hole and Trench Location

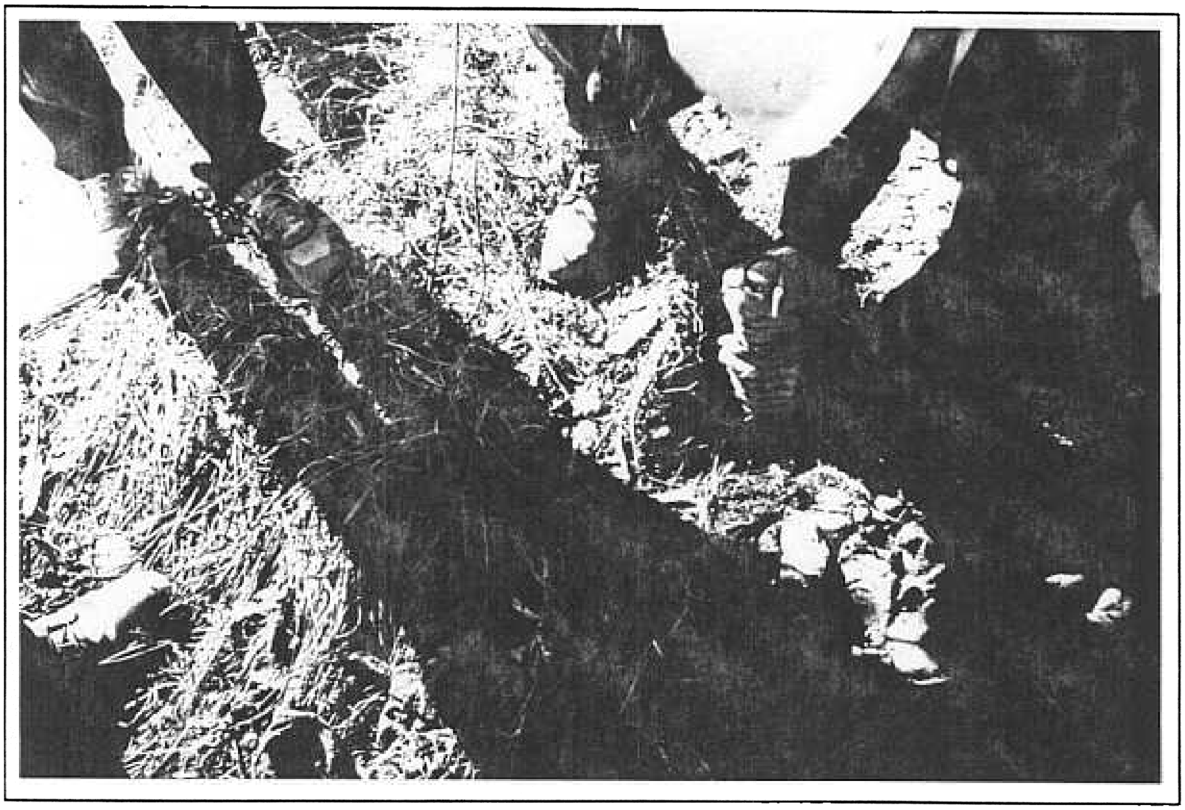


Figure E-3. Observation Well

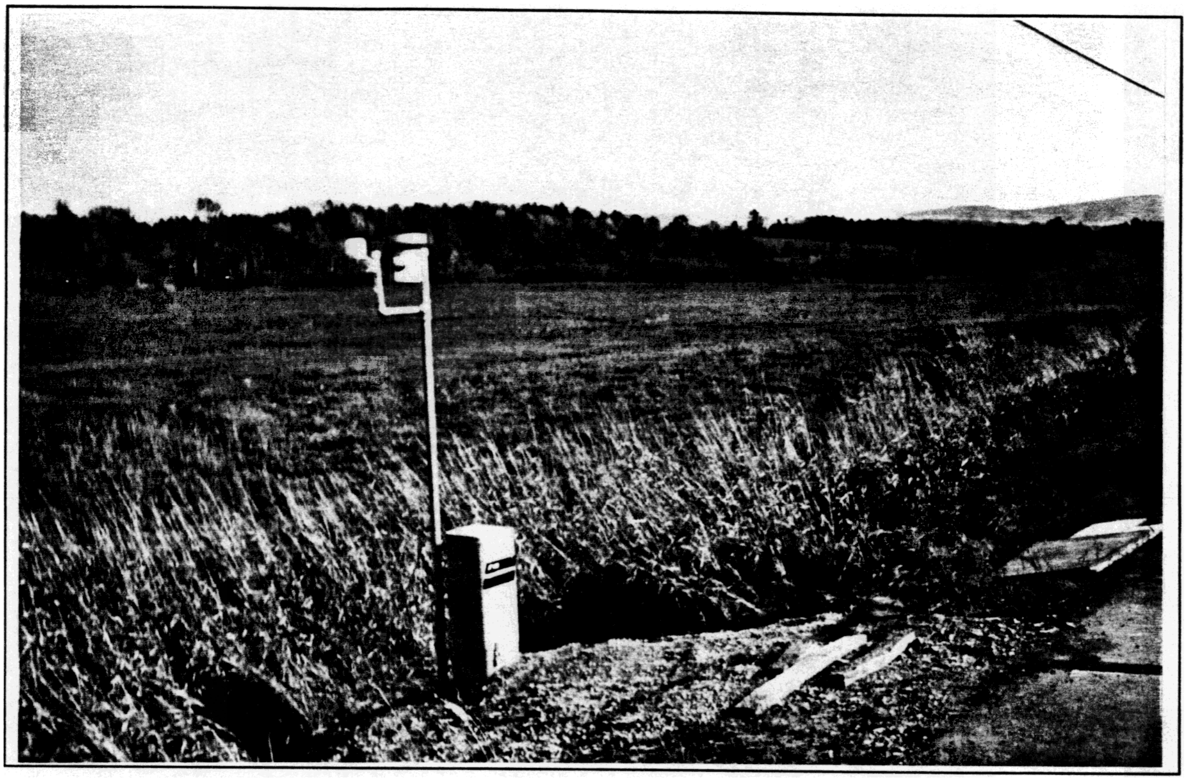


Figure E-4. Equipment Cabinet, Air Temperature Probe, and Rain Gage

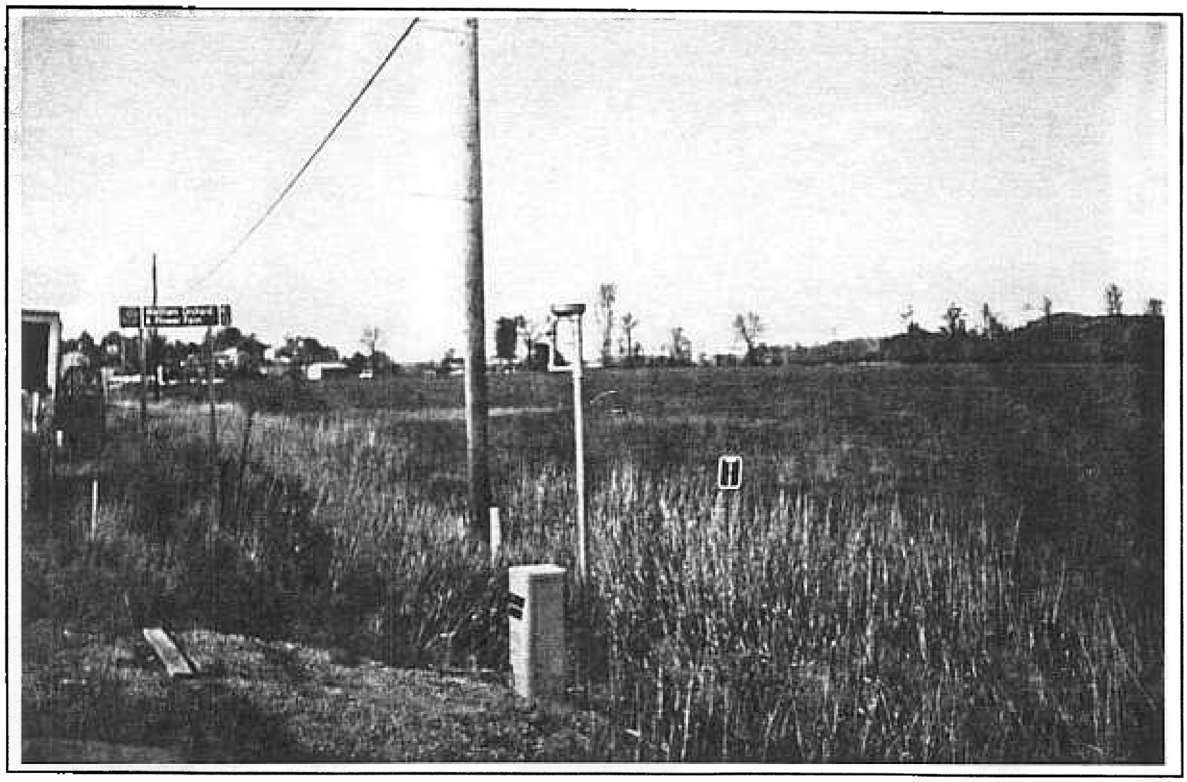


Figure E-5. Equipment Cabinet, Air Temperature Probe, and Rain Gage

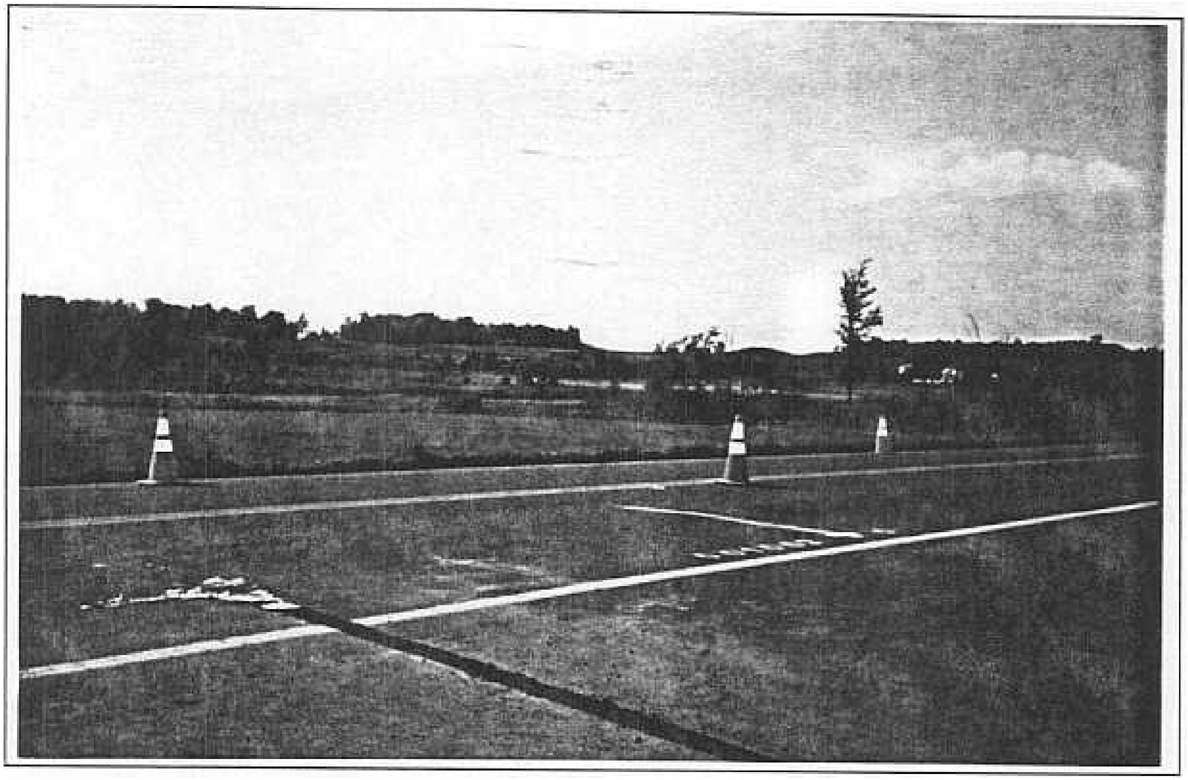


Figure E-6. Patch Area, the Day After Installation

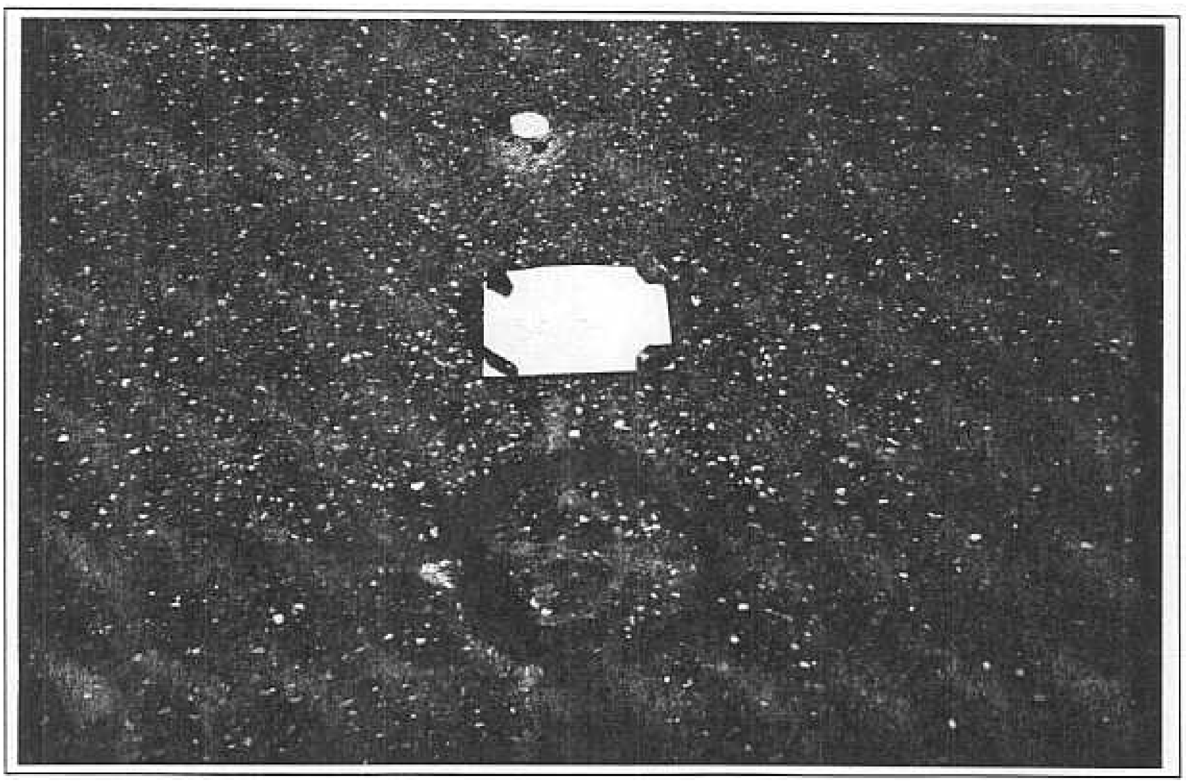


Figure E-7. Patch Area, Two and a Half Months After Installation

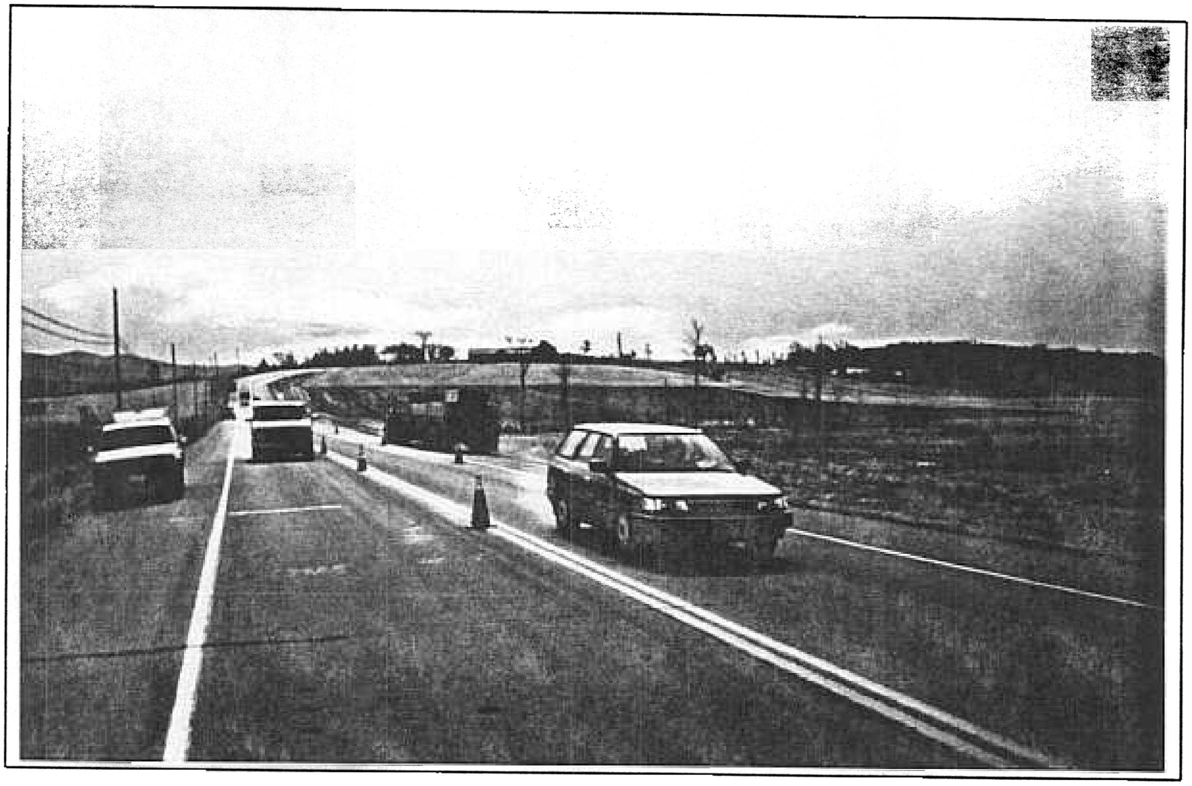


Figure E-8. Traffic Control and FWD Testing, Site 501002, April 3, 1991 (State Exp.

Figure E-9. Equipment Cabinet, Site 501002, April 3, 1991 (State Experiment)

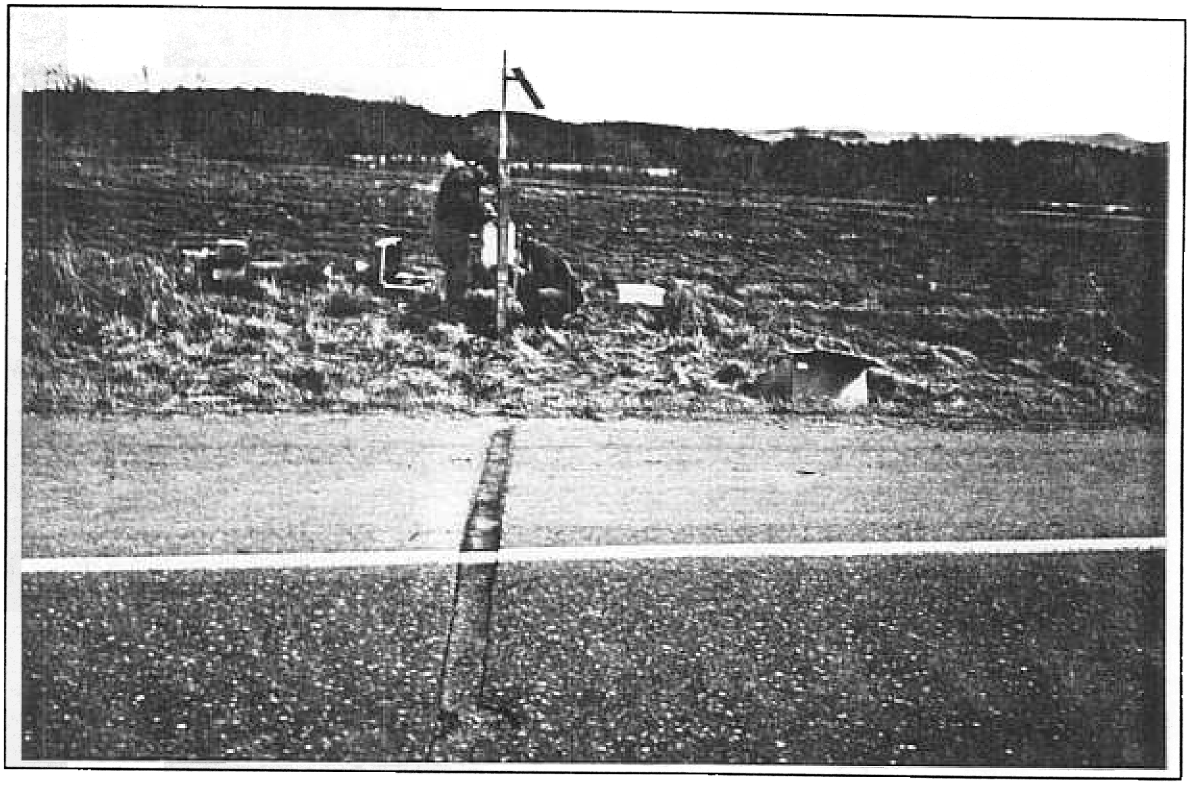


Figure E-10. Trench and Equipment Cabinet, Site 501002, April 3, 1991 (State Exp.)

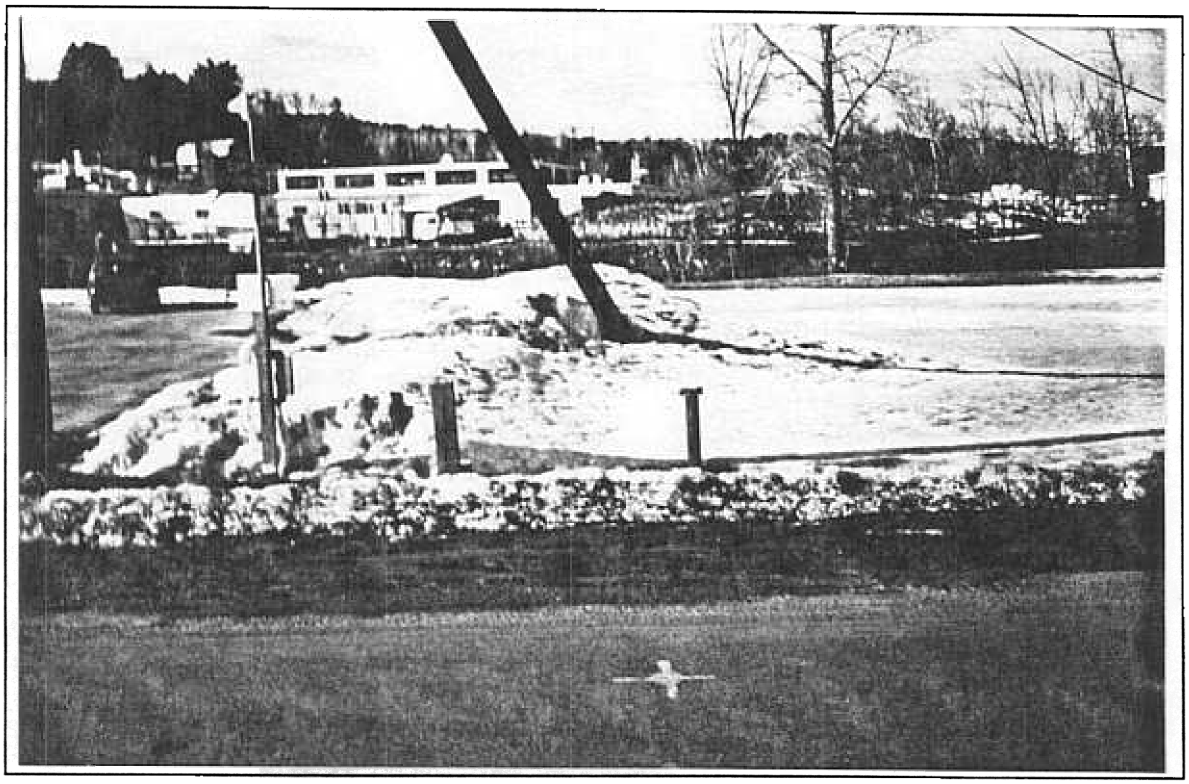


Figure E-11. Equipment Cabinet Location, Town Highway 27, April 4, 1991 (State Exp.)