

# LTPP Manual for Profile Measurements and Processing

August 2015



U.S. Department of Transportation  
Federal Highway Administration



LTPP Team  
Office of Infrastructure R&D

### **Notice**

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document. This report does not constitute a standard, specification, or regulation.

The U.S. Government does not endorse products or manufacturers. Trade or manufacturers' names appear in this report only because they are considered essential to the object of the document.

### **Quality Assurance Statement**

The Federal Highway Administration (FHWA) provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvements.

# Technical Report Documentation Page

|   |  |  |           |
|---|--|--|-----------|
| 1. Report No.   | 2. Government Accession No.                          | 3. Recipient's Catalog No.                                 |           |
| 4. Title and Subtitle<br>LTPP Manual for Profile Measurements and Processing  |  | 5. Report Date<br>August 2015                              |           |
|   |  | 6. Performing Organization Code                            |           |
| 7. Author(s)<br>R. W. Perera and G. E. Elkins   |  | 8. Performing Organization Report No.                      |           |
| 9. Performing Organization Name and Address<br>SME<br>43980 Plymouth Oaks Blvd.<br>Plymouth, MI 48170<br><br>AMEC Environmental & Infrastructure, Inc.<br>12000 Indian Creek Court, Suite F<br>Beltsville, MD 20705   |  | 10. Work Unit No. (TRAIS)                                  |           |
|   |  | 11. Contract or Grant No.<br>DTFH61-10-D-00003             |           |
| 12. Sponsoring Agency Name and Address<br>Federal Highway Administration<br>6300 Georgetown Pike<br>McLean, Virginia 22101-2296   |  | 13. Type of Report and Period Covered<br>Final August 2015 |           |
|   |  | 14. Sponsoring Agency Code                                 |           |
| 15. Supplementary Notes<br>Contracting Officer's Representative – Jane Jiang<br>FHWA Technical Reviewer – Larry Wiser   |  |  |           |
| 16. Abstract<br>This manual describes operational procedures for collecting longitudinal pavement profile and macrotexture data for the Long-Term Pavement Performance (LTPP) Program using the Ames Engineering profile/texture device. It also contains procedures for measuring the longitudinal and transverse profiles of the pavement using the Face Company Dipstick®, and procedures for measuring the longitudinal profile of the pavement using the rod and level. Procedures for calibration of equipment, performing calibration checks on the equipment, data collection, record keeping, and maintenance of equipment for each of these devices are also described in this manual. In addition, the manual describes procedures to be followed in the office for processing profile and texture data as well as guidelines for performing inter-regional comparison tests among the Ames Engineering profile/texture devices. |  |  |           |
| 17. Key Words<br>Pavement Profile, Profile Measurements, Inertial Profiler, Road Profiler, Pavement Data Collection, Pavement Macrotexture, Long Term Pavement Performance, IRI   |  | 18. Distribution Statement<br>No restrictions.             |           |
| 19. Security Classif. (of this report)<br>Unclassified  | 20. Security Classif. (of this page)<br>Unclassified | 21. No. of Pages<br>274                                    | 22. Price |





## FOREWORD

The Long-Term Pavement Performance (LTPP) program is a study of pavement performance at in-service pavement sections in the United States and Canada. The primary goal of the LTPP program is to answer how and why pavements perform as they do. The specific objectives of the LTPP program are to:

- Evaluate existing design methods.
- Develop improved design methods and strategies for the rehabilitation of existing pavements.
- Develop improved design equations for new and reconstructed pavements.
- Determine the effects of loading, environment, material properties and variability, construction quality, and maintenance levels on pavement distress and performance.
- Determine the effects of specific design features on pavement performance.
- Establish a national long-term pavement performance database.

Towards accomplishing the program goal and objectives, LTPP is collecting data on in-service pavements. The data collected at the test sections are stored in the LTPP Pavement Performance Database (PPDB). These data are being used and will continue to be used to achieve the goal and objectives of the LTPP program.

The collection of longitudinal profile data at each test section is a major task of LTPP. The left and right wheel path profile data for five repeat runs on a test section for each test date are stored in the LTPP PPDB. In addition, the International Roughness Index (IRI), Root Mean Square Vertical Acceleration (RMSVA), and Slope Variance (SV) that are computed from the profile data are also stored in the LTPP PPDB. A new data element that is being collected with the Ames Engineering devices is macrotexture data along the wheel paths.

This manual describes operational procedures to be followed when measuring longitudinal pavement profiles for the LTPP program using the Ames Engineering profile/texture device, Face Company Dipstick<sup>®</sup>, and the rod and level. The primary device currently used to obtain longitudinal pavement profile measurements for LTPP is the Ames Engineering profiling/texture device. However, when a profiler is not available, the Dipstick<sup>®</sup> is used to collect profile data. Also, a rod and level can be used to measure pavement profile if a profiler or a Dipstick<sup>®</sup> is not available. Procedures for collecting macrotexture data using the Ames Engineering profile/texture device and procedures for measuring pavement transverse profiles using the Face Company Dipstick<sup>®</sup> are also contained in this manual. In addition, the manual describes procedures to be followed in the office for processing profile and macrotexture data that were collected in the field as well as guidelines for performing inter-regional comparison tests among the four LTPP profilers.

The Ames Engineering profile/texture devices started collecting data for the LTPP program in April 2013. This manual is an update of the November 2008 LTPP Manual for Profile Measurements and Processing to reflect the operational procedures associated with the Ames Engineering device.

Four K.J. Law DNC 690 profilers collected data for the LTPP program from June 1989 until November 1996. The Manual for Profile Measurement: Operational Field Guidelines (Publication SHRP-P-378) contains the procedures that were used for collecting data with these profilers as well as with the Face Company Dipstick<sup>®</sup> and the rod and level.

Four K.J. Law T-6600 profilers collected data for the LTPP program from December 1996 to August 2002. The document LTPP Operational Procedures for K.J. Law T-6000 Profilometer – Legacy Document contains the procedures that were used for collecting profile data with these profilers as well as with the Face Company Dipstick<sup>®</sup> and the rod and level.

Four International Cybernetics Corporation (ICC) MDR 4086L3 profilers collected data for the LTPP program from September 2002 to March 2013. The document Long-Term Pavement Performance Program Manual for Profile Measurements and Processing (Publication No. FHWA-HRT-08-056) contains the procedures that were used for collecting profile data with these profilers as well as with the Face Company Dipstick<sup>®</sup> and the rod and level.

## **ACKNOWLEDGMENTS**

Many of the operating procedures described in this manual for the Ames Engineering profiling/texture device were obtained from documents provided by the manufacturer. Much of the information relating to the operation of the Face Company Dipstick<sup>®</sup> was obtained from the Instruction Manual for the Dipstick<sup>®</sup>.

The following registered trademarks are used in this document:

Dipstick<sup>®</sup> is a trademark of Face Company.

Windows is a registered trademark of Microsoft.



## TABLE OF CONTENTS

|   |          |
|---|----------|
| <b>CHAPTER 1. INTRODUCTION .....</b>  | <b>1</b> |
| 1.1 OVERVIEW OF THE LTPP PROGRAM .....  | 1        |
| 1.2 SIGNIFICANCE OF PAVEMENT PROFILE MEASUREMENTS .....   | 1        |
| 1.3 PROFILE DATA COLLECTION .....   | 1        |
| 1.4 OVERVIEW OF THE MANUAL .....  | 3        |
| <b>CHAPTER 2. PROFILE AND MACROTEXTURE MEASUREMENTS USING THE<br/>AMES ENGINEERING DEVICE .....</b> | <b>5</b> |
| 2.1 INTRODUCTION .....  | 5        |
| 2.2 OVERVIEW OF THE COMPONENTS IN THE PROFILE/TEXTURE DEVICE .....                                  | 6        |
| 2.2.1 Sensor Bar .....  | 6        |
| 2.2.2 Profile Height Sensors and Accelerometers .....   | 7        |
| 2.2.3 Texture Height Sensors and Control Units .....  | 8        |
| 2.2.4 Data Acquisition Unit .....   | 9        |
| 2.2.5 Photocells .....  | 11       |
| 2.2.6 Distance Measurement Instrument .....   | 11       |
| 2.2.7 Global Positioning System Receiver .....  | 15       |
| 2.2.8 Ambient Temperature Sensor .....  | 15       |
| 2.2.9 Pavement Surface Temperature Sensor .....   | 16       |
| 2.2.10 Light Bar, Directional Warning Light, and Strobe Lights .....                                | 17       |
| 2.2.11 Equipment Rack .....   | 21       |
| 2.2.12 Display Unit on Dashboard .....  | 23       |
| 2.2.13 Computer and Docking Station .....   | 25       |
| 2.2.14 Vehicle Security System .....  | 27       |
| 2.2.15 Master Power Switch .....  | 27       |
| 2.2.16 Fire Extinguishers .....   | 28       |
| 2.2.17 Calibration Block Kit .....  | 28       |
| 2.2.18 Texture Reference Test Device .....  | 29       |
| 2.2.19 Toolbox .....  | 30       |
| 2.2.20 Calibration Ramps .....  | 31       |
| 2.2.21 Camera .....   | 32       |
| 2.3 FEATURES OF THE DEVICE .....  | 35       |
| 2.3.1 Data Saved by the Device .....  | 35       |
| 2.3.2 Exporting Data to ProQual .....   | 35       |
| 2.3.3 First Data Point in a Section .....   | 36       |
| 2.3.4 Pre- and Post-Run Data .....  | 36       |
| 2.3.5 Event Keys .....  | 36       |
| 2.4 COMPUTER AND SOFTWARE SETTINGS .....  | 37       |
| 2.4.1 Computer Settings .....   | 37       |
| 2.4.2 Ames Engineering Software Settings .....  | 38       |
| 2.4.3 Ames Engineering Viewer Settings .....  | 46       |
| 2.4.4 ProQual Software .....  | 52       |
| 2.5 EQUIPMENT SPECIFIC OPERATIONAL GUIDELINES .....   | 52       |
| 2.5.1 Profile and Texture Laser Height Sensors .....  | 52       |

|          |   |    |
|----------|---|----|
| 2.5.2    | Cleaning Sensor Glass .....   | 53 |
| 2.5.3    | Sensor Bar and Sensor Spacing .....   | 54 |
| 2.5.4    | Photocell .....   | 54 |
| 2.5.5    | Tire Pressure .....   | 55 |
| 2.5.6    | Sensor Covers .....   | 55 |
| 2.5.8    | Interior Temperature of Vehicle .....                                       | 55 |
| 2.5.7    | Distance Measuring Instrument .....   | 56 |
| 2.5.9    | Equipment for Calibration Check of Profile and Texture Height Sensors ..... | 56 |
| 2.5.9.1  | <i>Calibration Base Plates</i> .....  | 57 |
| 2.5.9.2  | <i>Calibration Targets</i> .....  | 58 |
| 2.5.9.3  | <i>Calibration Blocks</i> .....   | 58 |
| 2.5.9.4  | <i>Digital Level</i> .....  | 60 |
| 2.5.10   | Auxiliary Battery .....   | 60 |
| 2.6      | LTPP OPERATIONAL GUIDELINES .....   | 62 |
| 2.6.1    | General LTPP Procedures .....   | 62 |
| 2.6.2    | Test Frequency and Priorities .....   | 63 |
| 2.6.3    | Major Repairs to Profile System Components .....                            | 63 |
| 2.6.3.1  | <i>General Procedures</i> .....   | 63 |
| 2.6.3.2  | <i>Profile Height Sensor</i> .....  | 64 |
| 2.6.3.3  | <i>Texture Height Sensor</i> .....  | 65 |
| 2.6.4    | Data from Previous Site Visit .....   | 65 |
| 2.6.5    | Software, Computer System, and Manuals .....                                | 65 |
| 2.7      | FIELD OPERATION GUIDELINES .....  | 66 |
| 2.7.1    | Turnarounds .....   | 66 |
| 2.7.2    | Light Bar, Directional Warning Light, and Strobe Lights .....               | 66 |
| 2.7.3    | File Naming Convention for GPS and SPS Sites .....                          | 66 |
| 2.7.4    | Operating Speed .....   | 68 |
| 2.7.5    | Obtaining Images with Camera at LTPP Sections .....                         | 68 |
| 2.7.5.1  | <i>Operational Guidelines</i> .....   | 68 |
| 2.7.5.2  | <i>Image File Names</i> .....   | 69 |
| 2.7.6    | Collection of Video .....   | 70 |
| 2.7.7    | Event Initiation .....  | 70 |
| 2.7.8    | Loading and Saving Files .....  | 71 |
| 2.7.9    | Inclement Weather and Other Interference .....                              | 71 |
| 2.7.10   | End of Run Comments .....   | 71 |
| 2.7.11   | Comments Input by Operator in ProQual .....                                 | 73 |
| 2.7.11.1 | <i>Surface Finish</i> .....   | 73 |
| 2.7.11.2 | <i>Texture Comment</i> .....  | 73 |
| 2.7.11.3 | <i>Operator Comment</i> .....   | 74 |
| 2.8      | POWER UP AND SHUTTING DOWN EQUIPMENT .....                                  | 76 |
| 2.8.1    | Power Up Procedure .....  | 76 |
| 2.8.2    | Shutting Down Procedure .....   | 79 |
| 2.9      | DATA COLLECTION .....   | 79 |
| 2.9.1    | General Background .....  | 79 |
| 2.9.2    | Daily Checks on Vehicle and Equipment .....                                 | 80 |
| 2.9.2.1  | <i>Introduction</i> .....   | 80 |

|  |     |
|--|-----|
| 2.9.2.2 Calibration Check of Profile Height Sensors .....                              | 80  |
| 2.9.2.3 Calibration Check of Texture Height Sensors .....                              | 84  |
| 2.9.2.4 Bounce Test.....   | 86  |
| 2.9.2.5 Pavement Temperature Sensor .....  | 90  |
| 2.9.3 Data Collection .....  | 90  |
| 2.9.3.1 Attaching Camera .....   | 90  |
| 2.9.3.2 Entering Header Information .....  | 90  |
| 2.9.3.3 Collecting Data.....   | 95  |
| 2.9.3.4 Evaluating Error Messages .....  | 99  |
| 2.9.3.5 Evaluating Diagnostic Messages.....  | 101 |
| 2.9.4 Evaluating the Collected Data Using ProQual 2014.....                            | 102 |
| 2.9.4.1. ProQual 2014 Software .....   | 102 |
| 2.9.4.2. Evaluating the Collected Data.....  | 105 |
| 2.9.4.3 Obtaining Additional Runs .....  | 108 |
| 2.9.4.4 Comparison of IRI and MPD with Previous Values.....                            | 109 |
| 2.9.5 Field XML File and Data Backup.....  | 109 |
| 2.10 PROFILING SPS SECTIONS .....  | 110 |
| 2.10.1 General Background .....  | 110 |
| 2.10.2 Length of Test Section .....  | 110 |
| 2.10.3 Operating Speed.....  | 110 |
| 2.10.4 Number of Runs .....  | 111 |
| 2.10.5 Header Information.....   | 111 |
| 2.10.6 Data Backup.....  | 111 |
| 2.11 PROFILING WIM SECTIONS .....  | 111 |
| 2.11.1 Background.....   | 111 |
| 2.11.2 Weigh-In-Motion (WIM) Section.....  | 112 |
| 2.11.3 Profile Measurements .....  | 114 |
| 2.11.3.1 General .....   | 114 |
| 2.11.3.2 Profiling Paths and File Naming Convention .....                              | 115 |
| 2.11.3.3 Data Collection Procedure .....   | 116 |
| 2.12 CALIBRATION/CALIBRATIONCHECKS .....   | 117 |
| 2.12.1 General Background .....  | 117 |
| 2.12.2 Calibration Menu .....  | 118 |
| 2.12.3 Calibration of Distance Measuring Instrument (DMI) .....                        | 119 |
| 2.12.4 Calibration Check of Accelerometers.....  | 125 |
| 2.12.5 Full Calibration Check of Profile and Texture Height Sensors .....              | 129 |
| 2.12.5.1 Overview .....  | 129 |
| 2.12.5.2 Supplies for Calibration Check.....   | 130 |
| 2.12.5.3 Setup Profiler.....   | 130 |
| 2.12.5.4 Full Calibration Check on Profile Height Sensors.....                         | 131 |
| 2.12.5.5 Full Calibration Check on Texture Height Sensors.....                         | 140 |
| 2.12.5.6 Failure of Full Calibration Check on a Profile or Texture Height Sensor ..... | 141 |
| 2.12.6 Calibration Check of Texture Height Sensors .....                               | 141 |
| 2.12.6.1 Setup Procedure for Test .....  | 142 |
| 2.12.6.2 Procedure for Performing Test.....  | 142 |
| 2.12.7 Bounce Test .....   | 147 |

|  |            |
|--|------------|
| 2.12.8 Calibration Check of Ambient Temperature Sensor.....  | 147        |
| 2.12.9 Calibration Check of Pavement Surface Temperature Sensor.....   | 148        |
| 2.12.10 Calibration Check of GPS Receiver .....  | 149        |
| 2.12.11 Check on Photocell Initiation.....   | 149        |
| 2.12.11.1 Site Preparation.....  | 150        |
| 2.12.11.2 Profile Data Collection.....   | 151        |
| 2.12.11.3 Data Analysis.....   | 153        |
| 2.13 EQUIPMENT MAINTENANCE AND REPAIR .....  | 153        |
| 2.13.1 General Background .....  | 153        |
| 2.13.2 Routine Maintenance .....   | 154        |
| 2.13.3 Scheduled Major Preventive Maintenance .....  | 155        |
| 2.13.4 Unscheduled Maintenance .....   | 155        |
| 2.14 RECORD KEEPING.....   | 155        |
| 2.14.1 LTPP Profiler Field Activity Report.....  | 156        |
| 2.14.2 Status of the Regions Test Sections .....   | 156        |
| 2.14.3 Profiler Log.....   | 156        |
| 2.14.4 LTPP Major Maintenance/Repair Form .....  | 156        |
| 2.14.5 Laser Sensor, Accelerometer, DMI Calibration/Calibration Check Form .....   | 156        |
| 2.14.6 Ambient Temperature Sensor, Pavement Surface Temperature Sensor, and GPS<br>Receiver Calibration Check Form ..... | 157        |
| 2.14.7 Profiling of WIM Sites: Data Summary Sheet .....  | 157        |
| 2.14.9 ProQual Outputs.....  | 157        |
| <b>CHAPTER 3. PROFILE MEASUREMENTS USING THE FACE DIPSTICK®.....</b>   | <b>159</b> |
| 3.1 INTRODUCTION.....  | 159        |
| 3.2 OPERATIONAL GUIDELINES .....   | 159        |
| 3.2.1 General Procedures .....   | 159        |
| 3.2.2 LTPP Procedures .....  | 160        |
| 3.2.3 Footpad Spacing of Dipstick® .....   | 160        |
| 3.3 FIELD TESTING .....  | 160        |
| 3.3.1 General Background .....   | 160        |
| 3.3.2 Site Inspection and Layout – Longitudinal Profile Measurements.....  | 161        |
| 3.3.3 Dipstick® Operation for Longitudinal Profile Measurements .....  | 164        |
| 3.3.3.1 Pre-operational Checks on Dipstick® .....  | 164        |
| 3.3.3.2 Longitudinal Profile Measurement.....  | 166        |
| 3.3.3.3. Post Data Collection Check.....   | 168        |
| 3.3.3.4 Closure Error Computations .....   | 168        |
| 3.3.3.5 Air Temperature Measurements .....   | 169        |
| 3.3.4 Site Inspection and Layout –Transverse Profile Measurements.....   | 170        |
| 3.3.5 Dipstick® Operation for Transverse Profile Measurements .....  | 170        |
| 3.3.5.1 Pre-operational Checks on Dipstick® .....  | 170        |
| 3.3.5.2 Entering Header Information in Transverse Profile Form.....  | 171        |
| 3.3.5.3 Transverse Profile Measurement.....  | 172        |
| 3.3.5.4 Post Data Collection Check.....  | 173        |
| 3.3.5.5 Closure Error Computation.....   | 174        |
| 3.3.6 Data Backup.....   | 174        |



|   |            |
|---|------------|
| 3.4 ZERO CHECK AND CALIBRATION CHECK .....                                | 175        |
| 3.4.1 General Background .....  | 175        |
| 3.4.2 Frequency of Checks.....  | 175        |
| 3.5 EQUIPMENT MAINTENANCE AND REPAIR .....                                | 175        |
| 3.5.1 General Background .....  | 175        |
| 3.5.2 Routine Maintenance .....   | 176        |
| 3.5.3 Scheduled Major Maintenance .....                                   | 176        |
| 3.5.4 Equipment Problems/Repairs.....                                     | 176        |
| 3.6 RECORD KEEPING.....   | 177        |
| 3.6.1 Longitudinal Profile Measurements.....                              | 177        |
| 3.6.2 Transverse Profile Measurements.....                                | 177        |
| 3.6.3 Zero and Calibration Check Form .....                               | 177        |
| 3.6.4 LTPP Major Maintenance/Repair Form .....                            | 177        |
| 3.6.5 Air Temperature Probe Calibration Check Form.....                   | 178        |
| <b>CHAPTER 4. PROFILE MEASUREMENTS USING THE ROD AND LEVEL.....</b>       | <b>179</b> |
| 4.1 INTRODUCTION.....   | 179        |
| 4.2 OPERATIONAL GUIDELINES .....  | 179        |
| 4.2.1 General Procedures .....  | 179        |
| 4.2.2 Equipment Requirements.....   | 179        |
| 4.2.3 LTPP Procedures .....   | 180        |
| 4.3 FIELD TESTING .....   | 180        |
| 4.3.1 General Background .....  | 180        |
| 4.3.2 Site Inspection and Preparation .....                               | 180        |
| 4.3.3 Longitudinal Profile Measurements.....                              | 181        |
| 4.3.4 Factors to be Considered During the Survey .....                    | 183        |
| 4.3.5 Profile Computation.....  | 183        |
| 4.3.6 Quality Control .....   | 184        |
| 4.4 CALIBRATION AND ADJUSTMENTS .....                                     | 184        |
| 4.5 EQUIPMENT MAINTENANCE .....   | 184        |
| 4.6 RECORD KEEPING.....   | 185        |
| 4.7 DATA BACKUP.....  | 185        |
| <b>CHAPTER 5. PROCESSING OF COLLECTED DATA IN THE OFFICE.....</b>         | <b>187</b> |
| 5.1 INTRODUCTION.....   | 187        |
| 5.2 AMES DEVICE DATA .....  | 187        |
| 5.3 LONGITUDINAL DIPSTICK® DATA .....                                     | 195        |
| 5.4 ASSIGNMENT OF RCO CODE .....  | 199        |
| 5.5 TRANSVERSE DIPSTICK® DATA .....                                       | 201        |
| 5.6 STORING WIM DATA .....  | 205        |
| 5.7 NAMING AND STORING IMAGE FILES .....                                  | 205        |
| 5.7.1 Image File Names for Images Collected at GPS and WIM Sections ..... | 205        |
| 5.7.2 Image File Names for Images Collected at SPS Sections.....          | 206        |
| <b>CHAPTER 6. INTER-REGIONAL COMPARISON TESTS.....</b>                    | <b>209</b> |
| 6.1 INTRODUCTION.....   | 209        |
| 6.2 PREPARATORY ACTIVITIES .....  | 209        |

|  |            |
|--|------------|
| 6.3 TEST SECTIONS .....  | 210        |
| 6.4 REFERENCE DATA COLLECTION AT TEST SECTIONS.....                                      | 210        |
| 6.5 COMPARISON TESTING OF DEVICES .....  | 211        |
| 6.5.1 Full Calibration Check of Profile and Texture Height Sensors .....                 | 211        |
| 6.5.2 Dynamic Calibration Check of Texture Height Sensors.....                           | 211        |
| 6.5.3 Calibration Check of Accelerometers .....  | 211        |
| 6.5.4 DMI Test.....  | 211        |
| 6.5.5 Profile/Texture Data Collection .....  | 211        |
| 6.5.6 Verification of DMI .....  | 212        |
| 6.6 REPORTS .....  | 212        |
| 6.6.1 Submission of Reports and Data by RSCs.....  | 212        |
| 6.6.2 Format of Report.....  | 212        |
| 6.6.3 Data Submission .....  | 213        |
| 6.6.4 Preparation of Report by TSSC .....  | 214        |
| <b>REFERENCES.....</b>   | <b>217</b> |
| <b>APPENDIX A. PROFILE/TEXTURE PROBLEM REPORT FORM.....</b>                              | <b>219</b> |
| <b>APPENDIX B. STANDARD FORMS FOR PROFILER OPERATIONS .....</b>                          | <b>221</b> |
| <b>APPENDIX C. PROFILE TROUBLE SHOOTING GUIDE.....</b>                                   | <b>231</b> |
| <b>APPENDIX D. DIFFERENCES BETWEEN ICC AND AMES PROFILE DATA.....</b>                    | <b>237</b> |
| <b>APPENDIX E. PROFILE AND TEXTURE HEIGHT SENSOR LINEARIZATION<br/>PROCEDURE .....</b>   | <b>241</b> |
| <b>APPENDIX F. STANDARD FORMS FOR DIPSTICK® MEASUREMENTS.....</b>                        | <b>245</b> |
| <b>APPENDIX G. PROCEDURE FOR DETERMINING DIPSTICK® FOOTPAD SPACING<br/>.....</b>         | <b>257</b> |
| <b>APPENDIX H. DATA COLLECTION FORM FOR ROD AND LEVEL PROFILE<br/>MEASUREMENTS .....</b> | <b>261</b> |
| <b>APPENDIX I. FORMS FOR INTER-REGIONAL PROFILER COMPARISON TESTS</b>                    | <b>267</b> |

## LIST OF FIGURES

|   |    |
|---|----|
| Figure 1. LTPP regions.....   | 2  |
| Figure 2. Sensor bar mounted on the front of the vehicle.....                             | 6  |
| Figure 3. Sensor bar with the cover open. ....  | 7  |
| Figure 4. Profile height sensors. ....  | 7  |
| Figure 5. Equipment associated with macrotexture data collection. ....                    | 9  |
| Figure 6. Data acquisition unit.....  | 10 |
| Figure 7. Ports in the DAU. ....  | 10 |
| Figure 8. Front view of the DAU.....  | 11 |
| Figure 9. Vertical photocell. ....  | 12 |
| Figure 10. Horizontal photocell. ....   | 12 |
| Figure 11. Cone with reflective tape.....   | 13 |
| Figure 12. DMI encoder.....   | 13 |
| Figure 13. DMI input connection.....  | 14 |
| Figure 14. Cap to protect input when DMI is disassembled.....                             | 14 |
| Figure 15. Location of the GPS receiver. ....   | 15 |
| Figure 16. Protective shield housing the ambient temperature sensor.....                  | 16 |
| Figure 17. Protective cover covering the pavement surface temperature sensor.....         | 17 |
| Figure 18. Protective cover open to permit pavement surface temperature measurements..... | 17 |
| Figure 19. Light bar on front of the vehicle.....   | 18 |
| Figure 20. Directional warning light on the rear of the vehicle.....                      | 18 |
| Figure 21. Uplifter switches used to control the safety lighting.....                     | 19 |
| Figure 22. Control switch for directional warning light. ....                             | 20 |
| Figure 23. Control button to change strobe pattern. ....                                  | 20 |
| Figure 24. Fuse and relay junction box of the safety lighting system. ....                | 21 |
| Figure 25. Front view of the equipment rack.....  | 21 |
| Figure 26. View of the bottom of the equipment rack with the front cover off.....         | 22 |
| Figure 27. Circuit breakers on the equipment rack.....                                    | 23 |
| Figure 28. Display unit mounted on the dashboard. ....                                    | 24 |
| Figure 29. Display unit showing four data items.....                                      | 24 |
| Figure 30. Display unit showing first and fourth rows. ....                               | 25 |
| Figure 31. Display unit showing all rows except for third row. ....                       | 26 |
| Figure 32. Display unit showing four rows (US customary units). ....                      | 26 |
| Figure 33. Laptop computer docking station with laptop computer.....                      | 27 |
| Figure 34. Master power switch.....   | 28 |
| Figure 35. Fire extinguishers in the vehicle.....   | 28 |
| Figure 36. Calibration block kit. ....  | 29 |
| Figure 37. Texture reference test device.....   | 30 |
| Figure 38. Toolbox provided with each device. ....  | 31 |
| Figure 39. Contents of the toolbox. ....  | 31 |
| Figure 40. Ramp used to elevate vehicle. ....   | 32 |
| Figure 41. Mechanism for securing the ramps.....  | 32 |
| Figure 42. Side view of the right-of-way camera. ....                                     | 33 |
| Figure 43. View from inside the vehicle of the right-of-way camera.....                   | 33 |

|   |     |
|---|-----|
| Figure 44. Example of an image obtained by the camera.....                          | 34  |
| Figure 45. Focus and aperture adjustment of the camera. ....                        | 34  |
| Figure 46. Camera preview window that appears during data collection.....           | 35  |
| Figure 47. Wireless adapter setting in the computer.....                            | 37  |
| Figure 48. Power management settings in the laptop computer. ....                   | 37  |
| Figure 49. Ames Engineering start-up screen.....                                    | 39  |
| Figure 50. Texture analysis screen.....   | 40  |
| Figure 51. Profiler setup screen. ....  | 41  |
| Figure 52. Sensors setup screen. ....   | 43  |
| Figure 53. Camera setup screen. ....  | 44  |
| Figure 54. Raytek options screen.....   | 46  |
| Figure 55. Main menu of data viewer.....  | 47  |
| Figure 56. Selecting preferences menus. ....  | 48  |
| Figure 57. General menu.....  | 49  |
| Figure 58. Profile processing menu. ....  | 49  |
| Figure 59. Texture processing menu.....   | 50  |
| Figure 60. Accessing the Mean Profile Depth analysis menu. ....                     | 51  |
| Figure 61. Mean Profile Depth analysis menu.....                                    | 51  |
| Figure 62. Protective cover that protects the laser sensors. ....                   | 56  |
| Figure 63. Bottom view of the base plate. ....                                      | 57  |
| Figure 64. Top view of the base plate.....  | 57  |
| Figure 65. Calibration target placed on the base plate.....                         | 58  |
| Figure 66. Calibration menu. ....   | 59  |
| Figure 67. Extensive test menu.....   | 59  |
| Figure 68. Menu for entering actual block heights. ....                             | 60  |
| Figure 69. Menu with actual block heights entered.....                              | 61  |
| Figure 70. Digital level. ....  | 61  |
| Figure 71. Ames Engineering software start-up screen. ....                          | 77  |
| Figure 72. Calibration menu. ....   | 81  |
| Figure 73. Extensive test menu.....   | 82  |
| Figure 74. Laser dot centered on base plate.....                                    | 82  |
| Figure 75. Readings taken on target placed on base plate. ....                      | 83  |
| Figure 76. Display after obtaining measurements on target placed on base plate..... | 83  |
| Figure 77. Readings being taken on target placed on the 25 mm block. ....           | 84  |
| Figure 78. Display after obtaining measurements on target placed on base plate..... | 85  |
| Figure 79. Bounce test start-up screen.....   | 87  |
| Figure 80. Filter warm-up in progress during bounce test.....                       | 87  |
| Figure 81. Filter cool-down process after bounce test is terminated. ....           | 88  |
| Figure 82. Display after completion of the bounce test. ....                        | 89  |
| Figure 83. Header menu.....   | 91  |
| Figure 84. Screen after initiating data collection. ....                            | 96  |
| Figure 85. End of run window. ....  | 97  |
| Figure 86. Diagnostic log.....  | 98  |
| Figure 87. Layout of WIM Site.....  | 113 |
| Figure 88. Calibration menu. ....   | 119 |
| Figure 89. Horizontal test screen. ....   | 120 |

|   |     |
|---|-----|
| Figure 90. Horizontal calibration screen.....   | 122 |
| Figure 91. DMI calibration screen after performing one run.....   | 123 |
| Figure 92. DMI calibration screen after obtaining six runs. ....  | 124 |
| Figure 93. DMI calibration screen showing seven runs with six selected.....                                   | 124 |
| Figure 94. Laser sensor warning during the accelerometer calibration check.....                               | 126 |
| Figure 95. Accelerometer test menu. ....  | 126 |
| Figure 96. Screen after starting accelerometer test. ....   | 127 |
| Figure 97. Screen after completion of test with lasers pointing downwards. ....                               | 127 |
| Figure 98. Screen after lasers are rotated with sensor glass on top. ....                                     | 128 |
| Figure 99. Screen after completion of test with lasers pointing upward. ....                                  | 129 |
| Figure 100. Ames Engineering software start-up screen. ....   | 132 |
| Figure 101. Ramps placed in front of the tire before driving vehicle up the ramp.....                         | 132 |
| Figure 102. Device on top of ramps.....   | 133 |
| Figure 103. Extensive test screen.....  | 134 |
| Figure 104. Laser dot centered on base plate.....   | 134 |
| Figure 105. Target placed on the base plate. ....   | 135 |
| Figure 106. Screen after readings have been obtained on target placed on base plate. ....                     | 136 |
| Figure 107. The 25 mm block with target on top of the block. ....   | 136 |
| Figure 108. Screen after readings have been obtained on the 25 mm block. ....                                 | 137 |
| Figure 109. Readings being taken on a 50 mm block.....  | 137 |
| Figure 110. Readings being taken on a 75 mm block.....  | 138 |
| Figure 111. Readings being taken on a 100 mm block.....   | 139 |
| Figure 112. Results after performing measurements on the four blocks. ....                                    | 139 |
| Figure 113. Texture disk test window.....   | 143 |
| Figure 114. Texture reference test device.....  | 143 |
| Figure 115. Target on texture reference test device.....  | 144 |
| Figure 116. Texture reference test screen after static test.....  | 145 |
| Figure 117. Cover open on texture reference test device.....  | 146 |
| Figure 118. Texture reference test screen after dynamic test on left sensor.....                              | 146 |
| Figure 119. Results from a completed texture calibration check.....   | 147 |
| Figure 120. Section starting stripe and bump target placed on the pavement. ....                              | 151 |
| Figure 121. Placement of vertical photocell target in relation to section starting location. ....             | 152 |
| Figure 122. Example plot of data from photocell initiation test with one point on the target. ....            | 154 |
| Figure 123. Example plot of data from photocell initiation test with two points on the target. ....           | 154 |
| Figure 124. Site layout and measurement procedure for measuring longitudinal profiles with the Dipstick®..... | 162 |
| Figure 125. Spike in profile data (profile data for run 4 has been offset for clarity).....                   | 232 |
| Figure 126. Data collected with a correctly calibrated and a miscalibrated DMI. ....                          | 233 |
| Figure 127. Example of early profile start. ....  | 234 |
| Figure 128. Differences in profile due to rehabilitation of section.....                                      | 235 |
| Figure 129. Differences in profile due to maintenance within section. ....                                    | 236 |
| Figure 130. ICC and Ames profile data collected at Section 1.....   | 237 |
| Figure 131. PSD plot of profile data collected by ICC and Ames devices at section 1. ....                     | 238 |
| Figure 132. ICC and Ames profile data collected at Section 4.....   | 238 |
| Figure 133. PSD plot of profile data collected by ICC and Ames devices at section 4. ....                     | 239 |
| Figure 134. Re-linearization software menu.....   | 242 |

|   |     |
|---|-----|
| Figure 135. Digital engine tab of re-linearization software. ....   | 244 |
| Figure 136. Test section layout. ....   | 257 |
| Figure 137. Location of back footpad of Dipstick® at start of the section. ....   | 258 |
| Figure 138. Back end of front footpad is past the end of the test section when the last reading is obtained. ....       | 259 |
| Figure 139. Back end of the front footpad is before the end of the test section when the last reading is obtained. .... | 259 |

## LIST OF TABLES

|   |     |
|---|-----|
| Table 1. Ames Engineering device assigned to each RSC. ....                   | 3   |
| Table 2. Dimensions of calibration blocks. ....                               | 30  |
| Table 3. Device addresses. ....   | 102 |
| Table 4. Components requiring calibration/calibration checks. ....            | 118 |
| Table 5. Allowable closure errors for transverse Dipstick® measurements. .... | 174 |
| Table 6. Resolution requirement for rod and level measurements. ....          | 179 |

## ACRONYMS

|        |  |
|--------|--|
| AC     | Asphalt Concrete   |
| AIMS   | Ancillary Information Management System                  |
| ARD    | Ames Raw Data  |
| CCD    | Charged Couple Device                                    |
| CSV    | Comma Separated File                                     |
| DAU    | Data Acquisition Unit                                    |
| DLL    | Dynamic Link Library                                     |
| DMI    | Distance Measuring Instrument                            |
| ERD    | Engineering Research Division                            |
| FHWA   | Federal Highway Administration                           |
| GPS    | General Pavement Studies                                 |
| GPSR   | Global Positioning System Receiver                       |
| ICC    | International Cybernetics Corporation                    |
| IRI    | International Roughness Index                            |
| JPEG   | Joint Photographic Expert Group                          |
| LCD    | Liquid Crystal Display                                   |
| LED    | Light Emitting Diode                                     |
| LTPP   | Long Term Pavement Performance                           |
| MPD    | Mean Profile Depth                                       |
| MSD    | Mean Segment Depth                                       |
| NIST   | National Institute of Standards and Technology           |
| PROFPR | Profile/Texture Problem Report                           |
| PSM    | Profile System Monitor                                   |
| PCC    | Portland Cement Concrete                                 |
| PPDB   | Pavement Performance Database                            |
| PSD    | Power Spectral Density                                   |
| RSC    | Regional Support Contractor                              |
| SHRP   | Strategic Highway Research Program                       |
| SMP    | Seasonal Monitoring Program                              |
| SPS    | Specific Pavement Studies                                |
| SV     | Slope Variance   |
| TSSC   | Technical Support Services Contractor                    |
| UMTRI  | University of Michigan Transportation Research Institute |
| USB    | Universal Serial Bus                                     |
| VIN    | Vehicle Identification Number                            |
| WAAS   | Wide Area Augmentation System                            |
| WIM    | Weigh-in-Motion  |





## **CHAPTER 1. INTRODUCTION**

### **1.1 OVERVIEW OF THE LTPP PROGRAM**

The Long-Term Pavement Performance (LTPP) program is a research program that investigates in-service pavement performance. Started in 1987 as part of the first Strategic Highway Research Program (SHRP), the LTPP program has been managed by the Federal Highway Administration (FHWA) since 1992. The primary goal of the LTPP program is to answer how and why pavements perform as they do. In order to accomplish this goal, LTPP collects pavement performance data using standard data collection procedures and protocols on a variety of pavement types. This information is stored in a database that can be used by pavement engineers and researchers worldwide to advance the science of pavement engineering.

For purposes of pavement data collection and coordination, the United States and participating Canadian provinces have been subdivided into four regions—North Atlantic, North Central, Southern, and Western—each served by a Regional Support Contractor (RSC). The boundaries defining the jurisdiction of each RSC are shown in figure 1.

### **1.2 SIGNIFICANCE OF PAVEMENT PROFILE MEASUREMENTS**

The longitudinal profile along the wheel paths in a pavement can be used to evaluate the roughness of the pavement by computing a roughness index such as the International Roughness Index (IRI). The change in longitudinal pavement profile over time, which is directly related to the change in roughness with time, is an important indicator of pavement performance. Hence, one aspect of the LTPP program is to collect pavement profile data on in-service pavement sections for use in many applications such as improving the prediction of pavement performance.

### **1.3 PROFILE DATA COLLECTION**

The primary method used to obtain pavement profile measurements for the LTPP program is to profile test sections using a road profiler. Each RSC operates a profiler to collect data within its region. From June 1989 until November 1996, profile data at test sections were collected using a model DNC 690 inertial profiler manufactured by K. J. Law Engineers, Inc. In December 1996, each RSC replaced their model K.J. Law DNC 690 profiler with a Model T-6600 inertial profiler manufactured by K. J. Law Engineers, Inc. In September 2002, each RSC replaced their K. J. Law T-6600 profiler with an International Cybernetics Corporation (ICC) MDR 4086L3 inertial profiler. In April 2013, each RSC replaced their ICC profiler with an Ames Engineering Model 8300 inertial profiler. In addition to profile data collection equipment, this device is equipped with texture lasers to collect macrotexture data along the wheel paths, a sensor to measure pavement surface temperature, a sensor to measure ambient temperature, a Global Positioning System Receiver (GPSR) to obtain position information, and a right-of-way camera mounted inside the cabin of the vehicle to obtain images. Previous equipment used to collect profile data for the LTPP program did not have the capability to collect these data elements except for the ambient temperature. The operation and maintenance of the profiler and storage of the collected data are the responsibility of each RSC.



Table 1 shows the Ames Engineering identification number, the license plate number, and the Vehicle Identification Number (VIN) of the device assigned to each RSC.

Table 1. Ames Engineering device assigned to each RSC.

| <b>Region</b>  | <b>Ames Identification Number</b> | <b>Plate Number</b> | <b>Vehicle VIN Number</b> |
|----------------|-----------------------------------|---------------------|---------------------------|
| North Atlantic | 830112                            | 45147               | 1FMNE1BW2CDA91456         |
| North Central  | 830412                            | 45148               | 1FMNE1BW4CDA91457         |
| Southern       | 830212                            | 45149               | 1FMNE1BW4CDA86601         |
| Western        | 830312                            | 45150               | 1FMNE1BW6CDA86602         |

When a profiler is not available, LTPP has elected to use the Dipstick<sup>®</sup>, which is a hand operated digital profiler manufactured by Face Company, as a backup device to collect longitudinal profile data. The Dipstick<sup>®</sup> is also used to obtain transverse profile data. The North Atlantic, North Central, and Western RSC's are in possession of three Dipsticks<sup>®</sup>, while the Southern RSC has two Dipsticks<sup>®</sup>. A rod and level can be used to measure pavement profiles if a profiler or a Dipstick<sup>®</sup> is not available, or where other special circumstance or requirements rule out the Dipstick<sup>®</sup> or the profiler. However, this method is very labor intensive and is not typically used within the LTPP program.

## **1.4 OVERVIEW OF THE MANUAL**

This manual describes procedures to be followed when measuring pavement profiles for the LTPP program using the Ames Engineering device, Face Company Dipstick<sup>®</sup>, and the rod and level. Procedures for calibration of equipment, data collection, record keeping, and maintenance of equipment for each of the devices are also described in this manual. In addition, the manual describes procedures to be followed in the office when processing profile data collected in the field as well as guidelines for performing inter-regional comparison tests among the four Ames Engineering devices.

This document addresses those aspects of profile measurements and macrotexture measurements that are unique to the LTPP program. Other references included in the References section of this manual should be consulted for general information about the equipment.



## **CHAPTER 2. PROFILE AND MACROTEXTURE MEASUREMENTS USING THE AMES ENGINEERING DEVICE**

### **2.1 INTRODUCTION**

The Ames Engineering Model 8300 profile/texture device uses a Ford E150 XLT Wagon as the host vehicle<sup>(1)</sup>. This device is equipped with specialized instruments to measure and record road profile data and surface macrotexture data. The device contains three laser height sensors with an accelerometer located above each height sensor to collect data to compute the longitudinal profile. These laser height sensors are hereafter referred to as profile height sensors. The device is also equipped with two additional laser height sensors to collect surface macrotexture data. These laser height sensors are hereafter referred to as texture height sensors. The profile and texture height sensors are mounted on a sensor bar that is installed on the front of the vehicle. One profile height sensor is located at the center of the vehicle, while the other two profile height sensors are located along each wheel path. A texture height sensor is located behind each profile height sensor that collects data along a wheel path such that profile data and macrotexture data are collected along the same path. The longitudinal distance measuring instrument (DMI) is mounted on the rear left wheel of the vehicle, and measures the distance traveled by the vehicle. A laptop computer is mounted on a stand between the driver and the passenger seats in the device. This laptop computer is used to control all data collection activities. All data collected by the device in a single run are saved in one file and is stored in this laptop computer.

Profile height sensors measure the distance from the sensor to the road while the accelerometers measure vertical acceleration. Signals from the profile height sensors, accelerometers, and DMI are saved onto a file in the laptop computer. These signals are also used to compute the profile of the pavement along the path traversed by each profile height sensor in real time. The data recorded by the profile height sensors, accelerometers, and DMI can be post-processed to obtain the longitudinal profile along the path that was traversed by each sensor at 25 mm intervals.

The two texture height sensors collect macrotexture data along each wheel path. The data collected by these two height sensors are recorded in the same data file where the profile data are stored. These data can be post-processed to obtain macrotexture data at 0.5 mm intervals.

The Ames Engineering device is equipped with two photocells that are mounted on the sensor bar. One photocell is mounted vertically to sense reflections from pre-placed marks on the road surface. The other photocell is mounted horizontally on the passenger side of the vehicle so it can sense reflective markings on a cone placed on the side of the road. The operator can select one of these photocells during a data collection run to trigger data collection at a specified location. The device is also equipped with a GPSR and sensors to measure the ambient temperature and the pavement surface temperature. In addition, the device has a camera mounted inside the cabin of the vehicle that takes pictures of the roadway as viewed from inside of the vehicle.

The host vehicle is equipped with both a heater and an air conditioner to provide a uniform temperature for the electronic equipment inside the vehicle. This device can measure road

profiles at speeds ranging from 10 to 112 km/h. The test speed normally used to collect profile data at LTPP sections is 80 km/h.

## **2.2 OVERVIEW OF THE COMPONENTS IN THE PROFILE/TEXTURE DEVICE**

This section presents an overview of the various components included in the Ames Engineering profile/texture device. Most of the information presented in this section was obtained from the documents provided by Ames Engineering during the training session and user manual (see references 2 through 5). These documents should be consulted for additional details about the components.

### **2.2.1 Sensor Bar**

A sensor bar is mounted on the front of the vehicle and houses the three profile height sensors, the accelerometers located on top of each profile height sensor, the two texture height sensors and the associated controllers, the interface box for processing macrotexture data, the vertical and horizontal photocells, and the data acquisition unit (DAU). The sensor bar is 1.825 m long and 0.37 m wide.

The sensor bar has a cover that is fixed to the bar by four retention knobs. The cover can be opened by removing the four knobs and lightly pulling on each side. The cover is fitted with a tilt sensor that sets off the vehicle alarm if the cover is opened when the vehicle alarm is on. The sensor bar has an approximate ground clearance of 268 mm. Figure 2 shows a view of the sensor bar. Figure 3 shows a view of the sensor bar with the cover open. A brief description of the various components that are located inside the sensor bar is presented later in this chapter.



Figure 2. Sensor bar mounted on the front of the vehicle.





Figure 3. Sensor bar with the cover open.

### 2.2.2 Profile Height Sensors and Accelerometers

Three LMI-Selcom laser sensors that collect elevation data to compute the longitudinal profile are located inside the sensor bar (see figure 4). One sensor is located at the center of the vehicle and the other two sensors are located on either side from the center of the vehicle at a distance of 838 mm. The profile height sensors are designated as SLS5000 200/300-RO. The 200 in the designation indicates the sensor has a 200 mm measurement range, the 300 indicates the sensor has a stand-off height of 300 mm, and the term RO indicates the sensor is optimized for road applications. The closest distance the sensor can see from the sensor glass is 200 mm, and the furthest distance the sensor can see from the glass is 400 mm. The stand-off height of 300 mm is the center point of the sensor's range and should be approximately at the ground surface. The profile height sensors are rated as 16 kHz lasers.



Figure 4. Profile height sensors.

The SLS sensor contains a light source and a detector integrated with optics and electronics. The laser light source illuminates a spot on the pavement surface, and the reflected light from the spot is detected by the detector that uses the signal to calculate the height. The emitted light can damage the eye if directly exposed, or if the laser light is reflected by a mirror or any mirror like surface directly into the eye. The three profile height sensors are designated as ODS1 (left wheel path), ODS 2 (right wheel path) and ODS3 (center sensor). Each height sensor is housed inside a customized box manufactured by Ames Engineering. This box can be removed from the sensor bar by releasing the two latches in each box. The profile height sensors are identified by a label on the top of the box. To ensure data are collected along the proper path, the labels should be in normal reading orientation when standing in front of the van.

An accelerometer is located on top of each profile height sensor to measure accelerations. The accelerometers are manufactured by Colibrys and can measure accelerations between  $\pm 5g$ . The accelerometer is also inside the customized box. Circuit boards manufactured by Ames Engineering located within each sensor box process the data collected by the height sensor and the accelerometer and combine these data elements with the DMI data to compute the profile in real time. It should be noted that the real time profile data are not computed in the device's laptop computer; computation of the real time profile data is performed by the circuit boards that are inside each sensor box.

### **2.2.3 Texture Height Sensors and Control Units**

The device is equipped with two LMI-Selcom Optocator sensors that collect macrotexture data (see figure 5). These sensors are mounted directly behind the left and right profile height sensors such that the profile data and the macrotexture data are collected along the same path. The texture height sensors are designated as Optocator 2008-180/390. The 180 in the designation indicates these sensors have a measurement range of 180 mm, and the 390 indicates the sensors have a stand-off height of 390 mm. The closest distance the sensor can see from the glass is 300 mm, and the furthest distance the sensor can see from the glass is 480 mm. The stand-off height of 390 mm is the center point of the sensor's range and is approximately at the ground surface. The texture height sensors are referred to as ODS4 (left wheel path sensor) and ODS5 (right wheel path sensor).

The Optocator sensor consists of two major parts, the Optocator head (sensor head) and the probe processing unit, which is referred to as the controller in this document. The Optocator head contains the laser light source that emits laser light to the road surface, the light receiver that detects the reflected light from the laser spot on the road surface, and a preamplifier. The controller contains the signal processing part of the Optocator. The output from each controller is fed into the interface box that is located inside the sensor bar on the passenger side of the vehicle. A cable from the interface box transmits the macrotexture data collected by both height sensors to the DAU. The texture height sensors are rated at 62.5 kHz and all of the data obtained by these sensors at this frequency are stored in the same data file where the profile data are stored.



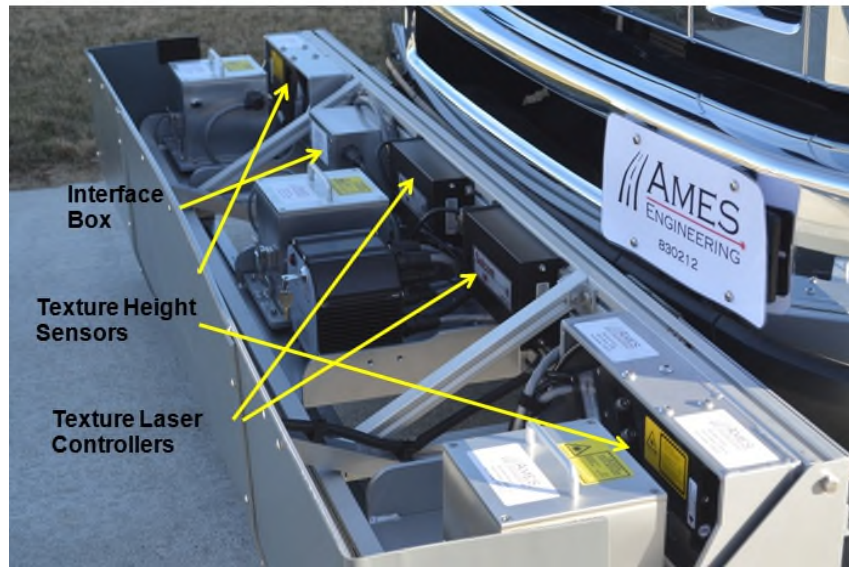


Figure 5. Equipment associated with macrotexture data collection.

#### 2.2.4 Data Acquisition Unit

The data acquisition unit (DAU) is mounted next to the center profile height sensor (see figure 6). Figure 7 shows the ports on the DAU. As seen in figure 7, the power connection, DMI, and GPSR have designated ports. The power connection provides power from the auxiliary battery and is used to provide power to the profile and texture height sensors, accelerometers, DMI, the two photocells, and the GPSR. The data collected by each profile height sensor, the accelerometer associated with that sensor, and the computed profile is input into a port in the DAU. The macrotexture data from both texture height sensors are input from the interface box into the DAU through one cable. One port in the DAU is not used. Except for the power input, GPSR, and DMI that have designated ports, data from other components described above can be connected to any port in the DAU.

It should be noted that Ames Engineering computer cards in each sensor box are independently processing the data, and the final data are transferred through an Ethernet protocol to the DAU that contains an Ethernet switch. From there the data are sent to the router located on the equipment rack, and from there the data are transferred to the laptop computer for permanent storage.

The front of the DAU has a power on/off switch and a keyway (see figure 8). The power to all components associated with data collection in the device is turned on by using the power switch (see section 2.2.15). Once this switch is turned on, the power button in the DAU can be used to turn-off power to the components. Pressing this switch again will turn the power on. The power switch on the DAU may be used to cut-off power when inspecting or servicing parts located inside the sensor bar.

The key can be used to cut-off power to the profile and texture laser height sensors. The key should always be inserted and set to the "On" position for data collection. The key can only be removed in the "Off" position. The key should only be removed when a need arises to cut-off power to the profile and texture height sensors.

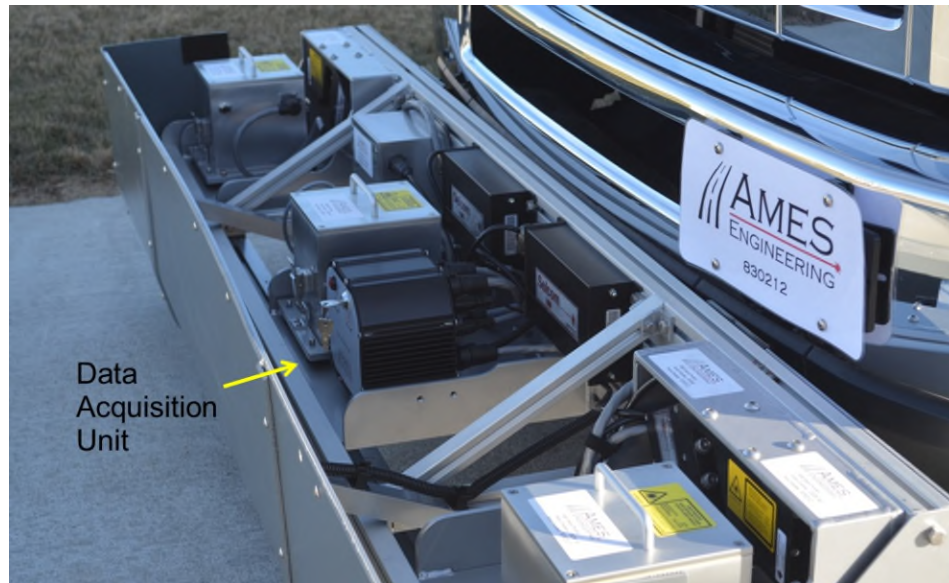


Figure 6. Data acquisition unit.



Figure 7. Ports in the DAU.



Figure 8. Front view of the DAU.

### 2.2.5 Photocells

There are two photocells mounted on the sensor bar, a downward facing photocell referred to as the vertical photocell (see figure 9) and a sideways facing photocell referred to as the horizontal photocell (see figure 10).

Both of these photocells are manufactured by Pepperl+Fuchs. The vertical photocell is mounted approximately at the center of the sensor bar. The horizontal photocell is mounted at the edge of the sensor bar on the passenger side. A cable connects the vertical photocell to the center sensor box and the horizontal photocell to the right wheel path sensor box. The vertical photocell can trigger off HVAC tape. The horizontal photocell triggers off reflective tape that is placed on a cone. Two cones with the reflective tape were provided with each device. Figure 11 shows a photograph of a cone. Manufacturers' literature indicates the horizontal photocell has a 15 m range. The reflective tape on the cone is manufactured by Reflexlite. Ames Engineering has recommended this reflective tape be used on the cone for optimum performance of the horizontal photocell.

### 2.2.6 Distance Measurement Instrument

An Encoder Products DMI encoder that transmits 500 pulses per revolution is installed on the rear left wheel of the van (see figure 12). This DMI is a quadrature output signal device, and a microcontroller installed in the DAU is able to analyze the signal utilizing single edge detection and increase the resolution to 2,000 pulses per revolution. The DMI encoder mounts directly over four of the lug studs on the wheel. Four nuts are used to hold the encoder in place. The encoder can be taken off the wheel by taking out the four nuts. A harness runs from the encoder to an input that is connected to the fender (see figure 13). The output from the encoder is



transmitted through a cable to the DAU located on the sensor bar. When the encoder is disassembled, a dust cap is provided to protect the connector (see figure 14).



Figure 9. Vertical photocell.

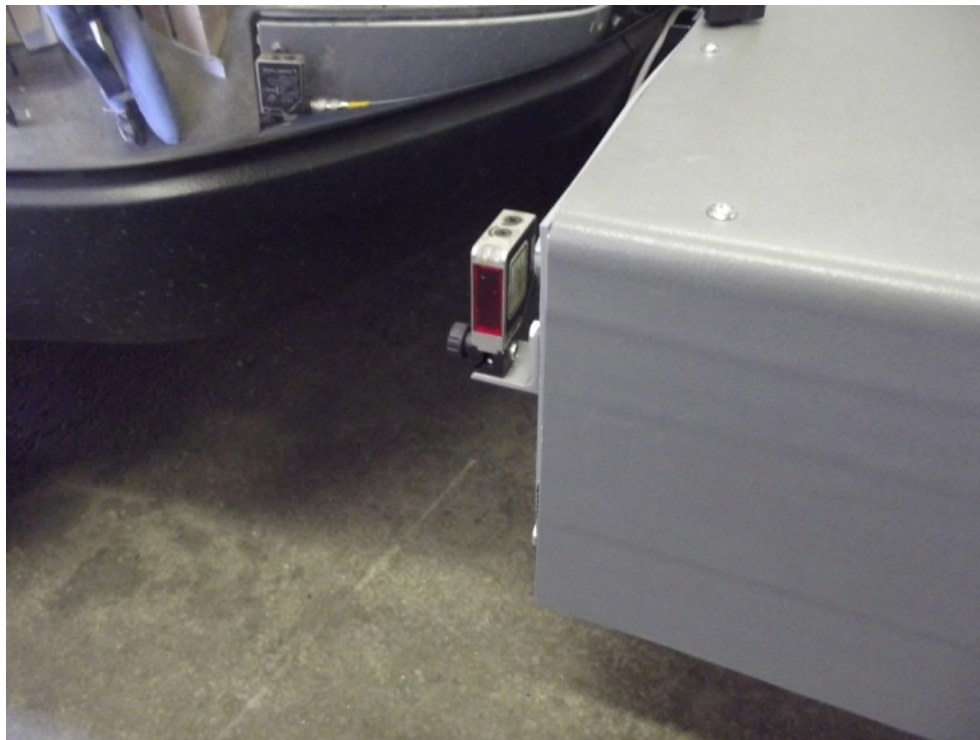


Figure 10. Horizontal photocell.



Figure 11. Cone with reflective tape.



Figure 12. DMI encoder.



Figure 13. DMI input connection.



Figure 14. Cap to protect input when DMI is disassembled.

If the short cable that connects the encoder to the fender is damaged, and a backup short cable is not available, it is possible to bypass this short cable by cutting some wire ties and extending the extra cable that is coiled up forward of the wheel well, and carefully routing it to the encoder directly. Care should be taken to not route the cable too close to the tire in the process. It is recommended that the DMI be removed from the wheel on days when the profiler is in transit with no testing being performed.

### 2.2.7 Global Positioning System Receiver

A Garmin 18X-5 Hz GPSR is installed on the vehicle within the light bar (see figure 15). The GPSR includes the capability of Wide Area Augmentation System (WAAS) differential GPS. Manufacturers' literature indicates the accuracy of the GPSR under standard positioning service to be within 15 m and with WAAS correction to be within 3 m. The earth datum in the GPSR is programmable and has been set to WGS 84. The output from the GPSR is fed into to the DAU located in the sensor bar. Signals are then transmitted from the DAU to the router located in the equipment rack and then to the laptop computer for storage. The GPSR is rated at 5 Hz, which means five readings are obtained every second. All of this data are stored in same data file where the profile and macrotexture data are stored.



Figure 15. Location of the GPS receiver.

### 2.2.8 Ambient Temperature Sensor

An ambient temperature sensor manufactured by Sensirion (model number SHT 15) is located within a protective shield that is mounted on the rear driver's side of the vehicle (see figure 16). This sensor has two ambient temperature probes that independently obtain the ambient temperature. Three wires from the sensor are connected to an interface board that is located inside the rear left tail light. The rear left tail light must be removed to access this sensor's interface board. The output from the sensor interface board is fed by a cable into the Profile Sensor Monitor (PSM) that is located within the equipment rack inside the vehicle. An Ethernet cable carries the data from the PSM to the router, and the data are then transferred from the router to the laptop computer through an Ethernet cable for storage. The ambient temperature sensor is rated at 1 Hz, which means ambient temperature data are obtained at one second intervals. All of the obtained data are stored in the same data file where the profile and the macrotexture data are stored.





Figure 16. Protective shield housing the ambient temperature sensor.

### 2.2.9 Pavement Surface Temperature Sensor

A non-contact Raytek infrared temperature sensor (model Number MID10LT-CB8) to measure the pavement surface temperature is mounted to the bottom of the vehicle on the driver's side at the rear of the vehicle. The temperature sensor is mounted within a PVC structure for protection from road debris and other contaminants. A protection window has been installed below the lens of the sensor to protect the lens from damage. There is a possibility for this protection window to crack if it has been installed too tightly. The protection window should be inspected at regular intervals to check for cracks. A sensor to measure a reference ambient temperature is also located in the pavement surface temperature sensor module. This reference temperature is needed to output the pavement surface temperature. A spring loaded protective cover is provided to protect the sensor when it is not being used. The protective cover is rotated by 90° when temperature measurements are needed. Figure 17 and 18 respectively show the protective cover in place and the protective cover rotated by 90° to obtain pavement surface temperature measurements.

A cable carries the outputs from the pavement surface temperature sensor to the Raytek controller that is located on the equipment rack inside the vehicle. The output from the Raytek controller is fed into the PSM, which is also located inside the equipment rack. An Ethernet cable carries the data from the PSM to the router, and the data are then transferred from the router through an Ethernet cable to the laptop computer for storage. The pavement surface temperature sensor obtains data at a frequency of 40 Hz, which means 40 samples are obtained every second. All of these data are stored in the same data file where the profile and the macrotexture data are stored.





Figure 17. Protective cover covering the pavement surface temperature sensor.



Figure 18. Protective cover open to permit pavement surface temperature measurements.

#### **2.2.10 Light Bar, Directional Warning Light, and Strobe Lights**

The vehicle is equipped with a Light Emitting Diode (LED) light bar mounted on the front of the vehicle (see figure 19), a directional warning light bar mounted on the rear of the vehicle (see figure 20), and LED strobe lights mounted inside the headlights and the taillights of the vehicle.



Figure 19. Light bar on front of the vehicle.



Figure 20. Directional warning light on the rear of the vehicle.

The front light bar is 1.6 m in length and is manufactured by Whelen. The rear directional warning light is 1.15 m long, has eight lamps, and is manufactured by Whelen. The strobe lights mounted inside the headlights and the taillights are also manufactured by Whelen.

The standard Ford uplifter switches mounted on the dashboard labeled AUX 1 through AUX 4 are used to control the lighting system (see figure 21).

The safety lighting controlled by each switch are:

- AUX 1: Provides power to the light bar.
- AUX 2: Provides power to the directional warning light.
- AUX 3: Controls the front strobe lights.
- AUX 4: Controls the rear strobe lights.



Figure 21. Uplifter switches used to control the safety lighting.

The end of the switch shows an amber color when turned on. These switches have a green backlight when the vehicle lights are turned on.

The controller for the directional warning light is mounted on the right side of the driver's seat at the base of the seat. The controller has a Low/Off/High position switch and a rotary switch to control the flash pattern (see figure 22). The "Low" position should be used for night time operations while the "High" position should be used for daytime operations.



Figure 22. Control switch for directional warning light.

The rotary switch has four positions, which are:

- Left: The lights flash from right to left.
- Right: The lights flash from left to right.
- Split: The lights starts from center and go towards both left and right side.
- Flash: The lights flash on continuously.

The flash patterns of the strobe lights can be changed by pressing the red button that is inside the engine compartment (see figure 23) while the strobe lights are turned on. Two persons are needed to set a flash pattern. One person must turn on the strobe lights while the other presses and holds the red button for two seconds.

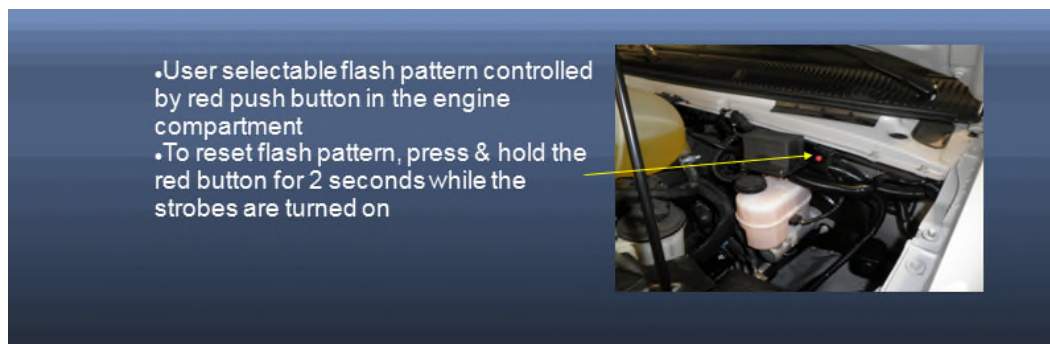


Figure 23. Control button to change strobe pattern.

The strobe lighting system contains a turn signal interrupt module. This module disables the strobe lights when a turn signal is activated, and enables the strobe lights five seconds after the turn signal is disabled.

Figure 24 shows the top view of the fuse and relay junction box that is associated with the safety lighting systems on the vehicle.



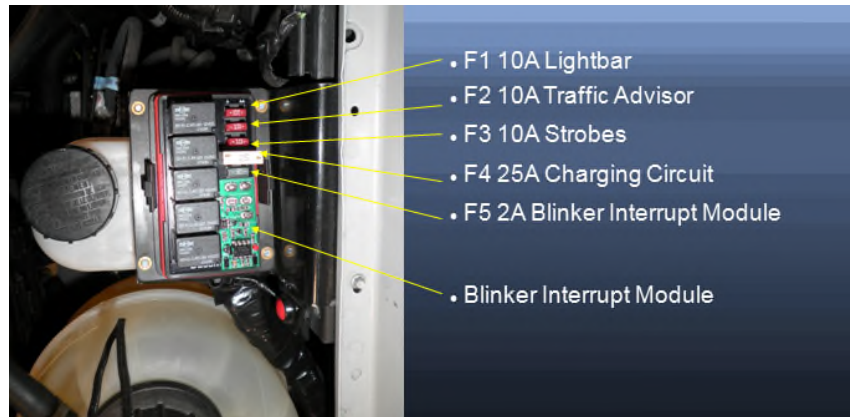


Figure 24. Fuse and relay junction box of the safety lighting system.

### 2.2.11 Equipment Rack

An equipment rack is located behind the driver's seat in the van. The following components/equipment are housed on or inside the equipment rack:

- Shore power port.
- Auxiliary battery.
- Auxiliary battery charger.
- Auxiliary battery status monitor.
- Inverter.
- Laser printer.
- Buzzer.
- PSM module.
- Network Router.
- Circuit breakers.

Figure 25 shows a front view of the equipment rack, while figure 26 shows a view of the bottom of the equipment rack with the front cover off.

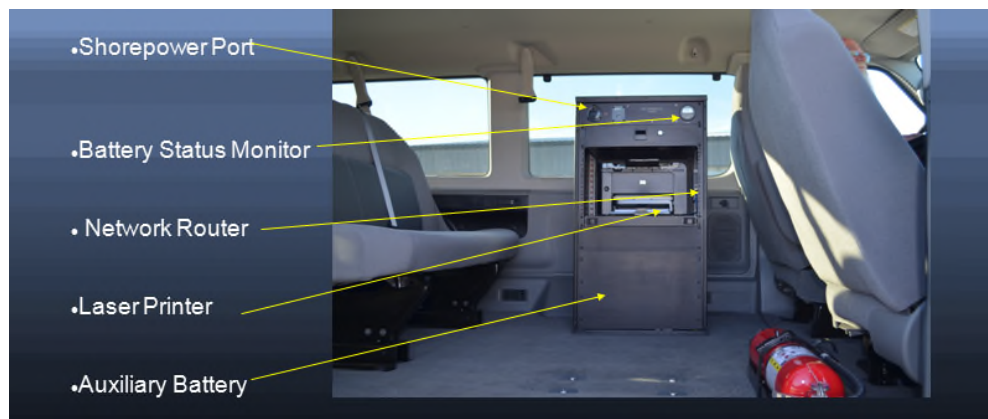


Figure 25. Front view of the equipment rack.

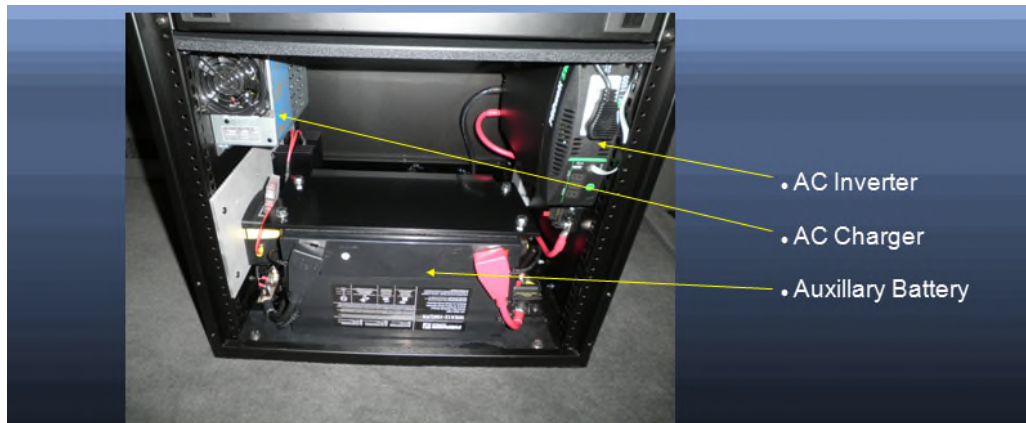


Figure 26. View of the bottom of the equipment rack with the front cover off.

**Shore power Port:** The top of the rack has a port for plugging in power from an outside source.

**Auxiliary Battery:** A 100 ampere, 12 V battery is located at the bottom of the rack. This battery is manufactured by Werker, and is located within a battery guard, and is sealed, and does not require maintenance. The battery supplies power to the DAU, all sensors mounted in the sensor bar, the ambient and surface temperature sensors, the GPSR, the display box mounted on the dashboard, the laptop computer, and the laser printer. When the vehicle is running, the alternator in the vehicle is used to charge and maintain the voltage of this battery; a maximum of 30 amperes will be drawn from the alternator to charge the battery. The battery has a low voltage disconnect at 11.8 V, and will shut off power when this voltage is reached.

**Auxiliary Battery Charger:** The battery charger charges the auxiliary battery when connected to shore power. The charger supplies 15 amperes of current for charging the auxiliary battery. The charger will first charge the auxiliary battery, and when the auxiliary battery voltage rises above 13.6 V, the automatic relay will combine the two batteries, which will allow the vehicle battery to be charged as well. The relay disconnects the auxiliary battery from the vehicle battery when the voltage falls below 12.75 V.

**Auxiliary Battery Status Monitor:** The auxiliary battery status monitor on the equipment rack shows the voltage of the auxiliary battery.

**Inverter:** A PROWatt sine wave inverter manufactured by Xantrex is located in the equipment rack and provides power to the laser printer and a power strip. The power strip can be used for charging any equipment. This inverter is rated at 1000 W. The inverter is turned on by a push button at the top of the rack.

**Laser Printer:** A Hewlett Packard Model P 1606 laserjet printer is located inside the equipment rack.

**Buzzer:** A buzzer is located inside the equipment rack. The buzzer goes off when the system is turned on. The buzzer will emit five rapid beeps when the photocell detects the reflective mark at the start of the section. When profiling SPS sections, the buzzer will emit a single short chirp when reflective marks located at the start of the subsequent sections are encountered. The buzzer

will emit five rapid beeps at the end of the section when the “Distance” option is used to terminate data collection, and thereafter will emit a long beep after 152.4 m of profile data has been collected after the end of the section.

**PSM Module:** A single cable that contains an Ethernet cable and a RS485 cable connected to one port in the DAU transmits the data collected by all sensors located in the sensor bar, the GPSR, and the DMI to the PSM. The Ethernet cable is then carried through and connected to an input port in the router that is located on the equipment rack. The output from the ambient temperature sensor and the Raytek controller that provides the output from the surface temperature sensor is fed into the PSM module. An Ethernet cable connects the PSM module to an input port in the router and transmits the ambient temperature and pavement surface temperature data from the PSM module to the router.

**Network Router:** One input port in the router receives the ambient and pavement surface temperature data from the PSM module through an Ethernet cable. Another input port in the router receives an Ethernet cable from PSM (which is connected to the DAU) that transmits the profile height sensor data, accelerometer data, profile computed from data collected by each profile height sensor, the macrotexture data, DMI data, GPSR data, and photocell signals. A single Ethernet cable connects the output port of the router to the laptop computer dock, and carries all of the data collected by various sensors in the device from the router to the laptop computer dock, and thereafter to the laptop computer for storage.

**Circuit Breakers:** There are two circuit breakers located at the bottom of the rack (see figure 27). The 100 ampere breaker mounted on the side of the rack disconnects power to the inverter. The 150 ampere breaker located next to the battery disconnects the battery from everything.

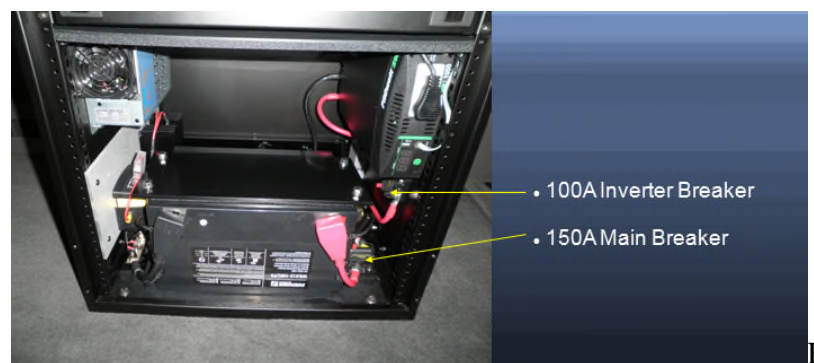


Figure 27. Circuit breakers on the equipment rack.

### 2.2.12 Display Unit on Dashboard

A display unit mounted on the top of the dashboard on the left side shows distance, speed, pavement surface temperature, reference temperature from the pavement surface temperature probe, ambient temperature, voltage, and current draw (see figure 28).

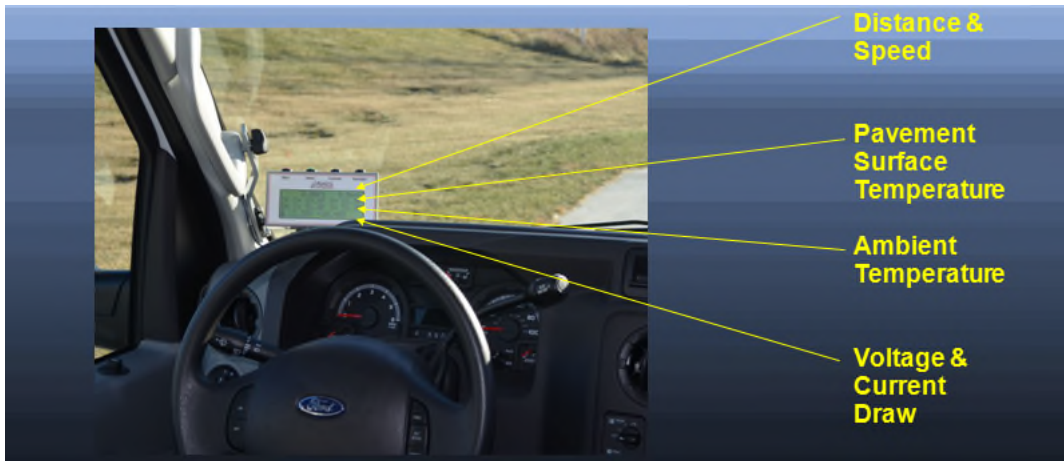


Figure 28. Display unit mounted on the dashboard.

The display unit is connected to the PSM, and obtains the displayed items through the PSM. There are four buttons on top of the display unit that are labeled as Mark, Select, Contrast, and Backlight (see figure 29).

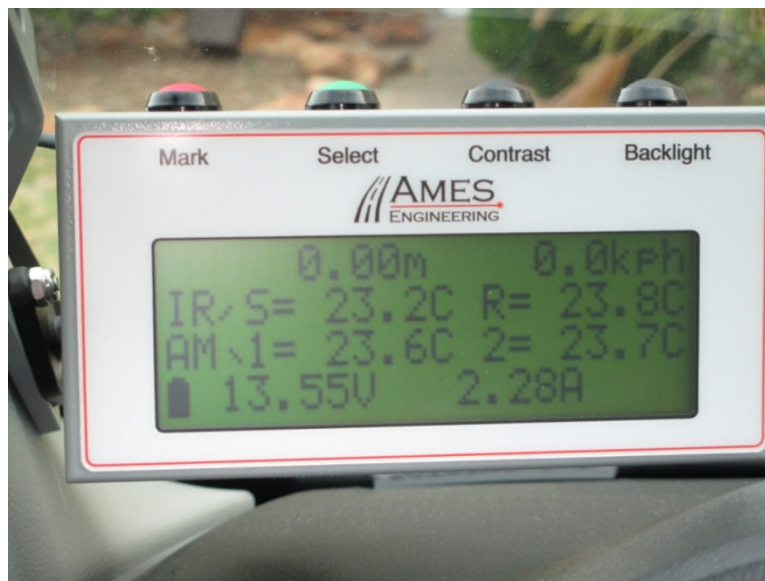


Figure 29. Display unit showing four data items.

**Mark:** When the Ames Engineering software is in the Horizontal Test mode, pressing this button will show the distance travelled. The vehicle can be stopped at any point and this button can be pressed again to re-zero the distance.

**Contrast:** This button controls the contrast of the display.

**Backlight:** This button controls the background light of the display.



Select: Pressing this button cycles through the amount of data that is shown on the display. The display can show a maximum of four data lines (see figure 29). The first row shows the travelled distance and the speed, the second row shows the temperatures measured by the pavement surface temperature sensor with S being the pavement surface temperature and R being the reference temperature. The third row shows the ambient temperature measured by the two probes in the ambient temperature sensor. The fourth row shows the voltage and current draw of the auxiliary battery.

Pressing the select button again will show only the first and the fourth rows (see figure 30).

Pressing the button again will display all rows except for the third row (see figure 31).

Continually pressing the Select button will cycle through the three display modes described above except that the display units will change from SI units to US Customary units (see figure 32).

### 2.2.13 Computer and Docking Station

A Ram Tough-Dock laptop computer docking station has been installed between the driver and passenger seats (see figure 33). The laptop computer provided in the device to record the collected data is a Panasonic Toughbook CF-52.



Figure 30. Display unit showing first and fourth rows.



Figure 31. Display unit showing all rows except for third row.

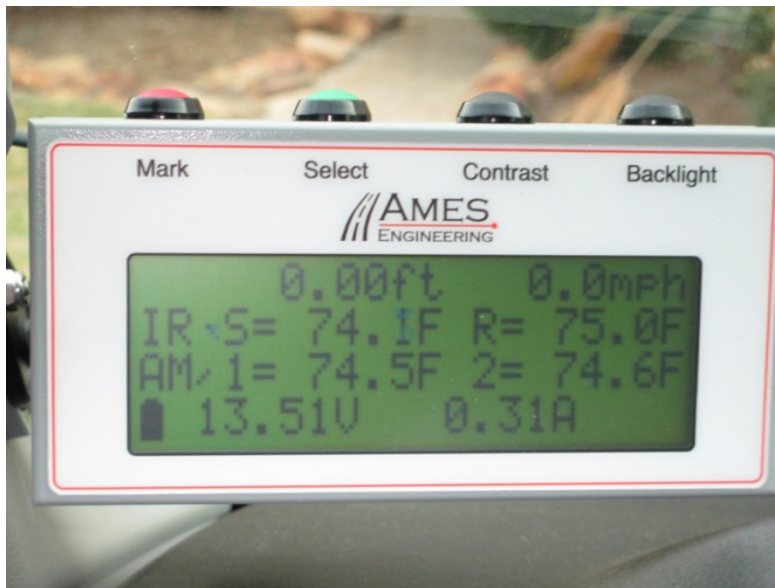


Figure 32. Display unit showing four rows (US customary units).



Figure 33. Laptop computer docking station with laptop computer.

The laptop computer has a Microsoft Windows 64 bit operating system, 16 GB of random access memory, a 500 Gb solid state hard drive, and 390 mm anti-glare display. A handle under the dock must be used to fully engage the laptop computer. The laptop computer can be locked onto the dock using the rotary key switch located on the front. The laptop computer dock has a secondary power switch located on the side.

#### **2.2.14 Vehicle Security System**

The van is equipped with a Clifford security system. The control box for the security system is mounted to the firewall near the brake pedal. A Liquid Crystal Display (LCD) remote with a pager is provided. The pager can be set to tone and a vibration mode or a vibration only mode. The security system includes a tilt sensor located on the sensor bar that will set off the alarm if the sensor bar cover is opened when the alarm is on.

#### **2.2.15 Master Power Switch**

The master power switch that provides power to all sensors in the device is located on the dashboard (see figure 34). Turning this switch on provides power from the auxiliary battery to the DAU, all sensors mounted in the sensor bar, the ambient and surface temperature sensors, the GPSR, the display unit mounted on the dashboard, the PSM, laptop computer, laser printer, and the power strip. However, the inverter must be “On” in order to provide power to the laser printer and the power strip.



Figure 34. Master power switch.

### 2.2.16 Fire Extinguishers

There are two 4.5 kg ABC rated fire extinguishers inside the vehicle. One fire extinguisher is mounted behind the passenger seat, while the other is at the rear of the vehicle (see figure 35).



Figure 35. Fire extinguishers in the vehicle.

### 2.2.17 Calibration Block Kit

Ames Engineering provided a calibration block kit with each profiler. The following items are included in the calibration block kit

- Three 25 mm blocks.
- Three 50 mm blocks.
- Three 75 mm blocks.



- Three 100 mm blocks.
- Three base plates.
- Three targets.
- A digital level.

The blocks and targets are in one case, while the base plates and the digital level are in a separate case (see figure 36).



Figure 36. Calibration block kit.

The calibration blocks are steel blocks with a rustproof black oxide coating. The target is a tungsten carbide plate that has been sand blasted. The target plate has a shiny side and dull (matte) side and measurements should always be obtained on the dull side. The base plate is made out of aluminum. The calibration blocks have a block label engraved on the side. Table 2 shows the exact dimensions of the blocks. One set of blocks is included in each device. The blocks assigned to each device are shown in table 2.

### 2.2.18 Texture Reference Test Device

Ames Engineering provided a texture reference test device to verify the accuracy of the texture height sensors. Figure 37 shows a photograph of this device. It consists of a hard disk that has been machined accurately to provide four steps alternating between 0.5 and 1 mm in height. This device is connected to the DMI port in the DAU by first disconnecting the DMI connection from the encoder to simulate travel distance and is powered from a photocell outlet in the laser box. The device is placed below a texture height sensor with the laser dot centered on the target indicated on this device. This disk is rotated at 7,200 rpm, which produces 120 rotations per second. This simulates data collection at 86.4 km/h. One rotation of the disk covers 200 mm of distance. The mean profile depth (MPD) value is computed from the collected data and displayed on the screen of the laptop computer. Ames Engineering has indicated the theoretical MPD computed from the step heights on the disk is 0.75 mm.

Table 2. Dimensions of calibration blocks.

| Ames<br>Serial<br>No, | Block<br>Label | Block<br>Height<br>(mm) | Block<br>Label | Block<br>Height<br>(mm) | Block<br>Label | Block<br>Height<br>(mm) | Block<br>Label | Block<br>Height<br>(mm) |
|-----------------------|----------------|-------------------------|----------------|-------------------------|----------------|-------------------------|----------------|-------------------------|
| 830112                | A-1            | 25.00422                | A-13           | 50.00445                | A-25           | 75.00381                | A-37           | 100.00356               |
|                       | A-2            | 25.00432                | A-14           | 50.00406                | A-26           | 75.00343                | A-38           | 100.00279               |
|                       | A-3            | 25.00381                | A-15           | 50.00419                | A-27           | 75.00381                | A-39           | 100.00305               |
| 830212                | A-4            | 25.00366                | A-16           | 50.00381                | A-28           | 75.00381                | A-40           | 100.00381               |
|                       | A-5            | 25.00427                | A-17           | 50.00432                | A-29           | 75.00406                | A-41           | 100.00381               |
|                       | A-6            | 25.00469                | A-18           | 50.00445                | A-30           | 75.00406                | A-42           | 100.00076               |
| 830312                | A-7            | 25.00396                | A-19           | 50.00394                | A-31           | 75.00356                | A-43           | 100.00254               |
|                       | A-8            | 25.00305                | A-20           | 50.00279                | A-32           | 75.00457                | A-44           | 100.00432               |
|                       | A-9            | 25.00348                | A-21           | 50.00432                | A-33           | 75.00356                | A-45           | 100.00406               |
| 830412                | A-10           | 25.00445                | A-22           | 50.00457                | A-34           | 75.0033                 | A-46           | 100.00152               |
|                       | A-11           | 25.00394                | A-23           | 50.00457                | A-35           | 75.00305                | A-47           | 100.00432               |
|                       | A-12           | 25.00457                | A-24           | 50.00356                | A-36           | 75.00406                | A-48           | 100.00406               |

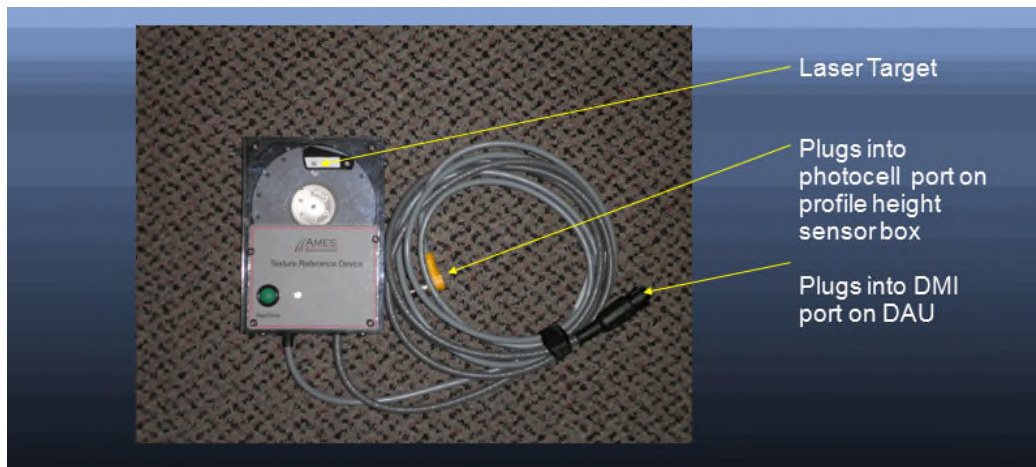


Figure 37. Texture reference test device.

## 2.2.19 Toolbox

Ames Engineering provided a toolbox with each profiler (see figure 38). Figure 39 shows the contents of the toolbox.



Figure 38. Toolbox provided with each device.

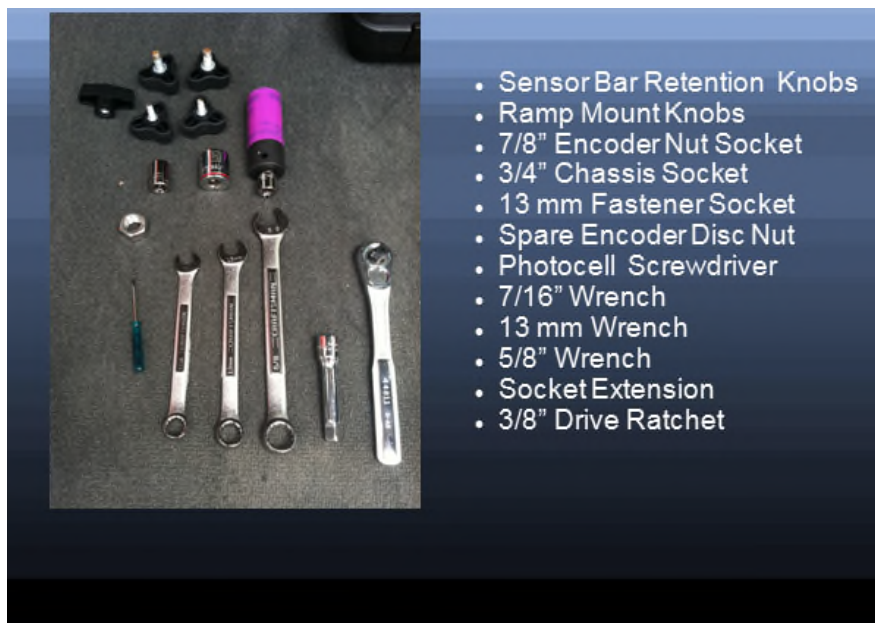


Figure 39. Contents of the toolbox.

## 2.2.20 Calibration Ramps

Four ramps that are used to elevate the vehicle when conducting the full calibration check of the profile and texture height sensors is provided with each device. Figure 40 shows a photograph of a ramp. There are two steps in the ramp, with each step being 38 mm in height. The ramps must

be secured after completing the full calibration check using the securing mechanism provided at the back of the bench seat in the vehicle (see figure 41). The securing mechanism consists of two vertical rods, and the ramps are inserted into these rods through the two holes in each ramp, and then tightened with a nut. A felt cloth is placed between the ramps to prevent them from sticking together.



Figure 40. Ramp used to elevate vehicle.

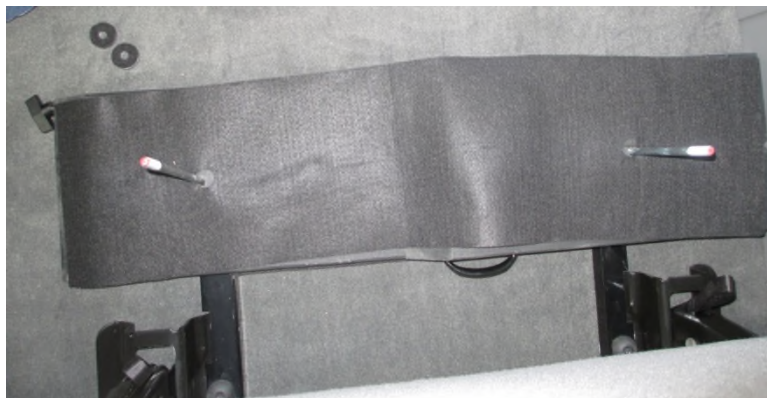


Figure 41. Mechanism for securing the ramps.

### 2.2.21 Camera

The device is equipped with an Ames right-of-way camera system that contains a Sony Charge Coupled Device (CCD) camera. This camera is mounted inside the vehicle on the metal mount that is attached to the windshield that supports the rear view mirror (see figures 42 and 43). The camera takes images of the roadway as viewed from inside of the vehicle. A cable from the camera is connected to a Universal Serial Bus (USB) port on the laptop computer. Figure 44 shows an example of an image obtained by this camera. The date, time, GPS information, and distance from start of the section are embedded onto the bottom of the image as shown in figure 44. The location of the data file in the computer is embedded on the top of the image. The camera will take the first image when the photocell is armed. The images taken are stored in the Joint Photographic Expert Group (JPEG) format.





Figure 42. Side view of the right-of-way camera.



Figure 43. View from inside the vehicle of the right-of-way camera.



Figure 44. Example of an image obtained by the camera.

The camera has an auto exposure mode that is always active. The lens aperture in the camera can be adjusted if needed to let in more light when taking images on a cloudy day (see figure 45).

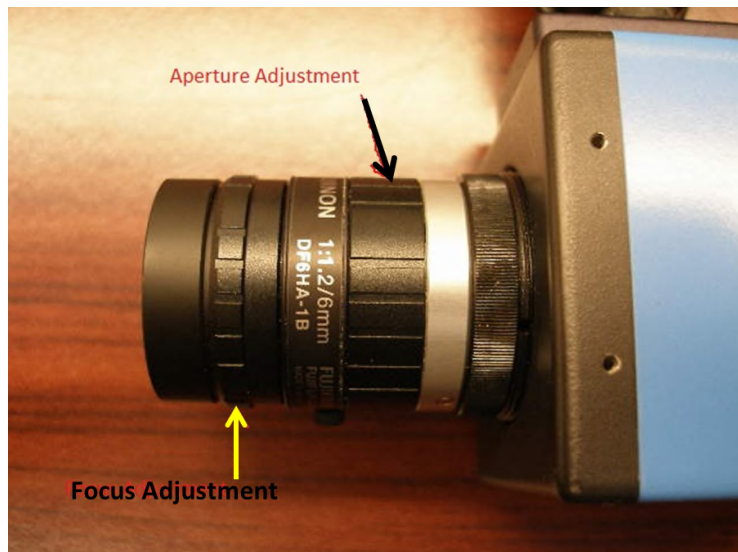


Figure 45. Focus and aperture adjustment of the camera.

The operator can elect to collect images or video using the camera in the setup menu (see step 5 in section 2.4.2). A camera preview window will appear as shown in figure 46 when the “Start” (F1 key) has been selected from the main menu (see step 1, section 2.9.3.3). The operator can toggle between “Photo” and “Video” modes between runs using this window instead of going to the setup menu to make this change.



Figure 46. Camera preview window that appears during data collection.

## 2.3 FEATURES OF THE DEVICE

### 2.3.1 Data Saved by the Device

All data collected by the device in a single run are saved in one file which is referred to as an Ames Raw Data (ARD) file that has a file extension of ARD. These files are hereafter referred to as ARD files. The following data items are contained in an ARD file: profile data, profile height sensor data, texture height sensor data, accelerometer data, DMI data, ambient temperature sensor data, pavement surface temperature data, GPSR data, event data from photocells, event keys entered by the user, and diagnostic information. The profile data saved in the ARD file has an upper wavelength filter applied on the data. However, the applied upper wavelength cut-off filter is greater than 100 m. A 100 m upper wavelength filter is applied when the collected profile data is viewed in the Ames Engineering Viewer software or when the data is exported to ProQual.

### 2.3.2 Exporting Data to ProQual

In the LTPP program, the ProQual software, is used to process the profile and macrotexture data collected by the Ames device. The data saved in ARD files are transferred into ProQual through a Dynamic Link Library (DLL). In the field, the ProQual software is used to perform quality

control checks on the data collected by the Ames device such as the profile data, texture data, ambient temperature data, pavement surface temperature data, and the data collected by the GPSR. In the office, the ProQual software is used to perform quality assurance checks on the data and to create data files that are uploaded to the LTPP Pavement Performance Database (PPDB), and also to create files that are stored in the Ancillary Information Management System (AIMS).

### **2.3.3 First Data Point in a Section**

Historically, in the LTPP program, the first profile data point assigned to a section has been at a distance of 114 mm from the leave edge of the start stripe located at the beginning of the section (i.e., Distance = 0 for profile data is located 114 mm from the leave edge of the start stripe at a section). Data collected by Ames Engineering devices also conform to this criterion.

The vertical photocell in the device triggers when the photocell detects the approach end of a reflective tape placed on the pavement. The horizontal photocell in the device triggers when the photocell detects the approach end of the reflective tape that is mounted on the cone that is placed on the shoulder. The width of the reflective tape that is used to trigger data collection is an input parameter in the header screen that must be filled before starting data collection. The distance of 114 mm that was mentioned previously is a parameter that is assigned in a setup screen in the Ames Engineering software. The Ames Engineering software uses this value and the width of the tape input in the header screen in order to assign the first profile and macrotexture data point at a section to be at a distance of 114 mm from the leave edge of the reflective tape at the beginning of the section.

### **2.3.4 Pre- and Post-Run Data**

Height sensor, accelerometer, DMI, and profile data for a distance of 152.4 m before the start of the section (pre-run) and after the end of the section (post-run) are stored in the ARD file. This pre- and post-run distance is a value that is specified in a setup screen in the Ames Engineering software. Proper application of the 100 m upper wavelength cut-off filter to the profile data requires 152.4 m of data before the start of the section and 152.4 m of data after the end of the section.

Macrotexture data for a distance of 30 m before start of the section and after end of the section are also stored in the ARD file. The pre- and post-run macrotexture data distance is set in an Ames Engineering software initialization file.

### **2.3.5 Event Keys**

The operator can press any letter key in the bottom row of the keyboard (i.e., keys Z through M) during data collection to include an event mark in the data file. Event keys are not used for normal LTPP data collection. However, these keys could be useful if these devices are used for non-LTPP data collection. For example, the following are some examples when event keys can be used:



- Mark start and end of a bridge.
- Mark start and end of a Weigh-in-Motion (WIM) scale located on the pavement.
- Mark location where the surface type of the pavement changes.

## 2.4 COMPUTER AND SOFTWARE SETTINGS

### 2.4.1 Computer Settings

1. The laptop computer contains a wireless adapter. The wireless adapter can interfere with data collection as the adapter is always looking for wireless connections. Therefore, the wireless adapter must be disabled. Figure 47 shows the Microsoft Windows menu where the status of the wireless adapter can be checked to ensure it is disabled.



Figure 47. Wireless adapter setting in the computer.

2. The power management in the laptop computer should be set to the settings shown in figure 48 to avoid the display from dimming, turning off, or putting the laptop computer to sleep, which all can affect data collection.



Figure 48. Power management settings in the laptop computer.

## 2.4.2 Ames Engineering Software Settings

The Ames Engineering software is used to collect, process, and save profile and macrotexture data. The settings in the Ames Engineering software were set at appropriate values when the FHWA took delivery of the devices. However, the software has been upgraded since FHWA took delivery of the vehicles. Therefore, these settings need to be checked to make sure they are correct, and if incorrect, necessary corrections must be made. These settings should be checked if the software is re-installed, if a newer version of the software is installed, or if problems are encountered with the software.

The setup menu in the software has the following four tabs to enter or select setup parameters:

- Profiler.
- Sensors.
- Camera.
- Raytek.

The Profiler tab has the following four menus: Report Options, Analysis Options, Profile Analysis, and Texture Analysis. The settings in the Report Options, Analysis Options and Profile Analysis have no impact on the data collected for the LTP Program. There is one setting in the Texture Analysis menu that has an impact on the MPD values computed by the Ames Engineering software as well as the MPD that is computed during the texture reference device test. The following steps take the operator through the different settings that need to be checked and/or updated.

1. Follow procedures described in section 2.8.1 to boot-up the laptop computer and launch the Ames Engineering software. The Ames Engineering start-up screen (see figure 49) should now be displayed on the laptop computer screen.
2. Press F1 key or select “Setup”. The Report Options screen will be displayed. Select the Texture Analysis tab and the screen shown in figure 50 will be displayed. The setting for “Spike Removal” has an impact on MPD values that are computed through the Ames Engineering software as well as the MPD that is computed during the texture reference device test. All other settings in this screen have no impact on data collected or processed for the LTPP program. When the “Spike Removal” field is enabled, spikes in texture data will be removed using an algorithm that was developed by Ames Engineering before computing the MPD value for data collected during the texture reference device test and also when computing MPD values through the Viewer menu in the Ames Engineering software. LTPP has decided not to use the “Spike Removal” option for MPD computations. Therefore, the “Spike Removal Field” should not be checked.

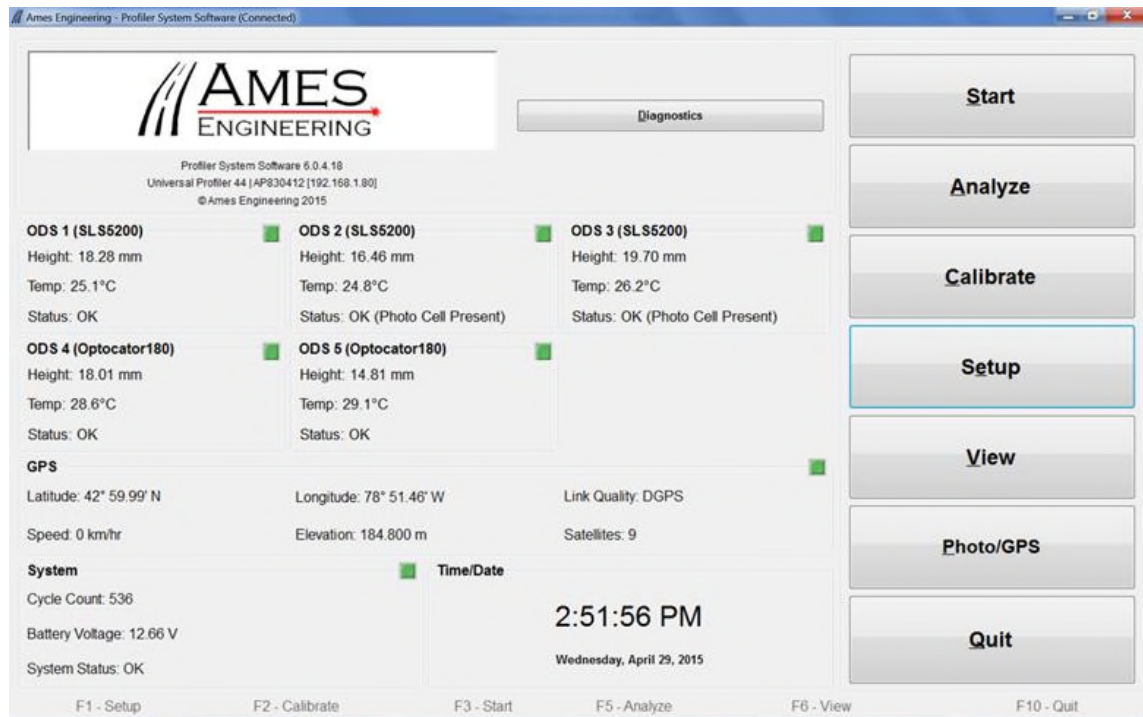


Figure 49. Ames Engineering start-up screen

3. Select “Profiler” tab. The Profiler Setup screen shown in figure 51 will be displayed. This screen should show the following settings:
  - Identification: All fields under “Identification”, which are Operator Name, Company Name, Certification #, and Certification date should be blank.
  - Collections Options: The “Show End of Run Note” should be checked; “Create ADF file” and “Single Block Extensive” should not be checked.
  - Profiler Settings: The entries under “Profiler Settings” are protected by a password. The password is ames60, and any entry under “Profiler Settings” can be changed by the operator after entering the password. The Serial # field should have the serial number assigned to the device. The serial number of the device assigned to each RSC is shown in table 1. All other entries under “Profiler Settings” should exactly match the values shown in figure 51 except for the Product Key. The Product Key will show the unique number that was provided for the camera for each device.

Setup

Profiler Sensors Camera Raytek

Report Options Analysis Options Profile Analysis Texture Analysis

**Texture Pre-Processing Settings**

☒ Fit Texture Spacing to 0.5 mm

☒ Bridge Dropouts Trim Before 1 Trim After 1

High Pass Filter Cutoff 0 mm

Low Pass Filter Cutoff 0 mm

☒ Apply 2.5mm Filter

☐ Spike Removal

**Texture Processing Settings**

☒ ASTM E1845

ETD = 0.20000 + 0.80000 \* MPD mm

<C:\ProgramData\Ames\AmesSetup60.xml>

Save Cancel

Figure 50. Texture analysis screen.



Setup

Report Options Analysis Options Profile Analysis Texture Analysis

Profiler Sensors Camera Raytek

**Identification**

Operator Name

Company Name

Certification #

Certification Date   
(mmddyyyy)

**Collection Options**

☐ Create ADF File

☐ Single-Block Extensive Test

☒ Show End of Run Note

**Profiler Settings**

Password

Serial #  830412

Model #  PSM8300

Product Key  97DF8166C183E076

Sample Rate  12.2 samples/foot

Pre/Post Run Length  500 feet

Analog Filter  0.8 radians

Anti-Aliasing Filter  132 Hz

Horizontal Calibration Divisor  20

RS485 Baud Rate Divisor  1

GPS Baud Rate  38400

DMI Source  Quadrature DMI

Communications Port  Ethernet (Wired/Wireless)

<C:\ProgramData\Ames\AmesSetup60.xml>

**Save** **Cancel**

Figure 51. Profiler setup screen.

4. Select “Sensors” tab. The Sensor Setup screen shown in figure 52 will be displayed. The items that are checked and the values shown on the laptop computer screen should exactly match parameters shown in figure 52. If any differences are noted, change the settings to match what is shown in figure 52 and then select the “Save” button to save the changes.

The following is a brief explanation of the items shown on the screen shown in figure 52:

- The checkmark for “Profile” under ODS1, ODS2, and ODS 3 indicates these sensors are enabled for profile data collection. Note: ODS1 is the left wheel path profile sensor, ODS 2 is the right wheel path profile sensor, and ODS3 is the center profile sensor.
  - The checkmark for “Texture” under ODS4 and ODS5 indicates these sensors are enabled for texture data collection. Note: ODS4 is the left wheel path texture sensor and ODS 5 is the right wheel path texture sensor.
  - The vertical photocell is connected to ODS3. Hence, photocell is checked for ODS3. The vertical photocell is in line with all three profile height sensors (i.e., ODS1, ODS2, and ODS3). Hence, the photocell offset for ODS3 is zero.
  - The horizontal photocell is connected to ODS2. Hence, photocell is checked for ODS2. The horizontal photocell is located 250 mm behind the profile height sensors. The photocell offset value of 250 mm is entered under ODS2 to account for this difference.
  - The texture laser height sensors (ODS4 and ODS5) are located 140 mm behind the profile height sensors. In order to ensure the post-processed texture data for the section starts exactly at the same location where profile data collection started, the Laser Offset value is set to 140 mm.
  - The tape offset is set to 114 mm in order for the first data point that appears in the post-processed data file to be 114 mm from the leave edge of the reflective tape that is either placed on the pavement or located on the cone that is placed on the side of the road.
  - Check marks for Ambient, Surface, and GPS Receiver respectively make the ambient temperature sensor, pavement surface temperature sensor, and GPSR active. The delay time for GPSR is set to 20 ms.
  - The check mark for Re-arm Event/Ignors makes the photocell look for a reflective tape mark after the photocell triggers off the mark at the start of the section. This function is used when SPS section are profiled, where the photocell looks for the reflective tape that is placed at the start of the SPS sections after the photocell is triggered by the reflective tape that is located at the start of the first section.
5. Select “Camera” tab to view the settings that are used for the right-of-way camera. Figure 53 shows an example of the displayed screen. When the camera is first installed, the product key for the camera that is provided by Ames Engineering has to be entered into the Product Key field that is under Profiler Settings in the Profiler Setup screen (see step 3).

Setup

Report Options Analysis Options Profile Analysis Texture Analysis

Profiler Sensors Camera Raytek

**ODS 1**

☒ Profile ☐ Texture

☐ Photocell Left

Laser X Offset -914.40 mm

Laser Y Offset 0.00 mm

Photocell Offset 0.00 mm

**ODS 2**

☒ Profile ☐ Texture

☐ Photocell Right

Laser X Offset 914.40 mm

Laser Y Offset 0.00 mm

Photocell Offset 250.00 mm

**ODS 3**

☒ Profile ☐ Texture

☒ Photocell Center

Laser X Offset 0.00 mm

Laser Y Offset 0.00 mm

Photocell Offset 0.00 mm

**ODS 4**

☐ Profile ☒ Texture

☐ Photocell Left

Laser X Offset -914.40 mm

Laser Y Offset 140.00 mm

Photocell Offset 0.00 mm

**ODS 5**

☐ Profile ☒ Texture

☐ Photocell Right

Laser X Offset 914.40 mm

Laser Y Offset 140.00 mm

Photocell Offset 0.00 mm

☒ GPS Receiver Offset (m) 0.00

Delay (ms) 20.0

☐ Switch Pod

☐ Auxiliary

☒ Re-arm Events/Ignores (32-bit only)

☐ Stand-alone Auto Trigger

Tape Offset (mm) 114.0

**PSM**

☒ Ambient ☒ Surface ☐ Battery

<C:\ProgramData\Ames\AmesSetup60.xml>

Save Cancel

Figure 52. Sensors setup screen.

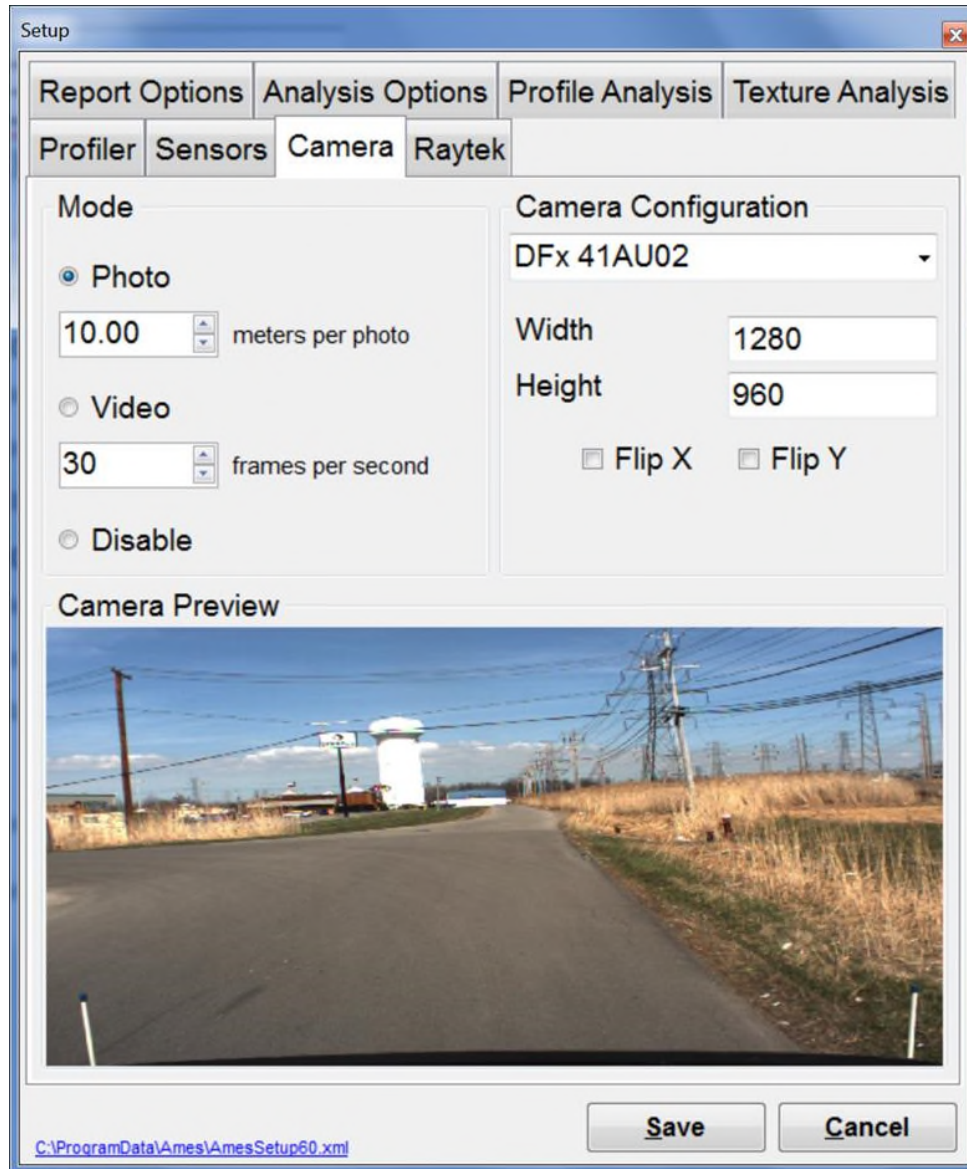


Figure 53. Camera setup screen.

In the Camera Setup screen, the “Photo” mode must be enabled to obtain images. The interval for obtaining images can be adjusted using the input field below “Photo”. Images must be obtained at LTPP sections at a 10 m interval. Therefore, select 10.00 for this field.

The following is a brief explanation of the other items shown on this screen:

- Camera Configuration: This field is automatically filled, and shows DFx 41AU02.
- Width and height: These fields are automatically filled with a width of 1,280 and a height of 960. These are image pixel sizes and indicate the highest resolution that is possible with the camera, which is 1,280 x 960. These values must not be changed.

The Camera Preview window at the bottom of the setup screen shows the view from the camera. The software requires the settings to be saved before exiting the screen.

Collection of video of a test section is not required for LTPP program purposes. However, a RSC can collect video of the test section if desired. The “Video” mode must be enabled to collect video. The user must select the desired frames per second in the field below “Video”. A value between 5 and 30 can be selected for this field, and typically a value of 15 can be used.

6. Select “Raytek” tab to view the settings for the surface temperature sensor that measures the pavement surface temperature. When this tab is selected, the software accesses the Raytek Controller board and displays the current settings that are stored in the controller board. Figure 54 shows an example of the displayed screen.

The following values should be seen in this setup:

- Emissivity: The value should be 0.95.
- Transmission: The value should be 0.75 with the protective window present on the sensor and 1.0 when the sensor does not have the protective window. In the normal operating mode, the protective cover is present in front of the lens. There have been reports that the protective sensor has had cracks. If the protective cover is cracked, the sensor can be used with the protective cover off, with the transmission value set to 1.0.
- Head Calibration: The head calibration value specific to each device was entered into this field by Ames Engineering prior to the delivery of the device. When the sensors are purchased as a complete set (controller and sensor head), they come pre-programmed with the head calibration that matches the head that was shipped with that controller. If the two items are replaced together, the head calibration value should already match. These values must be updated manually if the Raytek temperature sensor is replaced, but not the controller. These values are usually attached to a label on the sensor head cable and must be entered manually. Ames Engineering must be contacted to get their input on how the values for the head calibration should be entered on this screen if the temperature sensor, controller, or both are replaced.
- Gain Adjustment: This value should be set to 1.0. The gain adjustment is used to add a linear gain adjustment to the values that are transmitted by the sensor controller.
- Temperature Offset: The value should be set to 0. This field is used to add or subtract an offset bias in the temperature measurements. The range for the offset is -200 to 200, with a change of 3°C for a 100 change in offset. Hence, the maximum adjustment is  $\pm 6^{\circ}\text{C}$ .

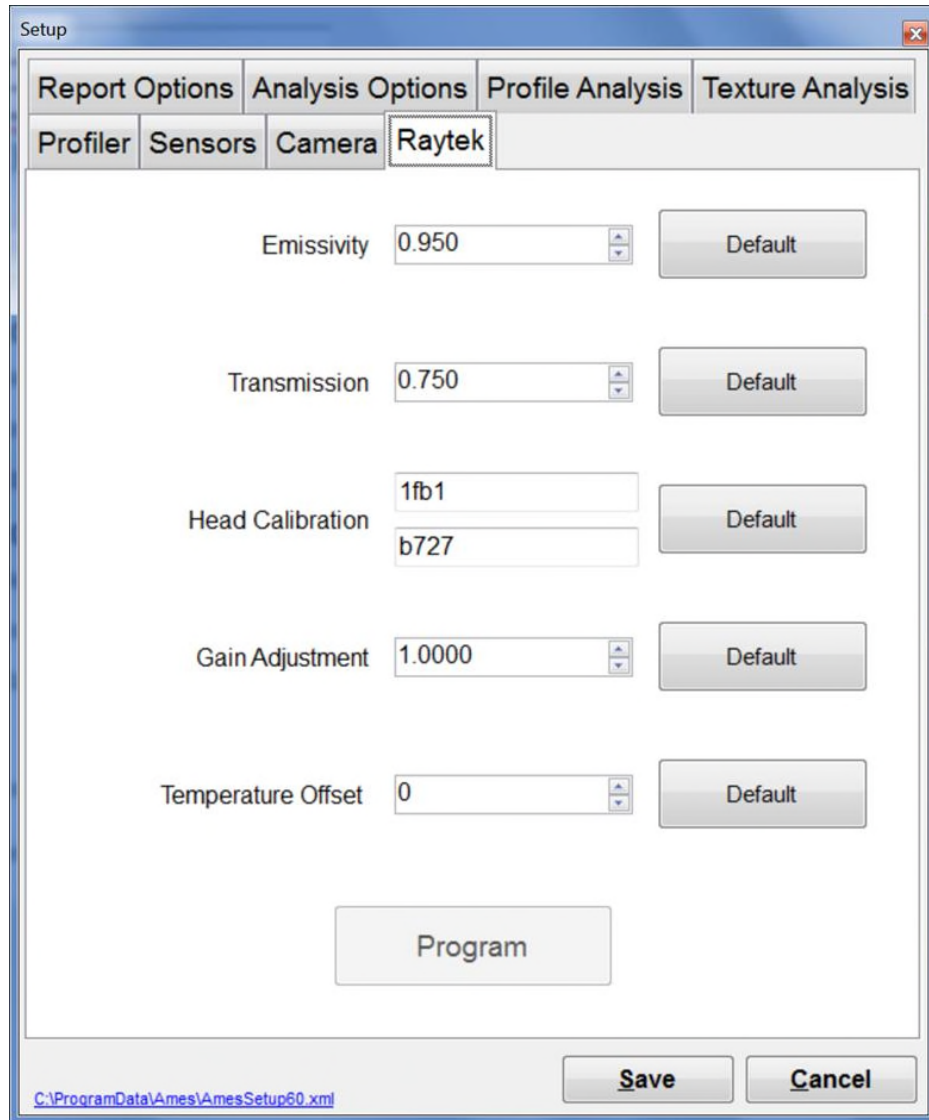


Figure 54. Raytek options screen.

Note: If any value on this set-up screen is changed, such as changing the value for Transmission if collecting data without the protective cover, the “Save” button must be selected to save the entered parameters.

### 2.4.3 Ames Engineering Viewer Settings

The Ames Engineering Data Viewer is accessed by pressing the F6 key or selecting “View” in the start-up screen (see figure 49). Figure 55 shows the main menu of the Data Viewer.



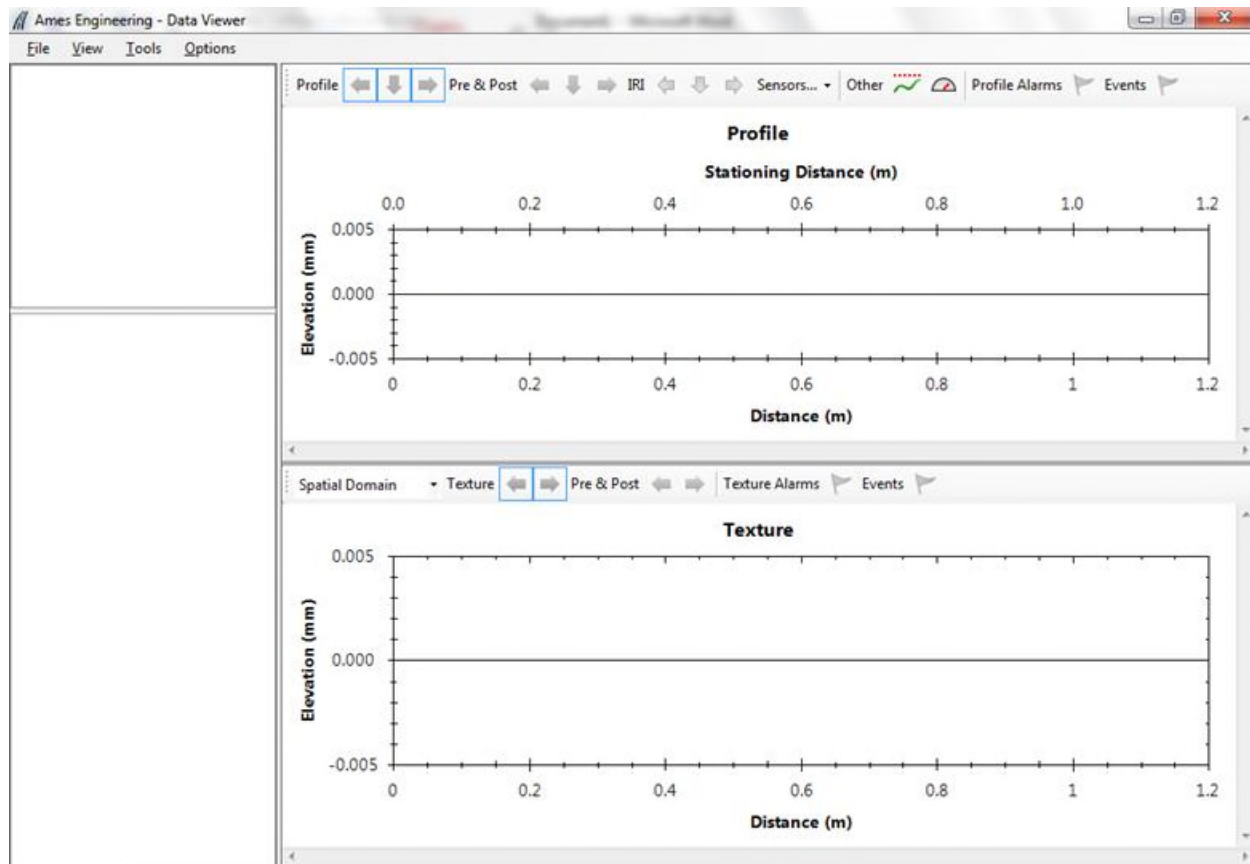


Figure 55. Main menu of data viewer.

The data viewer can be used to perform following functions:

- Plot profile and macrotexture data.
- Calculate IRI values.
- Calculate MPD values.
- Generate data files containing profile or macrotexture data conforming to the University of Michigan Transportation Research Institute (UMTRI) Engineering Research Division (ERD) file format, referred to as ERD format.
- Generate data files containing profile or macrotexture data conforming to the data format for pavement profile specified in ASTM standard E 2560, referred to as ppf files.

For the LTPP program purposes, profile data are generated at 25 mm intervals, while the texture data are generated at 0.5 mm intervals. In order to generate ERD or PPF files having this data recording interval, certain parameters have to be set in the “Preferences Menu” of the Viewer that is located under the “Options” menu. The upper wavelength cut-off filter that is applied to the profile data also has to be specified in the “Preferences” menu.

The following steps describe how to set the parameters referred to above:

1. From the main menu of the data viewer (see figure 55), select Options and then select preferences (see figure 56).

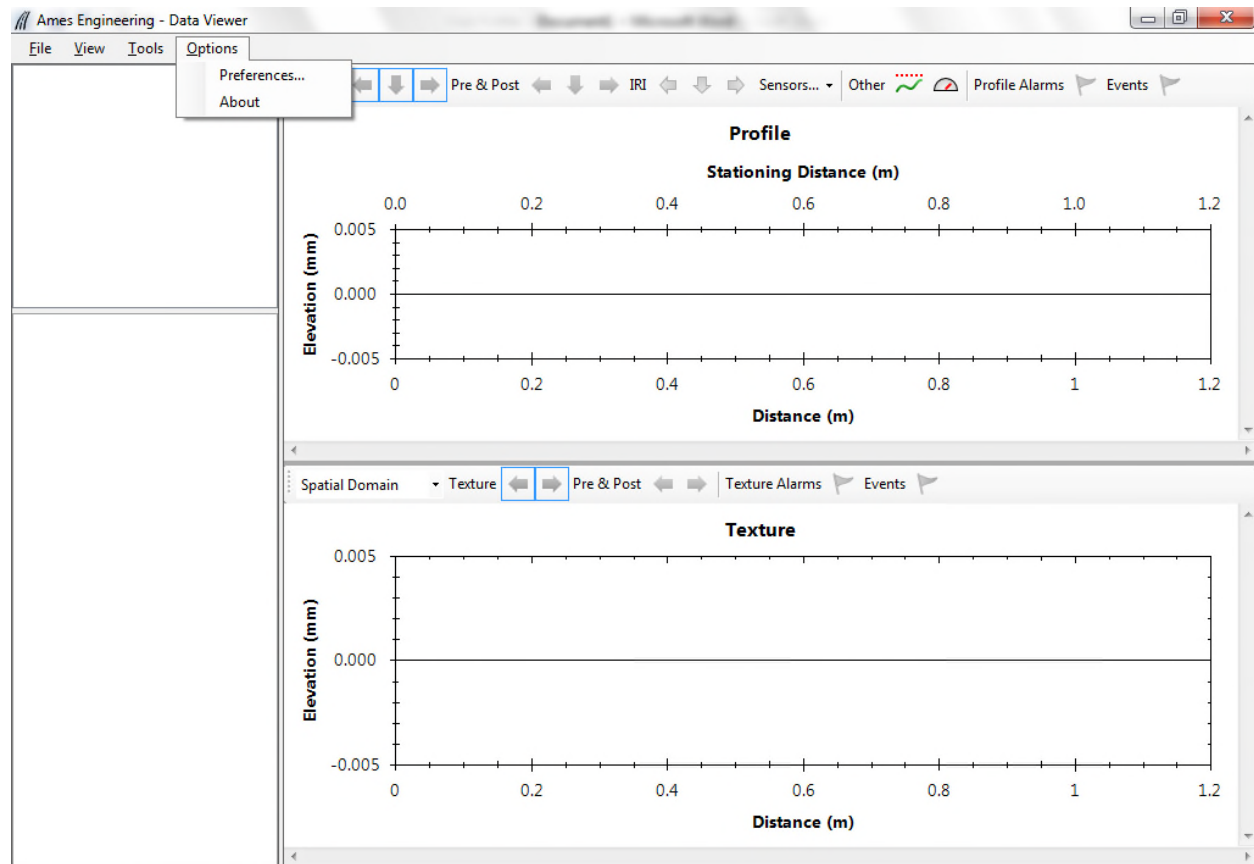


Figure 56. Selecting preferences menus.

2. The General menu shown in figure 57 will be displayed. Check all boxes under the heading General as shown in figure 57. Set Profile Units and Texture Units to meters. Check “Synchronize Profile and Texture Units” and “Synchronize Profile and Texture Reduction Lengths”. The Reduction Settings indicate the interval at which IRI and MPD values will be computed, and can be set to any desired value.
3. Select “Profile Processing” and the Profile Processing menu shown in figure 58 will be displayed. Set the parameters in the Profile Processing menu to match the settings and values shown in figure 58. It is very important to set Pre/Post Distance option to “No Padding” in order for the ERD file to contain only the data collected within the test section. Note: The IRI Baselength and IRI Threshold can be set to any desired value; however, these parameters are not typically used to analyze data in the LTPP program.
4. Select “Texture Processing” and the Texture Processing menu shown in figure 59 will be displayed. Set the parameters in the Texture Processing menu to match the settings and values shown in figure 59.



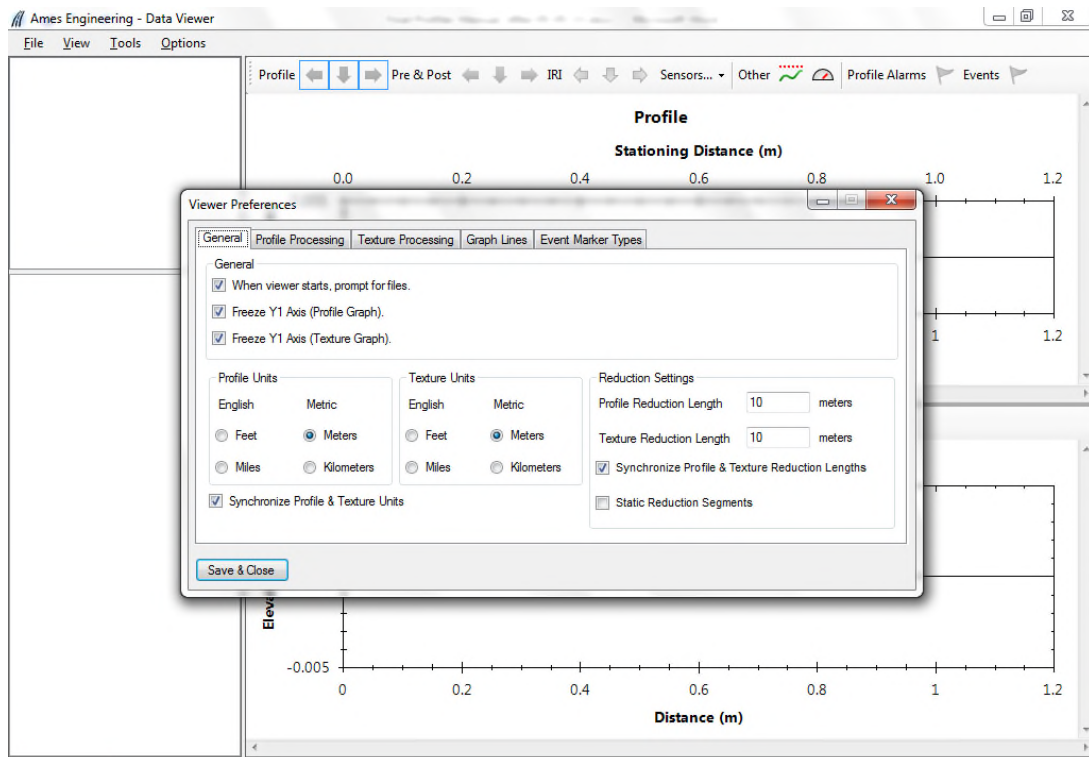


Figure 57. General menu.

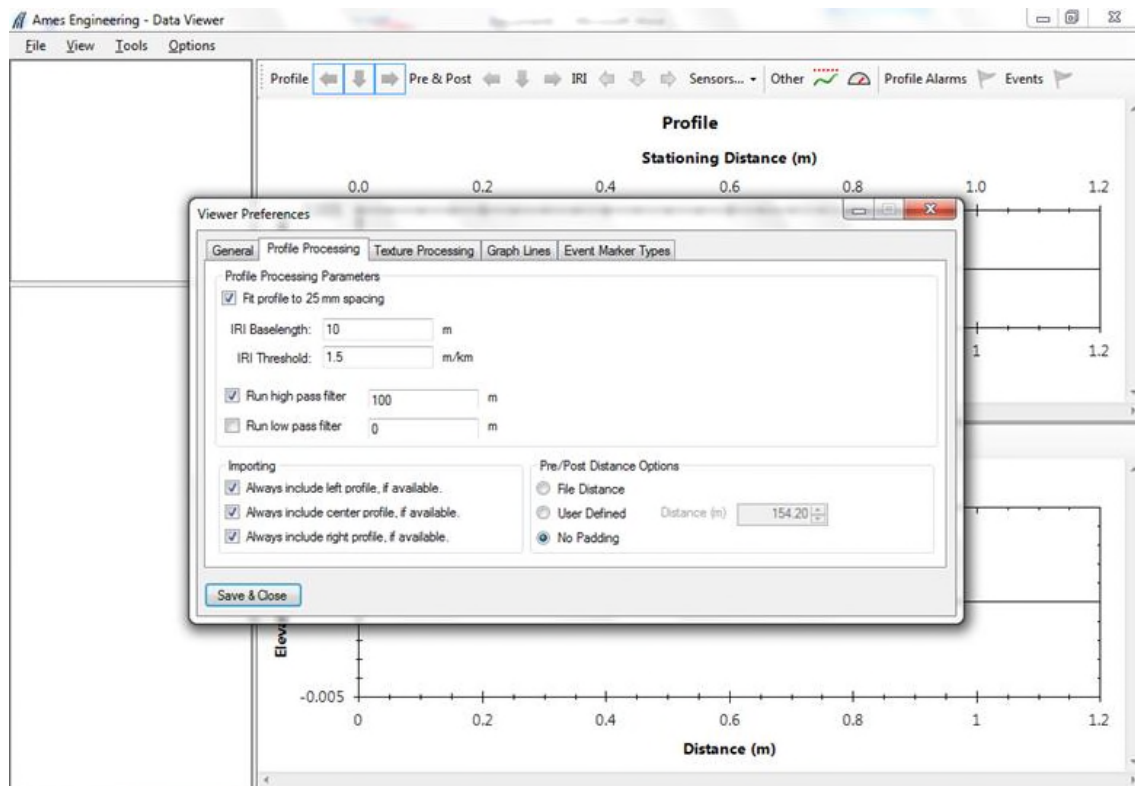


Figure 58. Profile processing menu.

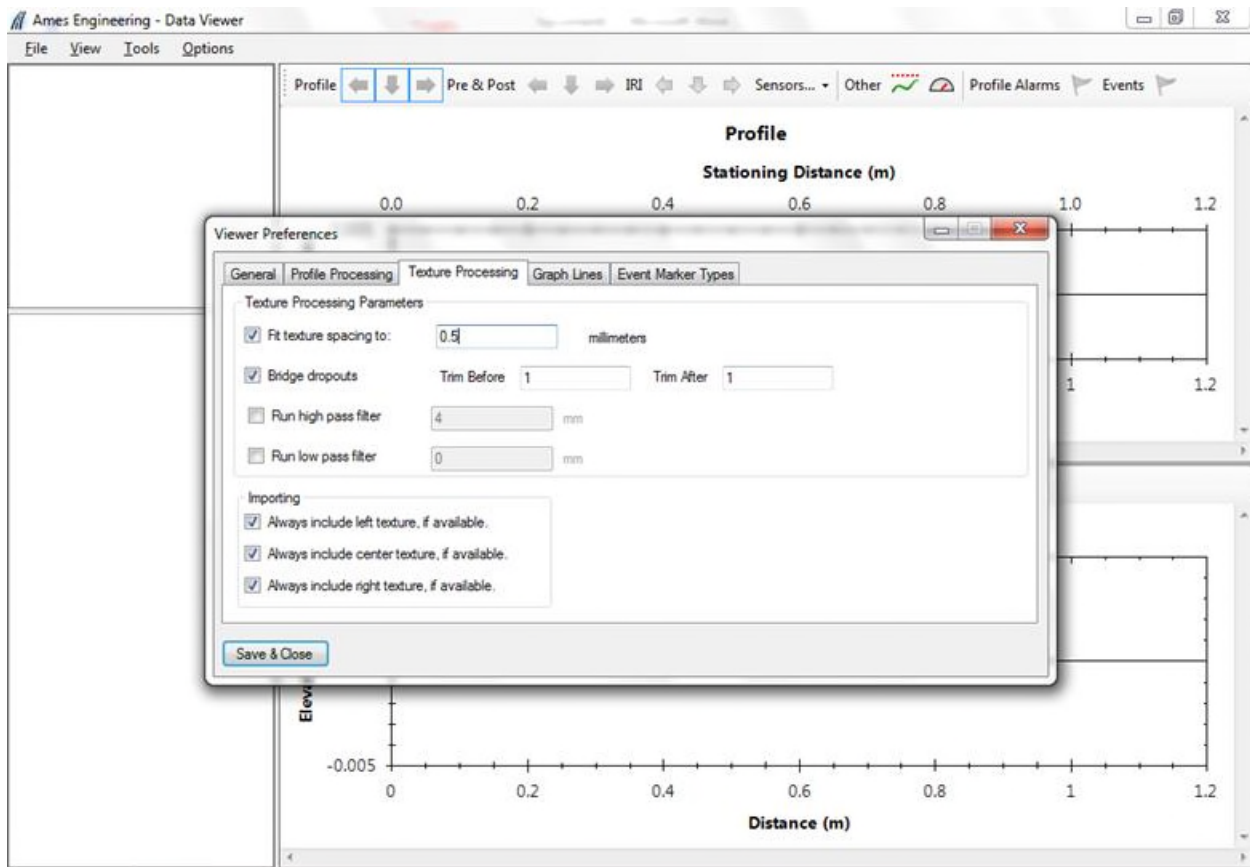


Figure 59. Texture processing menu.

5. If any changes were made because the displayed screens in the software were different from the ones shown in the manual, select “Save and Close” button to save the changes.

After these parameters have been set, ERD files containing profile data at 25 mm intervals and/or texture data at 0.5 mm intervals can be generated after loading the ARD files and going to the “Export Spatial Data” menu that is located under the File menu (see first menu shown in figure 55). The ERD files generated through the Viewer only contain the data collected within the test section. The file does not contain pre- or post-section data.

If desired, the MPD values from the left and right texture sensor data can be computed through the Mean Profile Depth Analysis Menu. Use the following procedure to compute MPD values after loading the ARD files.

1. Select “Tools” from the main menu of the data viewer (see figure 60) and then select Mean Profile Depth Analysis.
2. In the Mean Profile Depth Analysis menu, “Apply 2.5 mm low pass filter” option located on the left side of the menu must be checked when computing the MPD (see figure 61). Texture Track 1 and Texture Track 2 correspond to ODS4 (left wheel path texture data) and ODS5 (right wheel path texture data), respectively.

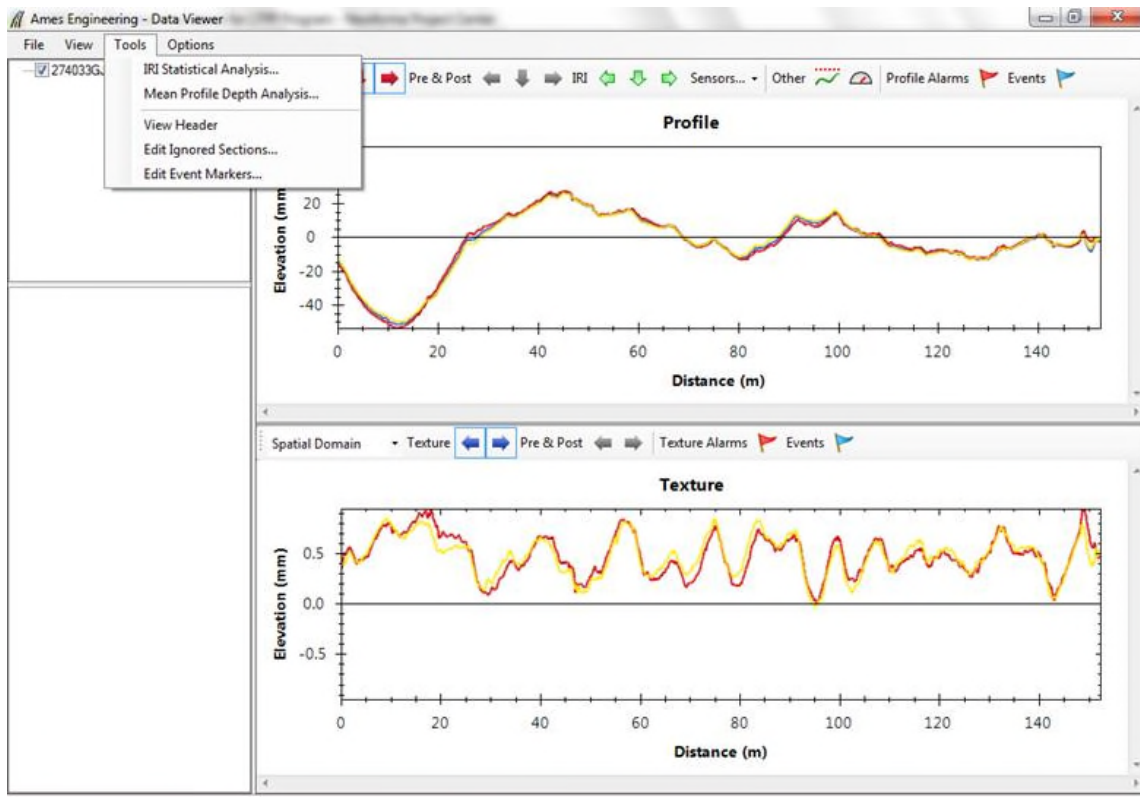


Figure 60. Accessing the Mean Profile Depth analysis menu.

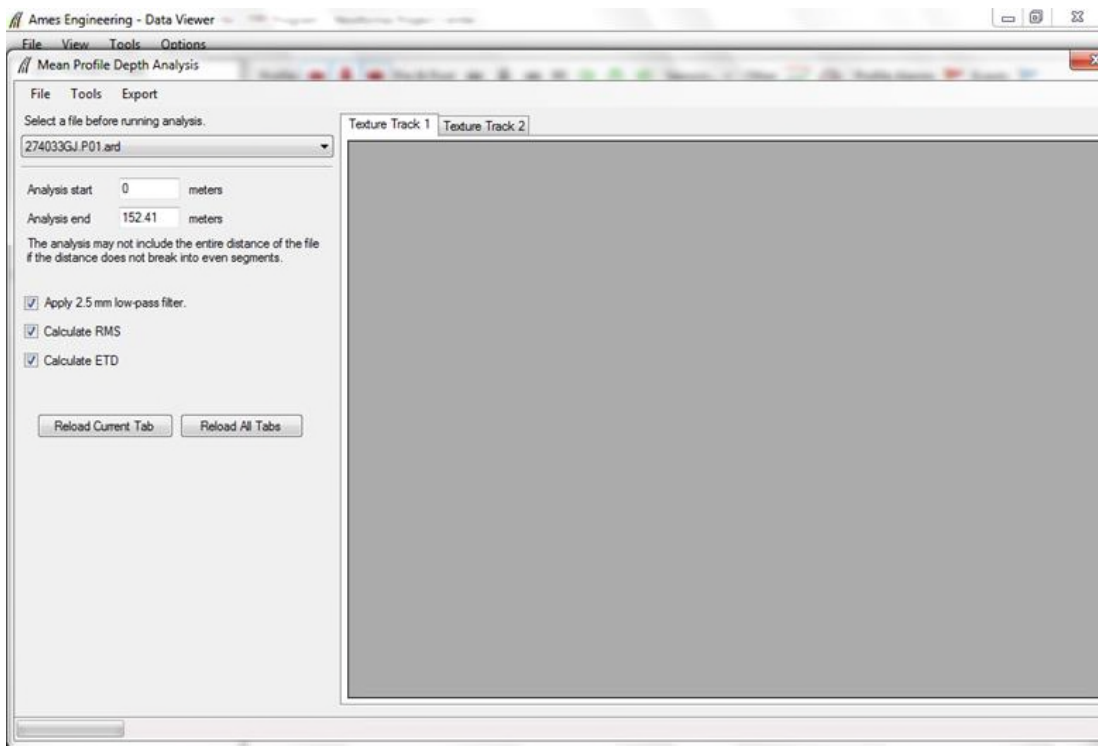


Figure 61. Mean Profile Depth analysis menu.

Note: In the “Texture Analysis Menu” (see step 2 in section 2.4.2), the “Spike Removal” field was not checked. Hence, the spikes in the texture data are not removed before the MPD values are computed. If the user wants to compute MPD with spikes removed from the data, check the “Spike Removal” field in the “Report Options” menu, save the changes, and then compute the MPD values. After computations are completed, go back to the “Report Options Menu”, and remove check mark for the “Spike Removal” field, and save the changes.

#### **2.4.4 ProQual Software**

The installation procedure and a description of the ProQual software are provided in reference 6. A user does not need to specify any settings in the ProQual software. The following parameters are assigned by ProQual, and are included in the files created for upload to the PPDB:

- Device Code: P
- Model Code: 3.
- Vendor: AMES ENGINEERING
- Model: PSM8300
- Serial Number: Value appropriate to the device that collected the data, which is either 30112, 830212, 830312, or 830412 (see table 1).

ProQual detects the following two types of spikes:

- Single Elevation Spikes: The spike threshold for single elevation spikes has been set to 5 mm in ProQual. If the absolute difference between the elevation at a location and the prior location is greater 5 mm, that location is defined to be having a single elevation spike.
- Double Elevation Spike: The spike threshold for double elevation spikes has been set to 2.5 mm in ProQual. If the absolute difference between the elevation at a location and both the prior and subsequent locations is greater than 2.5 mm, a double elevation spike is marked at that location.

### **2.5 EQUIPMENT SPECIFIC OPERATIONAL GUIDELINES**

#### **2.5.1 Profile and Texture Laser Height Sensors**

The device is equipped with three LMI-Selcom laser profile height sensors and two LMI-Selcom laser texture height sensors. According to LMI-Selcom literature, the laser light emitted from these sensors damage the eye if directly exposed, or if the laser light is reflected by a mirror or any mirror like surface directly into the eye. Hence, reflection of the laser beam from a surface such as a polished base plate, a gauge block, or a watch could damage the eyesight. Operators should take adequate precautions to avoid the laser light directly from the laser sensor or from a reflected surface come in contact with the eye. Always make sure that power to the laser sensors are turned-off when inspecting the sensor glass, cleaning the sensor, when performing maintenance on the sensors, and performing the accelerometer calibration check. The power switch located on the dashboard (see figure 34) will turn power off to the profile and texture

laser height sensors as well as other components in the device. If only the power to the profile and texture height sensors needs to be turned off, as during the accelerometer calibration check, use the key in the DAU to turn power off (see section 2.2.4).

According to the manufacturer's literature, the ambient operating temperature range of the profile and texture lasers is from 0 to 50 °C. LMI-Selcom has indicated to Ames Engineering that a laser sensor will automatically shut-off when the internal temperature of the sensor is less than 0 °C or higher than 70°C. LMI-Selcom has also indicated that the internal temperature of the sensor is typically about 10 °C higher than the ambient temperature. The profile height sensors in the device are housed inside a box manufactured by Ames Engineering; the temperature inside this box will be typically higher than the ambient temperature. Sensors to monitor the temperature inside each sensor box that houses the profile height sensors is included in the Ames Engineering circuit boards located inside each box. The temperature inside the interface box that processes texture data (see figure 5) is also monitored by a temperature sensor located on a circuit board. The Ames Engineering software start-up screen (see figure 49) shows the internal temperature of the sensor boxes under ODS1 (left wheel path), ODS2 (right wheel path), and ODS3 (center sensor). The temperature shown for ODS4 (left texture laser) and ODS5 (right texture laser) is the temperature inside the interface box, and both of these temperatures should show the same value. The displayed temperatures are measured at one second intervals.

Based on their testing, Ames Engineering has recommended an operating temperature range of 0 to 60 °C for the profile and texture lasers based on the temperature measured inside the sensor boxes for the profile height sensors and temperature measured inside the interface box for the texture height sensors. If the temperature for a sensor falls below 0 °C, the letters on the main screen that shows "Temp" will turn blue. If the temperature for a sensor is above 60 °C, the letters on the main screen that shows "Temp" will turn red. A warning message will be displayed on the screen if a monitored temperature goes outside the recommended range. Ames Engineering software will not shut-off either the profile or the texture height sensors. However, circuitry inside the laser sensor will automatically shut-off a profile or a texture height sensor when the internal temperature of the sensor is less than 0 °C or higher than 70°C.

If a profile or texture height sensor shuts-off due to high ambient temperature, the testing may have to be scheduled for early morning or after-sunset hours.

### **2.5.2 Cleaning Sensor Glass**

The sensor glass of the profile height sensors should be cleaned after performing the accelerometer calibration check that is specified to be performed at a maximum interval of 30 days (see section 2.12.4). During the accelerometer calibration check the power to the profile height sensors is turned off and the sensors are turned upside down such that the sensor glass is at the top. After performing the accelerometer calibration check, inspect sensor glass for any damage.

Clean sensor glass using compressed air. If the sensor glass appears to be clean, no further cleaning is needed. If excessive dirt is noted, water applied through a sprayer may be needed to clean the glass. After spraying water, wipe sensor glass with a damp lens-cleaning cloth or a lint

free cloth. Extreme care should be used when cleaning the sensor glass to prevent scratching the glass.

Wipe glass once in a single motion. Do not rub glass with the cloth. If the glass does not appear to be clean after a single swipe, repeat the procedure. Do not use paper towels to clean the sensor glass as these can scratch the sensor glass.

When power is turned-off to the profile height sensors for performing the accelerometer calibration test, power is also turned-off to the texture height sensors. After inspecting and cleaning the profile height sensors follow a similar procedure to inspect and clean the sensor glass of the texture height sensors. In the texture height sensors, the laser light emitting unit and the detection unit are separate, and the sensor glass in both units must be inspected and cleaned.

During the daily profile and texture height sensor checks, it is only necessary to inspect the sensor glass for damage. If dirt is visible on the sensor glass during this inspection, follow the procedure described above to clean the sensor glass. However, it is not necessary to unlatch and turn the profile height sensor upside down to clean the sensor glass. Clean glass either through the sensor cover or open the sensor bar and clean the sensor glass.

### **2.5.3 Sensor Bar and Sensor Spacing**

The sensor bar located in front of the vehicle is not designed to support the weight of the operator or other persons. Do not sit or stand on the sensor bar at any time. The sensor bars were set to a level position when the devices were delivered. However, equipment and material that were added to the back of the vans by the RSC's may have caused the sensor bar to go out of level. Accordingly, the levelness of the sensor bar should be checked periodically when the van is parked on a level surface. If the bar is not leveled, Ames Engineering should be contacted to obtain their guidance on the procedure to level the sensor bar. There are bolts on the two mounting plates that can be loosened to allow the entire beam assembly to be pivoted front to back, and therefore be brought back to a level position.

The center profile height sensor should be at the center of the vehicle. The laser dot on the pavement surface for the left and right profile height sensors should 838 mm from the laser dot on the pavement surface from the center sensor. The laser dot on the pavement surface from the texture height sensors located along the wheel paths should be directly behind the laser dot from the profile height sensors that are located along the wheel paths. The distance between the two laser dots on the pavement surface from the texture height sensors should be 1,676 mm apart.

### **2.5.4 Photocell**

There are two photocells mounted on the sensor bar, a downward facing photocell referred to as the vertical photocell and a sideways facing photocell referred to as the horizontal photocell. The vertical photocell is mounted approximately at the center of the sensor bar. The horizontal photocell is mounted at the end of the sensor bar on the passenger side. The vertical photocell triggers off reflective tape placed on the pavement, while the horizontal photocell triggers off reflective tape that is fixed to a cone placed on the side of the road.



The vertical as well as the horizontal photocells have a Light/Dark switch, and this switch must be set to the “Dark” position. The vertical photocell has a sensitivity adjustment knob. The profile operator needs to adjust the sensitivity setting if the photocell does not trigger. Refer to the Photocell documentation in the Ames Engineering Binder<sup>(4)</sup> on how to adjust the sensitivity of the photocell.

### **2.5.5 Tire Pressure**

The tire pressure should be checked before driving the vehicle in the morning to see if it is at the vehicle manufacturers recommended values that are listed on the door panel, which are 380 kPa (55 psi) for the front tires and 550 kPa (80 psi) for the rear tires. The listed tire pressures are cold tire pressure values.

The tires should be sufficiently warmed-up before testing. If the vehicle has traveled about 8 km (5 miles) at highway speeds after being parked, the tires are considered to have warmed-up sufficiently. However, the distance for warming-up tires may need to be changed depending on local weather conditions. Warming-up of the tires will cause a slight increase in tire pressure compared to cold tire pressure.

The DMI is affected by the tire pressure of the rear tire on the driver’s side. The operator should have a copy of the Distance Calibration Report that was printed when the DMI in the device was last calibrated. This report will indicate the tire pressure of the rear tires during calibration. The tire pressure of both rear tires of the vehicle for all data collection runs should be within  $\pm 13.8$  kPa (2 psi) of the tire pressure that was recorded when the DMI was last calibrated. Before performing a data collection run at a test section, the operator should adjust the tire pressure of the rear tires to ensure that the tire pressure is within this specified limit. The same tire pressure gauge should be used to measure tire pressure during calibration and testing.

### **2.5.6 Sensor Covers**

A protective cover protects the profile and texture height sensors in the device from debris. Figure 62 shows a view of a protective cover. The protective covers located along the wheel paths protect both the profile and texture height sensors. The protective cover is held in place by two retention knobs. The protective covers must be closed when device is not collecting data. The protective covers must be opened when performing sensor checks, performing bounce test, and collecting profile data. The protective cover is opened by loosening the knobs and sliding the cover off and then retightening the two knobs.

### **2.5.8 Interior Temperature of Vehicle**

The vehicle is equipped with a heater and an air conditioner to maintain the interior temperature within the vehicle at a temperature that is comfortable to the operator. On cold days when the van has been parked outside, it can take a considerable amount of time to warm-up interior of the vehicle. The laser printer manual indicates the operating temperature range of the printer to be between 15 and 32.5 °C, with the recommended operating temperature range being between 18

and 25 °C. The laptop computer specifications do not indicate an operating temperature range. However, a report on the web by Southwest Research Institute indicates the computer was able to function at a low temperature of 0 °C and a high temperature of 60 °C. The Ames Engineering electronics within the van should operate satisfactorily even at temperatures below 0 °C.



Figure 62. Protective cover that protects the laser sensors.

### **2.5.7 Distance Measuring Instrument**

The device is equipped with an encoder that is attached to the rear wheel on the driver's side (see section 2.2.6). It is recommended the encoder be dismantled from the wheel when travelling long distances without any testing being performed. As a general rule, dismantle the encoder from the wheel on days the device is travelling without testing being performed. After the encoder is dismantled from the wheel, place the cap on the connector to protect it from dust and other contaminants (see figure 14).

### **2.5.9 Equipment for Calibration Check of Profile and Texture Height Sensors**

The profile and texture height sensors have been calibrated in the factory and operators cannot calibrate these sensors. A calibration check on these sensors is performed before collecting data (see section 2.9.2.2). In the calibration check, profile and texture height sensors are checked to see if they can accurately measure the height within a specified tolerance by using a 25 mm block. However, this procedure only checks the accuracy of the height sensor over a 25-mm distance within its measuring range. A more comprehensive check of profile and texture height sensors is specified to be performed at a maximum interval of 30 days, which will check the accuracy of the height sensors over a 100-mm measuring range. This check is referred to as the full calibration check of height sensors to distinguish it from the calibration check of height sensors that is performed before collecting data.

The following items are needed to perform the calibration checks on the profile and texture height sensors:

1. Calibration base plates.

2. Calibration targets.
3. Calibration blocks.
4. Digital level.

#### ***2.5.9.1 Calibration Base Plates***

Three base plates are provided with each device. The base plates have three feet for support, and these can be used to level the plate. The bottom view of the calibration base plate is shown in figure 63, while figure 64 shows the top view of the plate. A square mark that corresponds to the shortest dimension of the calibration blocks (i.e., 25 mm) has been drawn on the middle of the base plate. This ensures the calibration blocks are placed exactly at the same location when performing the calibration check.



Figure 63. Bottom view of the base plate.

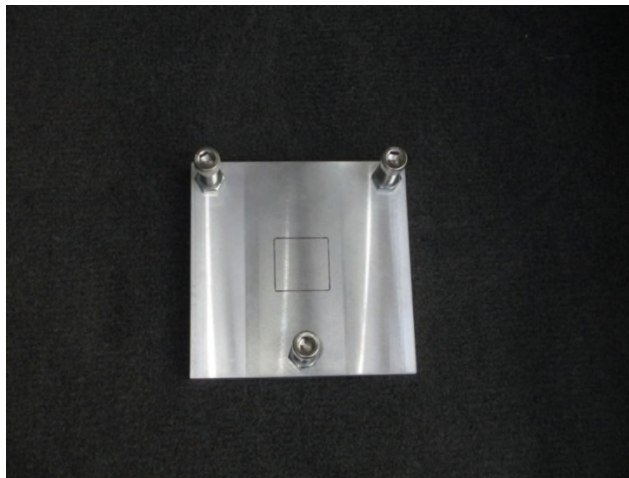


Figure 64. Top view of the base plate.

### **2.5.9.2 Calibration Targets**

Three calibration targets are provided with each device. Measurements are always obtained by the height sensors on these targets. After placing a calibration block on the base plate, the target is placed on top of the block and readings with the height sensor are obtained on the target. The target has a shiny side and a dull (matte) side and measurements should always be obtained on the dull side. Figure 65 shows a photograph of a target placed on top of the base plate.

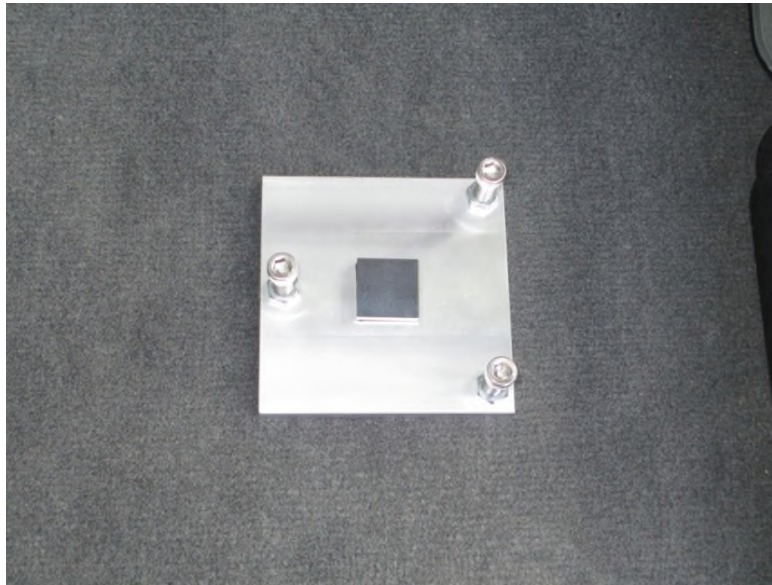


Figure 65. Calibration target placed on the base plate.

### **2.5.9.3 Calibration Blocks**

Three sets of blocks having nominal heights of 25, 50, 75, and 100 mm are provided with each device. The block number is engraved on the side of the block. The exact height of the blocks was shown in table 2. The exact height of the blocks to four decimal places must be entered into the Ames Engineering software before performing the calibration checks. This step needs to be done only once as the entered data can be saved. However, this step may have to be repeated if the software is reinstalled or updated. Always check and ensure the proper block height values are present in the settings following any changes, updates, or reinstallation of the software.

Use the following procedure to enter the exact block heights into the software:

1. Boot-up the laptop computer and start the Ames Engineering software as described in section 2.8.1.
2. Press F2 key or select “Calibrate” to bring-up the calibration menu (see figure 66).
3. Press F4 key or select “Extensive Vertical Test” and the Extensive Test menu (see figure 67) will be displayed on the laptop computer screen.

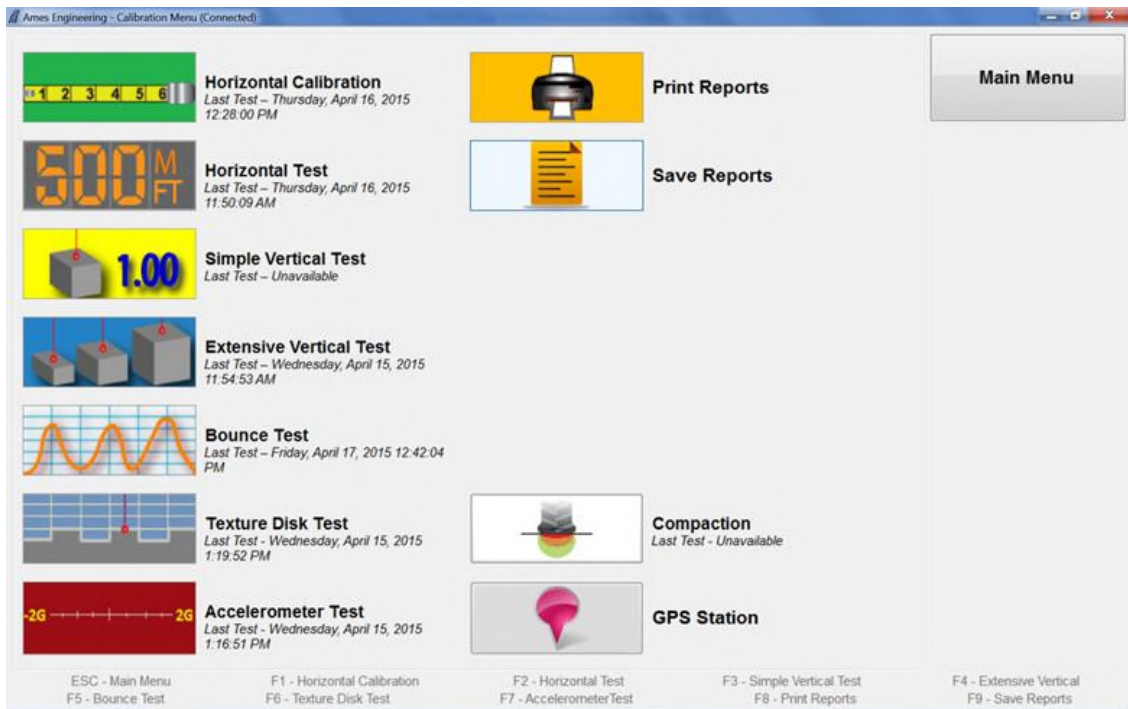


Figure 66. Calibration menu.

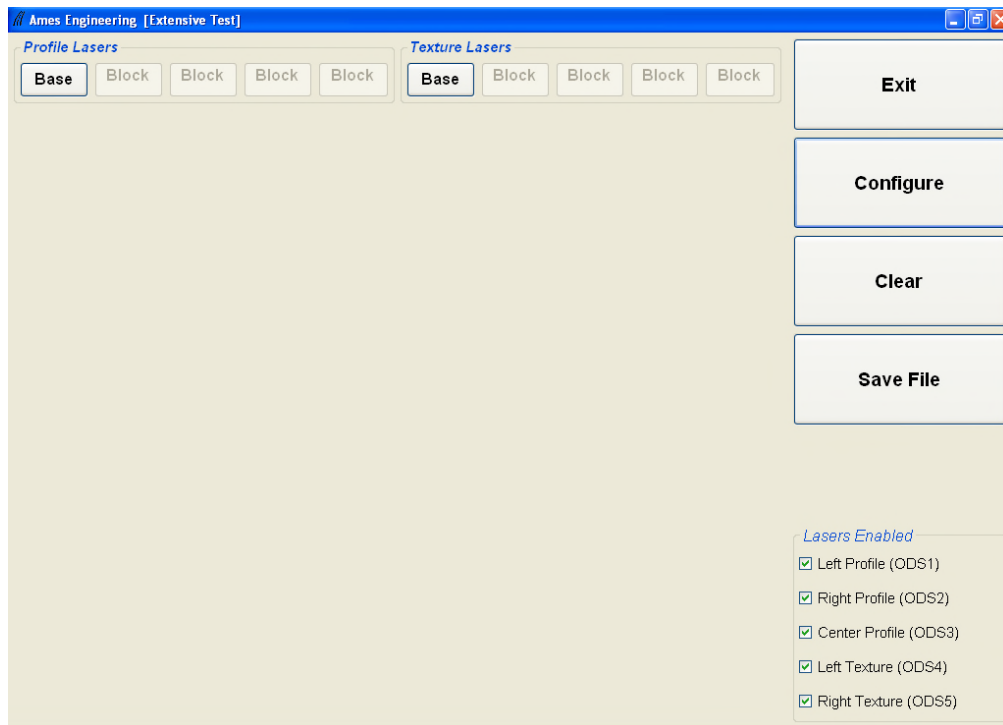


Figure 67. Extensive test menu.

4. Select configure and the menu to enter the block heights will be displayed (see figure 68).

|                | Left Laser  | Center Laser                                      | Right Laser                                       |
|----------------|---|---|---|
| <b>Block 1</b> | Height (mm) <input type="text" value="25.0000"/>  | Height (mm) <input type="text" value="25.0000"/>  | Height (mm) <input type="text" value="25.0000"/>  |
|                | Identifier <input type="text"/>                   | Identifier <input type="text"/>                   | Identifier <input type="text"/>                   |
| <b>Block 2</b> | Height (mm) <input type="text" value="50.0000"/>  | Height (mm) <input type="text" value="50.0000"/>  | Height (mm) <input type="text" value="50.0000"/>  |
|                | Identifier <input type="text"/>                   | Identifier <input type="text"/>                   | Identifier <input type="text"/>                   |
| <b>Block 3</b> | Height (mm) <input type="text" value="75.0000"/>  | Height (mm) <input type="text" value="75.0000"/>  | Height (mm) <input type="text" value="75.0000"/>  |
|                | Identifier <input type="text"/>                   | Identifier <input type="text"/>                   | Identifier <input type="text"/>                   |
| <b>Block 4</b> | Height (mm) <input type="text" value="100.0000"/> | Height (mm) <input type="text" value="100.0000"/> | Height (mm) <input type="text" value="100.0000"/> |
|                | Identifier <input type="text"/>                   | Identifier <input type="text"/>                   | Identifier <input type="text"/>                   |

Figure 68. Menu for entering actual block heights.

5. Enter the block identifier that is engraved on the side of the block and the exact height of the block shown in table 2 into this menu. Figure 69 shows an example of this screen with the block identifiers and block heights entered. Press “Save” to save the entered values. The operator should note the block identifier associated with each height sensor so that the correct block will be placed below each sensor when performing the calibration check or the full calibration check of the height sensors.

#### 2.5.9.4 Digital Level

A digital level is provided with each device (see figure 70) to level the base plate when performing the calibration check of the height sensors.

#### 2.5.10 Auxiliary Battery

When the device has been parked, not connected to shore power, and not used for a couple of days, a Lo-Battery alarm may be displayed on the auxiliary battery status monitor LCD display. This will be displayed when the main power switch is in the “On” or “Off” position.



|                                   | Left Laser                             | Center Laser                           | Right Laser                            |
|-----------------------------------|--|--|--|
| <b>Block 1</b>                    | Height (mm) 25.0045<br>Identifier A10  | Height (mm) 25.0039<br>Identifier A11  | Height (mm) 25.0046<br>Identifier A12  |
| <b>Block 2</b>                    | Height (mm) 50.0046<br>Identifier A22  | Height (mm) 50.0046<br>Identifier A23  | Height (mm) 50.0036<br>Identifier A24  |
| <b>Block 3</b>                    | Height (mm) 75.0033<br>Identifier A34  | Height (mm) 75.0031<br>Identifier A35  | Height (mm) 75.0041<br>Identifier A36  |
| <b>Block 4</b>                    | Height (mm) 100.0015<br>Identifier A46 | Height (mm) 100.0043<br>Identifier A47 | Height (mm) 100.0041<br>Identifier A48 |
| <div>Save</div> <div>Cancel</div> |  |  |  |

Figure 69. Menu with actual block heights entered.



Figure 70. Digital level.

When the engine of the van is off, shore power is not connected, and the main power switch has been turned off, there is still about a 0.05 ampere draw on the auxiliary battery because of the battery status monitor and other electronics that protect and charge the battery. The battery status monitor keeps track of this current flow. However, the battery status monitor can only resolve 0.1 amperes, and hence it overestimates the current draw out of the battery by twice the actual draw. This causes the Lo-Battery alarm to appear even though the battery has not reached the Lo-Battery stage.

This Lo-Battery alarm will not clear until operator manually synchronizes the display. However, the auxiliary battery must be fully charged before this synchronization is performed. This message does not necessarily mean the auxiliary battery does not have sufficient capacity to operate the equipment. The display unit on the dashboard will display the actual voltage of the auxiliary battery. It is possible to collect data if power to all components is provided when the main power switch is turned on with the battery status monitor indicating Lo-Battery. To get rid of the Lo-Battery warning message, connect device to shore power, and after charging the auxiliary battery overnight, press on the two arrow keys on the battery status monitor simultaneously for 3 seconds. Then a flashing “FULL” message will appear on the display indicating it is now synchronized at full capacity, and the Lo-Battery message will clear.

To avoid getting the Lo-Battery warning, connect the device to shore power when the device will be parked and not used for a couple of days. The shore power connector powers a smart battery charger that will charge the auxiliary battery and then drop down to a trickle charge when the battery is fully charged. The vehicle battery will also be charged to full capacity after the auxiliary battery is fully charged. When connected to shore power, the battery monitor will detect a small amount of charging current rather than a small amount of current draw from the auxiliary battery, and therefore the battery status monitor will indicate the auxiliary battery is fully charged. However, it is not possible to follow this procedure unless the device is parked in a garage.

A recommended procedure if shore power cannot be connected continuously is to inspect the battery status monitor before the device goes on a trip to collect data. If the Lo-Battery status indicates “on” in the battery status display, connect the device to shore power and wait until the battery is fully charged by checking the display unit on the dashboard, and then press on the two arrow keys on the battery status monitor simultaneously for 3 seconds. Usually the auxiliary battery will be fully charged in about 8 hours after connecting to shore power.

Ames Engineering should be contacted if the operator has any questions about the procedure to follow when the Lo-Battery alarm is displayed on the auxiliary battery status monitor LCD display.

## **2.6 LTPP OPERATIONAL GUIDELINES**

### **2.6.1 General LTPP Procedures**

**Accidents:** In the event of an accident, operator shall inform the RSC as soon as possible after the mishap. Details of accident should be reported in writing to the RSC. The corporate policy of

the RSC should be followed in event of an accident. A police report of the accident should be obtained. Photographs showing damage to the vehicle should also be obtained.

Maintenance of Records: Operator is responsible for preparing and forwarding the forms and records to the RSC associated with calibration or calibration checks (see section 2.12) and maintenance (see section 2.13).

Safety: Safety of the profiler operators and traveling public is of great concern to LTPP, and safe driving and roadside practices are expected from LTPP profiler operators **Whenever the vehicle is stopped on a roadway, and the occupants are inside the vehicle, the engine shall be running.** Note: if the engine is not running the air bag will not deploy.

Problem Reports: A profiler problem report (PROFPR) must be submitted whenever there are problems with equipment that affect the quality of data or data collection, problems with data collection or data processing software, data collection guidelines, or other problem related to data collection. The procedures described in appendix A must be followed when submitting a problem report.

## **2.6.2 Test Frequency and Priorities**

Profile measurement frequency and priorities described in the latest applicable FHWA directive should be followed when profiling GPS, SPS, and WIM sites.

## **2.6.3 Major Repairs to Profile System Components**

### ***2.6.3.1 General Procedures***

Form PROF-4, LTPP Major Maintenance/Repair Activity Report, which is included in appendix B, must be completed whenever repairs are performed on any component in the device that is associated with data collection such as profile height sensors, accelerometers, DMI, texture height sensors or controllers, ambient and pavement temperature sensors, GPSR, and DAU. This report must also be prepared if any of the referenced components is replaced due to a malfunction.

The following guidelines should be followed regarding performing checks and calibrations after a repair:

- DMI should be calibrated whenever repairs are performed on the DMI or if the DMI is replaced.
- An accelerometer calibration check should be performed whenever repairs are performed on the accelerometer or any circuit board associated with the accelerometer, or if the accelerometer is replaced.
- A full calibration check must be performed when repairs are performed on a profile height sensor or a texture height sensor or any circuit board associated with these sensors.

A full calibration check must also be performed if a profile height sensor or a texture height sensor is replaced.

- A bounce test must be performed after a profile height sensor or an accelerometer is repaired or replaced, or when circuit boards associated with these components are repaired or replaced.
- The texture reference device should be used to check the proper functioning of the texture height sensor when a texture height sensor is replaced, or any repairs or replacements are made to any component associated with texture data collection.

### ***2.6.3.2 Profile Height Sensor***

After repairing or replacing a profile height sensor, data collected by the device should be checked using the following procedure to ensure that accurate data are being collected.

1. Select a test section that has been profiled recently and is close to the current location of the device. When selecting the site, review comments that were made when the site was profiled to make sure that profile data available for this site is free of errors and that no unexplained spikes are present in the data. It is recommended that GPS-3 and SPS-2 sites be avoided as significant variations in profile can occur on these sections due to temperature effects. The RSC should use their judgment in selecting an appropriate site to perform this comparison taking into account the current location of the device and availability of a suitable site close to the location of the device.
2. Collect profile data at the selected site and obtain an acceptable set of runs as described in section 2.9.4.
3. Compare the current profile data and IRI value from the repaired or replaced sensor with the profile data and IRI obtained along that path during the previous site visit. Note: In ProQual version 1.4.1.1, profile plots from the current data collection and previous data collection can be viewed separately, but the data cannot be overlaid with each other. The ability to overlay plots from different visits may be available in a future version of ProQual.
4. If the evaluation indicates the collected data are comparable with the previously collected data, the repaired or replaced sensor is considered to be functioning correctly. If discrepancies are noted, the comparison should be performed at another section. If discrepancies are still noted, Ames Engineering should be contacted to resolve the problem.

If a malfunction is detected in a profile height sensor located along a wheel path, it may be replaced by the center profile height sensor to continue data collection. Ames Engineering should be consulted on how this can be accomplished. Once the repaired or replacement sensor is available, the center sensor that is now located at an outer position (left or right wheel path) should be moved back to the center position. The repaired or replaced sensor should be installed at the location of the defective sensor (either left or right wheel path). A full calibration check (see section 2.12.5) should be performed on the repaired or replacement sensor. Thereafter, the

accelerometer check (see section 2.12.4) and a bounce test (see section 2.9.2.4) should be performed. Procedures that were described previously (i.e., profiling at a previously profiled section) should be followed to ensure that the repaired/replaced sensor is functioning correctly.

### ***2.6.3.3 Texture Height Sensor***

After repairing or replacing a texture height sensor, data collected by repaired or replaced sensor must be checked using the following procedure to ensure that accurate data are being collected.

1. Select an asphalt concrete (AC) surfaced test section where texture data has been collected recently and is close to the current location of the device. Preferably the site should not have visible pavement distress. The RSC should use their judgment in selecting an appropriate site to perform this comparison taking into account the current location of the device and availability of a suitable site close to the location of the device.
2. Profile the selected site and obtain an acceptable set of runs.
3. Compute the MPD values for the data collected with the left and right texture height sensors.
4. Compare the MPD value computed from data collected with the repaired or replacement sensor with the MPD values that were obtained previously. The current MPD value should be within 10 percent of the previous MPD value. Also, the percentage difference in MPD for the sensor that was repaired or replaced should be close to the percentage difference that was obtained for the sensor that was not replaced. (To compute the percentage difference, deduct the current MPD from the previous MPD and divide this value by the previous MPD and then express the computed value as a percentage.) If discrepancies are noted, the comparison should be performed at another section. If discrepancies are still noted, Ames Engineering should be contacted to resolve the problem.

### **2.6.4 Data from Previous Site Visit**

After collecting data at a site, profiler operator is required to compare the profile data as well as the IRI with the data collected during the previous site visit as described in section 2.9.4.4. The profiler operator is also required to compare the current MPD values with the MPD values obtained during the previous site visit as described in section 2.9.4.4.

Before leaving the office, the operator must ensure the data files that are required to do this comparison for the previous site visit are available. Operator must also have the IRI values and MPD values for the site from the previous visit.

### **2.6.5 Software, Computer System, and Manuals**

The operator should maintain a copy of the Ames Engineering software and the ProQual software in the vehicle in case software problems occur in the software installed on the laptop computer. If the Ames Engineering software is re-installed, the operator must go through the

setup menus described in section 2.4 of this manual to make sure that appropriate parameters have been set to the correct values.

Apart from Ames Engineering Software, ProQual and Microsoft Office, other software should not be loaded onto the laptop computer, unless specifically approved in writing by FHWA.

Do not add hardware (extra drives or other device) to the laptop computer system before contacting Ames Engineering through FHWA to determine if they will interfere with Ames Engineering data collection and processing programs. Interference of programs due to additional devices may not be readily apparent.

Profiler data files should be organized into subdirectories in the hard drive as outlined in LTPP directive I-170, AIMS Data Storage Format Standards or the current version of that directive.

## **2.7 FIELD OPERATION GUIDELINES**

### **2.7.1 Turnarounds**

Applicable laws in each state regarding use of median turnarounds must be followed.

### **2.7.2 Light Bar, Directional Warning Light, and Strobe Lights**

Device is equipped with a light bar in front, a directional warning light mounted on the rear of the van, and strobe lights located within the headlamps and the tail lights. The light bar, directional warning light and strobe lights should be turned-on during testing or when parked on the shoulder of a roadway.

### **2.7.3 File Naming Convention for GPS and SPS Sites**

The file naming convention to be used in specifying name of data file when collecting data at GPS and SPS sections is described in this section. File naming conventions for collecting data at WIM sites are described in section 2.11. Failure to adhere to the file naming convention could produce errors when running ProQual, and will cause problems when archiving files. The file name should consist of eight characters as follows:

1. Characters one and two: State code of state in which site is located (e.g., 27 for Minnesota).
2. Characters three to six: Four-digit site number. For GPS sites this is the four-digit LTPP identification number (e.g., 1023). For SPS sites, the third character should be 0, A, B, etc., depending on project code (e.g., 0300, A300, B300, etc.). The fourth character for SPS sites is the experiment number (e.g., 2 for SPS-2 projects), while the fifth and sixth characters should be zero. However, if an RSC elects to do so, for SPS sites it is permissible to use the fifth and sixth character to indicate the first section encountered when the SPS section is profiled.



3. Character seven: Letter code defining section type; G for GPS, S for SPS, or C for Calibration test sections.
4. Character eight: Sequential visit identifier code that indicates the visit code for the current profile data collection. This identifier indicates the number of times a set of profile runs has been collected at a site since the site was first profiled with the K. J. Law T-6600 profiler. (When the site was first profiled with the K. J. Law T-6600 profiler, the letter A was used for the eighth character). Use an appropriate letter for the current profiling. For example if site is being profiled for second time use letter B, use C for the third time, H for eighth time and so on. If a site is being profiled for the first time (it has not been profiled before, as is the case for some GPS-6B or GPS-7B sites), the letter A should be used for the eighth character. Thereafter, this letter should be sequentially increased (B, C, and so on) during subsequent profile data collection visits. If a region has been using the sequential visit identifier to indicate the number of times a set of profiles has been obtained at the site since its inception into the LTPP program, that procedure is also acceptable. In such case, the letter A is used to denote the first time the site was/is profiled by the RSC, whether with the DNC690, T-6600, ICC or Ames device. Thereafter, this letter should be sequentially increased (B, C, and so on) during subsequent profile data collection visits.

After the sequential visit identifier code has been assigned as Z, use the following procedure for file naming when the site is profiled the next time.

- (a) If the site is a GPS site, change character seven to H, and assign site visit identifier to be A. For subsequent profile visits, maintain character seven as H and change sequential visit identifier to be B, C, D, etc.
- (c) If the site is a SPS site, change character seven to T, and assign site visit identifier to be A. For subsequent profile visits, maintain character seven as T and change sequential visit identifier to be B, C, D, etc.

The following are examples of valid data file names:

1. 171002GD: GPS section 1002 in Illinois (state code = 17), profiled for the fourth time.
2. 260200SB: SPS-2 site in Michigan (state code = 26), profiled for the second time.
3. 27A300SC: SPS-3 sites having project code A in Minnesota (state code = 27), profiled for the third time

If a long SPS project is not profiled continuously, but profiled in groups of sections, the sixth character in file name should be replaced by a character for each group. For example, consider SPS-2 project in state 26 that is profiled as two groups of sections. The file name for the first group could be 26020ASA, while that for the second group could be 26020BSA.

The first two digits of the file name for a section must be valid state codes when generating file names for demonstration purposes or comparative studies. ProQual will not operate on data files that do not follow this convention.

## **2.7.4 Operating Speed**

A constant vehicle speed of 80 km/h should be maintained during a data collection run. If maximum constant speed attainable is less than 80 km/h due to either traffic congestion or safety constraints, then a lower speed depending on prevailing conditions should be selected. If the speed limit at site is less than 80 km/h, the site should be profiled at the posted speed limit. If traffic traveling at high speeds is encountered at a test site, it is permissible to increase the profiling speed to 88 km/h. If the site is relatively flat, cruise control should be used to maintain a uniform speed. It is important to avoid changes in speed during a profile run that may jerk the vehicle or cause it to pitch on its suspension. Change in throttle pressure or use of brakes to correct vehicle speed should be applied slowly and smoothly.

## **2.7.5 Obtaining Images with Camera at LTPP Sections**

### ***2.7.5.1 Operational Guidelines***

For security purposes, the RSC may elect to remove the camera from the mounting bracket when the vehicle is parked outside. After removing the camera, it can be kept inside the vehicle at an appropriate location.

Obtain one set of images at 10 m intervals at all LTPP sections when collecting profile/texture data. This includes General Pavement Studies (GPS), Specific Pavement Studies (SPS) and WIM sites. At WIM sites obtain images when collecting data along the wheel paths.

The camera must be aimed properly such that consistent images are obtained every time it is used. After mounting camera, connect the camera to a USB port in the laptop computer, and then boot-up the laptop computer and start the Ames Engineering software as described in section 2.8.1. Thereafter, press F1 key or select “Setup” to get into the setup menu and then select the “Camera” tab to go to the Camera setup menu (See step 5 of section 2.4.2). Use the Camera Preview to properly aim the camera. The hood of the vehicle and the guide posts attached to the sensor bar on either side can be used as reference marks to aim the camera consistently. Adjust the aperture of the camera (see section 2.2.21) if needed to obtain the best possible image.

The camera will start taking images when the photocell is armed (see step 3, section 2.9.3.3) and will continue to take images for a distance of 152.4 m past the Stop Distance that is entered into the software in the header screen (see section 2.9.3.2).

Arm the photocell just before Sign A that is located 152.4 m before the start of the section. A white paint stripe is located across the lane at this location. As the camera obtains images at 10 m intervals, this procedure will result in about 15 images being obtained before the start of the section.

The images that are obtained during a data collection run are stored in a subdirectory that is created under the directory where the ARD file is stored. For example, if the ARD file is called 361111GD.P01.ARD, and the ARD file is stored in a directory called C:\Profiles, a subdirectory

called C:\Profiles\361111GD.P01Images will be created to store the images associated with that run. The operator cannot change the location where the images are stored.

The operator can use one of the following options for collection of images.

- Option 1: Elect to have the camera “on” and obtain images for all repeat runs performed at the section. Thereafter, after data collection is completed and data have been reviewed, review the images (e.g., using Windows explorer) and select one set of acceptable images for the section and delete unwanted images.
- Option 2: Review the obtained images (e.g., using Windows explorer) after the first run. If the obtained images are not satisfactory obtain images for next run(s) until a set of satisfactory images have been obtained. If the obtained images are satisfactory, close the camera window, so that images will not be obtained during subsequent runs at the section. Once the camera is closed it is disabled. In order to enable the camera again, go to the camera setup menu (see step 5 of section 2.4.2, and select “Photo”).

### ***2.7.5.2 Image File Names***

The camera takes the first image when the photocell is armed. This image will have an image number of 0001. The images obtained from the camera increase sequentially starting with 0001. The camera will obtain the last image 152.4 m past the Stop Distance that is entered in the header menu (see section 2.9.3.2). The Stop Distance is always 152.4 m for a GPS section. Hence, for a GPS section, the camera will obtain the last image approximately 152.4 m past the end of the section.

The images obtained by the camera will have the following file name assigned by the Ames Software based on the file name entered for saving the collected profile data:

HSSAASHRPBRYYYMMDDNNNN.jpg

|          |  |
|----------|--|
| HSS      | High-Speed survey. The first three characters of the filename will always be HSS.  |
| AA       | Numeric State Code (obtained from file name).  |
| SHRP     | SHRP_ID for Site (obtained from file name).  |
| B        | G for a GPS section, W for a WIM section, and S for data collected for a SPS project (obtained from file name). See section 2.7.3 for assignment of this character after sequential visit identifier Z has been reached. |
| R        | Sequential Visit Identifier Associated with the Profiler Visit (see section 2.7.3).  |
| YYYYMMDD | Profile date (Year/Month/Date).  |
| NNNN     | Number of image in sequence starting with 1 for the first image.   |

For a GPS or a WIM section, the value associated with SHRP will be the SHRP\_ID of the site. For a SPS project the SHRP\_ID will be the SPS project number (i.e., 0200, see section 2.7.3 for more information).

All images taken before the photocell is triggered at the start of the section will have the notation Lead In imprinted on the image. All images obtained from the time the photocell is triggered until the Stop Distance specified in the header screen is reached will have the station number in meters imprinted on the image. The station number 0 will correspond to the location when the photocell was triggered, which is the start of the section for a GPS or a WIM section, and the start of the first section in a SPS project. All images obtained for a distance of 152.4 m after the specified Stop Distance will have Lead Out imprinted on the image.

Example for a GPS Section: Assume images were obtained at GPS section 1018 located in Arizona (State Code 04) on December 9, 2014 during Sequential Visit Identifier K. Assume that 16 images were obtained before the test section, 15 images were obtained within the test section, and 15 images were obtained after the end of the test section. Therefore, the total number of images obtained during the data collection run will be 46. The first image obtained, which is when the photocell is armed, will have the following file name:

HSS041018GK201412090001.jpg. The last image taken at this section will have the following file name: HSS041018GK201412090046.jpg.

Example for a SPS Section: Assume images were obtained at the SPS 1 project in Delaware (State Code 10) during sequential visit identifier H on February 7, 2015. Assume that the Stop Distance specified when collecting data for this project was 3000 m, which resulted in 300 images being obtained from the time the photocell was triggered until the specified stop distance was reached. Assume 17 images were obtained from the time the photocell was armed until the start of the section. Assume that 15 images were obtained after the end of 3000 m that was specified as the Stop Distance. Therefore, at this section a total of 332 images would have been obtained. The first image obtained at this project will have the following file name:

HSS100100SH201502070001.jpg. The last image obtained at this section will have the following file name: HSS100100SH201502070332.jpg

### **2.7.6 Collection of Video**

Collection of video at the test sections is not required for the LTPP program. However, a RSC can collect video at the test section if desired. The Video mode must be selected in the Camera Setup Menu (See step 5 in section 2.4.2) in order to obtain video.

As for images, collection of video will start when the photocell is armed, and collection of video will continue for a distance of 152.4 m past the Stop Distance that is entered into the software in the header screen (see section 2.9.3.2). The file that records the video will have a file extension of “avi”.

### **2.7.7 Event Initiation**

During profile data collection, the data collection program uses an event mark to record the start of the section. Event marks are generated by the photocell. The vertical photocell detects the white paint stripe or the reflective tape at the beginning of test section and sends a signal to record that event in the data file. This information is used to generate the data corresponding to the test section. In those instances where the existing paint mark on pavement is not able to

trigger vertical photocell, the horizontal photocell should be used. The cone with a reflective marker provided with the device should be placed on the shoulder at the beginning of the test section to activate the horizontal photocell. The leave edge of the reflective marker should be aligned with the leave edge of the stripe at the beginning of the test section.

### **2.7.8 Loading and Saving Files**

Saving files to the hard disk or flash drive should not be done when the vehicle is in motion. At the completion of a profile run, driver should pull over to a safe location and come to a complete stop, enter the end of run comment, and then save the data file to hard disk.

### **2.7.9 Inclement Weather and Other Interference**

Inclement weather conditions (e.g., rain, snow, heavy cross winds) can interfere with the acquisition of acceptable profile/texture data. Profile/texture measurements should only be performed on dry pavements. In some cases, it may be possible to perform measurements on a damp pavement with no visible accumulation of surface water. Under such circumstances, the data should be monitored closely for run to run variations and potential data spikes. ProQual should be used to detect spikes. When reviewing the data, the operator should keep in mind that spikes could occur due to pavement conditions (e.g., potholes, transverse cracks, bumps), and electronic interferences.

Changing reflectivity on a drying pavement due to differences in brightness of pavement (light and dark areas) may yield results inconsistent with data collected on uniformly colored (dry) pavements. Run to run variations in data collected under such conditions should be carefully evaluated. If problems are suspected, data collection should be suspended until pavement is completely dry.

Electromagnetic radiation from radar or radio transmitters may affect data recorded by the device. If this occurs, operator should attempt to identify and to contact the source to learn if a time will be available when the source is turned-off. If such a time is not available, it may be necessary to schedule a Dipstick<sup>®</sup> survey of the test section.

### **2.7.10 End of Run Comments**

The Ames Engineering software allows the operator to enter comments at the end of each data collection run, and these comments are hereafter referred to as end of run comments. These comments can be edited, if required, in ProQual when the data files are imported into ProQual. Operator can also enter comments about the profiled site after profile data is imported to ProQual (see section 2.7.11.3) and those comments are hereafter referred to as operator comments. Both sets of comments can be up to 100 characters in length and are uploaded into the PPDB.

End of run comments entered for a group of sections profiled in one run (e.g., SPS site) are put into each individual file that is sub-sectioned from that profile run. Similarly, if a GPS section is profiled in conjunction with a SPS site in one run, end of run comments are common to all sections sub-sectioned from that profile run. Therefore, the operator should ensure end of run

comments that are entered when several test sections are profiled in one run are valid or applicable to all sections in that run (e.g., weather related comment). End of run comments should be typed in capital letters.

To ensure uniformity between the end of run comment that is made when a group of sections are profiled together (e.g. SPS section) and when a section is profiled as an individual section (e.g. GPS section), end of run comments have been grouped into the following three categories:

1. Good Profile Run: Comment used to indicate that profile run was good and that no problems were encountered. Example comment: RUN OK.
2. Environment Related Comments: Profile testing should not be performed when environmental conditions are such that they can affect the quality of the data. If the operator believes there is a possibility that environmental conditions may have affected quality of the data, a comment should be entered. Example comment: HEAVY WINDS.
3. Speed Related Comments: The following are examples where a comment related to speed of testing should be entered:
  - (a) Speed limit at site is lower than 80 km/h specified for profile data collection.  
Example comment: SPEED LIMIT AT SITE IS 60 KM/H.
  - (b) Heavy traffic, difficult to maintain a constant speed. Example comment: TRAFFIC CONGESTION: SPEED VARIABLE.
  - (c) Difficult to maintain constant speed because of grade (uphill or downhill). Example comment: DIFFICULT TO MAINTAIN CONSTANT SPEED: UPGRADE

End of run comment is made at end of the run before saving the data. Ames Engineering software offers six end of run comments that the user can select at the end of a run. Operator can only select one of the comments. If none of these comments are applicable, user can type any desired comment. The six end of run comments that are available in the Ames Engineering software are:

- RUN OK.
- PAVEMENT SURFACE DAMP.
- TRAFFIC CONGESTION: SPEED VARIABLE.
- DIFFICULT TO MAINTAIN CONSTANT SPEED: UPGRADE.
- DIFFICULT TO MAINTAIN WHEEL PATH LOCATION.
- LATE PHOTOCCELL INITIATION.

If a Late Photocell Initiation is encountered, that run should be discarded and an additional run should be made. Therefore, the operator should never make the comment “LATE PHOTOCCELL INITIATION” and save the data.

There should always be an end of run comment. If no problems were encountered during the run, the comment “RUN OK” should be entered as an end of run comment. If there were weather/environmental related comments, or speed related comments, these should be entered



following the guidelines that were presented previously. If a late photocell initiation is suspected, an additional run to replace that run should be obtained.

### **2.7.11 Comments Input by Operator in ProQual**

The operator has to enter the following three items in ProQual after reviewing the data: Surface Finish, Texture Comment, and Operator Comments.

#### ***2.7.11.1 Surface Finish***

The surface finish is entered using a pull-down menu. The surface finish that is entered must be the same for all runs. The operator should select an appropriate surface finish for the section from the following surface finish types that are available in the pull-down menu:

- ASPHALT - FINE
- ASPHALT - COARSE
- CHIP SEAL
- CONCRETE - DIAMOND GROUND
- CONCRETE - BROOM FINISH
- CONCRETE - TRANSVERSE TINES
- CONCRETE - LONGITUDINAL TINES
- OPEN GRADED/FRICTION COURSE

The RSC can maintain a logbook that describes the surface finish of the LTPP sections in the region to ensure consistent information about the surface finish is entered during the profiler visits. Another advantage from maintaining a log book is that the operator can inform the RSC if a change in the surface finish is noted at a test section, which would indicate a maintenance activity has been performed on the section.

#### ***2.7.11.2 Texture Comment***

The texture comment is entered using a pull-down menu. The operator has the option of typing a comment (maximum 100 characters) instead of using a comment that is available in the pull-down menu. The operator also has the option of selecting a comment from the pull-down menu and then typing additional comments after that. The texture comment that is entered must be the same for all runs. The following comments are available in the pull-down menu:

- ACC – DENSE GRADED HMA; FINE GRADE (.6-1.2MM)
- ACC - DENSE GRADED HMA; COARSE GRADE (.6-1.2MM)
- ACC - OPEN GRADED (1.5-3.5M)
- ACC - OPEN GRADED FRICTION COARSE (OGFC)
- ACC - POROUS EUROPEAN MIX (PEM)
- ACC - WARM MIX (WMA)
- ACC – SLURRY SEAL
- ACC - MICROSURFACING

- PCC – TURF DRAG BURLAP / ARTIFICIAL TURF
- PCC – TRANSVERSE TINING
- PCC – LONGITUDINAL TINING
- PCC – EXPOSED AGGREGATE
- PCC - TRANSVERSE DIAMOND GRIND
- PCC - LONGITUDINAL DIAMOND GRIND
- PCC - MICRO-MILLING
- PCC - MACRO-MILLING
- SKIDABRADER TREATED

### ***2.7.11.3 Operator Comment***

Operator comments are entered after profile data has been imported into ProQual and reviewed. Operator comments should be typed in capital letters. They can fall into one of the following six categories:

1. **Pavement Distress Related Comment:** A comment should be made if there are pavement distresses or features within the section that can affect the repeatability of profile data. Comment should specify the distress(es) present that the operator believes to be causing non-repeatability of profile data. The following are examples where such comments may be entered:
  - (a) For AC surfaced pavements, distresses such as rutting, fatigue/alligator cracking, potholes, patches, longitudinal and transverse cracking.  
Example comment: \_\_\_\_\_ IN SECTION (enter distress type for blank).
  - (b) For PCC surfaced pavements, distresses such as faulting, spalling, longitudinal, and transverse cracking.  
Example comment: \_\_\_\_\_ IN SECTION (enter distress type for blank).
  - (c) For pavements with a chip seal, a comment should be entered if chips are missing in areas within the section.  
Example comment: CHIP SEAL SECTION. CHIPS MISSING
  - (d) Comment should be made if there are dips within the section.  
Example comment: DIPS IN SECTION
2. **Maintenance Related Comments:** A comment should be made if operator is familiar with the test section and notes that recent maintenance and/or rehabilitation activities (e.g., overlays, patches, crack filling, or aggregate seals) have been performed on that section. The operator should specifically make a note if “overband” type crack filling has been performed on the section. (Overband type crack filling is typically about 100 mm wide and is placed over the crack.)  
Example comment: RECENT MAINTENANCE IN SECTION, PATCHES.
3. **Wheel Path Tracking Related Comments:** A comment should be entered if operator encountered problems in tracking the wheel path. Such a comment should be entered if one or more of the following conditions are encountered:
  - (a) During the profile run, path followed was either to the left or to right of wheel path.

- Example comment: RUN RIGHT OF WHEEL PATH
- (b) Difficulty in holding wheel path due to pavement distress(es) such as rutting.  
Example comment: DIFFICULT TO HOLD WHEEL PATH, RUTTING
- (c) Difficulty in holding wheel path due to truck traffic.  
Example comment: DIFFICULT TO HOLD WHEEL PATH, TRAFFIC
- (d) Difficulty in holding wheel path due to wind.  
Example comment: DIFFICULT TO HOLD WHEEL PATH, WINDY
- (e) Difficulty in holding wheel path because of grade, either uphill or downhill.  
Example comment: DIFFICULT TO HOLD WHEEL PATH, UPHILL
- (f) Difficulty in holding wheel path because section is on a curve.  
Example comment: DIFFICULT TO HOLD WHEEL PATH, CURVE
4. Location of Test Section Comments: A comment should be entered if the location of section has a potential impact in obtaining repeatable profile runs. Such conditions include:
- (a) Section or approach to section is on a curve.  
Example comment: APPROACH TO SECTION ON CURVE
- (b) Section or approach to section is on a grade (uphill or downhill).  
Example comment: SECTION ON A DOWNHILL
5. Miscellaneous Other Comments: A comment should be entered if conditions other than those not covered previously are encountered during profiling that may affect quality of the data. Such conditions include:
- (a) Contaminants on road such as sand/gravel or dead animals.  
Example comment: SAND ON ROAD
- (b) Traffic or WIM loops within test section.  
Example comment: WIM LOOPS WITHIN SECTION OR TRAFFIC LOOPS IN SECTION
- (c) Color variability of the pavement because of salt application.  
Example comment: COLOR VARIABILITY CAUSED BY SALT
- (d) Excessive vehicle movements just before test section because of pavement condition.  
Example comment: CORE HOLES ON WHEEL PATH BEFORE SECTION
6. Spike Related Comments: After ProQual has processed data, the operator should look for presence of spikes in the data. If spikes are present, enter comment indicating whether or not spikes are pavement related.  
Example comment: PAVEMENT RELATED SPIKES IN PROFILE.

After profile data are processed using ProQual, an operator comment can be entered for each run. ProQual offers nine comments that can be selected by the operator. These comments are:

- EQUIPMENT OK
- ROUGH SURFACE TEXTURE / RAVEL AND STONE LOSS
- MODERATE TO SEVERE SURFACE FLUSHING
- NOTICEABLE DISTRESS IN WHEEL PATH

- MODERATE TO SEVERE RUTTING
- FAULTING AND SPALLING OF JOINTS / CRACKS
- AGGREGATE SEGREGATION
- POLISHED AGGREGATE
- DIAMOND GRIND ENTIRE SECTION

Operator also has the option of typing any desired comment. The operator can also select one of the default comments available in ProQual, and type an additional comment at the end of the selected comment.

Operator comments can be up to 100 characters in length. If spikes are observed in the profile, it is mandatory for the operator to enter a comment regarding these spikes after running ProQual indicating whether or not the spikes are pavement related. Because of the 100 character constraint, it may not be possible to type in all of the applicable factors from the list of factors that were described previously. Therefore, when entering comments, it is recommended that the following order of priority (with first factor listed being given the highest priority) be followed:

1. Wheel path tracking related comments.
2. Pavement distress related comments.
3. Maintenance related comments.
4. Miscellaneous other comments.
5. Location of test section comments.

It should be noted that comments are used to indicate factors that could affect the quality of data or to indicate factors that cause variability between profile runs. Depending on conditions encountered in the field, the recommended priority order may be changed with the factor having greatest effect on quality or repeatability of profile data being listed first. If there are factors that cannot be entered because of space constraints, such factors should be entered in form PROF-1, LTPP Profiler Field Activity Report, which is included in appendix B under the field Additional Remarks Regarding Testing. (Note: If a factor has been entered as an operator comment into ProQual, it should not be repeated in the Field Activity Report).

## **2.8 POWER UP AND SHUTTING DOWN EQUIPMENT**

### **2.8.1 Power Up Procedure**

Use following procedure to power up the equipment:

1. Attach the laptop computer to the laptop computer dock.
2. Turn on the master power switch located on the dashboard (see figure 34). The switch will show an amber color at the bottom. Note: The master power switch can be turned on either before starting the vehicle or after starting the vehicle.

3. Turn on laptop computer. Look at the time shown on the task bar. If the time is different at the current location, use the Date/Time menu in Windows accessible through the control panel to set the correct time.
4. Start the Ames Engineering software, and the start-up screen shown in figure 71 will appear on the screen

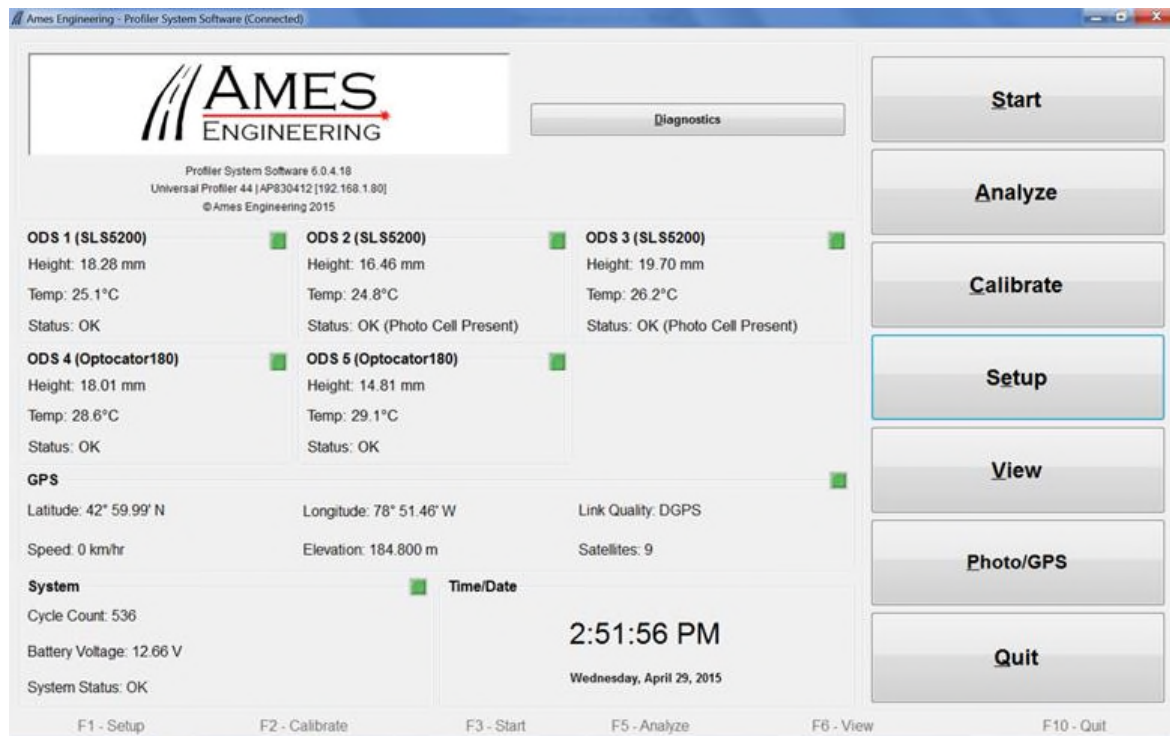


Figure 71. Ames Engineering software start-up screen.

5. Check the date and time on start-up screen to make sure they are correct.

The start-up screen will show the status of the following sensors through a status LED:

- ODS1, Left wheel path profile height sensor.
- ODS2, Right wheel path profile height sensor.
- ODS3, Center profile height sensor.
- ODS4, Left wheel path texture height sensor.
- ODS5, Right wheel path texture height sensor.
- Photocells.
- GPSR.
- System.

The status LED appears to the right of the sensor and will be green if the sensor is functioning properly and ready to collect data. The sensor covers must be open in order for ODS1, ODS2, ODS3, ODS4, and ODS5 to show a green LED. The LED will be yellow if the sensor is not

properly viewing the road surface, for example if the sensor covers have not been opened. The LED will be red if the sensor is not communicating with the DAU or the laptop computer.

The start-up screen displays the following information for the profile height sensors (ODS1, ODS2, and ODS3):

- Height: Indicates the height measured by the sensor. The height should be close to zero (generally within  $\pm 15$  mm of zero) if the vehicle is parked on a level surface.
- Temperature: This is the temperature inside the box in which the profile height sensor is housed.
- Status: The status will indicate OK if the sensor is ready to take measurements. The status will indicate “Photo Cell Present” if a photocell is connected to that sensor. Note: If the message “Photo Cell Present” does not appear for ODS3 sensor, it means the vertical photocell was not detected. This can happen if the pavement surface below the photocell is reflective (e.g. on a concrete surface). If this occurs, and data collection is to be performed on a portland cement concrete (PCC) surface, exit software, turn down sensitivity of photocell, turn main power switch off and then turn it on again, and then start-up software again and check if “Photo Cell Present” appears next to “Status” for ODS3. (Note: Refer to the photocell documentation included in the Ames Engineering Binder<sup>(4)</sup> on how to adjust the sensitivity of the photocell.) If data collection is to be performed on an AC surface, exit software, move profiler to an AC surface, and then start-up software again and check if “Photo Cell Present” appears next to Status for ODS3.

The start-up screen displays the following information for the texture height sensors (ODS3 and ODS4):

- Height: Indicates the height measured by the sensor. The height should be close to zero (generally within  $\pm 15$  mm of zero) if the vehicle is parked on a level surface.
- Temperature: This is the temperature inside the interface box located in the sensor bar that processes texture data.
- Status: The status will indicate OK if the sensor is ready to take measurements.

The start-up screen displays the following information for the GPSR:

- Latitude.
- Longitude.
- Link Quality: Will indicated DGPS if a WAAS correction is made to the data.
- Speed: Speed of vehicle in km/hr.
- Elevation.
- Satellites: Number of satellites that are being used by the GPSR.



The start-up screen displays the following information about the system:

- Cycle count.
- Battery voltage: Voltage of the auxiliary battery,
- Time: Time set in the laptop computer.
- Date: Date set in the laptop computer.
- System Status: Indicate OK if the system components are working satisfactorily.

The following menus can be accessed by pressing a function key or selecting the button located on the right side of the screen:

- Start (F3). Starts data collection.
- Analyze (F5): To analyze the collected data. This menu is not used for LTPP data collection or processing.
- Calibrate (F2): To calibrate or perform calibration checks on components.
- Setup (F1): To enter parameters associated with data collection.
- View (F6): To view the collected data and perform analysis on the collected data.
- Quit (F10): To exit program.

The Photo/GPS menu is not used for LTPP data collection activities.

## **2.8.2 Shutting Down Procedure**

Use the following procedure to shut down the system.

1. Go to the Ames Engineering start-up screen (see figure 71). Exit the software by pressing F10 key or select “Quit” and then shutdown laptop computer. If you plan to use the laptop computer, you can keep the laptop computer on and proceed to step 2 to turn power off to all components in the device. The laptop computer will then be powered by the laptop computer battery.
2. Turn the master power switch located on the dashboard to off position (see figure 34). Note: Never turn the master power switch off when the Ames Software is within a menu. Always exit Ames Engineering software before setting the master power switch to the “Off” position,
3. If the system was powered by shore power, unplug the shore power input.

## **2.9 DATA COLLECTION**

### **2.9.1 General Background**

Procedures to be followed each day before and during data collection with respect to daily checks of vehicle and equipment, start-up procedures, software set-up for data collection, and using software for data collection are described in the following sections. The procedures to be followed for testing GPS sections are described in this section; some of the procedures for testing SPS and WIM sections are different than those for GPS sections, Section 2.10 describes the

procedures for SPS sections that differ from those for GPS sections, while section 2.11 describes the procedures for WIM sections that differ from those for GPS sections.

## **2.9.2 Daily Checks on Vehicle and Equipment**

### ***2.9.2.1 Introduction***

The operator should follow the “Daily Check List” form included in appendix B and perform all checks outlined at the start of day. It is not necessary to fill this form. This form can be placed inside a plastic cover, and operator can go through items listed and make sure that everything is in proper working condition. The operator should maintain a log book in the profiler to note problems identified when going through the checklist. Suggested format of the logbook is shown in form PROF-3, which is included in appendix B.

In order to maintain the laptop computer and various associated equipment, care must be taken to either cool or warm equipment to the operating temperature described in section 2.5.8 before turning on the master power switch. After turning on the master power switch, wait for about 15 minutes for the equipment to warm-up before performing daily checks.

The following equipment checks should be performed daily before collecting data:

1. Calibration check on profile height sensors.
2. Calibration check on texture height sensors.
3. Bounce test.
4. Visual check of the pavement surface temperature sensor.

Complete the form PROF-1, LTPP Profiler Field Activity Report, which is included in appendix B after performing the daily checks.

### ***2.9.2.2 Calibration Check of Profile Height Sensors***

The exact heights of the calibration blocks should have been entered into the software following the procedures described in section 2.5.9. As the entered values are saved, these values need not be checked every time a calibration check is performed. However, the operator must check to make sure the entered block heights are correct if the software is re-installed or updated.

Handle the calibration blocks with care. Surfaces of the calibration blocks are measured precisely, and if they are damaged they will not be suitable to perform the calibration check.

Do not enter, bounce or bump the vehicle, or lean on vehicle when this check is performed. The operator should adjust the laptop computer so that the screen can be seen from outside the vehicle. The calibration check is performed simultaneously on all three sensors. The following procedure should be followed for performing this test.

1. Park van on a level surface.

2. Before powering up the system, open the sensor covers and inspect the glass face of sensor. There is no need to clean sensor glass if the glass does not appear to be dirty. If glass appears to be dirty, clean glass face using the procedures described in section 2.5.2.
3. Power up the system, start laptop computer, and start Ames Engineering software using the procedure described in section 2.8.1. Press F2 key or select “Calibrate” to enter the Calibration Menu shown in figure 72.

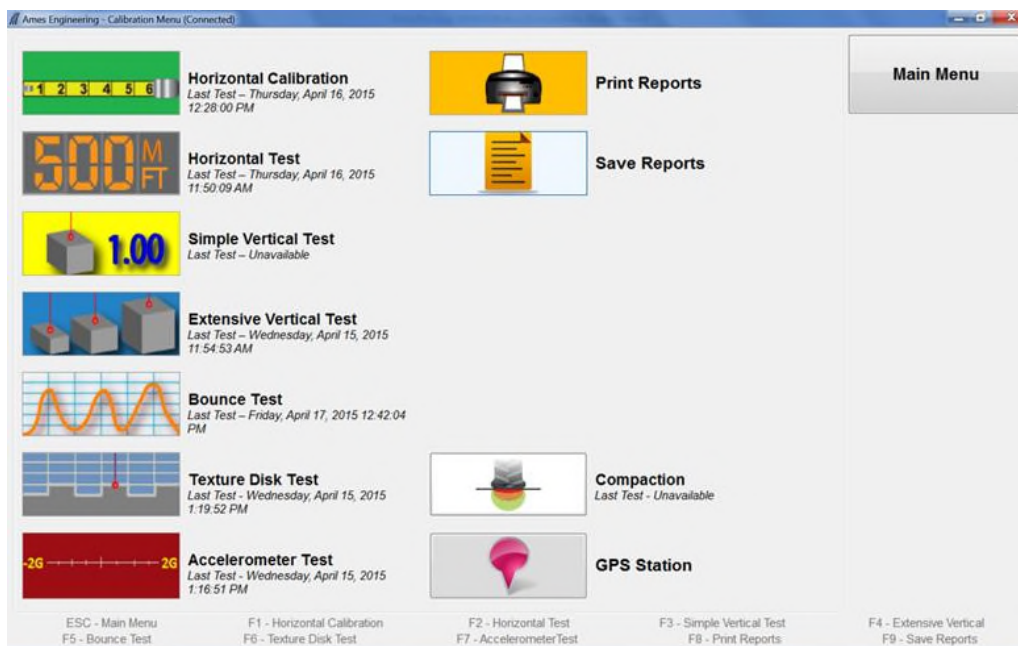


Figure 72. Calibration menu.

4. In the Calibration Menu, press F4 key or select “Extensive Vertical Test” and the Extensive Test menu shown in figure 73 will be displayed. All sensors shown on bottom right of the screen should have a check mark.
5. Clean the top of the calibration base plates as needed, and place a calibration base plate on the ground under each profile height sensor such that two screws on the base plate are parallel to the sensor bar and the red laser dot from the height sensor on each plate is centered on the plate (see figure 74). Place digital level parallel to the two screws that are parallel to the sensor bar and level base plate using these two screws and the digital level as a guide. Then place digital level perpendicular to the two screws that are parallel to the sensor bar and use other screw to level plate. The base plate is considered to be level when the reading on the digital level is less than or equal to  $0.05^\circ$  when placed parallel and perpendicular to the two screws that are parallel to the sensor bar.
6. Place a calibration target plate with the dull side facing up on top of each calibration base plate within the square marked on the base plate and place the 25 mm block behind the target plate to provide stability to the base plate (see figure 75).

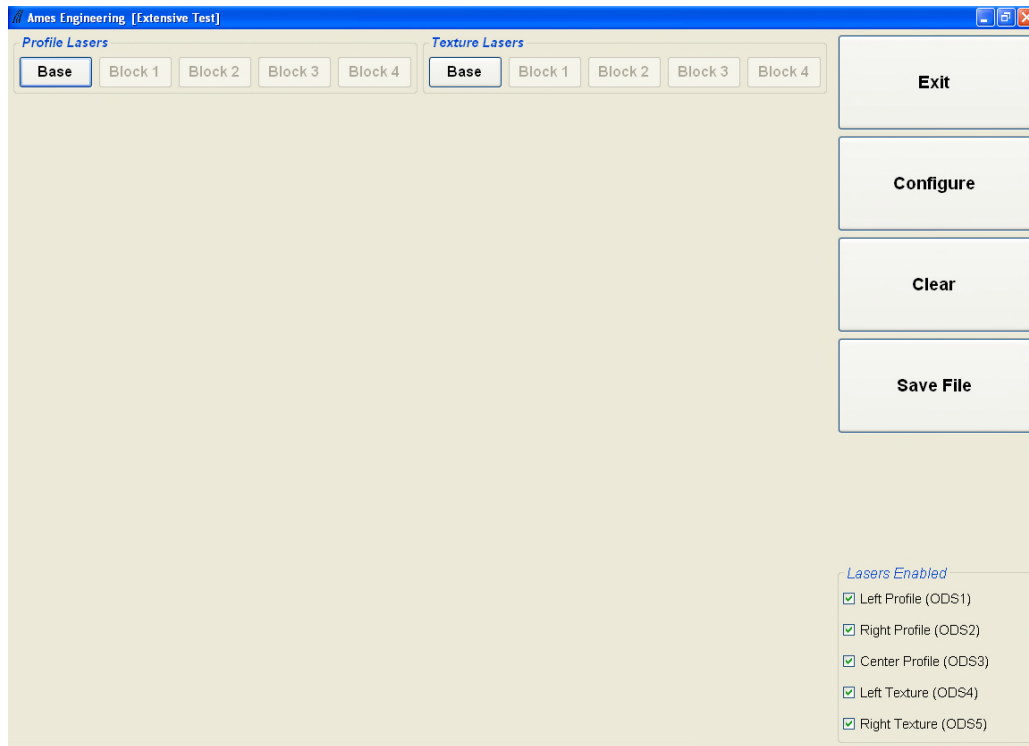


Figure 73. Extensive test menu.



Figure 74. Laser dot centered on base plate.



Figure 75. Readings taken on target placed on base plate.

7. In the software, under “Profile Lasers” select “Base” to take a measurement on top of the target that is placed on each base place. Six sets of measurements are taken on each target. Figure 76 shows an example screen capture after the measurements are obtained.

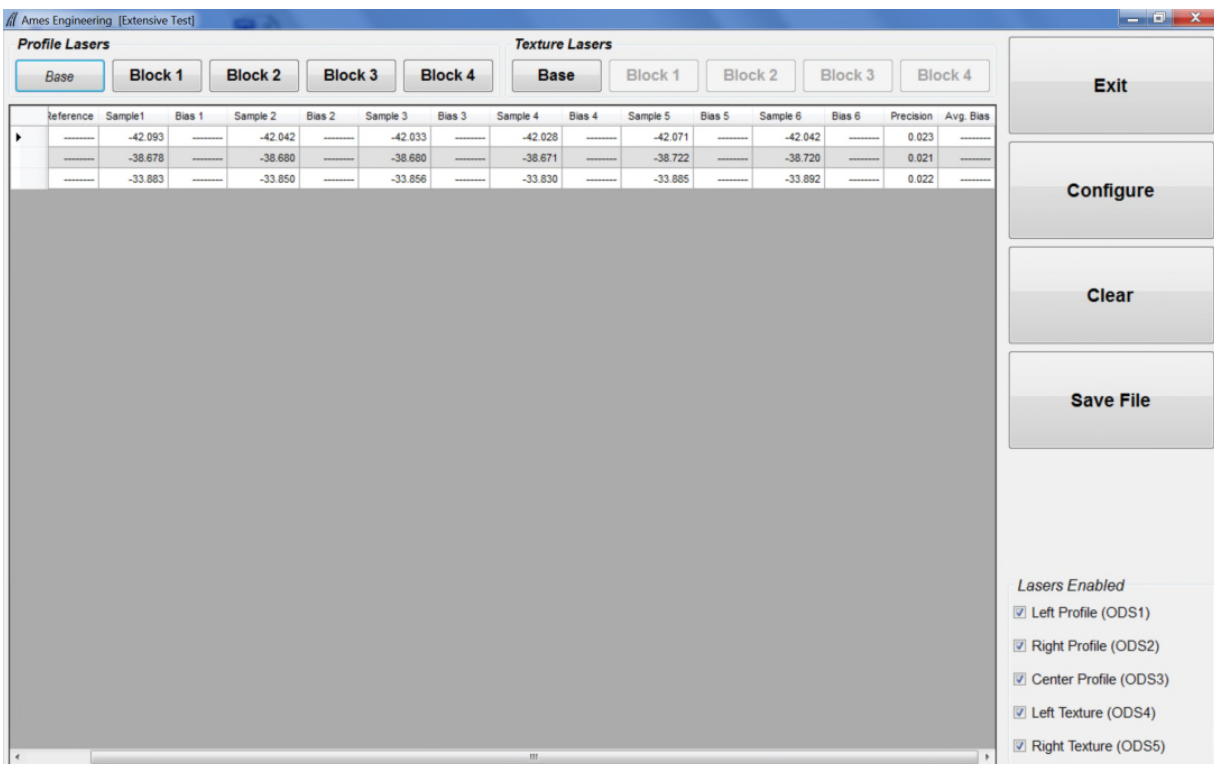


Figure 76. Display after obtaining measurements on target placed on base plate.

8. Remove calibration target plate from calibration base plate, place the 25 mm block associated with the sensor on top of base plate within the square marked on the base plate such that the block identifier faces the operator. Place calibration target on top of the block (see figure 77) with dull side facing up. Repeat procedure for the other two sensors. Thereafter in the software, under “Profile Lasers” select “Block 1” to take measurements on top of target. Six sets of measurements are taken on the target. Figure 78 shows an example screen capture after the measurements are obtained.



Figure 77. Readings being taken on target placed on the 25 mm block.

9. Check the average bias value (i.e., Avg. Bias in figure 78). The average bias value for each sensor must be within  $\pm 0.25$  mm. If bias values for all three sensors meet the specified criterion, select “Save” to save the results from the calibration check. Repeat test if average bias is outside this value. If the bias is still outside the specified tolerance, contact the RSC and decide on a suitable course of action.

### ***2.9.2.3 Calibration Check of Texture Height Sensors***

The calibration check on the texture height sensors should be performed immediately after the calibration check of the profile height sensors has been performed. Use following procedure to perform this check:

1. Place a calibration base plate on the ground under each texture height sensor such that two screws on the base plate are parallel to the sensor bar and the red laser dot on each plate is centered within the plate (see figure 74). Level the base plate following the procedure described in step 5 of previous section.



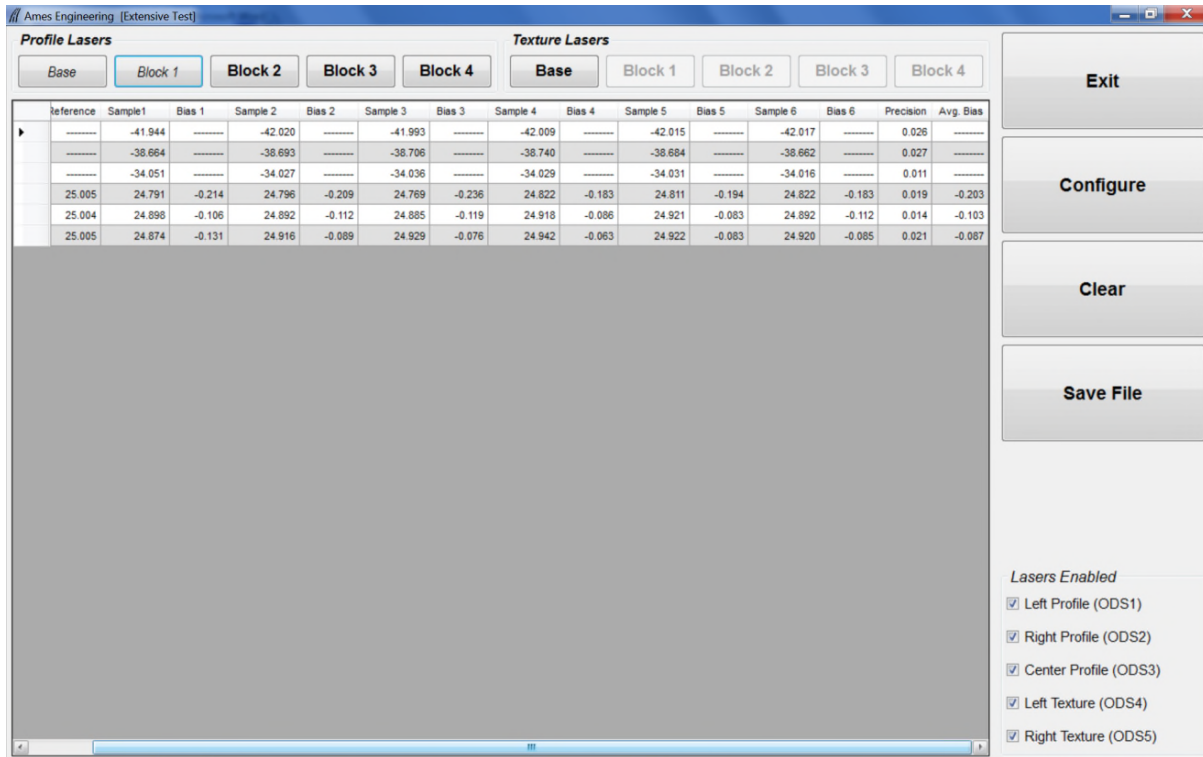


Figure 78. Display after obtaining measurements on target placed on base plate.

- Place a calibration target with the dull side facing up on top of each calibration base plate within the square marked on the base plate and place the 25 mm block behind the target plate to provide stability to base plate (see figure 75).
- In the software, under “Texture Lasers” select “Base” to take measurements on top of target that is placed on each base place. Six sets of measurements are taken on each target.
- Remove target from calibration base plate, place the 25 mm block associated with the sensor on top of base plate within the square marked on the base plate such that the block identifier faces the operator. Place target with dull side facing up on top of the block (see figure 77). Repeat procedure for the other sensor. Thereafter in the software, under “Texture Lasers” select “Block 1” to take measurements on top of target. Six sets of measurements are taken on the target by each sensor.
- Check the average bias value. The average bias value for each sensor must be within  $\pm 0.25$  mm. If bias values for both sensors meet the specified criterion, select “Save” to save the results from the calibration check. Repeat test if average bias is outside this value. If the bias is still outside the specified tolerance, contact the RSC and decide on a suitable course of action.



#### **2.9.2.4 Bounce Test**

The bounce test is performed to verify that profile height sensors and accelerometers in the profiler are functioning properly. This test must be performed immediately after the calibration checks on profile and texture height sensors have been performed. Vehicle engine may be on or off when performing this test.

The bounce test consists of two separate portions, a static test and a dynamic test. No movement is induced on the vehicle during the static portion of the test, while the vehicle is bounced while stationary during the dynamic portion of the test. The simulation speed used for the bounce test is 80 km/h, which means the profiler will collect data as if it was moving at 80 km/h. Profile data are recorded for the entire duration of the bounce test. The power to the equipment should have been provided at least for 15 minutes for the equipment to warm-up before performing this test.

The following procedure should be followed to perform the bounce test:

1. Park vehicle on a level surface. If the master power switch has been turned on, laptop computer turned on, and the Ames Engineering software started-up, go to step 2. Otherwise, power up equipment and start Ames Engineering software using the procedure described in section 2.8.1.
2. In main menu of Ames Engineering software (see figure 71) press F2 key or select “Calibrate” to go into the calibration menu (see figure 72).
3. In the calibration menu press F5 key or select “Bounce Test” icon to enter the bounce test menu. The bounce test screen shown in figure 79 will appear on the laptop computer screen. Under “Setup” that appears at the bottom right corner in this menu, check marks should be present in front of ODS1, ODS2, and ODS3. The “Distance” field should show a value of 1066.8 m. The distance of 1066.8 m means data will be collected over seven 152.4 m long sections during the bounce test. A beep will be heard at the start of the test, and thereafter at the end of each 152.4 m long segment for the duration of the test. The IRI of each 152.4 m segment will be displayed on the top of the graph corresponding to each sensor during this test.
4. Place a base plate under each profile height sensor such that the red laser dot appears at the center of the square that is marked on the base plate. Level the plate using the digital level as described in step 5 of section 2.9.2.2. Place calibration target with dull side facing up on the square marked on the base plate.
5. Select “Begin Test” in software (see figure 79) to start the test. The system will begin collecting pre run data during the filter warm-up process as shown in figure 80. Thereafter, the system will emit a beep to indicate the start of the bounce test. Do not induce any movement on the vehicle as data for the static portion of the bounce test is collected during this period. Wait until two more beeps are heard indicating that data have been collected over two 152.4 m long segments (Segments 1 and 2).

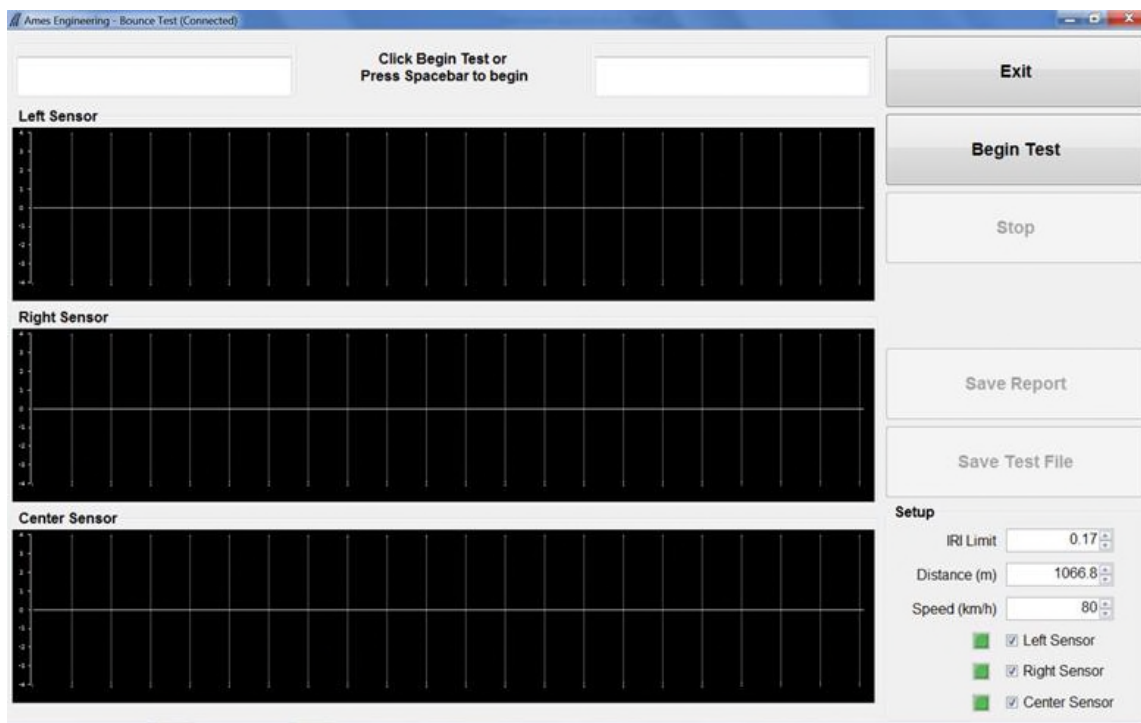


Figure 79. Bounce test start-up screen.

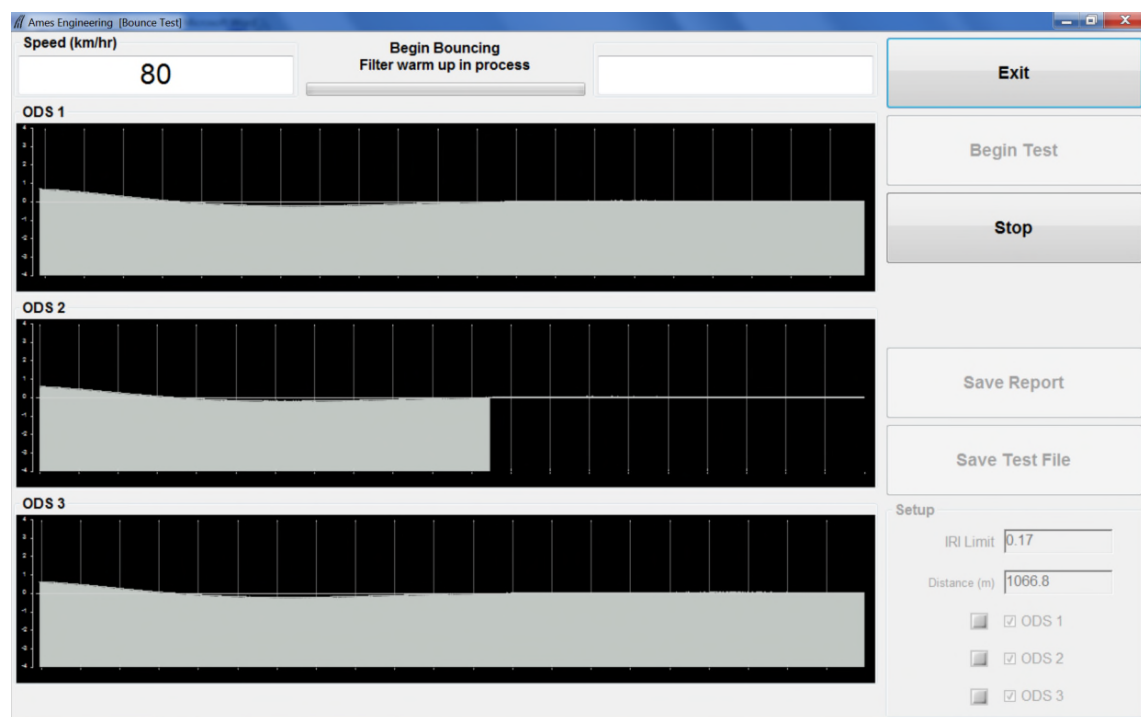


Figure 80. Filter warm-up in progress during bounce test.

6. Immediately after the third beep, the operator should get onto the rear bumper and start bouncing the vehicle such that a pitching motion is induced on the vehicle. This motion should pitch vehicle along the longitudinal direction with no sideways motion. Motion should correspond to a 25 mm displacement of rear bumper for each bounce (i.e., distance from highest position to lowest position is 25 mm during bouncing). The bouncing motion should continue until three more beeps are heard. Stop the bouncing motion thereafter. The system will automatically stop the bounce test after two more beeps are heard (i.e., the total simulated distance of 1066.8 m is reached). The screen will display the message “Filter cool down in process” (see figure 81), and thereafter will display the screen shown in figure 82 where the IRI value of each 152.4 m segment is displayed on the top of the graph for each sensor.

As the operator started bouncing the vehicle after the third beep, for the third 152.4 m long segment (Segment 3) that is from 304.8 to 457.2 m, the bouncing motion occurred only within a portion of this segment. For the fourth and fifth 152.4 m long segments (Segment 4 from 457.2 m to 609.6 m and segment 5 from 609.6 to 762 m) a bouncing motion was induced on the vehicle for the entire segment length. As the operator stopped the bouncing motion after the sixth beep, for the sixth 152.4 m long segment (Segment 6) that is from 762 to 914.4 m, the bouncing motion occurred only within a portion of this segment.

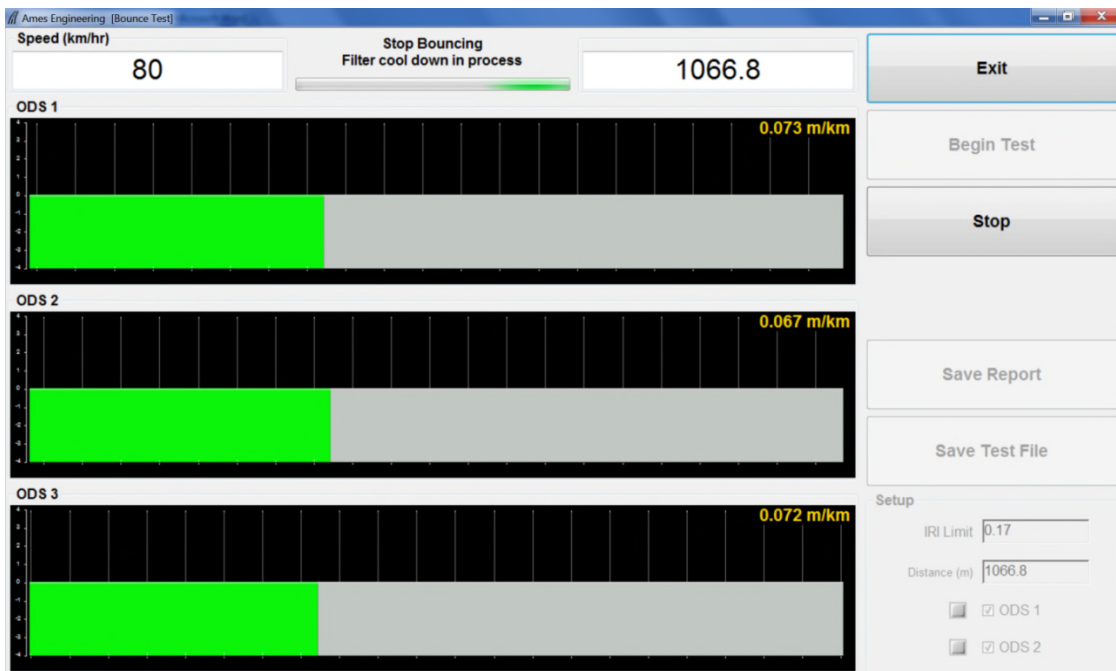


Figure 81. Filter cool-down process after bounce test is terminated.

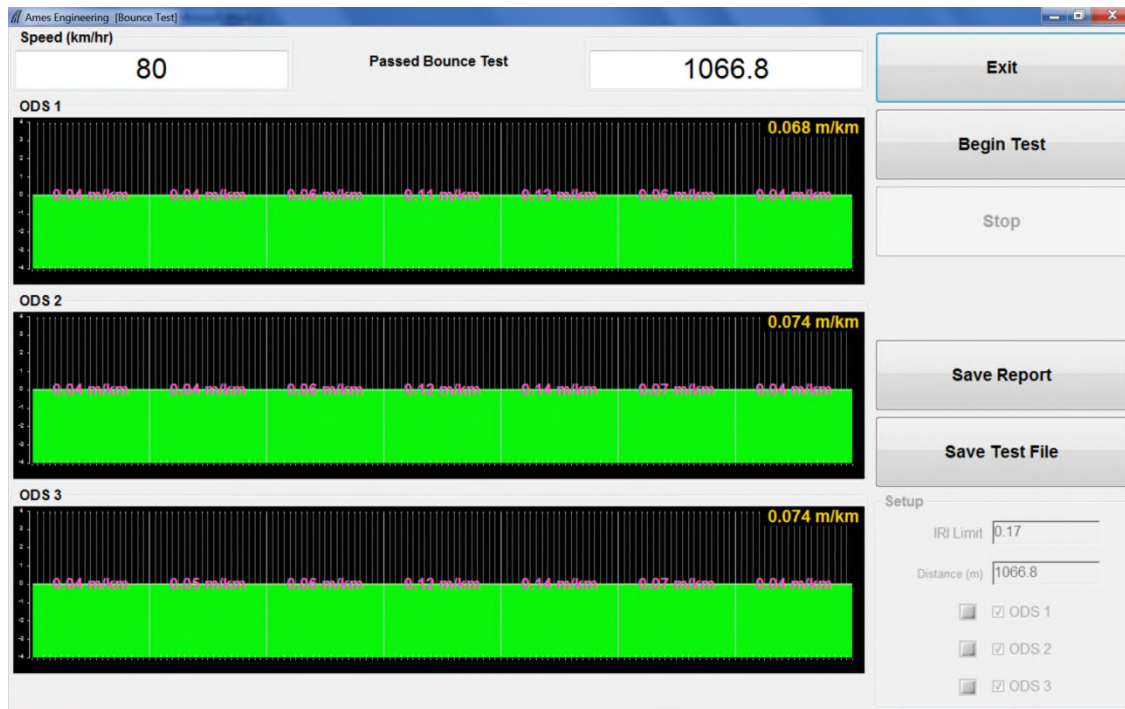


Figure 82. Display after completion of the bounce test.

7. Use the IRI of Segment 2 (i.e., from 152.4 to 304.8 m) to obtain the IRI corresponding to the initial static portion of the bounce test. Use the IRI of Segment 4 (i.e., from 457.2 to 609.6 m) to evaluate the IRI of the dynamic portion of the bounce test. Use the IRI of Segment 7 (i.e., from 914.4 to 1066.8 m) to obtain the IRI corresponding to the final static portion of the bounce test.

The IRI corresponding to Segment 2 (i.e., from 152.4 to 304.8 m) for all three sensors must be less than or equal 0.08 m/km. Also, for each sensor, the difference between IRI for segment 7 (i.e., from 914.4 m 1066.8 m) and IRI for segment 1 ((i.e., from 152.4 to 304.8 m) must be within  $\pm 0.01$  m/km. A sensor is considered to have passed the static portion of the bounce test if both criteria are met.

8. For each sensor (left, center and right), compute difference in IRI between the dynamic portion of the bounce and initial static portion of bounce test (i.e., deduct IRI obtained for Segment 2 from IRI obtained for Segment 4). If difference in IRI is less than or equal to 0.10 m/km, the sensor is considered to have passed the dynamic portion of the bounce test.
9. If all three sensors meet the criterion indicated in steps 7 and 8, go to step 10. If a sensor fails to pass the criterion indicated in step 7, step 8, or both steps, repeat the test until two consecutive tests pass the criterion. If one or both bounce test criterion indicated in steps 8 and 9 is not satisfied for two consecutive tests after repeating test several times, see the subsection “Failure of Bounce Test Criterion” at the end of this section.

Note: The passing of the bounce test must be based on meeting the requirements indicated in steps 8 and 9 and not on the message displayed by the software indicating “Passed Bounce

Test” (see top of figure 82) The software computes the IRI for the entire duration of the bounce test (over a distance of 1066.8 m) and then compares this IRI with the IRI that is present in the IRI Limit field, and displays “Passed Bounce Test” if the obtained IRI for entire run is less than the value in the IRI Limit field.

10. Press “Save Report” to save the IRI values from the bounce test. The report will indicate the IRI for each 152.4 m segment for all three sensors. The file name will have a date and time stamp.
11. Press “Save Test File” to save the data collected during the bounce test. The file name will have a date and time stamp.

**Failure of Bounce Test Criterion:** If the IRI during the initial static portion of the bounce test is greater than 0.08 m/km for a sensor, or if the difference in IRI for segment 7 and segment 1 is not within  $\pm 0.01$  m/km, or if difference in IRI between dynamic portion of bounce test and initial static portion of bounce test exceeds 0.10 m/km for a sensor, operator should contact RSC to decide on a course of action. If an error in the equipment is found and fixed, operator should re-evaluate profile data that were collected during the previous day. The IRI values obtained during the previous day as well as the profile data should be compared with those obtained from the last visit to that site. (Note: In ProQual 2014 Version 1.4.1.1, profile plots for data collected during two visits can be viewed individually, but the plots cannot be overlaid. This feature may be available in future versions of ProQual.)

If data problems are suspected, such sections should be re-profiled after equipment repairs.

### ***2.9.2.5 Pavement Temperature Sensor***

Open the protective cover of the temperature sensor (see figure 17), and visually look at the housing of the sensor to see if any damage is noted. Also check the protection window at the bottom of sensor for cracks.

## **2.9.3 Data Collection**

### ***2.9.3.1 Attaching Camera***

Mount the camera, connect cable from camera to a USB port in laptop computer, and power-up the system using the procedures described in section 2.8.1. Properly aim the camera using the procedures described in section 2.7.5.

### ***2.9.3.2 Entering Header Information***

Before collecting data at a site, the operator has to enter header information related to the site into the software. This section describes procedures to be followed to enter header information for a site into the software, and also describes procedures to be followed to get the system ready for data collection. Use the following procedures to enter header information at a site.

1. In the Ames Engineering software start-up screen (see figure 71) press F3 key or select “Start” button. The message “Make sure the door of the surface sensor is open before beginning collection” will be displayed. Make sure the protective cover covering the pavement surface temperature sensor is open and sensor covers for the profile/texture height sensors are open and select “OK” button and the Header Menu to enter file name to save data and other header information will be displayed (see figure 83).
2. The following items on the right side of the menu should have check marks:
  - ODS1: Profile should be checked.
  - ODS2: Profile should be checked. If using the horizontal photocell to initiate data collection, Autotrigger should be checked.
  - ODS3: Profile should be checked. If using the vertical photocell to initiate data collection, Autotrigger should be checked.
  - ODS4: Texture should be checked.
  - ODS5: Texture should be checked.
  - PSM: Ambient, Surface, and GPS should be checked.

A check mark indicates the sensor is enabled for data collection. Sensors that are available for use will show a dark green status indicator, and sensors that have been enabled will show a bright green status indicator.

**Output File**

File name: 360000CA

Suffix: ☐ None ☐ Date: 4/29/2015 ☐ Number: 1 Next Increase: 1

Full file path: C:\Profiles\360000CA.P01.ard

**Start/Stop**

Start Method: PHOTOCELL Stop Method: DISTANCE Stop Distance: 152.4 Units: Meters Direction: ☒ Positive ☐ Negative

Header Format: LTPP

Site Identification: 360000CA Operator and Driver: JD/JD Vehicle Identification: 830412

Road Description: I-990 Lane Measured: OUTSIDE Travel Direction: NORTH

Horizontal Offset (m): 0. Tape Width (mm): 50.8 Beginning Description: MP\_5.0

Ending Description: MP\_5.1 Beginning Station: 0. Ending Station: 152.4 Surface Type: P-CC

Surface Condition: FAIR Cloud Conditions: CLEAR Other Weather Conditions: STEADY CROSSWIND Filter Wavelength (m): 100.0

Spike Tolerance (mm): 5.0 Air Temperature: Surface Temperature:

**Return to Main** **Start Collection**

**ODS 1 (SLS5200)**

☒ Profile OK

**ODS 2 (SLS5200)**

☒ Profile OK

☐ Auto Trigger OK

**ODS 3 (SLS5200)**

☒ Profile OK

☒ Auto Trigger OK

**ODS 4 (Optocator180)**

☒ Texture OK

**ODS 5 (Optocator180)**

☒ Texture OK

**PSM**

☒ Ambient Connected (16.9°C) ☒

☒ Surface Connected (38.8°C) ☒

☒ GPS ☒

Link Quality: DGPS 42.99976 N 78.85766 W

Figure 83. Header menu.

A sensor that is not available for use will show a dark red light. If the status indicator is red that means the DAU or the laptop computer is not getting the data collected by that sensor. If the status indicator is orange, that means there is a problem with that sensor reading data, such as the protective window has not been opened for a height sensor. If a sensor is enabled and is having an error, a blinking red light will appear next to the sensor name. The operator must investigate and resolve problem(s) with a sensor if present.

The software will not allow the operator to continue data collection if any of the enabled sensors do not have a green status with the exception of the GPSR. Due to possible gaps in satellite coverage, it is possible to collect data without the GPSR receiving data. The device will start collecting GPSR data in the middle of the run if the link is established later.

3. If a header file has already been created for the site during a previous site visit, the previously created header file can be loaded. This will save some time in entering the header data. To load a previously created header file, select “Load” and then browse to select and load the appropriate header file. Some fields in the loaded header information will have to be changed to reflect current data collection. The fields that need to be changed or updated are: File Name, Operator/Driver, Surface Condition, and Other Weather Conditions. However, it is a good practice to check all header fields to make sure they are correct.

If a previously created header file for the site is not available, all header fields must be entered and checked to ensure that parameters that are appropriate for the current data set are shown in the header.

4. Select browse button next to “File name” and select the directory to store the data. If necessary make a new directory.
5. In the field “File Name” enter the file name to record the data. The default file name that is shown in this field is the file name from the last data run. Use the file naming conventions for GPS and SPS sites indicated in section 2.7.3 to determine and enter an appropriate filename. If the site is a WIM site, decide on an appropriate file name using the guidelines indicated in section 2.11
6. The parameters/settings for the fields under suffix should be set as follows:  
None: Should not be checked.  
Date: Should not be checked.  
Number: Should be checked and set to 1.  
Next Increase: Should be set to 1.
7. Start Method: The start method for data collection should always be Photocell. From drop-down menu select PHTOCELL. The other option available in this field is PENDANT. If PENDANT is selected, data collection is initiated manually by pressing F3 key in the keyboard. Start method PENDANT is not used for normal LTPP data collection.
8. Stop Method: Stop Method should always be DISTANCE. From drop-down menu select DISTANCE. The other options available in this field are PHOTOCCELL and PENDANT. The PHOTOCCELL option is used when data collection is terminated using the Photocell, while



PENDANT option is used when data collection is terminated manually. If PENDANT option is used, data collection is terminated manually by pressing the F4 key in the keyboard. Stop methods PHOTOCELL or PENDANT are not used for normal LTPP data collection.

9. When “Distance” is selected as the Stop Method, a field called “Distance” appears to the right of “Stop Method”. The distance over which data must be collected (in meters), starting from the start of the section, must be entered into this field. For GPS sites the distance is always 152.4, while for WIM sites the distance is always 305. For a SPS site determine the value of distance using the procedure described in section 2.10.2, and enter the value in this field.
10. Units should be set to Meters.
11. Direction: “Positive” should be checked.
12. Header Format: Header format should show LTPP.
13. Site Identification. Type the site identification in this field (e.g., 451024). Follow procedure described in steps 1 and 2 of section 2.7.3 to obtain the appropriate six-digit code for the Site ID. For WIM sites follow the procedure specified in section 2.11.
14. Operator/Driver: Operator and driver should be identified by a two digit character for each, which should be first letter of their first and last name. Operator and driver names should be separated by a backslash and typed in capital letters (e.g., CK/RS). If profiler is used as a one person operation, operator and driver name would be the same (e.g., CK/CK).
15. Vehicle ID: The Ames Engineering vehicle identification number assigned to the device should be entered in this field (see table 1). Once this parameter has been set to the correct value, it does not need to be changed when the header screen is brought up subsequently.
16. Road Description: Type route number where section is located (e.g., I-88). All letters should be capital.
17. Lane Measured: The valid entries for the field are INSIDE or OUTSIDE. Outside lane is the lane adjacent to shoulder at right edge of road. Select appropriate lane from the drop-down menu. For nearly all LTPP sections, lane measured is OUTSIDE.
18. Travel Direction: Select appropriate lane direction (NORTH, EAST, SOUTH, or WEST) by using the drop-down menu.
19. Horizontal Offset: The value for horizontal offset should be 0 (zero) for all sections. This value has to be set only once, as the system will retain the specified value when the header screen is brought up subsequently.
20. Tape Width: Enter the width of the reflective tape that is placed on the pavement in millimeters if data collection is initiated using the vertical photocell. Enter the width of the

reflective tape that is on the cone in millimeters if data collection is initiated using the horizontal photocell.

21. Beginning Description: Enter the milepost at the beginning of the section in this field. If the milepost is not known enter NONE in this field.
22. Ending Description: This field should indicate NONE.
23. Beginning Station: This field should be blank.
24. Ending Station: This field should be blank.
25. Surface Type: Valid entries for road surface type are A-CC for AC surfaced pavements and P-CC for PCC surfaced pavements. Use drop-down menu to select an appropriate entry.
26. Surface Condition: Describes surface condition of pavement; valid entries are V. GOOD (Very Good), GOOD, FAIR or POOR. Select an appropriate entry by using the drop-down box. Severity levels that are described correspond to the definitions given in the LTPP Distress Identification Manual<sup>(7)</sup>.
  - (a) V. GOOD: Pavement does not show any distress.
  - (b) GOOD: Pavement exhibits few visible signs of surface deterioration. AC surfaced pavements may show low severity cracks, and PCC surfaced pavements may show low severity cracks and spalling.
  - (c) FAIR: Typical distresses on AC surfaced sections can include the following distresses in a low to medium severity: rutting, block or edge cracking, transverse and longitudinal cracking, and patching. Typical distresses on PCC pavements can include the following distresses in a low to medium severity: spalling, transverse and longitudinal cracking, faulting, and patching.
  - (d) POOR: Pavements in this category have deteriorated to such an extent that they affect the speed of free-flow traffic. Typical distress on AC surfaced sections includes the following distresses in a medium to high severity: rutting, transverse and longitudinal cracking, alligator cracking, and potholes. Typical distress on PCC surfaced pavements can include the following distresses in a medium to high severity: spalling, transverse and longitudinal cracking, faulting and patching.
27. Cloud Conditions: Valid entries for this field are CLEAR, P. CLOUDY (Partly Cloudy), or CLOUDY. Use the following guidelines: Clear – sunny sky, Cloudy – sun cannot be observed, P. Cloudy – sun is sometimes covered by clouds. Select an appropriate entry using the drop-down menu.
28. Other Weather Conditions: Valid entries for this field are CONDITIONS OK, STEADY CROSSWIND, WIND GUSTS, HOT AND HUMID, HAZY, LOW SUN ANGLE. Select an appropriate entry using the drop-down menu.
29. Filter wavelength: Filter wavelength should be set to 100. Once this value is set, it should not be changed again as the system will retain this value.

30. Spike Tolerance: Enter 5.0 in this field.
31. Air Temperature: The Air Temperature field is used to manually enter an ambient temperature reading if the ambient temperature sensor is not enabled because it is not functioning correctly. Do not enter a value in this field if the air temperature sensor is functioning satisfactorily.
32. Surface Temperature: The Surface Temperature field is used to manually enter a pavement surface temperature if the pavement surface temperature sensor is not enabled because it is not functioning correctly. Do not enter a value in this field if the surface temperature sensor is functioning satisfactorily.
33. After all header information has been entered, check to make sure that all fields are correct, and select “Save” button to save the entered header information.

### **2.9.3.3 Collecting Data**

After header information has been entered and equipment has warmed-up sufficiently (allow 15 minutes after turning main power switch on for equipment to warm-up), device is ready to collect data. The following procedures should be followed to get an acceptable set of runs at GPS and SPS sites. Some of the procedures for profiling WIM sites are different from the procedures presented in this section. See section 2.11 for procedures for profiling WIM sections.

1. While in the Header Menu, press F1 key or select “Start Collection”. A screen showing the vehicle speed, distance, and data collection status in real time for the three selected profile or texture sensors will be displayed. Tabs on this screen can be used to display either profile data (ODS1, ODS2, and ODS3) or texture data (ODS4 and ODS5). The data for the sensors are displayed in real time as a white shaded trace. A pop-up window will appear on top of the display showing the camera preview.
2. Attain a constant test speed of 80 km/h at least 300 m before beginning of test section and align vehicle along wheel paths. As described in section 2.7.4, a speed different from 80 km/h may be used depending on site conditions. The profile data collected for a distance of 152.4 m before the start of the section and texture data collected for a distance of 30 m before the start of the section will be saved in the data file. If sufficient pre-run data is not available before the section due to a short available lead-in distance, the software will fill the missing data with a ramp to the first point.
3. Just before sign A located 150 m in advance of the start of the test section, press F5 key or select “Enable Autotrigger”. (Note: The lead in white stripe is located across the lane in line with Sign A. The F5 key must be pressed just before this stripe. If the Sign A or the lead in white stripe is not present in front of the section, press F5 key approximately 150 m before the start of the section.). The camera window showing the camera preview will appear as a window on the screen, and the camera will start to obtain images at 10 m intervals. An orange frame will appear around the preview window when an image is obtained. The photocell is now armed and will be looking for a reflective mark on pavement surface or cone with reflective

marking depending on photocell that was selected to begin data collection. Note: If the lead in stripe triggers the photocell, arm the photocell just after passing the lead in stripe.

If the photocell is triggered by an object that is located on the pavement between the white stripe that is 150 m before the start of the section and the start of the section, arm the photocell after this object is passed. If at least five images cannot be obtained prior to the start of a section, use the horizontal photocell to collect data. Using the horizontal photocell will result in 15 images being obtained prior to the start of the test section.

4. When the photocell detects the reflective tape, five rapid beeps will be heard and the profile/texture plot on the screen will become a solid green color to indicate that data are now being collected and recorded (see figure 84). The distance measurement value will increase as the profiler moves forward.



Figure 84. Screen after initiating data collection.

If the vertical photocell is not triggered by the reflective tape, clean photocell and repeat run and see if the photocell triggers. If the vertical photocell still fails to trigger, the operator should adjust sensitivity control for the photocell and see if the photocell will trigger. If this is not successful, the operator should use the horizontal photocell. Follow procedure described in step 2 of section 2.9.3.2 to select horizontal photocell to initiate data collection.

When profiling a SPS project, the buzzer will emit a short chirp whenever a white reflective mark is detected at the beginning of a SPS test section.

5. The buzzer will emit five rapid beeps at the end of the section after data have been collected for the specified distance. The buzzer will then emit long beep after 152.4 m of post-run data have been collected after the end of the section. Thereafter, the End of Run window will appear on the screen (see figure 85).

End of Run Summary

Note **Diagnostic Log**

Collection Summary

| 0 Encoder Errors      |                       | 0 Speed Errors        |                       |
|-----------------------|-----------------------|-----------------------|-----------------------|
| <b>ODS 1</b>          | <b>ODS 2</b>          | <b>ODS 3</b>          | <b>ODS 4</b>          |
| 0 Laser Alarms (0.0%) | 0 Laser Alarms (0.0%) | 0 Laser Alarms (0.0%) | 4 Laser Alarms (0.0%) |
| 0 Accel Alarms        | 0 Accel Alarms        | 0 Accel Alarms        | 0 Temp Alarms         |
| 0 Temp Alarms         | 0 Temp Alarms         | 0 Temp Alarms         | 0 Temp Alarms         |
|                       |                       | <b>ODS 5</b>          |                       |
|                       |                       | 2 Laser Alarms(0.0%)  |                       |
|                       |                       | 0 Temp Alarms         |                       |

☒ RUN OK  
☐ PAVEMENT SURFACE DAMP  
☐ TRAFFIC CONGESTION SPEED VARIABLE  
☐ DIFFICULT TO MAINTAIN CONSTANT SPEED – GRADE  
☐ DIFFICULT TO MAINTAIN WHEEL PATH LOCATION  
☐ Other

Save

Figure 85. End of run window.

6. Bring vehicle to a stop at a suitable location to evaluate alarms and error messages if any, enter end of run comment, and save data to hard disk.

The following information is displayed in the End of Run window for ODS1 (left profile sensor), ODS2 (right profile sensors), and ODS3 (center profile sensors):

- Laser alarms (number and percentage).
- Accelerometer alarms (number).
- Temperature alarms (number).

The following information is displayed in the End of Run Menu for ODS4 (left texture sensor) and ODS5 (right texture sensor):

- Laser alarms (number and percentage).
- Temperature alarms (number).

This screen will also display errors associated with the encoder and speed.

If error messages are present in the diagnostic log, then the Diagnostic tab on the window will be red (see figure 86). Selecting this tab will display all error messages sent by any sensor in the device.

Evaluate the laser alarms, accelerometer alarms, temperature alarms, and the information in the diagnostic tab according to the procedures presented in section 2.9.3.4 and 2.9.3.5.

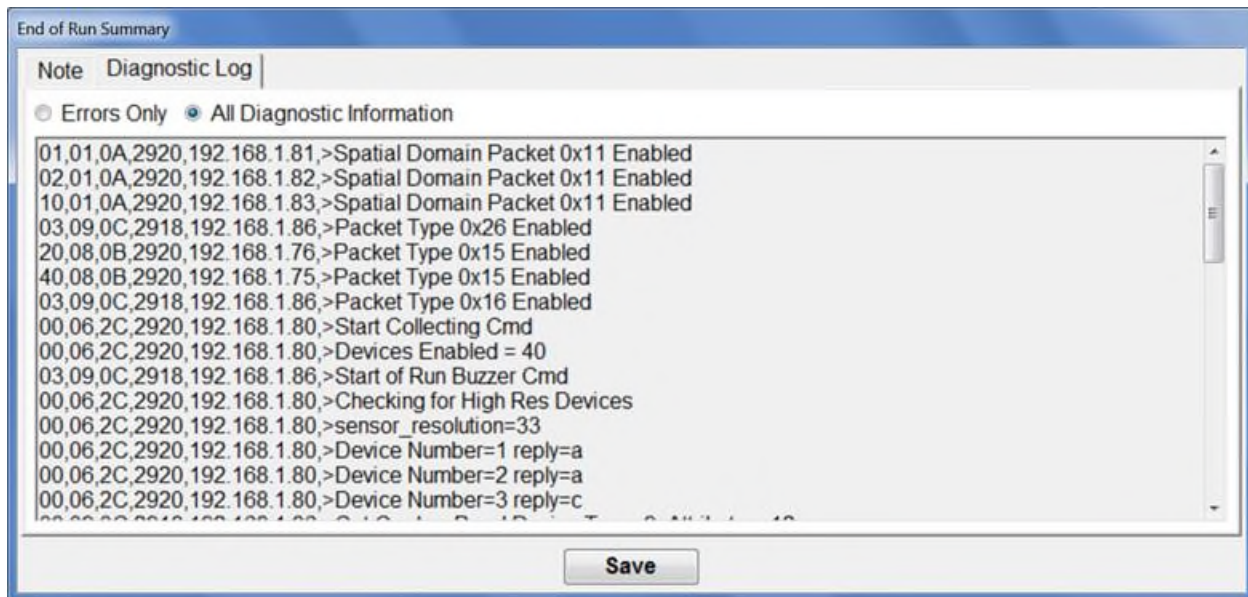


Figure 86. Diagnostic log.

7. Evaluate the end of run comments that are displayed, which are:

- RUN OK.
- PAVEMENT SURFACE DAMP.
- TRAFFIC CONGESTION: SPEED VARIABLE.
- DIFFICULT TO MAINTAIN CONSTANT SPEED: UPGRADE.
- DIFFICULT TO MAINTAIN WHEEL PATH LOCATION.
- LATE PHOTOCCELL INITIATION
- Other.

(Note: If photocell initiates late, discard that run and obtain an additional run. Do not save a run with the comment "LATE PHOTOCCELL INITIATION".)

8. Use guidelines presented in section 2.7.10 to select an appropriate end of run comment. End of run comment should only be based on conditions during the profile run. If one of the displayed comments is appropriate for the profile run, select appropriate comment and select "Save" button. If none of the displayed comments are appropriate for the data collection run and operator wants to type a different comment, select "Other" and type an end of run comment using capital letters and select "Save" button.
9. After the file is saved, laptop computer screen will show the Header screen, with the last digit of file name incremented by one.

Review obtained images if the operator has elected to follow option 2 for obtaining images as described in section 2.7.5.1.

10. Collect four more runs at the test section using steps 2 through 9 described above. Before starting a data collection run look at the right side of the header screen to make sure that all sensors are enabled and all sensors are showing the green status indicator.
11. After collecting five error free runs, follow procedures described in section 2.9.4 to use ProQual to evaluate all of the collected data.
12. If the collected five runs are acceptable go to step 14. If not, obtain additional runs as described in section 2.9.4.3, and review these runs using ProQual. Complete form PROF-1, LTPP Profiler Field Activity Report, which is included in appendix B after reviewing the data.
13. Backup Data: Use Windows Explorer to backup data to a flash drive. Ames Engineering data are saved in a file with extension ARD, and this file needs to be backed up. All files generated by ProQual when the profile data were processed should also be backed up.
14. Operator should verify that the form PROF-2, Status of Regions Test Section, which is included in appendix B is filled before leaving test site.

#### ***2.9.3.4 Evaluating Error Messages***

##### **Errors Associated with Profiling Sensors**

The following information is displayed in the End of Run window for ODS1 (left profile sensor), ODS2 (right profile sensors), and ODS3 (center profile sensors):

- Laser alarms (number and percentage).
- Accelerometer alarms (number).
- Temperature alarms (number).

**Laser Alarms:** Laser alarms indicate the number of data points that have invalid height sensor readings. An invalid height sensor reading occurs when the detector in the height sensor fails to detect the laser point on the pavement surface. For profile data, several measurements obtained by the height sensor are used to compute a profile data point at 25 mm intervals. The profile data point is tagged as having a laser alarm if one or more height sensor readings that are used to compute the profile data point have an error. When computing the profile at a point, an invalid height sensor reading is replaced by the previous reading. Laser alarms should normally be less than 1 percent for a profile height sensor.

**Accelerometer Alarms:** Accelerometer alarms indicate the number of readings where an accelerometer reading was not properly received. An accelerometer alarm occurs when the acceleration measured by the accelerometer goes outside the  $\pm 5g$  range that can be measured by the accelerometer or if the zero measurements of the accelerometer are not within the normal range. An accelerometer alarm will cause the laptop computer to beep. A warning message will also appear on the screen. Accelerometer alarms should not occur normally. There is a possibility for accelerometer alarms to occur on an extremely rough pavement that will cause the



accelerometers to go outside the  $\pm 5g$  range. However, such occurrences should be very rare. If an accelerometer alarm occurs, and the pavement is very rough, collect data at a lower speed to see if accelerometer alarms still happen. If this is the case, there may be a problem with the accelerometer.

**Temperature Alarms:** Temperature alarms indicate the number of readings where the temperature inside the laser box is outside the limits recommended by Ames Engineering. As indicated in section 2.5.1, Ames Engineering software monitors the temperature inside each individual sensor box that houses a profile height sensor. If a temperature alarm occurs, go to the start-up screen of Ames Engineering software and see if the displayed temperatures are close to the upper or lower limit of the temperatures indicated by Ames Engineering (see section 2.5.1). If the displayed temperatures are at or outside the recommended temperature range, data collection may have to be postponed to a suitable time when the temperature is satisfactory for data collection.

### **Errors Associated with Texture Sensors**

The following information is displayed in the End of Run Menu for ODS4 (left texture sensor) and ODS5 (right texture sensor):

- Laser alarms (number and percentage).
- Temperature alarms (number).

**Laser Alarms:** The macrotexture data are sampled at 62.5 KHz frequency. The number of laser alarms for a texture height sensor indicates the number of individual readings in the section that had invalid data. Laser alarms should normally be less than 5 percent for a texture sensor. An invalid height sensor reading occurs when the detector in the height sensor fails to detect the laser point on the pavement surface. The raw data file that is saved will have all locations with invalid data tagged as having invalid data.

When the collected data are used to compute the MPD values using the Ames Engineering software or when the data is exported through the DLL to be used in ProQual, the invalid data points are replaced. The following procedure is used to replace the invalid data points:

1. The invalid data point (point  $n$ ), the point before the invalid data point (point  $n-1$ ), and the point after the invalid data point ( $n+1$ ) are all replaced. This procedure was adopted as there is a possibility that the points adjacent to an invalid data point could also be erroneous.
2. A linear interpolation is performed between the data value at  $n-2$  and  $n+2$  to select data values to use for points  $n-1$ ,  $n$ , and  $n+1$ .
3. The replaced data values are used to create a macrotexture profile that do not have invalid data points, and this profile is used to compute the MPD by the Ames Engineering software and also exported through a DLL to ProQual.

Sometimes a series of invalid readings can appear in a row. An interpolation technique is used in such a case to replace all invalid data points. Interpolation is performed between the second

reading before the first invalid data point and the second reading after the last invalid data point to fill in the invalid data points.

Temperature Alarms: Temperature alarms indicate the number of readings where the temperature within the interface box for texture height sensors is outside the limits recommended by Ames Engineering. As indicated in section 2.5.1, Ames Engineering software monitors the temperature inside the interface box that processes macrotexture data. If a temperature alarm is displayed, go to the start-up screen of Ames Engineering software and see if the displayed temperature for the texture sensors is close to the upper or lower limit of the temperatures indicated by Ames Engineering (see section 2.5.1). If the displayed temperatures are at or outside the recommended temperature range, data collection may have to be postponed to a suitable time when the temperature is satisfactory for data collection.

## **Encoder Errors**

An encoder error is detected if the pulses from the encoder are coming in at a rate that is faster than the fastest speed that has been allowed for the device, which is about 160 km/h.

## **Speed Errors**

A speed error is an error detected by the DAU indicating that synchronization signals are not being sent out properly to the sensors and the system is getting behind because the DMI signal is indicating another sample is required before the last synchronization signal was sent out. An encoder error could cause a speed error to occur, but other problems on the RS485 serial bus could cause a speed error as well. For example if the sensor cable that contains both Ethernet and RS485 signals has the RS485 connections shorted out intermittently would cause a speed error.

### ***2.9.3.5 Evaluating Diagnostic Messages***

If error messages are present in the diagnostic log, then the Diagnostic tab on the End of Run window will be red. Selecting this tab will display all error messages sent by any sensor in the device (see figure 86).

The error messages consist of a comma delimited string that each sensor sends during data collection when an error condition is encountered. These error messages are stored in the ARD file. Examples of diagnostic messages are shown below:

```
01,01,0A,1,192.168.1.136,>Local IP address:192.168.1.136
01,01,0A,2,192.168.1.136,>Ethernet interface initialized
01,01,0A,10,192.168.1.136,!ERROR IN UDP PACKET CRC
```

Each error message field starts with a ">" for informational messages and a "!" for error messages. Each field in the definition is separated by a comma. Informational messages will include sensor calibration and settings information from each sensor and other start-up messages at the start of each run. The format for this string is

- Device address (see table 3).

- Device type.
- Device attributes.
- Seconds since boot.
- IP address.
- Log string.

Table 3. Device addresses.

| Device Address | Module        |
|----------------|---------------|
| 0x01           | ODS #1 Sensor |
| 0x02           | ODS #2 Sensor |
| 0x03           | PSM Modulus   |
| 0x10           | ODS #3 Sensor |
| 0x20           | ODS #4 Sensor |
| 0x40           | ODS #5 Sensor |

Some error messages are problems that have been corrected, like a UDP Ethernet packets that were resent and will have no effect on the data. A message indicating a Trigger Sequence Error means that the trigger message sent on the serial 485 bus did not get to the intended sensor because there was a skip in the trigger sequence numbers. This is not a correctable error because the sample was never taken. When this happens, that single sample will be bridged with the last good sample to fill in the space where this sample should have been taken. This could happen because of noise on the RS485 communication lines. A sample or two like this is not likely to have any effect on the results generated by these files, but if 10 or more samples are included in a run it is probably an indication that there is a problem with the cabling to that sensor or a communications driver in the sensor is damaged. In case of such an event, contact Ames Engineering to discuss the diagnostic messages.

## 2.9.4 Evaluating the Collected Data Using ProQual 2014

### 2.9.4.1. ProQual 2014 Software

ProQual 2014 software<sup>(6)</sup> is used to perform quality control checks in the field on the data collected by the Ames device. The software should be used in the Field Mode to perform quality control checks in the field. This software is used in the Office Mode in the office to perform quality assurance checks on the data, select the five runs whose data and computed parameters are uploaded to the PPDB, generate the files to be uploaded to the PPDB, and prepare files that are to be stored in AIMS.

Before loading the collected data (i.e., ARD files) to ProQual, make sure the sequence visit identifier in the file name is correct (see Section 2.7.3 for the file naming convention). The following information will be displayed in ProQual for each data collection run when the ARD files containing the data are read prior to loading:

- The header information and the End of Run comment that were entered into the Ames Engineering software are shown. This information can be reviewed and corrections can be made if needed.

- The date, time, and average speed of the vehicle will be displayed. The displayed speed is the average speed within the test section (i.e., average speed over the distance when photocell triggers at the start of the section and the Stop Distance value that is entered into the Ames Engineering software header). The time shown is the time when “Collect Data” was selected in the Ames Engineering software before the start of the section (see section 2.9.3.3).
- The profile count for “Pre”, “Run” and “Post” are displayed. The ARD file contains profile data for a distance of 152.4 m before the start of the section (i.e., pre-run), the data collected within the section (i.e., run), and data collected for a distance of 152.4 m after the end of the section (i.e., post-run). The software will display the profile count for each sensor (i.e., left, right, and center) for the pre-run, run, and post-run. The profile count is the number of 25 mm interval data points. For any section that is profiled, the profile count for “Pre” should be 6096 if data collection software was initiated at least 152.4 m before the start of the section; this value could be less if data collection software was initiated at a distance less than 152.4 m before the start of the section. For any section that is profiled, the profile count for “Post” should be 6096. For a GPS section, the profile count for “Run” will be approximately 6096. The profile count for “Run” for a SPS section will vary depending on the length over which data were collected.
- The texture count for “Pre”, “Run” and “Post” are displayed. The ARD file contains texture data for a distance of 30 m before the run (i.e., pre-run), data collected within the section (i.e., run), and data collected after the run (i.e., post-run). The software displays the texture count for each sensor (i.e., left and right) for the pre-run, run, and post-run. The texture count is the number of 0.5 mm interval data points. For any section that is profiled, the texture count for “Pre” and “Post” should be approximately 60,000. For a GPS section the texture count for “Run” will be approximately 304,800. The texture count for “Run” for a SPS section will vary depending on the length over which data were collected. The percentage of dropouts computed from the time based data for each sensor is displayed. The dropout percentage is computed using data collected for pre-run, run, and post-run.
- The number of events detected during the profile run is displayed.
- The initial air temperature for each of the two ambient air temperature sensors computed from the data collected during pre-run is displayed. The number of readings that were taken for each sensor is displayed in the “Count” field. The initial average temperature is computed using data for pre-run, run, and post-run. The “Count” field includes data collected for pre-run, run, and post-run.
- The average pavement surface temperature and the average reference pavement temperature computed from the collected data by these two probes during pre-run are displayed. The number of readings that were taken by each probe is displayed in the “Count” field. The “Count” field includes data collected for pre-run, run, and post-run.

- The number of readings obtained by the GPSR is shown. The readings shown include the readings obtained during pre-run, run, and post-run. The number of satellites that were detected by the GPSR at the start of the run and the dilution of precision of the data obtained by the GPSR are displayed.
- The number of events detected by the photocell will be displayed.

Under the Section menu in ProQual, the operator can see the subsectioning information for SPS sections that was automatically performed by ProQual. The operator has the ability to deselect sections that were identified incorrectly.

The profiler outputs data at 25 mm intervals. ProQual has the ability to apply a 300 mm moving average on the 25 mm interval data and then record the data at 150 mm intervals. Under the Profile option in the Data QC menu in ProQual, the following computed parameters can be viewed for either the 25 or 150 mm data for each run:

- IRI for the left, right, and center path.
- Standard deviation of IRI for the left, right, and center path.
- Spike count for the left, right, and center path.
- Profile bias for the left, right, and center path.
- Average slope variance (i.e., average of left and right wheel path).
- Average RMSVA values (i.e., average of left and right wheel path) for base lengths of 1, 2, 4, 8, 16, 32, 64, and 128 ft.

Under the Profile option in the Data QC menu in ProQual, the following parameters for a section that are based on the selected runs can be viewed for either 25 or 150 mm interval data:

- Elevation cross-correlation (%): average, standard deviation, minimum value, and maximum value.
- IRI-filtered cross-correlation (%): average, standard deviation, minimum value, and maximum value.
- IRI: average, standard deviation, coefficient of variation, minimum value, maximum value, precision, and bias.

Under the Profile option in the Data QC menu, ProQual has the ability to generate the following plots for the 25 or 150 mm interval profile data for data collected by the left, right, and center sensors, with the operator having the ability to select the runs to view:

- Profile elevation plots.
- Location of spikes in the data.
- Location of event marks in the data (Note: This feature is not currently active in version 1.4.1.1).
- The IRI distribution within the section.

Under the Texture option in the Data QC menu in ProQual, the following computed parameters can be viewed for the left and right texture sensors for each run:

- MPD for entire run.
- Standard deviation of the Mean Segment Depth (MSD) values.
- Dropout count.
- Dropout percentage.
- RMS value for entire run.
- Cubic skew value based on data from entire run.

Under the Texture option in the Data QC menu in ProQual, the following computed parameters that are average values of the selected runs will be displayed by ProQual:

- MPD.
- Standard deviation of the MSD values.
- Dropout percentage.
- RMS of texture.
- Texture Type (Note: This feature is not currently active in Version 1.4.1.1.)
- Cubic skew value.

Under the Texture option in the Data QC menu, ProQual has the ability to generate the following plots for the data collected by the left and right texture sensors, with the operator having the ability to select the runs to view:

- Left and right texture data.
- MSD values.
- Locations of dropouts (Note: This feature is not currently active in Version 1.4.1.1.).

After reviewing the data, the operator has the ability to input the following items into ProQual: surface finish type of the section, add a texture comment, and add an operator comment related to profile data collection.

#### ***2.9.4.2. Evaluating the Collected Data***

Once the operator is confident that a minimum of five error free runs has been obtained, the ProQual program is used to perform quality control checks on the profile and texture data. Procedures for running ProQual are described in the ProQual manual<sup>(6)</sup>. The following is the recommended procedure to evaluate the collected data.

##### **(a) Checks During Data Loading**

As the data are being read into ProQual, a status indicator is shown for Header, Texture (i.e., texture data), ambient (i.e., data from the air temperature probes), profile (i.e., profile data), GPS (i.e., data from the GPSR), and surface (i.e., data from the surface temperature probe). The status indicator will show a green color for each data element if there are no problems detected with the data. A red indicator means there are data errors, an orange indicator means a custom value has been entered into that field, and a yellow indicator means some parameters are outside the normal range. Generally, additional runs will be needed if a red indicator is shown as a red

indicator means there are errors for that data element. A yellow or an orange indicator does not necessarily mean that there are data errors. Refer to Chapter 8 of ProQual manual if a yellow, orange or a red status indicator is shown and take appropriate actions to correct the issue if possible and obtain additional data runs if needed.

### **(b) Checks on Profile Data**

Note: Operator should also be familiar with the trouble-shooting guide included in appendix C. The material presented in this appendix describes common errors that occur during profiling and is a valuable tool for identifying problems when profiles are being evaluated.

1. If data collection was performed for a SPS project, review the subsectioning that was performed by ProQual, and if there are issues, correct them.
2. Review the IRI values of the runs for the left, right, and center sensors for consistency.
3. Review the following parameters that are computed for the selected runs for each data collection path:
  - Elevation Cross-Correlation (Average): A value of at least 96 percent is desired.
  - Elevation Cross-Correlation (Standard Deviation): A value less than 1 percent is desired.
  - IRI Cross-Correlation (Average): A value greater than 80 percent is desired.
  - IRI Cross-Correlation (Standard Deviation): A value less than 10 percent is desired.
  - IRI (Standard Deviation): A values less than 0.04 m/km is desired.

Note: Cross-correlation is being used as a quality control tool for profile data in the LTPP program for the first time with the implementation of ProQual 2014. The thresholds specified for the various cross-correlation parameters may change in the future based on feedback from RSCs. Presence of distress along the wheel path and lateral wander between runs can reduce the average IRI Cross-Correlation and increase the standard deviation of IRI Cross-Correlation. Also, variations in tire pressure between the runs, which will affect the DMI, can cause a significant reduction in the average IRI Cross-Correlation.

4. Plot the profile data for the left, right, and center path and evaluate the repeatability of the collected data along each path. Operator should examine plots of all profile runs for discrepancies and features that cannot be explained by observed pavement features.
5. Use the graphical feature in ProQual to evaluate spikes if present. Operator should determine if spikes are pavement related or the result of equipment or operator error. Use the 150 mm data when reviewing spikes as the spike thresholds are based on the 150 mm data. Review the locations where spikes are detected by overlaying the runs and using the graphical feature in ProQual. If the spikes for the different runs are occurring at the same location it is very likely that the spike was caused by a pavement feature. If spikes are believed to be caused by operator or equipment error, the operator should correct cause of the anomalies and make additional runs until five runs free of equipment or operator errors are obtained.



6. Compare the current profile data for each path with those obtained during the previous site visit. The operator should select one representative profile run to perform the visit-to-visit comparison (it is permissible to select more than one run for the comparison). The data for the two site visits should be evaluated to determine if similar profile features are present in both data sets and to determine if profile shapes are similar. If differences are observed between profiles, further comparisons should be made using remaining runs from both the current and previous visit. If there are still discrepancies between profiles from the current visit and previous visit, operator should verify that these differences are not caused by equipment problems or due to incorrect sub-sectioning of SPS test sections. Operator should also explore if differences are due to pavement maintenance activities on the test section. Note: Version 1.4.1.1 of ProQual does not have the ability to overlay profile data from a previous visit with data collected during the current visit. However, data collected by the Ames Device during a previous visit as well as during the current visit can be viewed separately. A future version of ProQual might have the ability to overlay profile data from the current visit with past data collected by any profiler that was used previously in the LTPP program. When Ames Engineering data are compared to data collected with ICC profilers, differences in profile plots will be seen (see appendix D). However, sharp upward and downward features in both profiles that are indicative of short wavelength features should occur at the same location. When the comparison involves only Ames device data, both profile features as well as profile shapes should be similar.
7. An IRI comparison of current versus previous site visit data should be performed using procedures described in section 2.9.4.4.

#### **(c) Checks on Texture Data**

1. Review the left and right MPD values and the dropout percentages of the runs for consistency.
2. Review if the average MPD value that is computed from all runs for each wheel path is reasonable. The ProQual manual provides typical ranges of MPD for various pavement finishes.
3. Review the locations where dropouts occur for different runs using the graphical feature in ProQual. (Note: This feature is not currently active in Version 1.4.1.1).
4. A MPD comparison of current versus previous site visit data should be performed using procedures described in section 2.9.4.4.

#### **(d) Deciding if the Collected Data is Sufficient**

If the review of the profile data and texture data performed using the procedures described above does not find any issues, further data collection runs are not needed. If issues are found, follow the procedure described in Section 2.9.4.3 to perform additional runs such that five error free runs (i.e., no errors in profile or texture data) are obtained.

### **(e) Entering Comments in ProQual**

Once operator is confident five error-free (i.e., no errors in profile or texture data) runs have been obtained at a site, enter surface finish, texture comments, and operator comments into ProQual.

Under “SECTION – ALL RUNS” enter the Surface Finish and Texture Comment using the guidelines shown in section 2.7.11.1 and 2.7.11.2. The inputs for Surface Finish and Texture Comment must be the same for all runs.

Under “SECTION-BY RUNS” enter Operator Comment using the guidelines shown in section 2.7.11.3.

### ***2.9.4.3 Obtaining Additional Runs***

The operator is responsible for carefully reviewing profile and texture data to determine if a high degree of run-to-run variability is indicative of bad data or indicative of a pavement with a high degree of transverse variability. Based on the review described in Section 2.9.4.2, if the operator does not believe five error free runs were obtained, the operator should perform the following steps to determine if variability is the result of equipment or operator errors, environmental effects, or pavement factors.

1. Review end of run comments and determine if passing trucks, high winds, rapid acceleration or deceleration of vehicle could have affected collected data.
2. Use the graphical feature in ProQual to review spike locations and determine if spikes are result of field related effects (e.g., potholes, transverse cracks, bumps) or due to electronic failure or interference. This can be determined by reviewing the runs in ProQual and observing if spikes occur at the same location in all runs. Operator should also examine profile plots for discrepancies and features that cannot be explained by observed pavement features. ProQual provides user with the capability to compare all repeat runs collected at the site. This feature should be used to compare data when analyzing differences between profiler runs.
3. Compare current profile data with those collected during previous site visit. This comparison may indicate potential equipment problems.

If variability between runs or spikes are believed to be operator related or equipment error, identify and correct cause(s) of anomalies and make additional runs until a minimum of five runs free of equipment or operator errors are obtained.

Where data anomalies are believed to be caused by pavement features rather than errors, a total of seven runs should be obtained at that section and evaluated using the ProQual software. If data from last two runs are consistent with those from first five runs in terms of variability and presence of pavement-related anomalies, no further runs are required. If data from last two runs differ from those for first five runs, operator should re-evaluate cause of variability or apparent

spike condition. If no errors are found, obtain two additional runs and terminate data collection at that section.

Thereafter, IRI values along the left, right, and center paths should be compared with IRI values obtained during previous visit to test section as described in section 2.9.4.4. Also, the MPD values along the left and right paths should be compared with MPD values obtained during previous visit to test section as described in section 2.9.4.4.

#### ***2.9.4.4 Comparison of IRI and MPD with Previous Values***

##### **Comparison of IRI Values**

The operator should have IRI values obtained along the left, right and center path for the previous profile test dates for all test sections. (Note: The center path IRI values for the previous visit are currently only available if the site was tested previously with the Ames device. There are plans to upgrade ProQual to have the ability to import ERD files from ICC and K. J. Law T-6600 profilers. Once this upgrade has been performed, it will be possible to compute IRI values for the center path for data collected with these two devices.) Once the operator obtains an acceptable set of runs at a test section, the average IRI values along the left, right, and center paths should be compared with average IRI values that were obtained for the previous test date for the section. The operator should determine if current average IRI value along each path is higher or lower than 10 percent of average IRI value at the test section from the previous test date. If the difference in IRI is greater than 10 percent, the operator should see if the cause for change in IRI could be related to a pavement feature (e.g., maintenance activity, cracks or patches along wheel path). If the cause for change can be observed, it should be noted in the operator comments field in ProQual.

##### **Comparison of MPD Values**

Operator should have the average MPD values obtained along the left and right path for the previous test dates for all test sections. (Note: The previous MPD values will only be available if the site was tested previously with the Ames Device.) Once the operator obtains an acceptable set of runs at a test section, the average MPD values along the left and right wheel paths should be compared with the average MPD values that were obtained for the previous test date for the section. The operator should determine if current average MPD value along each path is higher or lower than 10 percent of average MPD value at the test section from the previous test date. If the difference in MPD is greater than 10 percent, operator should see if the cause for change in MPD could be related to a pavement feature (e.g., maintenance activity). If the cause for change can be observed, it should be noted in the texture comments field in ProQual.

#### **2.9.5 Field XML File and Data Backup**

Once the operator is satisfied that an acceptable set of runs has been obtained at the site, use the Field button under the Export tab in ProQual to create the field XML file.

The data collected at a site by the device (i.e., ARD files), the files generated by ProQual when the collected data were processed (i.e., Field XML), and the images obtained at a site should be

backed up to a flash drive before leaving the site. The Field XML file contains information about data processing performed by ProQual, and is located in the root directory. A recommended procedure to follow during backup of data for a site is to create separate directories in the flash drive for each site.

When a SPS site is processed, the ProQual files created for the sections as well as the raw profile data collected at the SPS site (i.e., ARD files) should be backed up. The operator should maintain a log to document files that are contained in each flash drive.

At the end of each day, an additional backup copy of all data collected on that day should be made. Therefore, at the end of each test day, there should be two backup copies that contain the data that were collected on that day. One of these backups should be kept in the device (device copy) while the other copy (RSC copy) should be forwarded to the RSC. Until the RSC copy is forwarded, the device copy must be removed from the vehicle whenever testing is not in progress. No collected data should be deleted from the hard drive of the laptop computer until the RSC has informed the operator that the RSC copy has been received and processed by the RSC. The flash drive can be recycled once the RSC informs the operator that data have been received, processed and backed up.

Profiler data files should be organized into subdirectories in the hard drive, as outlined in LTPP directive I-170, AIMS Data Storage Format Standards, or the current version of that directive.

## **2.10 PROFILING SPS SECTIONS**

### **2.10.1 General Background**

This section describes field testing procedures to be followed when testing SPS sites, which are different than the procedures used for GPS sections. However, other than the exceptions described in this section, all other information presented in earlier sections of this manual are valid when SPS sites are being tested. A SPS site consists of a number of test sections with a transition area between adjacent sections. During a data collection run at a SPS site, profile and texture data are collected for entire site, which includes test sections as well as transition areas.

### **2.10.2 Length of Test Section**

Unlike GPS test sections that are always 152.4 m in length, the total length of a SPS project that will include test sections and transition areas will vary from project to project. The operator may elect to break the SPS project into two segments for profiling depending on the location of test sections as well as turnaround locations in the SPS project. For example, if there is a large transition distance between two groups of test sections, and a turnaround is located in the transition area, the operator may elect to profile the SPS project as two groups of sections.

### **2.10.3 Operating Speed**

Guidelines regarding the operating speed described in section 2.7.4 should be followed when testing SPS test sections. When SPS test sections are tested, the transition area between sections

may be used to adjust the vehicle speed to 80 km/h (or appropriate speed depending on site conditions as described in section 2.7.4) before the next section is tested. If there is traffic in front of the device, the device speed can be initially decreased in the transition section to give more leeway with the vehicle in front. Thereafter, device must be brought up to a constant speed of 80 km/h or appropriate speed depending on site conditions before entering the next test section.

#### **2.10.4 Number of Runs**

The procedure for subsectioning individual test sections from a profile run made at a SPS project is described in the ProQual manual<sup>(6)</sup>. The ProQual program is capable of computing the IRI value of individual test sections within a SPS project by identifying test sections using stationing and event marks. The procedure outlined in section 2.9.4 should be followed in order to obtain an acceptable set of runs at a SPS project. The operator should follow this procedure to verify that accurate data have been collected at each individual test section in the SPS project.

#### **2.10.5 Header Information**

The procedures outlined in section 2.9.3.2 for entering header information should also be followed for SPS test sections. However, the Stop Distance that is entered in step 9 for a SPS project is different than that entered when collecting data at GPS sections.

The operator should refer to site layout plans and obtain the length of the SPS project that will encompass all test sections. To guard against discrepancies between layout plans and as-built sections, the operator may add a distance such as 30 m to the distance obtained from the site layout plan. This distance should be entered as the Stop Distance in step 9 of section 2.9.3.2.

If the operator is not certain about the length to be entered, the operator should perform a trial run to determine the length of the SPS project. Set Stop method to Pendant and terminate data collection once the end of the last test section is passed for the trial run. Use the distance noted from the trial run to obtain the length of the SPS project to be entered in the Stop Distance field in the header.

#### **2.10.6 Data Backup**

Data collected at SPS projects should be backed up using the procedures described in section 2.9.5.

### **2.11 PROFILING WIM SECTIONS**

#### **2.11.1 Background**

The collection of accurate axle weight data using WIM scales is of vital importance to achieving the LTPP program objectives. Pavement roughness affects the dynamic motion of trucks and therefore the accuracy of axle weights measured at the WIM scale. Therefore, a smooth

pavement section before and immediately after the WIM scale is required to minimize those motions.

The pavement smoothness specifications that must be met at WIM sections are not described in this manual. This section describes procedures that should be followed by the RSCs to collect longitudinal profile data at SPS-1, -2, -5, and -6 WIM sections using the Ames device. The resulting profile data will be used to determine if a WIM section meets the LTPP pavement smoothness specifications. (Note: This manual does not contain the procedures to make this determination).

The RSCs are responsible for working with the relevant highway agency to locate and correctly identify the WIM location for each SPS project. Working WIM equipment is not a condition for profiling. SPS projects for which more than one WIM site exists will only be profiled at the site most recently used for data collection. Profiling for SPS projects that are out-of-study will not be done without the explicit direction of the FHWA.

### **2.11.2 Weigh-In-Motion (WIM) Section**

A WIM section is defined as a section of pavement that is 305 m long, with the distance from the centerline of the WIM scale to the beginning of the test section being 275 m and the distance from the centerline of the WIM scale to the end of the test section being 30 m.

The WIM section should be marked as shown in figure 87. Monuments (in the form of nails, spikes, or re-bars) should be installed in the shoulders, exactly at the beginning and end of the test section, and at the WIM centerline as shown in figure 87. These monuments will serve as section markers in case of paint wear. The monument at the beginning of the section should be located 275 m before the centerline of the WIM scale. The monument at the end of the section should be located 30 m after the centerline of the WIM scale. The distances measured should be accurate to within  $\pm 0.10$  m. The centerline of the WIM scale is dependent on the sensor used and which of a series of multiple sensors is currently working. For a single sensor installation, the centerline is the middle of the sensor. For a multiple weight sensor array (i.e., bending plates staggered in alternate wheel paths) the centerline is the distance halfway between the approach edges of the first and last weight sensors in the array. Marking the centerline with a monument must avoid all electronics and other elements of the WIM scale installed below the pavement. When the WIM section does not overlap an active LTPP pavement test section, it should be marked by two white stripes, nominally 150 mm wide, across the test lane at the beginning and end of the WIM section. The leave edge of the stripes should be next to the applicable monument. If the WIM section overlaps an active LTPP pavement test section it should not be marked with white stripes.

At the centerline of the WIM weight sensor array, one of the following shall be painted near the outside shoulder for permanently marked sites: A WIM SHRP ID of the format PP99 where PP is the Project ID (first two characters of the project SHRP ID) and 99 is the section number assigned for WIM beginning with 99 and decreasing for every new or separate location at which WIM equipment is installed for the project, or the letters **WIM**.

NOT TO SCALE

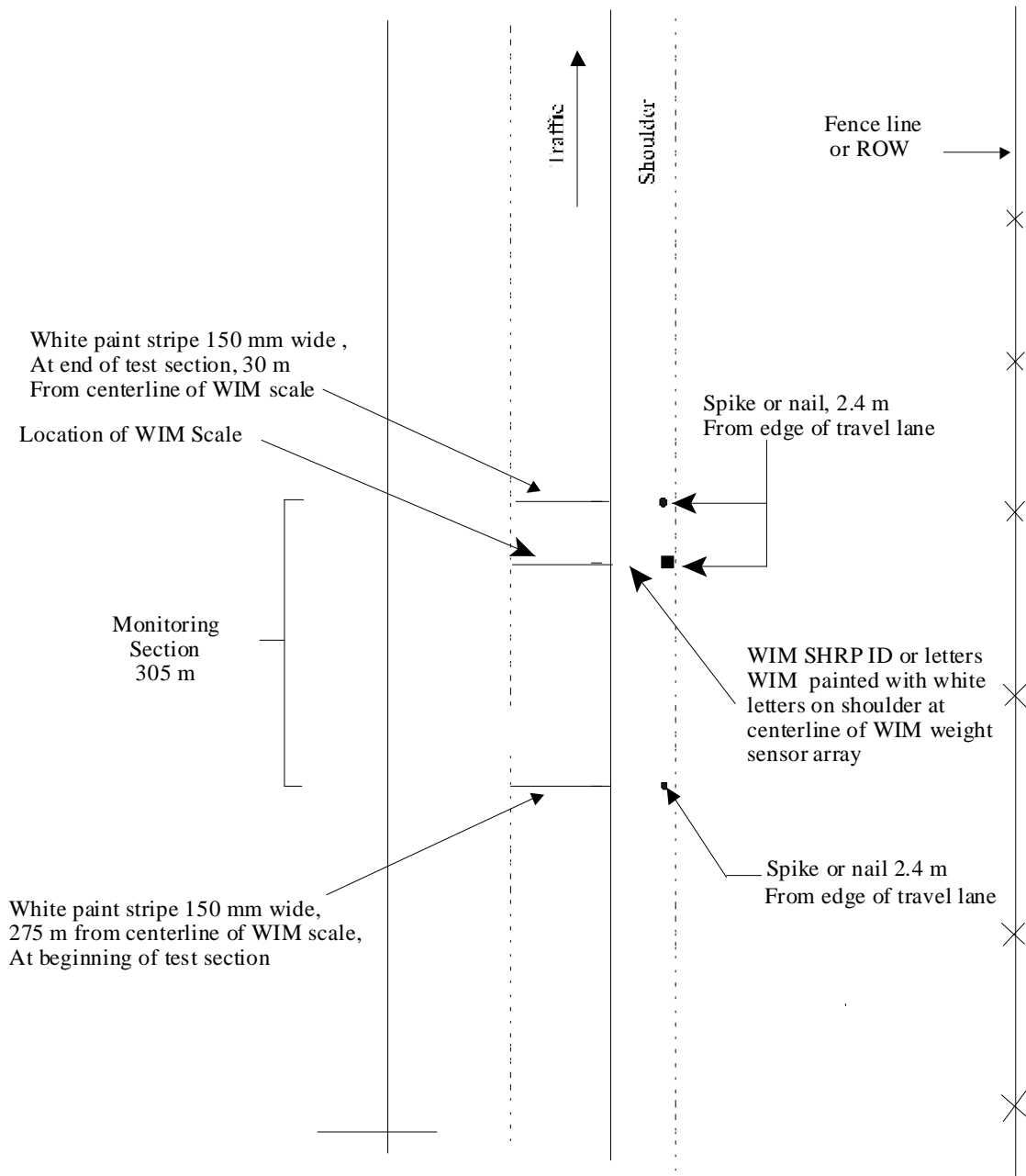


Figure 87. Layout of WIM Site.



For example, the Maryland SPS-5 project presently has a piezo system installed. The SHRP ID and appropriate marking for this WIM section is **0599**. If the piezo system is replaced with the same or a different sensor at another location, the new SHRP ID (and appropriate new marking) for this new WIM section is **0598**.

If permanent markings are not present at the WIM section, temporary markings such as tape, cones or other means appropriate to the requirements of the Ames device may be used to trigger the start of data collection. However, the RSCs are responsible for working with the relevant highway agency to ensure that their WIM sections are permanently marked before the second visit to the site.

### **2.11.3 Profile Measurements**

#### ***2.11.3.1 General***

Longitudinal profile measurements for smoothness evaluation of LTPP SPS-1, -2, -5, and -6 WIM sections fall into one of the following categories:

1. Verification of existing WIM sections: These WIM sections are already in operation, but they will be evaluated to determine if they satisfy the specified smoothness criteria.
2. Acceptance of newly constructed WIM sections: Newly constructed WIM sections will be evaluated to determine if they satisfy the specified smoothness criteria.
3. Annual check of WIM sections: Newly constructed WIM sections that are accepted into the LTPP program, as well as existing WIM sites that have been verified and accepted into the LTPP program will be monitored once a year to determine if they satisfy the specified smoothness criteria.

Profile measurements for use in the first two applications will typically be required only once unless special circumstances exist. Furthermore, they will not be done without explicit instructions from the FHWA. Longitudinal and transverse profile measurements using a straightedge will also be made for acceptance testing of newly constructed WIM sections, but applicable data collection procedures are not described in this manual.

With respect to the third category, installed SPS-1, 2, -5, and -6 WIM sections should be profiled during scheduled profile visits to their associated SPS projects. An installed section is a location at which sensors currently exist and at which data has been or is currently being collected. It may or may not be located within the project limits or immediate proximity to the SPS project. Only the LTPP lane will be profiled. In cases where the WIM site is not in the immediate proximity of the project or is in a different direction, the outside lane will be considered equivalent to the LTPP lane.

All profile measurements shall be done exclusively with the LTPP inertial profilers; Dipstick<sup>®</sup> cannot be used as a substitute for the inertial profilers. In addition, the profile measurements shall be performed in accordance with the guidelines and procedures described previously in this manual, except that the procedure for profiling a section and the number of acceptable runs that

are required at a WIM section are different from the procedures previously described in this manual. Procedures for profiling a WIM section and the number of profile runs that are required at a WIM section are described in the next sections.

### ***2.11.3.2 Profiling Paths and File Naming Convention***

Profile data collected at three lateral positions are used to evaluate pavement smoothness at WIM sections. The three lateral positions along which the device shall be driven to collect the data are:

1. Along the wheel paths.
2. Close to the shoulder (right of the wheel path).
3. Close to the inner edge of the lane (left of the wheel path).

The following convention shall be followed for naming files. Failure to adhere to this file naming convention could produce errors when running ProQual, and will cause problems when archiving files. The filename should consist of eight characters as follows:

SSDXLPEV

where:

- SS = State code in which site is located (e.g., 27 for Minnesota).
- D = First character of the SPS project SHRP ID, which should be 0, A, B, etc., depending on project code (e.g., 0600, A600, B600, etc.) if profiling in the same direction as the SPS project. If profiling in a different direction from SPS site, this character should indicate the direction traveled (i.e., E, W, N, S).
- X = SPS experiment number, which should be the same number as the second digit of the SPS project SHRP ID (e.g., 5 for project A500).
- L = Lane identification. Use O for outer, C for center, or I for inner on two or three lane facilities. In the event that there are more than three lanes in the travel direction, use successive numbers starting with 1 as the outer lane.
- P = Path followed along the lane which is right, center, or left (i.e., R, C, or L).
- E = Letter code defining section type; for WIM sites, this should always be W.
- V = Sequential visit identifier that indicates the visit code for the current profile data collection. This identifier indicates the number of times a set of profile runs has been collected at a site since the site was first profiled. Use an appropriate letter for the current profiling with A used for the first visit, B for the second, etc.

For example, the following are valid data filenames:

05A6OCWB: Arkansas SPS-6 WIM site profiled in the travel direction of the SPS project in the outer lane along the center path for the second visit.

30S1OLWA: Montana SPS-1 WIM site profiled in the southbound direction in the outer lane along the left path for the first visit.

29W6ORWC: Missouri SPS-6 project 29A6 profiled in the westbound direction in the outer lane along the right path at the third visit.

After the sequential visit identifier code has been assigned as Z, change character seven to X, and assign site visit identifier to be A. For subsequent profile visits, maintain character seven as X and change sequential visit identifier to B, C, D, etc.

### ***2.11.3.3 Data Collection Procedure***

Before collecting data at a WIM section, the operator should ensure that the following conditions are met:

1. Daily checks should be performed on the equipment (i.e., laser sensor check, accelerometer calibration check, bounce test).
2. The highway agency procedures relating to safety issues should be strictly followed (i.e., light bar, directional warning light, strobe lights, use of turnarounds, etc.).
3. The operating speed for collecting data should be 80 km/h. If the maximum constant speed attainable is less than 80 km/h due to either traffic congestion, or safety constraints, then a lower speed depending on prevailing conditions should be selected. If the speed limit at the site is less than 80 km/h, the site should be profiled at the posted speed limit. If traffic traveling at high speeds is encountered at a test site, it is permissible to increase the profiling speed to 88 km/h.
4. The photocell should always be used to initiate data collection at the beginning of test section.
5. When entering header information into the software, the section number assigned to the WIM should be entered as the Site ID.
6. The “Stop Distance” in the software should be specified as 305 m.

The procedure described below should be followed to obtain an acceptable set of profile runs at WIM sections. An acceptable set of profile runs is three error free runs in the wheel path and one error free run offset to both the right and the left of the wheel path.

1. The operator should make sure that the end of the WIM section is passed before terminating profile data collection.
2. Obtain at least three but no more than five profile runs by driving the profiler along the wheel paths.
3. Obtain at least one but not more than three profile runs by driving the profiler along a path that is as close as possible to the right edge of the traffic lane (i.e., right tire of vehicle aligned as close as possible to white stripe along the edge of the lane). The driver of the

profiler should judge the path to be followed based on the site conditions, such that the path followed does not cause any safety concerns.

4. Obtain at least one, but not more than three profiler runs by driving the profiler along a path that is as close as possible to the left edge of the traffic lane (i.e., left tire of vehicle aligned as close as possible to lane divider along the edge of the lane). The driver of the profiler shall judge the path to be followed based on the site conditions, such that the path followed does not cause any safety concerns.
5. After completing data collection, review the profile runs that were collected along each path. Evaluate the profiles for equipment related spikes following the procedures described in section 2.9.4. If the operator has determined that at least three error free runs along the wheel paths and one error free run along each of the other two paths have been obtained at the site, terminate data collection. If the operator believes that at least three error free runs along the wheel paths and one error free run along each of the other two paths have not been obtained, repeat data collection along appropriate path(s) and evaluate the profile data using the procedures described previously. Up to a maximum of five runs along the wheel paths and three runs along the other two paths should be performed.
6. Use form PROF-7, Profiling of WIM Sites: Data Summary Sheet, which is included in appendix B to maintain a log of the runs
7. Backup the data before leaving the site following procedures described in section 2.9.5.

## **2.12 CALIBRATION/CALIBRATION CHECKS**

### **2.12.1 General Background**

The only component in the device that can be calibrated is the DMI. However, there are several components in the device on which calibration checks must be performed to ensure the components are collecting accurate data. Table 4 shows the components in the device on which calibrations/calibration checks must be performed, as well as the maximum interval between calibration/calibration checks. This table also shows the section in the Profile Manual that describes the calibration/calibration check.

Each RSC must establish a calibration section close to the office and collect data at this section after all calibrations/calibration checks have been performed. The calibration section must be at least 152.4 m long. The texture and profile data collected at this section can be compared to previously collected data at this section to ensure that the device is collecting consistent data. The calibration section can also be profiled whenever there is a question about the quality of the data collected by the device.

Power to the electronic equipment should be turned-on for about 15 minutes before performing calibration/calibration checks so that the electronic equipment is allowed to warm-up and stabilize.

## 2.12.2 Calibration Menu

The calibration menu is accessed from the Ames Engineering software start-up screen (see figure 71) by pressing the F2 key or by selecting the “Calibration” button. The Calibration Menu shown in figure 88 will then be displayed on the laptop computer screen. All of the calibration or calibration checks shown in table 4 except for the checks on the ambient temperature sensor, pavement surface temperature sensor, GPSR, and photocell are performed by selecting the appropriate test from this menu.

Table 4. Components requiring calibration/calibration checks.

| Component  | Test                   | Maximum Interval Between Tests   | Section in Manual |
|--|------------------------|--|-------------------|
| DMI  | Calibrate              | 30 Days (Note 1)   | 2.12.3            |
| Accelerometer  | Calibration check      | 30 days (Note 2)   | 2.12.4            |
| Profile height sensors   | Full calibration check | 30 days (Note 3)   | 2.12.5            |
| Texture height sensor  | Full calibration check | 30 days (Note 4)   | 2.12.5            |
| Texture height sensor  | Dynamic check          | 30 Days (Note 4)   | 2.12.6            |
| Bounce test  |                        | Whenever full calibration check of profile height sensors are performed in addition to daily check | 2.12.7            |
| Ambient Temperature probe  | Calibration check      | 30 Days (Note 5)   | 2.12.8            |
| Pavement surface temperature probe   | Calibration check      | 30 Days (Note 5)   | 2.12.9            |
| GPS receiver   | Calibration check      | 30 Days (Note 5)   | 2.12.10           |
| Photocells   | Initiation Check       | 365 Days (Note 5)  | 2.12.11           |
| <p>Note 1: DMI must be calibrated whenever problems are suspected, tires are replaced, suspension repairs are performed, wheels are rotated or aligned, repairs are performed on the encoder, or if the encoder is replaced.</p> <p>Note 2: This test must be performed whenever problems are suspected, when repairs are performed on any components associated with the accelerometer, or when an accelerometer is repaired or replaced.</p> <p>Note 3 This test must be performed whenever problems are suspected, when repairs are performed on any components associated with the profile height sensor, or when a profile height sensor is replaced.</p> <p>Note 4 This test must be performed whenever problems are suspected, when repairs are performed on any components associated with the texture height sensor, or when a texture height sensor is replaced.</p> <p>Note 5: This test must be performed whenever problems are suspected with the sensor, and when repairs are performed on any components associated with the sensor</p> |                        |  |                   |

### 2.12.3 Calibration of Distance Measuring Instrument (DMI)

The DMI is calibrated by driving the vehicle over a known distance to count the number of pulses from the DMI to calculate a Horizontal Calibration Factor. An accurately measured section of 300 m should be used to calibrate the DMI. This section must be located on a straight portion of roadway that is reasonably level and has a low traffic volume. Speed limit at site should be at least 80 km/h. This section should be in an area where vehicle can be driven at a constant speed without interruptions. The section should be measured with a standard surveying tape using standard surveying procedures. Reflective tape that will trigger the vertical photocell should be placed on the pavement at the start and end of the section, such that the distance between leave edges of the two reflective tapes is 300 m. The reflective tape should be placed on the lane such that the vertical photocell will traverse over the tape when device traverses the test section.

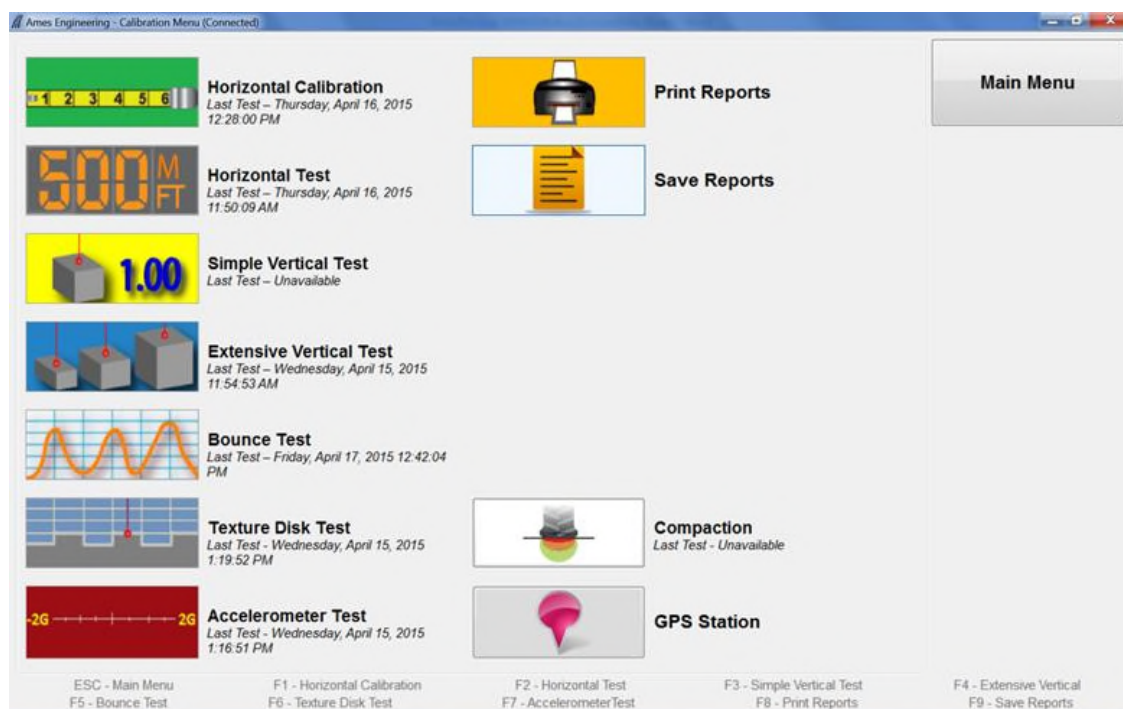


Figure 88. Calibration menu.

The calibration factor that is computed will depend on the tire pressure of the rear left tire, as the encoder is attached to the rear left wheel. Before driving the vehicle in the morning, the operator should check the tire pressure (cold) to ensure that the tire pressure of the front tires are at 380 kPa (55 psi) and 550 kPa (80 psi) for the rear tires, which are the manufacturers recommended tire pressures. Adjust the tire pressure if needed.

The operator should drive the vehicle for about 6 to 8 km (4 to 5 miles) at highway speeds before calibrating the DMI so that the tires can warm-up. Based on local weather conditions (e.g., cold weather) the operator may need to increase the distance the vehicle should be driven to warm-up the tires.

Before calibrating the DMI, do a “Horizontal Test” using the “Horizontal Test” option in the Calibration Menu (see figure 88) to obtain the distance the DMI is measuring at the section with the current calibration factor. This test will provide information about the stability of the DMI over time. Perform the Horizontal Test using the following procedure:

1. Adjust tire pressure of all tires so they match the tire pressure at the time the DMI was calibrated last.
2. In the calibration menu (see figure 88), press F2 key or select “Horizontal Test” icon, and the screen shown in figure 89 will be displayed. This screen shows the current calibration factor of the DMI.

Figure 89. Horizontal test screen.

- 3 Under Auto Start Sensor select “Attached to ODS3” to select the vertical photocell as the active photocell.
- 4 Under Direction, “+(Pos)” should be selected to indicate distance will be increasing.
- 5 Bring vehicle up to a speed of 80 km/h about 150 m before start of the section and select “Begin Test” button. Then press space bar on keyboard to arm the photocell.



6. As device crosses the start of the section, a beep will be heard when photocell is triggered by the reflective tape that is located at the start of the section. The Distance field will be reset to zero.
7. As the device approaches the end of the section press space bar on keyboard to activate the photocell. As device crosses the end of the section, a beep will be heard when photocell is detected by the reflective tape located at the end of the section. The Distance field will display the measured distance.

Note: If the photocell fails to trigger at the start or at the end of the section, the Stop button can be used to terminate the test. Clean the photocell and repeat the run and see if the photocell triggers. If photocell still fails to trigger, operator should adjust the sensitivity control for photocell and repeat the test. If this is not successful, operator should use the horizontal photocell. To use the horizontal photocell, place two cones on side of road at beginning and end of section such that leave edge of the reflective mark on each cone is aligned with the leave edge of the mark that is on the pavement surface. Under “Autostart Sensor” (see figure 89) select “Attached to ODS2” to select the horizontal photocell and perform test using procedure described in steps 5 and 6.

8. Note the distance displayed in the “Distance” field. This is the distance that was measured by the DMI between the reflective tapes at the start and the end of the section based on the current calibration factor. This value can be used to evaluate the stability of the DMI over time.

After performing the Horizontal Test, use the following procedure to calibrate the DMI:

1. Adjust tire pressure such that the tire pressure of the front tires are between 380 and 415 kPa (55 and 60 psi) and the tire pressure of the rear tires are between 550 and 585 kPa (80 and 85 psi). Note the tire pressures.
2. In the calibration menu (see figure 88), press F1 or select the icon “Horizontal Calibration” and the Horizontal Calibration Screen shown in figure 90 will be displayed on the computer screen. This screen shows the calibration factor for the DMI that was saved the last time the DMI was calibrated.
3. Under Auto Start Sensor select “Attached to ODS3” to select the vertical photocell as the active photocell.
4. In the Calibration Length field enter 300, which is the length of the calibration section in meters. Enter the tire pressures in psi in the Tire Pressure section of this screen, where FL is front left tire, FR is front right tire, RL is rear left tire and RR is rear right tire. In the “Operator Comment” field enter the distance that was noted in step 8 of the Horizontal Test.
5. Bring vehicle up to a speed of 80 km/h, and about 150 m before the start of the section press “Begin Test” button and then press space bar to arm photocell. As device crosses the start of

the section, a beep will be heard when photocell is triggered by the reflective tape that is located at the start of the section.

Ames Engineering [Horizontal Calibration]

To begin measuring:  
Enter the correct distance and  
Click the Begin Test button or  
Press the Spacebar

**Count**  
0

**Speed (km/hr)**  
0.0

**Auto Start Sensor**  
☐ None  
☐ Attached to ODS1  
☐ Attached to ODS2  
☒ Attached to ODS3  
☐ Standalone

**Switch Pod**  
☐ Enabled

**Calibration Length (meters)**  
300.00

**Operator Comments**

**Tire Pressure (psi)**  
FL 55 FR 55  
RL 80 RR 80

**Buttons:** Exit, Begin Test, Start, Stop, Arm Auto Trigger (Spacebar), Save Calibration, Save Report, View Log

**Summary:**  
Average Cal Factor:   
Standard Deviation:   
Change From Last:   
Last Cal Factor: 267.476

Figure 90. Horizontal calibration screen.

6. As the device approaches the end of the section press the space bar to arm the photocell. As device crosses the end of the section, a beep will be heard when photocell detects the reflective tape located at the end of the section. Figure 91 shows an example of the DMI calibration screen after performing one run. The Pulses and Factor field on the screen will be populated. The pulses field indicates the pulses counted by the encoder over the calibration section and the factor indicates the calibration factor that was computed.

Note: If the photocell fails to trigger at the start or at the end of the section the Stop button can be used to terminate the test. Clean the photocell and repeat the run and see if the photocell triggers. If the photocell still fails to trigger, operator should adjust the sensitivity control for photocell and repeat the test. If this is not successful, the operator should use horizontal photocell. To use the horizontal photocell, place two cones on side of road at beginning and end of section such that leave edge of the reflective mark on each cone is aligned with the leave edge of the mark that is on the pavement surface. Under “Autostart Sensor” (see figure 90) select “Attached to ODS2” to select the horizontal photocell and perform test using procedure described in steps 5 and 6.

Figure 91. DMI calibration screen after performing one run.

7. Repeat the calibration procedure (steps 5 and 6) five more times so that six calibration runs are obtained. At the start of each run adjust tire pressure to value noted in step 1. After six calibration runs have been obtained, select the six runs such that a check mark appears to the left of the run. An average calibration factor that is the average of the calibration factors obtained for all runs will be displayed on the screen. Figure 92 shows an example of screen at this stage. The screen will also display the standard deviation of the calibration factor as well as the percentage change in the calibration factor from the last value. If the standard deviation of the calibration factor is less than or equal to 0.07, sufficient DMI calibration runs have been obtained.
8. If the standard deviation of the calibration factor is greater than 0.07, obtain additional runs. Then select the runs that are to be used for computing the calibration factor. Figure 93 shows an example of where seven calibration runs were obtained, with six of the seven runs selected for computing the calibration factor. If the standard deviation of the calibration factor is greater than 0.07 after repeating the test, contact RSC and decide on a suitable course of action.
9. If the standard deviation of the calibration factor computed from the selected runs is less than 0.07, but the percent change in calibration factor from the previous value is not within  $\pm 1$  go to step 10. If the standard deviation of the calibration factor computed from the selected runs is less than 0.07 and the percent change in calibration factor from the previous value is within  $\pm 1$  go to step 11.

Ames Engineering [Horizontal Calibration]  
Average Calibration Saved

**Count**  
13166

**Speed (km/hr)**  
78.17

| Use                                 | Pulses | Factor |
|-------------------------------------|--------|--------|
| <input checked="" type="checkbox"/> | 13169  | 267.59 |
| <input checked="" type="checkbox"/> | 13168  | 267.57 |
| <input checked="" type="checkbox"/> | 13167  | 267.55 |
| <input checked="" type="checkbox"/> | 13165  | 267.51 |
| <input checked="" type="checkbox"/> | 13165  | 267.51 |
| <input checked="" type="checkbox"/> | 13166  | 267.53 |

**Auto Start Sensor**  
☐ None  
☐ Attached to ODS1  
☐ Attached to ODS2  
☒ Attached to ODS3  
☐ Standalone

**Switch Pod**  
☐ Enabled

**Calibration Length (meters)**  
300.00

**Operator Comments**

**Tire Pressure (psi)**  
FL 55 FR 55  
RL 80 RR 80

**Average Cal Factor** 267.5467  
**Standard Deviation** 0.0303  
**Change From Last** 0.10%  
**Last Cal Factor** 267.55

**Exit**  
**Begin Test**  
**Start**  
**Stop**  
**Arm Auto Trigger (Spacebar)**  
**Save Calibration**  
**Save Report**  
**View Log**

Figure 92. DMI calibration screen after obtaining six runs.

Ames Engineering [Horizontal Calibration]  
Autotrigger Armed

**Count**  
13152

**Speed (km/hr)**  
79.29

| Use                                 | Pulses | Factor |
|-------------------------------------|--------|--------|
| <input checked="" type="checkbox"/> | 13155  | 267.31 |
| <input checked="" type="checkbox"/> | 13155  | 267.31 |
| <input checked="" type="checkbox"/> | 13152  | 267.25 |
| <input checked="" type="checkbox"/> | 13156  | 267.33 |
| <input checked="" type="checkbox"/> | 13156  | 267.33 |
| <input checked="" type="checkbox"/> | 13152  | 267.25 |

**Auto Start Sensor**  
☐ None  
☐ Attached to ODS1  
☐ Attached to ODS2  
☒ Attached to ODS3  
☐ Standalone

**Switch Pod**  
☐ Enabled

**Calibration Length (meters)**  
300.00

**Operator Comments**

**Tire Pressure (psi)**  
FL 55 FR 55  
RL 80 RR 80

**Average Cal Factor** 267.2961  
**Standard Deviation** 0.0345  
**Change From Last** -0.07%  
**Last Cal Factor** 267.476

**Exit**  
**Begin Test**  
**Start**  
**Stop**  
**Arm Auto Trigger (Spacebar)**  
**Save Calibration**  
**Save Report**  
**View Log**

Figure 93. DMI calibration screen showing seven runs with six selected.

10. If the tires in the van are changed, there is a possibility that the percent change may not fall within  $\pm 1$  percent of the previous value. If this is the case, repeat test and if percent change is still not within  $\pm 1$  percent of the previous value, and the obtained values are similar to previous test, select "Save Calibration" to save the computed calibration factor, and then select "Save Report" to save the DMI calibration report that will have details about the current calibration. Go to step 12.
11. If the standard deviation of the calibration factor computed from the selected runs is less than 0.07 and the percent change in calibration factor is within  $\pm 1$  percent select "Save Calibration" to save the computed calibration factor, and then select "Save Report" to save the DMI calibration report that will have details about the current calibration.
12. The new calibration factor will be used from this point forward until this procedure is repeated again in the future. Fill form PROF-5, Laser Sensor, Accelerometer, DMI Calibration/Calibration Check Form, which is included in appendix B. Press Exit to exit the Horizontal Calibration menu.

#### **2.12.4 Calibration Check of Accelerometers**

The calibration check of accelerometers checks the scaling of the accelerometers using the acceleration of the earth's gravity by flipping the accelerometers over to measure a change in acceleration of 2g.

The accelerometer calibration check should be performed while the vehicle is parked on a level surface with the engine off. Location where calibration check is performed should be free of any vibrations and operator should be outside of vehicle when performing this check. Operator should adjust the docking station such that the screen of the laptop computer can be seen from outside vehicle and the keyboard is easily accessible. Do not enter vehicle, bounce or bump vehicle, or lean on vehicle during calibration check.

The following procedure should be followed to perform this check:

1. Open cover of sensor bar. Turn key to "Off" position in DAU to shut-off power to laser sensors and remove key (see section 2.2.4). The red laser dot should not be displayed on the ground. Unlatch all three laser boxes containing the profile height sensors from the mounting latches.
2. In the Calibration Menu (see figure 88) press F7 key or select "Accelerometer Test" icon. The laser sensor warning shown in figure 94 is displayed.

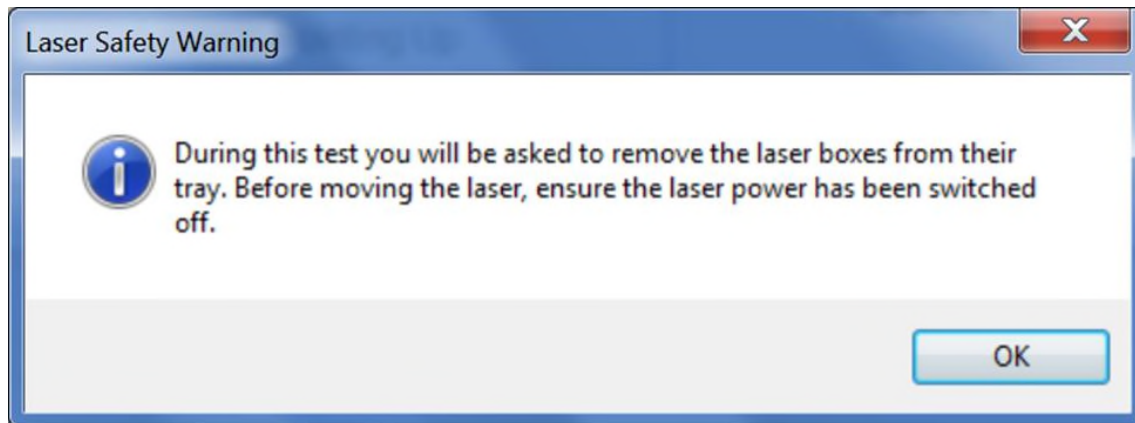


Figure 94. Laser sensor warning during the accelerometer calibration check.

3. Press OK on the Laser Safety Warning message and the Accelerometer Test menu shown in figure 95 will be displayed.

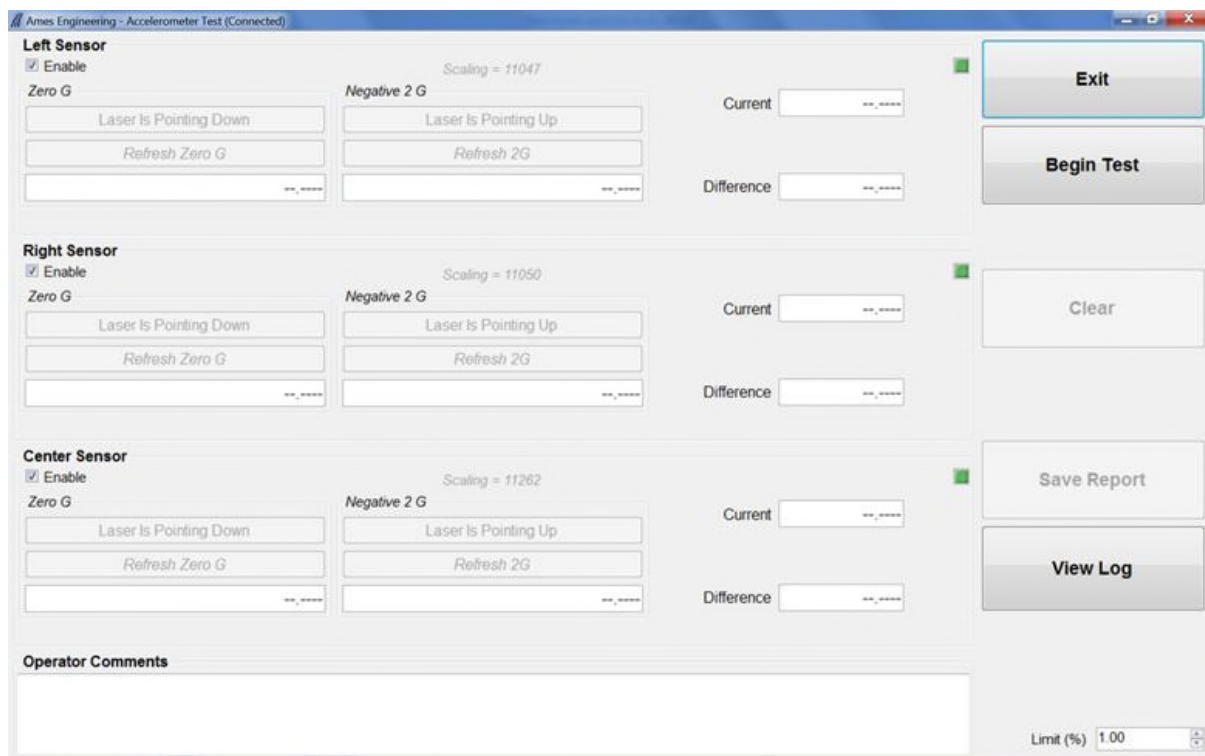


Figure 95. Accelerometer test menu.

4. Press Begin Test button. The system will start displaying the current measurements in g's from the accelerometers as shown in figure 96.
5. Select "Laser Is Pointing Down" button for all three accelerometers and the system will wait twenty seconds before storing the current value. This value is a moving average of the accelerometer over about a twenty second interval. The appearance of the screen at this stage is similar to the one shown in figure 97. If the operator wants to refresh the current value press the

Refresh Zero G button and the current value will replace the first value that was stored after 20 seconds.

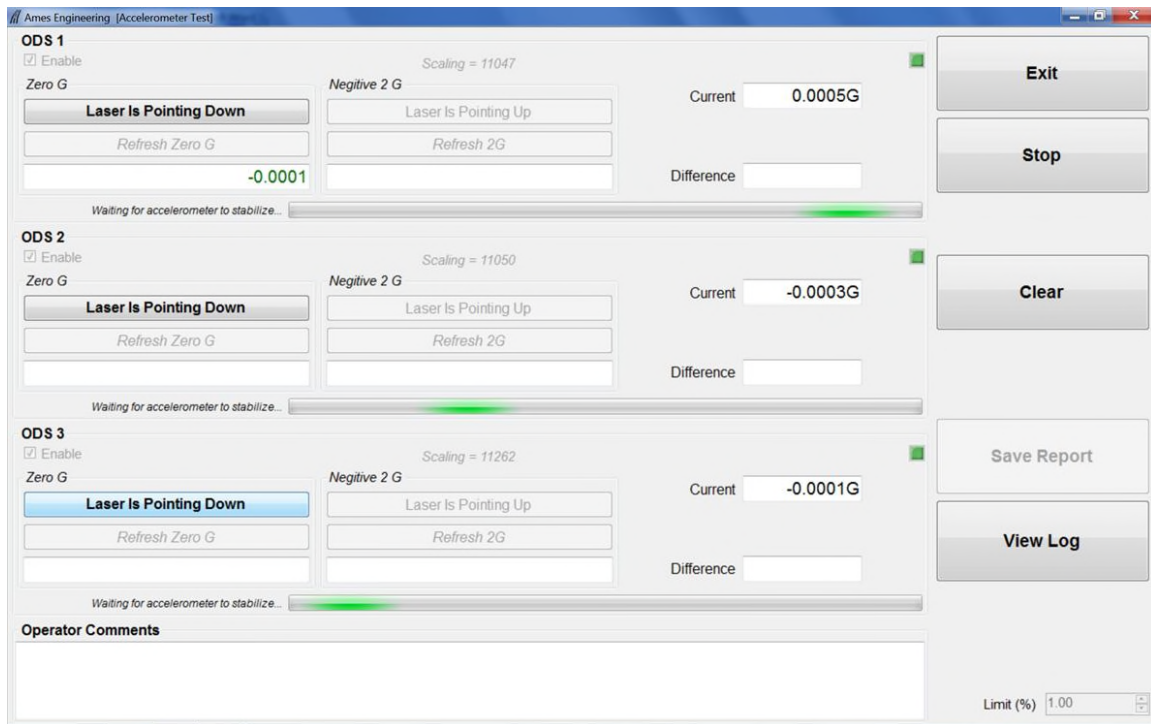


Figure 96. Screen after starting accelerometer test.

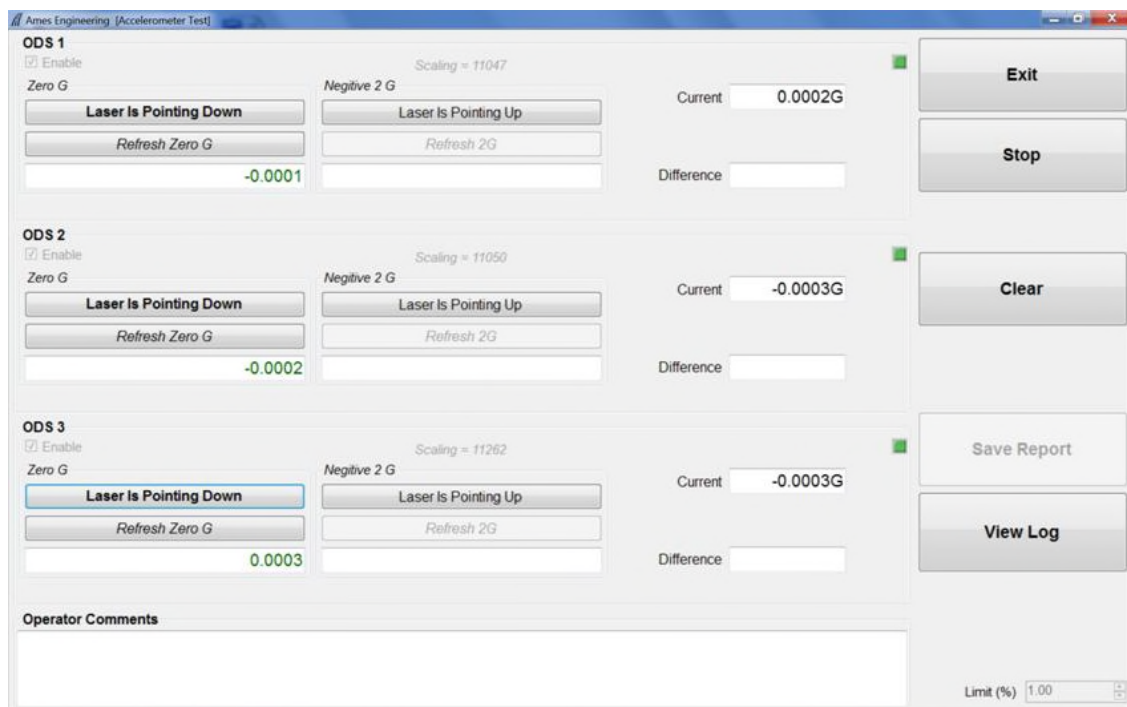


Figure 97. Screen after completion of test with lasers pointing downwards.



6. Rotate all three sensors by 180° such that the sensor glass is on the top, and place the rotated sensor within the enclosure associated with each sensor. Because of plugs coming in contact with the sensor bar frame, after being rotated, the center sensor needs to be turned by 180° and placed snug against the DAU so it will be stable. Select “Laser Is Pointing Up” button (see figure 98) for all three accelerometers.
7. After about twenty seconds, the system will store the current accelerometer reading and display it in the text box (see figure 99). If the operator wants to refresh the stored value, press the Refresh 2G button and the value that was stored after twenty seconds will be replaced.

The difference between the two measurements (laser pointing upward and downward) for each accelerometer is displayed in the “Difference” window (see figure 99).

The value displayed in the “Difference” window for each accelerometer must be within  $\pm 1\%$  of 2g (i.e., between 1.98g to 2.02g) in order for the accelerometer to pass the calibration check. A Pass or Fail message is displayed for each accelerometer. If an accelerometer fails to pass the check, repeat the test until two consecutive tests meet the required criterion. If the accelerometer is not able to pass the test, contact the RSC and decide on a suitable course of action.

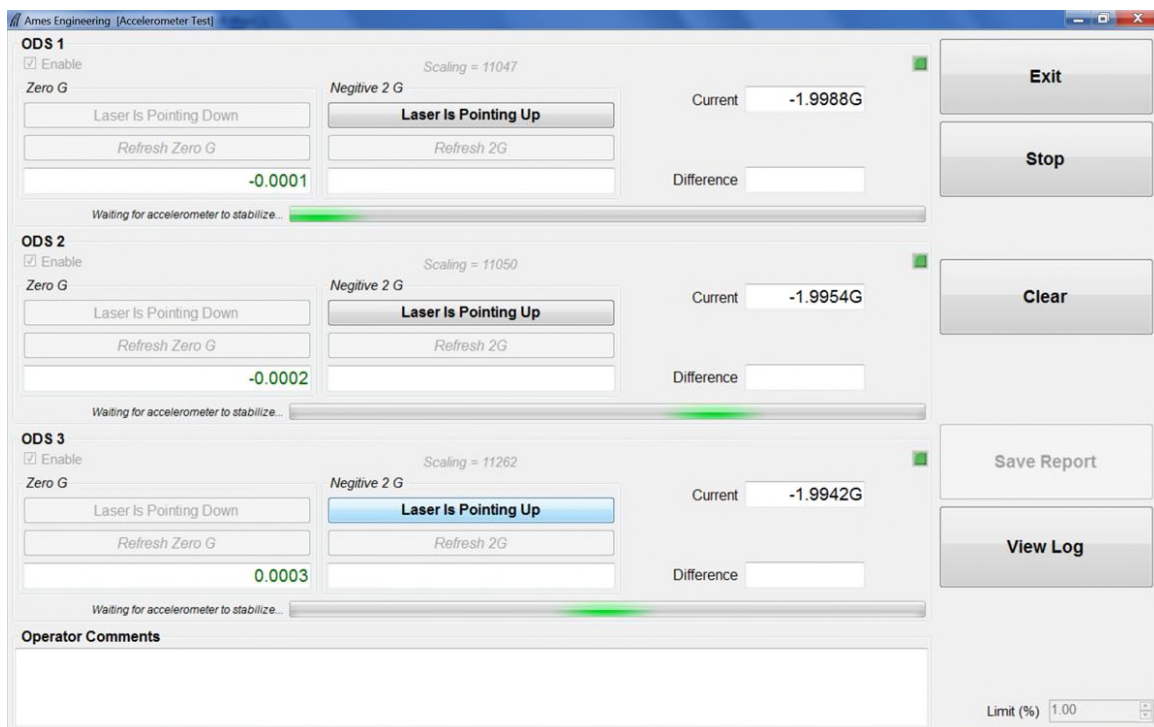


Figure 98. Screen after lasers are rotated with sensor glass on top.

Figure 99. Screen after completion of test with lasers pointing upward.

8. Select “Save Report” button to save results from the accelerometer test. The results are saved in a comma separated value (CSV) file. The results from test are appended to the file so that results from all tests are available in one file. Fill form PROF-5, Laser Sensor, Accelerometer, DMI Calibration/Calibration Check Form, which is included in appendix B.
9. At the end of the calibration check, the laser window in the height sensor will be in an upward position. Visually inspect the height sensor window for dirt and cracks. Clean the sensor glass using the procedures indicated in section 2.5.2. Visually inspect the rubber vibration mounts that hold the sensor boxes containing the profile height sensors to the beam. If any of the rubber mounts appear to be cracked they should be replaced. Turn the height sensor such that the laser is pointing down and latch the sensor box to the beam. The labels on the sensor box should be in normal reading orientation when standing in front of the van when the sensor box has been attached to the beam correctly.
10. Visually inspect the sensor glass of the texture height sensors for dirt and cracks. The texture height sensor has two sensor glass faces that must be inspected, one is associated with the part that emits the laser light and the other is associated with the part that detects the laser light. Clean the sensor glass using the procedures indicated in section 2.5.2.

## 2.12.5 Full Calibration Check of Profile and Texture Height Sensors

### 2.12.5.1 Overview

The profile height sensors and the texture height sensors have been calibrated in the factory and the operator cannot calibrate these sensors. A calibration check on these sensors is performed

before data collection in the field (see section 2.9.2.2). In the calibration check, profile and texture height sensors are checked to see if they can accurately measure the height within a specified tolerance by using a 25 mm block. However, this procedure only checks the accuracy of the height sensor over a 25-mm distance within its measuring range. A more comprehensive check of profile and texture height sensors must be performed at a maximum interval of 30 days, which will check the accuracy of the profile and texture height sensors over a 100-mm measuring range. This check is referred to as the Full Calibration Check of profile and texture height sensors to distinguish it from the Calibration Check of height sensors that is performed before data collection in the field. This check should be performed after the Accelerometer Calibration check is performed, as the sensor glass is specified to be inspected and cleaned at the end of the accelerometer calibration check (see steps 9 and 10 of section 2.12.4).

Both profile and texture height sensors are attached to the sensor bar such that the mid-point of the measuring range of the sensor is approximately at the ground surface. During the full calibration check, the vehicle is elevated so that the accuracy of each height sensor over a distance from below the mid-point of measuring range to above the mid-point of measuring range can be checked.

#### ***2.12.5.2 Supplies for Calibration Check***

**Van Support Ramps:** As described previously, the van is elevated when the full calibration check is performed. This is accomplished by driving the van onto ramps that are placed in front of the tires. Each ramp consists of two stacked 38-mm high boards screwed onto each other, with a portion of the ramp containing only one board. The ramps are securely mounted behind the rear bench sheet. To remove the ramps, loosen the two knobs and lift ramps vertically. A felt cloth is placed between the ramps to prevent the ramps from bonding together.

**Calibration Base Plates:** Three base plates are provided with each device (see section 2.2.17 and 2.5.9.1). Each base plate has three feet for support, and these can be used to level the plate.

**Calibration Targets:** Three targets are provided with each device (see section 2.2.17 and 2.5.9.2). Each target has a shiny side and a dull (matte) side. Measurements by the height sensors should always be obtained on the dull side.

**Calibration Blocks:** Three sets of blocks having nominal heights of 25, 50, 75, and 100 mm are provided with each device (see section 2.2.17 and 2.5.9.3). A block identifier is engraved on the side of the block. The exact heights of the blocks are shown in table 2. The exact height of each block should be entered into the Ames Engineering software following the procedures described in section 2.5.9.3 before performing the full calibration check. Once entered, the block heights are saved by the software, and do not need to be entered every time a check is performed.

#### ***2.12.5.3 Setup Profiler***

The full calibration check of profile and texture height sensors should be performed when the vehicle is parked on a level floor. Ideally this check should be performed in an enclosed building with a level concrete floor. The engine of the vehicle should be off when performing this test. If

the full calibration check is performed in the field, location where the check is performed should protect device from wind and other vibrations. The pavement surface should be as level as possible and lighting conditions should be consistent from sensor to sensor (i.e., face van away from the sun).

An external power source should be used when performing this check if the voltage of the auxiliary battery is low. The following procedure should be used to setup the profiler to perform the full calibration check and to check if the sensors are set at the correct position.

1. The tire pressure can have an effect on the results of this check. Therefore, the cold tire pressure of all tires must be checked to ensure that they are at the values specified in section 2.5.5.
2. Before elevating the vehicle onto ramps, with the operator outside the vehicle, in the Ames Engineering software start-up window (see figure 100) observe the “Height” values indicated below ODS1, ODS2, ODS3, ODS4, and ODS 5. The displayed Height values should be between -15 and 15 mm. If the sensor bar is perfectly level, the floor is perfectly level, and the height sensors are mounted such that the mid-point of the measurement range is located exactly at the ground surface, all height values should indicate zero. However, because variations in all of these factors, the displayed Height values are unlikely to be exactly zero. Record the Height values under ODS1, ODS2, ODS3, ODS4, and ODS 5 in form PROF-5, Laser Sensor, Accelerometer, DMI Calibration/Calibration Check Form, which is included in appendix B. From the Ames Engineering start-up screen (see figure 100), record the temperature corresponding to each height sensor in form PROF-5. The “Height” values should not change significantly between calibration checks unless the sensors have been moved or replaced since the previous calibration check. If any of the displayed “Height” values do not meet the specified tolerance, check the levelness of the bar (see section 2.5.3) and check if the sensor is latched on properly at the correct position.
3. Place a ramp in front of each tire as shown in figure 101, and then drive the vehicle onto the ramps such that all four tires rest on the upper part of each ramp. Figure 102 shows the van in the elevated position.

#### ***2.12.5.4 Full Calibration Check on Profile Height Sensors***

The full calibration check is first performed simultaneously on all three profile height sensors and thereafter this check is performed simultaneously on the two texture height sensors.

If a profile height sensor fails to meet the specified bias criterion (i.e., average bias within  $\pm 0.25$  mm) for any block position, check levelness of the sensor bar. If sensor bar is not level, level the bar following the procedures described in section 2.5.3 and repeat check until two consecutive tests meet the specified criterion. If a profile height sensor is unable to meet the specified bias criterion at any block position, follow the course of action described in Section 2.12.5.6.

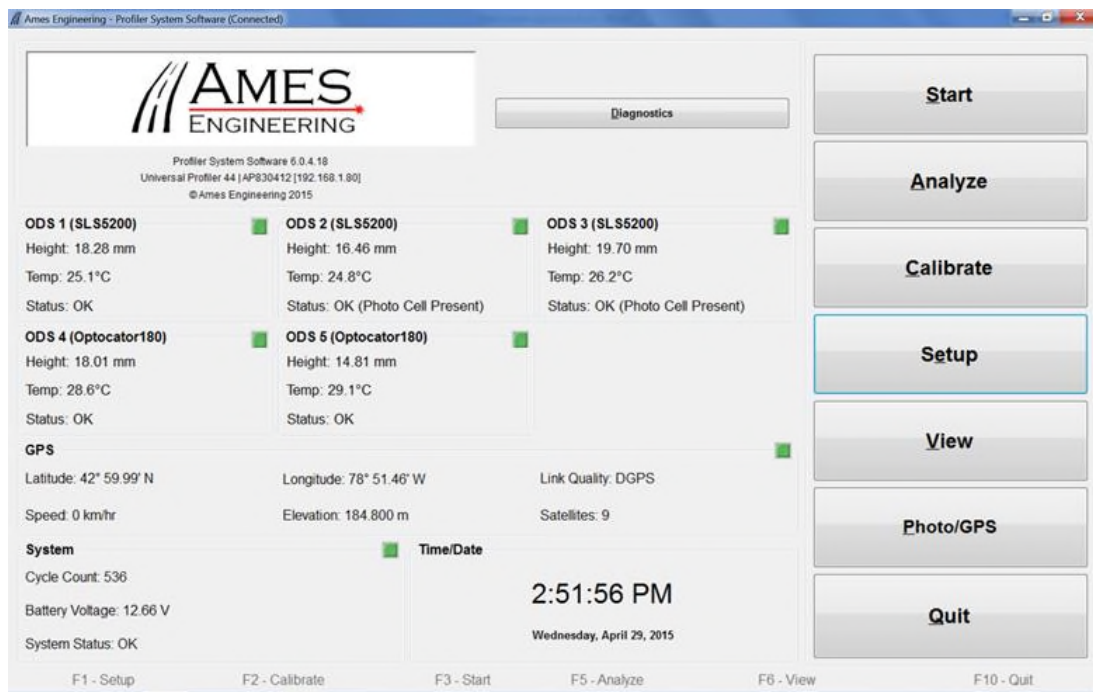


Figure 100. Ames Engineering software start-up screen.



Figure 101. Ramps placed in front of the tire before driving vehicle up the ramp.



Figure 102. Device on top of ramps.

Use the following procedure to perform the full calibration check on the profile height sensors:

1. In the Calibration Menu (see figure 88) press F4 key or select “Extensive Test” icon and the Extensive Test screen shown in figure 103 will be displayed. A check mark should appear in front of all sensors shown in the bottom right corner of the screen
2. The operator should be outside vehicle when this check is performed. The operator should adjust the laptop computer so that the screen can be seen from outside the vehicle, and the laptop computer dock should be rotated such that the keyboard is accessible from outside of the vehicle. Do not enter vehicle, bounce or bump vehicle, or lean on vehicle during calibration check.
3. Clean the top of the calibration base plates as needed, and place a calibration base plate on the ground under each profile height sensor such that two screws on the base plate are parallel to the sensor bar and the red laser dot on each plate is centered on the plate (see figure 104). Place digital level on plate parallel to the sensor bar, and level the plate using the two screws parallel to the sensor bar. Then place the digital level on plate perpendicular to the sensor bar and level plate using other screw. The plate is considered level when the reading on the digital level is less than or equal to  $0.05^{\circ}$  at the two positions described previously.



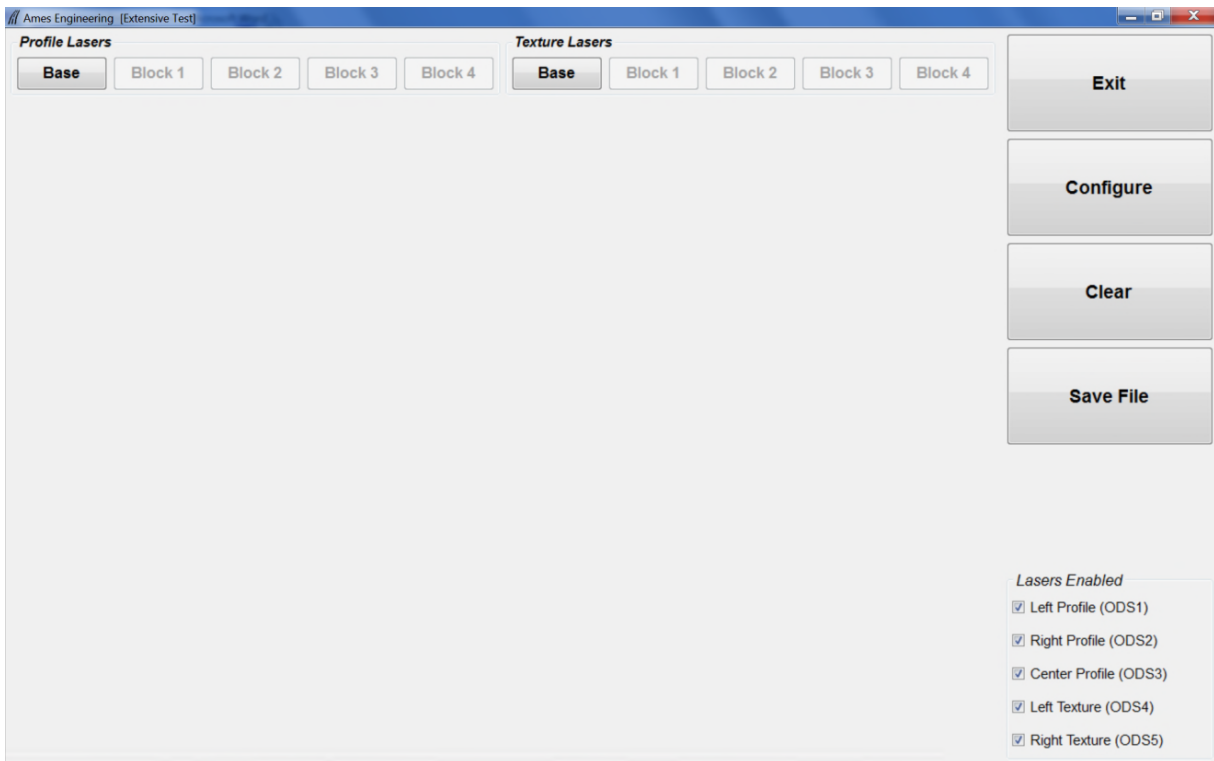


Figure 103. Extensive test screen.



Figure 104. Laser dot centered on base plate.



4. Place a calibration target on top of each base plate within the square marked on the base plate with the dull side of the target facing up, and place the 25 mm block behind the target to provide stability to base plate (see figure 105). In the software (see figure 103) under Profile Lasers select “Base” to take a measurement on top of the target that is placed on each base place. Six sets of measurements are taken on each target. Figure 106 shows an example of the screen after measurements have been obtained. The readings displayed are in the following order: left height sensor, center height sensor, and right height sensor.



Figure 105. Target placed on the base plate.

5. Remove the target and 25 mm block from calibration base plate, place the 25 mm block associated with the sensor on top of base plate within the square marked on the base plate such that the block identifier faces the operator. Place calibration target with dull side facing up on top of the block (see figure 107). Repeat procedure for the other two sensors. In the software, under Profile Lasers, select Block 1 to take measurements on top of target (see figure 106). Six sets of measurements are taken on each target plate. An example of the screen after readings have been obtained in this position is shown in figure 108. Check the average bias value. The average bias value for each sensor must be within  $\pm 0.25$  mm. If the average bias is outside this value, repeat the test until two consecutive tests meet the specified criterion.
6. Remove the 25 mm block and calibration target. Do step 4. Remove target and 25 mm block from calibration base plate and then place the 50 mm block associated with the sensor on top of base plate such that the 50 mm height is vertical and block is placed within the square marked on the base plate. Place calibration target with the dull side facing up on top of the block (see figure 109). Repeat procedure for the other two sensors. In software, under Profile Lasers, select Block 2 to take measurements on top of target plate (see figure 106). Six sets

of measurements are taken on the target plate. The average bias value for each sensor must be within  $\pm 0.25$  mm. If the average bias is outside this value, repeat the test until two consecutive tests meet the specified criterion.

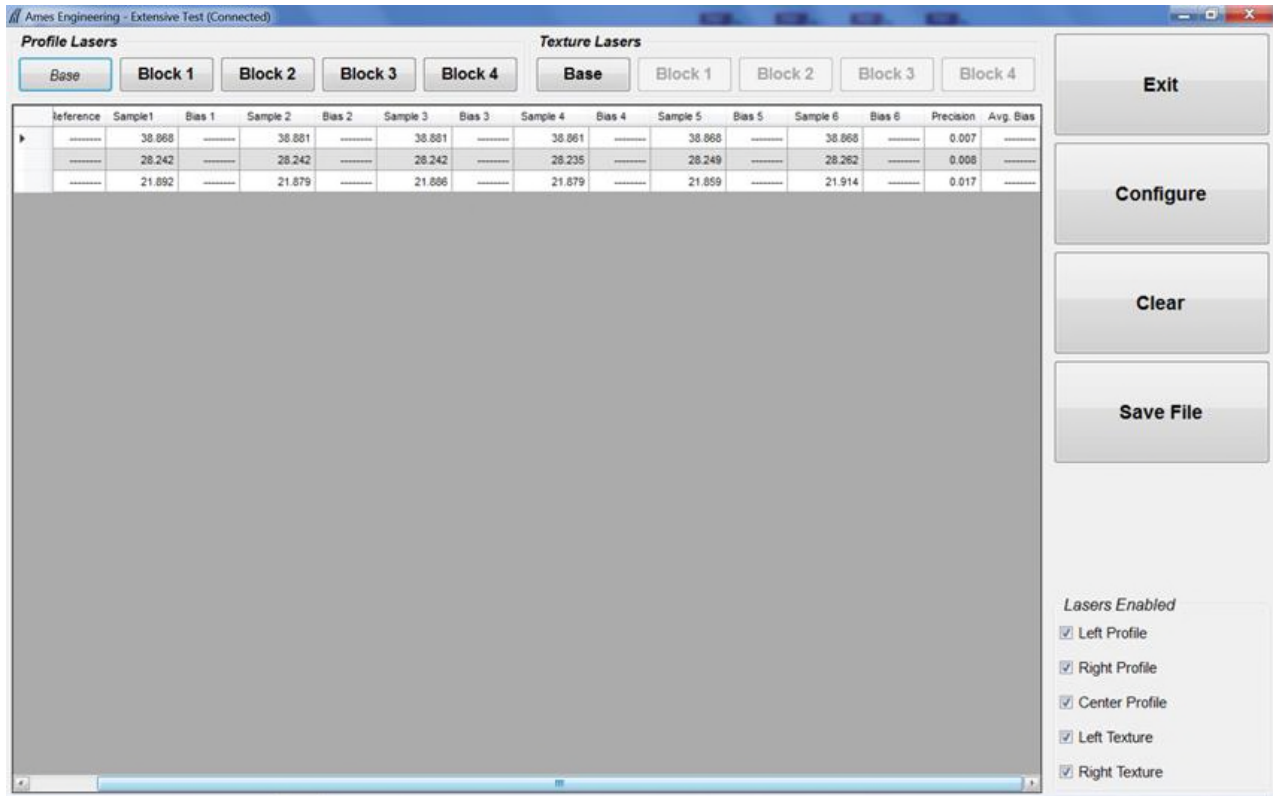


Figure 106. Screen after readings have been obtained on target placed on base plate.



Figure 107. The 25 mm block with target on top of the block.

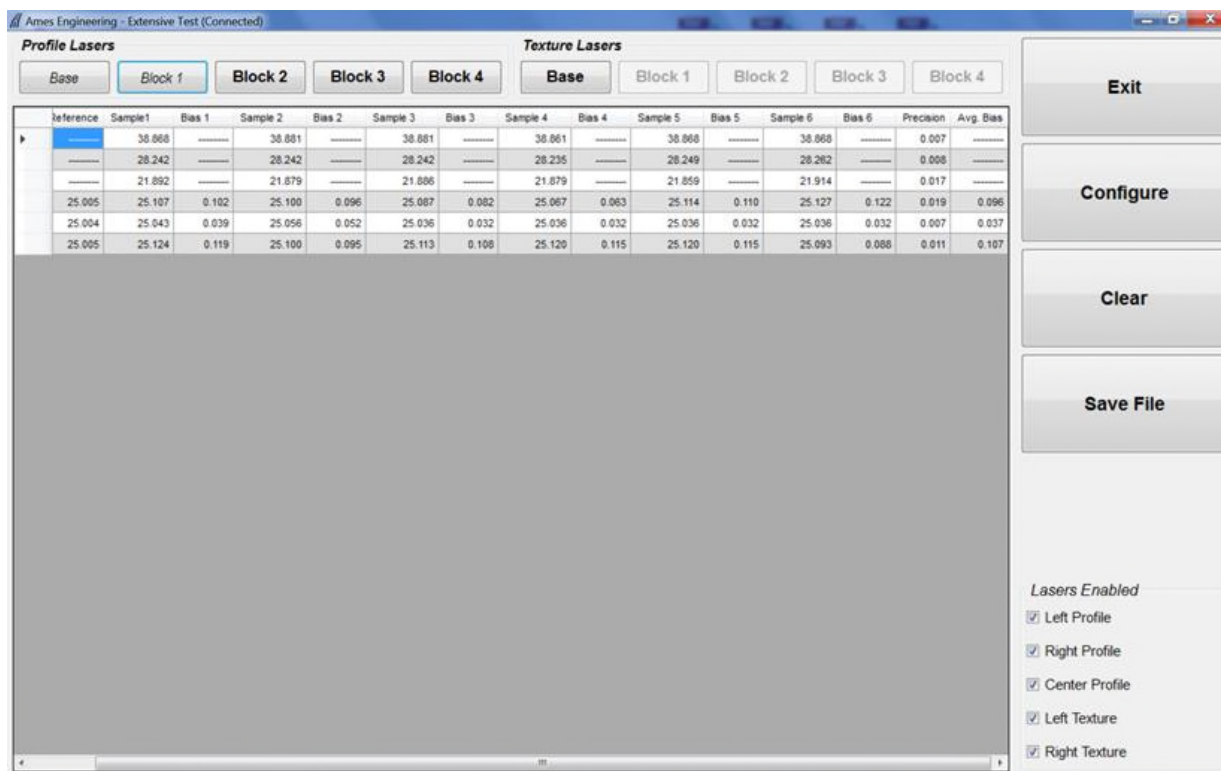


Figure 108. Screen after readings have been obtained on the 25 mm block.



Figure 109. Readings being taken on a 50 mm block.

7. Remove the 50 mm block and calibration target. Do step 4. Remove target and 50 mm block from calibration base plate and place the 75 mm block associated with the sensor on top of base plate such that the 75 mm height is vertical and block is placed within the square marked on the base plate. Place calibration target plate with dull side facing up on top of the block (see figure 110). Repeat procedure for the other two sensors. In software, under Profile Lasers, select Block 3 to take measurements on top of target plate. Six sets of measurements are taken on the target plate. The average bias value for each sensor must be within  $\pm 0.25$  mm. If the average bias is outside this value, repeat the test until two consecutive tests meet the specified criterion.
8. Remove the 75 mm block and calibration target. Do step 4. Remove target and 25 mm block from calibration base plate and place the 100 mm block associated with the sensor on top of base plate such that the 100 mm height is vertical and block is placed within the square marked on the base plate. Place calibration target with dull side facing up on top of the block (see figure 111). Repeat procedure for the other two sensors. In software, under Profile Lasers, select Block 4 to take measurements on top of target plate. Six sets of measurements are taken on the target plate. The average bias value for each sensor must be within  $\pm 0.25$  mm. If the average bias is outside this value, repeat the test until two consecutive tests meet the specified criterion.



Figure 110. Readings being taken on a 75 mm block.





Figure 111. Readings being taken on a 100 mm block.

9. Figure 112 shows how the screen appears after calibration check has been performed with all four blocks.

| Ames Engineering [Extensive Test]    |        |          |        |          |        |          |        |          |        |          |        |           |           |        |
|--------------------------------------|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|-----------|-----------|--------|
| Texture Lasers                       |        |          |        |          |        |          |        |          |        |          |        |           |           |        |
| Profile Lasers                       |        |          |        |          |        |          |        |          |        |          |        |           |           |        |
| Base Block 1 Block 2 Block 3 Block 4 |        |          |        |          |        |          |        |          |        |          |        |           |           |        |
| Sample                               | Bias 1 | Sample 2 | Bias 2 | Sample 3 | Bias 3 | Sample 4 | Bias 4 | Sample 5 | Bias 5 | Sample 6 | Bias 6 | Precision | Avg. Bias |        |
| 38.664                               |        | 38.693   |        | 38.706   |        | 38.740   |        | 38.684   |        | 38.662   |        | 0.027     |           |        |
| 34.051                               |        | 34.027   |        | 34.036   |        | 34.029   |        | 34.031   |        | 34.016   |        | 0.011     |           |        |
| 25.005                               | 24.791 | -0.214   | 24.796 | -0.209   | 24.769 | -0.236   | 24.822 | -0.183   | 24.811 | -0.194   | 24.822 | -0.183    | 0.019     | -0.203 |
| 25.004                               | 24.898 | -0.106   | 24.892 | -0.112   | 24.885 | -0.119   | 24.918 | -0.086   | 24.921 | -0.083   | 24.892 | -0.112    | 0.014     | -0.103 |
| 25.005                               | 24.874 | -0.131   | 24.916 | -0.089   | 24.929 | -0.076   | 24.942 | -0.063   | 24.922 | -0.083   | 24.920 | -0.085    | 0.021     | -0.087 |
|                                      | 41.825 |          | 41.862 |          | 41.878 |          | 41.858 |          | 41.856 |          | 41.829 |           | 0.019     |        |
|                                      | 38.531 |          | 38.542 |          | 38.494 |          | 38.507 |          | 38.509 |          | 38.556 |           | 0.022     |        |
|                                      | 33.843 |          | 33.812 |          | 33.823 |          | 33.827 |          | 33.819 |          | 33.827 |           | 0.009     |        |
| 50.005                               | 49.891 | -0.314   | 49.738 | -0.267   | 49.729 | -0.276   | 49.729 | -0.276   | 49.716 | -0.289   | 49.725 | -0.280    | 0.015     | -0.283 |
| 50.005                               | 49.723 | -0.282   | 49.734 | -0.271   | 49.745 | -0.260   | 49.736 | -0.269   | 49.719 | -0.286   | 49.739 | -0.266    | 0.009     | -0.272 |
| 50.004                               | 49.614 | -0.390   | 49.607 | -0.397   | 49.581 | -0.423   | 49.567 | -0.437   | 49.627 | -0.377   | 49.627 | -0.377    | 0.023     | -0.400 |
|                                      | 42.095 |          | 42.048 |          | 42.073 |          | 42.137 |          | 42.144 |          | 42.139 |           | 0.037     |        |
|                                      | 38.693 |          | 38.762 |          | 38.788 |          | 38.720 |          | 38.742 |          | 38.762 |           | 0.031     |        |
|                                      | 34.100 |          | 34.104 |          | 34.106 |          | 34.120 |          | 34.113 |          | 34.133 |           | 0.011     |        |
| 50.005                               | 49.939 | -0.066   | 49.946 | -0.059   | 49.900 | -0.105   | 49.964 | -0.041   | 49.931 | -0.074   | 49.946 | -0.059    | 0.020     | -0.067 |
| 50.005                               | 49.884 | -0.121   | 49.890 | -0.107   | 49.884 | -0.121   | 49.891 | -0.114   | 49.891 | -0.114   | 49.891 | -0.114    | 0.005     | -0.115 |
| 50.004                               | 49.881 | -0.123   | 49.888 | -0.116   | 49.881 | -0.123   | 49.875 | -0.129   | 49.895 | -0.109   | 49.888 | -0.116    | 0.006     | -0.119 |
|                                      | 41.871 |          | 41.927 |          | 41.929 |          | 41.964 |          | 41.896 |          | 41.878 |           | 0.032     |        |
|                                      | 38.686 |          | 38.664 |          | 38.693 |          | 38.642 |          | 38.720 |          | 38.735 |           | 0.031     |        |
|                                      | 34.042 |          | 34.009 |          | 33.956 |          | 33.978 |          | 34.064 |          | 33.993 |           | 0.037     |        |
| 75.003                               | 74.852 | -0.151   | 74.865 | -0.138   | 74.846 | -0.157   | 74.846 | -0.157   | 74.850 | -0.153   | 74.872 | -0.131    | 0.010     | -0.148 |
| 75.003                               | 74.885 | -0.118   | 74.903 | -0.100   | 74.863 | -0.140   | 74.885 | -0.118   | 74.883 | -0.120   | 74.876 | -0.127    | 0.012     | -0.121 |
| 75.004                               | 74.891 | -0.113   | 74.831 | -0.173   | 74.884 | -0.120   | 74.895 | -0.109   | 74.871 | -0.133   | 74.875 | -0.129    | 0.021     | -0.130 |
|                                      | 41.942 |          | 41.971 |          | 42.059 |          | 41.978 |          | 41.951 |          | 41.971 |           | 0.038     |        |
|                                      | 38.693 |          | 38.633 |          | 38.653 |          | 38.651 |          | 38.684 |          | 38.684 |           | 0.022     |        |
|                                      | 34.002 |          | 33.971 |          | 33.962 |          | 33.925 |          | 33.945 |          | 33.978 |           | 0.024     |        |
| 90.002                               | 99.882 | -0.119   | 99.895 | -0.106   | 99.895 | -0.106   | 99.909 | -0.092   | 99.895 | -0.106   | 99.882 | -0.119    | 0.009     | -0.109 |
| 90.004                               | 99.815 | -0.189   | 99.868 | -0.136   | 99.841 | -0.163   | 99.821 | -0.183   | 99.821 | -0.183   | 99.828 | -0.176    | 0.018     | -0.172 |
| 90.004                               | 99.860 | -0.144   | 99.834 | -0.170   | 99.854 | -0.150   | 99.834 | -0.170   | 99.860 | -0.144   | 99.834 | -0.170    | 0.012     | -0.158 |

Figure 112. Results after performing measurements on the four blocks.

#### ***2.12.5.5 Full Calibration Check on Texture Height Sensors***

The full calibration check of the texture height sensors should be performed immediately after performing the full calibration check on the profile height sensors.

If a texture height sensor fails to meet the specified bias criterion (i.e., average bias within  $\pm 0.25$  mm) for any block position, check the levelness of the sensor bar. If the sensor bar is not level, level the bar following the procedures described in section 2.5.3 and repeat the check until two consecutive tests meet the criterion. If a texture height sensor is unable to meet the specified bias criterion at any block position, follow the course of action described in Section 2.12.5.6.

Use the following procedure to perform the full calibration check on the texture height sensors:

1. Place a base plate below each texture height sensor and level plate as described in step 3 of Section 2.12.5.5
2. Place a calibration target on top of each calibration base plate with dull side facing up within the square marked on the base plate and place the 25 mm block behind the target plate to provide stability to base plate (see figure 105). In the software, under Texture Lasers select Base to take a measurement on top of target plate that is placed on each base plate (see figure 112). Six sets of measurements are taken on the target plate. Then remove the calibration target and the 25 mm block from the calibration base plate.
3. Place the 25 mm block associated with the sensor on top of base plate within the square marked on the base plate such that the block identifier faces the operator. Place the calibration target with the dull side facing up on top of the block (see figure 107). Repeat the procedure for the other sensor. In the software, under Texture Lasers, select Block 1 to take measurements on top of the target plate. Six sets of measurements are taken on the target. Check the average bias value. The average bias value for each sensor must be within  $\pm 0.25$  mm. If the average bias value is outside this value, repeat the test until two consecutive tests meet the specified criterion.
4. Do step 2. Place the 50 mm block associated with the sensor on top of base plate within the square marked on the base plate such that the block identifier faces the operator. Place the calibration target with the dull side facing up on top of the block. Repeat the procedure for the other sensor. In the software, under Texture Lasers, select Block 2 to take measurements on top of the target plate (see figure 107). Six sets of measurements are taken on the target plate. Check the average bias value. The average bias value for each sensor must be within  $\pm 0.25$  mm. If the average bias value is outside this value, repeat the test until two consecutive tests meet the specified criterion.
5. Do step 2. Place the 75 mm block associated with the sensor on top of the base plate within the square marked on the base plate such that the block identifier faces the operator. Place the calibration target with the dull side facing up on top of the block. Repeat procedure for the other sensor. In the software, under Texture Lasers, select Block 3 to take measurements on top of target plate (see figure 107). Six sets of measurements are taken on the target plate.

Check the average bias value. The average bias value for each sensor must be within  $\pm 0.25$  mm. If the average bias value is outside this value, repeat the test until two consecutive tests meet the specified criterion.

- 6 Do step 2. Place the 100 mm block associated with the sensor on top of the base plate within the square marked on the base plate such that the block identifier faces the operator. Place the calibration target with dull side facing up on top of the block. Repeat procedure for the other sensor. In the software, under Texture Lasers, select Block 4 to take measurements on top of the target plate (see figure 107). Six sets of measurements are taken on the target. Check the average bias value. The average bias value for each sensor must be within  $\pm 0.25$  mm. If the average bias value is outside this value, repeat the test until two consecutive tests meet the specified criterion.
7. Select “Save File” button to save the results from this test. The results from the test on profile height sensors as well as texture height sensors are saved to a single file. The results are saved in a CSV) file that can be imported into an Excel file. Fill form PROF-5, Laser Sensor, Accelerometer, DMI Calibration/Calibration Check Form, which is included in appendix B.

#### ***2.12.5.6 Failure of Full Calibration Check on a Profile or Texture Height Sensor***

The profile and texture height sensors were calibrated in the factory at a specific temperature. It is reported that for the texture height sensor, the scale factor change is typically less than 0.005 percent of the measuring range per  $^{\circ}\text{C}$ , with a maximum value of 0.01 percent of measuring range per  $^{\circ}\text{C}$ .

If a profile or a texture height sensor failed the full calibration check, compare the temperature of the lasers that are displayed on the Ames software start-up screen (see figure 100) with the temperature values that were recorded when the height sensor last passed the check. If there is a significant difference in temperature, it is possible that the temperature related drift of the sensor is the cause for the sensor to not pass the calibration check.

If a sensor fails the full calibration check, discuss issue with Ames Engineering and inform FHWA about the outcome of the discussions. If Ames Engineering recommends the sensors to be re-linearized to address this issue, obtain approval from the FHWA, and re-linearize the sensors that fail to pass the full calibration check using the procedures outlines in appendix E. The re-linearization procedure changes the calibration scale factor of the sensor through a software provided by Ames Engineering.

#### **2.12.6 Calibration Check of Texture Height Sensors**

A calibration check of the texture height sensors is performed using the texture reference test device provided by Ames Engineering. A description of this device was presented in section 2.2.18. This test consists of two components, a static test and a dynamic test. The static test is used to check the proper functioning of the sensor in the static mode, where the results from the test provide information about the noise in the sensor and whether the sensor is scaled properly. The dynamic test the functioning of the sensor in the dynamic mode.



### ***2.12.6.1 Setup Procedure for Test***

It is recommended this test be performed immediately after performing the full calibration check on the texture height sensors. Use following procedure to setup this test:

1. If performing this test after performing the full calibration check of the texture height sensors, drive the vehicle down from second step of the ramp to the first step, and proceed to step 2. Otherwise, place a ramp in front of each tire (see figure 101) and drive the vehicle up the ramp to the first step. Performing this test with the vehicle up on the first step of the ramp ensures the test occurs with the lasers taking measurements near the mid height of their measuring range.
2. In the Calibration Screen (see figure 88), press F6 key or select “Texture Disk Test” icon. This will bring up the Texture Disk Test window shown in figure 113.

The Setup parameters for the test are Segments, target MPD, and Limit. These setup parameters are shown in the lower right corner of the screen. The setup parameters should be set so they have the following values:

**Segments:** This value indicates the number of 100 mm segments that are averaged to compute the MPD. This parameter should be set to 100. The test will terminate once sufficient data have been collected.

**Target MPD:** This is the theoretical MPD value for the reference disk. This parameter should be set to 0.75 mm.

**Limit (%):** This value indicates the tolerance that is placed on the MPD computed from the data collected during test in order to pass this test. This parameter should be set to 7.5. Therefore, in order to pass this test, the MPD computed from the data collected during this test should be between 0.694 and 0.806 mm.

Once the parameters are set they are automatically saved when the program is exited. Therefore, the user does not need to enter these values at the start of each test after the values are set initially.

### ***2.12.6.2 Procedure for Performing Test***

1. Open the sensor bar cover. Disconnect the encoder input from the DAU. Plug in the black connector attached to the reference device (see figure 114) to the DMI input port in the DAU.
2. Disconnect the vertical photocell input from the center profile height sensor box. Plug in the yellow connector attached to the reference device (see figure 114) to the photocell input port. Power to the reference test device is provided from this port. Note: The yellow connector can be connected to photocell input in any laser box. However, because of length limitation of this cable, it may not be possible to perform the test on the right texture height sensor if the

cable is connected to the left sensor box and vice versa. Therefore, the best method to perform this test is to plug the yellow connector to the photocell input in the center sensor, so that the test can be easily performed on both texture sensors. However, the yellow cable can be plugged into the photocell input of the left laser box if the cable is of sufficient length so that the test can be performed easily on both sensors.



Figure 113. Texture disk test window.

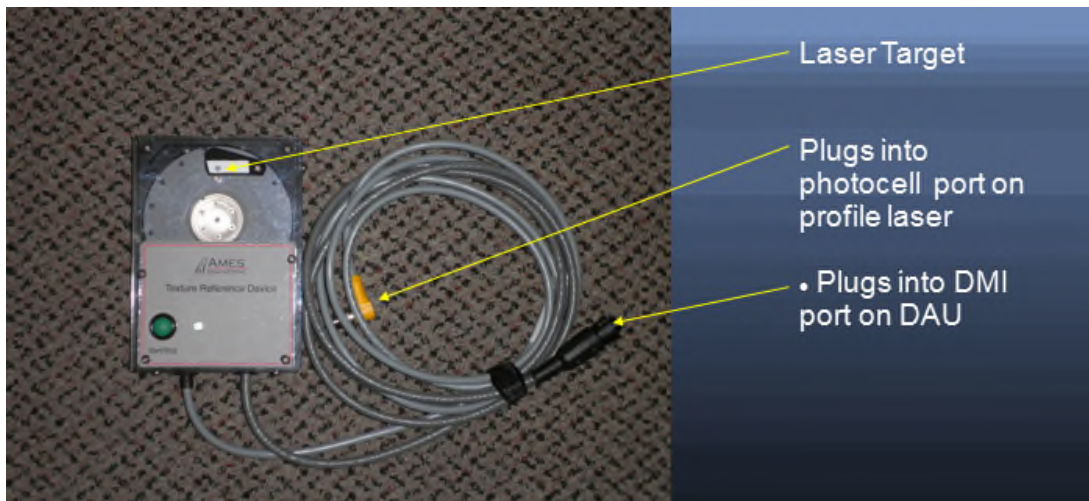


Figure 114. Texture reference test device.

3. Place reference test device below the left texture height sensor. The reference device has a moveable cover with a target label attached to the top (see figure 115). Aligning the laser dot on the target ensures the laser will strike the spinning disk in the proper spot. The static test is performed with the laser dot targeting the crosshairs (cover closed) and the dynamic test is performed with the laser dot targeting the spinning disk (cover open). With the cover closed, align the laser dot on the cross hairs of the target.

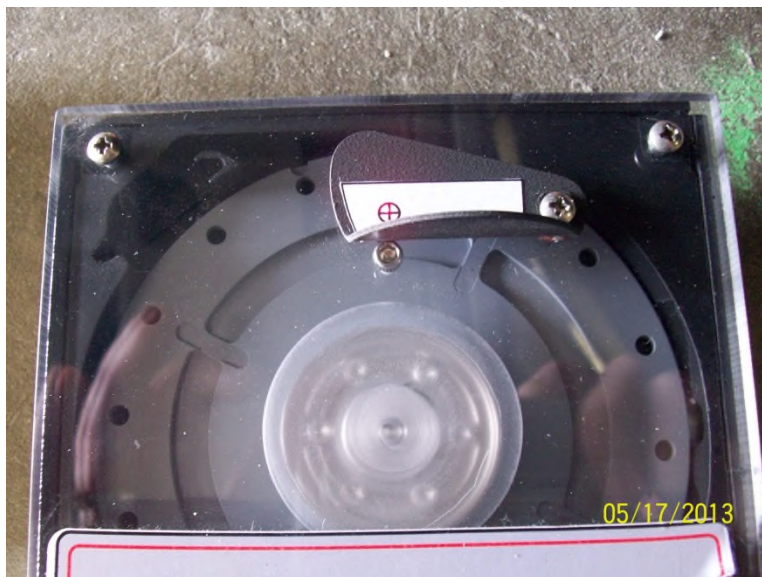


Figure 115. Target on texture reference test device.

4. To initiate the test select “Static Texture 1” (see figure 116). This puts the software in a standby mode. Hold the reference device firmly to the ground and make sure the laser dot is targeting the crosshairs of the cover. Press the green button on the reference device to spin the disk. After the disk is up to speed the test will automatically start and five rapid beeps will be heard. After a sufficient amount of data has been obtained the test will terminate automatically and a long single beep will be heard indicating that the test has ended. The green button must be pressed twice if a retest of the sensor is to be performed.

The operator has the option of stopping the spinning of the disk sooner after completion of the test rather than wait for the disk to spin down and stop automatically. This can be accomplished by pressing the green button after the beep at the end of the test is heard. If the test was terminated this way, and a retest is desired, press the green button once.

When the static test is complete, the laptop computer screen will display the average MPD for the static test (see Figure 116). Ames Engineering has established a threshold MPD of 0.33 mm for the static test. This threshold cannot be changed by the operator. If the MPD from the static test is above 0.33 mm the static test result will be displayed in red. If the static test MPD is above 0.33 mm repeat the test. Two consecutive tests must meet the specified threshold in order to pass the static test. If it is not possible to get two consecutive tests with a value less than 0.33 mm after repeating the test several times contact the RSC office and decide on a suitable course of action.



Figure 116. Texture reference test screen after static test.

5. After the static test has been performed, and if the MPD from static test is below 0.33 mm, select the “Dynamic Texture 1” button (see figure 116). Align laser on the cross hairs of the target on the cover, and then hold the reference device firmly to the ground. Gently open the cover on the texture reference device (see Figure 117) and press the green button on the reference device to spin the disk. After the disk is up to speed the test will automatically start and three beeps will be heard at the start of the test. After sufficient amount of data has been obtained the test will terminate automatically and three beeps will be heard indicating that the test has ended. When the test is completed, the laptop computer screen will display the average MPD for the segments tested, and a PASS or FAIL message will appear on the screen (see figure 118). In order for the PASS message to appear the MPD from the static test must be less than 0.33 mm and the MPD from the dynamic test must be within the specified 7.5 percent limit of 0.75 mm (i.e., between 0.694 and 0.806 mm). If a FAIL message appears repeat the test until two consecutive tests pass the test. If it is not possible to get a PASS for two consecutive tests after repeating test several times contact the RSC office and decide on a suitable course of action.
6. Repeat the procedure outlined in steps 3 through 5 for the right texture sensor. When performing the test for the right texture sensor “Static Texture 2” and “Dynamic Texture 2” have to be selected. Once the test has been completed for both sensors, and both sensors pass the test, select the “Save Dynamic Test” button on the software (see figure 119) to save the file that contains results from this test. Complete form PROF-5, Laser Sensor, Accelerometer, DMI Calibration/Calibration Check Form, which is included in appendix C.



Figure 117. Cover open on texture reference test device.

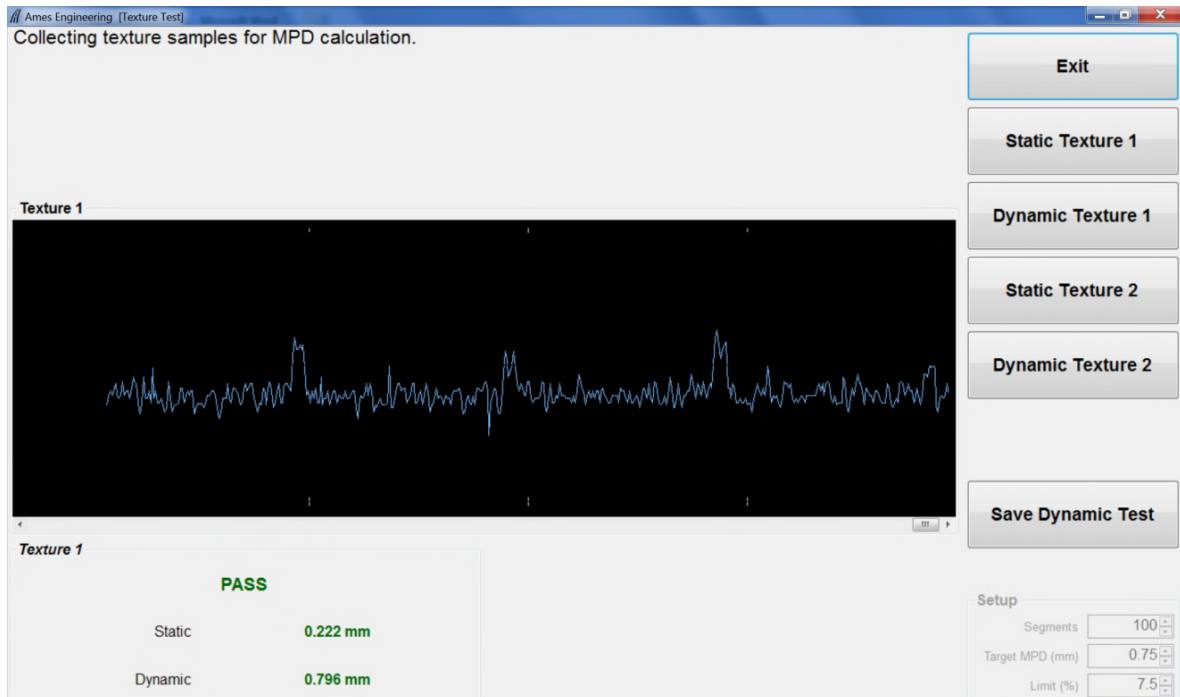


Figure 118. Texture reference test screen after dynamic test on left sensor.



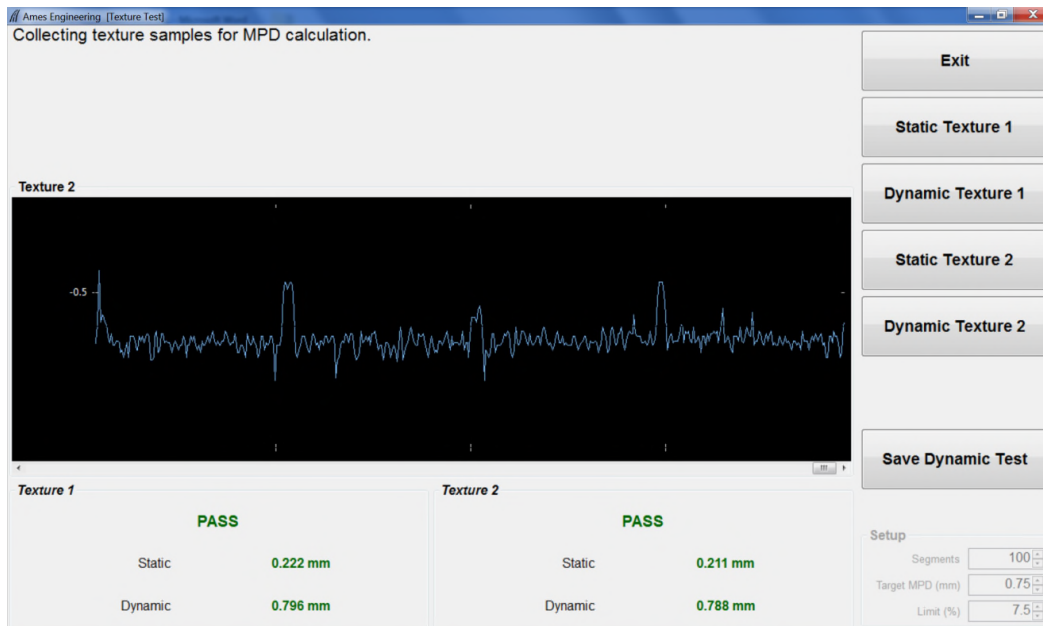


Figure 119. Results from a completed texture calibration check.

### 2.12.7 Bounce Test

After completing full calibration check on the profile and texture height sensors, drive the vehicle off the ramps to the ground. Perform a bounce test following the procedures indicated in section 2.9.2.4.

### 2.12.8 Calibration Check of Ambient Temperature Sensor

A National Institute of Standards and Technology (NIST) traceable mercury thermometer is required to perform this test. This test should be performed in the shade, using the following procedure.

1. Park the Ames device in the shade, and allow some time for the vehicle to cool off if the device was exposed to the sun.
2. Power up the system, start the laptop computer, and launch the Ames Engineering software using the procedures described in section 2.8.1. Wait 15 minutes for the equipment to warm-up.
3. The ambient temperature sensor has two temperature probes and the temperatures measured by both probes are displayed in the display unit located on the dashboard on the driver's side (see section 2.2.12). Observe the temperature readings displayed for the two probes and wait until the readings stabilize.
4. Place a thermometer close to the temperature probe and record the reading of the thermometer.

5. Note the readings for the two temperature probes that are displayed on the display box.
6. The following two conditions must be satisfied in order for the ambient temperature sensor to pass the calibration check:
  - (a) The difference between the two temperature readings from the two temperature probes that are shown on the display must be within  $\pm 2^{\circ}\text{C}$ .
  - (b) The difference between each temperature probe reading that is displayed on the display box and the temperature obtained from the thermometer must be within  $\pm 2^{\circ}\text{C}$ .
7. The ambient temperature sensor is considered to be acceptable if criterion (a) and (b) indicated in the previous step are met. If one or both criterion described in (a) and (b) above is not met, repeat steps 4 and 5. If one or both criterion is still not satisfied, contact RSC and decide on a suitable course of action.
8. Complete form PROF-6, Ambient Temperature Sensor, Pavement Surface Temperature Sensor, and GPS Calibration Check Form, which is included in appendix B.

#### **2.12.9 Calibration Check of Pavement Surface Temperature Sensor**

A NIST traceable mercury thermometer is required to perform this test

1. Power up the system, start the laptop computer, and launch the Ames Engineering software using the procedures described in section 2.8.1 Open cover of the temperature probe (see section 2.2.9). Wait 15 minutes for the equipment to warm-up.
2. Observe the pavement surface temperature that is shown on the display unit located on the dashboard on the driver's side (see section 2.2.12) and wait for reading to stabilize if it is changing.
3. Record pavement surface temperature measured by the temperature sensor that is shown on the display unit. Use an infra-red temperature gun to record the temperature of the pavement surface at the location that is directly below the temperature sensor.
4. Prepare an ice water bath. Place ice and water in a suitable container that can be placed under the van on the ground below the pavement surface temperature sensor. Stir until the temperature of the ice and water mix measured by the thermometer is less than or equal to  $2^{\circ}\text{C}$ .
5. Place container containing the ice and water mix under the temperature sensor and allow the temperature measured by the temperature sensor that is displayed on the display unit to stabilize. Record the temperature shown on the display unit and also record the temperature of the ice and water mix measured using the thermometer.



6. The pavement surface temperature sensor is considered to be acceptable if the difference between the two temperature readings noted in step 3 and step 5 are within  $\pm 2^{\circ}\text{C}$ .
7. If the difference between the two temperatures is outside this tolerance for either step 3 or step 5 or both, repeat appropriate test. If the difference between the two temperatures is still outside the specified tolerance consider the pavement surface temperature sensor to be unacceptable, and contact RSC and decide on a suitable course of action.
8. Complete form PROF-6, Ambient Temperature Sensor, Pavement Surface Temperature Sensor, and GPS Calibration Check Form, which is included in appendix B.

#### **2.12.10 Calibration Check of GPS Receiver**

Use following procedure to perform a calibration check on the GPSR:

1. Use Google Earth or an accurate hand-held GPSR to obtain the latitude and longitude of a known location where the device can be parked. This location can be in the parking lot of the office, or an adjacent location, and must be clear of any high buildings that might interfere with satellite signals. Record the latitude and longitude of the approximate location where the light bar of the device will be located when parked.
2. Park the vehicle at the location that was identified. Power up the system, start the laptop computer, and launch the Ames Engineering software using the procedures described in section 2.8.1
3. The latitude and longitude measured by the GPSR in the profiler is displayed on the start-up screen of Ames Engineering software (see figure 100). Look at Link Quality that is displayed on the screen to see if it is DGPS. If not, another location where Link Quality is DGPS is needed to perform this check.
4. Record the latitude and longitude values that are displayed on the start-up screen. If the recorded values agree up to four decimal places with the latitude and longitude that was obtained from Google earth or another accurate hand-held GPSR, the GPSR is considered to be functioning properly. If agreement is not obtained to four decimal places, pick-another location and repeat procedure. After repeating procedure, if agreement is still not obtained, consider the GPSR is not functioning properly and contact RSC and decide on a suitable course of action.
5. Complete form PROF-6, Ambient Temperature Sensor, Pavement Surface Temperature Sensor, and GPS Calibration Check Form, which is included in appendix B.

#### **2.12.11 Check on Photocell Initiation**

Historically in the LTPP program, the first profile data point recorded at a section has been at a distance of 114 mm from the leave edge of the section start stripe. Software settings in the Ames

Engineering devices are set such that the first data point obtained at a section is at a distance of 114 mm from the leave edge of the section start stripe.

Each RSC should annually verify if the device is obtaining the first data point between a distance of 114 and 152 mm from the leave edge of a reflective tape placed on the pavement surface if data collection is initiated using the vertical photocell, or from the leave edge of a reflective tape that is placed on a cone if data collection is initiated using the horizontal photocell. Each RSC should maintain a log that indicates the results from this test.

The following sections describe the field procedure for performing the test and the procedure to analyze the collected data.

#### ***2.12.11.1 Site Preparation***

The test procedure involves attaching artificial bump targets to the pavement and then collecting a series of profile runs. The testing location should be a straight stretch of pavement that is not subjected to traffic. The purpose of performing this test on a pavement that is not subjected to traffic is because of the artificial bump that is placed on the pavement. Ideally this test should be performed at a speed of 80 km/h. However, the test can be performed at 64 km/h. The ideal location should be a new or a recently overlaid pavement surface with no significant pavement distresses within 15 m of the target point. Pavements with rough surface textures such as chip seals or severe raveling should be avoided.

Once a location for testing has been selected, it is necessary to establish a beginning section mark. Place a 52 to 102 mm wide strip of white or silver adhesive tape at the testing location on the pavement, such that it is perpendicular to the direction of travel and in a location that will be detected by the vertical photocell when the device is driven over the location. Select a suitable bump target made of wood with the dimensions 13 mm thick, 38 mm wide and 750 mm long. Place the bump target on the pavement parallel to previously established starting stripe in a manner such that the 13 mm dimension is vertical to the pavement, the approach edge of the 750 mm dimension is 114 mm from the leave edge of the starting stripe, and the target spans the path that will be traversed by the center height sensor (approximately mid-lane). The bump target should be positioned in such a way that the right or left tires will not run over it during data collection runs. Affix the bump target to the pavement with an appropriate adhesive tape such that the adhesive tape will not affect the profile collected by the center laser. Figure 120 illustrates the positioning of the section stripe and bump target. Thereafter, place several layers of 38 mm wide duct tape along the left and right wheel paths such that the approach edge of the duct tape is in line with the approach edge of the bump target, and the layers of duct tape are at least 8 mm high. The duct tape should be placed in such a way that the left and the right profile height sensors of the device will run over the tape when collecting data.

Thereafter, the horizontal photocell target has to be established in relation to the starting stripe. Place the horizontal photocell target on the shoulder of the road in a position that will minimize the potential for disruption during testing. Align the horizontal photocell target such that the leave edge of the reflector is in line with the leave edge of the stripe placed on the pavement. The placement of the vertical and horizontal photocell targets is intended to replicate standard profile

operations. Figure 121 illustrates the proper placement of the horizontal photocell target in relation to the starting stripe and bump target.

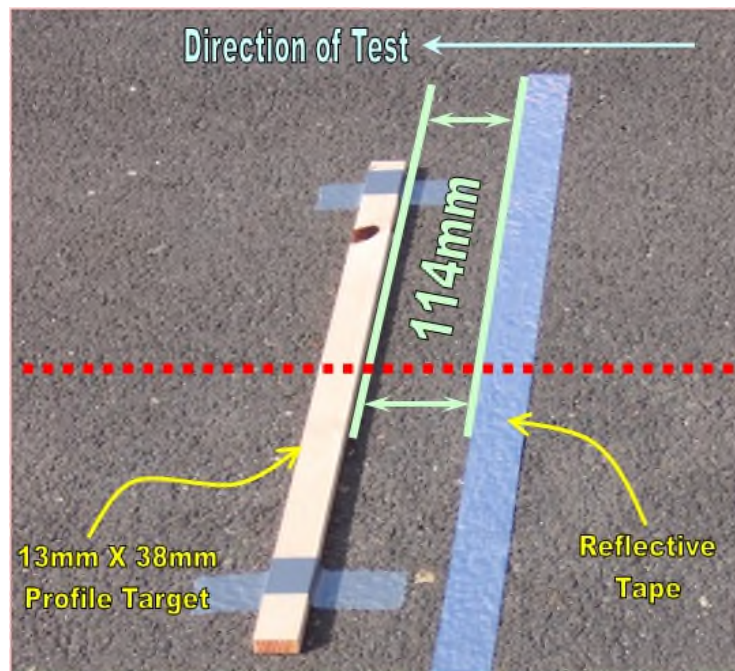


Figure 120. Section starting stripe and bump target placed on the pavement.

#### ***2.12.11.2 Profile Data Collection***

The photocell initiation test is performed in a manner consistent with standard LTPP profile data collection procedures. It is important that the DMI be calibrated beforehand in accordance with section 2.12.3 of this manual, and the tires in the profiler are sufficiently warmed-up with air pressures matching the pressure noted during the DMI calibration. Perform the standard daily height sensor check and bounce test in accordance with section 2.9.2 of this manual before collecting data.

For this test, a set of data (three runs) is collected with the vertical photocell being used to initiate data collection. Thereafter, a set of data (three runs) is collected with data collection initiated using the horizontal photocell. For this testing, the profile data of concern is the data immediately after the start stripe. Therefore, it is not necessary to collect a large amount of profile data during each run. Only about 20 m of profile data after the section start stripe need to be collected.

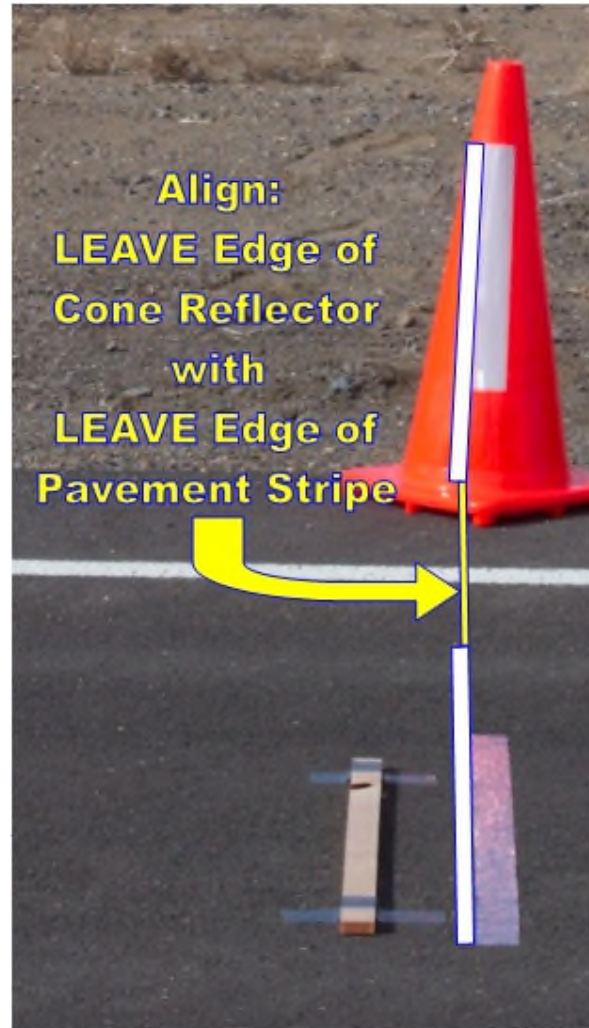


Figure 121. Placement of vertical photocell target in relation to section starting location.

The following procedure should be followed for collecting data:

1. In the Header Screen (see figure 83) set the Stop Method to DISTANCE and enter a value of 20 in the Distance field.
2. Set the vertical photocell to be active by checking the Auto Trigger under ODS 3 (see figure 83). Auto Trigger under ODS2 should not be checked. Collect three profile runs at the section using standard LTPP data collection procedures. Data collection for these runs is initiated by the vertical photocell.
3. Set the horizontal photocell to be active by checking the Auto Trigger under ODS 2 (see figure 83). Auto Trigger under ODS3 should not be checked. Collect three profile runs at the section using standard LTPP data collection procedures. Data collection for these runs is initiated by the vertical horizontal photocell.

### **2.12.11.3 Data Analysis**

If the device obtains the first data point within at a distance between 114 to 152 mm from the leave edge of the stripe placed at the start of the section, the first data point would have been obtained on the targets that was placed on the pavement. Use following procedure to analyze the data:

1. Create ERD files for the collected profile and texture data.
2. Import the profile data into Excel and plot the center sensor profile data in each file vs. distance for a distance of 500 mm. Evaluate the plots to see if the first data point or the first two data points are at a higher elevation compared to the rest of the data. Figures 122 and 123 show example plots illustrating such a situation. If the collected center sensor data exhibits such a feature for all profile runs collected with the vertical photocell, the vertical photocell is considered to be functioning properly. If the collected center sensor data exhibits such a feature for all profile runs collected with the horizontal photocell, the horizontal photocell is considered to be functioning properly. If collected data does not show such a feature for data collection initiated with vertical photocell, horizontal photocell, or both, repeat appropriate test or tests, and evaluate the data. If the collected data is still not satisfactory, contact RSC and decide on a suitable course of action.
3. Plot the data for the left and right profile sensors vs. distance for a distance of 500 mm for data in each file. Also import the collected texture data into Excel and plot the data in each file for the left and right texture sensors vs. distance for a distance of 500 mm. Evaluate the plots to see if the first data point or the first two data points are at a higher elevation compared to the rest of the data. The elevation difference will not be as high as that seen for the center sensor where the height of the bump target was 13 mm, as the height of the layers of duct tape placed on the pavement will not be that high. If the first data point or the first two data points are at a higher elevation for data collected by the left and right profile and texture sensors this means the first data point by these sensors are collected at a distance between 114 and 152 mm from the leave edge of the start stripe. If the collected data does not show such a feature for data collection initiated with vertical photocell, horizontal photocell, or both, repeat appropriate test or tests, and evaluate the data. If the collected data is still not satisfactory, contact RSC and decide on a suitable course of action.

## **2.13 EQUIPMENT MAINTENANCE AND REPAIR**

### **2.13.1 General Background**

Responsibility for equipment maintenance and repair rests with each RSC. Decisions required for proper maintenance and repair should be based on testing schedule and expedited as necessary to prevent disruption of testing. Maintenance activities on the device should be performed before mobilization for testing. During a testing period, there will be little time to do more than the required daily checks before testing. Specific detailed maintenance procedures are contained in the manuals provided with each piece of equipment (see references). Operator must become familiar with maintenance recommendations contained in all equipment manuals.

Maintenance/repair work to be performed can be classified as routine maintenance, preventive maintenance, and unscheduled maintenance.

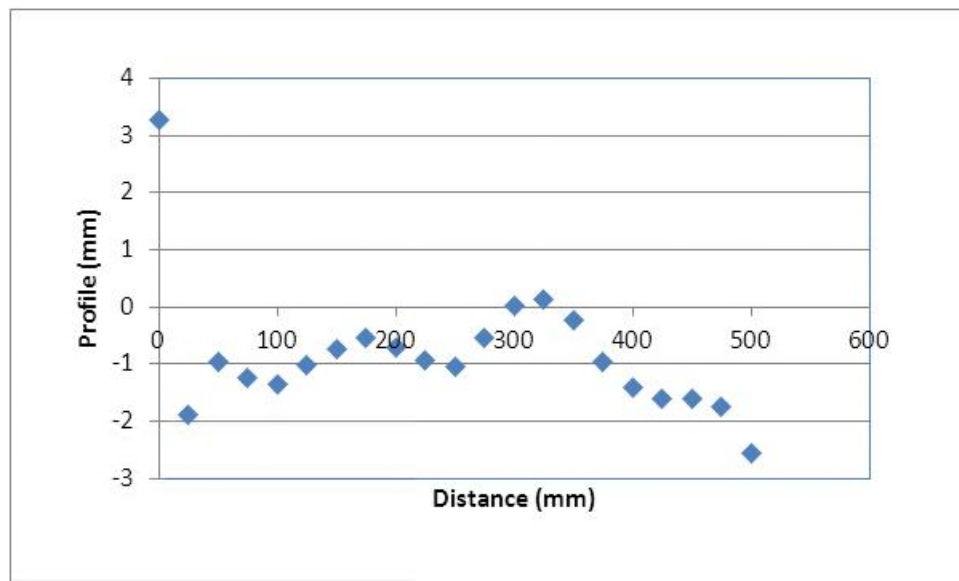


Figure 122. Example plot of data from photocell initiation test with one point on the target.

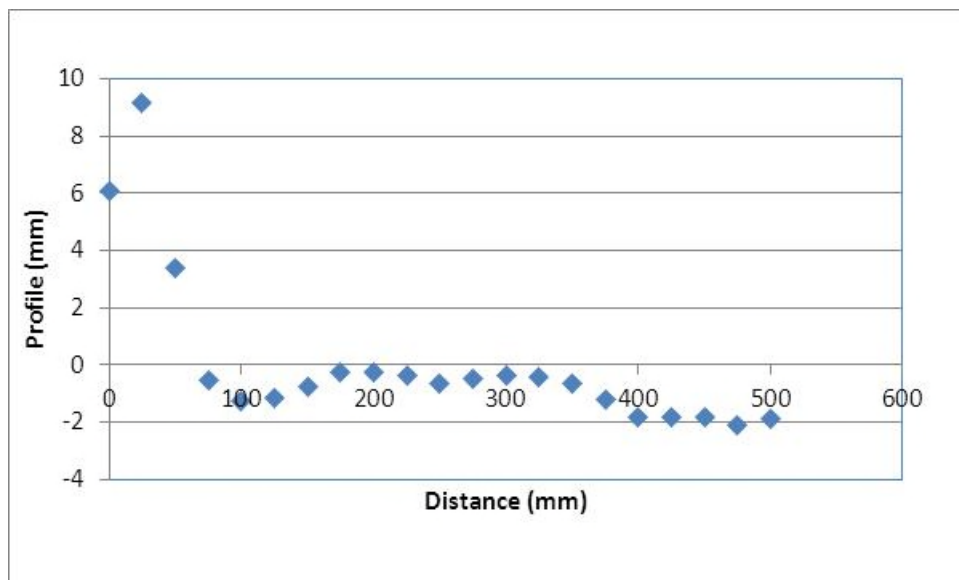


Figure 123. Example plot of data from photocell initiation test with two points on the target.

### 2.13.2 Routine Maintenance

Routine maintenance includes work that can be performed by operator. The Daily Check List (see appendix B) includes a list of activities to be performed every day. These include checking

vehicle lights, checking under the vehicle for fluid leaks, checking fluid levels in vehicle, and inspecting glass face of profile and texture height sensors. These items are the most basic and easily performed maintenance measures and should always be done before using the equipment every day. If any problems are noted, they should be entered in the Profiler Log (section 2.14.3), which should be maintained in the vehicle, and appropriate action should be taken to correct noted problems.

Profile and texture height sensors are sealed units and they will not function correctly if seal is broken. Cracked or chipped glass in the height sensor may cause moisture damage to occur and this can lead to failure of sensor. If any sign of physical damage is noted on the sensor glass, Ames Engineering should be contacted to decide on a repair procedure.

### **2.13.3 Scheduled Major Preventive Maintenance**

Scheduled major preventive maintenance services are those that are performed at scheduled intervals. Scheduled preventive maintenance activities on the vehicle should be performed following manufacturer's heavy use guidelines. These include activities such as oil change. Checking drive belts, hoses, battery cable connections etc., should be performed when the oil is changed in the vehicle.

Form PROF-4, LTPP Major Maintenance/Repair Form, which is included in appendix B must be used by operator to report necessary services performed and will also serve to inform RSC of the condition of device on a regular basis.

### **2.13.4 Unscheduled Maintenance**

These are unscheduled repairs. These repairs must be reported on form PROF-4, LTPP Major Maintenance/Repair, which is included in appendix B as an unscheduled maintenance activity. The LTPP Major Maintenance/Repair Form should be completed whenever a sensor is replaced or repaired. The procedures described in section 2.6.3 should be followed after a sensor is replaced or repaired.

## **2.14 RECORD KEEPING**

There are eight types of records that should be forwarded to the RSC by the profiler operator. They are:

1. LTPP Profiler Field Activity Report.
2. Status of the Regions Test Sections.
3. Profiler Log.
4. LTPP Major Maintenance/Repair Form.
5. Laser Sensor, Accelerometer, DMI Calibration/Calibration Check Form.
6. Ambient Temperature Sensor, Pavement Surface Temperature Sensor, and GPS Receiver Calibration Check Form
7. Profiling of WIM Sites: Data Summary Sheet.
8. ProQual outputs.



A description of each of these forms/reports is presented in the following sections. If items described for the Profiler Log or the LTPP Major Maintenance/Repair Form are being recorded by the operator following standard operating procedures of RSC, the completion of these forms may be omitted. It is acceptable for a region to use forms that have a different format as long as the modified form contains all of the items indicated in the forms included in this manual.

#### **2.14.1 LTPP Profiler Field Activity Report**

The Field Activity Report (form PROF-1 in appendix B) records all activities to and from a site, as well as activities at the test site. This report should be filled out for all travel and testing days. For travel-only days, the section for which traveling is being done should be noted. Entering IRI readings requested on this form is optional. However, the IRI values should be entered if a region keeps this form in the vehicle and uses IRI values as a check when the section is profiled subsequently.

#### **2.14.2 Status of the Regions Test Sections**

The Status of the Regions Test Sections Form (form PROF-2 in appendix B) should be filled out at every test section. Recent maintenance or rehabilitation activities, condition of paint marks, missing LTPP signs and delineators as well as any other comments regarding the test section should be recorded on this form.

#### **2.14.3 Profiler Log**

The operator should maintain a Profiler Log in the vehicle. The format of log is shown in form PROF-3 that is included in appendix B. When the operator performs daily checks on equipment, items needing attention should be noted on the Profiler Log.

#### **2.14.4 LTPP Major Maintenance/Repair Form**

This form (see form PROF-4 in appendix B) should be filled when scheduled or unscheduled maintenance or repairs are performed on the profiler. Vehicle and equipment operating costs are monitored with this form. This form should be submitted along with all receipts for maintenance activities.

#### **2.14.5 Laser Sensor, Accelerometer, DMI Calibration/Calibration Check Form**

The form PROF-5 included in appendix B must be filled when the following activities are performed at a maximum interval of 30-days:

- Full calibration check is performed on the profile and texture height sensors.
- Accelerometer calibration check is performed on the accelerometers.
- DMI is calibrated.
- Texture lasers are checked using the texture laser reference device.

The operator should regularly backup the calibration/calibration log files. Results from the accelerometer calibration check are appended to a single log file. The results from the DMI calibration and full calibration check of the profile and texture height sensors are saved in separate files that have the date stamp in the file name.

#### **2.14.6 Ambient Temperature Sensor, Pavement Surface Temperature Sensor, and GPS Receiver Calibration Check Form**

The form PROF-6 included in appendix B must be filled when the following activities are performed at a maximum interval of 30-days:

- Calibration check of the ambient temperature sensor.
- Calibration check of the accelerometers.
- Calibration check of the GPSR.

#### **2.14.7 Profiling of WIM Sites: Data Summary Sheet**

The profiler operator is required to fill form PROF-7, Profiling of WIM Sites: Data Summary Sheet, when profile data are collected at a WIM site. This form is included in appendix B.

#### **2.14.9 ProQual Outputs**

ProQual 2014 does not have the ability to generate reports or to print profile plots. If a RSC desires ProQual outputs, screen captures have to be obtained and pasted to a Word file and printed.



## **CHAPTER 3. PROFILE MEASUREMENTS USING THE FACE DIPSTICK®**

### **3.1 INTRODUCTION**

The Dipstick®, which is manufactured by Face Company, is a manually operated device for collection of precision profile measurements, and can collect data at rates greater than traditional rod and level survey procedures (see references 8, 9, and 10). However, the profile obtained from Dipstick® measurements may have a vertical shift from the true profile because of systematic cumulative errors in the Dipstick® readings. The body of the Dipstick® houses an inclinometer (pendulum), liquid crystal display (LCD) panels, and a battery for power supply. The Dipstick® sensor is mounted in such a way that its axis and line passing through footpad contact points are co-planar. The sensor becomes unbalanced as the Dipstick® is pivoted from one leg to the other as it is moved down the pavement, causing the display to become blank. After the sensor achieves equilibrium, the difference in elevation between the two points is displayed. Swivel footpads having an approximate diameter of 32 mm should be used for all measurements.

Each RSC is in possession of at least one manual Dipstick® (Model 1500) and two automated Dipsticks® (Model 2000 and Model 2200). Both the manual and the automated Dipsticks® display data in millimeters. The spacing between the two feet of the Dipstick® is approximately 304.8 mm for both models. When the automated Dipstick® is used for data collection, it should be used in manual mode, with data recorded manually.

Profile measurements on GPS and SPS sites that cannot be obtained using the LTPP profiler should be obtained using the Dipstick®. Decisions with respect to the need for Dipstick® measurements at these test sections should be made on a case-by-case basis by responsible RSC personnel.

### **3.2 OPERATIONAL GUIDELINES**

#### **3.2.1 General Procedures**

Dipstick® measurements are to be taken by personnel who have been trained in using the device and are familiar with the procedures described in this manual. Data collection using the Dipstick® is a two-person operation, with one person operating the Dipstick® and the other person recording the data. However, a single person can collect the data if that person uses a voice-activated tape recorder to record the readings.

Detailed scheduling and traffic control at test sites must be coordinated by the RSC. Traffic control at test sites will be provided by either the state highway agency (in United States) or provincial highway agency (in Canada). Layout of site should not be undertaken until all applicable traffic control equipment/devices are in-place.

### **3.2.2 LTPP Procedures**

Maintenance of Records: Operator is responsible for forwarding all data collected during testing (see forms in appendix F). In addition, operator is also required to forward other records related to the Dipstick<sup>®</sup> operation, which are described in section 3.6, to the RSC.

Equipment Repairs: RSCs are responsible for ensuring that LTPP owned equipment is properly maintained. Decisions required for proper maintenance and repair should be made based on testing schedule and expedited as necessary to prevent disruption of testing.

Accidents: In event of an accident, operator shall inform RSC of incident as soon as practical after mishap. Details of event shall subsequently be reported in writing to RSC. The corporate policy of the RSC should be followed in event of an accident. A police report of the accident should be obtained.

### **3.2.3 Footpad Spacing of Dipstick<sup>®</sup>**

Field studies performed with LTPP Dipsticks<sup>®</sup> have indicated that the actual spacing between the centerline of the two footpads is not exactly 304.8 mm. Testing has shown that the footpad spacing for the various Dipsticks<sup>®</sup> used by the RSCs can vary between 304.280 and 306.176 mm.

The RSCs are required to determine the footpad spacing of all Dipsticks<sup>®</sup> in their possession annually using the procedures described in appendix G. The RSC should maintain a log documenting the test date and the computed footpad spacing for each Dipstick<sup>®</sup>.

Note: The RSCs performed the test specified in appendix G in December 2003, and should know the footpad spacing of each Dipstick<sup>®</sup> in their possession. For RSCs that do not routinely perform longitudinal Dipstick<sup>®</sup> measurements, it is acceptable to perform this test annually only on the Dipstick<sup>®</sup> that has the footpad spacing closest to 304.8 mm. If during this test, the offset at the end of the section is not within  $\pm 25$  mm of the offset obtained from the previous year's test, the procedure described in appendix G should be used to obtain the footpad spacing of all Dipsticks<sup>®</sup> operated by the RSC.

When performing longitudinal Dipstick<sup>®</sup> measurements, the RSC should select the Dipstick<sup>®</sup> in their possession that has a footpad spacing that is closest to 304.8 mm.

## **3.3 FIELD TESTING**

### **3.3.1 General Background**

The following sequence of fieldwork tasks and requirements provides an overall perspective of the typical workday at a test section.

Task 1: Personnel Coordination.

- a. Dipstick<sup>®</sup> crew (operator and recorder).

- b. Traffic control crew supplied by highway agency or traffic control contractor working for the highway agency.
- c. Other LTPP, State or Provincial highway agency, and RSC personnel (they are observers and are not required to be present).

Task 2: Site Inspection

- a. General pavement condition (within test section limits).
- b. Identify wheel paths (when performing longitudinal measurements).

Task 3: Dipstick<sup>®</sup> Measurements

- a. Mark wheel paths (when performing longitudinal measurements).
- b. Operational checks on Dipstick<sup>®</sup>.
- c. Obtain Dipstick<sup>®</sup> measurements.
- d. Quality control.

Task 4: Forms DS-1 through DS-7 should be completed for longitudinal profile measurements. Form DS-7 and DS-8 should be completed for transverse profile measurements. These forms are included in appendix F.

On arrival at a site, operator will carefully plan activities to be conducted to insure most efficient utilization of time. While many activities can only be accomplished by operator and/or recorder, it may be necessary to enlist the assistance of other personnel at the site to mark wheel paths. In general, arrangements for this assistance should be made in advance by the RSC.

Assuming that a manual distress survey is also to be performed at the site, traffic control typically should be available for six to eight hours. This should provide adequate time for Dipstick<sup>®</sup> measurements in both wheel paths as well as for the manual distress survey to be completed. Experienced Dipstick<sup>®</sup> operators can obtain approximately 500 readings per hour.

Collecting profile data is the primary responsibility of operator. In order to ensure that data collected in the four LTPP regions are identical in format, certain guidelines and standards have been established for data acquisition and handling.

### **3.3.2 Site Inspection and Layout – Longitudinal Profile Measurements**

The pavement must be clear of ice, snow, and puddles of water before profile measurements can be taken with the Dipstick<sup>®</sup>, as such conditions can affect profile measurements. Pools of water can cause the feet of the Dipstick<sup>®</sup> to get wet resulting in a potential for slippage and can also possibly damage electronics in the Dipstick<sup>®</sup>.

The longitudinal Dipstick<sup>®</sup> measurement procedure consists of performing an elevation survey in each wheel path, and using transverse measurements at the section ends to form a closed loop. As illustrated in figure 124, measurements start at Station 0+00 in the right wheel path and proceed in the direction of traffic toward end of section.

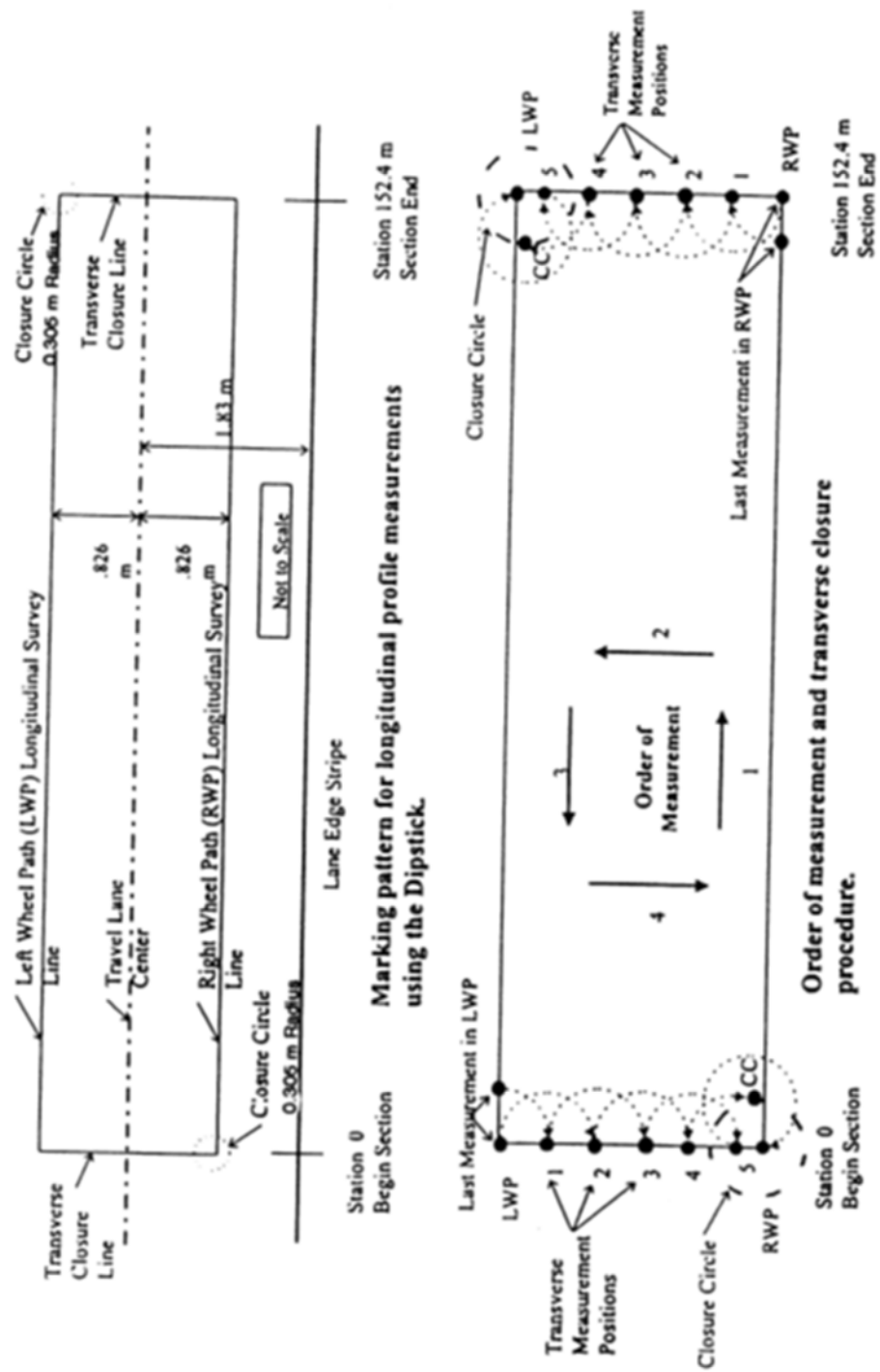


Figure 124. Site layout and measurement procedure for measuring longitudinal profiles with the Dipstick®.



At end of section, transverse measurements are made to the end point of survey line in left wheel path. A 0.61 m diameter closure circle around this point is used to close transverse measurements on this start location for measurements in the left wheel path. Longitudinal measurements are then performed in the left wheel path back to Station 0+00. Transverse measurements and closure circle are used to close the survey on the starting point. This procedure is designed for a 152.4 m test section; however, the concept can be applied to test sections of any length.

If acceptable conditions are present to perform the Dipstick® measurements, clean both wheel paths of loose stones and debris to prevent slippage of the Dipstick® footpads during measurements. The first step in the site layout is to locate the wheel paths, where each wheel path is located at a distance of 0.826 m from the center of travel lane. Use following procedure to locate center of travel lane:

Case I: Where wheel paths are easily identified, midway point between two wheel paths should be used as center of lane.

Case II: If wheel paths are not clearly identifiable, but two lane edges are well defined, center of travel lane is considered to be midway between two lane edges.

Case III: Where wheel paths are not apparent and only one lane edge can be clearly distinguished, center of lane should be established at 1.83 m from that edge.

Once center of travel lane has been identified, use following procedure to layout site:

1. Dipstick® measurements along the right wheel path will begin with the back edge of the Dipstick® footpad located immediately adjacent to leave edge of white stripe at beginning of monitoring portion of test section. If this location is not marked with a stripe, establish a transverse chalk line to define the beginning of the test section. At a 16 mm offset (radius of footpad of Dipstick®) in front of the leave edge of the white stripe at the beginning of the section (or in front of the transverse line that was marked if the white stripe was missing) use a chalk line to mark a transverse line parallel to the start line of the section. This transverse line is considered to be Station 0+00. Identify location of two longitudinal elevation survey lines 0.826 m from center of lane. Mark these locations at intervals equal to length of chalk line used for marking. Use chalk line to mark a straight line between previously established points. Using a tape measure (measuring wheels are not acceptable), carefully measure length of each longitudinal elevation survey line to establish end points at 152.4 m, or at specified length for test sections that are not 152.4 m long, from the previously established Station 0+00. An accurate measurement of this length is required since it is used as a quality control check on the measurement process. Mark a transverse chalk line to connect the end points of two longitudinal lines.
2. At the end of the section in the left wheel path, mark a 0.61 m diameter circle centered on the intersection of the marked transverse line and the longitudinal survey line. At the beginning of the section on the right wheel path mark a 0.61 m diameter circle centered on the intersection of the longitudinal survey line and the transverse line connecting the left and right wheel paths at Station 0+00. This closure circle will be used for completion of elevation survey loop.

3. On data collection sheet or field notebook note method used to establish location of lane center and any discrepancies between painted and measured section end locations. This information will help to collect consistent data in future profile measurements at that section.

### **3.3.3 Dipstick<sup>®</sup> Operation for Longitudinal Profile Measurements**

#### ***3.3.3.1 Pre-operational Checks on Dipstick<sup>®</sup>***

Checks to be performed on the Dipstick<sup>®</sup> before testing are described in this section.

1. Check condition of footpads and replace if necessary with extra set in the Dipstick<sup>®</sup> case. Clean and lubricate ball and socket joints on the footpads to insure smooth pivoting of instrument. When joint is dirty, pivoting becomes difficult and slippage of footpad can occur. A cleaning agent such as WD-40 or a light oil for lubrication will work for the ball and socket joint.
2. If using Model 1500 Dipstick<sup>®</sup>, install a fresh set of rechargeable batteries in the instrument and securely close battery compartment. The batteries in this unit have to be taken out in order to recharge them. The Model 2000 and 2200 Dipstick<sup>®</sup> is equipped with rechargeable batteries that can be charged while the batteries are still within the unit. If the batteries have not been charged overnight, install a fresh set of rechargeable batteries in the instrument and securely close battery compartment. Batteries in either of these units should be changed after 4 hours of usage to insure continuity of measurements. The Model 1500 Dipstick<sup>®</sup> is powered with 9-volt batteries, while the Model 2000 and 2200 Dipsticks<sup>®</sup> are powered with AA size batteries. An extra set of rechargeable batteries should be kept on hand for each of these units.
3. Check and if necessary, re-tighten handle on the instrument.
4. Perform Zero Check and Calibration Check, which are described next. According to manufacturer, calibration check is needed only if adjustments were required during the zero check. However, for LTPP related measurements, both the zero and calibration checks are required at the beginning of data collection. The Dipstick<sup>®</sup> should be fully assembled, turned-on, and allowed to warm-up for several minutes before performing these two checks.

#### **Manual Dipstick<sup>®</sup> (Model 1500)**

**Zero Check:** Form DS-7 included in appendix F should be filled when this test is carried out. A zero verification is performed by this test. Test should be performed on a relatively level, smooth, clean, and stable location where instrument can be properly positioned. A suitable fabricated plate or a wood board that can be fitted inside the Dipstick<sup>®</sup> case can be utilized to perform this check. After positioning the Dipstick<sup>®</sup>, draw two circles around footpads and note reading on display at switch end (reading = R1). The instrument should then be rotated 180 degrees and the footpads placed on the two circles that were drawn earlier; note reading obtained at switch end (reading = R2). If readings from the two placements (R1 and R2) add up to within  $\pm 0.1$  mm, the Dipstick<sup>®</sup> has passed the zero check. If they do not fall within these limits, zero adjustment is necessary. The zero adjustment should be performed using the following procedure:

1. Obtain average of two Dipstick<sup>®</sup> readings;  $e = 0.5 (R1 + R2)$ .
2. Subtract average value from R2 to obtain R2o;  $R2o = R2 - e$
3. With Dipstick<sup>®</sup> still in R2 reading position, loosen the set screw and adjust start/end pin up or down so that display reads R2o.
4. Tighten set screw, rotate the Dipstick<sup>®</sup> back to R1 reading position and read display at switch end (reading = R1o).
5. Addition of R1o and R2o readings should be within tolerance; if not, repeat adjustment procedure until two readings are within tolerance.

This is the only adjustment operator is allowed to make on the Dipstick<sup>®</sup>.

**Calibration Check:** Calibration of the Dipstick<sup>®</sup> is fixed during manufacture and cannot be altered by the user. User can verify calibration against a standard calibration block that is provided with the Dipstick<sup>®</sup>. After zero check and adjustments are performed, calibration of device must be checked. Test should be performed on a relatively level, smooth, clean, and stable location where instrument can be properly positioned. A suitable fabricated plate or a wood board that can be fitted inside the Dipstick<sup>®</sup> case can be utilized to perform this check. Form DS-7 (see appendix F) should be completed when this test is carried out. To check calibration, note the Dipstick<sup>®</sup> reading and place the 3.2 mm calibration block under one of the Dipstick<sup>®</sup> footpads. The reading displayed minus 3.2 should be within  $\pm 0.1$  mm of previous reading. If this tolerance is not obtained, a LTPP Major Maintenance/Repair Form (form DS-10 in appendix F) should be completed and the Face Company should be contacted through RSC office to repair Dipstick<sup>®</sup>.

### **Automated Dipstick<sup>®</sup> (Model 2000 and 2200)**

**Zero Check:** This check should be performed on a relatively level, smooth, clean, and stable location where instrument can be properly positioned. A suitable fabricated plate or a wood board that can be fitted inside the Dipstick<sup>®</sup> case can be utilized to perform this check. Circles should be drawn around the two footpads and the CAL button depressed once. The instrument should then be rotated 180 degrees and the two footpads placed in the circles drawn earlier. The CAL button should again be depressed once. The display will flash CAL three times after which the error is automatically stripped out of the readings. Note the reading at switch end of Dipstick<sup>®</sup>. Rotate Dipstick<sup>®</sup> and place two footpads in the circles, and note reading at switch end. If these two readings are within  $\pm 0.1$  mm, the Dipstick<sup>®</sup> has passed the zero check. The zero check can only be performed once after the Dipstick<sup>®</sup> is turned-on. If check is not successful, the Dipstick<sup>®</sup> must be turned-off and then turned on again, and the zero check repeated. A check mark should be placed on form DS-7 (see appendix F) at the appropriate location to indicate that the zero check was performed.

**Calibration Check:** Follow procedure described for the manual Dipstick<sup>®</sup> (Model 1500) to perform this check. Form DS-7 (see appendix F) should be completed when this test is carried out.

### ***3.3.3.2 Longitudinal Profile Measurement***

Complete header information on form DS-1 (see appendix F). Use guidelines presented in section 3.3.5.2 to enter the header information in form DS-1, except for the air temperature. Use guidelines presented in section 3.3.3.5 to enter air temperature before and after profile measurements.

The following procedure should be followed to collect longitudinal profile data using the Dipstick<sup>®</sup>.

1. To start profile measurement, Dipstick<sup>®</sup> should be placed on marked survey line in right wheel path with start arrow pointed forward in direction of traffic, and back edge of the footpad located immediately adjacent to leave edge of white stripe at beginning of test section. In this position, the center of the back footpad of the Dipstick<sup>®</sup> will be at Station 0+00.
2. After reading stabilizes, reading should be recorded under the right wheel path (RWP) column on form DS-2 (included in appendix F) on the row corresponding to Reading Number 1. The Dipstick<sup>®</sup> should then be rotated to the next measuring point using a clockwise rotation. The reason a clockwise rotation is specified is because with such a motion the handle of the Dipstick<sup>®</sup> will not get loose. However, if an operator has any problems in using a clockwise rotation it is acceptable to use a counter-clockwise rotation to advance the Dipstick<sup>®</sup>. If a counter-clockwise rotation is used, operator should check the handle of the Dipstick<sup>®</sup> at frequent intervals to make sure it is not loose, and if handle is loose it should be tightened. After reading has stabilized, it should be recorded on the next row of form DS-2 labeled Reading Number 2. This procedure should be repeated for entire length of test section. During measurements, the following precautions and procedures should be followed:
  - (a) Use a consistent motion to advance the Dipstick<sup>®</sup> (either clockwise or counter-clockwise).
  - (b) Handle of Dipstick<sup>®</sup> should be held in a vertical position when taking measurements.
  - (c) Lateral pressure should not be applied to handle during a measurement.
  - (d) If at a particular placement, a footpad is to fall into a wide crack or a pothole in the pavement, avoid placing the footpad into such a feature. If such a condition is encountered, offset the placement of the footpad so it will rest on the pavement that is adjacent to the feature.
  - (e) If for any reason measurements must be stopped, circles should be drawn around both footpads with the start arrow in the direction of traffic at last measurement position. When restarting, the Dipstick<sup>®</sup> shall be returned to this position and adjusted so that current measurement agrees with the measurement prior to stoppage.
  - (f) If it is not possible to mark the footpad positions prior to stoppage or to successfully reposition the Dipstick<sup>®</sup> in the same position, then data must be discarded and the measurement procedure restarted from the beginning.

3. After last measurement in right wheel path at Station 152.4 m, the location of the back end of front Dipstick<sup>®</sup> footpad should be compared with the location of the transverse line that was marked at the end of the test section. If the back end of the front footpad is within 275 mm of marked transverse line, proceed with transverse closure measurements as indicated in step 4. If front footpad is not within this interval, perform the following:
  - (a) Draw circles around each footpad and note direction of start arrow.
  - (b) Check data sheets for skipped or missing measurements.
  - (c) If no apparent anomalies are present in data, re-measure length of longitudinal survey line to verify position of end point. If re-measured location of end point is within 304 mm of back end of front footpad of the Dipstick<sup>®</sup>, remark transverse line at this location and proceed. If end-point is not within 304 mm of the back end of the front foot, discard data as suspect and restart survey from Station 0+00.
4. After location of last measurement in right wheel path has been verified, transverse closure measurements should be initiated by rotating rear foot of the Dipstick<sup>®</sup> toward left wheel path and placing it on pre-marked transverse closure line. Measurements along transverse closure line should be recorded in the table labeled “Transverse Closure Measurements from Right Wheel Path to Left Wheel Path at Station 152.4 m” which is at the bottom of form DS-6 (included in appendix F). When the Dipstick<sup>®</sup> reaches point in which next measurement along transverse survey line passes location of left wheel path, it should be rotated so that the footpad rests at any point on the closure circle (CC). After recording this measurement in the column labeled 5-CC, rotate device so that footpad rests on top of intersection between the longitudinal survey line in the left wheel path and the transverse closure line. Record this measurement under CC-LWP. This procedure is illustrated in figure 130.
5. Begin measurements along longitudinal survey line in left wheel path, recording readings in column labeled LWP on forms DS-6 through DS-2. These measurements will be entered in reverse order from those in RWP.
6. When last measurement in left wheel path is made at Station 0+00, verify that position of back edge of front Dipstick<sup>®</sup> foot is within 275 mm of end point. If not, follow procedures for end point verification previously described for the measurements in right wheel path. If a problem is found with a missing or skipped measurement or final location of Dipstick<sup>®</sup> in left wheel path, measurements in left wheel path should be discarded as suspect and survey restarted from beginning point in the left wheel path.
7. After location of last measurement in left wheel path has been verified, transverse closure measurements should be initiated by rotating rear foot of Dipstick<sup>®</sup> toward right wheel path and placing it on pre-marked transverse closure line (located at Station 0+00). Measurements along transverse closure line should be recorded in the table labeled “Transverse Closure Measurements from Left Wheel Path to Right Wheel Path at Station 0+00” which is at the bottom of form DS-2 (included in appendix F). When the Dipstick<sup>®</sup> reaches point in which next measurement along transverse survey line passes location of right wheel path, it should be rotated so that the footpad rests at any point on the closure circle (CC). After recording this measurement in the column labeled 5-CC, rotate device so that footpad rests on top of intersection between the longitudinal survey line in the right wheel path and the transverse closure line. Record this measurement under CC-RWP. This procedure is illustrated in figure 130.

### **3.3.3.3. Post Data Collection Check**

After completing survey, operator must conduct the zero and calibration checks.

The following procedure should be followed for performing the zero check for both manual Dipstick<sup>®</sup> (Model 1500) and automated Dipstick<sup>®</sup> (Model 2000 and 2200). Place Dipstick<sup>®</sup> on a smooth, clean, and stable location where the instrument can be properly positioned (i.e., carrying case for the Dipstick<sup>®</sup> or a flat board will suffice). Draw circles around the two footpads, and note reading at the switch-end of the instrument (R1). Then rotate instrument 180 degrees and place the two footpads in the circles that were drawn earlier. Note the reading at the switch-end of the Dipstick<sup>®</sup> (R2). The two readings (R1 and R2) should add up to within  $\pm 0.1$  mm in order to pass the zero check. If the addition of the two readings is outside these limits, the device has failed the zero check.

For both manual Dipstick<sup>®</sup> (Model 1500) and automated Dipstick<sup>®</sup> (Model 2000 and 2200), the calibration check should be performed as described in section 3.3.3.1 for the manual Dipstick<sup>®</sup>.

Results from zero check as well as calibration check should be entered on form DS-7 (see appendix F). Based on results from these checks, follow one of the applicable procedures presented below:

1. If Dipstick<sup>®</sup> fails zero check, data should be discarded as suspect and another survey should be performed.
2. If Dipstick<sup>®</sup> passes zero check, but fails calibration check, data should be discarded as suspect and the Face Company should be contacted for repair, as discussed under calibration check in section 3.3.3.1.
3. If Dipstick<sup>®</sup> passes both tests, the closure error computations that are described in section 3.3.3.4 should be performed.

If Dipstick<sup>®</sup> failed zero check, but can successfully be adjusted to pass zero check and also passes the calibration check, another survey should be performed.

### **3.3.3.4 Closure Error Computations**

The following procedures should be followed when performing closure error computations.

1. Closure error computations must be performed in the field prior to leaving site.
2. Readings in each column on forms DS-2 through 6 (see appendix F) should be summed and recorded in last row of each column. Measurements in transverse closure measurement tables on forms DS-2 and DS-6 (see appendix F) should be summed across row and entered in last column.

3. Column summations should be entered on form DS-1 (see appendix F) in locations corresponding to labels shown in each summation cell.
4. On form DS-1 (see appendix F), elevation sums in the RWP and LWP should be added together and recorded in indicated cells.
5. Transverse sums should then be added to each of these sums and the result recorded in the total row at bottom of closure calculation table.
6. The two totals should then be added together and the result entered into cell labeled closure error.
7. If closure error is not within  $\pm 76$  mm, data should be discarded as suspect and test section re-surveyed until closure error is within allowable limits.

### ***3.3.3.5 Air Temperature Measurements***

Air temperature measurements must be obtained at the start and end of longitudinal Dipstick data collection and recorded on form DS-1. The average of these two temperatures must also be recorded on form DS-1. Air temperature measurements must be obtained using one of the following equipment:

- K-type, 2 inch, Handheld Thermocouple Probe (Omega Model KHSS-18U-2).
- Microprocessor Thermometer Display (Omega Model HH21, HH22, HH33 or HH64).

Measurements should be taken at an adequate distance from any heat source such as vehicle engine, vehicle exhaust, and pavement surface. Operators must also ensure that the probe is not held in direct sunlight when allowing the probe to reach a stable value before recording it.

A calibration check of the temperature probe must be performed within 30 days prior to air temperature measurements or whenever the operator observes suspicious temperature readings. A NIST traceable mercury thermometer is required to perform the check. The check should be performed in a shade area, using the following procedure.

1. Place thermometer close to the temperature probe, and after they have reached a stable value, observe the readings of the thermometer and probe.
2. If the difference between the two temperature readings is less than or equal to  $2^{\circ}\text{C}$ , the temperature probe is considered to be acceptable.
3. If the difference between the two temperatures is greater than  $2^{\circ}\text{C}$ , wait at least 5 minutes and repeat steps 1 and 2. If the difference is still greater than  $2^{\circ}\text{C}$ , wait at least 5 minutes and repeat steps 1 and 2 again. If the difference between the temperatures is still greater than  $2^{\circ}\text{C}$  consider the air temperature probe to be unacceptable, and contact manufacturer of probe to resolve the problem.
4. If there are any questions regarding the accuracy of the temperature probe, a cold temperature check shall be performed on the sensor. In this check, a plastic bag containing crushed ice is placed around the temperature probe. Allow sufficient time for the temperature



probe to stabilize and check the reading displayed. The temperature should be within  $\pm 2$  °C of 0 °C. If not, consider the air temperature probe to be unacceptable, and contact manufacturer of probe to resolve the problem.

Results of the calibration check must be recorded on form DS-11.

### **3.3.4 Site Inspection and Layout –Transverse Profile Measurements**

Transverse profile measurements should be performed when manual surveys are conducted on AC surfaced pavements including PCC pavements with AC overlays. One round of transverse profile measurements should be taken on all LTPP PCC (jointed concrete and continuously reinforced concrete) test sections. The purpose of obtaining transverse profile measurements on PCC sections is to determine transverse cross slope of pavement.

Pavement must be clear of ice, snow, and puddles of water before profile measurements can be taken with the Dipstick<sup>®</sup>, as such conditions can affect profile measurements. Pools of water can cause the feet of the Dipstick<sup>®</sup> to get wet resulting in a potential for slippage and can also possibly damage electronics in the Dipstick<sup>®</sup>. Testing under such conditions must be avoided either through adjusting schedule of profiling trips, or by delaying actual measurements until acceptable conditions exist. Layout and mark straight lines for transverse profile measurements. Lines should be perpendicular to edge of pavement and located at 15.24 m intervals, starting at station 0 and ending at station 152.4 m (or end of section if length of test sections is greater than 152.4 m). For each test section (GPS or SPS), eleven transverse lines will be present (or more if length of test sections is greater than 152.4 m).

For AC surfaced sections the location of the transverse lines should be offset to avoid pavement markings and other anomalies such as patches, potholes, and areas that have high severity cracking with missing material. This offset must not exceed 1 m either way. If the anomalies cannot be avoided, the transverse profile is taken at the best location within the allowable offsets. The need for and magnitude of such adjustments must be recorded on form DS-8.

For PCC pavements, the location of the transverse lines should be offset to avoid joints, cracks, and any other localized anomalies like patches and surface defects that would cause the measurements to be non-representative of the transverse profile as related to transverse surface drainage effectiveness. Unlike for AC surfaced pavements, offsets greater than 1 m are allowed for PCC pavements.

### **3.3.5 Dipstick<sup>®</sup> Operation for Transverse Profile Measurements**

#### ***3.3.5.1 Pre-operational Checks on Dipstick<sup>®</sup>***

Operator should check equipment using procedures described in section 3.3.3.1. Checks will include both the zero check and the calibration check. Operator should fill out the LTPP Dipstick<sup>®</sup> Data Collection Form DS-7 (see appendix F).

### ***3.3.5.2 Entering Header Information in Transverse Profile Form***

After performing the pre-operational checks on the equipment, the operator should fill the header information in the Transverse Profile Data Collection Form (form DS-8 in appendix F).

Guidelines for filling this form are presented in this section. As this information is used in ProQual, it is important that the operator strictly follow these guidelines. (Note: The guidelines presented in this section should also be used to fill the header information in Form DS-1 that is used for longitudinal profile measurements. However, the air temperature is recorded on form DS-1 while the pavement temperature is recorded on form DS-8)

State Code: Code of state or province in which the site is located.

LTPP Section ID: Four digit LTPP Section ID of site.

Date: Current date.

Time: Current time, use military format (e.g., 09:30, 15:30. etc.).

Dipstick<sup>®</sup> Serial #: Five digit serial number on base or side of Dipstick<sup>®</sup> (e.g., 30021).

Dipstick<sup>®</sup> Model #: 1500 for manual model and 2000 or 2200 for automated model.

Operator: First and last initial of operator in capital letters (e.g., JD).

Recorder: First and last initial of recorder in capital letters (e.g., AM).

Site Type: GPS or SPS.

Visit: Sequential visit identifier. (e.g., A for first visit to site, B for second visit, C for third visit, etc.).

Surface Type: A-CC for AC surfaced pavements and P-CC for PCC surfaced pavements.

Condition: Enter condition of pavement as either V.GOOD, GOOD, FAIR, or POOR (use capital letters). Use following guidelines to select condition: (a) V. GOOD – Pavement does not show any distress, (b) GOOD – Pavement exhibits few visible signs of surface deterioration. Pavement may show low severity cracks, (c) FAIR – Typical distresses can include the following in a low to medium severity: rutting, transverse and longitudinal cracking, block cracking, fatigue cracking, edge cracking, and patching, (d) POOR – Typical distresses can include the following in a medium to high severity: rutting, transverse and longitudinal cracking, block cracking, fatigue cracking, patching, and potholes.

Road Name: Highway or route designation in capital letters (e.g., INTERSTATE 57, US 395, S.R. 31).

Lane: Circle either Outside or Inside. Outside lane is the outermost traffic lane. Nearly all LTPP sections are located in the outside lane. Inside lane is any lane that is not an outside lane.

Direction: Direction should be NORTH, EAST, WEST, or SOUTH (use capital letters).

Clouds: Valid entries for this field are CLEAR, P. CLOUDY, or CLOUDY (use capital letters). Use following guidelines to select an appropriate entry to this field: (a) CLEAR – Sunny sky, (b) P. CLOUDY – sun is sometimes covered by clouds, and (c) CLOUDY – sun cannot be observed.

Temperature: Pavement temperature in degrees Centigrade obtained using an infrared device.

Weather Comment: Any additional comments about the weather conditions at the time of testing. ProQual contains the following in-built comments, but the crew is not limited to the use of these comments exclusively: CONDITIONS OK, STEADY CROSSWIND, WIND GUSTS, HOT AND HUMID, HAZY, LOW SUN ANGLE. Use capital letters for weather comment.

### ***3.3.5.3 Transverse Profile Measurement***

#### **AC Surfaced Pavements**

Transverse profile measurements should be collected at the transverse lines that were laid out within the section (see section 3.3.4) starting with the transverse line marked at Station 0+00. Elevations for each transverse profile should be measured from outside edge of pavement and should extend over full lane width, with actual distance depending on lane width and pavement striping. Starting point should be junction of transverse measurement line and inside edge of white paint stripe along outside edge of the lane. If no outside edge stripe is present, or if outside edge stripe is on the shoulder, then beginning point for measurements should be either shoulder-lane joint or a point approximately 0.91 m from center of outside wheel path. A comment should be entered in the data sheet indicating how starting point was determined. The starting point on subsequent surveys should be the same. The initial elevation is arbitrarily established as zero and subsequent readings are recorded relative to this benchmark. The combination of these measurements provides a measure of pavement cross slope.

To begin transverse profile measurements, Dipstick<sup>®</sup> is placed at outside edge of pavement starting at Station 0+00 with start arrow pointed towards pavement center line. Measurements should be recorded on the Transverse Profile Data Collection Form DS-8 (see appendix F). Operator should complete two runs per transverse profile of each LTPP section; one run up the transverse line and a return run along same line to complete a closed loop survey.

After the last transverse profile measurement is completed, enter any additional comments on the last line of the form. The comment should be entered in capital letters (e.g., ELEVEN DATA POINTS DUE TO HEAVY TRAFFIC).

#### **PCC Pavements**

Transverse profile measurements should be collected at the transverse lines that were laid out within the section (see section 3.3.4) starting with the transverse line marked at Station 0+00. Measurements should be taken within the lateral extent of the test section measured from the shoulder joint to the centerline longitudinal joint. On widened test sections, the lateral extent of the test section includes the full width (4.3 m) of the slab measured from the shoulder joint to the centerline longitudinal joint.

Starting point for Dipstick<sup>®</sup> measurements should be the shoulder joint. The initial elevation is arbitrarily established as zero and subsequent readings are recorded relative to this benchmark. To begin transverse profile measurements, Dipstick<sup>®</sup> is placed at Station 0+00 at the shoulder joint with start arrow pointed towards pavement center line. Measurements should be recorded on the Transverse Profile Data Collection Form DS-8 (see appendix F). Operator should complete two runs at each transverse profile location; one run up the transverse line and a return run along same line to complete a closed loop survey.

After the last transverse profile measurement is completed, enter any additional comments on the last line of the form. The comment should be entered in capital letters (e.g., ELEVEN DATA POINTS DUE TO HEAVY TRAFFIC).

#### ***3.3.5.4 Post Data Collection Check***

After completing survey, operator must conduct zero and calibration checks.

The following procedure should be followed for performing the zero check for both manual Dipstick<sup>®</sup> (Model 1500) and automated Dipstick<sup>®</sup> (Model 2000 or 2200). Place Dipstick<sup>®</sup> on a smooth, clean, and stable location where the instrument can be properly positioned (e.g., carrying case for the Dipstick<sup>®</sup> or a flat board). Draw circles around the two footpads, and note reading at the switch-end of the instrument (R1). Then rotate instrument 180 degrees and place the two footpads in the circles that were drawn earlier. Note the reading at the switch-end of the Dipstick<sup>®</sup> (R2). The two readings (R1 and R2) should add up to within  $\pm 0.1$  mm in order to pass the zero check. If the addition of the two readings is outside these limits, the device has failed the zero check.

For both manual Dipstick<sup>®</sup> (Model 1500) and automated Dipstick<sup>®</sup> (Model 2000 or 2200), the calibration check should be performed as described in section 3.3.3.1 for the manual Dipstick<sup>®</sup>.

Results of these checks should be entered on form DS-7 (see appendix F). Based on results from these checks, follow one of the applicable procedures presented below:

1. If Dipstick<sup>®</sup> fails zero check then data should be discarded as suspect.
2. If Dipstick<sup>®</sup> passes zero check, but fails calibration check, data should be discarded as suspect and the Face Company should be contacted for repair, as discussed under calibration check in section 3.3.3.1.
3. If Dipstick<sup>®</sup> passes both tests, the closure error computations that are described in section 3.3.5.5 should be performed.

If Dipstick<sup>®</sup> failed zero check, but can successfully be adjusted to pass zero check and also passes calibration check, another survey should be performed.

### 3.3.5.5 Closure Error Computation

The total accumulated error in a transverse profile is established by a closed loop survey. The forward and return run along a transverse line is utilized to compute this error. At each station, sum the readings for the forward and return runs separately, and record the values in Sum column of form DS-8. Then at each station, add the values in Sum column for the forward and return run, and record the result in the Closure column. At each station, for each Dipstick<sup>®</sup> reading, add the reading for the forward and return run, and record the value in the field Difference.

To compute the allowable closure error for a transverse profile run, multiply total number of Dipstick<sup>®</sup> readings (sum of number of readings for forward and return run) by 0.076 mm. The allowable closure errors for typical lane widths that are encountered are presented in table 5.1.

Table 5. Allowable closure errors for transverse Dipstick<sup>®</sup> measurements.

| Lane Width<br>(m) | Total Number of<br>Dipstick <sup>®</sup> Readings | Allowable Closure<br>Error (mm) |
|-------------------|---|---------------------------------|
| 3.05              | 20  | ±1.5                            |
| 3.35              | 22  | ±1.7                            |
| 3.66              | 24  | ±1.8                            |
| 3.96              | 26  | ±2.0                            |

If the closure error for a transverse profile is outside the allowable range, the transverse profile measurements at that location must be repeated once. If the closure error for the repeat run is also outside the allowable range, then the transverse profile line should be offset no more than 1 m and the run repeated once. The value in the Difference field at a specific position gives the difference in readings between the forward and return runs at that position. This information can be used by the operator to identify locations where problem readings may be occurring. If after the offset, the closure error for a transverse profile run is still outside the allowable range, and the Dipstick<sup>®</sup> is able to pass post data collection checks, enter a comment on why closure error is outside the allowable value (e.g., ROUGH SURFACE TEXTURE OF CHIP SEAL MADE CLOSURE DIFFICULT). The data from the third run will be submitted to FHWA, with a copy to the Technical Support Services Contractor (TSSC). A decision on including that data in the database will be made on a case-by-case basis.

### 3.3.6 Data Backup

The importance of safeguarding Dipstick<sup>®</sup> data cannot be overstated. Backup copies of the Dipstick<sup>®</sup> data sheets for both longitudinal and transverse profile data collection must be made without exception as soon as possible. A minimum of two copies must be made for each data sheet. One copy should be transmitted to the RSC office while the second copy should be retained by operator in case the first copy fails to reach the RSC.

### **3.4 ZERO CHECK AND CALIBRATION CHECK**

#### **3.4.1 General Background**

The zero and calibration checks described in section 3.3.3.1 are performed to ensure that the Dipstick<sup>®</sup> is operating properly. If Dipstick<sup>®</sup> fails calibration check it should be returned to manufacturer for repair.

The RSC should ensure that the gauge block used for calibration check is calibrated annually to an accuracy of  $3.18 \pm 0.03$  mm using a local calibration laboratory or a calibration micrometer. Calibration of gauge block may need to be performed more frequently, depending on presence of oxidation, evidence of corrosion, and possible damage caused by accidental mishandling in field. If the calibration block is not within an accuracy of  $3.18 \pm 0.03$  mm, a new block that satisfies the criteria should be obtained.

If calibration block thickness is not within  $3.18 \pm 0.03$  mm, all data collected since last check of block are suspect and may have to be disregarded.

#### **3.4.2 Frequency of Checks**

The zero and calibration checks should be conducted by operator prior to and after Dipstick<sup>®</sup> measurements. Procedures for performing pre-operational zero check and calibration check are described in section 3.3.3.1. Procedures for performing post-operational zero check and calibration check are described in section 3.3.3.3. If Dipstick<sup>®</sup> fails calibration check, approval from an RSC engineer is required before shipping equipment to manufacturer.

### **3.5 EQUIPMENT MAINTENANCE AND REPAIR**

#### **3.5.1 General Background**

Scheduled preventive maintenance will serve as a means of ensuring proper operation of equipment as well as identifying potential problems. Timely identification of problems will help to avoid costly delays or incomplete data that could result from on-site equipment malfunction. Time constraints on the profile testing program require that maintenance activities be performed prior to mobilization for testing. During testing, it is necessary that operator be constantly aware of proper functioning of equipment. There will be little time to accomplish more than the required initial checks at site in preparation for test day. Therefore, there is a paramount need for preventive maintenance to be performed on the Dipstick<sup>®</sup> as a routine function at the end of each test day.

Minimizing rate of equipment deterioration is the responsibility of the RSC and individual operators. Detailed maintenance procedures are contained in the equipment manuals and operator must become familiar with these procedures. This section is intended to reinforce the concept of maximum equipment dependability, which is critical to the effectiveness of the LTPP program.

The guidelines presented in this section are not intended to supersede manufacturers' recommendations regarding maintenance, but to provide supplementary service requirements.

Where there is a conflict between this guide and the manufacturers' instructions, the more stringent requirements should be followed.

### **3.5.2 Routine Maintenance**

Routine maintenance includes those functions that can be easily performed by operator with minimal disassembly of the device. Routine maintenance for the Dipstick® includes cleaning and lubrication of ball and socket joints on footpads, replacement of batteries, and cleaning of battery contacts. These items can be performed easily and should always be completed prior to and after operation of equipment.

The following list of pre- and post-operation preventive maintenance items is not complete, but is intended to show the extent and detail required before equipment checks are performed. This list of items should not supersede manufacturers' minimum requirements for warranty compliance.

1. Exterior: Check general appearance, glass display (should be clean), and ball and socket joint of footpads (should be properly lubricated).
2. Accessories: Be sure adequate supplies of consumables are on hand (e.g., Batteries, WD-40).

### **3.5.3 Scheduled Major Maintenance**

Scheduled major preventive services should include much more than routine checks and will require some disassembly of equipment by personnel with technical capabilities beyond skill of operators or RSC staff. The LTPP Major Maintenance/Repair Form DS-10 (see appendix F) should be used by operator to report repairs that are performed. This form will also serve to inform RSC of condition of Dipstick® on a regular basis. Items such as battery connector replacement would fall into the major maintenance category. Appropriate service intervals are outlined in the equipment manufacturer's manual.

### **3.5.4 Equipment Problems/Repairs**

Regardless of the quality of the preventive program, there will probably be equipment failures during the LTPP program. When these occur, it is extremely important that repairs or replacement of items be accomplished in a timely fashion. Such problems can be easily handled during periods when there is no scheduled testing. However, if they occur during mobilization or while on-site, significant problems in scheduling and coordination could develop. To help minimize impact of equipment problems, it is essential that operator immediately notify RSC and any other agencies or individuals about such problems.

Responsibility for equipment maintenance/repair activity rests with each RSC. However, RSC should keep LTPP staff informed of any major problems concerning equipment. When repairs are necessary and must be performed by an outside agency, operator should report this information on the LTPP Major Maintenance Report/ Repair Form (form DS-10 in appendix F) as an unscheduled maintenance activity.



### **3.6 RECORD KEEPING**

Dipstick<sup>®</sup> operator will be responsible for maintaining the following Forms/Records.

1. For Longitudinal Profile Measurements: Longitudinal Profile Forms DS-1 through DS-6.
2. For Transverse Profile Measurements: Dipstick<sup>®</sup> Data Collection Form - Transverse Profile, form DS-8.
3. Zero and Calibration Check Records (form DS-7) for both longitudinal and transverse profile measurements
4. Major Maintenance/Repair Form, Form DS-10.
5. Air Temperature Probe Calibration Check Form, Form DS-11.

All these forms are included in appendix F. Each of these forms must be kept on files by each RSC with one complete set kept on file at the regional office. The following sections describe each of these forms.

#### **3.6.1 Longitudinal Profile Measurements**

Forms DS-1 through DS-6 should be filled at every section where longitudinal profile measurements are performed with a Dipstick<sup>®</sup>. Follow guidelines presented in section 3.3.5.2 to fill the header fields in form DS-1 (Note: Pavement temperature is not recorded for longitudinal profile measurements. However air temperature is recorded. Follow guidelines in section 3.3.3.5 to record air temperature.) Comments section in this form should include any downtime and any factors that might affect collected data. Names and organizations of other personnel present at site should be included in this form. Names of these personnel will be invaluable if an accident occurs at test site. Operator should keep original of these forms and forward copies to RSC.

#### **3.6.2 Transverse Profile Measurements**

The form DS-8 should be filled at every section where transverse profile measurements are performed. Follow guidelines presented in section 3.3.5.2 to fill the header fields in this form. Operator should keep original of this form and forward a copy to RSC.

#### **3.6.3 Zero and Calibration Check Form**

This form DS-7 should be completed whenever the zero and calibration checks are performed.

#### **3.6.4 LTPP Major Maintenance/Repair Form**

The LTPP Major Maintenance/Repair Form (form DS-10) must be completed when any major maintenance or repair is performed by an outside agency,

### **3.6.5 Air Temperature Probe Calibration Check Form**

The form DS-11 must be filled when a calibration check is performed on the temperature probe that is used to measure the air temperature when longitudinal profile measurements are performed with the Dipstick<sup>®</sup>.

## CHAPTER 4. PROFILE MEASUREMENTS USING THE ROD AND LEVEL

### 4.1 INTRODUCTION

The rod and level can be used to accurately measure the profile of a pavement. The collected data can be used to evaluate the roughness of a pavement by computing a roughness index such as the IRI. In computing roughness indices, only relative elevations and not absolute elevations are needed. The guidelines in this section can be applied to conventional survey equipment such as an optical level and graduated staff, which requires readings to be manually recorded as well as automated equipment that are capable of automatically storing the measured data.

### 4.2 OPERATIONAL GUIDELINES

#### 4.2.1 General Procedures

Detailed scheduling and traffic control at test sites must be coordinated by the RSC. However, all traffic control activities at the test sites will be performed by personnel from either the state or provincial highway agency. Layout of the test site should not be undertaken until all applicable traffic control devices are in-place.

#### 4.2.2 Equipment Requirements

The rod and level used in routine surveying and road construction will generally not have the resolution needed for pavement profile measurements. Precision leveling instruments are required for pavement profile measurements. Instrument used for profile measurement should satisfy the resolution criterion given in table 6, which was obtained from the ASTM Standard on Measuring Road Roughness by Static Level<sup>(11)</sup>.

Table 6. Resolution requirement for rod and level measurements.

| IRI Range<br>(m/km)         | Resolution<br>(mm) |
|-----------------------------|--------------------|
| $0 \leq \text{IRI} < 0.5$   | 0.125              |
| $0.5 \leq \text{IRI} < 1.0$ | 0.25               |
| $1.0 \leq \text{IRI} < 3.0$ | 0.5                |
| $3.0 \leq \text{IRI} < 5.0$ | 1.0                |
| $5.0 \leq \text{IRI} < 7.0$ | 1.5                |
| $\text{IRI} \geq 7.0$       | 2.0                |

The rod used should be equipped with a bubble level so that it can be accurately held vertically. A suitable base may be selected for the rod in order to reduce the sensitivity to small variations in rod placement. For smooth textured pavements, any type of base is suitable. For textured surfaces a circular pad with a diameter of at least 20 mm is recommended.<sup>(11)</sup> As only relative elevations are required for computing roughness indices, no correction is required if a pad is attached to the bottom of the rod.

### **4.2.3 LTPP Procedures**

**Maintenance of Records:** The operator is responsible for forwarding all data collected during testing to the RSC.

**Accidents:** In event of an accident, the operator shall inform the RSC of the incident as soon as practical after the mishap. Details of the event shall subsequently be reported in writing to the RSC. The corporate policy of the RSC should be followed in the event of an accident. A police report of the accident should be obtained.

## **4.3 FIELD TESTING**

### **4.3.1 General Background**

The following sequences of fieldwork tasks are required.

#### **Task 1: Personnel Coordination**

- a: Personnel for rod and level survey.
- b: Traffic control crew supplied by the highway agency or traffic control contractor working for the highway agency.
- c: Other LTPP, State or Provincial highway agency, and RSC personnel (they are observers and are not required to be present).

#### **Task 2: Site Inspection**

- a: General pavement condition (within test section limits).
- b: Identify wheel paths.

#### **Task 3: Rod and Level measurements.**

- a: Mark wheel paths.
- b: Obtain rod and level readings.

Two persons are needed to measure the pavement profile using the rod and level. One person is needed to hold the rod (rod-person) and another to operate the level and take readings (instrument operator). If the level is not capable of automatically recording readings, having an additional person to record the readings (record keeper) will make the process quicker.

According to the ASTM Standard on Measuring Road Roughness by Static Level<sup>(11)</sup>, an experienced crew of three would require less than 10 seconds to obtain one reading. This involves positioning of the rod by the rod-person, reading the level by the instrument operator, and recording the measurements by the record keeper.

### **4.3.2 Site Inspection and Preparation**

The two wheel paths in the outside travel lane should be marked using the following procedure.

1. Clean area of both wheel paths of loose stones and debris to prevent slippage of the rod during measurements.

2. Identify the location of the two longitudinal elevation survey lines 0.826 m from center of the lane.

Case I: Where wheel paths are easily identified, the midway point between the two wheels paths should be used as the center of the lane.

Case II: If wheel paths are not clearly identifiable, but the two lane edges are well defined, the center of the travel lane is considered to be the midway between the two lane edges.

Case III: Where wheel paths are not apparent and only one lane edge can be clearly distinguished, the center of the lane should be established at 1.83 m from that edge.

3. Mark these locations at intervals equal to length of chalk line used for marking. Use the chalk line to mark a straight line between previously established points.

The method by which the wheel paths were located should be noted in the comments field of the Rod and Level Data Collection Form (see appendix H). This will help in locating the wheel paths used for profile measurements at a future date.

Measurements have to be taken along the wheel paths at 0.3 m intervals. Locations at which readings are to be taken can be determined by either of the following methods:

1. Lay a surveyor's tape along the chalk line, with the zero mark of the tape at station 0+00. Station 0+00 is at the at the leave edge of the white stripe at the beginning of the section. Mark distances on pavement at 0.3 m intervals using a suitable marker. Markings have to be made along the entire length of the section on both wheel paths.
2. Place a surveyor's tape at a slight offset from the wheel path so it will not interfere with the rod placement. The zero mark of the tape should be at station 0+00. Station 0+00 is at the leave edge of the white stripe at the beginning of the test section. Secure both ends of the tape, as well as several intermediate points on the tape to the ground with adhesive tape. Distances along the section can be referenced from the tape. After the distance corresponding to the length of the tape is leveled, the tape will have to be repositioned.

#### **4.3.3 Longitudinal Profile Measurements**

The first reading taken after the level is setup is referred to as a backsight, while the last reading taken at that setup before the level is moved is referred to as a foresight. Other readings taken in-between a backsight and a foresight are referred to as intermediate sights. Use the following procedure to measure the longitudinal profile:

1. Complete the required header information in the Rod and Level Data Collection Form (form is included in appendix H).
2. Setup the level at a suitable location taking into account the range of the level. With some instruments, it might be possible to cover the entire test length from one instrument setup that is located near the center of the test section. The level should be setup at a position where it will not be disturbed by the passing traffic. In addition, it should be setup at a stable location

that will not settle. Set the tripod as low as practical to reduce the error caused by rod not being held exactly vertical. Thereafter, level the instrument using the leveling screws.

3. The rod-person should place the rod at the zero position of the section and using the bubble level attached to rod as a reference, hold the rod vertically. Once the rod is held vertically, the rod-person should signal to instrument operator to take a reading. If readings are recorded manually by a third crew member, the instrument operator should call out the reading to the record-keeper. Readings should be recorded in the form included in appendix H. If an automated system is being used, the instrument operator should make sure that the reading is saved.
4. Next, the rod-person should place the rod 0.3 m away from the initial reading, and a new reading should be recorded. This process should be continued until either the entire test section is surveyed or the horizontal range or the vertical range of the level is exceeded. The horizontal range of the level is exceeded if the distance between the level and the rod is too short or too long to focus properly. The vertical range of the level is exceeded if the rod cannot be read due to the slope of the road. When the range of the level is exceeded, the level has to be relocated.
5. If the range of the level is exceeded during measurements, the instrument has to be relocated. Mark the location at which the rod is to be held for the last reading. This position is called a pivot point. Thereafter, place the rod at the location where the first reading was taken with the current setup of the level, and take a reading. Compare this reading with the first reading that was taken at this location. If they do not agree within the resolution of the instrument, all readings taken from the current level position have to be repeated. If the readings agree, place the rod on the pivot point and take the last reading from the current setup of instrument (foresight). Then setup the instrument at the new location. Place the rod at the pivot point and take the reading (backsight). Continue the leveling process as before, taking readings at 0.3 m intervals. If the instrument has to be repositioned again, the procedure has to be repeated.
6. When the end of the test section is reached, use one of the following procedures depending on how the measurements were performed.
  - (a) Entire survey performed from one instrument setup: Place the rod at zero position (point from which survey was initially started) and take a reading. This reading should agree with the first reading taken at this location at the start of the survey within the resolution of the instrument. If the readings do not agree, the profile measurement has to be repeated.
  - (b) Instrument Repositioned During Survey: Place the rod at the last pivot point and take a reading. This reading has to agree with earlier reading taken at this position within the resolution of the instrument. If they do not agree, profile has to be measured again from last pivot point to the end of the section.

The measurement of pavement profiles using the rod and level is labor intensive, and time consuming. Therefore, it is advisable to check the accuracy of measured data at regular intervals. This can be performed by establishing a set of control points along the wheel path, for example at 30 m intervals starting from the beginning of the section. After leveling a distance of 30 m, the rod has to be placed at the previous control point and another reading taken. This reading has to agree with the previous reading taken at this control point within the resolution of the instrument. If the readings do not agree, rod and level measurements must be performed again between the

control points. This procedure can be used if the instrument setup is not changed between the two control points being considered. If the instrument setup is changed between the two control points, the above procedure can still be applied by treating the pivot point as a control point.

#### **4.3.4 Factors to be Considered During the Survey**

The following factors have to be considered when performing profile measurements with the rod and level.

1. If the level is sensitive to temperature variations, it might need to be covered with an umbrella to protect it from direct sunlight.
2. During windy conditions profile measurements should be avoided, as the movement of level could occur.
3. If the level has to be setup at more than one position during profile measurements, make length to backsights and foresights equal. This will eliminate errors due to curvature and refraction at turning points.
4. Setup the level as low as possible to reduce the error caused by the rod not being exactly vertical.

#### **4.3.5 Profile Computation**

During profile measurements in the field, the crew is only expected to record the readings from the level using the procedures described in section 4.3.3. The computation of elevation profile from these data will be done in the office. This section briefly describes how the data recorded in the field is used to obtain the longitudinal profile of the pavement.

For profile computations, the elevation of the location where the first reading (first backsight) was measured is needed. However, as only relative elevations are needed to compute roughness indices (such as IRI), an arbitrary value can be selected for the elevation of this point. Relative elevation of any point measured from the initial instrument setup can be obtained from the following equations:

$$\text{Instrument Height (IS)} = \text{BM} + \text{RR1} \dots\dots(4.1)$$

$$\text{Relative Elevation of a Point} = \text{IS} - \text{RR} \dots\dots(4.2)$$

where,

- IS = Initial instrument height,
- BM = Elevation of point where the first backsight was taken (assume any value e.g. 30 m),
- RR1 = Rod reading at first backsight, and
- RR = Rod reading at any point from initial instrument setup.

Once the position of the level is changed, the instrument height will also change. The new instrument height can be obtained from the following equation.



$$Nht = Oht + BS - FS \dots\dots(4.3)$$

where,

Nht = New instrument height,  
 Oht = Old instrument height,  
 BS = Backsight at pivot point, and  
 FS = Foresight at pivot point.

The relative elevation of points measured from this new instrument location can be determined by using equation 4.2 and using the new instrument height (Nht) instead of the Initial Instrument Height (IS).

#### **4.3.6 Quality Control**

A quality control check must be performed in the field to ensure that no movement of the level took place during the current setup of the level. This check must be performed every time before the level is moved and when the end of the test section is reached. Once the last reading at the current location of the level has been taken, before moving the level, place the rod at the location at which the first reading was taken with the current setup of the level, and take a reading. Both readings have to agree within the resolution of the instrument. This check can also be performed at regular intervals by establishing a set of control points as described in section 4.3.3.

### **4.4 CALIBRATION AND ADJUSTMENTS**

The user manual of the level should be consulted on how to perform adjustments to the instrument. Different makes/models of levels will require different adjustments. The following are some common adjustments that are required to levels in order to obtain accurate measurements. The user manual should be consulted to determine if the following adjustments are needed for the level being used and, if so, how to perform the specific adjustment.

1. **Make Axis of Level Bubble Perpendicular to Vertical Axis:** After setting up the level, center the bubble. Move the telescope 180 degrees about the vertical axis. If the bubble moves, the instrument needs adjustment.
2. **Adjust Horizontal Cross Hairs:** This adjustment will ensure that horizontal cross hairs are truly horizontal when the instrument is leveled.
3. **Adjust Line of Sight:** This adjustment will make the axis of sight perpendicular to the vertical axis and also make it parallel to the axis of the level. The method of adjustment for this error is commonly referred to as the two-peg method.

The rod has to be checked to verify the accuracy of the markings. A standardized tape should be used for this.

### **4.5 EQUIPMENT MAINTENANCE**

Shockproof packaging should be used when transporting the instrument. Always clean the instrument after measurements are completed. Before cleaning the lenses, blow dust off lenses,

then clean lenses using a soft cloth. Lenses should not be touched with fingers. If the instrument becomes wet in the field, make sure that it is completely dry before packing. The tripod should be inspected regularly to ensure that connections are not loose.

#### **4.6 RECORD KEEPING**

The Rod and Level Data Collection Form (see appendix H) should be used to record readings when profile measurements are performed using the rod and level. A comment should be made on this form as to how the wheel paths were located. All items in this form should be completed by the instrument operator or the record-keeper. The location information in this form should be completed even when an automated instrument that is capable of saving the data is used.

#### **4.7 DATA BACKUP**

Backup copies of the rod and level data sheets must be made without exception as soon as possible. A minimum of two copies must be made for each data sheet. One copy should be transmitted to the RSC office while the second copy should be retained by the operator in case the first copy fails to reach the RSC.



## **CHAPTER 5. PROCESSING OF COLLECTED DATA IN THE OFFICE**

### **5.1 INTRODUCTION**

The data collected by the Ames device, longitudinal profile data collected with a Dipstick<sup>®</sup>, and transverse profile data collected with a Dipstick<sup>®</sup> are sent to the RSC office for processing.

In the LTPP program, the ProQual 2014 software<sup>(6)</sup> is used in the Office Mode to process the data collected by the Ames device and to perform quality assurance checks on the data. The longitudinal and transverse profile data collected by the Dipstick<sup>®</sup> are processed and quality assurance checks are performed using ProQual 2012 (see references 12 to 14). After the data are processed and quality assurance tests have been performed, data files for upload to the LTPP PPDB are created by ProQual. The data files to be saved in AIMS are also created by ProQual. This chapter presents guidelines for processing, performing quality assurance checks, and creating data files for upload to the PPDB in the office for all three data types described previously to ensure consistency and uniformity among the RSCs.

These guidelines should be viewed as the minimum required amount of data checking to be performed by the RSCs. The RSCs may already have procedures in place that exceed the minimum requirements described in this chapter. In such circumstances, the RSCs should continue to use those procedures in addition to those presented in this chapter. The guidelines for processing and performing quality assurance checks are presented separately for each data type. As described previously, processing and evaluation of data for all three data types are performed using ProQual. For each type of data, general guidelines on data processing and quality assurance checks to be performed using ProQual are described. Detailed information on the operation of ProQual 2014 software is presented in reference 6, while detailed information on the operation of ProQual 2012 software is presented in references 12 through 14.

The RSCs are not required to process profile data collected at WIM sites except to perform quality assurance checks, if needed, to make sure that data are error free. However, the RSCs are required to store the profile data at WIM sites according to the procedures described in section 5.6.

The RSCs are required to name the image files obtained by the camera in the Ames device using the file naming convention described in section 5.7 and store the image files according to the procedures described in section 5.7.

### **5.2 AMES DEVICE DATA**

The following are the recommended procedures to be used in the office for processing and performing quality assurance checks on the data collected by the Ames device. ProQual 2014 must be in the Office Mode when processing the data.

1. Copy the field XML file and the ARD files to C:\Profiles and click on “Read XML” button in ProQual. All ARD files indicated in the XML file that is found in C:\profiles will be read into ProQual. Evaluate data collected at each site by using the following procedures.

Review Information Shown on the Header Menu and End of Run Comments. The header information and End of Run Comments for all profile runs can be reviewed after reading the data files into ProQual. The header information will be shown in the “Data Import” primary tab in ProQual.

If there are errors in any of the headers that can be corrected, correct them. If there are errors that cannot be corrected (e.g., not using photocell to initiate data collection) discard the data; profile data will have to be re-collected.

The following are the fields that need to be reviewed after a set of data has been read into ProQual.

*Sequence:* Check if the sequence identifier for the visit is correct. If it is incorrect, rename the raw data files and import the data files into ProQual.

*Time:* The time when the data collection program in the Ames Engineering software is activated before the start of the section is shown. Review the time to see if it is reasonable. If unreasonable, the time shown in the laptop computer of the device should be checked for possible errors. If errors are detected, check with the operator to obtain correct time when profile data were collected.

*Start Method:* The start method for profile data collection is always PHOTOCCELL. If a method other than Photocell has been used to collect the profile data, discard the profile data; profile data will have to be re-collected.

*Stop Method:* The stop method for profile data collection should show DISTANCE.

*Road:* This field should show the route number where section is located (e.g., I-88). Check if information is correct.

*Begin:* This is the entry made for the field Beginning Description in the software. Check to see if the milepost has been entered in this field. If not, this field should show NONE.

*End:* This is the entry made for the field Ending Description in the profiler software. This field should show NONE.

*Lane:* This field refers to the lane that was profiled. Valid entries are INSIDE or OUTSIDE. Check if the entry in this field is correct.

*Direction:* This field refers to the travel direction when profiling the site. Valid entries for this field are NORTH, EAST, SOUTH, or WEST. Check if travel direction is correct.

*Stop Distance:* The stop distance for GPS sections is 152.40 meters; verify that value is correct. For SPS projects see if the value appears reasonable; stop distance shown for SPS projects is the length of entire profile run.

*Average Speed:* This field shows average speed during profiling, which should normally be 80 km/h. However, higher values are also possible as this manual indicates the operating speed may be increased to 88 km/h depending on traffic conditions. If a speed higher than 88

km/h is entered, the reason for the higher speed should be checked. If the speed is less than 80 km/h, the reason for the lower speed must be checked to verify it was due to the posted speed limit or prevailing traffic conditions.

*Crew:* Check if the operator and driver initials have been entered correctly. The operator and the driver should be identified by two characters each, first letter of their first and last names. Operator and driver names should be separated by a forward slash and typed in capital letters (e.g., CK/RS). If profiling is done as one person operation, operator and driver name should be the same (e.g., CK/CK).

*Surface Type:* Should be A-CC or P-CC. Check if the entered surface type is correct.

*Surface:* This field shows surface condition of road. Valid entries are V. GOOD, GOOD, FAIR, and POOR. As this field is selected in the profiler software by toggling through these four possible values, an entry will always be present for this field. This is a subjective entry made in the field by the operator based on a set of guidelines described in section 2.9.3.2. It is recommended that the value assigned to the section during the previous site visit be reviewed when checking this field. Otherwise, there could be variability in the value assigned to this field from one year to another (e.g., V. GOOD during latest visit, but value for previous visit was GOOD).

*Clouds:* This field shows cloud condition at the time of profiling. Valid entries are CLEAR, P. CLOUDY (Partly Cloudy), or CLOUDY. As this field is selected in the profiler software by toggling through the three possible values, an entry will always be present for this field. However, there is no easy way to check if the entry is correct.

*Collection:* This value in this field should always be Positive. The available options for this field are Positive or Negative.

*Units:* Should show mm.

*Weather:* The value in this field corresponds to the field “Other Weather Conditions” that was entered into the profiler software. In the software, the operator has the option of toggling through the following entries and selecting the appropriate one: CONDITIONS OK, STEADY CROSSWIND, WIND GUSTS, HOT AND HUMID, HAZY, LOW SUN ANGLE. As this field is selected in the header screen of the data collection software by selecting an appropriate entry from the six available choices, an entry will always be present for this field. If there is a question about this entry, check with profiler operator to verify that the entry is correct. The information in this field may be used when evaluating profile data.

*Run End Comment:* This field shows the entry made in field by operator at end of a profile run. The operator has the option of choosing one of the following entries at the end of a run: RUN OK, PAVEMENT SURFACE DAMP, TRAFFIC CONGESTION: SPEED VARIABLE, DIFFICULT TO MAINTAIN CONSTANT SPEED: UPGRADE, DIFFICULT TO MAINTAIN WHEEL PATH LOCATION, and LATE PHOTOCCELL INITIATION. If none of these comments is appropriate, the operator has the option of typing in an entry. If the Run End Comment is not one of the available options, check if Run End Note follows the guidelines described in section 2.7.10. If necessary, edit the comment. The comment in this field may be useful when comparing profile plots and when comparing IRI

values of profiler runs. (Note: There should not be runs with the comment “LATE PHOTOCCELL INITIATION”, as the operator is required to obtain additional runs if this condition is encountered. If there are runs with the comment “LATE PHOTOCCELL INITIATION” discard those runs.)

*Profile Counts:* The “Pre”, “Run” and “Post” counts for the left, right, and center sensor are shown. The profile count is the number of 25 mm interval data points. The ARD file contains profile data for a distance of 152.4 m before the start of the section (i.e., pre-run), the data collected within the section (i.e., run), and data collected for a distance of 152.4 m after the end of the section (i.e., post-run). The software will display the profile count for each sensor (i.e., left, right, and center) for the pre-run, run, and post-run. For any section that is profiled, the profile count for “Pre” should be 6096 if data collection software was initiated at least 152.4 m before the start of the section; this value could be less if data collection software was initiated at a distance less than 152.4 m before the start of the section. For any section that is profiled, the profile count for “Post” should be 6096. For a GPS section, the profile count for “Run” will be approximately 6096. The profile count for “Run” for a SPS section will vary depending on the length over which data were collected. Evaluate if the shown count values are satisfactory.

*Texture Counts:* The “Pre”, “Run” and “Post” counts for the left and the right sensor are shown. The texture count is the number of 0.5 mm interval data points. The ARD file contains texture data for a distance of 30 m before the run (i.e., pre-run), data collected within the section (i.e., run), and data collected after the run (i.e., post-run). The software displays the texture count for each sensor (i.e., left and right) for the pre-run, run, and post-run. For any section that is profiled, the texture count for “Pre” and “Post” should be approximately 60,000. For a GPS section the texture count for “Run” will be approximately 304,800. The texture count for “Run” for a SPS section will vary depending on the length over which data were collected. Evaluate if the shown count values are satisfactory.

*Air Temperature:* The “Average” and “Count” for the two ambient temperature sensors are shown. The number of readings that were taken for each sensor is displayed in the “Count” field. The average temperature is computed using data for pre-run, run, and post-run. The “Count” field includes data collected for pre-run, run, and post-run. Check if the average values appear to be reasonable based on date and month of testing. If the temperatures appear to be questionable, check with the operator who collected the data.

*Surface/Reference Temperature:* The “Average” and “Count” for the surface temperature sensor and the reference temperature sensor are shown. The number of readings that were taken by each probe is displayed in the “Count” field. The “Count” field includes data collected for pre-run, run, and post-run. The average temperatures are computed using data for pre-run, run, and post-run. Check if the surface temperature value appears to be reasonable based on the time and date of testing. If the surface temperature appears to be questionable, check with operator who collected the data.

*GPS:* The number of readings obtained by the GPSR is shown in the “Count” field. This field includes data collected for pre-run, run, and post-run. The number of satellites that were detected by the GPSR at the start of the run and the dilution of precision of the data obtained by the GPSR are displayed. Check if readings were obtained by the GPSR.

*Event Count:* The number of events recorded during the run is shown.

## 2. Review the Subsectioning Information

Review the sub-sectioning information shown in the “Section” primary tab for data collected at SPS sections to verify that the sections have been subsectioned properly. If errors are detected, perform subsectioning using correct values.

## 3. Review Indices Computed from Profile Data and Profile Data

Use the following procedures to review the indices computed from profile data and the profile data. This review is performed in the “Profile” secondary tab that is under “Data QC” primary tab except when reviewing the Operator Comments. The Operator Comments are in the “Header” secondary tab. The review need not be performed in the order described; however, all of the items described below should be reviewed.

- (a) Evaluate Computed Indices: Review the IRI values of the runs for the left, right, and center sensors for consistency. Also review the displayed Slope Variance and RMSVA values, which are average values for the left and the right sensor data.
- (b) Review Operator Comments: This field shows the comments made by the operator in the field after the data have been reviewed through ProQual. Review the comments and see if they follow the guidelines presented in section 2.7.11.3. These comments will be useful when graphically comparing profile data and when evaluating the IRI values.
- (c) Review Computed Indices for Section: Review the following parameters that are computed for the selected runs for each data collection path:
  - Elevation Cross-Correlation (Average): A value of at least 96 percent is desired.
  - Elevation Cross-Correlation (Standard Deviation): A value less than 1 percent is desired.
  - IRI Cross-Correlation (Average): A value greater than 80 percent is desired.
  - IRI Cross-Correlation (Standard Deviation): A value less than 10 percent is desired.
  - IRI (Standard Deviation): A values less than 0.04 m/km is desired.

Note: Cross-correlation is being used as a quality control and quality assurance tool for profile data in the LTPP program for the first time with the implementation of ProQual 2014. The thresholds specified above for the various cross-correlation parameters may change in the future based on feedback from RSCs. Presence of distress along the wheel path and lateral wander between runs can reduce the average IRI Cross-Correlation and increase the standard deviation of IRI Cross-Correlation. Also, variations in tire pressure between the runs, which will affect the DMI, can cause a significant reduction in the average IRI Cross-Correlation.

- (d) Evaluate Repeatability of Profile Data: Plot the profile data for the left, right, and center path and evaluate the repeatability of the collected data along each path. Operator should examine plots of all profile runs for discrepancies and features that cannot be explained by the observed pavement features. End of Run and Operator Comments entered by the operator in the field should be reviewed when the comparison between profiles is made. In addition, the



Field Activity Report (form PROF-1) should also be reviewed to see if the operator has made any additional comments related to profiler runs in that report. If variations between the profile runs are noted, the runs showing the variability should be reviewed to see if any of the following conditions contributed to the variability: DMI shift, testing out of the wheel path, or variability that is not pavement related.

- (e) Evaluate Profiles for Spikes: Review the spike count for each run. If spikes are present, review the spike locations using the graphical feature in ProQual. If present, the operator should determine if spikes are pavement related or the result of equipment or operator error. Use the 150 mm data when reviewing spikes as the spike thresholds are based on the 150 mm data. Review the locations where spikes are detected by overlaying the runs and using the graphical feature in ProQual. If the spikes for the different runs are occurring at the same location it is very likely that the spike was caused by a pavement feature. The results of the previous distress survey can also be used as a tool to evaluate if pavement features caused the spikes. The visit-to-visit profile comparison described in the next step can also be used to check if spikes were noted in the previous visit. If spikes were noted, it is mandatory that the operator comment indicate that the spikes were pavement related.
- (f) Compare Profile Data with Previous Data: Compare the current profile data for each path with those obtained during the previous site visit. Select one representative profile run to perform the visit-to-visit comparison (it is permissible to select more than one run for the comparison). The data for the two site visits should be evaluated to determine if similar profile features are present in both data sets and to determine if profile shapes are similar. If differences are observed between profiles, further comparisons should be made using remaining runs from both the current and previous visit. If there are still discrepancies between profiles from the current visit and previous visit, verify that these differences are not caused by equipment problems or due to incorrect sub-sectioning of SPS test sections. If horizontal offset of profile features is noted between visits, this may indicate a problem with sub-sectioning. Based on feedback provided by the regions on typical profile shifts noted between visits, a shift of up to 1-m between visits is acceptable. If a sub-sectioning problem is suspected, re-evaluate the sub-sectioning performed for the SPS project (or other cases where sub-sectioning was performed). If a good match is not obtained, use data from two previous site visits and perform comparison. If no explanation for the differences in profiles is found submit data to appropriate RSC personnel for review.

Note: Version 1.4.1.1 of ProQual does not have the ability to overlay profile data from a previous visit with data collected during the current visit. However, data collected by the Ames Device during a previous visit as well as during the current visit can be viewed separately. A future version of ProQual might have the ability to overlay profile data from the current visit with past data collected by any profiler that was used previously in the LTPP program. When Ames Engineering data are compared to data collected with ICC profilers, differences in profile plots will be seen (see appendix D). However, sharp upward and downward features in both profiles that are indicative of short wavelength features should occur at the same location. When the comparison involves only Ames device data, both profile features as well as profile shapes should be similar.

- (g) Compare IRI Values with Previous IRI Values: Perform an IRI comparison of current versus previous site visit data for each path (i.e., left, right, and center). If difference in IRI value for a path exceeds 10%, check to see if cause for IRI change can be identified. If a cause for the

change cannot be identified, submit data for appropriate RSC personnel for review to verify that the change in IRI was not caused by an equipment issue.

#### 4. Review Texture Data

Use the following procedures to review the texture data and the indices computed from texture data. This review is performed in the “Texture” secondary tab that is under “Data QC” primary tab except when reviewing the Surface Finish and Texture Comment. The Surface Finish and Texture Comment are in the “Header” secondary tab. The review need not be performed in the order described; however, all of the items described below should be reviewed.

- (a) Surface Finish: Evaluate Surface Finish entered by the operator and modify if needed. If the section has been profiled previously, check if the Surface Finish is consistent with the Surface Finish that was entered during the previous visit. If different, investigate and see if the operator entry is correct.
- (b) Texture Comment: Evaluate the Texture Comment entered by the operator and modify if needed. If the section has been profiled previously, check if the Texture Comment is consistent with the Texture Comment that was entered during the previous visit. . If different, investigate and see if the operator entry is correct.
- (c) MPD Values and Dropouts: Review the left and right MPD values and the dropout percentages of the runs for consistency.
- (d) Dropouts: Review the locations where dropouts occur for different runs using the graphical feature in ProQual. (Note: This feature is not currently active in Version 1.4.1.1).
- (e) Section Averages: Review if the average MPD value that is computed from all runs for each wheel path is reasonable. The ProQual manual provides typical ranges of MPD for various pavement finishes.
- (f) Compare MPD with Previous MPD: Compare MPD from current visit with previous site visit data for each path (i.e., left and right). If difference in MPD value for a wheel path exceeds 10%, check to see if the cause for the MPD change can be identified. If a cause for the change cannot be identified, submit data for appropriate RSC personnel for review to verify that the change in MPD was not caused by an equipment issue.

#### 5. Assign RCO Code and RCO Note

These activities are performed in the “Header” secondary tab under the “Data QC” primary tab.

##### *RCO Code*

A RCO Code must be assigned to each profile run after quality assurance checks are performed on the data. Those checks include: (a) review operator comments, (b) compare IRI values and review standard deviation of IRI for each path (i.e., left, right, and center), (c) compare profile data of replicate runs collected along each path (i.e., left, right, and center)

during the site visit, (d) review spikes in profile data and review operator comments regarding spikes, (e) compare profile data with those collected during previous site visit(s), and (f) if required, review distress maps to investigate spikes in the data.

Once these tasks have been completed, assign a RCO Code in ProQual for each profile run using the guidelines presented in section 5.4.

#### *RCO Note*

A RCO Note must be made for each profile run in ProQual. A drop-down list is available in this field to select an appropriate comment. The person reviewing the data also has the option of typing in a comment in this field, or to select a comment from the drop-down list and then type in additional comments.

The following are reasons for making an entry in the RCO Note field: (a) indicate improper DMI calibration, (b) indicate if spikes are pavement related, and (c) indicate cause(s) for variability in profiles.

The following comments are available in the drop-down list: PROFILE DATA OK, SPIKES ARE PAVEMENT RELATED, VARIABLE PROFILES, POOR PROFILE MATCH: DMI DIFFERENCE, and POOR PROFILE OVERLAY: ROUGH PAVEMENT, SPIKES IN WHEELPATH REMOVED. Any comments typed in this field must be in capital letters. (Note: ProQual version 1.4.1.1 does not have the ability to remove spikes. Hence, the comment SPIKES IN WHEELPATH REMOVED is currently not applicable.)

If there are no specific comments to make regarding a profile run, the comment “PROFILE DATA OK” must be selected from the drop-down list in the RCO Note field.

#### 6. Select Runs for Upload to LTPP PPDB and Create Upload Files

From all available profile runs select five profile runs for upload. Use the procedure the RSC has historically used to select the five profile runs for upload. Thereafter, create upload files. The upload files are created using the “Data QC” primary tab in ProQual in the tree (on the left side), and selecting the PPDB button. Submit the upload files to appropriate RSC personnel for review and upload to LTPP PPDB. If any problems are encountered during upload of data to LTPP PPDB they should be resolved and the corrected data should be uploaded to the LTPP PPDB.

#### 7. Store Data

Use ProQual to create data files that are to be stored in AIMS. The files are created by selecting the AIMS button in the “Data QC” primary tab. Use the procedures indicated in LTPP directive I-170, AIMS Data Storage Format Standards or the current version of that directive to store these data files and the raw data collected by the Ames device (i.e., ARD files).

### 5.3 LONGITUDINAL DIPSTICK® DATA

The current version of ProQual 2014 (Version 1.4.1.1) cannot process longitudinal Dipstick® data. Future versions of ProQual 2014 may have the ability to process longitudinal Dipstick® data. The latest version of ProQual that can process longitudinal Dipstick® data is ProQual 2012, Version 6.3.1.2.

The following are the recommended procedures to be used in the office for processing and performing quality assurance checks on longitudinal profile data collected with a Dipstick®.

1. Check if Dipstick® Passed Pre- and Post-Measurement Checks and if Data Met Closure Error

Check form DS-7 to verify that Dipstick® passed zero check and calibration check prior to and after data collection. Check form DS-1 to verify that closure error was within acceptable value.

2. Enter Header Information

This section presents general procedures on navigating through the different ProQual menus and specifies the information that should be present in the header fields. Details on procedures for navigating between menus are presented in the ProQual Manuals (see references 12 through 14).

Appropriate parameters that have to be entered into ProQual to process the Dipstick® data must be entered using the guidelines presented in the ProQual manuals (see references 12 through 14).

To enter header information of a site into ProQual, select “Manual” from main menu, and then select “Longitudinal” option. Thereafter, select site from the left side of the screen (if the site has not been created in ProQual, create site by selecting “System” in Main menu and then selecting “Sites” option). Select “Insert Data Set” icon (+ icon) and edit/enter information in the following fields in the Manual Data Set part of the screen:

*Name:* The default entry shown in this field contains the LTPP Section ID, Current Date, and Current Time. (For example, if the + icon was selected on 13 May 2003 at 1:36:10 PM for site 261000, the entry shown in this field will be, 261000 Manual Data Set: 13/May/2003 1:36:10 PM.) Edit date and time in this field to show data collection date and time at which data collection was started. This information is contained in form DS- 1.

*Sample Interval:* This field shows a default value of 304.8 mm. The spacing between the two footpads of all Dipsticks® used in the LTPP program is 304.8 mm. No change is required to this field.

*Date:* Enter date of data collection from sheet DS-1.

*Time:* Enter time data collection started from sheet DS-1.

*Equipment:* Select appropriate Dipstick<sup>®</sup> model number from drop-down list such that Model Number and Equipment # corresponds to the Serial Number and Model Number shown in form DS-1. If the required Dipstick<sup>®</sup> Model Number and Serial Number is not available in the drop-down list, then the appropriate Dipstick<sup>®</sup> information should be entered in the “Equipment” screen of ProQual.

Check if all entries are correct and save the data. After the data are saved, the Manual Header entry fields will appear on the screen and the information in the following fields have to be edited or entered: Road Name, Site Type, Visit, Run Length, Units, Lane, Direction, Crew, Clouds, Temperature, Weather, Surface Type, Surface Condition, Operator Comment, and Run End Comment. The entries for Road Name, Site Type, Visit, Lane, Direction, Crew, Clouds, Temperature, Weather, Surface Type, and Surface Condition are available in form DS-1. Check if entries meet the following criteria (described in section 3.3.5.2) and enter the information into the appropriate field in ProQual.

*Road Name:* The highway or route designation is entered in this field. Enter information in capital letters (e.g., INTERSTATE 57, US 395, S.R. 31).

*Site Type:* The drop-down list gives the following options: SPS, GPS, SMP, CAL, and WIM. Select the appropriate site type. This information is not entered into the PPDB.

*Visit:* Select the appropriate sequential visit identifier. (e.g., A for first visit to site, B for second visit, C for third visit, etc.). Check if the visit identifier is correct and enter the value. This information is not entered into the PPDB.

*Run Length:* This field is used to enter the length of the test section in meters, which will usually be 152.4 m. Once the data set is saved, this value cannot be edited. Therefore, make sure that the correct value is entered as it is used to generate the data entry tables in the “Profiles” tab.

*Units:* This field shows a default value of mm. All Dipsticks<sup>®</sup> used in the LTPP program show readings in millimeters. Therefore, no change is required to the value shown in this field.

*Lane:* Use the drop-down list and enter lane, which can be either OUTSIDE or INSIDE.

*Direction:* This is the traffic direction of test section. Use the drop-down list and select NORTH, EAST, WEST, or SOUTH.

*Crew:* The operator and the recorder should be identified by two characters each, first letter of their first and last names. Operator and recorder names should be separated by a forward slash and typed in capital letters (e.g., CK/RS).

*Clouds (Cloud Conditions):* Valid entries for this field are CLEAR, P. CLOUDY, or CLOUDY. Use the drop-down list in ProQual to select appropriate entry.

*Temperature:* The average of the air temperatures obtained from the air temperature probe before and after longitudinal Dipstick<sup>®</sup> measurements is entered in this field. Check if the

temperature appears to be reasonable based on season/month when test was performed and, if reasonable, enter the value. If not, check with operator.

*Weather Comment:* ProQual contains the following predetermined comments: CONDITIONS OK, STEADY CROSSWIND, WIND GUSTS, HOT AND HUMID, HAZY, LOW SUN ANGLE. Select the appropriate comment based on the information contained in form DS-1 using the drop-down list. If there is a weather related comment that is different from those available in the drop-down list, type the comment in this field using capital letters.

*Surface Type:* Use the drop-down list to select surface type; A-CC for asphalt surfaced pavements and P-CC for portland cement concrete surfaced pavements based on surface type entered in form DS-1.

*Surface Condition:* Enter the condition of the pavement as either V. GOOD, GOOD, FAIR, or POOR. Use the drop-down list to select the entry that is noted in form DS-1. Since this is a subjective entry made in the field by the operator, it is recommended that the value assigned to the section during the previous site visit be reviewed when checking this field. Otherwise, there could be variability in the value assigned to this field from one year to another (e.g., V.GOOD during latest visit, but value for previous visit was GOOD).

*Operator Comment:* Enter the operator comments in capital letters, if the operator made any comments.

*Run End Comment:* Enter Run End Comment in capital letters, if the operator made a comment.

Once all header entries have been entered and checked, save the header information.

### 3. Enter Longitudinal Dipstick® Data

Enter the Dipstick® survey readings recorded on Forms DS-2 through DS-6 into the “Profiles” sheet in ProQual. The exact sign convention used in the data sheets should be followed when entering the data (i.e., a negative value in data sheet should be entered as a negative value into ProQual). Once data have been entered for the left and the right wheel paths, print data by selecting the Printer icon. Check the Dipstick® data values along the left and right wheel paths in the printout with values in Forms DS-2 through DS-6 to make sure all data have been entered correctly.

### 4. Sum Dipstick® Data and Filter Profile Using Surface Dynamics Filter

After checking the data and making corrections as needed, select sum button to obtain elevation profile as well as elevation profile that has been filtered with the Surface Dynamics upper wavelength cut-off filter. This action will cause the four data columns right of the left profile reading column to be populated with data. (Note: The Surface Dynamics filter included with the ProQual software was used in the K.J. Law T-6600 profilers as the upper wavelength cut-off filter). Thereafter, select Update Main Tables icon to update the main tables with the filtered profile data. (Note: ProQual provides the option of filtering the

Dipstick<sup>®</sup> elevation profile with either the Surface Dynamics or ICC filter. Longitudinal Dipstick<sup>®</sup> data are collected on a regular basis at test sections in Alaska, Hawaii, and Puerto Rico. In order to provide consistency in data collected at these sites, the Surface Dynamics filter must be used to filter Dipstick<sup>®</sup> profiles.)

## 5 Compute Ride Indices and Review Data

The data set can now be treated as a profiler run that was obtained using an inertial profiler by selecting “Profiles” menu from the main menu of ProQual, and then selecting the “Data” submenu. Select data set to be analyzed and in the “Analysis” submenu of “Data Sets” menu select “All” icon to compute all roughness indices (i.e., IRI, RMSVA, Slope Variance). Review if spikes are present in the profile. If spikes are present, check to make sure that spikes were not caused by errors during data entry. Print Site Summary Report to review the values computed for IRI, Spike Count, RMSVAs, Mays Output, and Slope Variance. Plot profiles along left and right wheel paths and review the profile plots to see if they are reasonable.

## 6. Compare Data With Data From Previous Visit.

Compare IRI values obtained along each wheel path with those obtained during the previous site visit. If difference is greater than 10% for a wheel path, investigate reason for difference. Graphically compare profiles along each wheel path with those generated from previous site visit. If major differences are noted between the two data sets, and no explanation for differences is found, paper copies of the profiles should be submitted to appropriate RSC personnel for review.

## 7. Review Operator Comment and Run End Comment

The Operator Comment as well as the Run End comment were entered into the header menu in step 2 (Enter Header Information). If needed, make changes to the Operator Comment or Run End Comment based on the review of profile data.

## 8. Assign RCO Code and RCO Note

### *RCO Code*

A RCO Code must be assigned to the profile data after quality assurance checks have been performed on the data. Those checks include: (a) review operator comments, (b) compare IRI values along each wheel path with those obtained during previous site visit, (c) review spikes in profile data and review operator comments (if any) regarding spikes, (d) compare profile data with those collected during previous site visit(s), and (e) if required, review distress maps to investigate spikes in data.

Once these tasks are completed, assign the RCO Code to profile runs using guidelines presented in section 5.4. The RCO Code is assigned in the “Results and Status” tab of the “Run Details” sheet in ProQual.

### *RCO Note*

A RCO Note must be made for each profile run. The RCO Note is assigned in the “Results and Status” tab of the “Run Details” sheet in ProQual. A drop-down list is available in this field to select an appropriate comment. The operator also has the option of typing in a comment in this field, or to select a comment from the drop-down list and then type in additional comments.

An entry in the RCO Note field should be made to indicate locations where spikes were logically marked and/or to indicate if spikes are pavement related.

The following comments are available in the drop-down list: PROFILE DATA OK, SPIKES ARE PAVEMENT RELATED, VARIABLE PROFILES, SPIKE(S) IN \_\_\_\_ WHEELPATH REMOVED, POOR PROFILE MATCH: DMI DIFFERENCE, and POOR PROFILE OVERLAY: ROUGH PAVEMENT. Any comments typed in this field must be in capital letters. If there are no specific comments to make regarding a profile run, the comment “PROFILE DATA OK” must be selected from the drop-down list in the RCO Note field.

#### 9. Create LTPP PPDB Upload Files

Select longitudinal Dipstick<sup>®</sup> profile file for upload and create RIMS upload file. Check the ProQual Export Review Summary Report for errors and exceptions, and if any are found resolve issue(s) and recreate RIMS upload files, as needed.

#### 10. Submit RIMS files to Appropriate RSC Personnel for Review and Upload

If any problems are encountered during upload of RIMS data to PPDB, resolve the problems and upload corrected data to PPDB.

#### 11. Store Data

Store all files related to the site that were created by ProQual. Use the file structure described in LTPP directive I-170, AIMS Data Storage Format Standards or the current version of that directive.

### **5.4 ASSIGNMENT OF RCO CODE**

A RCO Code must be assigned to the longitudinal profile data collected by the profiler as well as by the Dipstick<sup>®</sup> after quality assurance checks have been performed on the data. The assignment of RCO code to profiler data and Dipstick<sup>®</sup> data were described in sections 5.2 and 5.3, respectively.

The assignment of RCO Code should be performed by a person knowledgeable in profile data analysis. This section provides guidance to the person who is performing the quality assurance checks in selecting the appropriate RCO Code to be assigned to each profile run. The following guidelines should be used to assign the RCO Code for a profile run.



### *RCO Code = 1*

A RCO Code of 1 should be assigned to a profile run if there are no data problems. Such profile runs have the following characteristics:

- If there is variability between multiple profile runs, the operator comments explain that the cause of this variability is pavement related.
- If spikes are present in data, they occur because of pavement features and they are documented by the operator comments/notes to be pavement related.
- Profile data plots are in good agreement with those collected during previous site visits. This procedure provides a check on errors caused by incorrect sub-sectioning of SPS sites, incorrect labeling of sites, and incorrect start locations for profile data collection.

### *RCO Code = 2*

A RCO Code of 2 should be assigned to a profile run if any of the following features are identified in the data:

- Poor repeatability between the multiple profile runs, and operator comments do not indicate that this variability was caused by pavement features. It has been observed that sometimes profilers have poor repeatability on rough sections and on sections where the approach to the section is rough (e.g., patched core holes prior to section). On such sections, the data from multiple profiler runs are generally different from each other, with the operator having no comments regarding wheel path tracking problems. Although there are large differences in profile data, the IRI values from these runs are generally in good agreement with each other and may meet the ProQual IRI acceptance criteria. This occurs because differences in profile data are caused by long wavelengths that do not contribute to the IRI. Such profile runs should be assigned a RCO Code of 2.
- Spikes in profile: If there are spikes in the profile data, and the operator comments indicate that the spikes are not pavement related, such data points shall be logically marked and the profile run should be assigned a RCO code of 2. (Note: It is not possible to logically mark profile data points in ProQual 2014 Version 1.4.1.1. This feature may be included in a future version of ProQual.) It has been reported that the white pavement markings at the beginning and end of a test section as well as 30-m crosses that are in the wheel path can cause spikes in the profile data. In such cases, the spikes will generally occur at the indicated locations for the replicate runs. If operator indicates that these spikes are not explained by pavement features, such profile data points should be logically marked and the profile run assigned a RCO Code of 2.

### *RCO Code = 3*

A RCO Code of 3 should be assigned to a profile run if any of the following conditions are identified:

- When compared to other profile runs collected during site visit, there is a large IRI difference that cannot be explained.
- There are spikes in the profile data that are not explained by operator comments.
- There are differences in the profile data when compared to other profile runs collected during the site visit, but differences cannot be explained by operator.
- Profiler runs collected during site visit are repeatable, but they are different from those collected during previous site visits, and differences are identified to be caused by conditions at the time of testing (e.g., damp pavement). It should be noted that data collection at LTPP test sections should be performed on dry pavements. But there could be cases where data were collected on a damp surface due to existing circumstances.

## 5.5 TRANSVERSE DIPSTICK<sup>®</sup> DATA

The current version of ProQual 2014 (Version 1.4.1.1) cannot process longitudinal Dipstick<sup>®</sup> data. Future versions of ProQual 2014 may have the ability to process transverse Dipstick<sup>®</sup> data. The latest version of ProQual that can process transverse Dipstick<sup>®</sup> data is ProQual 2012, Version 6.3.1.2.

The following are the recommended procedures to be used in the office for processing and performing quality assurance checks on transverse profile data collected with a Dipstick<sup>®</sup>.

### 1. Check if Dipstick<sup>®</sup> Passed Pre- and Post-Measurement Checks

Check form DS-7 to verify that Dipstick<sup>®</sup> passed zero check and calibration check prior to and after data collection.

### 2. Enter Header Information

This section presents general procedures on navigating through the different ProQual menus and specifies the information that needs to be entered into the header fields. Details on procedures for navigating between menus are presented in the ProQual Manuals (see references 12, 13, and 14). There are several header entries that are not uploaded to the PPDB. However, these entries may be useful if the ProQual files are reviewed at a future date.

To enter the header information for a site into ProQual, select “Manual” from main menu, and then select “Transverse” option. Thereafter, select the site from the left side of the screen (if the site has not been created in ProQual, create site by selecting “System” in Main menu and then selecting “Sites” option). Select “Insert Data Set” icon (+ icon) and edit/enter information in the following fields in the Manual Data Set part of the screen:

*Name:* The default entry shown in this field contains the LTPP Section ID, Current Date, and Current Time. (For example, if the + icon was selected on 13 May 2003 at 1:36:10 PM for site 261000 the entry shown in this field will be, 261000 Manual Data Set: 13/May/2003

1:36:10 PM.) Edit date and time in this field to show the data collection date and time at which data collection was started. This information is contained in form DS-8.

*Station Interval:* The default value shown in this field is 15.24 m. This is the station interval at which transverse data are collected at LTPP sections. No changes are needed to this field.

*Tests:* The number of readings taken for a transverse profile. Enter number of readings by reviewing data on form DS-8.

*Date:* Enter date of data collection from sheet DS-8.

*Time:* Enter time data collection started from sheet DS-8.

*Equipment:* Select appropriate Dipstick<sup>®</sup> model number from drop-down list such that Model Number and Equipment # corresponds to the Serial Number and Model Number shown in form DS-8. If the required Dipstick<sup>®</sup> Model Number and Serial Number is not available in the drop-down list, then the appropriate Dipstick<sup>®</sup> information should be entered in the equipment parameters screen of ProQual.

Check if all entries are correct and save data. After data are saved, the Manual Header entry fields will appear on the screen and the information in following fields have to be edited or entered: Road Name, Site Type, Visit, Run Length, Units, Lane, Direction, Crew, Clouds, Temperature, Weather, Surface Type, Surface Condition, Operator Comment, and Run End Comment. The entries for Road Name, Site Type, Visit, Lane, Direction, Crew, Clouds, Temperature, Weather, Surface Type and Surface Condition are available in form DS-8. Check if entries meet the following criteria (described in section 3.3.5.2) and enter information into appropriate field in ProQual.

*Road Name:* This is the highway or route designation. Enter the information in capital letters (e.g., INTERSTATE 57, US 395, S.R. 31). This information is not entered into the PPDB.

*Site Type:* The drop-down list gives the following options: SPS, GPS, SMP, CAL, and WIM. Select the appropriate site type. This information is not entered into the PPDB.

*Visit:* Sequential visit identifier. (e.g., A for first visit to site, B for second visit, C for third visit, etc.). Check if visit identifier is correct and enter the value. This information is not entered into the PPDB.

*Units:* This field shows a default value of mm. All Dipsticks<sup>®</sup> used in the LTPP program show readings in millimeters. Therefore, no change is required to the value shown in this field.

*Lane:* Use the drop-down list to select lane, which can be either OUTSIDE or INSIDE. This information is not entered into the PPDB.

*Direction:* This is traffic direction of test section. Use the drop-down list to select NORTH, EAST, WEST or SOUTH. This information is not entered into the PPDB.

*Crew:* Operator and recorder should be identified by two characters each; first letter of their first and last names. Operator and recorder names should be separated by a forward slash and typed in capital letters (e.g., CK/RS).

*Clouds (Cloud Conditions):* Valid entries for this field are CLEAR, P. CLOUDY, or CLOUDY. Use the drop-down list in ProQual and enter cloud the conditions. This information is not entered into the PPDB.

*Temperature:* The pavement temperature in degrees Celsius obtained with an infrared device is entered in this field. Check if the temperature appears to be reasonable based on date and month when the test was performed and enter value. This information is not entered into the PPDB.

*Weather Comment:* ProQual contains the following predetermined comments: CONDITIONS OK, STEADY CROSSWIND, WIND GUSTS, HOT AND HUMID, HAZY, LOW SUN ANGLE. If a comment indicated in Form DS-8 corresponds to one of the predetermined comments, use the drop-down list to select appropriate entry. If the comment is different, type the comment noted in form DS-8 (use capital letters). This information is not entered into the PPDB.

*Surface Type:* Use the drop-down list to select surface type noted in form DS-8. A-CC for asphalt surfaced pavements and P-CC for portland cement concrete surfaced pavements. This information is not entered into the PPDB.

*Surface Condition:* Enter condition of pavement as either V.GOOD, GOOD, FAIR, or POOR. Use drop-down list to select entry that was made in form DS-8. Since this is a subjective entry made in the field by the operator, it is recommended that the value assigned to the section during the previous site visit be reviewed when checking this field. Otherwise, there could be variability in the value assigned to this field from one year to another (e.g., V.GOOD during latest visit, but value for previous visit was GOOD). This information is not entered into the PPDB.

There are three more header fields in the header menu: Operator Comment, Run End Comment, and RCO Comment. It is recommended that these three fields be completed after the transverse Dipstick<sup>®</sup> data has been entered and evaluated.

Once all header entries have been made and checked, save the header information.

### 3. Enter Transverse Dipstick<sup>®</sup> Data

The transverse Dipstick<sup>®</sup> data collected in the field and recorded on form DS-8 are entered into ProQual through the Profiles tab. The readings taken from Edge of Pavement to Center Line should be entered in the left column. The data for the return run (center of pavement to edge of pavement) should be entered in the right column. All measurements should be entered exactly as recorded on form DS-8, with negative values on form DS-8 entered into ProQual as negative values.

All three boxes on top of the graph should be checked so that elevations are displayed for: (a) run from edge of pavement to centerline, (b) from centerline to edge of pavement, and (c) sum of two elevation measurements.

Once the data have been entered, review and see if graphical “Sum” plot is a horizontal line. If the line is not horizontal and spikes are noted at some locations, the data at those locations may have been incorrectly entered. If so, check if data have been entered correctly.

After data have been checked for accuracy, select “Verify Profiles.” Confirm that closure error limit has been met. If not, recheck data entry. If the data do not meet the closure limit, the data from that run should be submitted to the FHWA with a copy to the LTPP Technical Services Support Contractor.

Enter data for other transverse locations. Follow the procedures outlined above to check those data.

#### 4. Use Graphic Profile Option to Check Profiles

After data for all transverse profile runs have been entered, use “Graphic Profile” option to plot the profile data. When this option is selected, a graph showing the profile plots for all transverse locations is displayed. Check if profiles reasonably match between stations. If a plot for any specific station appears to be different from the rest of the profiles, check the data that were entered for that location.

#### 5. Run Rut Analysis

Select “Rut Analysis” icon to compute rut depths and then print the Rut Report using the “Rut Report” icon. Review rut depths computed along the left and right wheel paths at different transverse locations. If the rut depth at any location appears to be different from those for the other locations, check if the data have been entered correctly.

If the RSC maintains record of rut depths computed by ProQual for previous site visit, compare current rut depths with those from previous visit. The comparison should be made at each transverse location for each wheel path. If there are large differences, investigate if correct data have been entered.

#### 6. Enter Operator Comment, Run End Comment, and RCO Comment

Operator Comment, Run End Comment, or RCO Comment is not uploaded to the PPDB. Therefore, entries made to these fields are only useful if the ProQual data files are reviewed at a future date. If the operator has made comments in form DS-8 related to data collection, enter comments in the Operator Comment field. If all comments cannot be entered into this field, enter remaining comments in the Run End Comment field. Also, enter a RCO Comment if needed to comment on the data.

#### 7. Create PPDB Upload Files

Run “IMS Export” to create RIMS files. If problems are encountered, resolve issue and recreate RIMS upload files, as needed.

## 8. Submit RIMS files to Appropriate RSC Personnel for Review and Upload

The RIMS files should be submitted to appropriate RSC personnel for review and then uploaded to the LTPP PPDB. Resolve any issues that may arise during upload.

## 9. Store Data

Store all files related to the site that were created by ProQual. Use guidelines in directive I-170, AIMS Data Storage Format Standards or the current version of that directive to store the data.

### 5.6 STORING WIM DATA

Profile data collected at WIM sections should be stored at the RSC offices in external hard disk-based media with a USB interface. The RSCs should maintain a file with the completed Profiling of WIM Sections: Data Summary Sheet (form PROF-7 in appendix B) for each occasion a WIM section has been profiled.

The RSCs should store the WIM data using the procedures described in LTPP directive I-170, AIMS Data Storage Format Standards or current version of that directive. The storage of working files should be done in accordance with the procedures described in LTPP directive I-170, AIMS Data Storage Format Standards or the current version of that directive.

For the ICC profiler, the raw profile data files that need to be stored are the files with extensions of p, e, and v. For the Ames devices store the files with file extension ARD that contain the raw data. All files generated by ProQual for each site should be stored in conjunction with the raw profile data files.

### 5.7 NAMING AND STORING IMAGE FILES

The image files obtained from the camera in the Ames device must be named according to the procedures described in this section. The RSCs should store the image files using the procedures described in LTPP directive I-170, AIMS Data Storage Format Standards or the current version of that directive.

#### 5.7.1 Image File Names for Images Collected at GPS and WIM Sections

Use the following file naming convention to name images obtained at GPS and WIM sections:

HSSAASHRPBrYYYYMMDDNNNN.jpg

|      |  |
|------|--|
| HSS  | High-Speed survey. The first three characters of the filename will always be HSS.  |
| AA   | Numeric state code.  |
| SHRP | SHRP_ID for site.  |
| B    | G for a GPS section and W for a WIM section. After Sequential Visit Identifier Z has been reached at a GPS section, change G to H; after sequential visit identifier Z has been reached at a WIM section, change W to X. |

|          |  |
|----------|--|
| r        | Sequential visit identifier associated with the profiler visit (see section 2.7.3). After visit identifier Z has been reached restart with visit identifier A. |
| YYYYMMDD | Profile date (Year/Month/Date).  |
| NNNN     | Number of image in sequence starting with 1 for the first image.   |

For images obtained with the Ames Engineering Software v6.0.1.69 that was released under Directive P-47, the first image was obtained when the photocell was triggered at the start of the section. Hence, the image number for this image will be 0001. With this version of software, the last image was obtained at the end of the section.

For images obtained with Ames Engineering Software v6.0.1.116 that was released under Directive P-50, the first image is obtained when the photocell is armed. It was specified that the operator should arm the photocell just before Sign A, which is located 152 m before the start of the section. A white paint stripe is located across the lane at this location. The first image obtained with the camera, which is when the photocell is armed at approximately 152 m before the start of the section, will have the image number 0001. The camera continues to take images for a distance of 152.4 m past the end of the section.

Starting with Ames Engineering software version 6.0.4.18, the Ames Engineering software will automatically name files according to the convention described above. All image files obtained before that will have to be renamed manually to meet the file naming convention described above.

**Example:** This example applies to images obtained with Ames Engineering Software v6.0.1.116 and future versions of software. (Note: This is because with Version 6.0.1.69 of Ames Engineering software, images were not obtained before the start of the section and after the end of the section). Assume images were obtained at GPS section 1018 located in Arizona (State Code 04) on December 9, 2014 during Sequential Visit Identifier K. Assume that 16 images were obtained before the test section, 15 images were obtained within the test section, and 15 images were obtained after the end of the test section. The first image obtained at this section, which is when the photocell is armed, will have the following file name: HSS041018GK201412090001.jpg. The last image taken at this section will have the following file name: HSS041018GK201412090046.jpg.

## 5.7.2 Image File Names for Images Collected at SPS Sections

Use the following file naming convention for images taken at SPS sections:

HSSAASHRPSRYYYYMMDDNNNN.jpg

|          |   |
|----------|---|
| HSS      | High-Speed survey. The first three characters of the filename will always be HSS.   |
| AA       | Numeric state code.   |
| SHRP     | SHRP_ID for the site.   |
| S        | This digit will always be S to indicate the image was obtained at a SPS section. However, after visit identifier “Z”, change this digit to T. |
| R        | Sequential visit identifier associated with the profiler visit. After visit identifier Z has been reached, restart with visit identifier A.   |
| YYYYMMDD | Profile date (Year/Month/Date).   |

NNNN            Number of image in sequence starting with 1 for the first image.

Name the image files according to the convention described above for each section. The files will have to be named manually.

Use the following rules to treat images taken within transition areas between sections.

- (a) If more than 30 images were obtained in the transition area between sections, assign the first 15 images to the lead out area of the first section and the last 15 images to the lead in area of the second section. Discard the other images.
- (b) If less than 30 images were obtained in the transition area, assign half of the images to the lead out area of first section and the other half to the lead in area of the second section. If the number of images obtained in the transition area is an odd number, assign the extra image to the lead in area of the second section.

For images obtained with Ames Engineering Software v6.0.1.69 that was released under Directive P-47, the camera obtains the first image when the photocell was triggered at the start of the first section in the SPS project. Therefore, no images are obtained before the start of the first section. The camera obtains the last image at the Stop Distance that was specified in the header menu in the Ames Engineering software (see section 2.9.3).

In Ames Engineering Software v6.0.1.116 that was released under Directive P-50, the first image is obtained when the photocell is armed. It was specified that the photocell be armed just before Sign A that is located 152 m before the start of the first section in a SPS project. A white paint stripe is located across the lane at this location. Hence, the first image obtained in a SPS project is located approximately 152 m before the start of the first section in the SPS project. Hence, for this version of software, images are available before the start of the section. The camera continues to take pictures for a distance of 152.4 m past the Stop Distance specified in the header menu of the Ames Engineering software (see section 2.9.3).

If the photocell was armed before Sign A, which resulted in more than 15 images obtained before the start of the first section of the SPS project, keep only 15 images that were taken immediately before the start of the section, and discard the extra images. (Note the first image should have the sequence number 0001). Keep only 15 images past the end of the last section in the SPS project and discard the extra images.

**Example:** This example applies to images obtained with Ames Engineering Software v6.0.1.116 and future versions of software (Note: This is because with Version 6.0.1.69 of Ames Engineering software, images were not obtained before the start of the first section in a SPS project). For the Delaware SPS-1 project, the first test section encountered during profiling is section 0160 and the second section encountered is section 0107. (Note: State code for Delaware is 10.) The transition area between these two sections is 60 m. Assume that this section was profiled on 7 February 2015, and that images were taken during Sequential Visit Identifier H. Assume that 15 images were obtained before test section 0160, 15 images were obtained within sections 0160 and 0107, and six images were obtained within the transition area between the sections. Six images were obtained within the transition area; three images will be assigned as lead out images for section 0160 and three images will be assigned as lead in images for section 0107.



Section 0160: The first image obtained at this section, which is when the photocell is armed will have the following file name: HSS100160SH201502070001.jpg. The last image assigned to this section will be the third picture after the end of the section, which will have the following file name: HSS100160SH201502070033.jpg.

Section 0107: The first image assigned to this section is obtained in the lead in area and will have the following file name HSS100107SH201502070001.jpg.

## **CHAPTER 6. INTER-REGIONAL COMPARISON TESTS**

### **6.1 INTRODUCTION**

This chapter describes a plan for periodic comparison of the Ames Engineering profile/texture devices used in the LTPP program. This comparison is usually performed on an annual basis at a date and location determined by the FHWA. The FHWA will select a host RSC who will be responsible for coordination of logistical arrangements (hotel, maps, traffic control, meeting places, etc.), selection and marking of test sections, and measurement of longitudinal profile on those test sections using a suitable reference device. The annual profiler comparison will be rotated among the four RSCs, so that they are responsible for preparatory activities once every four years. After completion of preparatory activities, but within 14 days of reference profile measurements, non-host RSCs will travel to the test sites and, together with host RSC perform data collection over an approximately four-day period with their respective device.

The Dipstick<sup>®</sup> has been traditionally used to collect the longitudinal reference data at test sections. The Dipstick<sup>®</sup> collects data at 304.8 mm intervals. Currently, rolling profilers, such as the SurPRO manufactured by ICC can collect data at 25 mm intervals. As LTPP profilers collect data at 25 mm intervals, the Dipstick<sup>®</sup> is not the best device to use to collect reference profile data as it has a data recording interval of 304.8 mm. A rolling profiler such as the SurPRO is ideal for collecting reference profile data as its data recording interval matches the data recording interval of the LTPP profilers. However, the LTPP program currently does not have a SurPRO in its possession.

A report summarizing the results of the comparison tests and associated data must be submitted by each RSC to the FHWA LTPP Office, with a copy to the LTPP TSSC contractor within 21 days after completion of the tests. Inter-regional comparison and analyses of the data will be performed by the TSSC, who will produce and submit to the FHWA LTPP Office a report of the results within 45 days after receipt of the individual RSC reports.

### **6.2 PREPARATORY ACTIVITIES**

The host RSC will be responsible for the following activities:

- Selecting dates for comparison testing of devices in coordination with the FHWA, TSSC, and other RSCs.
- Site selection.
- Logistical arrangements (reserve block of rooms at or near selected site, meal arrangements, traffic control arrangements, etc.).
- Communication of final logistical arrangements to the FHWA, TSSC, and other RSCs.
- Measurement of longitudinal profiles at the test sections using a suitable reference device.

## 6.3 TEST SECTIONS

The host RSC will be responsible for selecting and marking the test sections that will be used for the comparison of devices. Five test sections for profile/texture testing and one test section for DMI testing should be selected by the host RSC. The five test sections for profile/texture testing should be selected based on the following guidelines.

- Section 1 (AC-1), Smooth AC: AC pavement with a mean IRI < 1.6 m/km.
- Section 2 (AC-2), Rough AC: AC pavement with a mean IRI > 2.2 m/km.
- Section 3 (PCC-1), Smooth PCC: Jointed PCC pavement with a mean IRI < 1.6 m/km.
- Section 4 (PCC-2), Rough PCC: Jointed PCC pavement with a mean IRI > 2.2 m/km.
- Section 5: Chip sealed section.

The test sections used for profile/texture testing should meet the following criteria:

- The AC pavement sections should not be PCC sections that have been overlaid with AC.
- The test sections should have a marked outside lane edge stripe that can be used as an outside lane edge reference.
- All test sections should be located on flat tangent sections with sufficient length at each end to allow for acceleration to a constant speed before the section and safe deceleration past its end.
- The speed limit of the roadways containing the test sections should be at least 80 km/h.
- Each test section should be 152.4-m in length, with the beginning and end marked.
- Where possible, test sections should be located within a centralized locale with short travel distances between each test section to reduce travel time.
- Test sections do not have to be located on LTPP test sections. However, LTPP test sections can be used when convenient.

An accurately measured 300 m long section should be established as the DMI section. A standard surveying tape should be used in conformance with standard surveying practice to accurately locate the end point relative to the start point. The DMI test section should be located on reasonably level pavement suitable for such testing (i.e., low traffic volume, adequate sight distances, operator safety, etc.).

## 6.4 REFERENCE DATA COLLECTION AT TEST SECTIONS

A suitable reference device (e.g., SurPRO, Dipstick<sup>®</sup>) that has been approved by the FHWA should be used to obtain longitudinal reference measurements along both wheel paths and along the center of the lane at all test sections. If a Dipstick<sup>®</sup> is used, measurements should be obtained using the procedure described in section 3.3.3 of this manual. If a SurPRO is used, the procedures described in section 3.3.3 modified accordingly to accommodate the SurPRO should be used. The reference data collection should be performed within 14-days of the comparison

tests. On PCC test sections, the reference data collection should be performed after noon, at the same approximate time of day as expected for the collection of profiler data. If sufficient resources are not available for performing reference data collection at all test sections, with approval from FHWA, the RSC should perform data collection only at the smooth AC test section

## **6.5 COMPARISON TESTING OF DEVICES**

The following sequence should be followed in performing tests during the comparison test.

1. Full calibration check of profile and texture height sensors.
2. Dynamic calibration check of texture height sensors.
3. Calibration check of accelerometers and bounce test.
4. Calibration of DMI and collecting data to check bias and precision of DMI.
5. Collection of profile/texture data at the test sections.
6. Verification of DMI.

Details on each of these tests/checks are described in the following sections.

### **6.5.1 Full Calibration Check of Profile and Texture Height Sensors**

A full calibration check of the profile and texture height sensors should be performed following the procedures described in section 2.12.5 of this manual.

### **6.5.2 Dynamic Calibration Check of Texture Height Sensors**

A dynamic calibration check of the texture height sensors should be performed following the procedures described in section 2.12.6 of this manual.

### **6.5.3 Calibration Check of Accelerometers**

A calibration check of the accelerometers should be performed following the procedures described in section 2.12.4 of this manual. Thereafter, perform a bounce test following the procedure described in section 2.9.2.4 of this manual.

### **6.5.4 DMI Test**

Calibrate the DMI following the procedures described in section 2.12.3 of this manual. Then perform a “Horizontal Test” using the “Horizontal Test” option in the Ames Engineering software (see section 2.12.3) to obtain the distance between the reflective marks on the DMI section. Record the displayed distance. Repeat this procedure five more times. The tire pressure may be checked and adjusted if necessary before performing each run such that it matches the tire pressure during DMI calibration. Compute the average and standard deviation of the six recorded distances.

### **6.5.5 Profile/Texture Data Collection**

Profile and texture data collection at each test section should be performed following the procedures that are used when performing data collection at GPS sections as outlined in this

manual. Testing should be performed at a speed of 80 km/h. The PCC test sections should be profiled approximately at the same time when reference data were collected at the sections.

### **6.5.6 Verification of DMI**

The purpose of this test is to evaluate the stability of the DMI over time. This test should be performed after all five test sections have been profiled. The DMI should not be calibrated before performing the verification testing. Warm-up the tires using the procedures that were used when the tires were warmed-up before calibrating the DMI. Then perform a “Horizontal Test” using the “Horizontal Test” option in the Ames Engineering software (see section 2.12.3) to obtain the distance between the reflective marks on the DMI section. Record the displayed distance. Repeat this procedure five more times. The tire pressure may be checked and adjusted if necessary before performing each run such that it matches the tire pressure during DMI calibration.

## **6.6 REPORTS**

### **6.6.1 Submission of Reports and Data by RSCs**

Within 21-days after completion of the comparison testing, each RSC should submit a report and the data collected during the comparison test to the FHWA LTPP Office, with a copy to the TSSC. Section 6.6.2 presents the format for this report and section 6.6.3 describes the data that should be submitted.

### **6.6.2 Format of Report**

The report should consist of the following items:

1. Height sensor measurements form for profile height sensors (see form COMP-1 in appendix I).
2. Height sensor measurements form for texture height sensors (see form COMP-2 in appendix I).
3. Accelerometer calibration check, bounce test, and texture sensor dynamic check form (see form COMP-3 in appendix I). Report the results from bounce test performed immediately after full calibration check of height sensors.
4. DMI Measurement form (see form COMP-4 in appendix I).
5. DMI Verification form (see form COMP-5 in appendix I).
6. IRI Values Table: Compute the IRI of the five runs at each site that would have been selected for upload to the PPDB using the current version of ProQual. Enter the IRI values into the IRI Values table that is included in appendix I (form COMP-6). Compute average and standard deviation of IRI for each wheel path at each site.
7. MPD Values Table: Compute the MPD values for the five runs that were included in the IRI Values table. Enter the MPD values into the MPD Values table that is included in appendix

H (form COMP-7). Compute average and standard deviation of MPD for each wheel path at each site.

8. Profile Plots: Use ProQual to overlay the five selected runs at each site. Create the following graphs separately for each site and cut and paste them into the report: (a) five overlaid runs for left wheel path, (b) five overlaid runs for the right wheel path, (c) five overlaid runs for the center path, (d) overlay two runs and show left, right, and center profiles on same graph. Create these graphs for all five sites. Indicate test section, surface type, and date of testing with each set of graphs.
9. If any data anomalies are noted for the full calibration check of the profile and texture height sensors, DMI testing, IRI values at a test section, MPD values at a test section, or repeatability of profile plots, discuss the possible causes for these anomalies.

The host RSC should include the following items in the report.

1. Provide a description of structural attributes (if known) and observed distresses for all test sections. Details should be given on those attributes of the test section which are suspected of influencing profile/texture measurements, such as meandering cracks in the wheel paths, highly variable transverse profile, etc. Detailed measurements are not required and subjective based descriptions are satisfactory. Include photographs of test sections in the report.
2. Include a table showing the IRI values computed from reference device measurements. Indicate date, start time, and end time for reference data collection

### **6.6.3 Data Submission**

The following data should be submitted on a CD. Organize the data into the CD in a logical manner.

1. Results from the full calibration check of the profile and texture height sensors that are saved after the test.
2. The accelerometer calibration check log.
3. The texture data (ARD file) that is saved after performing the dynamic check on the texture height sensors.
4. The DMI calibration report that is saved after calibrating the DMI.
5. The bounce test files (ERD format) for the test that was performed immediately after the full calibration check on the height sensors was performed.
6. Raw data files (ARD files) containing the data collected at the five test sections.
7. ERD files containing profile data collected at the five test sections at 25 mm intervals.
8. Submit an Excel file with separate sheets in the file for each of the following items: (a) height sensor measurements form for profile height sensors (see form COMP-1 in appendix

I), (b) height sensor measurements form for texture height sensors (see form COMP-2 in appendix I), (c) DMI Measurements Form (see form COMP-3 in appendix I), (d) DMI Verification Form (see form COM-4 in appendix I), (e) Results from the accelerometer calibration check, bounce test, and texture sensor dynamic check (see form COMP-5 in appendix I), (f) IRI values form (see form COMP-6 in appendix I), and (g) MPD values form (see form COMP-7 in appendix I).

9. The host RSC should submit the data files containing the reference profile data.

#### **6.6.4 Preparation of Report by TSSC**

On receipt of the RSC reports and data, an inter-regional comparison and analyses of the test results will be performed by the TSSC. A report summarizing the results of this effort should be submitted to the FHWA LTPP Office within 45 days after receipt of the individual RSC reports.

The report will document the results of the following analyses:

1. Static accuracy of the profile and texture height sensors: The results from the static height sensor test will be evaluated to determine if the bias of each height sensor at each measurement position is within 0.25 mm, and if the precision of each height sensor at each measurement position is less than 0.125 mm.
2. Results from the accelerometer check: The results from the accelerometer check will be evaluated to determine if they meet the criterion specified in this manual
3. Results from the bounce test: The static and dynamic IRI values from the bounce test will be evaluated to determine if they meet the criteria specified in this manual
4. Results from the dynamic check of the texture height sensors: The MPD values obtained from the test will be evaluated to determine if they meet the criterion specified in this manual
5. Accuracy and Stability of the DMI: The results obtained from the DMI tests will be evaluated to determine if bias of the DMI is within 0.15 m (0.05% of the length of the section), and that the precision of the DMI is less than 0.075 m. The data from the tests performed immediately after the DMI was calibrated as well as the data from the DMI verification testing will both be analyzed to evaluate the accuracy and stability of the DMI.
6. IRI values obtained by the devices: The IRI values obtained from the reference device data will be compared with IRI values obtained for the data collected by the devices: The IRI values will be evaluated to determine if: (a) the precision of the IRI along a profiled path is less than 0.04 m/km, and (b) if difference in IRI for a profiled path between the reference device IRI and average device IRI obtained from the five runs is within 0.10 m/km. for paths having an IRI less than 1.6 m/km and within 0.15 m/km for paths having an IRI greater than 2.2 m/km.
7. Repeatability of devices using cross-correlation: The IRI-filtered cross-correlation for all possible profile pairs for each profiled path at each section will be computed, and then these values will be used to compute the average IRI-filtered cross-correlation value. The average

IRI-filtered cross-correlation for each profiled path at all sections must be greater than or equal to 0.92.

8. Accuracy of devices using cross-correlation: This analysis will only be performed if reference profile data are available at 25-mm intervals or less. The IRI-filtered cross-correlation between the reference profile data and each repeat profile run for each profiled path will be computed, and these values will be used to compute the average IRI-filtered cross-correlation value for each path. The average IRI-filtered cross-correlation must be greater than or equal to 0.90 for each profiled path.
9. Repeatability of profile data using profile plots: The profile data collected by each device along each profiled path at all sites will be visually evaluated by examining overlaid profile plots.
- 10 Compare profile data obtained by the four devices: The profile data collected by the four devices will be visually evaluated by preparing overlaid profile plots for each path at each test section by selecting one representative profile run for each device at each test section.
11. Compare MPD values obtained by the devices: The average MPD values obtained along each wheel path at each section will be compared among the four devices.





## REFERENCES

1. Ford Motor Corporation, Ford E-150 XLT Vehicle Manual.
2. Ames Engineering, Ames Engineering Profiler Software, Software Version 6.0, Users Manual, December 2013.
3. Ames Engineering, Hardware Presentation Handout, Operator Training, College Station, Texas, April 2013.
4. Ames Engineering, Binder Containing Manuals for Components in the Ames Engineering Device.
5. Ames Engineering, Software Presentation Handout, Operator Training, College Station, Texas, April 2013.
6. Olmedo, C. and Jackola, D., ProQual 2014, User Guide, Federal Highway Administration.
7. Distress Identification Manual for the Long-Term Pavement Performance Program, Fifth Revised Edition, Report No. FHWA-HRT-13-092, Federal Highway Administration, Washington, DC, May 2014.
8. Dipstick<sup>®</sup> Model 1500 User Manual, Face Company.
9. Dipstick<sup>®</sup> Model 2000 Manual, Face Company.
10. Dipstick<sup>®</sup> Model 2200 Manual, Face Company.
11. Standard Test Method for Measuring Road Roughness by Static Level Method, Designation E 1364-95, American Society of Testing and Materials.
12. Macpherson, D., Olmedo, C., and Merrill, C., ProQual 2012, User Guide, Federal Highway Administration, March 2013.
13. Macpherson, D., ProQual 2012 Overview, Federal Highway Administration, March 2013.
14. Macpherson, D., ProQual 2012, Utilities, Federal Highway Administration, March 2013.



## **APPENDIX A. PROFILE/TEXTURE PROBLEM REPORT FORM**

In an effort to provide for a more uniform way of reporting, handling, and tracking problems associated with the LTPP pavement profile/texture monitoring activities, the FHWA LTPP team has designed a Profile/Texture Problem Report (PROFPR) form that is included in the next page for use by the regional contractors.

The PROFPR form provides several major benefits including a standard format for submitting problems associated with the profile/texture monitoring activities, an easy means of tracking when a problem was submitted, who is responsible for resolving it, whether or not it has been resolved, and how and when it was resolved, and reduces probability of problems being forgotten or falling through the cracks.

A PROFPR must be submitted whenever there are equipment problems in the profile/texture device, problems with data collection or data processing software, problems with data collection guidelines, other problems related to profile/texture activities, or profile and texture data. If a problem was encountered, and it was resolved, and the profiler operator/coordinator feels that this information would be useful to the other RSCs, an informational PROFPR should be submitted. When submitting an informational PROFPR, indicate that the PROFPR is being submitted for informational purposes in the description part of the form.

The PROFPR is self-explanatory except for the PROFPR number. The number consists of two parts as follows:

A letter code representing the agency submitting the problem, F for FHWA LTPP Division, NA for North Atlantic RSC, NC for North Central RSC, S for Southern RSC, W for Western RSC, and TSSC for Technical Support Services Contractor, and O for others.

A number code representing the PROFPR number for the submitting agency is sequential, starting from 1. For example, F-07 represents the seventh problem reported by the FHWA LTPP Team; and NA-23 represents the 23<sup>rd</sup> problem reported by the North Atlantic RSC.

Completed PROFPR forms must be submitted to the FHWA LTPP Team, with copies to the TSSC and to the profiler coordinator at each RSC office. Forms must be transmitted electronically by an attachment to an e-mail message. A complete set of the PROFPR submittals will be maintained by the FHWA LTPP Team and LTPP TSSC. A copy of the report with the bottom part completed will be sent to the RSCs for their information and action as appropriate after the problem report has been reviewed/resolved by the FHWA and TSSC.

Agency: \_\_\_\_\_

PROFPR #: \_\_\_\_\_

## LONG-TERM PAVEMENT PERFORMANCE (LTPP)

Attention: \_\_\_\_\_

|                  |                     |
|------------------|---------------------|
| Type of Problem  | Reported by: _____  |
| Guidelines _____ | Agency: _____       |
| Equipment _____  |                     |
| Software _____   | Date: _____         |
| Name _____       | Urgent (Y/N) _____  |
| Version _____    |                     |
| Other _____      | Page _____ of _____ |

THIS SECTION FOR USE BY FHWA AND TSSC

Received by: \_\_\_\_\_

Referred to: \_\_\_\_\_

Date Referred: \_\_\_\_\_

Date Received: \_\_\_\_\_

Approved by: \_\_\_\_\_

Date Approved: \_\_\_\_\_

Resolution:

Notes:

## **APPENDIX B. STANDARD FORMS FOR PROFILER OPERATIONS**

## DAILY CHECK LIST

| ITEM                                     |
|--|
| <b>Under Hood</b>                        |
| Fluids                                   |
| Engine Oil                               |
| Brake Oil                                |
| Windshield Washer Fluid                  |
| Radiator Coolant                         |
| Transmission Oil                         |
| <b>Exterior</b>                          |
| Lights                                   |
| Front                                    |
| Rear                                     |
| Emergency                                |
| Turning Signals                          |
| Light Bar                                |
| Directional Warning Light                |
| Strobe lights                            |
| <b>Glass Cleaning</b>                    |
| Windshield                               |
| <b>Check Cleanliness of Sensor Glass</b> |
| Profile and Texture Height Sensor        |
| Photocell                                |
| <b>Other</b>                             |
| Tires Properly Inflated                  |
| Fluid Leaks                              |
| Ambient and Pavement Temperature Sensors |
| <b>Interior</b>                          |
| Temperature Range                        |

|   |  |
|---|--|
| <b>LTPP PROFILER OPERATIONS</b><br><b>LTPP PROFILER FIELD ACTIVITY REPORT</b><br><b>FORM PROF-1</b> | <b>REGION</b><br><b>STATE CODE</b><br><b>LTPP SECTION ID</b> |
|---|--|

|                                    |                                     |                                  |
|------------------------------------|-------------------------------------|----------------------------------|
| <b>FILE NAME:</b> _____            | <b>TESTING:</b> _____               | <b>UNIT:</b> _____               |
| <small>ID+TYPE+SEQ</small>         |                                     |                                  |
| <b>LTPP EXPERIMENT CODE:</b> _____ | <b>ROUTE/HIGHWAY NUMBER:</b> _____  | <b>DIRECTION:</b> _____          |
| <small>Ex: GPS/SPS</small>         | <small>Ex: I-90/US-27/SR-23</small> | <small>N,E,S,W</small>           |
| <b>TESTING DATE:</b> _____         | <b>SURFACE:</b> _____               | <b>TIME ZONE:</b> _____          |
| <small>DD-MMM-YYYY</small>         | <small>AC/POC</small>               | <b>STANDARD/DAYLIGHT SAVINGS</b> |

**PROFILOMETER VEHICLE BEFORE OPERATION CHECKS:** \_\_\_\_\_ (Initials)

|              | TIME | ODOMETER |
|--------------|------|----------|
| START TRAVEL |      |          |
| BEGIN TEST   |      |          |
| END TEST     |      |          |
| END TRAVEL   |      |          |

**DOWN TIME:** \_\_\_\_\_ **REASON :** \_\_\_\_\_

| LASER SENSOR DAILY CHECK  | RUN TO RUN IRI SUMMARY              |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
|---|-------------------------------------|------------|------------|------------------|----------------|-------------------|-------|--|---------------|--|------------------|-------|--|--|--|------------|-------|--|--|--|-------------|------------|-------|-----------|------|---|-------|------|------|-------|-----------|---------|--|--|--|---|------------|----------|-----------|------------|------------------|-----------|--|--|--|--|-----|------|------|-------|---------|---|--|--|-----------|--|---|--|-----------|--|--|---|--|--|--|--|---|--|--|--|--|---|--|--|--|--|---|--|--|--|--|---|--|--|--|--|
| <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th>Profile</th> <th>Identifier</th> <th>Label</th> <th>Reference</th> <th>Bias</th> </tr> <tr> <td>LEFT (1)</td> <td>ODS 1</td> <td></td> <td></td> <td></td> </tr> <tr> <td>CENTER (3)</td> <td>ODS 3</td> <td></td> <td></td> <td></td> </tr> <tr> <td>RIGHT (2)</td> <td>ODS 2</td> <td></td> <td></td> <td></td> </tr> <tr> <th>Texture</th> <th>Identifier</th> <th>Label</th> <th>Reference</th> <th>Bias</th> </tr> <tr> <td>LEFT (1)</td> <td>ODS 4</td> <td></td> <td></td> <td></td> </tr> <tr> <td>RIGHT (2)</td> <td>ODS 5</td> <td></td> <td></td> <td></td> </tr> </table> <p>Identifier: Laser Sensor <b>PASS (Y/N):</b> _____</p> <p>Label: Assigned 25mm block (ex. A-1) Bias Pass: <math>\pm 0.25</math> mm</p> <p>Reference: 25mm Block Actual Height (mm)</p> <p>Bias: Average Difference between Sample and Reference</p> | Profile                             | Identifier | Label      | Reference        | Bias           | LEFT (1)          | ODS 1 |  |               |  | CENTER (3)       | ODS 3 |  |  |  | RIGHT (2)  | ODS 2 |  |  |  | Texture     | Identifier | Label | Reference | Bias | LEFT (1)  | ODS 4 |      |      |       | RIGHT (2) | ODS 5   |  |  |  | <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th>Run Number</th> <th>Left IRI</th> <th>Right IRI</th> <th>Center IRI</th> <th>Selected Run Y/N</th> </tr> <tr><td>1</td><td></td><td></td><td></td><td></td></tr> <tr><td>2</td><td></td><td></td><td></td><td></td></tr> <tr><td>3</td><td></td><td></td><td></td><td></td></tr> <tr><td>4</td><td></td><td></td><td></td><td></td></tr> <tr><td>5</td><td></td><td></td><td></td><td></td></tr> <tr><td>6</td><td></td><td></td><td></td><td></td></tr> <tr><td>7</td><td></td><td></td><td></td><td></td></tr> <tr><td>8</td><td></td><td></td><td></td><td></td></tr> <tr><td>9</td><td></td><td></td><td></td><td></td></tr> </table> | Run Number | Left IRI | Right IRI | Center IRI | Selected Run Y/N | 1         |  |  |  |  | 2   |      |      |       |         | 3 |  |  |           |  | 4 |  |           |  |  | 5 |  |  |  |  | 6 |  |  |  |  | 7 |  |  |  |  | 8 |  |  |  |  | 9 |  |  |  |  |
| Profile   | Identifier                          | Label      | Reference  | Bias             |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| LEFT (1)  | ODS 1                               |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| CENTER (3)  | ODS 3                               |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| RIGHT (2)   | ODS 2                               |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| Texture   | Identifier                          | Label      | Reference  | Bias             |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| LEFT (1)  | ODS 4                               |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| RIGHT (2)   | ODS 5                               |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| Run Number  | Left IRI                            | Right IRI  | Center IRI | Selected Run Y/N |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| 1   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| 2   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| 3   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| 4   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| 5   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| 6   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| 7   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| 8   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| 9   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| DAILY BOUNCE TEST   | 10% IRI AND MPD CHECK AFTER TESTING |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th></th> <th>LEFT (1)</th> <th>RIGHT (2)</th> <th>CENTER (3)</th> <th>Pass (Y/N)</th> </tr> <tr> <td>Static IRI, Seg 2</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Dyna. IRI, Seg 4</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Difference</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Seg 2-Seg 7</td> <td></td> <td></td> <td></td> <td></td> </tr> </table> <p>Static IRI <math>\leq 0.08</math>/ IRI Difference <math>\leq 0.10</math>/ Seg2-Seg7 <math>\pm 0.01</math></p>  |                                     | LEFT (1)   | RIGHT (2)  | CENTER (3)       | Pass (Y/N)     | Static IRI, Seg 2 |       |  |               |  | Dyna. IRI, Seg 4 |       |  |  |  | Difference |       |  |  |  | Seg 2-Seg 7 |            |       |           |      | <p>FORMULA FOR 10 % CHECK = <math>100 \times (\text{CURRENT VISIT} - \text{OLD VISIT}) / \text{OLD VISIT}</math></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th>IRI</th> <th>DATE</th> <th>LEFT</th> <th>RIGHT</th> <th>CENTER</th> </tr> <tr> <td>CURRENT</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>OLD VISIT</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>10% CHECK</td> <td></td> <td></td> <td></td> <td></td> </tr> </table><br><table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th>MPD</th> <th>DATE</th> <th>LEFT</th> <th>RIGHT</th> </tr> <tr> <td>CURRENT</td> <td></td> <td></td> <td></td> </tr> <tr> <td>OLD VISIT</td> <td></td> <td></td> <td></td> </tr> <tr> <td>10% CHECK</td> <td></td> <td></td> <td></td> </tr> </table> | IRI   | DATE | LEFT | RIGHT | CENTER    | CURRENT |  |  |  |   | OLD VISIT  |          |           |            |                  | 10% CHECK |  |  |  |  | MPD | DATE | LEFT | RIGHT | CURRENT |   |  |  | OLD VISIT |  |   |  | 10% CHECK |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
|   | LEFT (1)                            | RIGHT (2)  | CENTER (3) | Pass (Y/N)       |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| Static IRI, Seg 2   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| Dyna. IRI, Seg 4  |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| Difference  |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| Seg 2-Seg 7   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| IRI   | DATE                                | LEFT       | RIGHT      | CENTER           |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| CURRENT   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| OLD VISIT   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| 10% CHECK   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| MPD   | DATE                                | LEFT       | RIGHT      |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| CURRENT   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| OLD VISIT   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| 10% CHECK   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| TIRE PRESSURE (psi)   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th></th> <th>LEFT</th> <th>RIGHT</th> <th>COMMENTS</th> </tr> <tr> <td>FRONT (55 psi)</td> <td></td> <td></td> <td></td> </tr> <tr> <td>REAR (80 psi)</td> <td></td> <td></td> <td></td> </tr> </table>  |                                     | LEFT       | RIGHT      | COMMENTS         | FRONT (55 psi) |                   |       |  | REAR (80 psi) |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
|   | LEFT                                | RIGHT      | COMMENTS   |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| FRONT (55 psi)  |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |
| REAR (80 psi)   |                                     |            |            |                  |                |                   |       |  |               |  |                  |       |  |  |  |            |       |  |  |  |             |            |       |           |      |   |       |      |      |       |           |         |  |  |  |   |            |          |           |            |                  |           |  |  |  |  |     |      |      |       |         |   |  |  |           |  |   |  |           |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |   |  |  |  |  |

**ADDITIONAL REMARKS :**

**PROFILER CREW :** **DRIVER:** \_\_\_\_\_ **OPERATOR :** \_\_\_\_\_

**OTHERS PRESENT (LIST NAMES AND AGENCIES) :** \_\_\_\_\_



**LTPP Profiler Operations  
Status of Regions Test Sections  
Form PROF-2**

[illegible]

**LTPP Profiler Operations  
Profiler Log  
Form PROF-3**

| <b>Date</b> | <b>Noted Problem</b> | <b>Action Taken and Date</b> |
|-------------|----------------------|------------------------------|
|             |                      |                              |
|             |                      |                              |
|             |                      |                              |
|             |                      |                              |
|             |                      |                              |
|             |                      |                              |
|             |                      |                              |

|  |                           |       |
|--|---------------------------|-------|
| <b>LTPP Profiler Operations</b><br><b>LTPP Major Maintenance/Repair</b><br><b>Work Order</b><br><b>Form PROF-4</b> | <b>Region</b>             | _____ |
|  | <b>Serial Number</b>      | _____ |
|  | <b>Odometer</b>           | _____ |
|  | <b>Scheduled (Yes/No)</b> | _____ |

|   |   |
|---|---|
| <b>Problem Identification / Scheduled Maintenance</b><br><br>Equipment: _____<br>Description: _____<br>_____<br>_____<br>_____  | Performed By: _____<br>Date: _____<br>Start Time: _____<br>End Time: _____                                      |
| <b>Troubleshooting</b><br><br>Description: _____<br>_____<br>_____<br>_____<br>_____  | Performed By: _____<br>Date: _____<br>Start Time: _____<br>End Time: _____<br>Hours: _____                      |
| <b>Reporting</b><br><br>Referred to: _____<br>_____<br><br>Actions (Return/Order Parts): _____<br>_____<br>_____<br>_____   | Date: _____<br>Time: _____<br><br>Date: _____<br>Time: _____  |
| <b>Service</b><br><br>Description (Repairs Performed/Replacement Part Information): _____<br>_____<br>_____<br>_____<br><br>Agency Performing Maintenance: _____<br>_____<br>_____<br>_____ | Performed By: _____<br>Date: _____<br>Start Time: _____<br>End Time: _____<br>Hours: _____<br>Total Cost: _____ |
| <b>Verification</b><br><br>Description (Check/Calibration): _____<br>_____<br>_____<br>_____<br>_____   | Performed By: _____<br>Date: _____<br>Start Time: _____<br>End Time: _____<br>Hours: _____                      |
| <b>Return to Service</b><br><br>Status: _____<br>_____<br>_____   | Performed By: _____<br>Date: _____  |

| LASER SENSOR, ACCELEROMETER, DMI CALIBRATION/CALIBRATION CHECK FORM   |                      |                                 |                      |                              |  |            | Form PROF-5           |                 |
|---|----------------------|---------------------------------|----------------------|------------------------------|--|------------|-----------------------|-----------------|
| PROFILOMETER  |                      |                                 |                      |                              | DATE (DD/MMM/YYYY)                           |            |                       |                 |
| OPERATOR  |                      |                                 |                      |                              | TIME (24Hr)                                  |            |                       |                 |
|   |                      |                                 |                      |                              | MILEAGE                                      |            |                       |                 |
| SENSOR CALIBRATION CHECK PERFORMED WITH VAN ON SECOND STEP OF RAMP. RECORD "HEIGHT" WITH VEHICLE ON GROUND                              |                      |                                 |                      |                              |  |            |                       |                 |
|   |                      | Block                           | 25 mm                | 50 mm                        | 75 mm  | 100 mm     | GROUND LEVEL CHECK    |                 |
| IRI SENSORS   |                      | Height (mm)                     | Bias                 | Bias                         | Bias   | Bias       | 25 mm Block           | Pass (Yes / No) |
| LEFT (ODS 1)  |                      |                                 |                      |                              |  |            |                       |                 |
| Internal Temp.  |                      |                                 |                      |                              |  |            |                       |                 |
| Laser Height (mm)   |                      |                                 |                      |                              |  |            |                       |                 |
| Truck on Ground   |                      |                                 |                      |                              |  |            |                       |                 |
| Center (ODS 3)  |                      |                                 |                      |                              |  |            |                       |                 |
| Internal Temp.  |                      |                                 |                      |                              |  |            |                       |                 |
| Laser Height (mm)   |                      |                                 |                      |                              |  |            |                       |                 |
| Truck on Ground   |                      |                                 |                      |                              |  |            |                       |                 |
| RIGHT (ODS 2)   |                      |                                 |                      |                              |  |            |                       |                 |
| Internal Temp.  |                      |                                 |                      |                              |  |            |                       |                 |
| Laser Height (mm)   |                      |                                 |                      |                              |  |            |                       |                 |
| Truck on Ground   |                      |                                 |                      |                              |  |            |                       |                 |
| TEXTURE SENSORS   |                      |                                 |                      |                              |  |            |                       |                 |
| LEFT (ODS 4)  |                      |                                 |                      |                              |  |            |                       |                 |
| Internal Temp.  |                      |                                 |                      |                              |  |            |                       |                 |
| Laser Height (mm)   |                      |                                 |                      |                              |  |            |                       |                 |
| Truck on Ground   |                      |                                 |                      |                              |  |            |                       |                 |
| RIGHT (ODS 5)   |                      |                                 |                      |                              |  |            |                       |                 |
| Internal Temp.  |                      |                                 |                      |                              |  |            |                       |                 |
| Laser Height (mm)   |                      |                                 |                      |                              |  |            |                       |                 |
| Truck on Ground   |                      |                                 |                      |                              |  |            |                       |                 |
| Laser Height allow able range: -15 mm to 15 mm  |                      | Comments:                       |                      |                              |  |            | Tolerance $\leq 0.25$ |                 |
| BOUNCE TEST RESULTS   |                      |                                 |                      |                              |  |            |                       |                 |
| Sensor  | Initial Static       | Dynamic                         | Final Static         | Seg 2                        | Seg 2 - Seg 7                                |            | Seg 4 - Seg 2         |                 |
|   | Segment 2 IRI (m/km) | Segment 4 IRI (m/km)            | Segment 7 IRI (m/km) | IRI $\leq 0.08$ ? Pass (Y/N) | IRI (m/km) Difference                        | Pass (Y/N) | IRI (m/km) Difference | Pass (Y/N)      |
| LEFT (ODS 1)  |                      |                                 |                      |                              |  |            |                       |                 |
| RIGHT (ODS 2)   |                      |                                 |                      |                              |  |            |                       |                 |
| CENTER (ODS 3)  |                      |                                 |                      |                              |  |            |                       |                 |
| Segment 2 must be $\leq 0.08$ m/km, Segment 2 - Segment 7 must be within $\pm 0.01$ m/km. Segment 4 - Segment 2 must be $\leq 0.1$ m/km |                      |                                 |                      |                              |  |            |                       |                 |
| COMMENTS:   |                      |                                 |                      |                              |  |            |                       |                 |
| DISTANCE MEASURING INSTRUMENT (DMI) CALIBRATION   |                      |                                 |                      |                              |  |            |                       |                 |
| Photocell Used (Horizontal or Vertical)   |                      | Calibration Length (m):         |                      |                              | Date Performed:                              |            |                       |                 |
| Distance from Horizontal Test (m):  |                      | Number of Runs Used in Average: |                      |                              |  |            |                       |                 |
| TIRE PRESSURE (Rear tire pressure to be adjusted per DMI run)   |                      |                                 |                      |                              | OLD CALIBRATION FACTOR:                      |            |                       |                 |
| FRONT (50-55)   |                      |                                 |                      |                              | REAR (80-85)                                 |            |                       |                 |
| LEFT  |                      |                                 |                      |                              | NEW CALIBRATION FACTOR:                      |            |                       |                 |
| RIGHT   |                      |                                 |                      |                              | % CHANGE FROM LAST:                          |            |                       |                 |
|   |                      |                                 |                      |                              | STD DEV OF CAL FACTOR (must be $\leq 0.07$ ) |            |                       |                 |
| ACCELEROMETER CALIBRATION   |                      |                                 |                      |                              | TEXTURE SENSOR CALIBRATION CHECK             |            |                       |                 |
| ACCELEROMETER   | ZERO G               | NEG. 2 G                        | DIFFERENCE           | PASS (Y/N)                   | Performed with van on first step of ramp     |            |                       |                 |
| Left-ODS 1  |                      |                                 |                      |                              | Static Texture Test                          |            | MPD VALUE             | PASS (Y/N)      |
| Right-ODS 2   |                      |                                 |                      |                              | Left -Texture 1 (ODS 4)                      |            |                       |                 |
| Center-ODS 3  |                      |                                 |                      |                              | Right-Texture 2 (ODS 5)                      |            |                       |                 |
| To pass Difference must be between 1.98 and 2.02  |                      |                                 |                      |                              | To Pass MPD less than 0.33                   |            |                       |                 |
| COMMENTS:   |                      |                                 |                      |                              | Dynamic Texture Test                         |            | MPD VALUE             | PASS (Y/N)      |
|   |                      |                                 |                      |                              | Left -Texture 1 (ODS 4)                      |            |                       |                 |
|   |                      |                                 |                      |                              | Right-Texture 2 (ODS 5)                      |            |                       |                 |
|   |                      |                                 |                      |                              | To Pass MPD between 0.694 and 0.806 mm       |            |                       |                 |

|   |  |                        |                           |   |           |                    |  |
|---|--|------------------------|---------------------------|---|-----------|--------------------|--|
| <b>AMBIENT TEMPERATURE SENSOR, PAVEMENT SURFACE TEMPERATURE SENSOR,<br/>AND GPS RECEIVER CALIBRATION CHECK FORM</b>   |  |                        |                           |   |           | <b>Form PROF-6</b> |  |
|   |  |                        |                           |   |           |                    |  |
| <b>PROFILOMETER</b>   |  |                        | <b>DATE (DD/MMM/YYYY)</b> |   |           |                    |  |
|   |  |                        | <b>TIME</b>               |   |           |                    |  |
| <b>OPERATOR</b>   |  |                        | <b>MILEAGE</b>            |   |           |                    |  |
|   |  |                        |                           |   |           |                    |  |
| <b>AMBIENT TEMPERATURE SENSOR CALIBRATION CHECK</b>   |  |                        |                           |   |           |                    |  |
| Probe 1 Temp. (°C)  |  | Thermometer Temp. (°C) |                           | Difference (°C)                                     |           | Pass (Y/N)         |  |
| Probe 2 Temp. (°C)  |  | Thermometer Temp. (°C) |                           | Difference (°C)                                     |           | Pass (Y/N)         |  |
|   |  |                        |                           |   |           |                    |  |
| Diff. between Probe 1 and Probe 2 Temp. (°C)  |  |                        |                           | Pass (Y/N)  |           |                    |  |
| Difference between Probe 1 Temperature and Thermometer Temperature must be within $\pm 2^{\circ}\text{C}$<br>Difference between Probe 2 Temperature and Thermometer Temperature must be within $\pm 2^{\circ}\text{C}$<br>Difference between Probe 1 Temperature and Probe 2 Temperature must be within $\pm 2^{\circ}\text{C}$ |  |                        |                           |   |           |                    |  |
| <b>COMMENTS</b>   |  |                        |                           |   |           |                    |  |
|   |  |                        |                           |   |           |                    |  |
| <b>PAVEMENT SURFACE TEMPERATURE SENSOR CALIBRATION CHECK</b>  |  |                        |                           |   |           |                    |  |
| <b>Readings Taken on Ground Surface</b>   |  |                        |                           |   |           |                    |  |
| Reading from Pavement Temperature Sensor (°C)   |  |                        |                           | <div>         Pass (Y/N)         <div></div> </div> |           |                    |  |
| Reading from Temperature Gun (°C)   |  |                        |                           |   |           |                    |  |
| Difference (°C)   |  |                        |                           |   |           |                    |  |
| <b>Reading Taken on Ice and Water Mix</b>   |  |                        |                           |   |           |                    |  |
| Reading from Pavement Temperature Sensor (°C)   |  |                        |                           | <div>         Pass (Y/N)         <div></div> </div> |           |                    |  |
| Reading from Thermometer (°C)   |  |                        |                           |   |           |                    |  |
| Difference (°C)   |  |                        |                           |   |           |                    |  |
| Difference in temperature must be within $\pm 2^{\circ}\text{C}$ for both cases   |  |                        |                           |   |           |                    |  |
| <b>COMMENTS</b>   |  |                        |                           |   |           |                    |  |
|   |  |                        |                           |   |           |                    |  |
| <b>GPS RECEIVER CHECK</b>   |  |                        |                           |   |           |                    |  |
|   |  |                        |                           | Latitude  | Longitude |                    |  |
| Reference Latitude and Longitude of Location (e.g., Google Earth)   |  |                        |                           |   |           |                    |  |
| Latitude and Longitude from GPS Receiver  |  |                        |                           |   |           |                    |  |
| Latitude/Longitude Agree to Four Decimal Places (Y/N)?  |  |                        |                           |   |           |                    |  |
|   |  |                        |                           |   |           |                    |  |
| <b>ADDITIONAL<br/>COMMENTS</b>  |  |                        |                           |   |           |                    |  |

**LTPP Profiler Operations**  
**Profiling of WIM Sections**  
**Data Summary Sheet**  
**Form PROF-7**

State Code: \_\_\_\_\_

SHRP ID Assigned to WIM Location: \_\_\_\_\_

Date Tested: \_\_\_\_ / \_\_\_\_ / \_\_\_\_ Pavement Type: \_\_\_\_\_

Operator/Driver: \_\_\_\_\_

Test Reason:    Verification \_\_\_\_\_    Acceptance Testing \_\_\_\_\_    Annual Check \_\_\_\_\_

\_\_\_\_\_ m distance from Station \_\_\_\_\_ + \_\_\_\_\_ m of LTPP Section \_\_\_\_\_

| Run<br>Number | Location<br>(Note 1) | Offset Reference and Distance<br>(Note 2) | Time at Start<br>of Run | File<br>Name | Error<br>Free? |
|---------------|----------------------|---|-------------------------|--------------|----------------|
| 1             |                      |   |                         |              |                |
| 2             |                      |   |                         |              |                |
| 3             |                      |   |                         |              |                |
| 4             |                      |   |                         |              |                |
| 5             |                      |   |                         |              |                |
| 6             |                      |   |                         |              |                |
| 7             |                      |   |                         |              |                |
| 8             |                      |   |                         |              |                |
| 9             |                      |   |                         |              |                |
| 10            |                      |   |                         |              |                |
| 11            |                      |   |                         |              |                |

Note 1: Indicate location of run -- WP for wheel path, Left for left of wheel path, Right for right of wheel path

Note 2: For runs obtained left and right of wheel path, indicate the offset and reference for the offset (e.g., for runs left of the wheel path - 0.75 m left of wheel path; for runs right of wheel path - 0.5 m from right shoulder stripe).

Pavement condition at time of data collection that may have influenced profile measurements (e.g., crack sealant condition, joint sealant condition, distresses within section).

---



---



---

Other information related to WIM site that may have influenced data collection (e.g., length of sensor array for multiple sensor configuration).

---



---



---



## APPENDIX C. PROFILE TROUBLE SHOOTING GUIDE

This appendix contains a catalog of problems commonly encountered by LTPP operators when collecting and reviewing profile data. Knowledge of these problems will help operators to collect more accurate and valid profile data for the LTPP program. These commonly encountered problems can be grouped into the following four categories:

1. Spikes in profile data.
2. Miscalibrated DMI, incorrect tire pressure, or tires not properly warmed-up.
3. Early start of data collection.
4. Different profiles.

To detect items 3 and 4, the profile data in question must be compared to those collected during the previous site visit. However, item 3 can also be detected when comparing repeat runs obtained at a section. Previous site visit profile data is needed to detect a miscalibrated DMI or tires that are set to an incorrect tire pressure. Tires not being properly warmed-up can be detected when evaluating data collected by the repeat runs.

A brief description of each of these problems is presented in this appendix along with plots illustrating such conditions. In order to perform an accurate and valid comparison with profile data from the previous site visit, the previous site visit data must be error free. Descriptions and references made later in this appendix to the profile data comparisons assume that data from the previous site visit are error free.

### 1. Spikes in Profile Data

Spikes can be introduced in the profile data as a result of pavement features, equipment problems, due debris on the road, or objects blowing below the sensor. Objects blowing past below the sensor can include paper, leaves, weeds, insects, etc. Debris on the road can include paper, leaves, tire pieces, etc. The spikes can be identified by comparing multiple profile runs at a section. Accordingly, once a set of profile runs has been collected, the operator should compare the data from the repeat runs using ProQual. This comparison should be performed separately for the left, right, and center path profile data. Figure 125 illustrates the presence of a spike in the profile data. This figure shows five profile runs collected on the left wheel path. The profile data for run 4 indicates a spike that is not present in the other four runs. Profile data for run 4 has been offset in figure for clarity. In the ProQual the repeat profile runs are color-coded (i.e., different color for each run). Since the spike only occurs in one run of the data set, it is possible that this spike may not have been caused by a pavement feature. When such a condition is encountered, the operator should determine if the spike is due to a pavement feature, debris on the road, objects blowing below the sensor, or due to equipment problems. The operator can observe the pavement at the location where the spike occurred to determine if the spike was caused by a pavement feature. It will not be possible to determine if the spike was caused by objects blowing past below the sensor unless operator noted such a situation when collecting data. If it was caused by debris, the location of the debris may have shifted or it may have blown outside of the pavement by passing traffic. If multiple upward spikes are noted on a run, or in repeat runs, with



no pavement feature or debris on the road that can explain the cause of the spikes, equipment problems can be suspected.

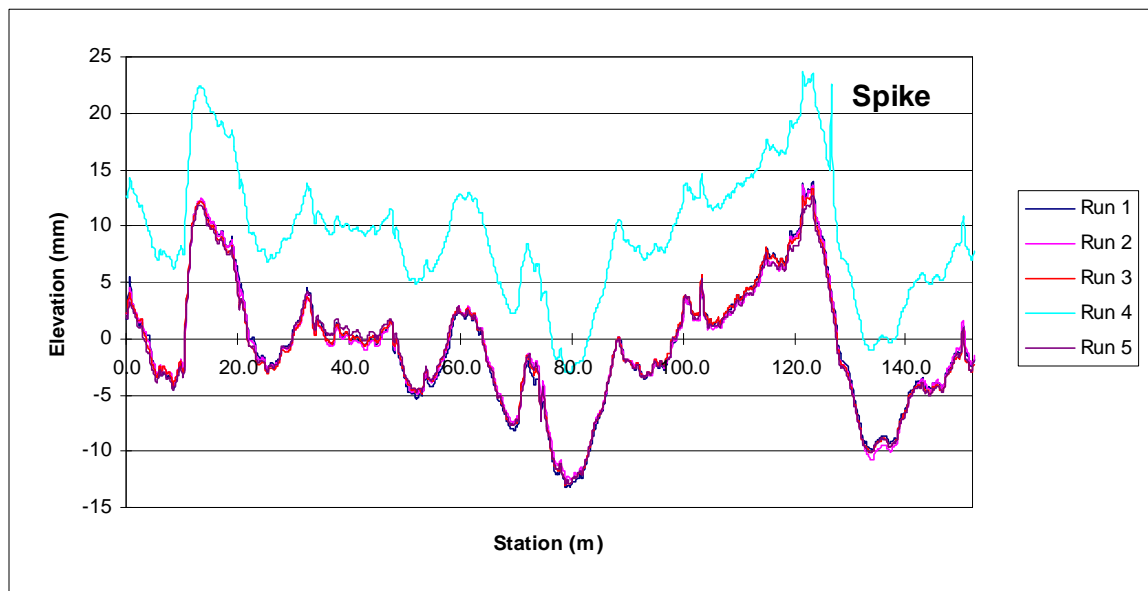


Figure 125. Spike in profile data (profile data for run 4 has been offset for clarity).

## 2. Miscalibrated DMI, incorrect tire pressure, or tires not properly warmed-up.

A miscalibrated DMI or tires being set to an incorrect tire pressure cannot be detected by comparing the five repeat profile runs obtained during a site visit. However, when those runs are compared with the profile runs collected during the previous site visit, the profile (elevation versus distance) plot for the more recently collected data will appear squeezed or stretched in the x (distance) direction if the vehicle has a miscalibrated DMI or if tires have been set to an incorrect tire pressure. The comparison of the current and the previous profile data should be carried out using ProQual. An example of profile data associated with a miscalibrated DMI is shown in figure 126; data for May 2, 1990 was collected using a miscalibrated DMI.

When this problem is encountered, operator should check tire pressure of vehicle to ensure it is at the values at which the DMI was calibrated. If the current tire pressure is different, operator should adjust tire pressure so it matches tire pressure when DMI was calibrated, and obtain a new set of measurements at the section. If the difference in the distance between the current data and previous data at the end of the section is less than or equal to 0.5 m for a GPS section, the current data set is considered to be acceptable. If the difference in the distance between the current data and the previous data is greater than 0.5 m, the operator should determine if the difference is occurring because the DMI is incorrect during the current visit or if it was incorrect during the previous visit. The following procedures can be used by the operator to make this determination.

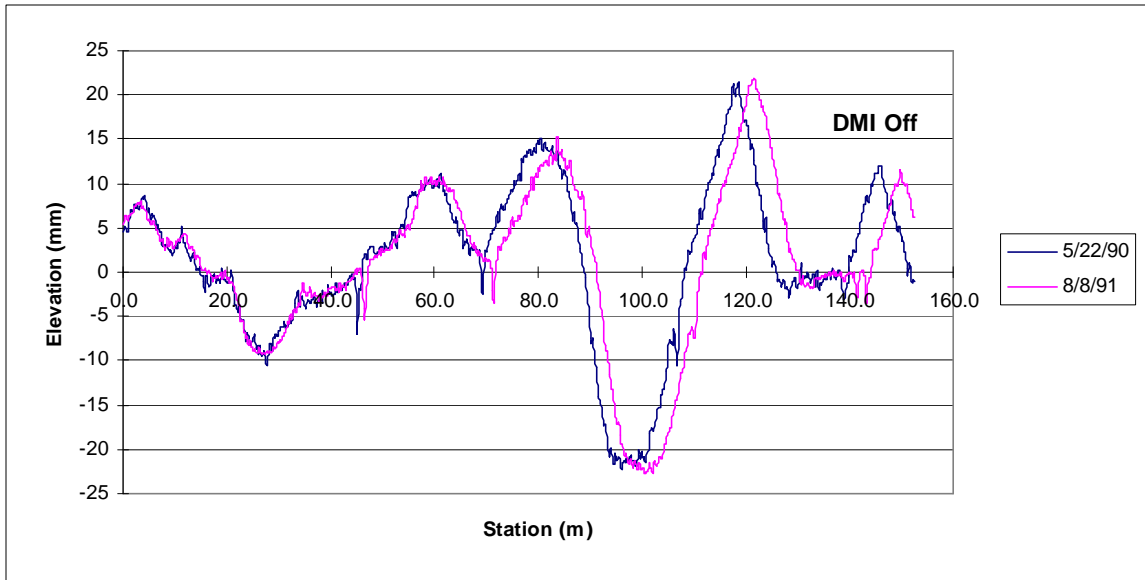


Figure 126. Data collected with a correctly calibrated and a miscalibrated DMI.

1. The operator can determine if the DMI is calibrated correctly by running the section using the photocell as the stop option and noting the length over which data were collected. If the length of the section obtained when the section is profiled using this procedure is within  $\pm 0.3$  m of 152.4 m, the DMI can be assumed to be working properly. However, there may be cases where the actual length of the site is not 152.4 m. So if the distance obtained using the described procedure is outside the specified limit, it cannot be concluded that the DMI is working incorrectly. If such a case is encountered, the operator should follow the procedure described in the next step.
2. Currently it is expected that all test sections would have at least two previous profile data sets. The operator can check on the accuracy of the DMI for the previous visit by calling the office and asking the office personnel to compare the previous year data with other data that is available for the site. The purpose of this comparison is to determine if there is any error in DMI associated with the data from the previous visit. The office personnel should compare the relative position of the profile at the end of the section for previous visits to the section by the profiler, and convey that information to the operator. The office personnel together with operator can then use the available information to judge the accuracy of the DMI for the current data. If all available data indicates that the DMI for the previous visit is accurate, the indications are that the DMI in the profiler is out of calibration. The operator should proceed to another site, and compare the profile plots following the procedures described previously. If the data at that site also indicates the DMI is out of calibration, the DMI should be calibrated before further profile data are collected.

For SPS sites differences between runs can occur because of wheel path wander. This effect will usually be more pronounced in sections that are located towards the end of the SPS site. When comparing profile data between two site visits at SPS sections, close attention should be paid to the first two sections in the SPS site. If the profile for the current data and the previous site visit data satisfies the criteria that were described previously at the first two sites, it can be concluded

that the DMI is functioning correctly for the current visit. In such a case, a difference in distance of up to 1 m can be considered to be acceptable for the other sections in the SPS project.

If a profile plot similar to that shown in figure 126 is observed when repeat runs collected by the device at the site are compared, this means the tires in the device have not been warmed-up sufficiently.

### 3. Early Start of Data Collection

An early profile start can occur when the photocell triggers data collection before the start of the test section. It is possible for all repeat profile runs during a site visit to have the same starting location, with all runs having an early start. This problem can occur if there is a mark on the pavement that triggers data collection to start at the same location, but this location is before the beginning of the test section. When the current profile data are compared with those collected during the previous site visit, the early start problem can be easily identified by a clear shift in the two profile data sets. This profile comparison should be carried out using ProQual. The early start problem is illustrated in figure 127, which shows the profile plot for a single run along the left wheel path conducted on three different dates—April 8, 1990; October 18, 1990; and August 10, 1994. The profile plot for the last two dates have similar start locations, but that for the earlier date (April 8, 1990) is shifted to the left because of an early start. If the early start problem is caused by a mark on the pavement that is located before the start of the test section, the operator can use the horizontal photocell to initiate data collection.

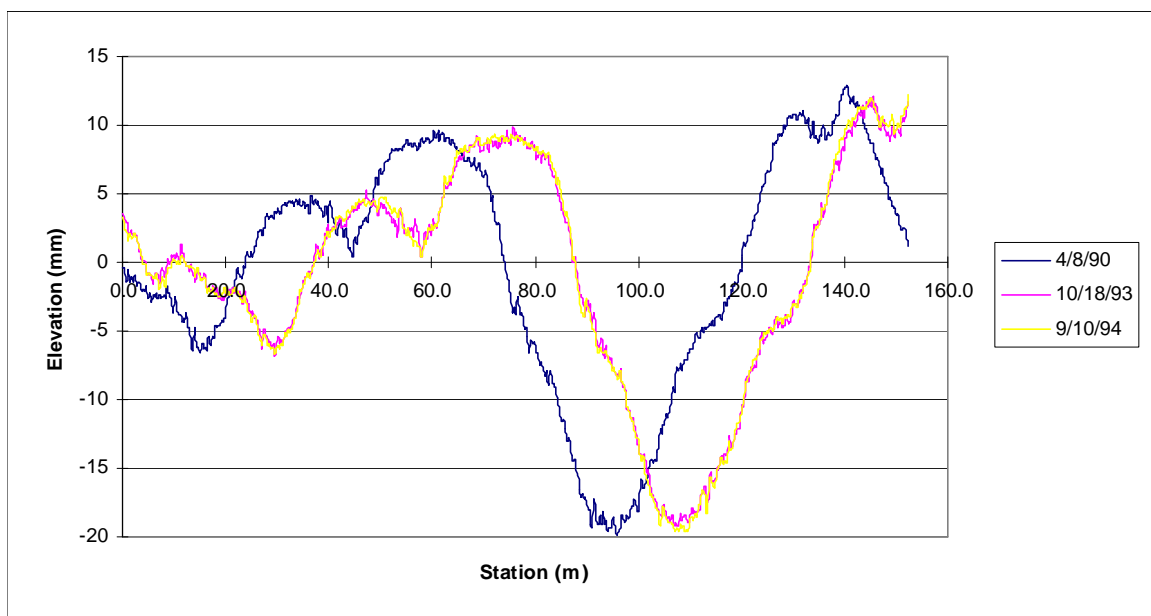


Figure 127. Example of early profile start.

The early start problem can also occur in one or more runs within a profile data set collected during a single site visit. This problem can be easily identified by comparing the repeat profiler runs using ProQual; one or more of runs will be shifted to left of the others if there is an early start. Although a plot illustrating the early start problem within a set of repeat runs is not

included in this appendix, that plot will be very similar to that shown in figure 127. If an early start is detected in one or more profile runs, the operator should perform additional profile runs until a set of error free data (meeting the criteria described in section 2.9.4) is obtained. If the early start problem is caused by a mark on the pavement that is located before the start of the test section, the operator can use the horizontal photocell to initiate data collection.

#### 4. Different Profiles

The term “different profiles” is used to describe the occurrence of the following conditions: (a) when operator compares repeat profile runs collected during a single site visit, no problems are observed in the data (i.e., error free) and (b) when operator compares current data with that from previous site visit (also error free), the two sets of profiles appear to be different.

Such a condition can be caused by rehabilitation or maintenance activities to the section between profiler site visits. It can also occur when the location of test section is incorrectly selected during one of the site visits.

Figure 128 illustrates the case where rehabilitation has been performed on a test section between site visits. This figure shows a plot of the left wheel path profile obtained on two separate site visits—September 10, 1991 and October 4, 1994. The two profiles shown in this plot are completely different. In this particular example, the profile differences were caused by an overlay that was placed on the section sometime between the two site visits. When the location of the test section has been incorrectly selected during one of the site visits, differences in profile similar to those shown in figure 128 will also be seen.

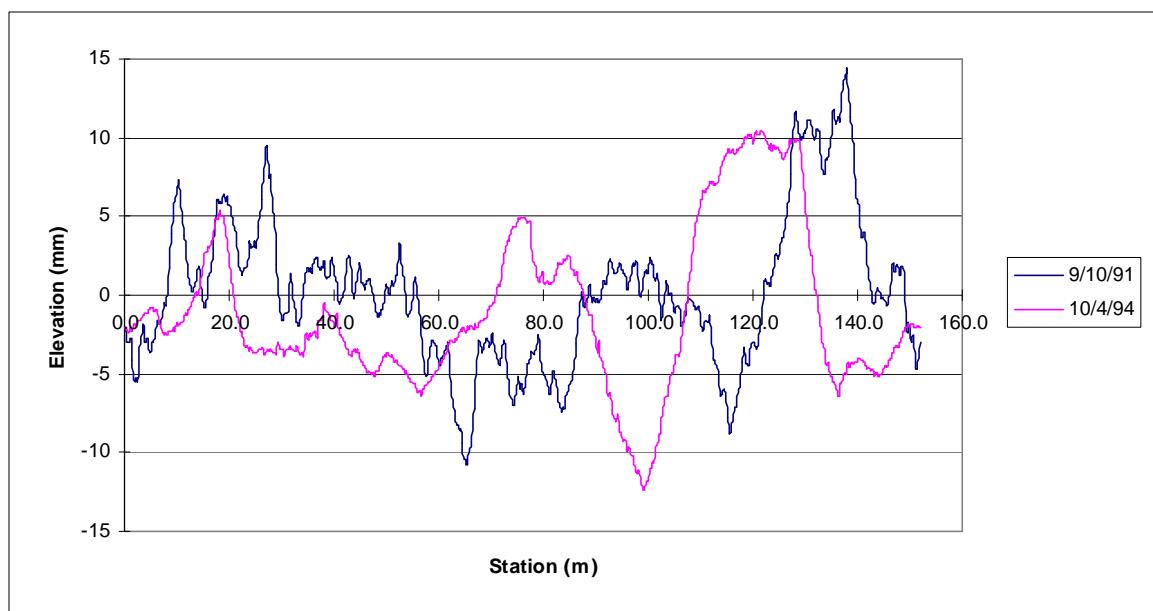


Figure 128. Differences in profile due to rehabilitation of section.

If a case such as that shown in figure 128 is encountered, the operator should first verify that the test section location is correct. If such a condition is encountered at a SPS section or at a GPS section that was profiled in conjunction with a SPS section, the operator should verify that the

stationing used for subsectioning is correct. If evidence of rehabilitation is noted at the section, it should be entered as an Operator Comment and also noted in the form Status of Regions Test Sections.

An example where maintenance has occurred on a portion of the test section between site visits is illustrated in figure 129. This figure shows a plot of the left wheel path profile obtained on two separate site visits—August 8, 1991 and August 5, 1992. This plot shows the profile at the beginning of the test section for the two site visits are different, indicating possible maintenance at the test section. If a case such as that shown in figure 129 is encountered, the operator should look to see if there is evidence of maintenance activities in the portion of the pavement where profiles are different. If evidence of maintenance is found, the operator should indicate that maintenance has been performed on the test section in the Operator Comment Field (e.g., POSSIBLE MAINTENANCE IN SECTION) and also note it in the Status of Regions Test Sections form.

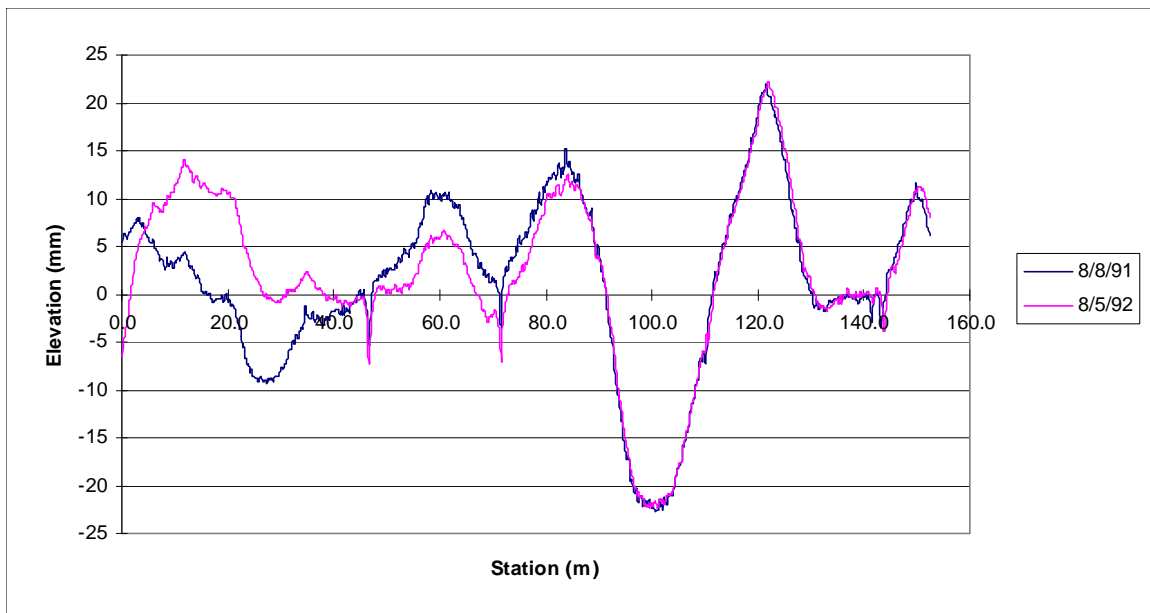


Figure 129. Differences in profile due to maintenance within section.

## APPENDIX D. DIFFERENCES BETWEEN ICC AND AMES PROFILE DATA

When profile data are plotted, differences between profile data collected by ICC devices and Ames Engineering devices can be observed. These differences occur because of differences in the upper wavelength cut-off filter that is applied on the data by the two devices. Although both devices apply a 100 m upper wavelength cut-off filter on the profile data, there are differences in the upper wavelength cut-off filter that is used by each device.

Figure 130 shows the left wheel path profile data collected by the ICC and Ames Engineering devices at a test section (i.e., section 1). The profile data collected at this section by the two devices look very different. Figure 131 shows the power spectral density (PSD) plot of the profile data shown in figure 130, and this plot shows the two devices collected similar spectral content at this section with some differences seen for wavelengths after about 90 m, which is close to the 80 m upper wavelength cut-off used for both data sets. Differences in data are also seen for wavelengths below 0.2 m, which occurs because of a low pass filter that is applied on the Ames data.

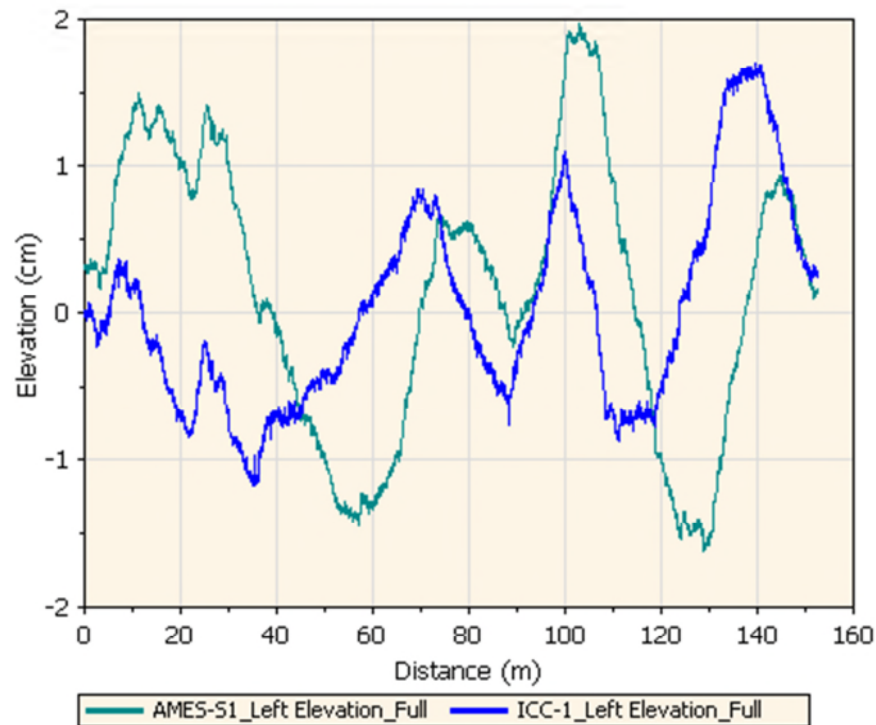


Figure 130. ICC and Ames profile data collected at Section 1.

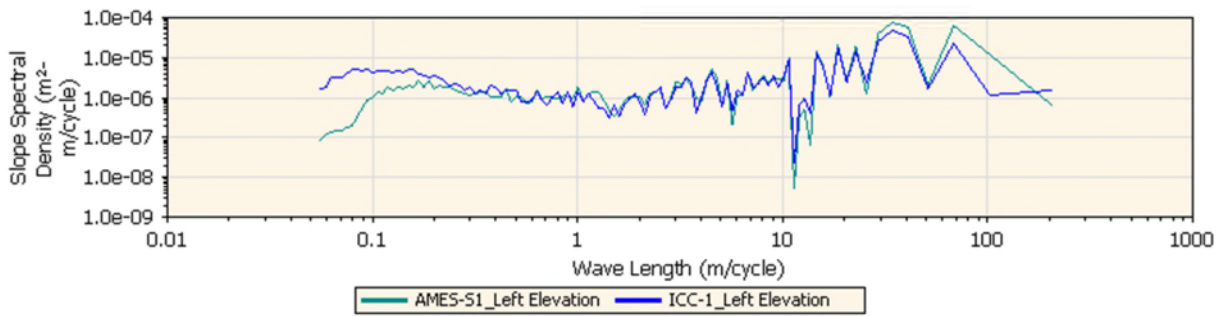


Figure 131. PSD plot of profile data collected by ICC and Ames devices at section 1.

Figure 132 show the left wheel path profile data collected by the ICC and Ames Engineering devices at another test section (section 4). As for figure 130, the profile data collected at this section by the two devices look very different. However, some of the sharp upward and downward features in the two profiles occur at the same distance. Figure 133 shows the PSD plot of the profile data shown in figure 133, and the PSD plot shows the two devices collected similar spectral content at this section, except for some content at higher wavelengths, and for content having a wavelength less than 0.2 m.

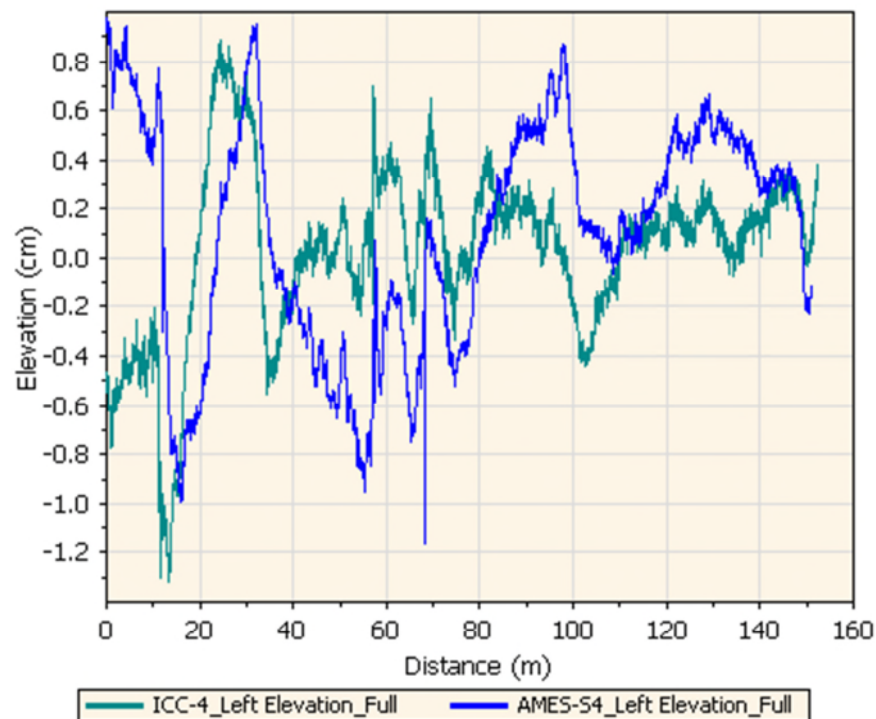


Figure 132. ICC and Ames profile data collected at Section 4.

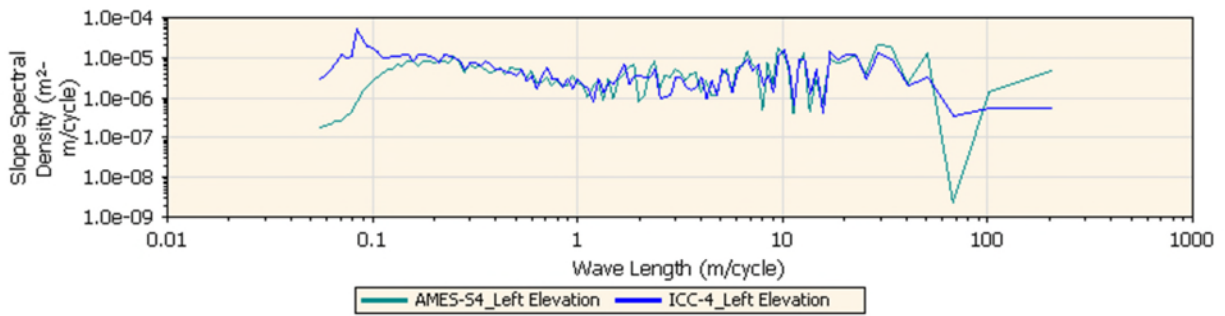


Figure 133. PSD plot of profile data collected by ICC and Ames devices at section 4.

Section 2.9.4.2 of this manual indicates that operators should compare profile data collected during a site visit with previous data collected at the site as a quality control measure. However, as shown by the two examples in this appendix, comparing profile data collected by the Ames device with profile data collected by the ICC device at the same section can be problematic as profile plots of the two data sets look different. Instead of an overall comparison of profiles, the operator should look at sharp upward and downward features in the two profile plots to see if they coincide.





## APPENDIX E. PROFILE AND TEXTURE HEIGHT SENSOR LINEARIZATION PROCEDURE

A profile or texture height sensor may have to be re-linearized if the sensor fails to meet the specified bias criterion during the full calibration check. The re-linearization procedure changes the calibration scale factor of the sensor through a software provided by Ames Engineering. Approval from the FHWA must be sought before re-linearizing a sensor.

This appendix presents the procedure to be followed for re-linearizing a sensor. It is recommended that Ames Engineering be contacted if a RSC has never performed this procedure previously so that the RSC can go through this procedure with Ames Engineering so they become familiar with the procedure.

The Ames Engineering sensor configuration software must be installed on the profiler laptop. The following are the steps for re-linearizing each sensor using Ames Engineering linearization software:

1. Power up the height sensors and wait until the height sensor temperatures shown on the main screen of the profiler software has stabilized. Before doing the re-linearization it is recommended that the temperature indicated on this screen be between 35 and 40 °C in the warmer regions and be between 30 and 35 °C in the cooler regions. Hence, a suitable location where these temperatures can be achieved must be selected to perform the re-linearization.
2. **In the “Main” tab, the default setting is “Global”, and it is very important that the appropriate sensor is selected before pressing any other button. Pressing another button while the setting is at “Global” can make changes to the system that is very difficult to correct. From the “Main” tab in the software (see figure 134), select the sensor that requires re-linearization (i.e., ODS1, ODS2, ODS3, ODS4, or ODS5) using the appropriate radio button. Warning: As described previously, it is very important that the appropriate sensor be selected before pressing any other buttons, because if “Global” is selected, the software will attempt to re-linearize all the sensors in the network at the same time. Also make sure not to press any of the "Program as" buttons on the left side of the window with the “Global” button selected, because this will change all the sensors on the network to be identically set to the same address, or device type.**

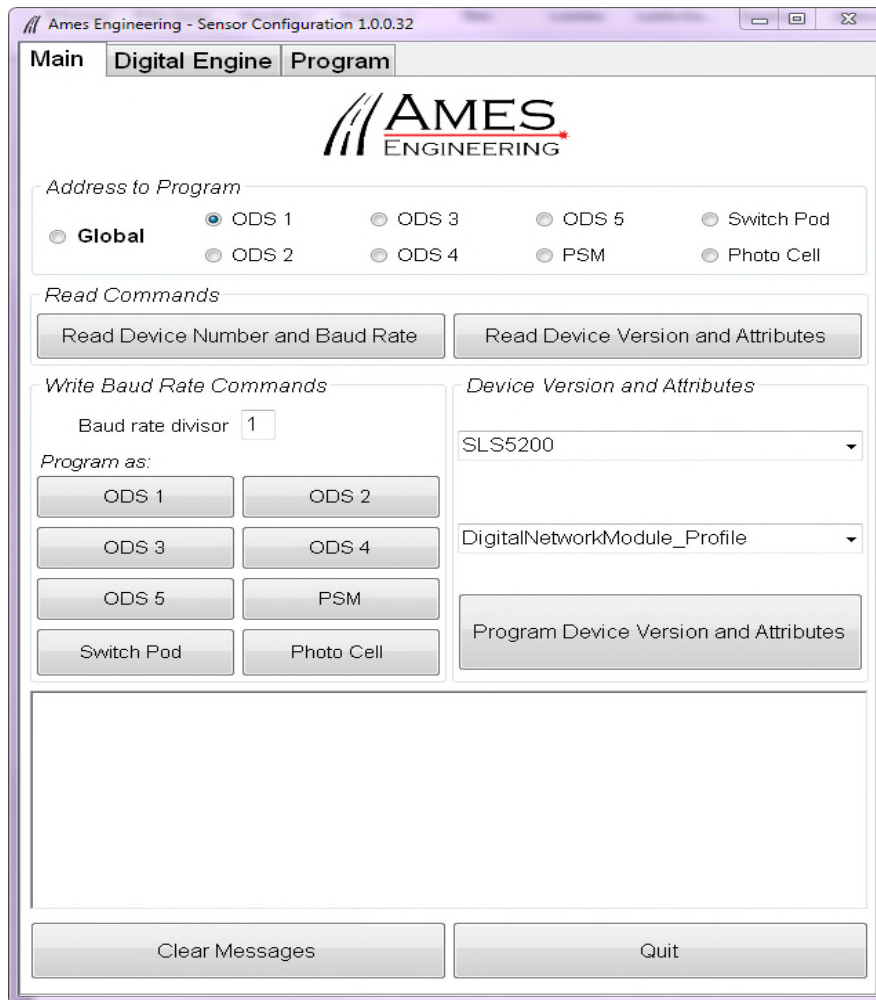


Figure 134. Re-linearization software menu.

3. Click on “Read Device Number and Baud Rate”. If the connection between the system and the sensor is working, the baud rate should be displayed as 1, and the device number of the selected sensor should match the value shown below that corresponds to the sensor:

0x01 Hex(1 dec) ODS #1 Sensor  
 0x02 Hex(2 dec) ODS #2 Sensor  
 0x03 Hex (3 dec) PSM Module  
 0x10 Hex (16 dec) ODS #3 Sensor  
 0x20 Hex (32 dec) ODS #4 Sensor  
 0x40 Hex (64 dec) ODS #5 Sensor

Note: The Device number is the same as the address for that device.

If the value appropriate for the sensor is not displayed, contact Ames Engineering for assistance.

4. Click on “Read Device Version and Attributes”. The following information should be displayed in the dialogue box and in the two drop-down menus on the right hand side.

ODS 1 ,ODS 2 and ODS 3: The Device Type should show up as SLS5200, with attributes of DigitalNetworkModule\_Profile.

For ODS 4 and ODS 5 the Device Type should show up as Optocator180, with attributes of DigitalNetworkModule\_Texture.

If these values are not displayed, contact Ames Engineering for assistance.

5. Place calibration ramps in front of the tires and move the vehicle onto the first step of the calibration ramps. Do this at the same place where all of the calibration checks take place. Place and level the base plate underneath the height sensor that is to be re-linearized so that the laser dot is as close as possible to the center of the square that is marked on the base plate. Place the target on the base plate within the marked square with the dull side facing up. It is recommended that the 100 mm block be placed behind the target to provide further stability to the base plate.
6. Go to the “Digital Engine” tab of the software (see figure 135), and click on “Zero Laser”. A statement to that effect will show up in the dialogue box next to it.
7. Place the 100 mm block on the square marked on the base plate and put the target on top of it with the dull side facing up. Make sure the laser dot is at the center of the target plate.
8. Click on “Scale 100 mm”. A “Scaled Laser Value” will be displayed in the dialogue box next to it. Write this value and the sensor number (i.e., ODS 1, ODS 2, ODS 3, ODS 4, or ODS 5) down for future reference. The "Scaled Laser Value" for a profile laser should be  $2000 \pm 15$ , while this value for the texture laser should be  $2222 \pm 15$ . If the displayed value is outside of this range the procedure should be repeated. If results that are outside of the required range are obtained after several attempts, then the sensor should be sent to Ames Engineering for service.
9. If another sensor is to be linearized, repeat the procedure. Otherwise, go to Step 10.
10. Go to main menu and select “Quit” to get out of the program.
11. Shut down the system using the procedure described in Section 2.8.2. Power up the system using the procedure described in Section 2.8.1. This power off and power on procedure is needed to load the new calibration factors to the system. From this point forward, the new calibration factors will be used for data collection.
12. The “Scaled Laser Values” that were written down in Step 8 should be filed in an appropriate folder with the date and time of calibration also recorded on that sheet.

Ames Engineering - Sensor Configuration 1.0.0.32

**Main** **Digital Engine** **Program**

---

*Laser*

Press the zero laser button to zero the laser

Zero laser

Place a 1 in. block under the laser  
Then press the scale laser button to write the laser scaling to flash  
The current laser scaling value is displayed in the textbox

Scale 1"  Scale 100 mm  Scaled laser value

Write current laser position as zero point  
The current laser zero point is displayed in the textbox

Write zero  Laser zero point

---

*Accelerometer*

Scale zero

This will scale the accelerometer to 2G and then write the scaled value to flash  
The scaled value is then displayed in the textbox

Scale 2G  Scaled accel value

Write current accelerometer position as zero point  
The current accelerometer zero point is displayed in the textbox

Write zero  Accel zero point

---

*High-Pass Filter*

Read high-pass  High-pass read value

Write high-pass  High-pass write value

Figure 135. Digital engine tab of re-linearization software.

## **APPENDIX F. STANDARD FORMS FOR DIPSTICK® MEASUREMENTS**

|   |  |
|---|--|
| LTPP Dipstick Data Collection Form<br>Longitudinal Profile Form DS-1<br>Measurement Information and Closure Computation | State Code [ _ _ ]<br>LTPP Section [ _ _ _ _ ]<br>Date (dd/mm/yy) ____/____/____ |
|---|--|

Dipstick Serial Number: [ \_ \_ \_ \_ \_ ]    Dipstick Model Number: 1500/2000/2200    Dipstick Fitted With 32 mm footpads? \_\_\_\_  
 Footpad Spacing (mm): [ \_ \_ \_ . \_ \_ ]    Operator: [ \_ \_ ]    Recorder: [ \_ \_ ]  
 Site Type: GPS/SPS/WIM/Other    Surface Type: [ \_ - \_ \_ ]    Pavement Condition: V.GOOD/GOOD/FAIR/POOR  
 Road Name: \_\_\_\_\_    Lane: Inside/Outside  
 Direction: NORTH/EAST/SOUTH/WEST    Cloud Conditions: CLEAR/P. CLOUDY/CLOUDY  
 Start Air Temperature: \_\_\_\_ °C    End Air Temperature: \_\_\_\_ °C    Average Air Temperature: \_\_\_\_ °C  
 Weather Comment: \_\_\_\_\_

Start Time (military): \_\_\_\_ : \_\_\_\_    \_\_\_\_ Stop Time (military): \_\_\_\_ : \_\_\_\_ \_\_\_\_

**Closure Error Computation**

| Right Wheel Path  |               | Left Wheel Path   |               |                      |
|-------------------|---------------|-------------------|---------------|----------------------|
| No                | Elevation Sum | No                | Elevation Sum |                      |
| O1                |               | I1                |               |                      |
| O2                |               | I2                |               |                      |
| O3                |               | I3                |               |                      |
| O4                |               | I4                |               |                      |
| O5                |               | I5                |               |                      |
| O6                |               | I6                |               |                      |
| O7                |               | I7                |               |                      |
| O8                |               | I8                |               |                      |
| O9                |               | I9                |               |                      |
| O10               |               | I10               |               |                      |
| O11               |               | I11               |               |                      |
| O12               |               | I12               |               |                      |
| O13               |               | I13               |               |                      |
| O14               |               | I14               |               |                      |
| O15               |               | I15               |               |                      |
| O16               |               | I16               |               |                      |
| O17               |               | I17               |               |                      |
| O18               |               | I18               |               |                      |
| O19               |               | I19               |               |                      |
| O20               |               | I20               |               |                      |
| Total O1 to O20   | OA            | Total I1 to I20   | IA            |                      |
| Transverse Sum T2 | OB            | Transverse Sum T1 | IB            | <b>Closure Error</b> |
| Total OA+OB       | OC            | Total IA + IB     | IC            | OC+IC                |

**Traffic Control  
Crew:**

**Other Personnel  
At Site:**

|  |   |
|--|---|
| LTPP Dipstick Data Collection Form<br>Longitudinal Profile Form DS-2<br>Reading 1 to 100 | State Code      [ _ _ ]<br>LTPP Section ID      [ _ _ _ _ ]<br>Date (dd/mm/yy)      [ _ _ / _ _ _ _ / _ _ ] |
|--|---|

| Reading No. | Reading (mm) |       | Reading No. | Reading (mm) |       | Reading No. | Reading (mm) |       | Reading No. | Reading (mm.) |       |
|-------------|--------------|-------|-------------|--------------|-------|-------------|--------------|-------|-------------|---------------|-------|
|             | RWP ↓        | LWP ↑ |             | RWP ↓        | LWP ↑ |             | RWP ↓        | LWP ↑ |             | RWP ↓         | LWP ↑ |
|             |              |       |             |              |       |             |              |       |             |               |       |
| 1           |              |       | 26          |              |       | 51          |              |       | 76          |               |       |
| 2           |              |       | 27          |              |       | 52          |              |       | 77          |               |       |
| 3           |              |       | 28          |              |       | 53          |              |       | 78          |               |       |
| 4           |              |       | 29          |              |       | 54          |              |       | 79          |               |       |
| 5           |              |       | 30          |              |       | 55          |              |       | 80          |               |       |
| 6           |              |       | 31          |              |       | 56          |              |       | 81          |               |       |
| 7           |              |       | 32          |              |       | 57          |              |       | 82          |               |       |
| 8           |              |       | 33          |              |       | 58          |              |       | 83          |               |       |
| 9           |              |       | 34          |              |       | 59          |              |       | 84          |               |       |
| 10          |              |       | 35          |              |       | 60          |              |       | 85          |               |       |
| 11          |              |       | 36          |              |       | 61          |              |       | 86          |               |       |
| 12          |              |       | 37          |              |       | 62          |              |       | 87          |               |       |
| 13          |              |       | 38          |              |       | 63          |              |       | 88          |               |       |
| 14          |              |       | 39          |              |       | 64          |              |       | 89          |               |       |
| 15          |              |       | 40          |              |       | 65          |              |       | 90          |               |       |
| 16          |              |       | 41          |              |       | 66          |              |       | 91          |               |       |
| 17          |              |       | 42          |              |       | 67          |              |       | 92          |               |       |
| 18          |              |       | 43          |              |       | 68          |              |       | 93          |               |       |
| 19          |              |       | 44          |              |       | 69          |              |       | 94          |               |       |
| 20          |              |       | 45          |              |       | 70          |              |       | 95          |               |       |
| 21          |              |       | 46          |              |       | 71          |              |       | 96          |               |       |
| 22          |              |       | 47          |              |       | 72          |              |       | 97          |               |       |
| 23          |              |       | 48          |              |       | 73          |              |       | 98          |               |       |
| 24          |              |       | 49          |              |       | 74          |              |       | 99          |               |       |
| 25          |              |       | 50          |              |       | 75          |              |       | 100         |               |       |
| Sum         | O1           | I1    |             | O2           | I2    |             | O3           | I3    |             | O4            | I4    |

Transverse Closure Measurements from Left Wheel Path to Right Wheel Path at Station 0+00

|              | Transverse Position |     |     |     |     |        |          | Sum |
|--------------|---------------------|-----|-----|-----|-----|--------|----------|-----|
|              | LWP-1               | 1-2 | 2-3 | 3-4 | 4-5 | 5 - CC | CC - RWP |     |
| Reading (mm) |                     |     |     |     |     |        |          | T1  |



|  |  |
|--|--|
| LTPP Dipstick Data Collection Form<br>Longitudinal Profile Form DS-3<br>Reading 101 to 200 | State Code [ _ _ ]<br>LTPP Section ID [ _ _ - _ - ]<br>Date (dd/mm/yy) [ _ _ / _ _ _ _ / _ _ ] |
|--|--|

| Reading No | Reading (mm) |       | Reading No | Reading (mm) |       | Reading No | Reading (mm) |       | Reading No | Reading (mm) |       |
|------------|--------------|-------|------------|--------------|-------|------------|--------------|-------|------------|--------------|-------|
|            | RWP ↓        | LWP ↑ |            | RWP ↓        | LWP ↑ |            | RWP ↓        | LWP ↑ |            | RWP ↓        | LWP ↑ |
|            |              |       |            |              |       |            |              |       |            |              |       |
| 101        |              |       | 126        |              |       | 151        |              |       | 176        |              |       |
| 102        |              |       | 127        |              |       | 152        |              |       | 177        |              |       |
| 103        |              |       | 128        |              |       | 153        |              |       | 178        |              |       |
| 104        |              |       | 129        |              |       | 154        |              |       | 179        |              |       |
| 105        |              |       | 130        |              |       | 155        |              |       | 180        |              |       |
| 106        |              |       | 131        |              |       | 156        |              |       | 181        |              |       |
| 107        |              |       | 132        |              |       | 157        |              |       | 182        |              |       |
| 108        |              |       | 133        |              |       | 158        |              |       | 183        |              |       |
| 109        |              |       | 134        |              |       | 159        |              |       | 184        |              |       |
| 110        |              |       | 135        |              |       | 160        |              |       | 185        |              |       |
| 111        |              |       | 136        |              |       | 161        |              |       | 186        |              |       |
| 112        |              |       | 137        |              |       | 162        |              |       | 187        |              |       |
| 113        |              |       | 138        |              |       | 163        |              |       | 188        |              |       |
| 114        |              |       | 139        |              |       | 164        |              |       | 189        |              |       |
| 115        |              |       | 140        |              |       | 165        |              |       | 190        |              |       |
| 116        |              |       | 141        |              |       | 166        |              |       | 191        |              |       |
| 117        |              |       | 142        |              |       | 167        |              |       | 192        |              |       |
| 118        |              |       | 143        |              |       | 168        |              |       | 193        |              |       |
| 119        |              |       | 144        |              |       | 169        |              |       | 194        |              |       |
| 120        |              |       | 145        |              |       | 170        |              |       | 195        |              |       |
| 121        |              |       | 146        |              |       | 171        |              |       | 196        |              |       |
| 122        |              |       | 147        |              |       | 172        |              |       | 197        |              |       |
| 123        |              |       | 148        |              |       | 173        |              |       | 198        |              |       |
| 124        |              |       | 149        |              |       | 174        |              |       | 199        |              |       |
| 125        |              |       | 150        |              |       | 175        |              |       | 200        |              |       |
| Sum        | O5           | I5    |            | O6           | I6    |            | O7           | I7    |            | O8           | I8    |

LTPP Dipstick Data Collection Form  
Longitudinal Profile Form DS-4  
Readings 201 to 300

State Code [ \_ \_ ]  
LTPP Section ID [ \_ \_ \_ \_ ]  
Date (dd/mm/yy) [ \_ \_ / \_ \_ \_ \_ / \_ \_ ]

| Reading No. | Reading (mm) |       | Reading No. | Reading (mm) |       | Reading No. | Reading (mm) |       | Reading No. | Reading (mm) |       |
|-------------|--------------|-------|-------------|--------------|-------|-------------|--------------|-------|-------------|--------------|-------|
|             | RWP ↓        | LWP ↑ |             | RWP ↓        | LWP ↑ |             | RWP ↓        | LWP ↑ |             | RWP ↓        | LWP ↑ |
|             |              |       |             |              |       |             |              |       |             |              |       |
| 201         |              |       | 226         |              |       | 251         |              |       | 276         |              |       |
| 202         |              |       | 227         |              |       | 252         |              |       | 277         |              |       |
| 203         |              |       | 228         |              |       | 253         |              |       | 278         |              |       |
| 204         |              |       | 229         |              |       | 254         |              |       | 279         |              |       |
| 205         |              |       | 230         |              |       | 255         |              |       | 280         |              |       |
| 206         |              |       | 231         |              |       | 256         |              |       | 281         |              |       |
| 207         |              |       | 232         |              |       | 257         |              |       | 282         |              |       |
| 208         |              |       | 233         |              |       | 258         |              |       | 283         |              |       |
| 209         |              |       | 234         |              |       | 259         |              |       | 284         |              |       |
| 210         |              |       | 235         |              |       | 260         |              |       | 285         |              |       |
| 211         |              |       | 236         |              |       | 261         |              |       | 286         |              |       |
| 212         |              |       | 237         |              |       | 262         |              |       | 287         |              |       |
| 213         |              |       | 238         |              |       | 263         |              |       | 288         |              |       |
| 214         |              |       | 239         |              |       | 264         |              |       | 289         |              |       |
| 215         |              |       | 240         |              |       | 265         |              |       | 290         |              |       |
| 216         |              |       | 241         |              |       | 266         |              |       | 291         |              |       |
| 217         |              |       | 242         |              |       | 267         |              |       | 292         |              |       |
| 218         |              |       | 243         |              |       | 268         |              |       | 293         |              |       |
| 219         |              |       | 244         |              |       | 269         |              |       | 294         |              |       |
| 220         |              |       | 245         |              |       | 270         |              |       | 295         |              |       |
| 221         |              |       | 246         |              |       | 271         |              |       | 296         |              |       |
| 222         |              |       | 247         |              |       | 272         |              |       | 297         |              |       |
| 223         |              |       | 248         |              |       | 273         |              |       | 298         |              |       |
| 224         |              |       | 249         |              |       | 274         |              |       | 299         |              |       |
| 225         |              |       | 250         |              |       | 275         |              |       | 300         |              |       |
| Sum         | O9           | I9    |             | O10          | I10   |             | O11          | I11   |             | O12          | I12   |

|   |  |
|---|--|
| LTPP Dipstick Data Collection Form<br>Longitudinal Profile Form DS-5<br>Readings 301 to 400 | State Code [ _ _ ]<br>LTPP Section ID [ _ _ - _ - ]<br>Date (dd/mm/yy) [ _ _ / _ _ _ _ / _ _ ] |
|---|--|

| Reading No. | Reading (mm) |       | Reading No. | Reading (mm) |       | Reading No. | Reading (mm) |       | Reading No. | Reading (mm) |       |
|-------------|--------------|-------|-------------|--------------|-------|-------------|--------------|-------|-------------|--------------|-------|
|             | RWP ↓        | LWP ↑ |             | RWP ↓        | LWP ↑ |             | RWP ↓        | LWP ↑ |             | RWP ↓        | LWP ↑ |
|             |              |       |             |              |       |             |              |       |             |              |       |
| 301         |              |       | 326         |              |       | 351         |              |       | 376         |              |       |
| 302         |              |       | 327         |              |       | 352         |              |       | 377         |              |       |
| 303         |              |       | 328         |              |       | 353         |              |       | 378         |              |       |
| 304         |              |       | 329         |              |       | 354         |              |       | 379         |              |       |
| 305         |              |       | 330         |              |       | 355         |              |       | 380         |              |       |
| 306         |              |       | 331         |              |       | 356         |              |       | 381         |              |       |
| 307         |              |       | 332         |              |       | 357         |              |       | 382         |              |       |
| 308         |              |       | 333         |              |       | 358         |              |       | 383         |              |       |
| 309         |              |       | 334         |              |       | 359         |              |       | 384         |              |       |
| 310         |              |       | 335         |              |       | 360         |              |       | 385         |              |       |
| 311         |              |       | 336         |              |       | 361         |              |       | 386         |              |       |
| 312         |              |       | 337         |              |       | 362         |              |       | 387         |              |       |
| 313         |              |       | 338         |              |       | 363         |              |       | 388         |              |       |
| 314         |              |       | 339         |              |       | 364         |              |       | 389         |              |       |
| 315         |              |       | 340         |              |       | 365         |              |       | 390         |              |       |
| 316         |              |       | 341         |              |       | 366         |              |       | 391         |              |       |
| 317         |              |       | 342         |              |       | 367         |              |       | 392         |              |       |
| 318         |              |       | 343         |              |       | 368         |              |       | 393         |              |       |
| 319         |              |       | 344         |              |       | 369         |              |       | 394         |              |       |
| 320         |              |       | 345         |              |       | 370         |              |       | 395         |              |       |
| 321         |              |       | 346         |              |       | 371         |              |       | 396         |              |       |
| 322         |              |       | 347         |              |       | 372         |              |       | 397         |              |       |
| 323         |              |       | 348         |              |       | 373         |              |       | 398         |              |       |
| 324         |              |       | 349         |              |       | 374         |              |       | 399         |              |       |
| 325         |              |       | 350         |              |       | 375         |              |       | 400         |              |       |
| Sum         | O13          | I13   |             | O14          | I14   |             | O15          | I15   |             | O16          | I16   |

|   |   |
|---|---|
| LTPP Manual Dipstick Data Collection Form<br>Longitudinal Profile Form DS-6<br>Station 401 to 500 | State Code [ _ _ ]<br>LTPP Section ID [ _ _ ]<br>Date (dd/mmm/yy) [ _ _ / _ _ _ / _ _ ] |
|---|---|

| Reading No | Reading (mm) |       | Reading No | Reading (mm) |       | Reading No | Reading (mm) |       | Reading No | Reading (mm) |       |
|------------|--------------|-------|------------|--------------|-------|------------|--------------|-------|------------|--------------|-------|
|            | RWP ↓        | LWP ↑ |            | RWP ↓        | LWP ↑ |            | RWP ↓        | LWP ↑ |            | RWP ↓        | LWP ↑ |
|            |              |       |            |              |       |            |              |       |            |              |       |
| 401        |              |       | 426        |              |       | 451        |              |       | 476        |              |       |
| 402        |              |       | 427        |              |       | 452        |              |       | 477        |              |       |
| 403        |              |       | 428        |              |       | 453        |              |       | 478        |              |       |
| 404        |              |       | 429        |              |       | 454        |              |       | 479        |              |       |
| 405        |              |       | 430        |              |       | 455        |              |       | 480        |              |       |
| 406        |              |       | 431        |              |       | 456        |              |       | 481        |              |       |
| 407        |              |       | 432        |              |       | 457        |              |       | 482        |              |       |
| 408        |              |       | 433        |              |       | 458        |              |       | 483        |              |       |
| 409        |              |       | 434        |              |       | 459        |              |       | 484        |              |       |
| 410        |              |       | 435        |              |       | 460        |              |       | 485        |              |       |
| 411        |              |       | 436        |              |       | 461        |              |       | 486        |              |       |
| 412        |              |       | 437        |              |       | 462        |              |       | 487        |              |       |
| 413        |              |       | 438        |              |       | 463        |              |       | 488        |              |       |
| 414        |              |       | 439        |              |       | 464        |              |       | 489        |              |       |
| 415        |              |       | 440        |              |       | 465        |              |       | 490        |              |       |
| 416        |              |       | 441        |              |       | 466        |              |       | 491        |              |       |
| 417        |              |       | 442        |              |       | 467        |              |       | 492        |              |       |
| 418        |              |       | 443        |              |       | 468        |              |       | 493        |              |       |
| 419        |              |       | 444        |              |       | 469        |              |       | 494        |              |       |
| 420        |              |       | 445        |              |       | 470        |              |       | 495        |              |       |
| 421        |              |       | 446        |              |       | 471        |              |       | 496        |              |       |
| 422        |              |       | 447        |              |       | 472        |              |       | 497        |              |       |
| 423        |              |       | 448        |              |       | 473        |              |       | 498        |              |       |
| 424        |              |       | 449        |              |       | 474        |              |       | 499        |              |       |
| 425        |              |       | 450        |              |       | 475        |              |       | 500        |              |       |
| Sum        | O17          | I17   |            | O18          | I18   |            | O19          | I19   |            | O20          | I20   |

Transverse Closure Measurements from Right Wheel Path to Left Wheel Path at Station (152.40 m)

|              | Transverse Position |     |     |     |     |        |         | Sum |
|--------------|---------------------|-----|-----|-----|-----|--------|---------|-----|
|              | RWP-1               | 1-2 | 2-3 | 3-4 | 4-5 | 5 - CC | CC -LWP |     |
| Reading (mm) |                     |     |     |     |     |        |         | T2  |

|   |   |
|---|---|
| LTPP Dipstick Data Collection Form<br>Longitudinal Profile Form DS-7<br>Pre/Post Measurement Zero and Calibration<br>Checks | State Code [ _ _ ]<br>LTPP Section ID [ _ _ _ _ ]<br>Date (dd/mmm/yy) [ _ _ / _ _ _ / _ _ ] |
|---|---|

Operator: \_\_\_\_\_ Employer: \_\_\_\_\_

Dipstick Serial Number: \_\_\_\_\_ Diameter of Dipstick Foot Pad: \_ \_ . \_ \_ mm

### Pre Measurement Checks

Time (military): \_ \_ : \_ \_ Automated Dipstick - Zero Check Performed: \_\_\_\_\_

| Zero Check - Manual Dipstick       |              | Calibration Check                    |              |
|------------------------------------|--------------|--------------------------------------|--------------|
| Measurement                        | Reading (mm) | Measurement                          | Reading (mm) |
| First Reading                      |              | First Reading                        |              |
| Second Reading after 180° Rotation |              | Second Reading on Calibration Block  |              |
| First + Second Reading             | <sup>A</sup> | Second Reading - 3.2 - First Reading | <sup>B</sup> |

Notes:

- A. First + Second Reading must be less than  $\pm 0.1$ . If not, adjust the start pin as suggested in the LTPP Profile Measurement Manual and repeat zero check.
- B. Second Reading - 3.2 - First Reading must be less than  $\pm 0.1$ . If not, notify the RSC office and contact Face Company for repair.

### Post Measurement Checks

Time (military): \_ \_ : \_ \_

| Zero Check                         |              | Calibration Check                    |              |
|------------------------------------|--------------|--------------------------------------|--------------|
| Measurement                        | Reading (mm) | Measurement                          | Reading (mm) |
| First Reading                      |              | First Reading                        |              |
| Second Reading after 180° Rotation |              | Second Reading on Calibration Block  |              |
| First + Second Reading             | <sup>A</sup> | Second Reading - 3.2 - First Reading | <sup>B</sup> |

Notes:

- A. First + Second Reading must be less than  $\pm 0.1$ . If not, discard data as suspect, adjust the start pin as suggested in the LTPP Profile Measurement Manual, repeat zero check until it passes, perform calibration check and if it passes, resurvey section.
- B. Second Reading - 3.2 - First Reading must be less than  $\pm 0.1$ . If not, notify the RSC office and contact Face Company for repair.

Comments: \_\_\_\_\_

\_\_\_\_\_

LTPP Dipstick® Data Collection Form  
Transverse Profile  
Form DS-8

Dipstick® Serial #: [ ] Dipstick® Model #: [ ]  
Operator: [ ] Recorder: [ ] Site Type: [ ] Visit: [ ]  
Surface Type: [ ] Condition: [ ]

State Code [ ]  
LTPP Section ID [ ]  
Date (dd/mm/yy) [ ] / [ ] / [ ]  
Time [ ] : [ ] : [ ]

Road Name: [ ] Lane: Outside / Inside (Circle One) Direction: [ ]  
Clouds: [ ] Temperature (°C): [ ] Weather Comment: [ ]

| Location   | Dipstick® Readings (mm) |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    | Sum | Closure |
|------------|-------------------------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|-----|---------|
|            | 1                       | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |     |         |
| 0 m        |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| Difference |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| 15.24 m    |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| Difference |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| 30.48 m    |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| Difference |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| 45.72 m    |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| Difference |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| 60.96 m    |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| Difference |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| 76.20 m    |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| Difference |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| 91.44 m    |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| Difference |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| 106.68 m   |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| Difference |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| 121.92 m   |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| Difference |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| 137.16 m   |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| Difference |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| 152.4 m    |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |
| Difference |                         |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |     |         |

COMMENTS: [ ]

**There is no Form DS-9**

|   |  |
|---|--|
| <b>LTPP Dip stick Operations</b><br><b>LTPP Major Maintenance/Repair</b><br><br><b>Form DS-10</b> | <b>Region</b> [            ]<br><b>Serial Number</b> [            ]<br><br><b>Scheduled</b> [ YES / NO ] |
|---|--|

|  |  |
|--|--|
| <b>Problem Identification / Scheduled Maintenance</b><br>Equipment: _____<br>Description: _____<br>_____<br>_____<br>_____   | Performed By: _____<br>Date: [    /    /    ]<br>Start Time: [    :    ]<br>End Time: [    :    ]  |
| <b>Troubleshooting</b><br>Description: _____<br>_____<br>_____<br>_____<br>_____   | Performed By: _____<br>Date: [    /    /    ]<br>Start Time: [    :    ]<br>End Time: [    :    ]<br>Hours: _____                                  |
| <b>Reporting</b><br>Referred to: _____<br>_____<br>Actions (Return Order Parts): _____<br>_____<br>_____<br>_____  | Date: [    /    /    ]<br>Time: [    :    ]<br><br>Date: [    /    /    ]<br>Time: [    :    ]   |
| <b>Service</b><br>Description (Repairs Performed/Replacement Part Information): _____<br>_____<br>_____<br>_____<br>Agency Performing Maintenance: _____<br>_____<br>_____ | Performed By: _____<br>Date: [    /    /    ]<br>Start Time: [    :    ]<br>End Time: [    :    ]<br>Hours: _____<br>Total Cost: [ \$       .    ] |
| <b>Verification</b><br>Description (Check/Calibration): _____<br>_____<br>_____<br>_____<br>_____  | Performed By: _____<br>Date: [    /    /    ]<br>Start Time: [    :    ]<br>End Time: [    :    ]<br>Hours: _____                                  |
| <b>Return to Service</b><br>Status: _____<br>_____   | Performed By: _____<br>Date: [    /    /    ]  |



|   |                                     |
|---|-------------------------------------|
| <b>LTPP Dipstick Operations</b><br><br><b>Air Temperature Probe Calibration Check</b><br><br><br><b>Longitudinal Profile Form DS-11</b> | <b>Region</b> [ ____ ]              |
|   | <b>Probe Serial Number</b> [ ____ ] |
|   | <b>NIST Serial Number</b> [ ____ ]  |
|   | <b>Date</b> [ ____ / ____ / ____ ]  |
|   | <b>Scheduled</b> [ YES / NO ]       |

|  |                           |
|--|---------------------------|
| <b>Ambient Temperature Check - Trial # 1</b>                       |                           |
| Time   | [ ____ : ____ ]           |
| Air Probe  | [ ____ °C ]               |
| NIST Thermometer   | [ ____ °C ]               |
| Is Air Probe within $\pm 2^{\circ}\text{C}$ of NIST Thermometer?   | <sup>1</sup> [ YES / NO ] |
| <sup>1</sup> If yes, Trial # 2 and Trial # 3 are not required.     |                           |
| <b>Ambient Temperature Check - Trial # 2</b>                       |                           |
| Time   | [ ____ : ____ ]           |
| Air Probe  | [ ____ °C ]               |
| NIST Thermometer   | [ ____ °C ]               |
| Is Air Probe within $\pm 2^{\circ}\text{C}$ of NIST Thermometer?   | <sup>2</sup> [ YES / NO ] |
| <sup>2</sup> If yes, Trial # 3 is not required.                    |                           |
| <b>Ambient Temperature Check - Trial # 3</b>                       |                           |
| Time   | [ ____ : ____ ]           |
| Air Probe  | [ ____ °C ]               |
| NIST Thermometer   | [ ____ °C ]               |
| Is Air Probe within $\pm 2^{\circ}\text{C}$ of NIST Thermometer?   | <sup>3</sup> [ YES / NO ] |
| <sup>3</sup> If no, air probe is unacceptable.                     |                           |
| <b>Cold Temperature Check</b>                                      |                           |
| Is Cold Temperature Check required?                                | [ YES / NO ]              |
| Air Probe  | [ ____ °C ]               |
| Is Air Probe Measurement $0^{\circ}\text{C} \pm 2^{\circ}\text{C}$ | <sup>4</sup> [ YES / NO ] |
| <sup>4</sup> If no, air probe is unacceptable.                     |                           |

Performed by: \_\_\_\_\_

Employer: \_\_\_\_\_

## APPENDIX G. PROCEDURE FOR DETERMINING DIPSTICK® FOOTPAD SPACING

### Background

Testing performed in the field has indicated that the spacing between the centerline of the footpads in various Dipsticks® that are used in the LTPP program is not exactly 304.8 mm. Therefore, each RSC is required to perform a field test annually to determine the footpad spacing of each Dipstick® in their possession. This appendix describes the procedures for performing the field test and the procedure for computing the footpad spacing of the Dipstick® from that data.

### Test Plan

This test should be performed on a smooth AC or PCC pavement that is free of distress. Use the following procedure to layout the section and perform the test.

1. Layout a 30.48 m long test section. Use a tape that is in a good condition to layout the section. A longitudinal chalk line should be marked on the section. When marking the chalk line, extend the chalk line 0.3 m past the end on the test section. Two transverse chalk lines should be marked perpendicular to the longitudinal survey line at the start (0 m) and the end (30.48 m) of the section. Figure 136 shows the layout of the test section.

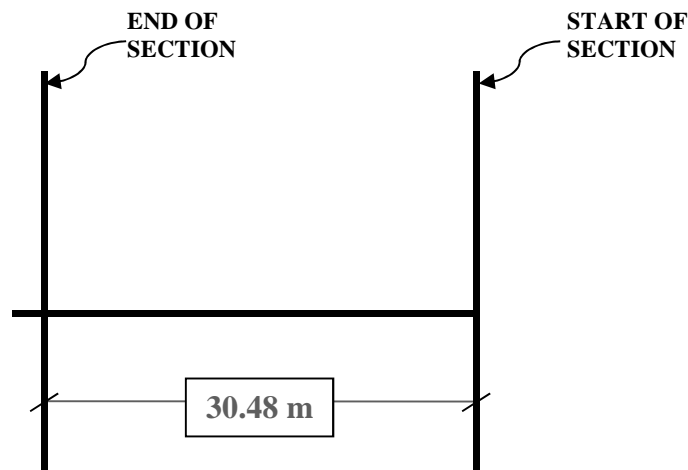


Figure 136. Test section layout.

2. Measure the diameter (in mm) of each footpad in the Dipstick® using a caliper and record the values.
3. Place the back end of the back footpad of the Dipstick® in line with the transverse line marked at the beginning of the test section (see figure 137).

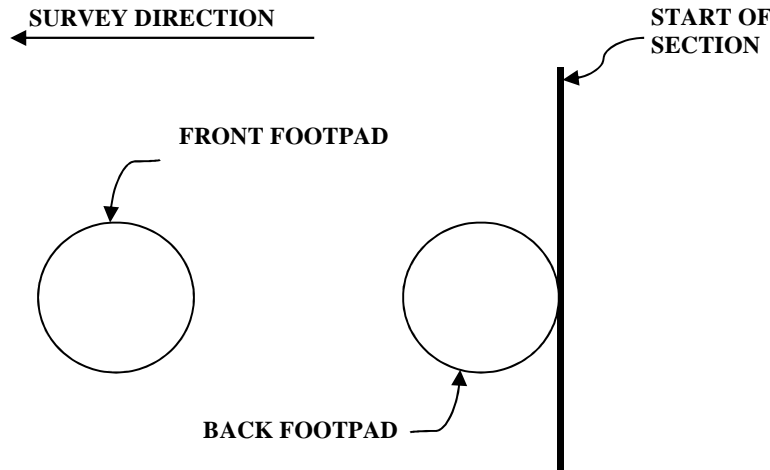


Figure 137. Location of back footpad of Dipstick® at start of the section.

4. Walk the Dipstick® along the section following the procedures outlined in section 3.3.3 of this manual. After taking the 100<sup>th</sup> reading, measure the distance (in mm) from the back end of the front footpad of the Dipstick® to the transverse line that was marked at the end of the section. The following possible scenarios can occur:
  - (a) The back end of front footpad is past the transverse line at the end of the test section (see figure 138). The distance to be measured is the distance X indicated in figure 138. Measure this distance (in mm).
  - (b) Back end of the front footpad is before the transverse line at the end of the section (see figure 139). The distance to be measured is the distance X indicated in figure 139. Measure this distance (in mm).
  - (c) Back end of the front footpad is exactly on the transverse line at the end of the section, in which case the offset X is zero.
5. Repeat steps 3 and 4 two additional times.

### Computation of Dipstick® Footpad Spacing

1. Compute the footpad spacing for the Dipstick® for each run using the following procedure:

If back edge of front footpad was past the end of the section when the last reading was obtained (case shown in figure 138), use the following formula to compute the footpad spacing.

Footpad spacing (mm) =  $(30480 + X) / 100$ , where X is in mm.

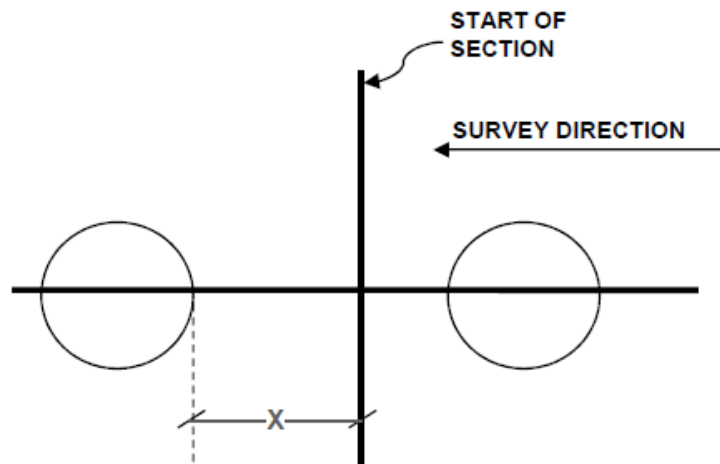


Figure 138. Back end of front footpad is past the end of the test section when the last reading is obtained.

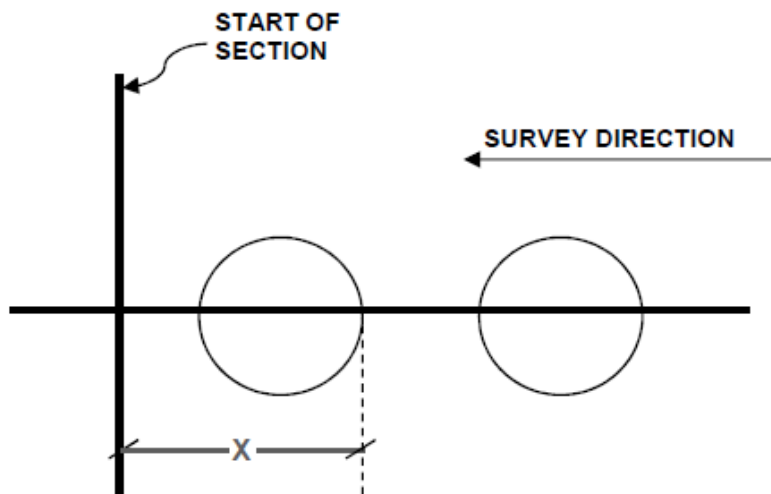


Figure 139. Back end of the front footpad is before the end of the test section when the last reading is obtained.

If back edge of front footpad was before the end of the test section when the last reading was obtained (case shown in figure 139), use the following formula to compute the footpad spacing.

Footpad spacing (mm) =  $(30480 - X)/100$ , where X is in mm.

If the back edge of the front footpad is exactly in line with the end of the section, the footpad spacing of the Dipstick<sup>®</sup> is 304.8 mm.

Compute the average footpad spacing for each Dipstick<sup>®</sup> by averaging the values obtained for the three runs to two decimal places.

2. Maintain a log in the RSC office that indicate the following information: date when testing was performed, Dipstick<sup>®</sup> model number, diameter of the Dipstick<sup>®</sup> footpads, results from the field tests, computed footpad spacing for each run, and the average footpad spacing. The suggested format of the log is shown in the following table (date of testing should be included in the log).

| Dipstick Model   | Serial Number | Diameter of Footpad (mm) |      | Test Number | Offset at End of Section <sup>(1)</sup> (mm) | Footpad Spacing (mm) | Average Footpad Spacing (mm) |
|--|---------------|--------------------------|------|-------------|--|----------------------|------------------------------|
|  |               | Front                    | Back |             |  |                      |                              |
|  |               |                          |      | 1           |  |                      |                              |
|  |               |                          |      | 2           |  |                      |                              |
|  |               |                          |      | 3           |  |                      |                              |
|  |               |                          |      | 1           |  |                      |                              |
|  |               |                          |      | 2           |  |                      |                              |
|  |               |                          |      | 3           |  |                      |                              |
|  |               |                          |      | 1           |  |                      |                              |
|  |               |                          |      | 2           |  |                      |                              |
|  |               |                          |      | 3           |  |                      |                              |
| Note 1: Offset is positive if back end of front footpad is past end of section at last reading, offset is negative if back end of front footpad is before end of the section when last reading is obtained |               |                          |      |             |  |                      |                              |

3. Write the average Dipstick<sup>®</sup> footpad spacing and date when testing was performed on a sheet of paper and securely tape it to the inside of the Dipstick<sup>®</sup> carrying case.

**APPENDIX H. DATA COLLECTION FORM FOR ROD AND LEVEL PROFILE  
MEASUREMENTS**

|   |
|---|
| LTPP Rod and Level Data Collection Form<br>Longitudinal Profile Measurements<br>Form RL-1 |
|---|

|   |
|---|
| LTPP Code [ _ _ ]<br>LTPP Section [ _ _ _ _ ]<br>Date (dd/mmm/yy) _ _ / _ _ _ _ / _ _ |
|---|

| Reading Number | I.S. | B.S. | F.S. | Reading Number | I.S. | B.S. | F.S. | Reading Number | I.S. | B.S. | F.S. |
|----------------|------|------|------|----------------|------|------|------|----------------|------|------|------|
| Stn 0+00       |      |      |      | 34             |      |      |      | 68             |      |      |      |
| 1              |      |      |      | 35             |      |      |      | 69             |      |      |      |
| 2              |      |      |      | 36             |      |      |      | 70             |      |      |      |
| 3              |      |      |      | 37             |      |      |      | 71             |      |      |      |
| 4              |      |      |      | 38             |      |      |      | 72             |      |      |      |
| 5              |      |      |      | 39             |      |      |      | 73             |      |      |      |
| 6              |      |      |      | 40             |      |      |      | 74             |      |      |      |
| 7              |      |      |      | 41             |      |      |      | 75             |      |      |      |
| 8              |      |      |      | 42             |      |      |      | 76             |      |      |      |
| 9              |      |      |      | 43             |      |      |      | 77             |      |      |      |
| 10             |      |      |      | 44             |      |      |      | 78             |      |      |      |
| 11             |      |      |      | 45             |      |      |      | 79             |      |      |      |
| 12             |      |      |      | 46             |      |      |      | 80             |      |      |      |
| 13             |      |      |      | 47             |      |      |      | 81             |      |      |      |
| 14             |      |      |      | 48             |      |      |      | 82             |      |      |      |
| 15             |      |      |      | 49             |      |      |      | 83             |      |      |      |
| 16             |      |      |      | 50             |      |      |      | 84             |      |      |      |
| 17             |      |      |      | 51             |      |      |      | 85             |      |      |      |
| 18             |      |      |      | 52             |      |      |      | 86             |      |      |      |
| 19             |      |      |      | 53             |      |      |      | 87             |      |      |      |
| 20             |      |      |      | 54             |      |      |      | 88             |      |      |      |
| 21             |      |      |      | 55             |      |      |      | 89             |      |      |      |
| 22             |      |      |      | 56             |      |      |      | 90             |      |      |      |
| 23             |      |      |      | 57             |      |      |      | 91             |      |      |      |
| 24             |      |      |      | 58             |      |      |      | 92             |      |      |      |
| 25             |      |      |      | 59             |      |      |      | 93             |      |      |      |
| 26             |      |      |      | 60             |      |      |      | 94             |      |      |      |
| 27             |      |      |      | 61             |      |      |      | 95             |      |      |      |
| 28             |      |      |      | 62             |      |      |      | 96             |      |      |      |
| 29             |      |      |      | 63             |      |      |      | 97             |      |      |      |
| 30             |      |      |      | 64             |      |      |      | 98             |      |      |      |
| 31             |      |      |      | 65             |      |      |      | 99             |      |      |      |
| 32             |      |      |      | 66             |      |      |      | 100            |      |      |      |
| 33             |      |      |      | 67             |      |      |      |                |      |      |      |

t, F.S. = Foresight

Comments:

---



---

LTPP Rod and Level Data Collection Form  
Longitudinal Profile Measurements  
Form RL-2

LTPP Code [ \_ \_ ]  
LTPP Section [ \_ \_ \_ \_ ]  
Date (dd/mm/yy) \_ \_ / \_ \_ / \_ \_

| Reading Number | I.S. | B.S. | F.S. | Reading Number | I.S. | B.S. | F.S. | Reading Number | I.S. | B.S. | F.S. |
|----------------|------|------|------|----------------|------|------|------|----------------|------|------|------|
| 101            |      |      |      | 135            |      |      |      | 169            |      |      |      |
| 102            |      |      |      | 136            |      |      |      | 170            |      |      |      |
| 103            |      |      |      | 137            |      |      |      | 171            |      |      |      |
| 104            |      |      |      | 138            |      |      |      | 172            |      |      |      |
| 105            |      |      |      | 139            |      |      |      | 173            |      |      |      |
| 106            |      |      |      | 140            |      |      |      | 174            |      |      |      |
| 107            |      |      |      | 141            |      |      |      | 175            |      |      |      |
| 108            |      |      |      | 142            |      |      |      | 176            |      |      |      |
| 109            |      |      |      | 143            |      |      |      | 177            |      |      |      |
| 110            |      |      |      | 144            |      |      |      | 178            |      |      |      |
| 111            |      |      |      | 145            |      |      |      | 179            |      |      |      |
| 112            |      |      |      | 146            |      |      |      | 180            |      |      |      |
| 113            |      |      |      | 147            |      |      |      | 181            |      |      |      |
| 114            |      |      |      | 148            |      |      |      | 182            |      |      |      |
| 115            |      |      |      | 149            |      |      |      | 183            |      |      |      |
| 116            |      |      |      | 150            |      |      |      | 184            |      |      |      |
| 117            |      |      |      | 151            |      |      |      | 185            |      |      |      |
| 118            |      |      |      | 152            |      |      |      | 186            |      |      |      |
| 119            |      |      |      | 153            |      |      |      | 187            |      |      |      |
| 120            |      |      |      | 154            |      |      |      | 188            |      |      |      |
| 121            |      |      |      | 155            |      |      |      | 189            |      |      |      |
| 122            |      |      |      | 156            |      |      |      | 190            |      |      |      |
| 123            |      |      |      | 157            |      |      |      | 191            |      |      |      |
| 124            |      |      |      | 158            |      |      |      | 192            |      |      |      |
| 125            |      |      |      | 159            |      |      |      | 193            |      |      |      |
| 126            |      |      |      | 160            |      |      |      | 194            |      |      |      |
| 127            |      |      |      | 161            |      |      |      | 195            |      |      |      |
| 128            |      |      |      | 162            |      |      |      | 196            |      |      |      |
| 129            |      |      |      | 163            |      |      |      | 197            |      |      |      |
| 130            |      |      |      | 164            |      |      |      | 198            |      |      |      |
| 131            |      |      |      | 165            |      |      |      | 199            |      |      |      |
| 132            |      |      |      | 166            |      |      |      | 200            |      |      |      |
| 133            |      |      |      | 167            |      |      |      |                |      |      |      |
| 134            |      |      |      | 168            |      |      |      |                |      |      |      |

ht, F.S. = Foresight

Comments:



LTPP Rod and Level Data Collection Form  
 Longitudinal Profile Measurements  
 Form RL-3

LTPP Code [ \_ \_ ]  
 LTPP Section [ \_ \_ \_ \_ ]  
 Date (dd/mmm/yy) \_ \_ / \_ \_ \_ \_ / \_ \_

| Reading Number | I.S. | B.S. | F.S. | Reading Number | I.S. | B.S. | F.S. | Reading Number | I.S. | B.S. | F.S. |
|----------------|------|------|------|----------------|------|------|------|----------------|------|------|------|
| 201            |      |      |      | 235            |      |      |      | 269            |      |      |      |
| 202            |      |      |      | 236            |      |      |      | 270            |      |      |      |
| 203            |      |      |      | 237            |      |      |      | 271            |      |      |      |
| 204            |      |      |      | 238            |      |      |      | 272            |      |      |      |
| 205            |      |      |      | 239            |      |      |      | 273            |      |      |      |
| 206            |      |      |      | 240            |      |      |      | 274            |      |      |      |
| 207            |      |      |      | 241            |      |      |      | 275            |      |      |      |
| 208            |      |      |      | 242            |      |      |      | 276            |      |      |      |
| 209            |      |      |      | 243            |      |      |      | 277            |      |      |      |
| 210            |      |      |      | 244            |      |      |      | 278            |      |      |      |
| 211            |      |      |      | 245            |      |      |      | 279            |      |      |      |
| 212            |      |      |      | 246            |      |      |      | 280            |      |      |      |
| 213            |      |      |      | 247            |      |      |      | 281            |      |      |      |
| 214            |      |      |      | 248            |      |      |      | 282            |      |      |      |
| 215            |      |      |      | 249            |      |      |      | 283            |      |      |      |
| 216            |      |      |      | 250            |      |      |      | 284            |      |      |      |
| 217            |      |      |      | 251            |      |      |      | 285            |      |      |      |
| 218            |      |      |      | 252            |      |      |      | 286            |      |      |      |
| 219            |      |      |      | 253            |      |      |      | 287            |      |      |      |
| 220            |      |      |      | 254            |      |      |      | 288            |      |      |      |
| 221            |      |      |      | 255            |      |      |      | 289            |      |      |      |
| 222            |      |      |      | 256            |      |      |      | 290            |      |      |      |
| 223            |      |      |      | 257            |      |      |      | 291            |      |      |      |
| 224            |      |      |      | 258            |      |      |      | 292            |      |      |      |
| 225            |      |      |      | 259            |      |      |      | 293            |      |      |      |
| 226            |      |      |      | 260            |      |      |      | 294            |      |      |      |
| 227            |      |      |      | 261            |      |      |      | 295            |      |      |      |
| 228            |      |      |      | 262            |      |      |      | 296            |      |      |      |
| 229            |      |      |      | 263            |      |      |      | 297            |      |      |      |
| 230            |      |      |      | 264            |      |      |      | 298            |      |      |      |
| 231            |      |      |      | 265            |      |      |      | 299            |      |      |      |
| 232            |      |      |      | 266            |      |      |      | 300            |      |      |      |
| 233            |      |      |      | 267            |      |      |      |                |      |      |      |
| 234            |      |      |      | 268            |      |      |      |                |      |      |      |

ht, F.S. = Foresight

Comments:

LTPP Rod and Level Data Collection Form  
Longitudinal Profile Measurements  
Form RL-4

LTPP Code [ \_ \_ ]  
LTPP Section [ \_ \_ \_ \_ ]  
Date (dd/mmm/yy) \_ \_ / \_ \_ / \_ \_

| Reading Number | I.S. | B.S. | F.S. | Reading Number | I.S. | B.S. | F.S. | Reading Number | I.S. | B.S. | F.S. |
|----------------|------|------|------|----------------|------|------|------|----------------|------|------|------|
| 301            |      |      |      | 335            |      |      |      | 369            |      |      |      |
| 302            |      |      |      | 336            |      |      |      | 370            |      |      |      |
| 303            |      |      |      | 337            |      |      |      | 371            |      |      |      |
| 304            |      |      |      | 338            |      |      |      | 372            |      |      |      |
| 305            |      |      |      | 339            |      |      |      | 373            |      |      |      |
| 306            |      |      |      | 340            |      |      |      | 374            |      |      |      |
| 307            |      |      |      | 341            |      |      |      | 375            |      |      |      |
| 308            |      |      |      | 342            |      |      |      | 376            |      |      |      |
| 309            |      |      |      | 343            |      |      |      | 377            |      |      |      |
| 310            |      |      |      | 344            |      |      |      | 378            |      |      |      |
| 311            |      |      |      | 345            |      |      |      | 379            |      |      |      |
| 312            |      |      |      | 346            |      |      |      | 380            |      |      |      |
| 313            |      |      |      | 347            |      |      |      | 381            |      |      |      |
| 314            |      |      |      | 348            |      |      |      | 382            |      |      |      |
| 315            |      |      |      | 349            |      |      |      | 383            |      |      |      |
| 316            |      |      |      | 350            |      |      |      | 384            |      |      |      |
| 317            |      |      |      | 351            |      |      |      | 385            |      |      |      |
| 318            |      |      |      | 352            |      |      |      | 386            |      |      |      |
| 319            |      |      |      | 353            |      |      |      | 387            |      |      |      |
| 320            |      |      |      | 354            |      |      |      | 388            |      |      |      |
| 321            |      |      |      | 355            |      |      |      | 389            |      |      |      |
| 322            |      |      |      | 356            |      |      |      | 390            |      |      |      |
| 323            |      |      |      | 357            |      |      |      | 391            |      |      |      |
| 324            |      |      |      | 358            |      |      |      | 392            |      |      |      |
| 325            |      |      |      | 359            |      |      |      | 393            |      |      |      |
| 326            |      |      |      | 360            |      |      |      | 394            |      |      |      |
| 327            |      |      |      | 361            |      |      |      | 395            |      |      |      |
| 328            |      |      |      | 362            |      |      |      | 396            |      |      |      |
| 329            |      |      |      | 363            |      |      |      | 397            |      |      |      |
| 330            |      |      |      | 364            |      |      |      | 398            |      |      |      |
| 331            |      |      |      | 365            |      |      |      | 399            |      |      |      |
| 332            |      |      |      | 366            |      |      |      | 400            |      |      |      |
| 333            |      |      |      | 367            |      |      |      |                |      |      |      |
| 334            |      |      |      | 368            |      |      |      |                |      |      |      |

ht, F.S. = Foresight

Comments:

LTPP Rod and Level Data Collection Form  
Longitudinal Profile Measurements  
Form RL-5

LTPP Code [ \_ \_ ]  
LTPP Section [ \_ \_ \_ \_ ]  
Date (dd/mm/yy) \_ \_ / \_ \_ / \_ \_

| Reading Number | I.S. | B.S. | F.S. | Reading Number | I.S. | B.S. | F.S. | Reading Number | I.S. | B.S. | F.S. |
|----------------|------|------|------|----------------|------|------|------|----------------|------|------|------|
| 401            |      |      |      | 437            |      |      |      | 473            |      |      |      |
| 402            |      |      |      | 438            |      |      |      | 474            |      |      |      |
| 403            |      |      |      | 439            |      |      |      | 475            |      |      |      |
| 404            |      |      |      | 440            |      |      |      | 476            |      |      |      |
| 405            |      |      |      | 441            |      |      |      | 477            |      |      |      |
| 406            |      |      |      | 442            |      |      |      | 478            |      |      |      |
| 407            |      |      |      | 443            |      |      |      | 479            |      |      |      |
| 408            |      |      |      | 444            |      |      |      | 480            |      |      |      |
| 409            |      |      |      | 445            |      |      |      | 481            |      |      |      |
| 410            |      |      |      | 446            |      |      |      | 482            |      |      |      |
| 411            |      |      |      | 447            |      |      |      | 483            |      |      |      |
| 412            |      |      |      | 448            |      |      |      | 484            |      |      |      |
| 413            |      |      |      | 449            |      |      |      | 485            |      |      |      |
| 414            |      |      |      | 450            |      |      |      | 486            |      |      |      |
| 415            |      |      |      | 451            |      |      |      | 487            |      |      |      |
| 416            |      |      |      | 452            |      |      |      | 488            |      |      |      |
| 417            |      |      |      | 453            |      |      |      | 489            |      |      |      |
| 418            |      |      |      | 454            |      |      |      | 490            |      |      |      |
| 419            |      |      |      | 455            |      |      |      | 491            |      |      |      |
| 420            |      |      |      | 456            |      |      |      | 492            |      |      |      |
| 421            |      |      |      | 457            |      |      |      | 493            |      |      |      |
| 422            |      |      |      | 458            |      |      |      | 494            |      |      |      |
| 423            |      |      |      | 459            |      |      |      | 495            |      |      |      |
| 424            |      |      |      | 460            |      |      |      | 496            |      |      |      |
| 425            |      |      |      | 461            |      |      |      | 497            |      |      |      |
| 426            |      |      |      | 462            |      |      |      | 498            |      |      |      |
| 427            |      |      |      | 463            |      |      |      | 499            |      |      |      |
| 428            |      |      |      | 464            |      |      |      | 500            |      |      |      |
| 429            |      |      |      | 465            |      |      |      | 501            |      |      |      |
| 430            |      |      |      | 466            |      |      |      | 502            |      |      |      |
| 431            |      |      |      | 467            |      |      |      | 503            |      |      |      |
| 432            |      |      |      | 468            |      |      |      | 504            |      |      |      |
| 433            |      |      |      | 469            |      |      |      | 505            |      |      |      |
| 434            |      |      |      | 470            |      |      |      | 506            |      |      |      |
| 435            |      |      |      | 471            |      |      |      | 507            |      |      |      |
| 436            |      |      |      | 472            |      |      |      | 508            |      |      |      |

t, F.S. = Foresight

Comments:

## **APPENDIX I. FORMS FOR INTER-REGIONAL PROFILER COMPARISON TESTS**

|   |                    |
|---|--------------------|
| <b>PROFILE HEIGHT SENSORS - STATIC HEIGHT SENSOR MEASUREMENTS</b> | <b>FORM COMP-1</b> |
|---|--------------------|

RSC: \_\_\_\_\_  
 Date: \_\_\_\_\_

Value of Height (mm) when Device is on Ground      ODS1: \_\_\_\_\_ ODS2: \_\_\_\_\_ ODS3: \_\_\_\_\_  
 on a Level Surface:

**Left Sensor**

| Position                                       | Block Height (mm) |   |   |   |   |   | Avg. of Heights (mm) | Actual Block Height (mm) | Bias (Average-Actual) (mm) | Std Dev. of Heights (mm) (Note 1) |
|--|-------------------|---|---|---|---|---|----------------------|--------------------------|----------------------------|-----------------------------------|
|  | Sample Number     |   |   |   |   |   |                      |                          |                            |                                   |
|  | 1                 | 2 | 3 | 4 | 5 | 6 |                      |                          |                            |                                   |
| Block Height Measured by System - 25 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
| Block Height Measured by System - 50 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
| Block Height Measured by System - 75 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
| Block Height Measured by System - 100 mm Block |                   |   |   |   |   |   |                      |                          |                            |                                   |

**Center Sensor**

| Sensor, Sensor Position | Position                                       | Block Height (mm) |   |   |   |   |   | Avg. of Heights (mm) | Actual Block Height (mm) | Bias (Average-Actual) (mm) | Std Dev. of Heights (mm) (Note 1) |
|-------------------------|--|-------------------|---|---|---|---|---|----------------------|--------------------------|----------------------------|-----------------------------------|
|                         |  | Sample Number     |   |   |   |   |   |                      |                          |                            |                                   |
|                         |  | 1                 | 2 | 3 | 4 | 5 | 6 |                      |                          |                            |                                   |
|                         | Block Height Measured by System - 25 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
|                         | Block Height Measured by System - 50 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
|                         | Block Height Measured by System - 75 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
|                         | Block Height Measured by System - 100 mm Block |                   |   |   |   |   |   |                      |                          |                            |                                   |

**Right Sensor**

| Position                                       | Block Height (mm) |   |   |   |   |   | Avg. of Heights (mm) | Actual Block Height (mm) | Bias (Average-Actual) (mm) | Std Dev. of Heights (mm) (Note 1) |
|--|-------------------|---|---|---|---|---|----------------------|--------------------------|----------------------------|-----------------------------------|
|  | Sample Number     |   |   |   |   |   |                      |                          |                            |                                   |
|  | 1                 | 2 | 3 | 4 | 5 | 6 |                      |                          |                            |                                   |
| Block Height Measured by System - 25 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
| Block Height Measured by System - 50 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
| Block Height Measured by System - 75 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
| Block Height Measured by System - 100 mm Block |                   |   |   |   |   |   |                      |                          |                            |                                   |

Note 1: Calculate standard deviation using the STDEV.P function in Excel

|   |                    |
|---|--------------------|
| <b>TEXTURE HEIGHT SENSORS - STATIC HEIGHT SENSOR MEASUREMENTS</b> | <b>FORM COMP-2</b> |
|---|--------------------|

RSC: \_\_\_\_\_  
 Date: \_\_\_\_\_

Value of Height (mm) when Device is on Ground      ODS4: \_\_\_\_\_ ODS5: \_\_\_\_\_  
 on a Level Surface:

| Left Sensor | Position                                       | Block Height (mm) |   |   |   |   |   | Avg. of Heights (mm) | Actual Block Height (mm) | Bias (Average-Actual) (mm) | Std Dev. of Heights (mm) (Note 1) |
|-------------|--|-------------------|---|---|---|---|---|----------------------|--------------------------|----------------------------|-----------------------------------|
|             |  | Sample Number     |   |   |   |   |   |                      |                          |                            |                                   |
|             |  | 1                 | 2 | 3 | 4 | 5 | 6 |                      |                          |                            |                                   |
|             |  |                   |   |   |   |   |   |                      |                          |                            |                                   |
|             | Block Height Measured by System - 25 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
|             | Block Height Measured by System - 50 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
|             | Block Height Measured by System - 75 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
|             | Block Height Measured by System - 100 mm Block |                   |   |   |   |   |   |                      |                          |                            |                                   |

| Right Sensor | Position                                       | Block Height (mm) |   |   |   |   |   | Avg. of Heights (mm) | Actual Block Height (mm) | Bias (Average-Actual) (mm) | Std Dev. of Heights (mm) (Note 1) |
|--------------|--|-------------------|---|---|---|---|---|----------------------|--------------------------|----------------------------|-----------------------------------|
|              |  | Sample Number     |   |   |   |   |   |                      |                          |                            |                                   |
|              |  | 1                 | 2 | 3 | 4 | 5 | 6 |                      |                          |                            |                                   |
|              |  |                   |   |   |   |   |   |                      |                          |                            |                                   |
|              | Block Height Measured by System - 25 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
|              | Block Height Measured by System - 50 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
|              | Block Height Measured by System - 75 mm Block  |                   |   |   |   |   |   |                      |                          |                            |                                   |
|              | Block Height Measured by System - 100 mm Block |                   |   |   |   |   |   |                      |                          |                            |                                   |

Note 1: Calculate standard deviation using the STDEV.P function in Excel

|   |                    |
|---|--------------------|
| <b>ACCELEROMETER CALIBRATION CHECK, BOUNCE TEST, AND TEXTURE DYNAMIC CHECK FORM</b> | <b>FORM COMP-3</b> |
|---|--------------------|

|  |   |                                    |   |                                  |               |                                  |               |
|--|---|------------------------------------|---|----------------------------------|---------------|----------------------------------|---------------|
| Region                                 |   |                                    |   |                                  |               |                                  |               |
| <b>STATIC AND DYNAMIC BOUNCE CHECK</b> |   |                                    |   |                                  |               |                                  |               |
|  | Initial Static<br>Segment 2<br>IRI (m/km) | Dynamic<br>Segment 4<br>IRI (m/km) | Final Static<br>Segment 7<br>IRI (m/km) | IRI<br>Seg. 4 - Seg. 2<br>(m/km) | Pass<br>(Y/N) | IRI<br>Seg. 7 - Seg. 2<br>(m/km) | Pass<br>(Y/N) |
| LEFT (ODS 1)                           |   |                                    |   |                                  |               |                                  |               |
| RIGHT (ODS 2)                          |   |                                    |   |                                  |               |                                  |               |
| CENTER (ODS 3)                         |   |                                    |   |                                  |               |                                  |               |
| COMMENTS                               |   |                                    |   |                                  |               |                                  |               |

| ACCELEROMETER CALIBRATION |        |          |            |            |
|---------------------------|--------|----------|------------|------------|
| ACCELEROMETER             | ZERO G | NEG. 2 G | DIFFERENCE | PASS (Y/N) |
| Left-ODS 1                |        |          |            |            |
| Right-ODS 2               |        |          |            |            |
| Center-ODS 3              |        |          |            |            |
| COMMENTS                  |        |          |            |            |

| TEXTURE SENSOR CALIBRATION CHECK         |          |            |
|--|----------|------------|
| Performed with van on first step of ramp |          |            |
| Results From Static Test                 |          |            |
| SENSOR                                   | MPD (mm) | PASS (Y/N) |
| Left -Texture (ODS 4)                    |          |            |
| Right-Texture (ODS 5)                    |          |            |
| TEXTURE SENSOR CALIBRATION CHECK         |          |            |
| Performed with van on first step of ramp |          |            |
| Results From Dynamic Test                |          |            |
| SENSOR                                   | MPD (mm) | PASS (Y/N) |
| Left -Texture (ODS 4)                    |          |            |
| Right-Texture (ODS 5)                    |          |            |

|                              |                    |
|------------------------------|--------------------|
| <b>DMI MEASUREMENTS FORM</b> | <b>FORM COMP-4</b> |
|------------------------------|--------------------|

RSC \_\_\_\_\_

Date \_\_\_\_\_

Left Rear Tire Pressure Before Test (psi): \_\_\_\_\_

Right Rear Tire Pressure Before Test (psi): \_\_\_\_\_

Left Rear Tire Pressure After Last Run (psi): \_\_\_\_\_

Right Rear Tire Pressure After Last Run (psi): \_\_\_\_\_

Note: Calibrate DMI before performing DMI Measurements.

| Run Number | Air Temp. (°C) | Distance (m) |
|------------|----------------|--------------|
| 1          |                |              |
| 2          |                |              |
| 3          |                |              |
| 4          |                |              |
| 5          |                |              |
| 6          |                |              |
| Average    |                |              |
| Std Dev    |                |              |

Note 1: Use the STDEVP function in Excel to calculate Std.Deviation



|                              |                    |
|------------------------------|--------------------|
| <b>DMI VERIFICATION FORM</b> | <b>FORM COMP-5</b> |
|------------------------------|--------------------|

RSC \_\_\_\_\_

Date \_\_\_\_\_

Left Rear Tire Pressure Before Test (psi): \_\_\_\_\_

Right Rear Tire Pressure Before Test (psi): \_\_\_\_\_

Left Rear Tire Pressure After Last Run (psi): \_\_\_\_\_

Right Rear Tire Pressure After Last Run (psi): \_\_\_\_\_

Note: Do Not Calibrate DMI before performing Measurements.

| Run Number | Air Temp. (°C) | Distance (m) |
|------------|----------------|--------------|
| 1          |                |              |
| 2          |                |              |
| 3          |                |              |
| 4          |                |              |
| 5          |                |              |
| 6          |                |              |
| Average    |                |              |
| Std Dev    |                |              |

Note 1: Use the STDEVP function in Excel to calculate Std.Deviation

| IRI VALUES | FORM COMP-6 |
|------------|-------------|
|------------|-------------|

#### Left Wheelpath

| Site Number   | Site Description | Left Wheelpath, Runs and IRI |  |  |  |  | Average IRI (m/km) | Standard Deviation of IRI (m/km) |
|---------------|------------------|------------------------------|--|--|--|--|--------------------|----------------------------------|
| 1, Smooth AC  | Runs             |                              |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                              |  |  |  |  |                    |                                  |
| 2, Rough AC   | Runs             |                              |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                              |  |  |  |  |                    |                                  |
| 3, Smooth PCC | Runs             |                              |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                              |  |  |  |  |                    |                                  |
| 4, Rough PCC  | Runs             |                              |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                              |  |  |  |  |                    |                                  |
| 5, Chip Seal  | Runs             |                              |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                              |  |  |  |  |                    |                                  |

#### Right Wheelpath

| Site Number   | Site Description | Right Wheelpath, Runs and IRI |  |  |  |  | Average IRI (m/km) | Standard Deviation of IRI (m/km) |
|---------------|------------------|-------------------------------|--|--|--|--|--------------------|----------------------------------|
| 1, Smooth AC  | Runs             |                               |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                               |  |  |  |  |                    |                                  |
| 2, Rough AC   | Runs             |                               |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                               |  |  |  |  |                    |                                  |
| 3, Smooth PCC | Runs             |                               |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                               |  |  |  |  |                    |                                  |
| 4, Rough PCC  | Runs             |                               |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                               |  |  |  |  |                    |                                  |
| 5, Chip Seal  | Runs             |                               |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                               |  |  |  |  |                    |                                  |

#### Center

| Site Number   | Site Description | Center Lane, Runs and IRI |  |  |  |  | Average IRI (m/km) | Standard Deviation of IRI (m/km) |
|---------------|------------------|---------------------------|--|--|--|--|--------------------|----------------------------------|
| 1, Smooth AC  | Runs             |                           |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                           |  |  |  |  |                    |                                  |
| 2, Rough AC   | Runs             |                           |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                           |  |  |  |  |                    |                                  |
| 3, Smooth PCC | Runs             |                           |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                           |  |  |  |  |                    |                                  |
| 4, Rough PCC  | Runs             |                           |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                           |  |  |  |  |                    |                                  |
| 5, Chip Seal  | Runs             |                           |  |  |  |  |                    |                                  |
|               | IRI (m/km)       |                           |  |  |  |  |                    |                                  |

|                   |                    |
|-------------------|--------------------|
| <b>MPD VALUES</b> | <b>FORM COMP-7</b> |
|-------------------|--------------------|

**Left Wheelpath**

| Site Number   | Site Description | Left Wheelpath, Runs and MPD |  |  |  |  | Average MPD (mm) | Standard Deviation of MPD (mm) |
|---------------|------------------|------------------------------|--|--|--|--|------------------|--------------------------------|
| 1, Smooth AC  | Runs             |                              |  |  |  |  |                  |                                |
|               | MPD (mm)         |                              |  |  |  |  |                  |                                |
| 2, Rough AC   | Runs             |                              |  |  |  |  |                  |                                |
|               | MPD (mm)         |                              |  |  |  |  |                  |                                |
| 3, Smooth PCC | Runs             |                              |  |  |  |  |                  |                                |
|               | MPD (mm)         |                              |  |  |  |  |                  |                                |
| 4, Rough PCC  | Runs             |                              |  |  |  |  |                  |                                |
|               | MPD (mm)         |                              |  |  |  |  |                  |                                |
| 5, Chip Seal  | Runs             |                              |  |  |  |  |                  |                                |
|               | MPD (mm)         |                              |  |  |  |  |                  |                                |

**Right Wheelpath**

| Site Number   | Site Description | Right Wheelpath, Runs and MPD |  |  |  |  | Average MPD (mm) | Standard Deviation of MPD (mm) |
|---------------|------------------|-------------------------------|--|--|--|--|------------------|--------------------------------|
| 1, Smooth AC  | Runs             |                               |  |  |  |  |                  |                                |
|               | MPD (mm)         |                               |  |  |  |  |                  |                                |
| 2, Rough AC   | Runs             |                               |  |  |  |  |                  |                                |
|               | MPD (mm)         |                               |  |  |  |  |                  |                                |
| 3, Smooth PCC | Runs             |                               |  |  |  |  |                  |                                |
|               | MPD (mm)         |                               |  |  |  |  |                  |                                |
| 4, Rough PCC  | Runs             |                               |  |  |  |  |                  |                                |
|               | MPD (mm)         |                               |  |  |  |  |                  |                                |
| 5, Chip Seal  | Runs             |                               |  |  |  |  |                  |                                |
|               | MPD (mm)         |                               |  |  |  |  |                  |                                |