

# LTPP Manual for Collecting and Processing Longitudinal Profile, Macrotexture, and Transverse Profile Data

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## FOREWORD

This manual describes operational procedures for collecting longitudinal profile, macrotexture, and transverse profile data for the Long-Term Pavement Performance (LTPP) program. The 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 data collected at the test sections are stored in the LTPP Pavement Performance Database and made available on LTPP InfoPave™. These data are being used and will continue to be used to achieve the goal and objectives of the LTPP program.

Described in this manual are procedures for calibrating equipment, performing calibration checks on the equipment, collecting data, keeping records, and maintaining equipment for each of these devices. In addition, this manual describes procedures for processing longitudinal profile, macrotexture, and transverse profile data. This manual also addresses guidelines for performing comparison tests with other longitudinal profiling devices. This manual will be of interest to highway agency engineers and equipment operators involved in the collection and processing of data used to characterize the pavement surface.

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16. Abstract This manual describes operational procedures for collecting longitudinal profile, macrottexture, and transverse profile data for the Long-Term Pavement Performance program using a High-Speed Survey Vehicle. This manual also contains procedures for measuring the longitudinal and transverse profiles of the pavement using a Dipstick® and the longitudinal profile of the pavement using a rod and level. Procedures for calibrating equipment, performing calibration checks on the equipment, data collection, recordkeeping, and maintaining equipment for each of these devices are described in this manual. In addition, this manual describes procedures for processing longitudinal profile, macrottexture, and transverse profile data.			
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## SI\* (MODERN METRIC) CONVERSION FACTORS

### APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
<b>LENGTH</b>				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
<b>AREA</b>				
in <sup>2</sup>	square inches	645.2	square millimeters	mm <sup>2</sup>
ft <sup>2</sup>	square feet	0.093	square meters	m <sup>2</sup>
yd <sup>2</sup>	square yard	0.836	square meters	m <sup>2</sup>
ac	acres	0.405	hectares	ha
mi <sup>2</sup>	square miles	2.59	square kilometers	km <sup>2</sup>
<b>VOLUME</b>				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft <sup>3</sup>	cubic feet	0.028	cubic meters	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.765	cubic meters	m <sup>3</sup>
NOTE: volumes greater than 1,000 L shall be shown in m <sup>3</sup>				
<b>MASS</b>				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
<b>TEMPERATURE (exact degrees)</b>				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
<b>ILLUMINATION</b>				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m <sup>2</sup>	cd/m <sup>2</sup>
<b>FORCE and PRESSURE or STRESS</b>				
lbf	poundforce	4.45	newtons	N
lbf/in <sup>2</sup>	poundforce per square inch	6.89	kilopascals	kPa

### APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
<b>LENGTH</b>				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
<b>AREA</b>				
mm <sup>2</sup>	square millimeters	0.0016	square inches	in <sup>2</sup>
m <sup>2</sup>	square meters	10.764	square feet	ft <sup>2</sup>
m <sup>2</sup>	square meters	1.195	square yards	yd <sup>2</sup>
ha	hectares	2.47	acres	ac
km <sup>2</sup>	square kilometers	0.386	square miles	mi <sup>2</sup>
<b>VOLUME</b>				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m <sup>3</sup>	cubic meters	35.314	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	cubic meters	1.307	cubic yards	yd <sup>3</sup>
<b>MASS</b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
<b>TEMPERATURE (exact degrees)</b>				
°C	Celsius	1.8C+32	Fahrenheit	°F
<b>ILLUMINATION</b>				
lx	lux	0.0929	foot-candles	fc
cd/m <sup>2</sup>	candela/m <sup>2</sup>	0.2919	foot-Lamberts	fl
<b>FORCE and PRESSURE or STRESS</b>				
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in <sup>2</sup>

\*SI is the symbol for International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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## LIST OF ACRONYMS

AC	asphalt concrete
AIMS	Ancillary Information Management System
ARD	Ames Raw Data
CCD	charge-coupled device
CSV	comma-separated value
DAU	data acquisition unit
DCC	data collection contractor
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
HSSV	high-speed survey vehicle
ICC	International Cybernetics Corporation
IRI	International Roughness Index
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
PCC	portland cement concrete
PPDB	Pavement Performance Database
PPF	Standard Specification for Data Format for Pavement Profile
PROFPR	Longitudinal Profile/Texture/Transverse Profile Problem Report
PSD	power spectral density
PSM	profile system monitor
RMSVA	root-mean-square vertical acceleration
RSC	regional support contractor
SHRP	Strategic Highway Research Program
SPS	Specific Pavement Studies
SV	slope variance
TPMS	Transverse Profile Measuring System
TPS	Transverse Profiling System
TSSC	technical support services contractor
WAAS	Wide Area Augmentation System
WIM	weigh-in-motion

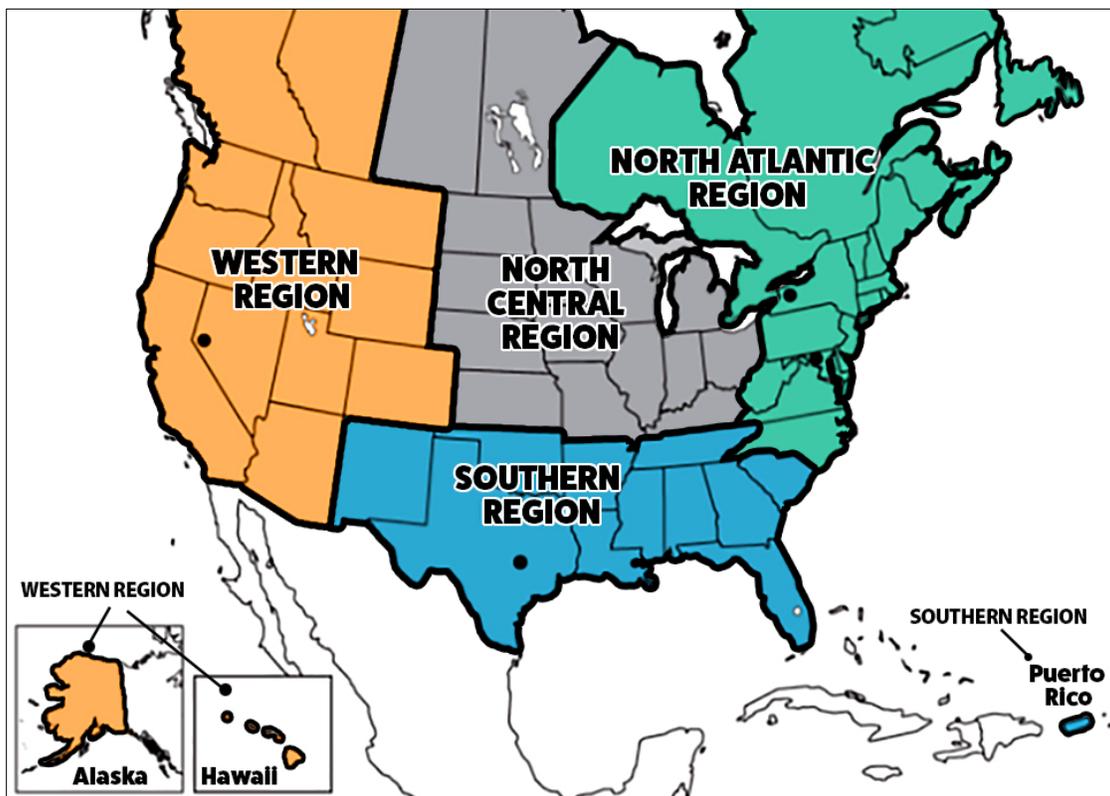


## CHAPTER 1. INTRODUCTION

### 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 study how and why pavements perform as they do by collecting pavement performance data using standard data collection procedures and protocols on a variety of pavement types. This information is stored in a database that pavement engineers and researchers worldwide can use to advance the science of pavement engineering.

From the start of the LTPP program until 2018, when FHWA awarded a contract to a data collection contractor (DCC) to collect data at all LTPP test sections, the United States and participating Canadian provinces were subdivided into four regions—North Atlantic, North Central, Southern, and Western—for purposes of pavement data collection and coordination, each served by a regional support contractor (RSC). Figure 1 shows the jurisdictional boundaries of each RSC.



Source: FHWA.

Figure 1. Map. LTPP regions.

## 1.2 SIGNIFICANCE OF PAVEMENT PROFILE MEASUREMENTS

The longitudinal pavement profile along the wheel paths 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 over time, is an important indicator of pavement performance. Hence, one aspect of the LTPP program is to collect longitudinal 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

Data collectors primarily use road profilers to obtain longitudinal pavement profile measurements on test sections for the LTPP program. Each RSC operated a profiler to collect longitudinal data within its region until FHWA awarded the DCC the contract to collect data at all test sections in 2018. From June 1989 to November 1996, longitudinal profile data at test sections were collected using a model DNC 690 inertial profiler. In December 1996, each RSC replaced their model DNC 690 with a model T-6600. In September 2002, each RSC replaced their model T-6600 with a model MDR 4086L3 inertial profiler. In April 2013, each RSC replaced their model MDR 4086L3 with a model 8300 inertial profiler.<sup>(1)</sup> In addition to longitudinal profile data collection equipment, the model 8300 is equipped with texture lasers to collect macrotexture data along the wheel paths, sensors to measure pavement surface temperature and 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 longitudinal profile data for the LTPP program did not have the capability to collect the aforementioned data elements, except for ambient temperature. A transverse profile measuring system (TPMS) was added to model 8300 in late 2018, and transverse profile data collection at LTPP test sections was initiated in May 2019. The data collection equipment used in the LTPP program to collect longitudinal profile, macrotexture, and transverse profile data is referred to as a high-speed survey vehicle (HSSV) in this manual. Before the HSSVs were equipped with a TPMS, transverse profile data at LTPP test sections were collected using a hand-operated digital profiler called Dipstick®. When an HSSV is not available, Dipstick is used as a backup. A rod and level can also be used to measure longitudinal profiles if an HSSV or Dipstick is not available or under certain circumstances where using an HSSV or Dipstick is impractical.

The DCC is responsible for the operation and maintenance of the four FHWA HSSVs and storage of the collected data. The HSSV identification numbers are as follows:

- 830112
- 830212
- 830312
- 830412

## **1.4 OVERVIEW OF THE MANUAL**

This manual describes procedures for measuring longitudinal pavement profiles for the LTPP program using an HSSV, Dipstick, and rod and level, as well as for collecting macrotexture and transverse profile data using an HSSV and transverse profile data using a Dipstick. Procedures for checking the proper functioning of the equipment used to collect data, calibrating equipment, data collection, recordkeeping, and maintaining equipment for each of the devices are also described in this manual. In addition, this manual describes procedures for processing longitudinal profile, transverse profile, and macrotexture data collected in the field.

Guidelines for performing comparison tests among the four FHWA HSSVs to evaluate the collected data are also described in this manual. This manual addresses those aspects of longitudinal profile, macrotexture, and transverse profile 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. LONGITUDINAL PROFILE, MACROTEXTURE, AND TRANSVERSE PROFILE MEASUREMENTS USING THE LTPP HIGH-SPEED SURVEY VEHICLE**

### **2.1 INTRODUCTION**

The LTPP HSSV uses a full-sized van as the host vehicle.<sup>(2)</sup> The HSSV is equipped with specialized instruments to simultaneously measure and record longitudinal profile data, surface macrotexture data, and transverse profiles of the pavement during data collection. The HSSV 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 HSSV 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 and macrotexture data are collected along the same path. The TPMS consists of a laser, camera, and associated equipment and is center-mounted on the rear of the vehicle. 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 vehicle. This laptop computer controls all data collection activities. All data collected by the HSSV in a single run are saved onto one file and stored in this laptop computer.

Profile height sensors measure the distance from the sensor to the road, while 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 longitudinal 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 longitudinal profile data are stored. These data can be post-processed to obtain macrotexture data at 0.5-mm intervals.

The TPMS collects transverse profile data along a 3.96-m width at approximately 25-mm intervals. The data collection and recording interval is not exactly 25 mm, but very close. The TPMS collects 2,048 data points along this 3.96-m width, providing a data point every 1.93 mm. Data collected by the TPMS are recorded in the same data file where the longitudinal profile and macrotexture data are stored.

The HSSV is equipped with two photocells that are mounted on the sensor bar. One photocell is mounted vertically to sense reflections from preplaced marks on the road surface, while the other is mounted horizontally on the passenger side of the vehicle to 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 HSSV is also equipped with a GPSR and sensors to measure the ambient and pavement surface temperature. In addition, the HSSV 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 air conditioner to provide a uniform temperature for the electronic equipment inside the vehicle. The HSSV can measure longitudinal profiles and collect macrotexture and transverse profile data on a pavement at speeds ranging from 10 to 112 km/h. The test speed normally used to collect data at LTPP sections is 80 km/h.

## **2.2 OVERVIEW OF THE COMPONENTS IN THE HSSV**

This section presents an overview of the various components included in the HSSV. Most of the information presented in this section was obtained from the manufacturer's User Manual and documents provided during the training session. (See references 3, 4, 5, and 6.) These documents should be consulted for additional details about the components.

### **2.2.1 Sensor Bar**

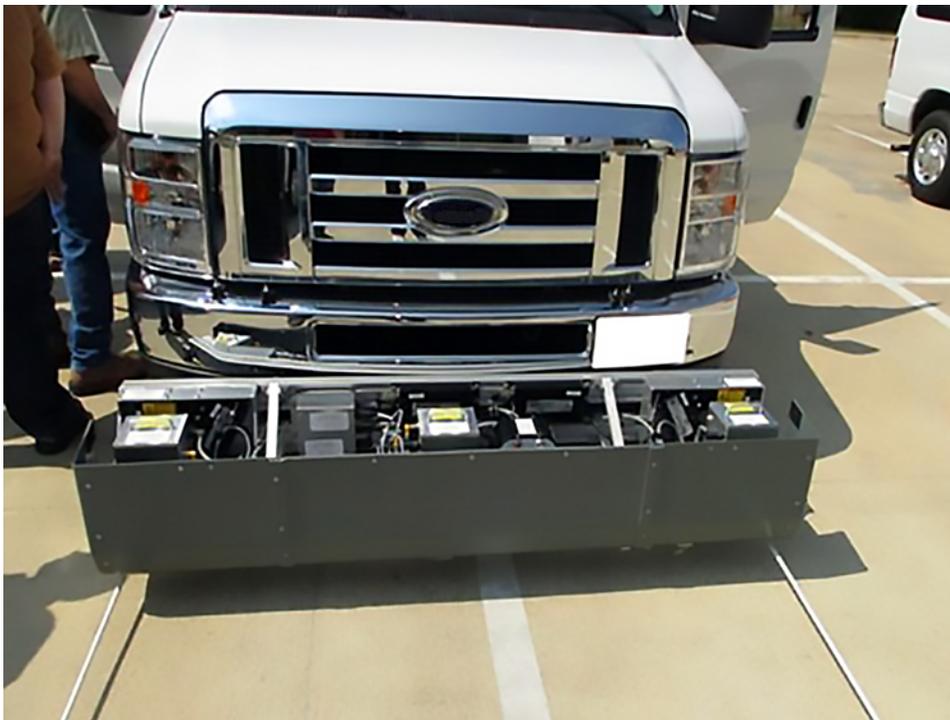
A sensor bar is mounted on the front of the vehicle and houses the three profile height sensors, the accelerometers located on top of each profile height sensor, the two texture height sensors and associated controllers, the interface box for processing macrotexture data, the vertical and horizontal photocells, and the data acquisition unit (DAU). The sensor bar is 1.825 m long and 0.37 m wide.<sup>(5)</sup>

The sensor bar has a cover 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.<sup>(4)</sup> 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 inside the sensor bar is presented later in this chapter.



Source: FHWA.

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

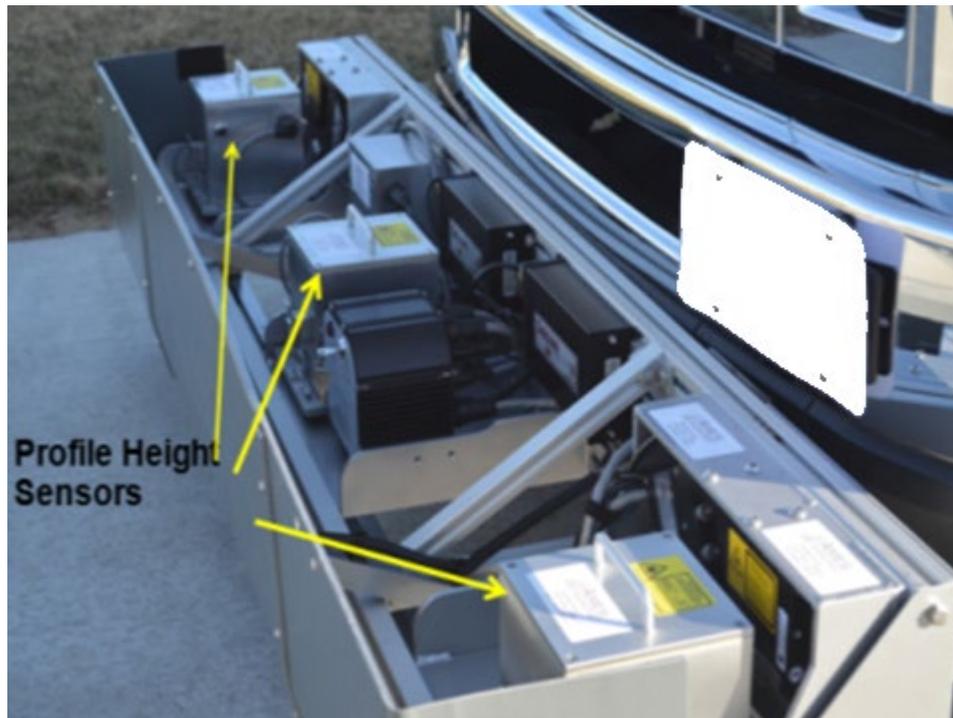


Source: FHWA.

**Figure 3. Photo. Sensor bar with the cover open.**

## 2.2.2 Profile Height Sensors and Accelerometers

Three laser sensors that collect elevation data to compute the longitudinal profile are located inside the sensor bar (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.<sup>(4)</sup> The profile height sensors are designated as SLS5000 200/300-RO.<sup>(4)</sup> 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.<sup>(5)</sup> The closest distance the sensor can see from the sensor glass is 200 mm, and the furthest distance is 400 mm. The stand-off height of 300 mm is the centerpoint of the sensor's range and should be approximately at the ground surface. The profile height sensors are rated as 16-kHz lasers.<sup>(5)</sup>



Source: FHWA.

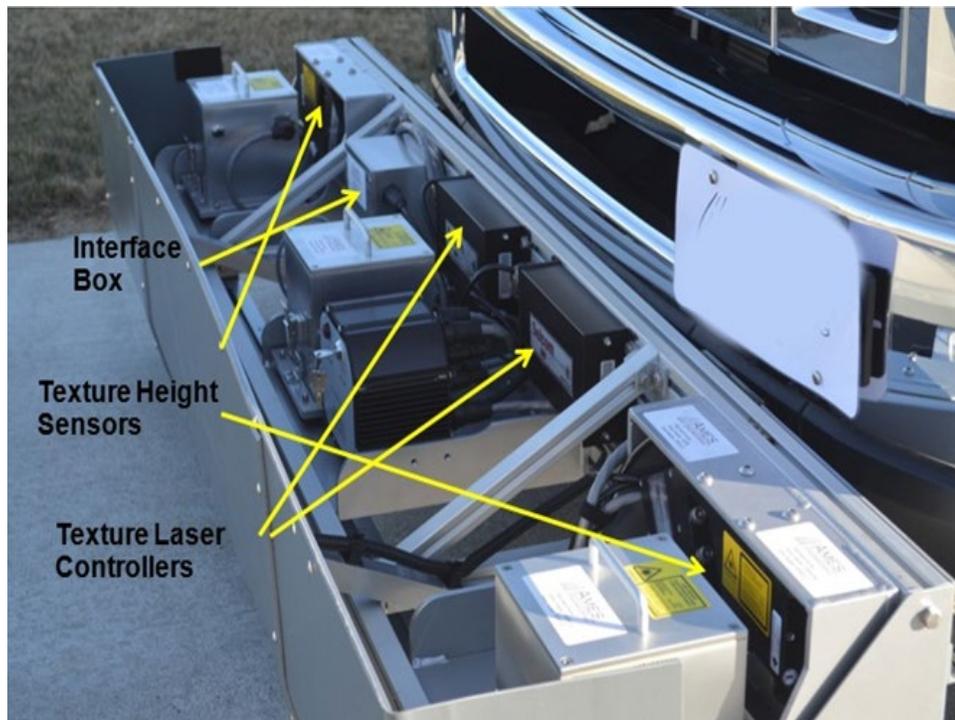
**Figure 4. Photo. Profile height sensors.**

The laser 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.<sup>(5)</sup> 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 ODS 1 (left wheel path), ODS 2 (right wheel path) and ODS 3 (center sensor). Each height sensor is housed inside a customized box that 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 able to be read (not upside down) when standing in front of the vehicle.

An accelerometer is located inside the customized box on top of each profile height sensor to measure accelerations, capable of measuring between  $\pm 5$  g. Circuit boards located within each sensor box process the data collected by the height sensor and accelerometer and combine these data elements with the DMI data to compute the longitudinal profile in real time. Real-time longitudinal profile data are not computed in the HSSV's laptop computer; circuit boards inside each sensor box compute the real-time longitudinal profile data.

### 2.2.3 Texture Height Sensors and Control Units

The HSSV is equipped with two laser sensors that collect macrotexture data (figure 5). These sensors are mounted directly behind the left and right profile height sensors such that the longitudinal 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 sensor glass is 300 mm, and the furthest 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.<sup>(4)</sup> The texture height sensors are referred to as ODS 4 (left wheel path sensor) and ODS 5 (right wheel path sensor).



Source: FHWA.

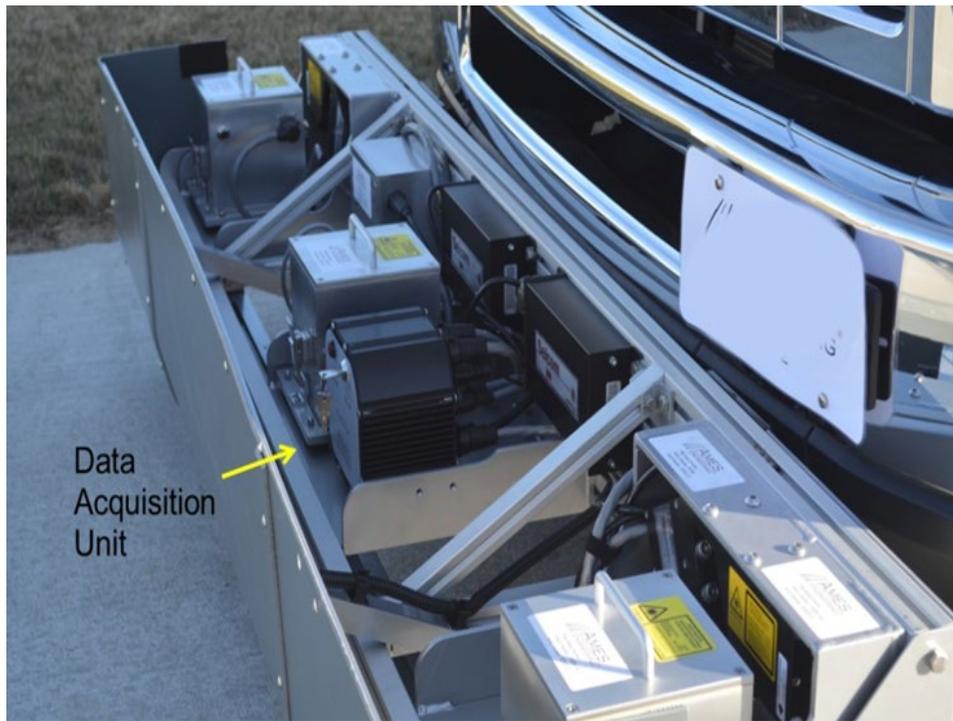
**Figure 5. Photo. Equipment associated with macrotexture data collection.**

The texture sensor consists of two major parts, the sensor head and the probe processing unit, which is referred to as the controller in this document. The sensor 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 texture sensor. 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 longitudinal profile data are stored.<sup>(5)</sup>

### 2.2.4 DAU

The DAU is mounted next to the center profile height sensor (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, two photocells, and GPSR. Data collected by each profile height sensor, the accelerometer associated with that sensor, and the computed longitudinal profile are input into a port on 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 on the DAU.<sup>(4)</sup>



Source: FHWA.

**Figure 6. Photo. DAU.**



Source: FHWA.

**Figure 7. Photo. Ports on the DAU.**

The computer cards in each sensor box independently process 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 then are transferred to the laptop computer for permanent storage.<sup>(4)</sup>

The front of the DAU has a power on/off switch and a key (figure 8). The power to all components associated with longitudinal profile and macrotexture data collection in the HSSV is turned on by using the power switch (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 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.



Source: FHWA.

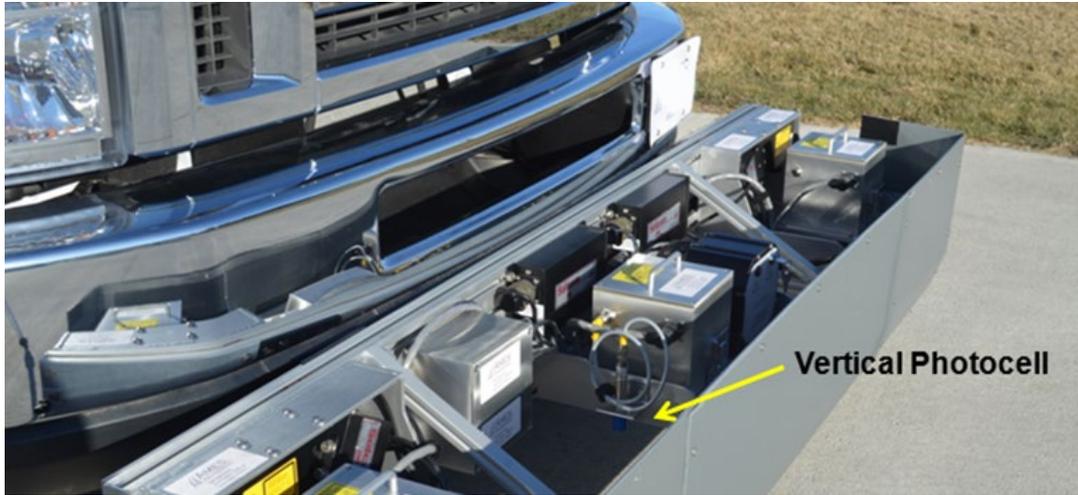
**Figure 8. Photo. Front view of the DAU.**

### **2.2.5 Photocells**

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

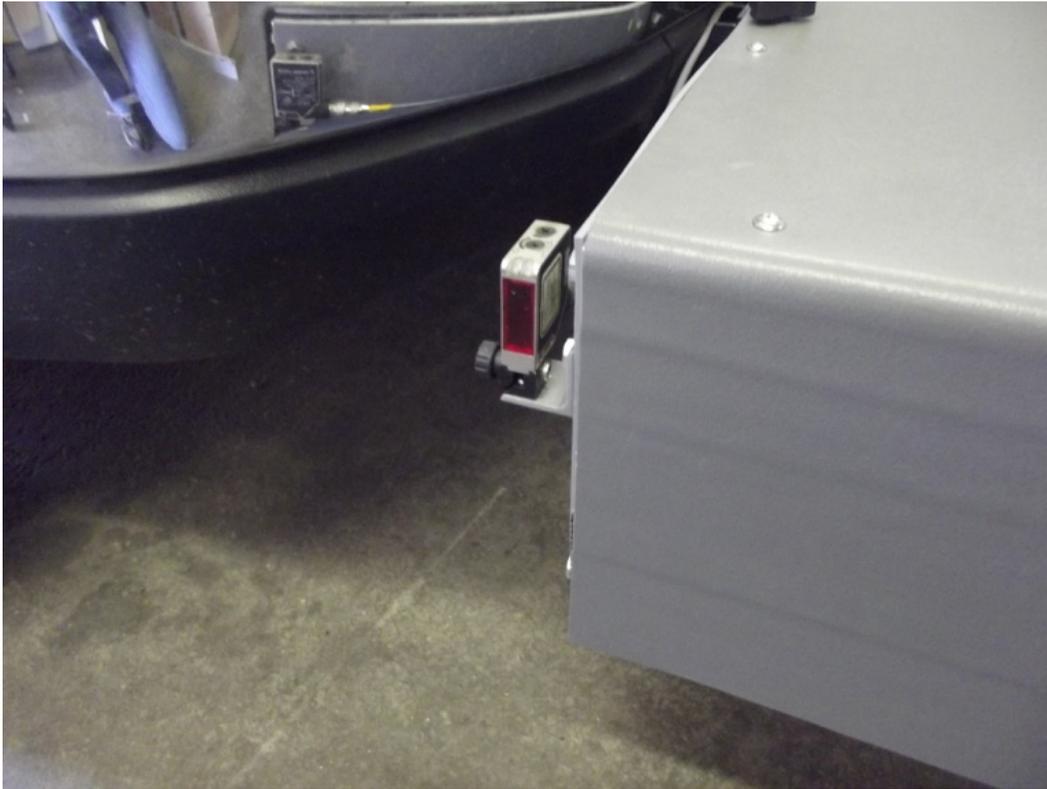
The vertical photocell is mounted at the center of the sensor bar. The horizontal photocell is mounted at the edge of the sensor bar on the passenger side. A cable connects the vertical photocell to the center sensor box and the horizontal photocell to the right wheel path sensor box. The vertical photocell can trigger off duct tape. The horizontal photocell triggers off reflective tape that is placed on a cone. Two cones with reflective tape were provided with each HSSV.<sup>(4)</sup>

Figure 11 shows a cone with reflective tape. Manufacturers' literature indicates the horizontal photocell has a 15-m range and a recommendation on the type of tape to use on the cone.<sup>(5)</sup>



Source: FHWA.

**Figure 9. Photo. Vertical photocell.**



Source: FHWA.

**Figure 10. Photo. Horizontal photocell.**



Source: FHWA.

**Figure 11. Photo. Cone with reflective tape.**

### **2.2.6 DMI**

A DMI encoder that transmits 500 pulses per revolution is installed on the left rear wheel of the vehicle (figure 12). This DMI is a quadrature output signal device, and a microcontroller installed in the DAU analyzes the signal using 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 removed from the wheel by removing the four nuts. A harness runs from the encoder to an input connected to the fender (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 (figure 14).<sup>(4)</sup>

If the short cable that connects the encoder to the fender is damaged, and a backup 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 rout the cable too close to the tire in the process. It is recommended by FHWA that the DMI be removed from the wheel on days when the HSSV is in transit with no testing being performed.<sup>(4)</sup>



Source: FHWA.

**Figure 12. Photo. DMI encoder.**



Source: FHWA.

**Figure 13. Photo. DMI input connection.**



Source: FHWA.

**Figure 14. Photo. Cap to protect input when the DMI is disassembled.**

### **2.2.7 GPSR**

A GPSR is installed on the vehicle within the light bar (figure 15). The GPSR has Wide Area Augmentation System (WAAS) differential global positioning system capability. 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.<sup>(5)</sup> The earth datum in the GPSR is programmable and has been set to WGS84 (an Earth-centered, Earth-fixed terrestrial reference system and geodetic datum). 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. Data are stored in same data file where the longitudinal profile and macrotexture data are stored.<sup>(4)</sup>



Source: FHWA.

**Figure 15. Photo. Location of the GPSR.**

### **2.2.8 Ambient Temperature Sensor**

An ambient temperature sensor is located within a protective shield mounted on the rear driver's side of the vehicle (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 located inside the left rear taillight. The left rear taillight 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 system monitor (PSM) located within the equipment rack inside the vehicle. An Ethernet cable carries 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 1-s intervals. All obtained data are stored in the same data file where the longitudinal profile and macrotexture data are stored.<sup>(4)</sup>



Source: FHWA.

**Figure 16. Photo. Protective shield housing the ambient temperature sensor.**

### **2.2.9 Pavement Surface Temperature Sensor**

A non-contact infrared temperature sensor that measures the pavement surface temperature is mounted to the bottom of the vehicle on the rear driver's side. The temperature sensor is mounted within a polyvinyl chloride structure for protection from road debris and other contaminants. A protection window was installed below the lens of the sensor to protect the lens from damage. This protection window can crack if it has been installed too tightly, so it 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 ambient 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 degrees when temperature measurements are needed. Figure 17 and figure 18, respectively, show the protective cover in place and the protective cover rotated by 90 degrees to obtain pavement surface temperature measurements.<sup>(5)</sup>



Source: FHWA.

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



Source: FHWA.

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

A cable carries the outputs from the pavement surface temperature sensor to the controller located on the equipment rack inside the vehicle. The output from the controller is fed into the PSM, which is also located inside the equipment rack. An Ethernet cable carries data from the PSM to the router and from the router 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. These data are stored in the same data file where the longitudinal profile and macrotexture data are stored.<sup>(4)</sup>

### **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 (figure 19), a directional warning light bar mounted on the rear of the vehicle (figure 20), and LED strobe lights mounted inside the headlights and taillights of the vehicle.



Source: FHWA.

**Figure 19. Photo. Light bar on the front of the vehicle.**



Source: FHWA.

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

The front light bar is 1.6 m in length. The rear directional warning light is 1.15 m in length and has eight lamps. Strobe lights are mounted inside the headlights and taillights.<sup>(4)</sup>

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

The following safety lighting is controlled by each switch:

- 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.



Source: FHWA.

**Figure 21. Photo. 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.<sup>(4)</sup>

The controller for the directional warning light is mounted on the right side of the base of the driver’s seat. The controller has a Low/Off/High position switch and a rotary switch to control the flash pattern (figure 22). The “Low” position should be used for nighttime operations, while the “High” position should be used for daytime operations.<sup>(4)</sup>



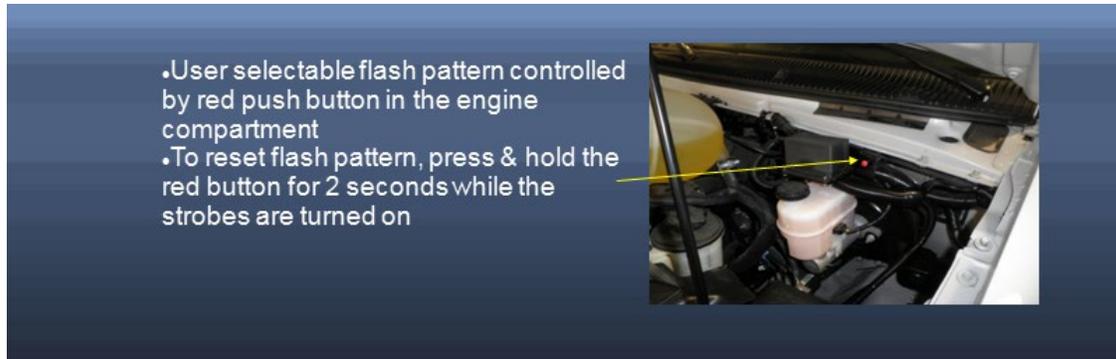
Source: FHWA.

**Figure 22. Photo. Control switch for directional warning light.**

The rotary switch has the following four positions:

- Left—the lights flash from right to left.
- Right—the lights flash from left to right.
- Split—the lights start from center and go toward both the left and right side.
- Flash—the lights flash continuously.

The flash pattern of the strobe lights can be changed by pressing the red button inside the engine compartment while the strobe lights are turned on (figure 23). Two people 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 2 s.

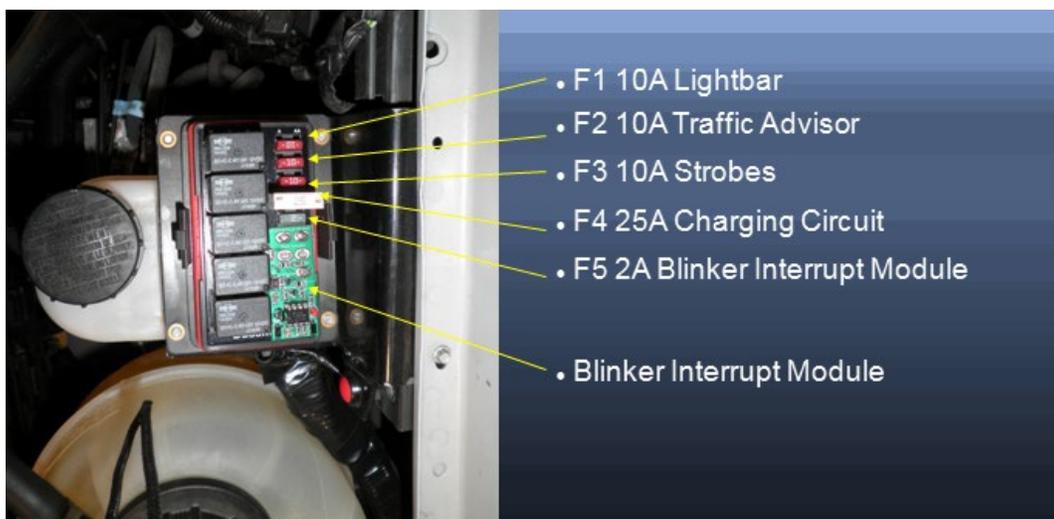


Source: FHWA.

**Figure 23. Photo. 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 5 s after the turn signal is disabled.<sup>(4)</sup>

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



Source: FHWA.

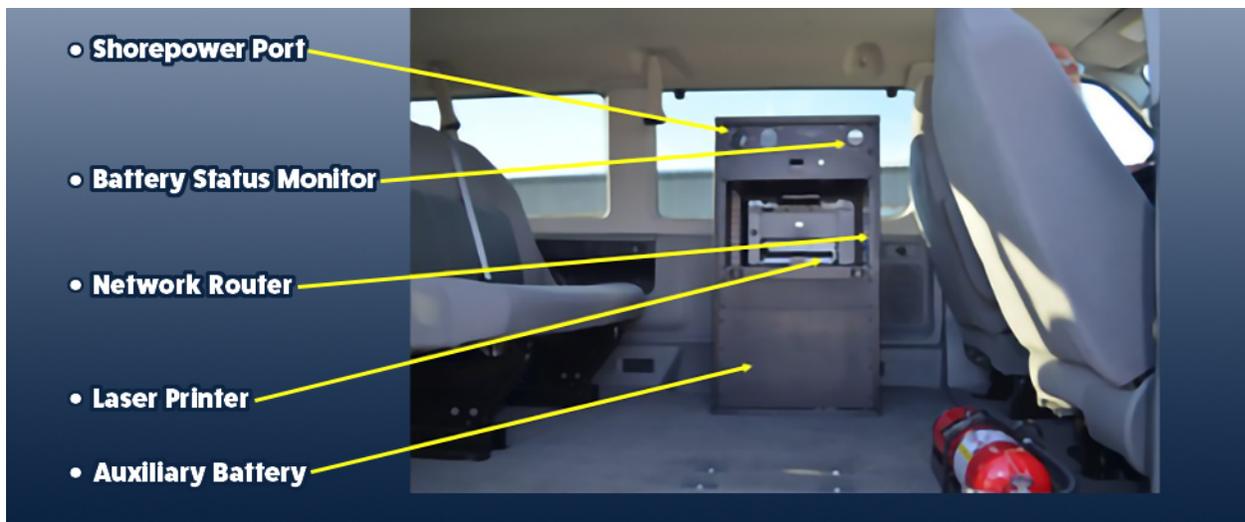
**Figure 24. Photo. Fuse and relay junction box of the safety lighting system.**

### 2.2.11 Equipment Rack

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

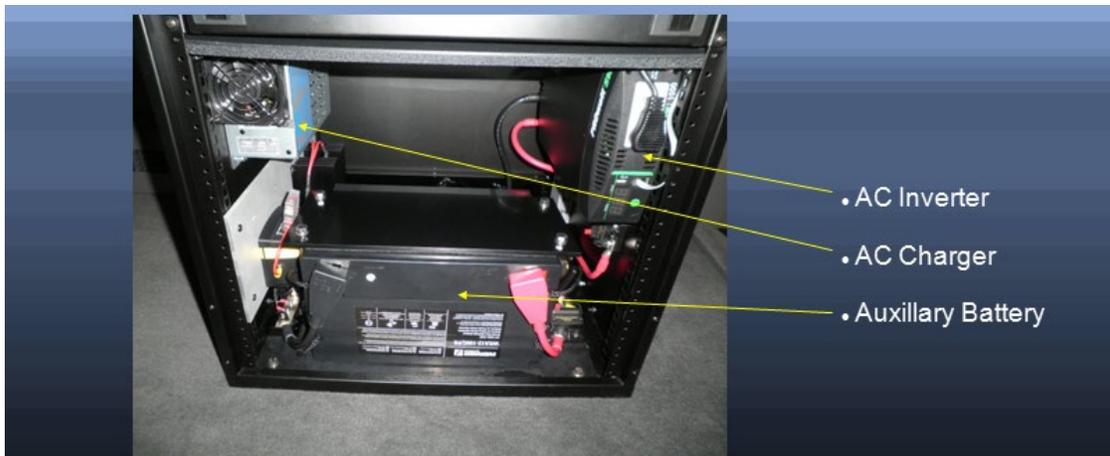
- Shore power port.
- Auxiliary battery.
- Auxiliary battery charger.
- Auxiliary battery status monitor.
- Inverter.
- Laser printer.
- Buzzer.
- PSM module.
- Network router.
- Circuit breakers.

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.



Source: FHWA.

**Figure 25. Photo. Front view of the equipment rack.**



Source: FHWA.

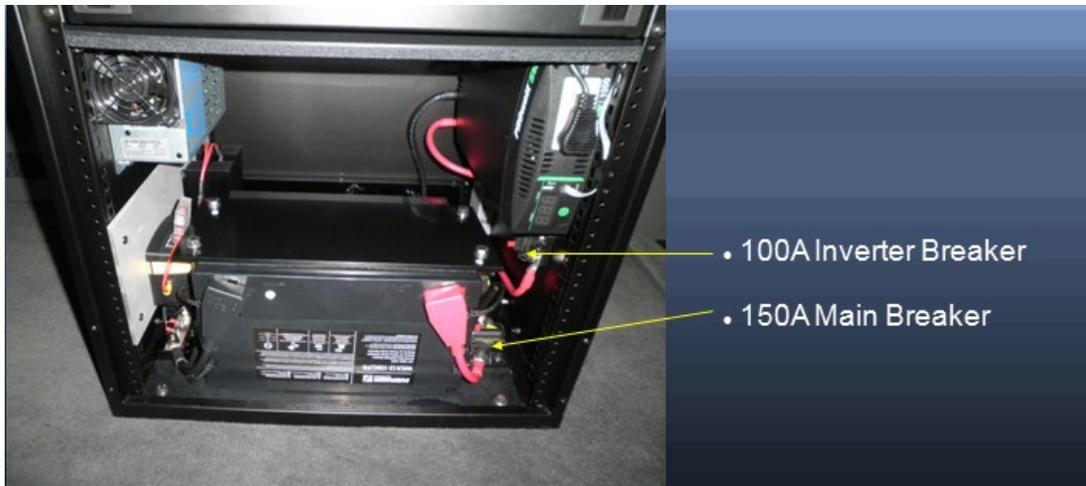
AC = alternating current.

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

Details about the components housed on or inside the equipment rack include the following:

- 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 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 charges and maintains 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.<sup>(4)</sup>
- 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.<sup>(4)</sup>
- Auxiliary battery status monitor—the auxiliary battery status monitor on the equipment rack shows the voltage of the auxiliary battery.<sup>(4)</sup>
- Inverter—a sine wave inverter 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 1,000 W. The inverter is turned on by a push button at the top of the rack.<sup>(4)</sup>

- Laser printer—a laserjet printer is located inside the equipment rack.<sup>(4)</sup>
- 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 test section. When profiling Specific Pavement Studies (SPS) sections, the buzzer will emit a single, short chirp when reflective marks located at the start of the subsequent test sections are encountered. The buzzer will emit five rapid beeps at the end of the test section when the “Distance” option is used to terminate data collection, and thereafter will emit a long beep after 152.4 m of longitudinal profile data have been collected after the end of the test section.<sup>(4)</sup>
- PSM module—a single cable that contains an Ethernet cable and an RS485 (which is a standard defining the electrical characteristics of drivers and receivers for use in serial communications systems) cable connected to one port in the DAU transmits the data collected by all sensors located in the sensor bar, GPSR, and DMI to the PSM module. The Ethernet cable is then carried through and connected to an input port in the router located on the equipment rack. The output from the ambient temperature sensor and the 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 and pavement surface temperature data from the PSM module to the router.<sup>(4)</sup>
- 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 the PSM module—which is connected to the DAU—that transmits the profile height sensor data, accelerometer data, longitudinal profile computed from data collected by each profile height sensor, 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 data collected by various sensors in the HSSV from the router to the laptop computer dock, and thereafter to the laptop computer for storage.<sup>(4)</sup>
- Circuit breakers—there are two circuit breakers located at the bottom of the rack (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.<sup>(4)</sup>



Source: FHWA.

**Figure 27. Photo. Circuit breakers on the equipment rack.**

### 2.2.12 Display Unit on Dashboard

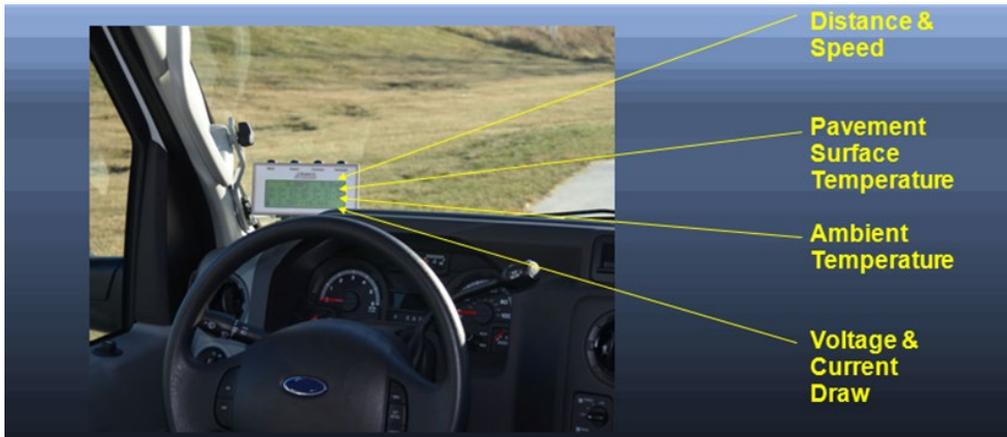
A display unit mounted on the left side of the dashboard shows distance, speed, pavement surface temperature, reference temperature from the pavement surface temperature probe, ambient temperature, voltage, and current draw (figure 28).<sup>(4)</sup>

The display unit is connected to the PSM module and obtains the displayed items through the PSM module.

There are four buttons on top of the display unit labeled “Mark,” “Select,” “Contrast,” and “Backlight” (figure 29).<sup>(4)</sup> Details about the four buttons are as follows:

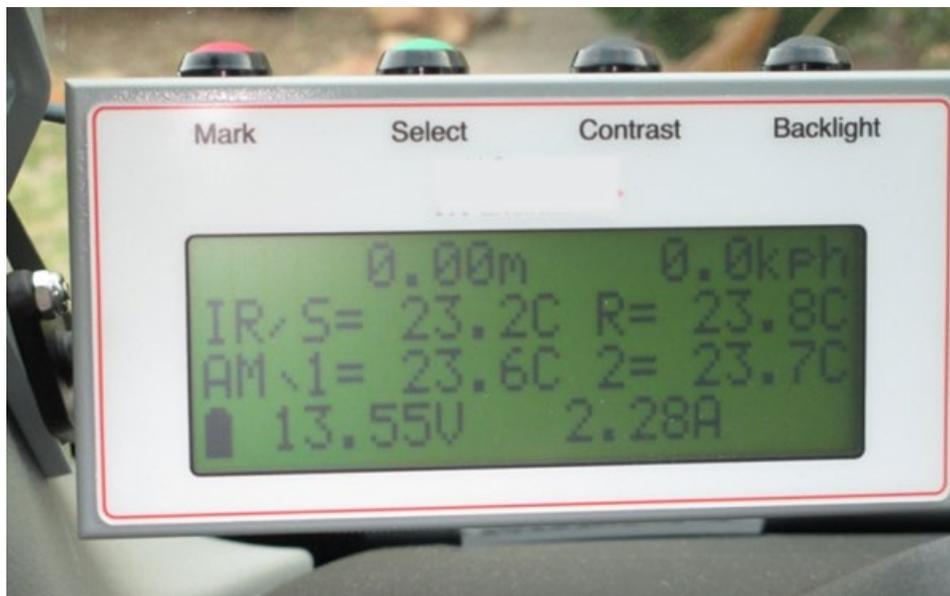
- Mark—when the HSSV software is in Horizontal Test mode, pressing this button will show the distance travelled. The vehicle can be stopped at any point and this button can be pressed again to re-zero the distance.<sup>(4)</sup>
- Contrast—this button controls the contrast of the display.<sup>(4)</sup>
- Backlight—this button controls the background light of the display.<sup>(4)</sup>
- Select—pressing this button cycles through the amount of data shown on the display. The display can show a maximum of four data lines (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.<sup>(4)</sup> Pressing the Select button a second time will show only the first and the fourth rows (figure 30). Pressing the Select button a third time will display all rows except for the third row (figure 31). Continually pressing the Select button will cycle through the three display modes described above, except that

the display units will change from International System of Units to U.S. Customary Units (figure 32).<sup>(4)</sup>



Source: FHWA.

**Figure 28. Photo. Display unit mounted on the dashboard.**



Source: FHWA.

**Figure 29. Photo. Display unit showing four data items.**



Source: FHWA.

**Figure 30. Photo. Display unit showing first and fourth rows.**



Source: FHWA.

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



Source: FHWA.

**Figure 32. Photo. Display unit showing four rows (U.S. Customary Units).**

### **2.2.13 Computer and Docking Station**

A laptop computer docking station is located between the driver and passenger seats in the HSSV (figure 33). The laptop computer that records the collected data is ruggedized.

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 docking station using the rotary key switch located on the front. The laptop computer docking station has a secondary power switch located on the side.<sup>(5)</sup>



Source: FHWA.

**Figure 33. Photo. Laptop computer docking station with laptop computer.**

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

The vehicle is equipped with a 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 to drivers to alert them if the system is activated. The pager can be set to a tone-and-vibration mode or a vibration-only mode. The security system includes a tilt sensor on the sensor bar that will activate the alarm if the sensor bar cover is opened when the alarm is on.<sup>(4)</sup>

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

The master power switch that provides power to all sensors in the HSSV is located on the dashboard (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, and the laptop computer, laser printer, and power strip. However, the inverter must be set to “On” to provide power to the laser printer and power strip.<sup>(4)</sup>



Source: FHWA.

**Figure 34. Photo. 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 (figure 35), while the other is at the rear of the vehicle (figure 36).<sup>(4)</sup>



Source: FHWA.

**Figure 35. Photo. Forward fire extinguisher.**



Source: FHWA.

**Figure 36. Photo. Rear fire extinguisher.**

### **2.2.17 Calibration Block Kit for Laser Height Sensors**

The HSSV manufacturer provided a calibration block kit with each HSSV to check the accuracy of laser height sensors. 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.
- One digital level.

The blocks and targets are in one case, while the base plates and digital level are in a separate case (figure 37).<sup>(4)</sup>



Source: FHWA.

**Figure 37. Photo. 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 glossy and matte side, and measurements should always be obtained on the matte side. The base plate is made out of aluminum. The calibration blocks have a block label engraved on the side. Table 1 shows the exact dimensions of the blocks. One set of blocks is included in each HSSV. The blocks assigned to each HSSV are shown in table 1.

**Table 1. Dimensions of calibration blocks.**

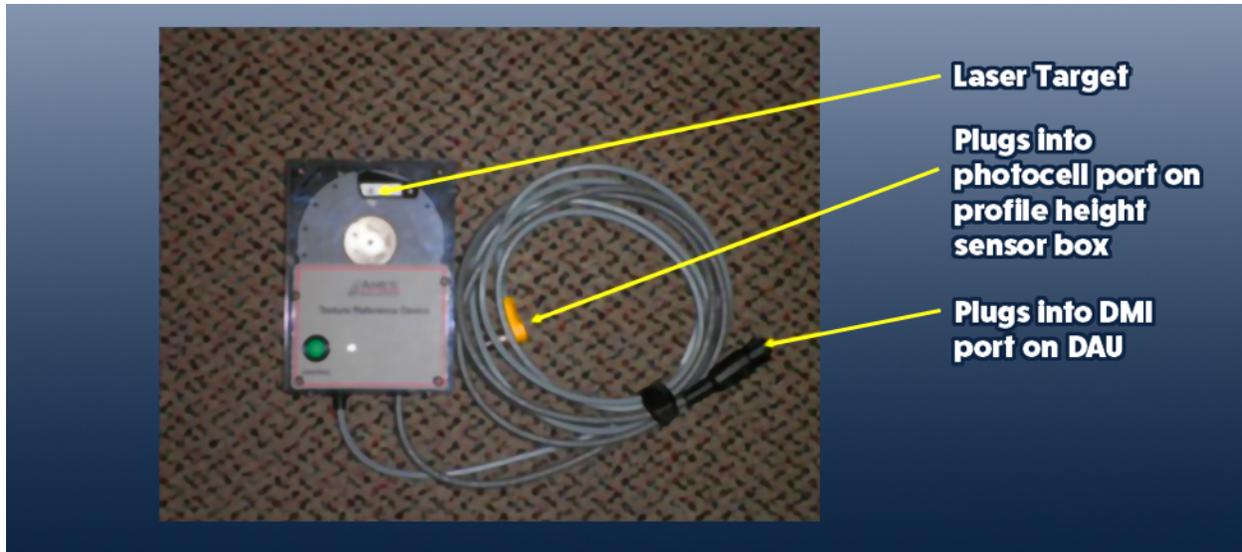
HSSV Identification Number	Block Label	Block Height (mm)
830112	A-1	25.00422
830112	A-2	25.00432
830112	A-3	25.00381
830112	A-13	50.00445
830112	A-14	50.00406
830112	A-15	50.00419
830112	A-25	75.00381
830112	A-26	75.00343
830112	A-27	75.00381
830112	A-37	100.00356
830112	A-38	100.00279
830112	A-39	100.00305
830212	A-4	25.00366
830212	A-5	25.00427

<b>HSSV Identification Number</b>	<b>Block Label</b>	<b>Block Height (mm)</b>
830212	A-6	25.00469
830212	A-16	50.00381
830212	A-17	50.00432
830212	A-18	50.00445
830212	A-28	75.00381
830212	A-29	75.00406
830212	A-30	75.00406
830212	A-40	100.00381
830212	A-41	100.00381
830212	A-42	100.00076
830312	A-7	25.00396
830312	A-8	25.00305
830312	A-9	25.00348
830312	A-19	50.00394
830312	A-20	50.00279
830312	A-21	50.00432
830312	A-31	75.00356
830312	A-32	75.00457
830312	A-33	75.00356
830312	A-43	100.00254
830312	A-44	100.00432
830312	A-45	100.00406
830412	A-10	25.00445
830412	A-11	25.00394
830412	A-12	25.00457
830412	A-22	50.00457
830412	A-23	50.00457
830412	A-24	50.00356
830412	A-34	75.0033
830412	A-35	75.00305
830412	A-36	75.00406
830412	A-46	100.00152
830412	A-47	100.00432
830412	A-48	100.00406

### **2.2.18 Texture Reference Test Device**

The HSSV manufacturer provided a texture reference test device to verify the accuracy of the texture height sensors (figure 38). The device consists of a hard disk that has been machined to provide four steps alternating between 0.5 and 1 mm in height. This device, which is connected to the DMI port in the DAU by disconnecting the DMI connection from the encoder to simulate travel distance, is powered by 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 the device. This disk is rotated at 7,200 rpm, which produces 120 rotations per second. The rotation process 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. The HSSV manufacturer has indicated the theoretical MPD computed from the step heights on the disk is 0.75 mm.<sup>(3)</sup>



Source: FHWA.

**Figure 38. Photo. Texture reference test device.**

### **2.2.19 Toolbox**

Each HSSV came supplied with a toolbox (figure 39). Figure 40 shows the contents of the toolbox.



Source: FHWA.

**Figure 39. Photo. Toolbox provided with each device.**



- **Sensor Bar Retention Knobs**
- **Ramp Mount Knobs**
- **7/8" Encoder Nut Socket**
- **3/4" Chassis Socket**
- **13mm Fastener Socket**
- **Spare Encoder Disc Nut**
- **Photocell Screwdriver**
- **7/16" Wrench**
- **13mm Wrench**
- **5/8" Wrench**
- **Socket Extension**
- **3/8" Drive Ratchet**

Source: FHWA.  
1 inch = 25.4 mm.

**Figure 40. Photo. Contents of the toolbox.**

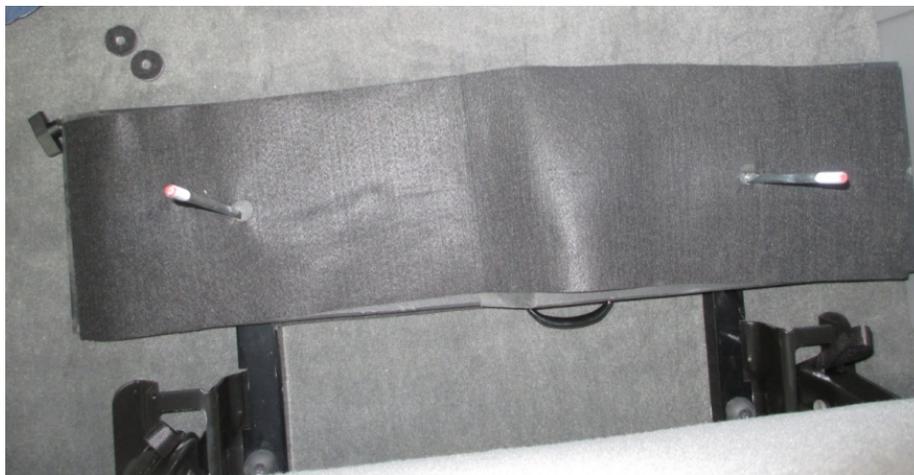
### 2.2.20 Calibration Ramps

Four ramps used to elevate the vehicle when conducting the full calibration check of the profile and texture height sensors are provided with each HSSV (figure 41). There are two steps in the ramp, each 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 (figure 42). The securing mechanism consists of two vertical rods; 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.



Source: FHWA.

**Figure 41. Photo. Ramp used to elevate vehicle.**



Source: FHWA.

**Figure 42. Photo. Mechanism for securing the ramps.**

### 2.2.21 Camera

The HSSV is equipped with a right-of-way camera system that contains a charge-coupled device (CCD) camera. The CCD camera is attached to the mount that supports the rear-view mirror on the windshield (figure 43 and figure 44). The CCD camera captures images of the roadway as viewed from inside of the vehicle. A cable from the CCD camera is connected to a USB port on

the laptop computer. Figure 45 shows an example of an image obtained by the CCD camera. The date, time, global positioning system information, and distance from the start of the test section are embedded onto the bottom of the image, as shown in figure 45.



Source: FHWA.

**Figure 43. Photo. Side view of the CCD camera.**



Source: FHWA.

**Figure 44. Photo. View from inside the vehicle of the CCD camera.**



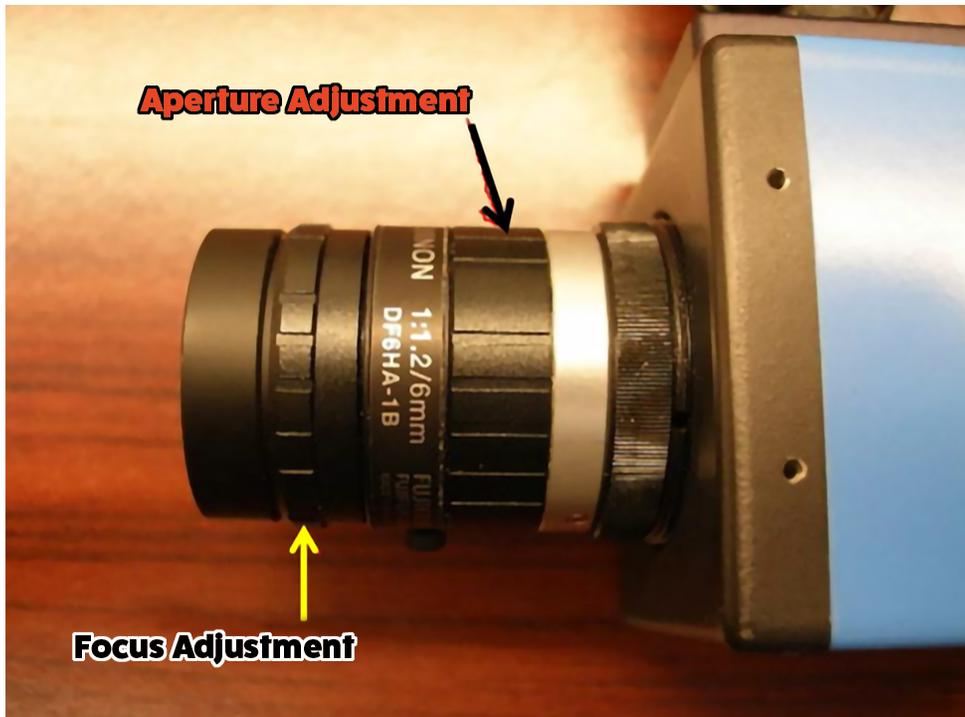
Source: FHWA.

**Figure 45. Photo. Example of an image obtained by the CCD camera.**

The CCD camera will capture the first image when the photocell is armed, and these images will have the notation “Lead In” imprinted on the bottom right corner. The images captured from the time the photocell triggers at the start of the test section until the Stop Distance specified in the Header screen of the software will have the distance from the start of the test section imprinted on the bottom right corner in meters as stations. The camera will continue to capture images for 152.4 m past the Stop Distance specified, and the images will have the notation “Lead Out” at the bottom right corner of the image. The images stored in JPEG format on the laptop computer.<sup>(4)</sup>

The CCD camera has an autoexposure mode that is always active. The lens aperture in the CCD camera can be adjusted to let in more light when capturing images on a cloudy day (figure 46).

The operator can elect to collect images or video using the CCD camera in the Setup menu (section 2.4.2.1.4). A camera preview window will appear when the “Start” (F1 key) has been selected from the Main menu (figure 47). 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.



Source: FHWA.

**Figure 46. Photo. Aperture and focus adjustment of the CCD camera.**



Source: FHWA.

**Figure 47. Screenshot. Camera preview window that appears during data collection.**

## 2.2.22 TPMS

The manufacturer installed a TPMS on the back of each HSSV in late 2017. Figure 48 and figure 49, respectively, show the back and the side view of the TPMS. All components of the TPMS are housed in a box attached to a frame supporting the TPMS mounted at the center of the vehicle by eight screws (figure 50). The components housed inside the box are the laser, CCD camera, cooling fan, and TPMS controller. The TPMS box is mounted such that the distance from the ground to the bottom face of the TPMS box is 213 mm. A temperature sensor monitors the temperature inside the box, and this temperature is displayed on the main screen of the HSSV software. The cooling fan has five speeds, and the speed of the fan automatically adjusts based on the temperature inside the box. There is a cloth filter in front of the fan, and this filter must be checked monthly and replaced if dirty. Power to the laser and the CCD camera will be cut off when the temperature inside the box exceeds 50°C. A cable connects the TPMS controller to the PSM, and power to the components inside the box is supplied through this cable. The output from the TPMS is transmitted through an Ethernet cable that is connected directly to the laptop computer.<sup>(5)</sup>



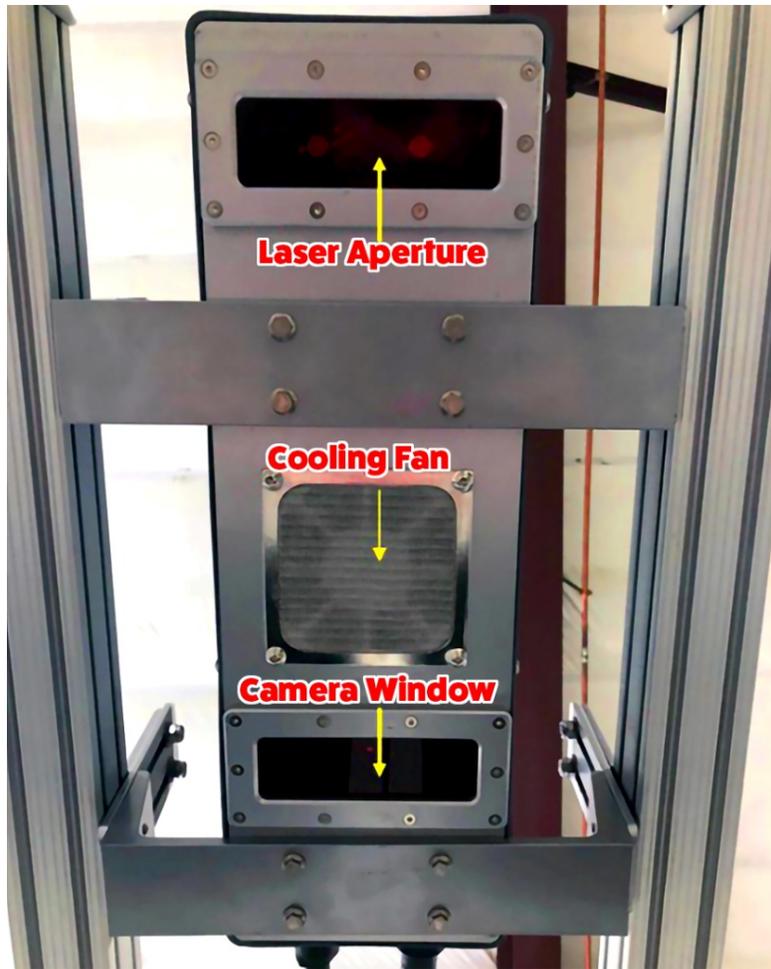
Source: FHWA.

**Figure 48. Photo. Back view of the TPMS.**



Source: FHWA.

**Figure 49. Photo. Side view of the TPMS.**



Source: FHWA.

**Figure 50. Photo. Components of the TPMS.**

The TPMS box can be removed from the frame by unscrewing the eight screws that connect the TPMS box to the supporting frame. Dummy block connectors are provided in the supporting rail to cover the connections to PSM and Ethernet cable to prevent dust or any contaminants from entering the connectors when the TPMS box is removed. A laser safety key switch that can manually enable and disable the TPMS is provided on the equipment rack (figure 51). This switch must be in the “On” position for normal operations. When the TPMS is enabled, and the user accesses the Header screen of the HSSV software, the TPMS will emit a beeping sound. This beeping does not mean power has been provided to the TPMS; it is a warning to indicate power will be supplied to the TPMS when the vehicle reaches a speed above 5 km/h. Once the speed of the vehicle exceeds 5 km/h, power will be provided to the TPMS and red LED lights will flash on the CCD camera indicating that the laser is on. The beeping will continue when data collection is in progress. Power to the TPMS will cut off when the speed of the vehicle falls below 5 km/h.<sup>(3)</sup>



Source: FHWA.

**Figure 51. Photo. Laser safety key switch.**

The TPMS can measure a transverse profile that is 3.96 m wide, with 2,048 data points collected over this width. This combination of width and data points means the interval between the data points in a transverse profile is 1.93 mm. A transverse profile is recorded approximately every 25 mm. The transverse profile recording interval is not exactly 25 mm, but it is very close to 25 mm. The TPMS has a measuring range of  $\pm 102$  mm and a vertical resolution of 0.65 mm. Data collected by the TPMS are saved in the same data file where the longitudinal profile and macrotexture data are saved.<sup>(3)</sup>

### **2.2.23 Calibration Check Block for TPMS**

The HSSV manufacturer provided a calibration block to check the accuracy of the TPMS. Figure 52 and figure 53 show a side and plan view of the calibration block, respectively.



Source: FHWA.

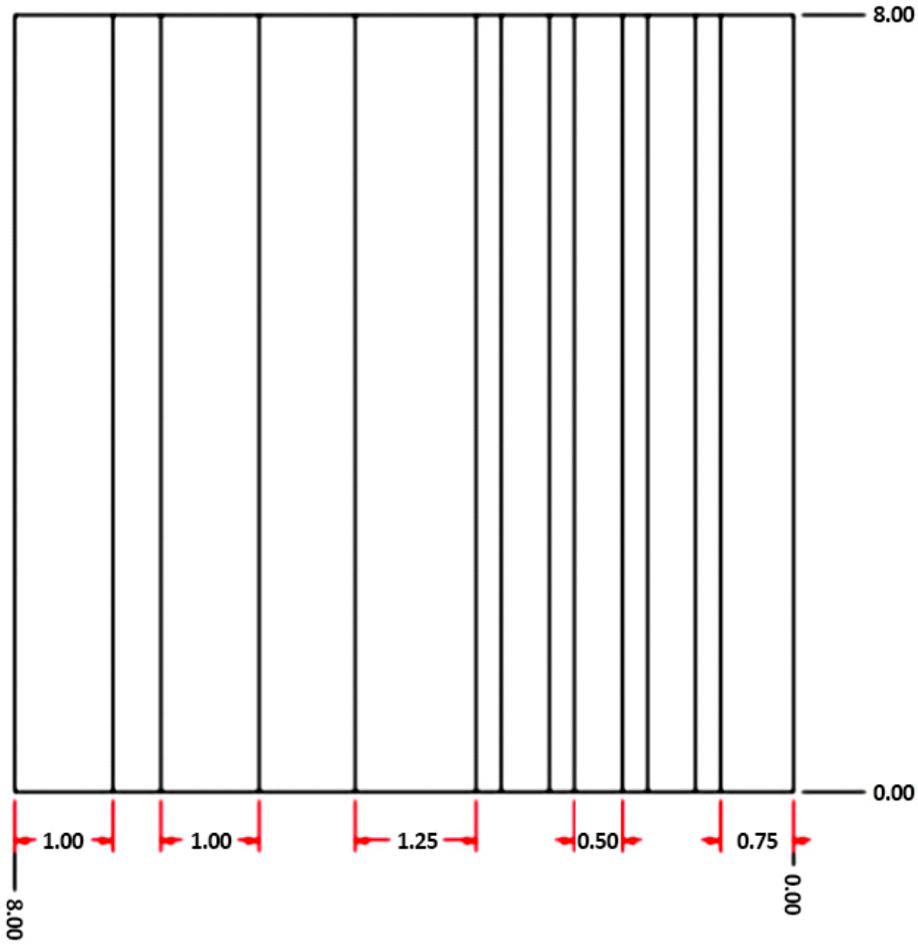
**Figure 52. Photo. Side view of the TPMS calibration block.**



Source: FHWA.

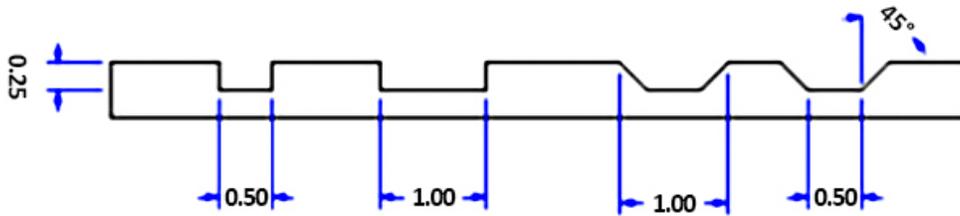
**Figure 53. Photo. Plan view of the TPMS calibration block.**

The dimensions of the TPMS calibration block are shown in figure 54 and figure 55, where figure 54 shows a plan view and figure 55 shows a side view. The dimensions of the two grooves with beveled edges are similar.



Source: FHWA.  
 Measurements are in inches.  
 1 inch = 25.4 mm.

**Figure 54. Diagram. Plan view of the dimensions of the TPMS calibration block.**



Source: FHWA.  
 Linear measurements are in inches.  
 1 inch = 25.4 mm.

**Figure 55. Diagram. Side view of the dimensions of the TPMS calibration block.**

## **2.3 FEATURES OF THE HSSV**

### **2.3.1 Recorded Data**

All data collected by the HSSV in a single run are saved in one Ames Raw Data (ARD) file. The following data items are contained in an ARD file: longitudinal profile data, profile height sensor data, texture height sensor data, accelerometer data, DMI data, ambient temperature sensor data, pavement surface temperature data, GPSR data, transverse profile data, event data from photocells, event keys entered by the user, and diagnostic information. Longitudinal profile data saved in the ARD file have an upper wavelength filter applied. However, the applied upper wavelength cut-off filter is greater than 100 m. A 100-m upper wavelength filter is applied when the collected longitudinal profile data are viewed in the HSSV Viewer software or when the data are exported to ProQual.<sup>(6)</sup>

### **2.3.2 Exporting Data to ProQual**

In the LTPP program, ProQual software is used to process the longitudinal profile and macrotexture data collected by the HSSV. The data saved in ARD files are transferred into ProQual through a dynamic link library (DLL). In the field, ProQual software is used to perform quality control checks on data collected by the HSSV, such as the longitudinal profile data, macrotexture data, ambient temperature data, pavement surface temperature data, and data collected by the GPSR. ProQual cannot be used to perform quality control checks on transverse profile data. In the office, ProQual software is used to perform the following functions on data collected by the HSSV except for transverse profile data: perform quality assurance checks on the data, create data files that are uploaded to the LTPP Pavement Performance Database (PPDB), and create files that are stored in the Ancillary Information Management System (AIMS).<sup>(7)</sup>

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

Historically, in the LTPP program, the first profile data point in the longitudinal profile assigned to a test section has been at a distance of 114 mm from the leave edge of the start stripe at the beginning of the test section (i.e., Distance = 0 for profile data located 114 mm from the leave edge of the start stripe at a test section). Profile and macrotexture data collected by the HSSV also conform to this criterion.<sup>(7)</sup>

The vertical photocell in the HSSV triggers when the photocell detects the approach end of reflective tape placed on the pavement. The horizontal photocell in the HSSV triggers when the photocell detects the approach end of the reflective tape mounted on the cone placed on the shoulder. The width of the reflective tape 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 is a parameter assigned in a setup screen in the HSSV software. The HSSV software uses this value and the width of the tape input in the Header screen to assign the first longitudinal profile and macrotexture data point at a test section to be at a distance of 114 mm from the leave edge of the reflective tape at the beginning of the test section.

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

The ARD file stores profile height sensor, accelerometer, and longitudinal profile data for a distance of 152.4 m before the start of the test section (i.e., pre-run) and after the end of the test section (i.e., post-run). This pre- and post-run distance is a value specified in a setup screen in the HSSV software. Proper application of the 100-m upper wavelength cut-off filter to the longitudinal profile data requires 152.4 m of data before the start of the test section and 152.4 m of data after the end of the test section.

Macrotexture data for a distance of 30 m before the start and after the end of the test section are also stored in the ARD file. The pre- and post-run macrotexture data distance is set in an HSSV software initialization file.<sup>(6)</sup>

Transverse profile data from the location where the photocell was armed to a distance of 152.4 m past the end of the test section are stored in the ARD file. Therefore, the ARD file contains transverse profile data for the pre-run from the location where the photocell was armed to the start of the test section, data collected within the test section, and post-run data for a distance of 152.4 m past the end of the test section.<sup>(6)</sup>

### **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 the HSSVs are used for non-LTPP data collection. The following are examples when event keys can be used:

- Marking the start and end of a bridge.
- Marking the start and end of a weigh-in-motion (WIM) scale located on the pavement.
- Marking the location where the surface type of the pavement changes.

## **2.4 COMPUTER AND SOFTWARE SETTINGS**

### **2.4.1 Computer Settings**

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 56 shows the Microsoft Windows menu where the status of the wireless adapter can be checked to ensure it is disabled.

The power management in the laptop computer should be set to the settings shown in figure 57 to avoid the display from dimming, turning off, or putting the laptop computer to sleep, all of which can affect data collection.



Source: FHWA.

**Figure 56. Screenshot. Wireless adapter setting in the computer.**



Source: FHWA.

**Figure 57. Screenshot. Power management settings in the laptop computer.**

## 2.4.2 HSSV Software Settings

The HSSV software is used to collect longitudinal profile, macrotexture, and transverse profile data. In the LTPP program, transverse profile data is also processed using this software. To collect data at LTPP test sections based on LTPP requirements and process the transverse profile data based on LTPP requirements, the settings in various menus of the HSSV software must be set to appropriate values. This section describes the required settings in various menus of the HSSV software. 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 tab in the HSSV software provides access to the following menus:

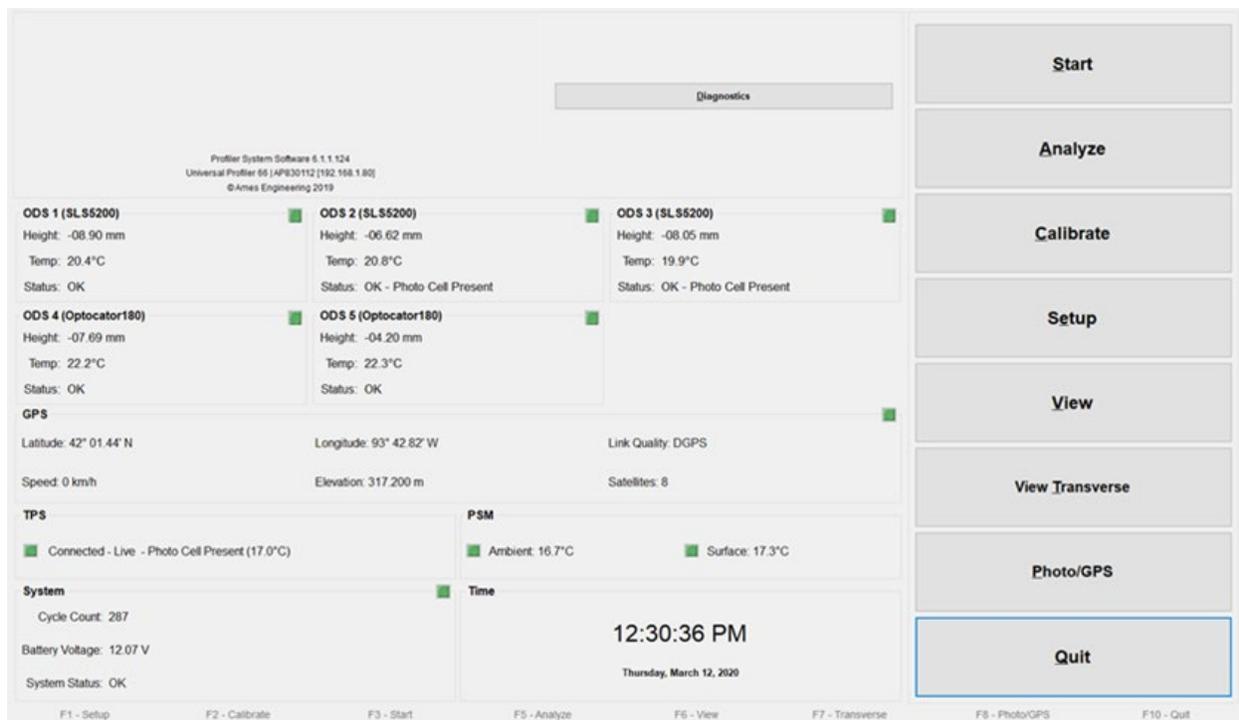
- Report Options.
- Analysis Options.
- Profile Analysis.
- Texture Analysis.

- Transverse Analysis.
- Profiler.
- Sensors.
- Raytek.
- Camera.
- Printer.

These menus can be categorized as:

- Menus whose settings impact data collection and field review of the data (i.e., Texture Analysis, Profiler, Sensors, Camera, Raytek, and Transverse Analysis).
- Menus whose settings impact processing of transverse profile data in the office (i.e., Analysis Options and Transverse Analysis).
- Menus whose setting do not have an impact on LTPP operations (i.e., Report Options, Profile Analysis, and Printer).

Follow the procedures described in section 2.8.1 to boot up the laptop computer and launch the HSSV software. To start, the HSSV startup screen should be displayed on the laptop computer screen (figure 58). Press the “F1” key or select “Setup” to access the menus in the HSSV software.



Source: FHWA.

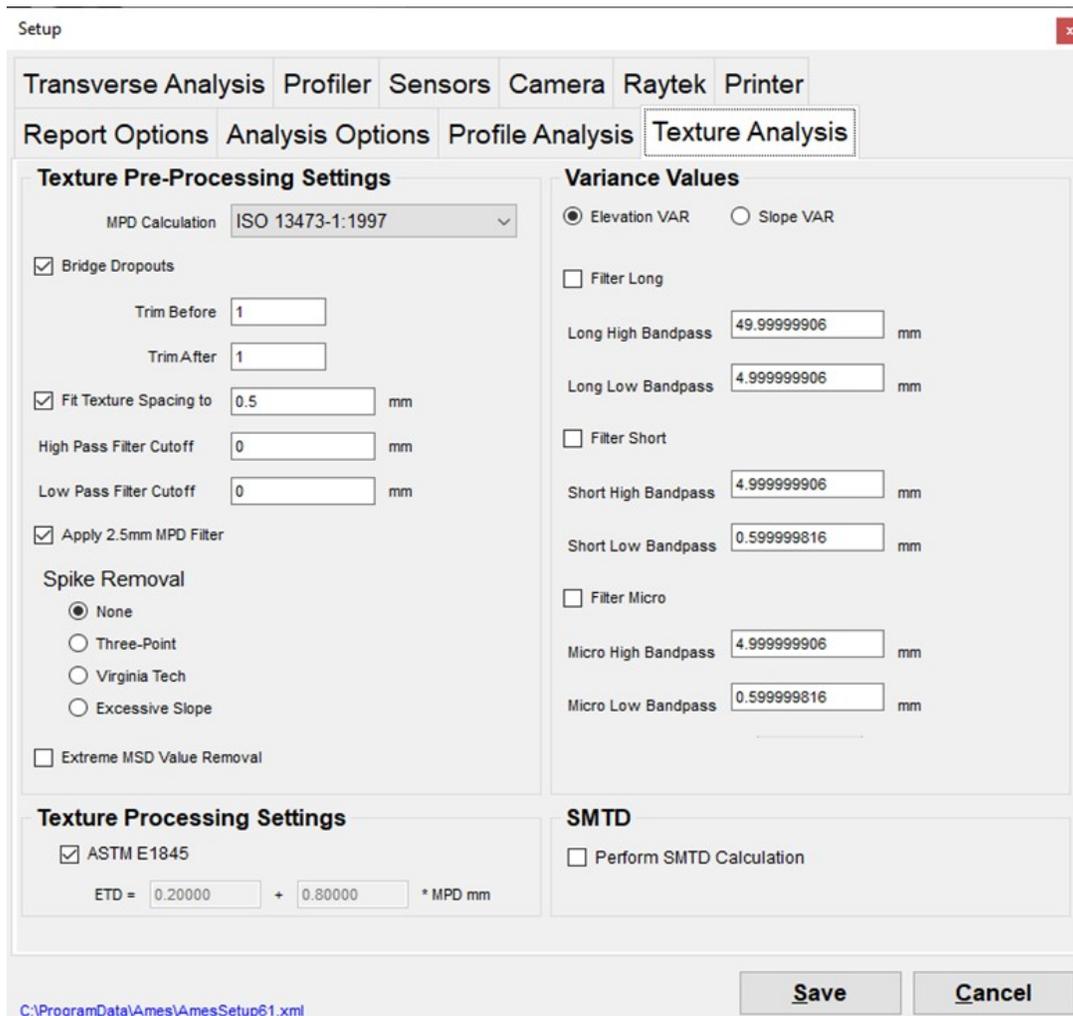
**Figure 58. Screenshot. HSSV software startup screen.**

### 2.4.2.1 Menus That Impact Field Operations

Settings in the following menus impact LTPP field operations: Texture Analysis, Profiler, Sensors, Camera, Raytek, and Transverse Analysis. These menus in the HSSV software in all HSSVs should have the settings described in this section.

#### 2.4.2.1.1 Texture Analysis Menu

A screenshot of the Texture Analysis menu is shown in figure 59. The settings under Texture Pre-Processing Settings impacts the MPD values that are computed through the HSSV software, as well as the MPD that is computed during the texture reference device test. As MPD values obtained from the texture reference device are used for the proper functioning of the texture lasers, the settings under Texture Pre-Processing Settings must be set to the values shown in figure 59. The settings under Variance Values have no impact on LTPP operations. As shown in figure 59, Spike Removal is set to None. When computing MPD, LTPP has elected not perform any spike removal on the data, which is why Spike Removal is set to None for this field.



Source: FHWA.

Figure 59. Screenshot. Texture Analysis menu.

### 2.4.2.1.2 Profiler Menu

A screenshot of the Profiler menu is shown in figure 60.

Setup

Report Options Analysis Options Profile Analysis Texture Analysis

Transverse Analysis Profiler Sensors Camera Raytek Printer

**Identification**

Operator Name

Company Name

Certification #

Certification Date (mmdyyy)

Certification Level

**Collection Options**

Single-Block Extensive Test

Show End of Run Note

Enable Laptop Sounds

Enable PSM Sounds

**Profiler Settings**

Password

Serial #

Model #

Product Key

Profile Sample Rate  (12.263 actual) samples/foot

TPS Sample Rate  (12.263 actual) samples/foot

Pre/Post Run Length  feet

Analog Filter  radians

Anti-Aliasing Filter  Hz

Horizontal Calibration Divisor

RS485 Baud Rate Divisor

GPS Baud Rate

DMI Source

Communications Port

[C:\ProgramData\Ames\AmesSetup61.xml](#)

Source: FHWA.  
1 ft = 0.3048 m.

**Figure 60. Screenshot. Profiler menu.**

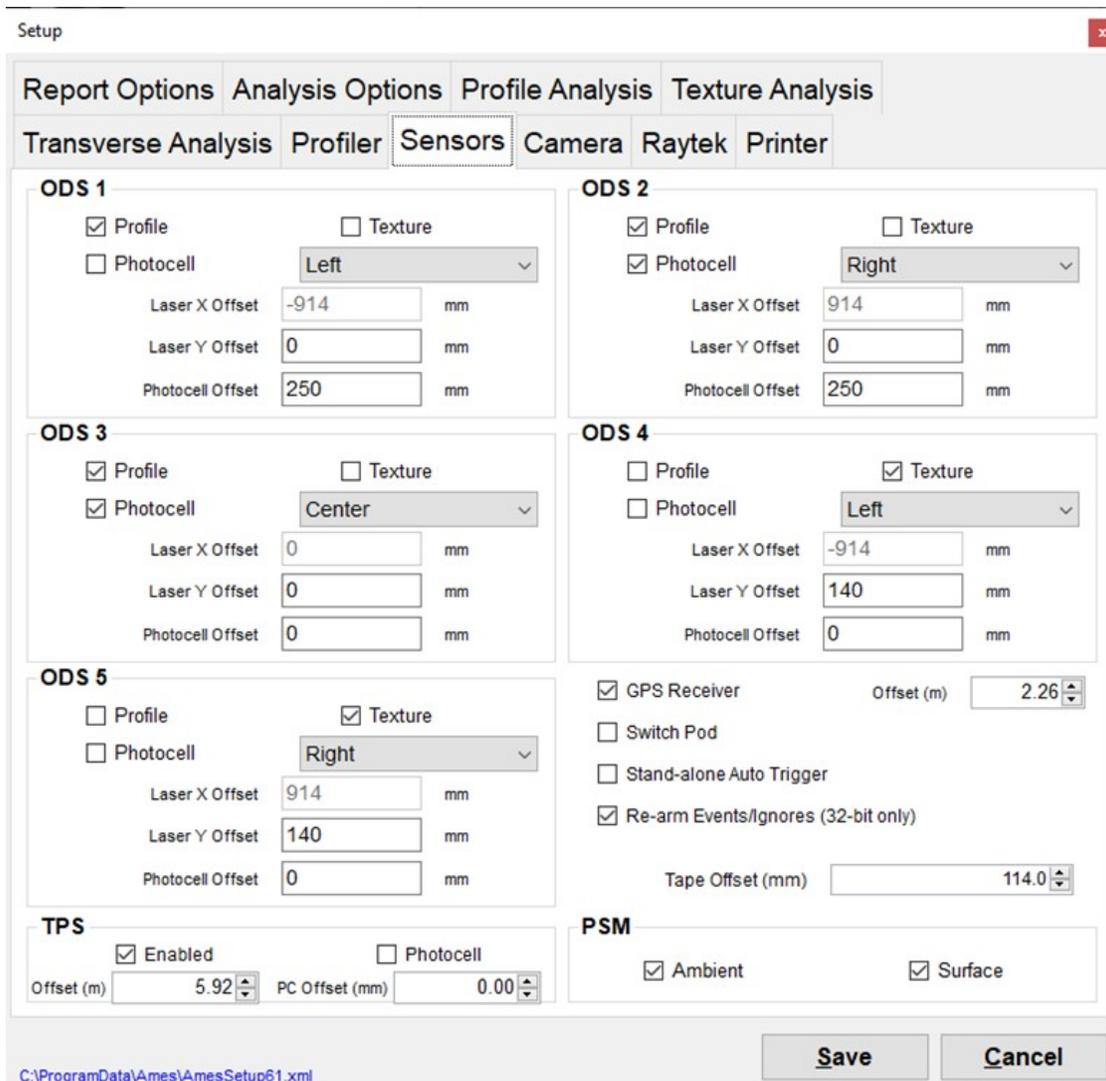
The parameters under Identification, Collection Options, and Profiler Settings should show the following values:

- Identification—all fields under “Identification” (e.g., Operator Name, Company Name, Certification #, and Certification Date) should be blank.
- Collections Options—only the “Show End of Run Note” and “Enable PSM Sounds” should be checked.

- Profiler Settings—the entries under “Profiler Settings” are protected by a password. The password is “ames60” (case sensitive), and any entry under “Profiler Settings” can be changed by the operator after entering the password. The Serial # field should have the identification number assigned to the HSSV. The serial number or identification number of each HSSV is shown in section 1.3. All other entries under “Profiler Settings” should exactly match the values shown in figure 60, except for the Product Key. The Product Key will show the unique number provided for the CCD camera for each HSSV.

### 2.4.2.1.3 Sensors Menu

A screenshot of the Sensors menu is shown in figure 61. The items that are checked and the values shown on the laptop computer screen should exactly match the parameters shown in figure 61. If any differences are noted, change the settings to match what is shown in figure 61 and then select the “Save” button to save the changes.



Source: FHWA.

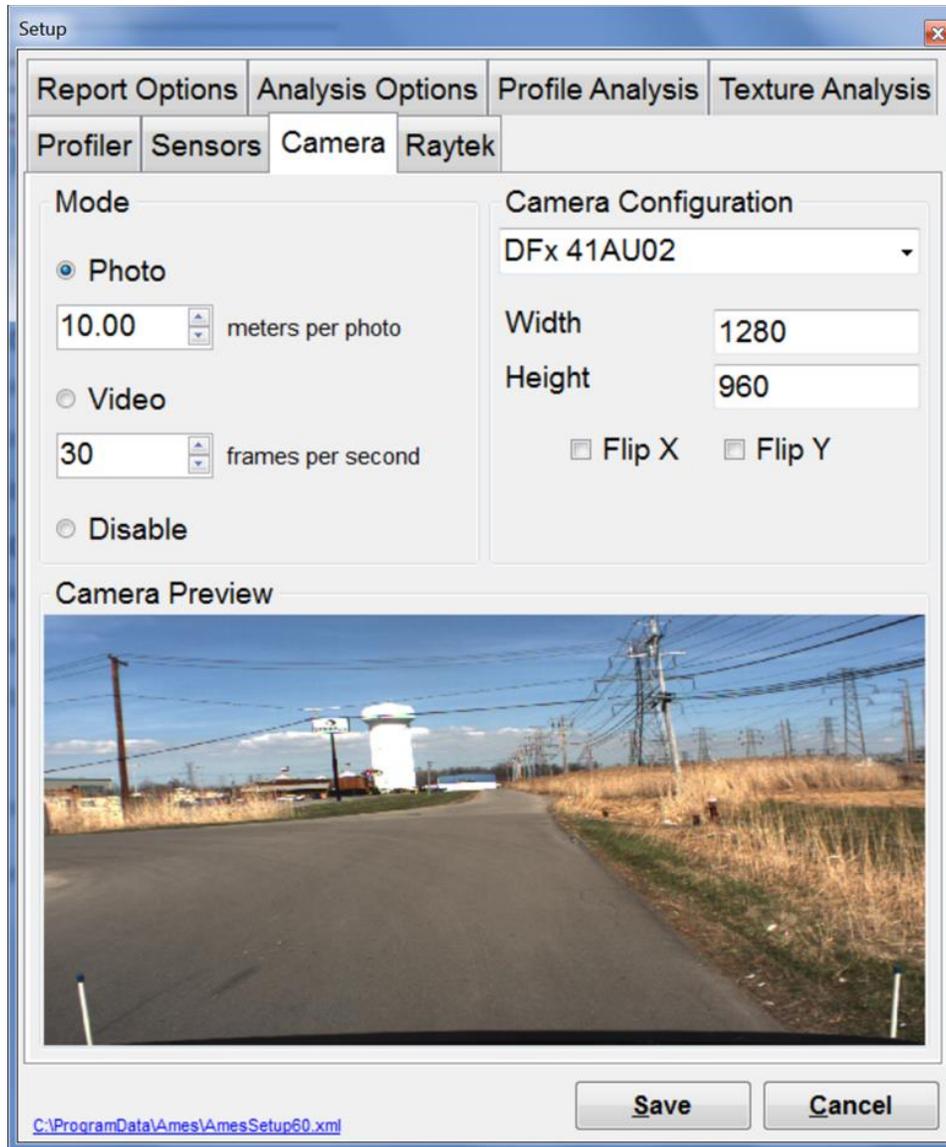
**Figure 61. Screenshot. Sensors menu.**

The following is a brief explanation of the items shown in figure 61:

- The checkmark for “Profile” under ODS 1, ODS 2, and ODS 3 indicates these sensors are enabled for profile data collection. ODS 1 is the left wheel path profile sensor, ODS 2 is the right wheel path profile sensor, and ODS 3 is the center profile sensor.
- The checkmark for “Texture” under ODS 4 and ODS 5 indicates these sensors are enabled for texture data collection. ODS 4 is the left wheel path texture sensor and ODS 5 is the right wheel path texture sensor.
- The vertical photocell is connected to ODS 3. Hence, photocell is checked for ODS 3. The vertical photocell is in line with all three profile height sensors (i.e., ODS 1, ODS 2, and ODS 3). Hence, the photocell offset for ODS 3 is 0.
- The horizontal photocell is connected to ODS 2. Hence, photocell is checked for ODS 2. The horizontal photocell is located 250 mm behind the profile height sensor. The photocell offset value of 250 mm is entered under ODS 2 to account for this difference.
- The texture laser height sensors (i.e., ODS 4 and ODS 5) are located 140 mm behind the profile height sensors. To ensure the post-processed macrottexture data for the test section starts exactly at the same location where profile data collection started, the Laser Offset value is set to 140 mm for ODS 4 and ODS 5.
- The tape offset is set to 114 mm 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 GPSR, respectively, make the ambient temperature sensor, pavement surface temperature sensor, and GPSR active. The offset for GPSR is set to 2.26 m.
- Under Transver Profiling System (TPS), a checkmark for enabled indicates the TPMS has been enabled for data collection. The offset for the TPMS is set at 5.92 m.
- The checkmark for Re-arm Event/Ignores makes the photocell look for a reflective tape mark after the photocell triggers off the mark at the start of the test section. This function is used when data are collected at SPS test sections.

#### ***2.4.2.1.4 Camera Menu***

The Camera menu shows the settings for the right-of-way camera (figure 62). When the camera was first installed, the product key for the camera provided by the manufacturer was entered into the Product Key field in the Profiler menu (figure 60).



Source: FHWA.

**Figure 62. Screenshot. Camera menu.**

In the Camera menu, “Photo” mode must be enabled to obtain images. The interval for obtaining images can be adjusted using the meters per photo field below “Photo.” Images must be obtained at LTPP test sections at 10-m intervals. Therefore, select 10.00 for this field.

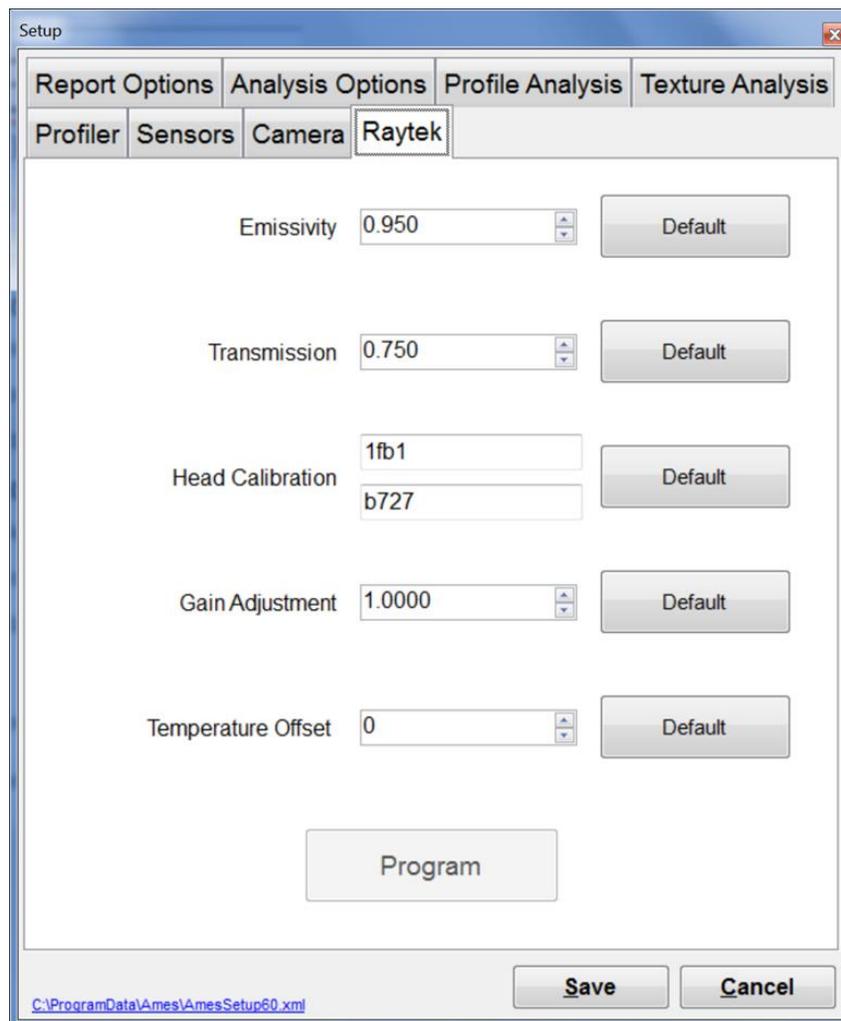
The following is a brief explanation of the other items shown in figure 62:

- 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 × 960 pixels. These values must not be changed.

- Camera Preview—the window at the bottom of the Setup screen shows the view from the CCD camera. The HSSV software requires the settings to be saved before exiting the screen.
- Video—collecting video of a test section is not required for LTPP program purposes. However, the DCC can collect video of a 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 is used.

#### 2.4.2.1.5 Raytek Menu

The Raytek menu shows the settings for the surface temperature sensor that measures the pavement surface temperature. When this menu is selected, the HSSV software accesses the infrared temperature sensor controller board and displays the current settings that are stored in the controller board. Figure 63 shows an example of the Raytek menu.



Source: FHWA.

**Figure 63. Screenshot. Raytek menu.**

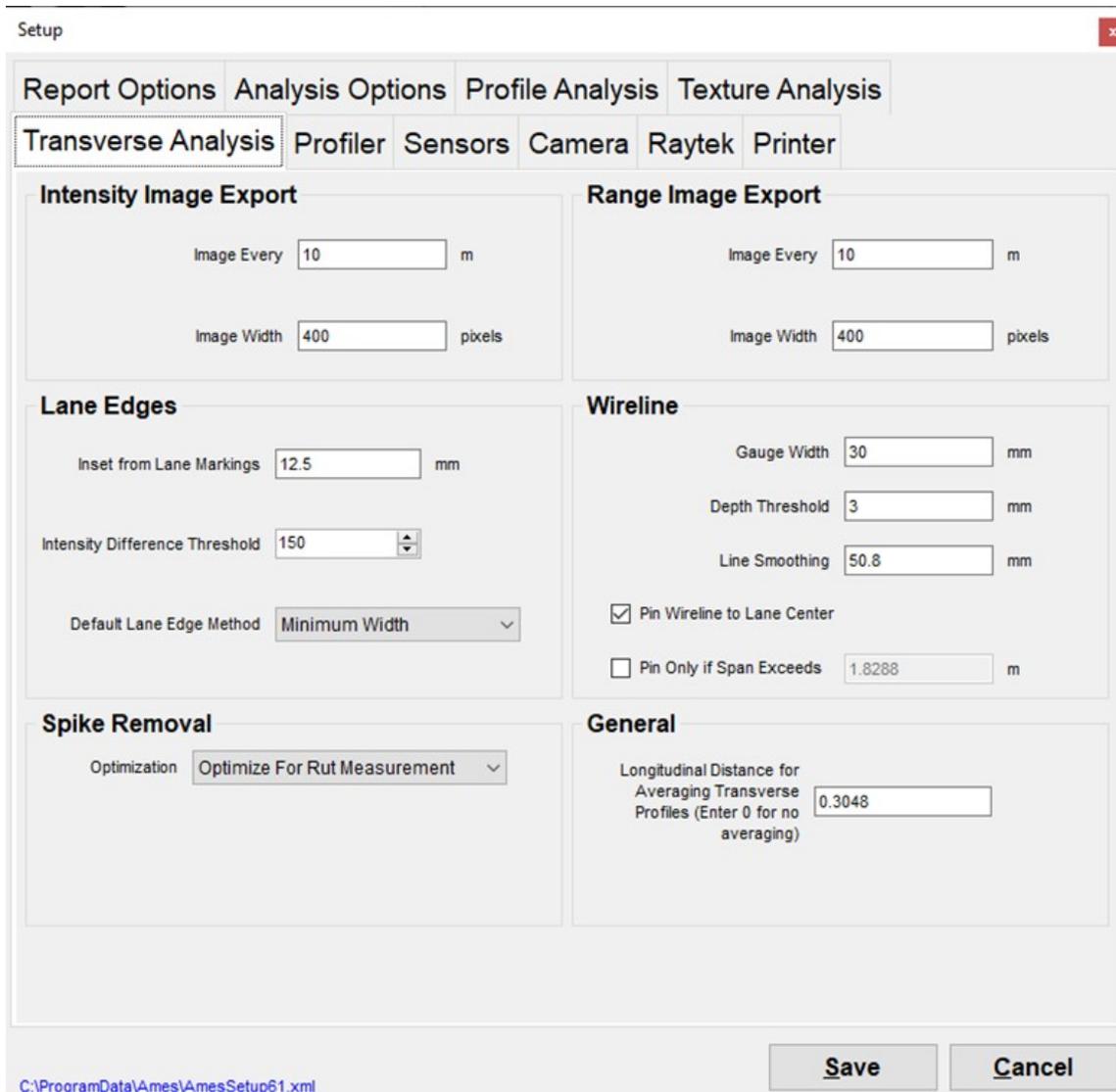
Figure 63 shows the following values:

- Emissivity—the value should be 0.95.
- Transmission—the value should be 0.75 with the protective cover present on the sensor and 1.0 when the sensor does not have the protective cover. In the normal operating mode, the protective cover is present in front of the lens. There have been reports that the protective cover has had cracks. If the protective cover is cracked, the sensor can be used with the protective cover off and the Transmission value set to 1.0.
- Head Calibration—the value specific to each HSSV was entered into this field prior to the delivery of the HSSV. When the sensors are purchased as a complete set (i.e., 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 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. The manufacturer must be contacted for 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—the value should be set to 1.0. This field 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  $3^{\circ}\text{C}$  for a 100 change in offset. Hence, the maximum adjustment is  $\pm 6^{\circ}\text{C}$ .

If any value on this menu 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.

#### ***2.4.2.1.6 Transverse Analysis Menu***

A screenshot of the Transverse Analysis menu is shown in figure 64. The settings in this menu do not impact data collection. However, the settings in this menu will impact the transverse profile data displayed when viewed using the HSSV software and also impact the processing of transverse profile data. Therefore, the settings on the Transverse Analysis menu should match the parameters shown in figure 64 in the HSSV software on all HSSVs and in the computers in the office that process transverse profile data. The settings under Lane Edges, Spike Removal, General, and Wireline will impact the transverse profile data that are exported to an XML file for upload to the PPDB. The values under Intensity Image Export and Range Image Export affect the images exported that will be included in InfoPave™.



Source: FHWA.

**Figure 64. Screenshot. Transverse Analysis menu.**

The settings under “Intensity Image Export” and “Range Image Export” specify the distance interval for exporting the intensity images and range images, respectively.

The “Inset from Lane Markings” field under Lane Edges indicates the distance from the lane marking at the right edge to the start location where a transverse profile for export is generated (i.e., this is the  $X = 0$  location). With the shown setting, the first data point at the right edge of the lane that is exported is 12.5 mm from the inside edge of the lane stripe at the edge of the lane.

The settings under Wireline will affect the rut depths computed using the HSSV software as well as the smoothing performed on the transverse profile. Therefore, the value for “Line Smoothing” should be set to 50.8 mm, as shown in figure 64. Rut depths computed from the HSSV software may be used in the LTPP program as a quality control measure.

Under Spike Removal, “Optimize for Rut Measurements” must be selected. During data collection, when part of the pavement on which data is collected is exposed to sunlight and other parts are within a shadow, a hump or a dip can be created at the transition from sunlight to shadow. When data are collected when the sun angle is low, spikes can be created at portland cement concrete (PCC) pavement joints. When part of the pavement on which data are collected is PCC and other parts are asphalt concrete (AC) (e.g., AC patches on a PCC pavement), spikes may occur on the AC surface. The setting “Optimize for Rut Measurements” eliminates spikes or humps that are present on the transverse profile data. This setting causes a grinding simulation to be applied in the transverse direction on each transverse profile collected within the lane to eliminate spikes and humps. First, this routine makes a pass in the forward direction using a grinding simulation that has a 200-mm base length to identify spikes that exceed a 10-mm threshold and eliminates such spikes. This pass is made on the top and bottom of the transverse profile. Next, this routine makes a pass in the reverse direction using a grinding simulation with a 100-mm base length to identify humps that exceed a 1.1-mm threshold and eliminates such humps. This pass is made on the top and bottom of the transverse profile.

In the General menu, the value set for “Longitudinal Distance for Averaging Transverse Profiles” indicates the distance over which transverse profiles are averaged to output a transverse profile for upload to the PPDB. For LTPP operations, when creating files for upload to the PPDB, transverse profiles over a distance of 0.3048 m centered at a location are averaged to produce a transverse profile. As a transverse profile is obtained at approximately 25-mm intervals, transverse profile data collected at 12 or 13 locations are averaged to produce an averaged transverse profile at 0.3048-m intervals.

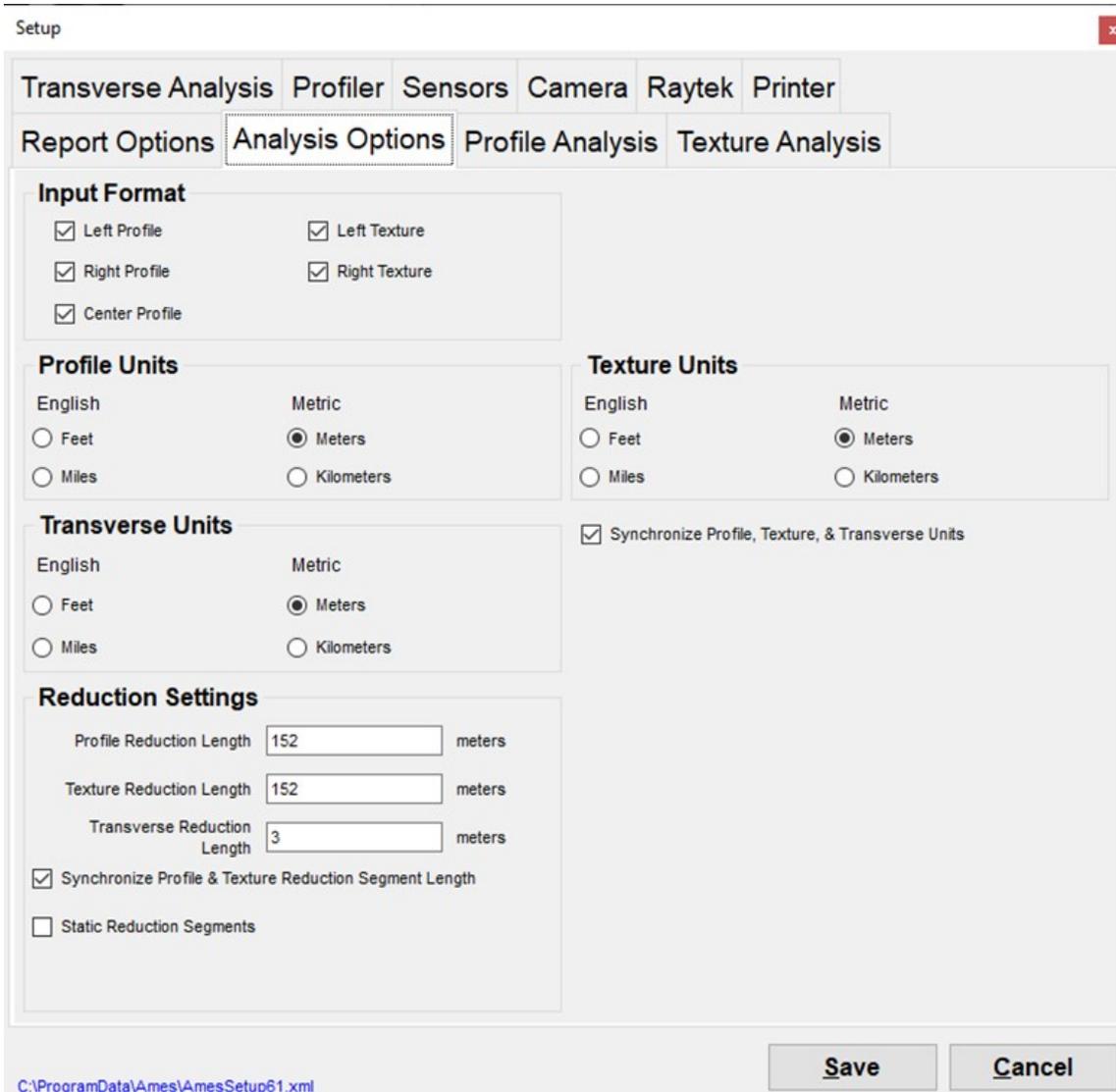
#### ***2.4.2.2 Menus Impacting Processing of Transverse Profile Data***

The Analysis Options and Transverse Options menus should be set to the values described in this section for all computers used to process data collected by HSSVs.

##### ***2.4.2.2.1 Analysis Options Menu***

A screenshot of the Analysis Options menu is shown in figure 65. The settings in this menu are associated with analyses performed with the HSSV software.

In the LTPP program, analysis of longitudinal profile and macrotexture data is not performed using the HSSV software. Therefore, the settings associated with profile and texture data in this menu have no impact on LTPP operations. However, in the LTPP program, transverse profile data are exported using the HSSV software. Therefore, the values for “Longitudinal Distance for Averaging Transverse Profiles” and “Transverse Reduction” must be set to the values shown in figure 65. Also, under Transverse Units, meters must be selected. The value set for “Transverse Reduction” indicates the distance interval for reporting rut depths when rut depths are computed using the HSSV software. For LTPP operations, a value of 3 m is used. Therefore, when rut depths are analyzed using the HSSV software, the rut depths computed at approximately 25-mm intervals will be averaged and reported at 3-m intervals.



Source: FHWA.

**Figure 65. Screenshot. Analysis Options menu.**

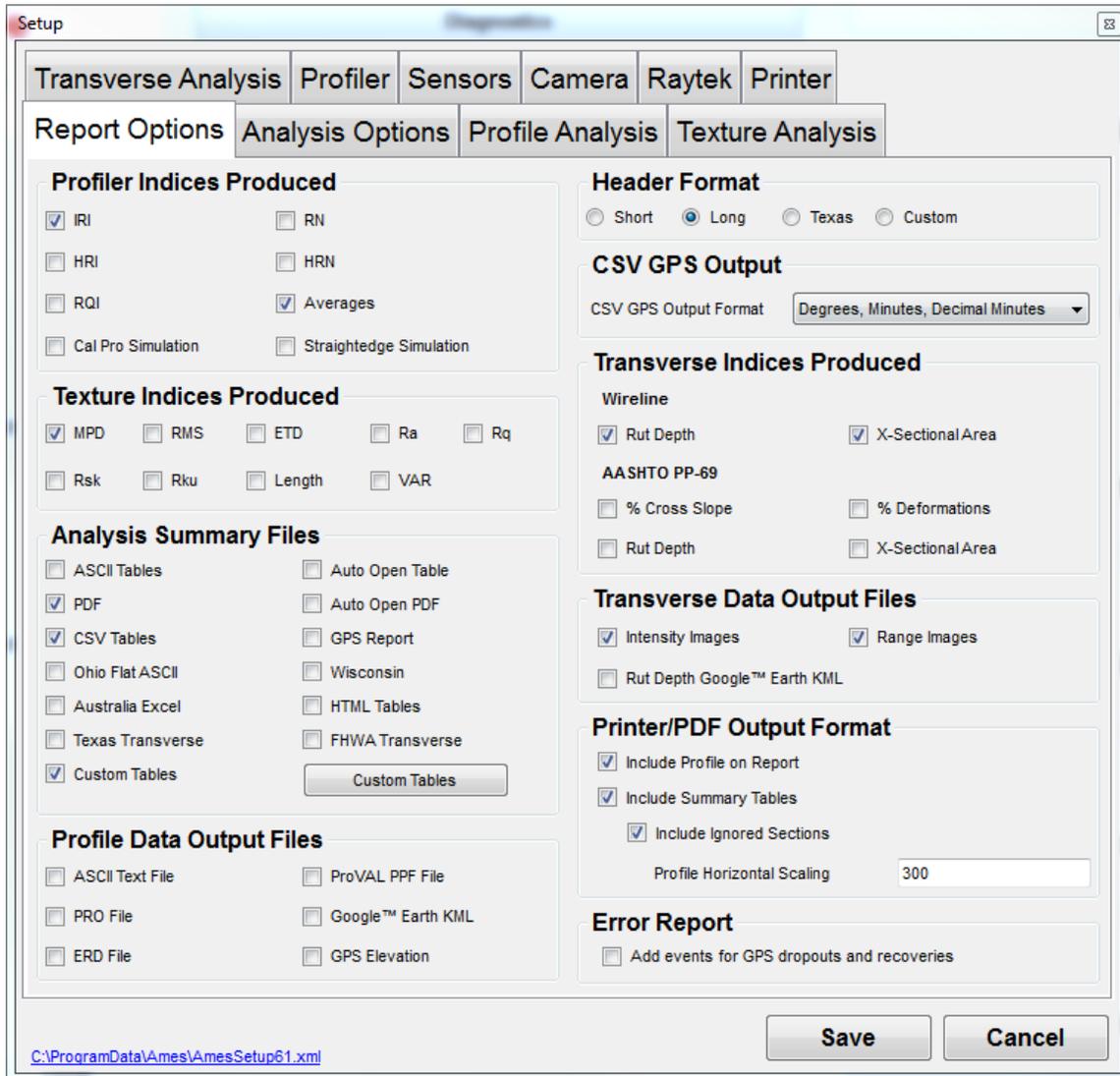
#### ***2.4.2.2.2 Transverse Analysis Menu***

The settings shown in figure 65 will impact the processing of transverse profile data. Therefore, the settings on the Analysis Options menu should match the parameters shown in figure 64 in the HSSV software on all computers that process transverse profile data. Refer to section 2.4.2.1.6 for a description of the Transverse Analysis menu.

#### ***2.4.2.2.3 Report Options Menus***

A screenshot of the Report Options menus is shown in figure 66. Parameters in this menu are associated with reports produced using the HSSV software. The only items in this menu that impact LTPP operations are the settings under Transverse Data Output Files. Both “Intensity Images” and “Range Images” must be checked to produce Intensity Images and Range Images.

No other reports are produced for LTPP operations using the HSSV software. Therefore, other settings in this menu have no impact on LTPP operations.



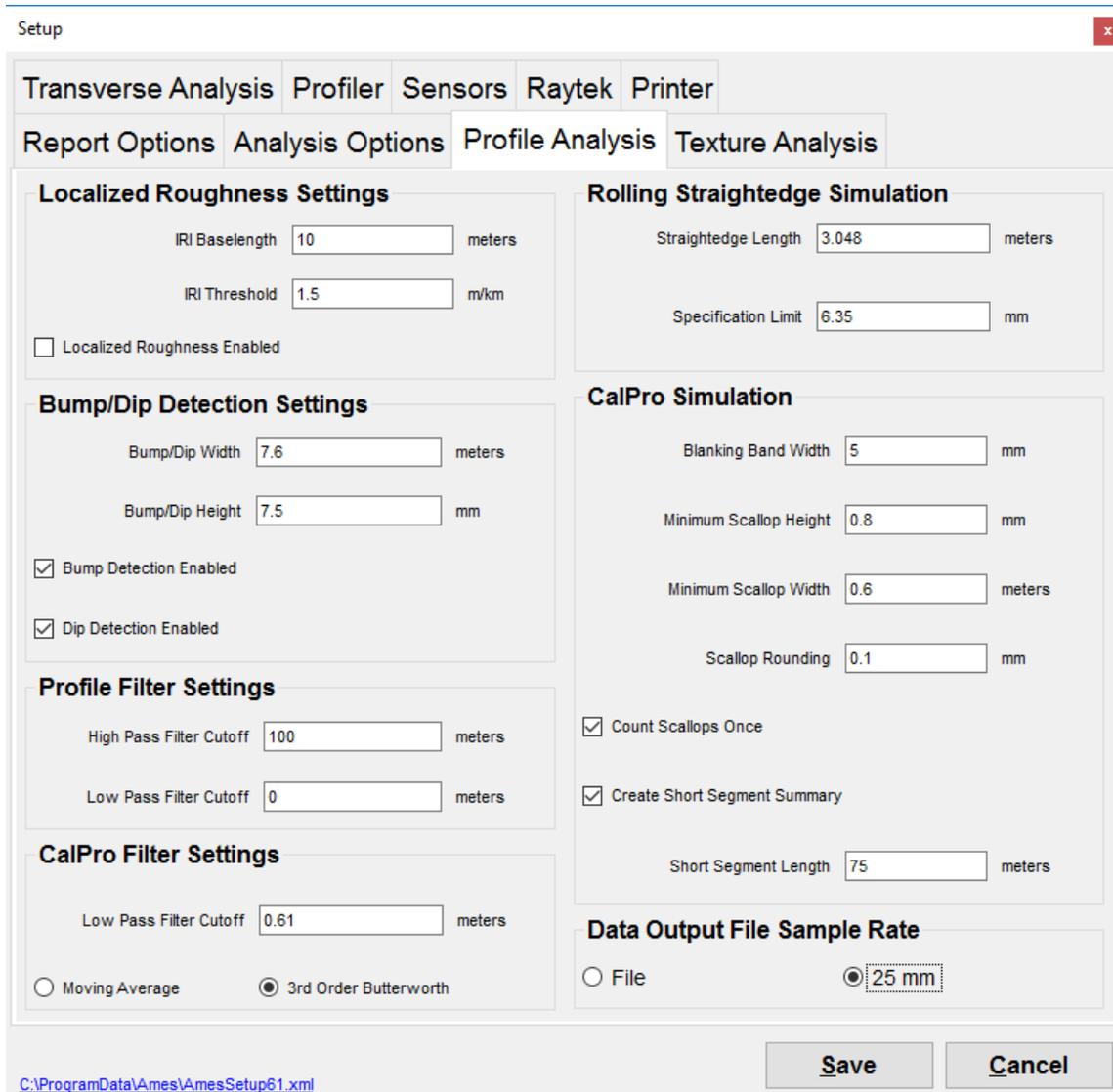
Source: FHWA.

**Figure 66. Screenshot. Report Options menu.**

### ***2.4.2.3 Menus That Have No Impact on LTPP Operations***

The settings in the Profile Analysis menu have no impact on LTPP operations, as no analyses of profile data are performed for LTPP operations using the HSSV software.

A screenshot of the Profile Analysis menus is shown in figure 67. The settings in this menu are used if longitudinal profile data are analyzed using the HSSV software. As longitudinal profile data are not analyzed using the HSSV software in the LTPP program, the settings in this menu have no impact on LTPP operations.



Source: FHWA.

**Figure 67. Screenshot. Profile Analysis menu.**

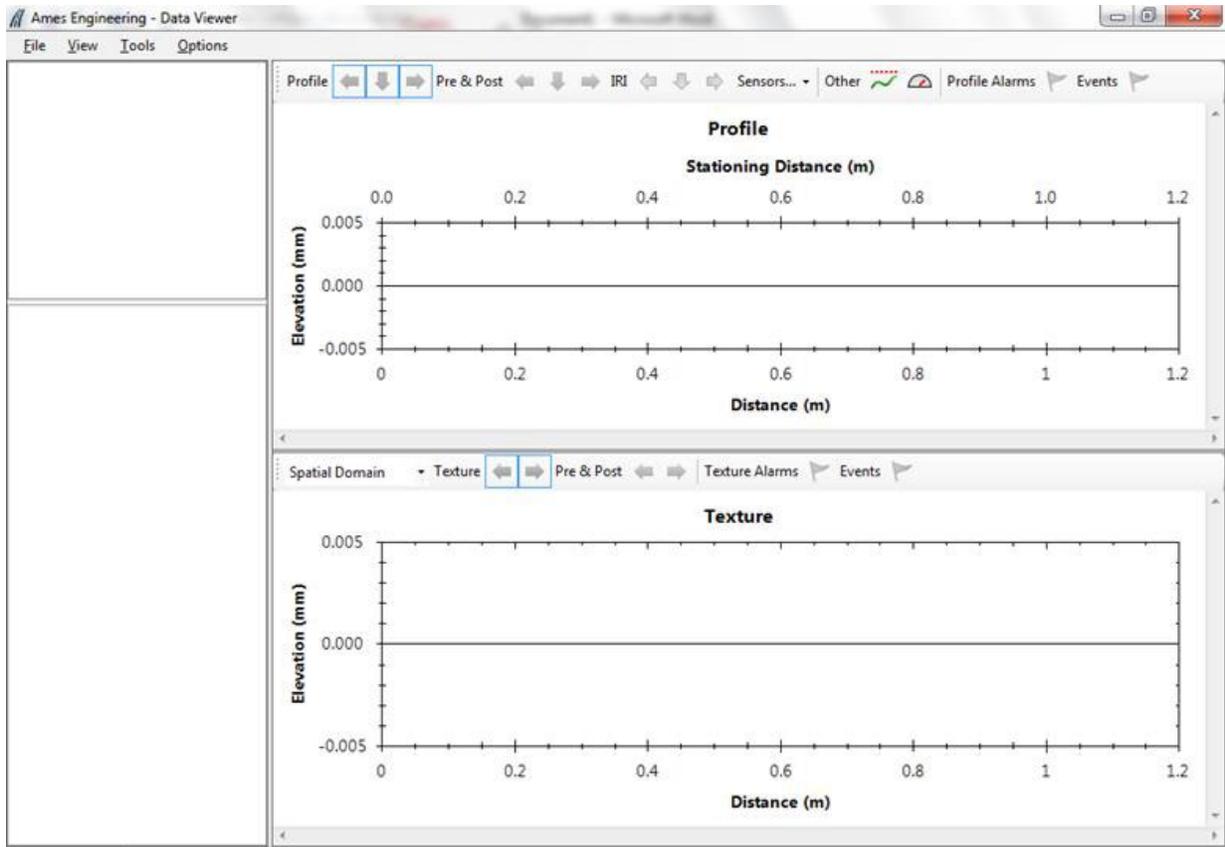
### 2.4.3 HSSV Viewer Settings

The HSSV Data Viewer is accessed by pressing the F6 key or selecting “View” in the startup screen (figure 58). Figure 68 shows the main menu of the Data Viewer.

The data viewer can be used to perform following functions:

- Plot longitudinal profile and macrotexture data.
- Calculate IRI values.
- Calculate MPD values.
- Generate data files containing longitudinal profile or macrotexture data conforming to the University of Michigan Transportation Research Institute Engineering Research Division (ERD) file format, referred to as ERD format.

- Generate data files containing longitudinal profile or macrotexture data conforming to the data format for pavement profile specified in ASTM E2560, *Standard Specification for Data Format for Pavement Profile*, referred to as PPF files.<sup>(8)</sup>



Source: FHWA.

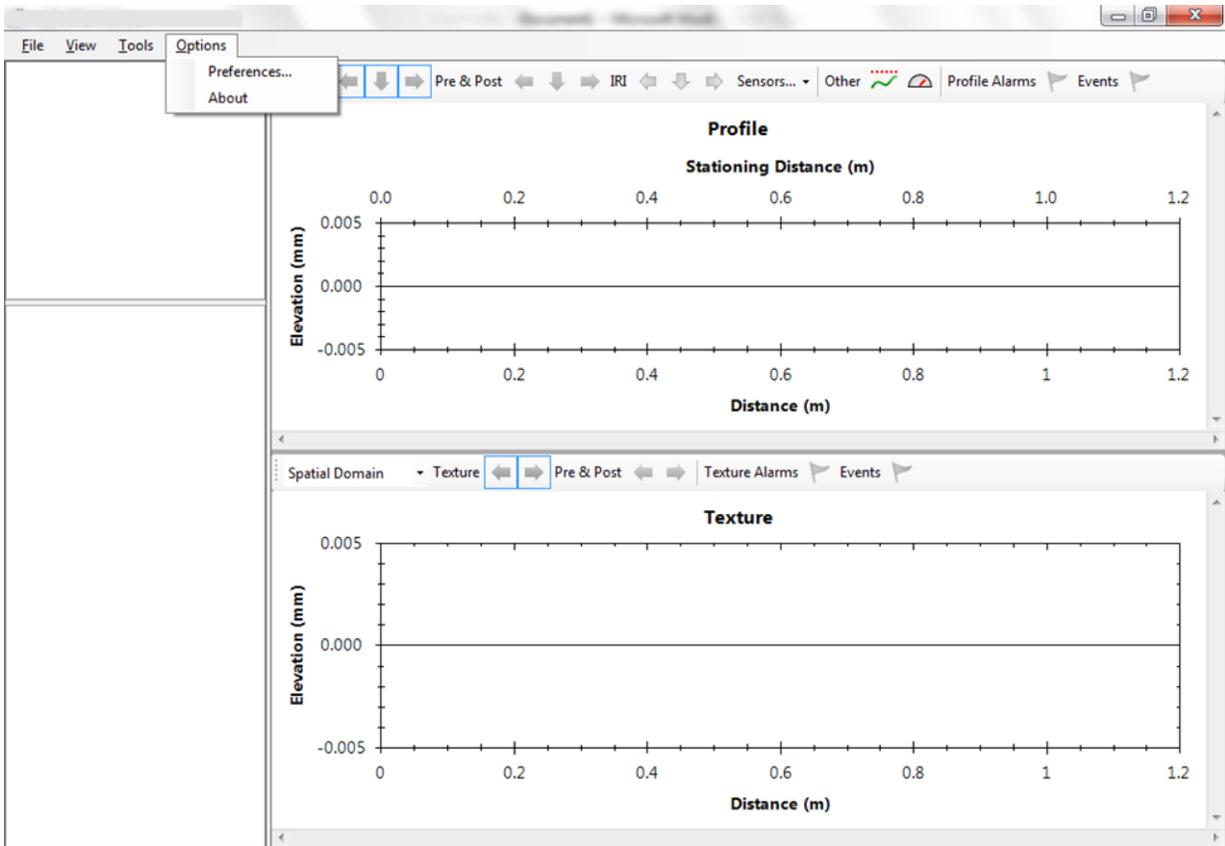
**Figure 68. Screenshot. Main menu of Data Viewer.**

For the LTPP program purposes, longitudinal profile data are generated at 25-mm intervals, while macrotexture data are generated at 0.5-mm intervals. To generate ERD or PPF files with this data recording interval, certain parameters must be set in the “Preferences Menu” of the Viewer located under the “Options” menu. The upper wavelength cut-off filter applied to longitudinal profile data must also be specified in the “Preferences” menu.

The following steps describe how to set the parameters:

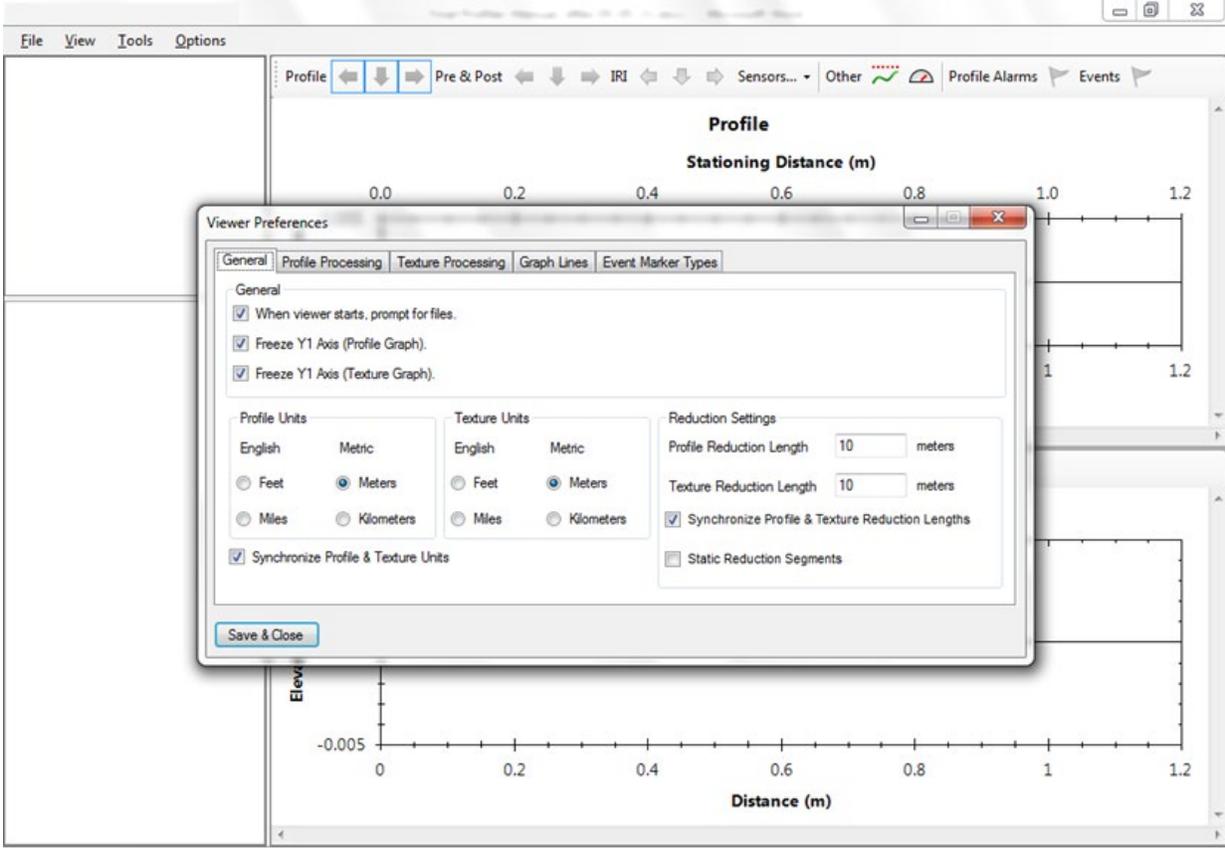
1. From the main menu of the data viewer, select “Options” and then select “Preferences” (figure 69).
2. The General menu shown in figure 70 will be displayed. Check all boxes under the heading “General,” as shown in figure 70. Set “Profile Units” and “Texture Units” to meters. Check “Synchronize Profile 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 71 will be displayed. Set the parameters in the Profile Processing menu to match the settings and values shown in figure 71. It is important to set the Pre/Post Distance option to “No Padding” for the ERD file to contain only data collected within the test section. 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 72 will be displayed. Set the parameters in the Texture Processing menu to match the settings and values shown in figure 72.
5. If any changes were made because the displayed screens in the software were different from the ones shown in the manual, select the “Save and Close” button to save the changes.



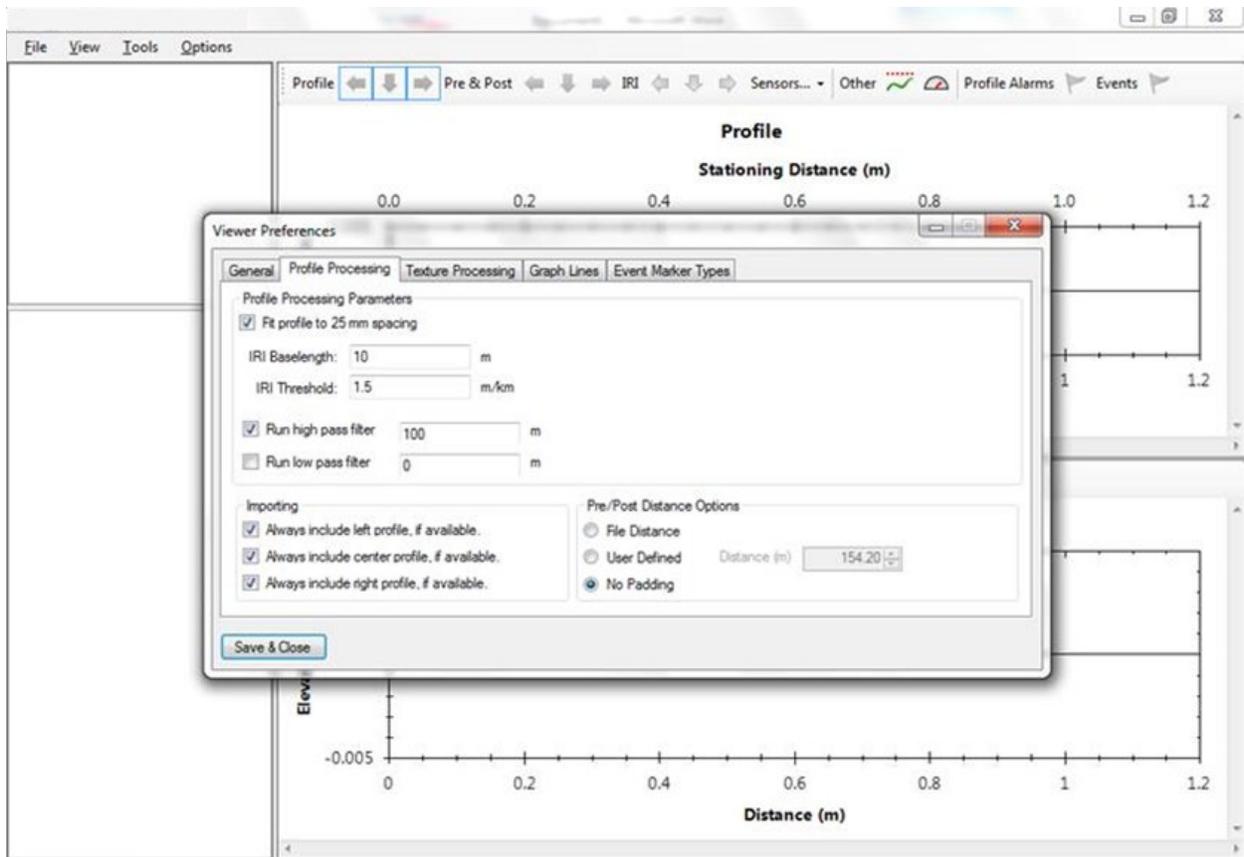
Source: FHWA.

**Figure 69. Screenshot. Selecting Preferences menu.**



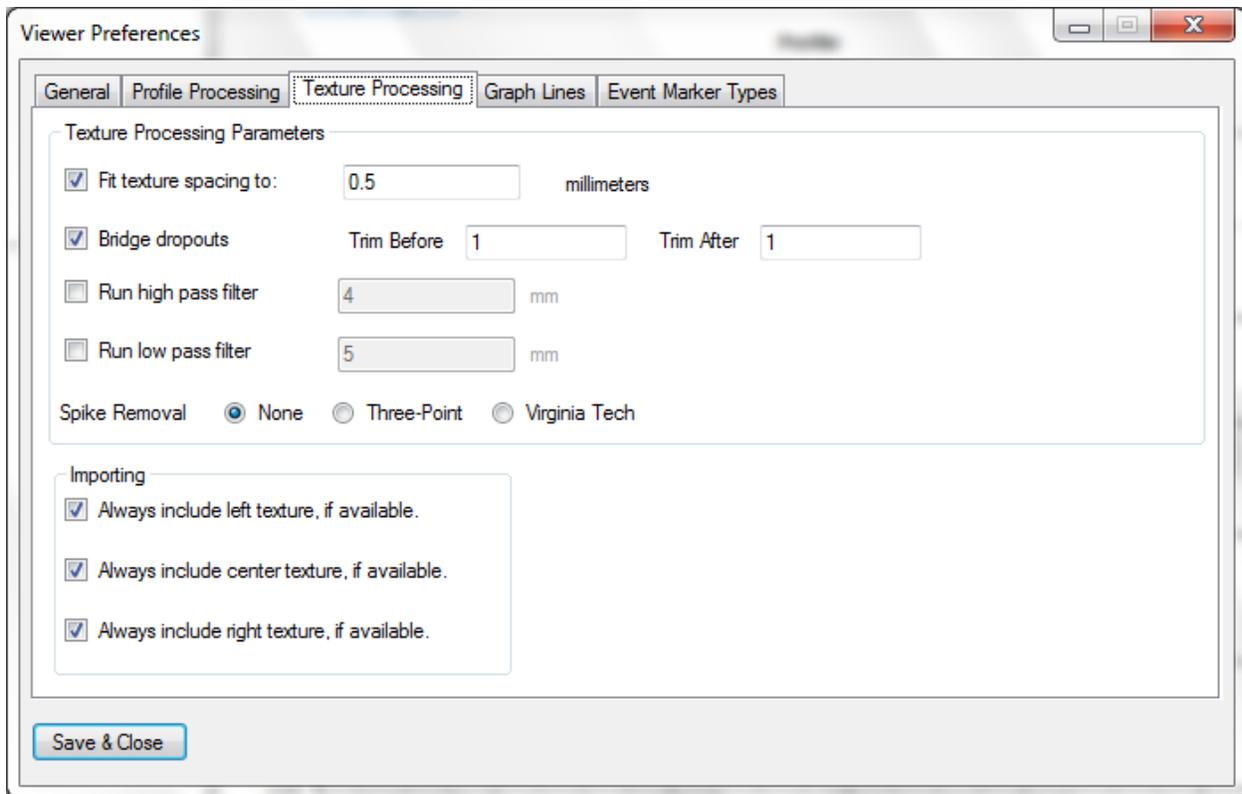
Source: FHWA.

**Figure 70. Screenshot. General menu.**



Source: FHWA.

**Figure 71. Screenshot. Profile Processing menu.**



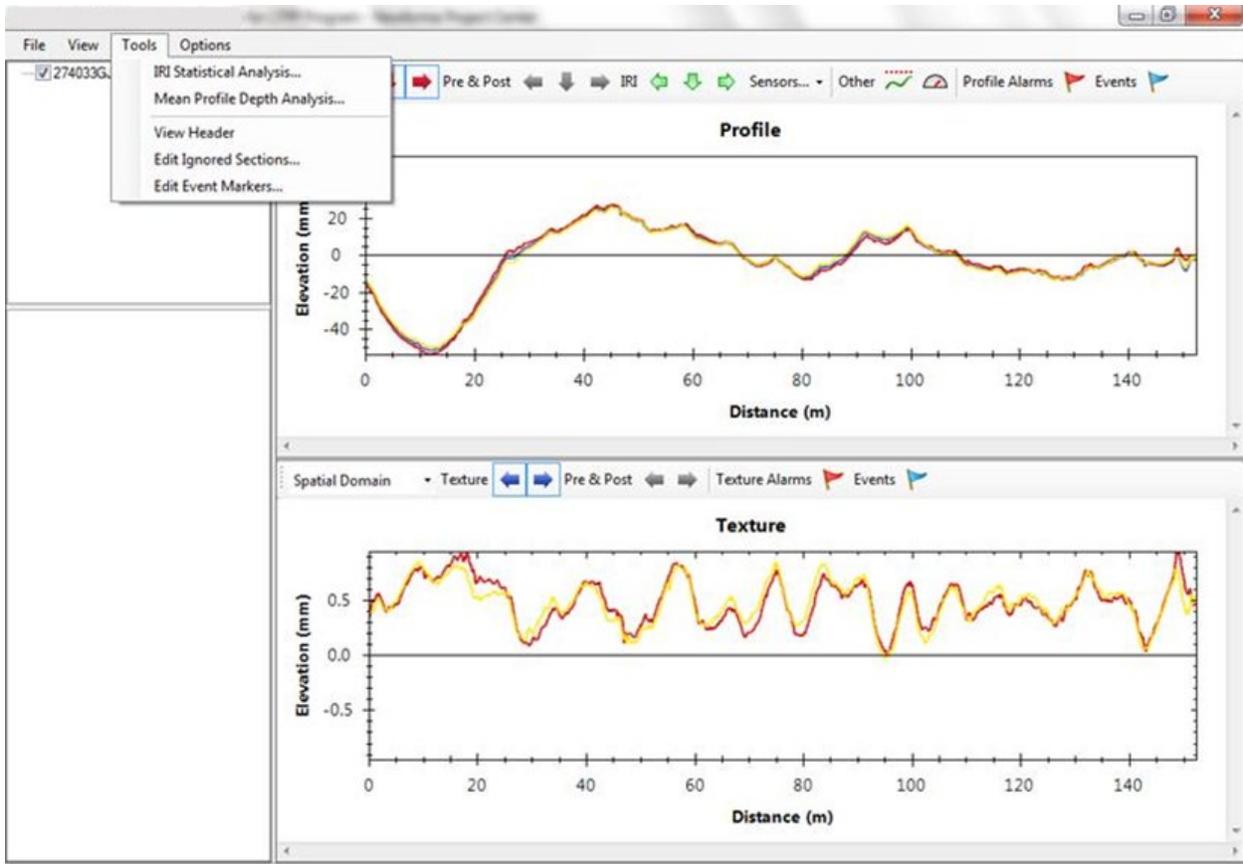
Source: FHWA.

**Figure 72. Screenshot. Texture Processing menu.**

After these parameters have been set, ERD files containing longitudinal profile data at 25-mm intervals and/or macrotexture data at 0.5-mm intervals can be generated after loading the ARD files and going to the “Export Spatial Data” menu located under the File menu (figure 69). 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.

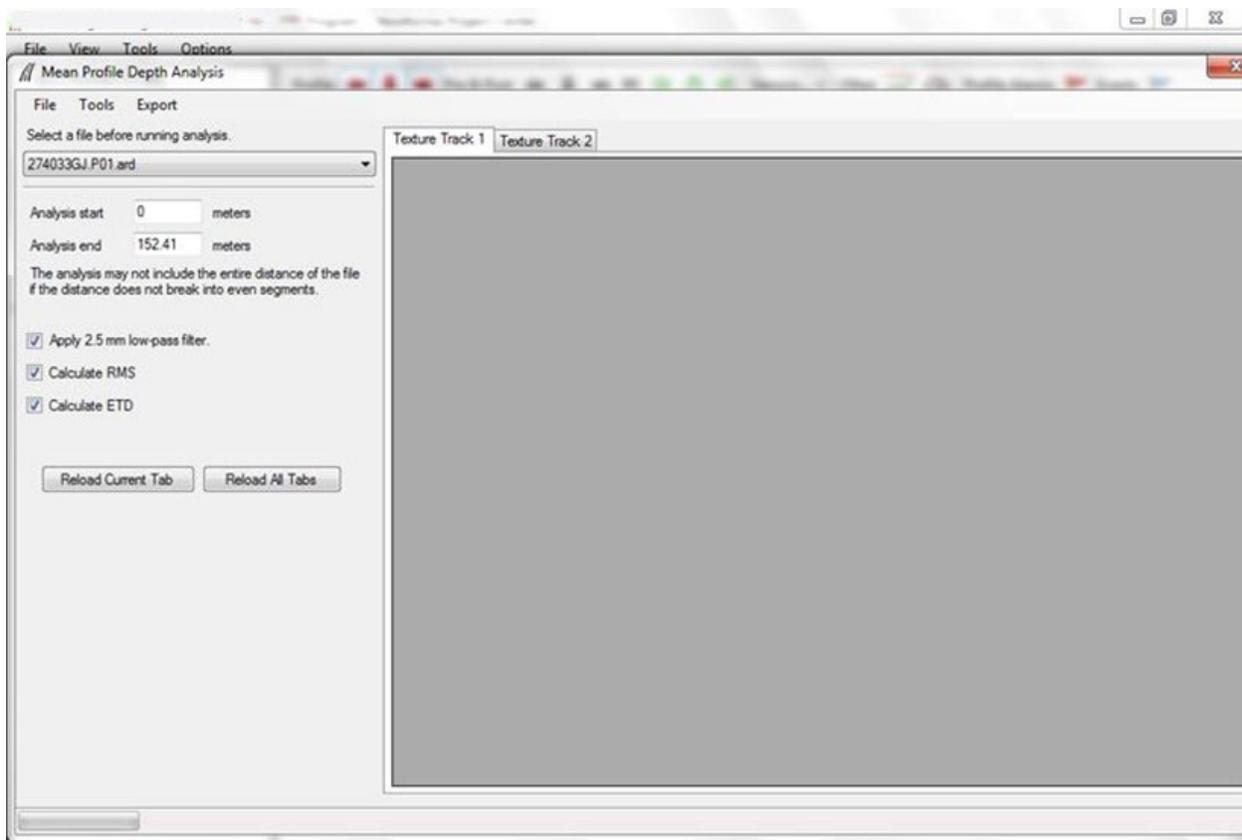
If desired, the MPD values from the left and right texture sensor data can be computed through the Mean Profile Depth Analysis menu. Use the following procedure to compute MPD values after loading the ARD files:

1. Select “Tools” from the main menu of the Data viewer (figure 73) and then select “Mean Profile Depth Analysis.”
2. In the Mean Profile Depth Analysis menu, the “Apply 2.5 mm low pass filter” option on the left side of the menu must be checked when computing the MPD (figure 74). Texture Track 1 and Texture Track 2 correspond to ODS 4 (left wheel path texture data) and ODS 5 (right wheel path texture data), respectively.
3. Then, click “Reload All Tabs,” and the computed MPD values will be displayed.



Source: FHWA.

**Figure 73. Screenshot. Accessing the Mean Profile Depth Analysis menu.**



Source: FHWA.

**Figure 74. Screenshot. Mean Profile Depth Analysis menu.**

In the Texture Processing Menu (figure 72), the “Spike Removal” field was set to “None.” Hence, spikes in the texture data are not removed before the MPD values are computed. Spikes are not removed from the macrotexture data before computing MPD in the LTPP program. If a user wants to compute MPD with spikes removed from the data, the user has the option of selecting either the three-point method or the Virginia Tech method in the Texture Processing Menu and then computing the MPD.

#### **2.4.4 ProQual Software**

The installation procedure and a description of the ProQual software are provided in reference 7. 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 HSSV that collected the data, which is either 830112, 830212, 830312, or 830412 (section 1.3).

ProQual detects the following two types of spikes:

- Single Elevation Spikes—the spike threshold for single elevation spikes is 5 mm in ProQual. If the absolute difference between the elevation at a location and the prior location is greater than 5 mm, that location is defined as having a single elevation spike.
- Double Elevation Spike—the spike threshold for double elevation spikes is 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, that location is defined as having a double elevation spike.

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

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

The HSSV is equipped with three laser profile height sensors and two laser texture height sensors. The laser light emitted from these sensors 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.<sup>(5)</sup> Hence, reflection of the laser beam from a surface, such as a polished base plate, a gauge block, or a watch, could damage one's eyesight. Operators should take adequate precautions to avoid the laser light directly from the laser sensor or from a reflected surface coming into contact with the eye. Always ensure power to the laser sensors is turned off when inspecting the sensor glass, cleaning the sensor, performing maintenance on the sensors, and performing the accelerometer calibration check. The power switch located on the dashboard (figure 34) will turn off power to the profile and texture laser height sensors and other components in the HSSV. If only the power to the profile and texture height sensors needs to be turned off, such as during the accelerometer calibration check, use the key in the DAU to turn power off (section 2.2.4).

The ambient operating temperature range of the profile and texture lasers is from 0 to 50°C.<sup>(5)</sup> The laser sensor manufacturer has indicated to the HSSV manufacturer 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. The laser sensor manufacturer 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 HSSV are housed inside a box; the temperature inside this box will typically be higher than the ambient temperature. Sensors to monitor the temperature inside each sensor box that houses the profile height sensors are included in the circuit boards inside each box. The temperature inside the interface box that processes texture data (figure 5) is also monitored by a temperature sensor located on a circuit board. The HSSV software startup screen (figure 58) shows the internal temperature of the sensor boxes under ODS 1 (left wheel path), ODS 2 (right wheel path), and ODS 3 (center sensor). The temperature shown for ODS 4 (left texture laser) and ODS 5 (right texture laser) is the temperature inside the interface box, and both temperatures should show the same value. The displayed temperatures are measured at 1-s intervals.

Based on their testing, the manufacturer has recommended an operating temperature range of 0°C 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. HSSV software will not shut off either the profile or texture height sensors. However, circuitry inside the laser sensor will automatically shut off a profile or 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 rescheduled for early morning or after-sunset hours.

### **2.5.2 Cleaning Sensor Glass of Profile and Texture Sensors**

The sensor glass of the profile height sensors should be cleaned after performing the accelerometer calibration check, which is specified to be performed at a maximum interval of 30 d (section 2.12.4). During the accelerometer calibration check, 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 the sensor glass for any damage.

Clean the sensor glass using compressed air. If the sensor glass appears to be clean, no further cleaning is needed. If excessive dirt is noted, spray water and wipe the sensor glass with a damp lens-cleaning or lint-free cloth. Extreme care should be used when cleaning the sensor glass to prevent scratching.

Wipe the glass once in a single motion. Do not rub the 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 cause scratches.

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 and detection units 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 the 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 on the 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 HSSVs were delivered. However, equipment and materials added to the back of the vehicles by the DCC may have caused the sensor bar to go out of level. Accordingly, the levelness of the sensor bar should be checked periodically when the vehicle is parked on a level surface. If the bar is not leveled, the manufacturer 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 thus 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 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.

#### **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 fixed to a cone placed on the side of the road.

The vertical and 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 HSSV operator needs to adjust the sensitivity setting if the photocell does not trigger. Refer to the photocell documentation in the equipment binder on how to adjust the sensitivity of the photocell.<sup>(5)</sup>

#### **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 manufacturer’s recommended values listed on the door panel, which are 380 kPa for the front tires and 550 kPa 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 at highway speeds after being parked, the tires are considered to have warmed up sufficiently. However, the distance for warming up tires may need changing depending on local weather conditions. Warming up 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 driver’s side tire. The operator should have a copy of the Distance Calibration Report that was printed when the DMI in the HSSV 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 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 pressure of the rear tires to ensure that it 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 HSSV from debris. Figure 75 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 the HSSV is not collecting data. The protective covers must be opened when performing sensor checks, during bounce tests, and while collecting longitudinal profile and macrotexture data. The protective cover is opened by loosening the knobs and sliding the cover off and then retightening the two knobs.



Source: FHWA.

**Figure 75. Photo. Protective cover that protects the laser sensors.**

### 2.5.7 Interior Temperature of Vehicle

The vehicle is equipped with a heater and air conditioner to maintain a temperature comfortable to the operator. On cold days when the vehicle has been parked outside, it can take a considerable amount of time to warm up interior of the vehicle. The laser printer manual indicates an operating temperature range between 15 and 32.5°C, with a recommended operating temperature between 18 and 25°C. The laptop computer operations manual indicates the computer can function at a low temperature of 0°C and a high temperature of 50°C.<sup>(5)</sup> The electronics within the vehicle should operate satisfactorily even at temperatures below 0°C.

### 2.5.8 DMI

The HSSV is equipped with an encoder attached to the rear driver's side wheel (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 HSSV 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 (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 (section 2.9.2.2). During 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 d, 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 performed before collecting data.

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

- Calibration base plates.
- Calibration targets.
- Calibration blocks.
- Digital level.

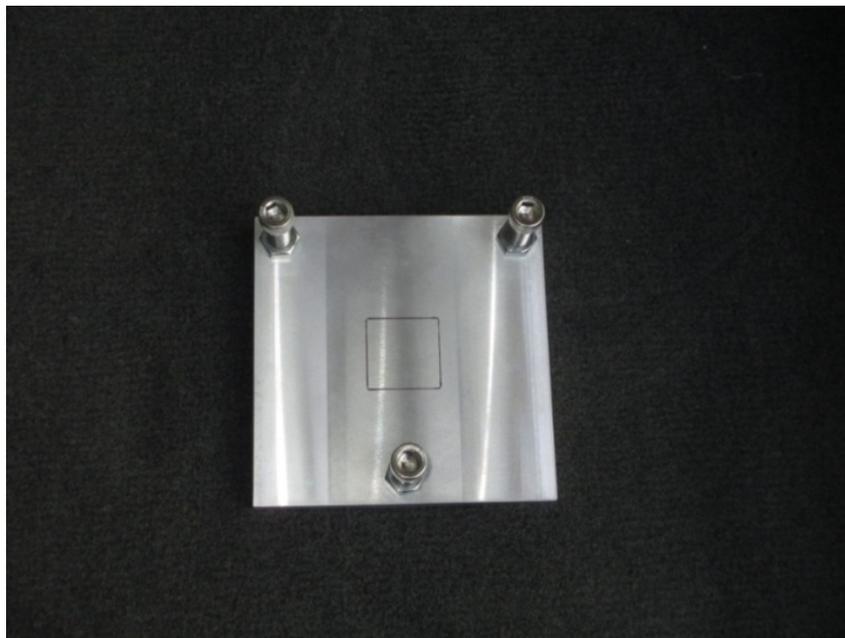
#### ***2.5.9.1 Calibration Base Plates***

Three base plates are provided in each HSSV. The base plates have three feet for support, which can be used to level the plate. The bottom view of the calibration base plate is shown in figure 76, while the top view of the plate is shown in figure 77. 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 mark ensures the calibration blocks are placed exactly at the same location when performing the calibration check.



Source: FHWA.

**Figure 76. Photo. Bottom view of the base plate.**



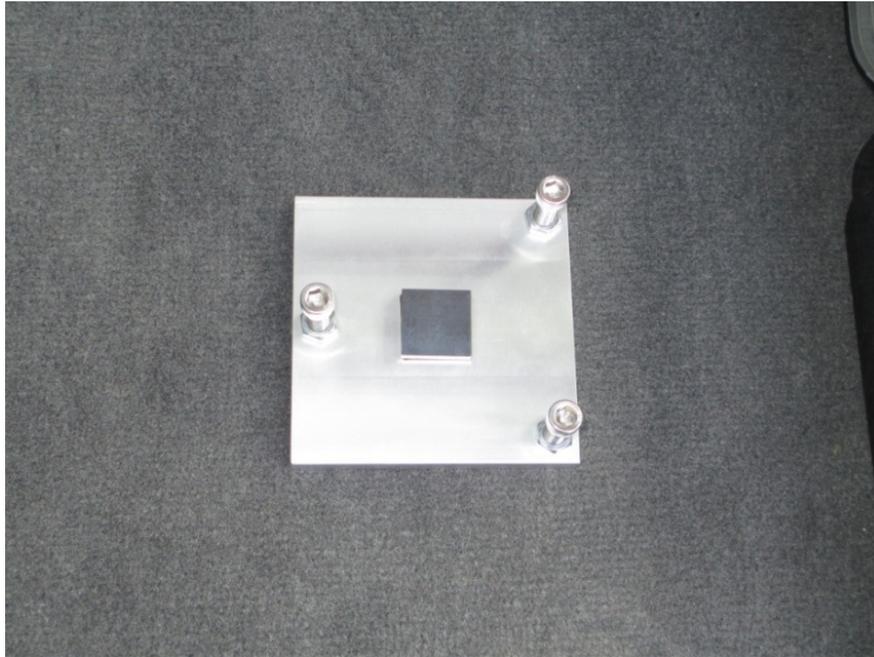
Source: FHWA.

**Figure 77. Photo. Top view of the base plate.**

### ***2.5.9.2 Calibration Targets***

Three calibration targets are provided with each HSSV. 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 glossy side and a matte side, and measurements should always be obtained on the matte side. Figure 78 shows a target placed on top of the base plate.



Source: FHWA.

**Figure 78. Photo. Calibration target placed on the base plate.**

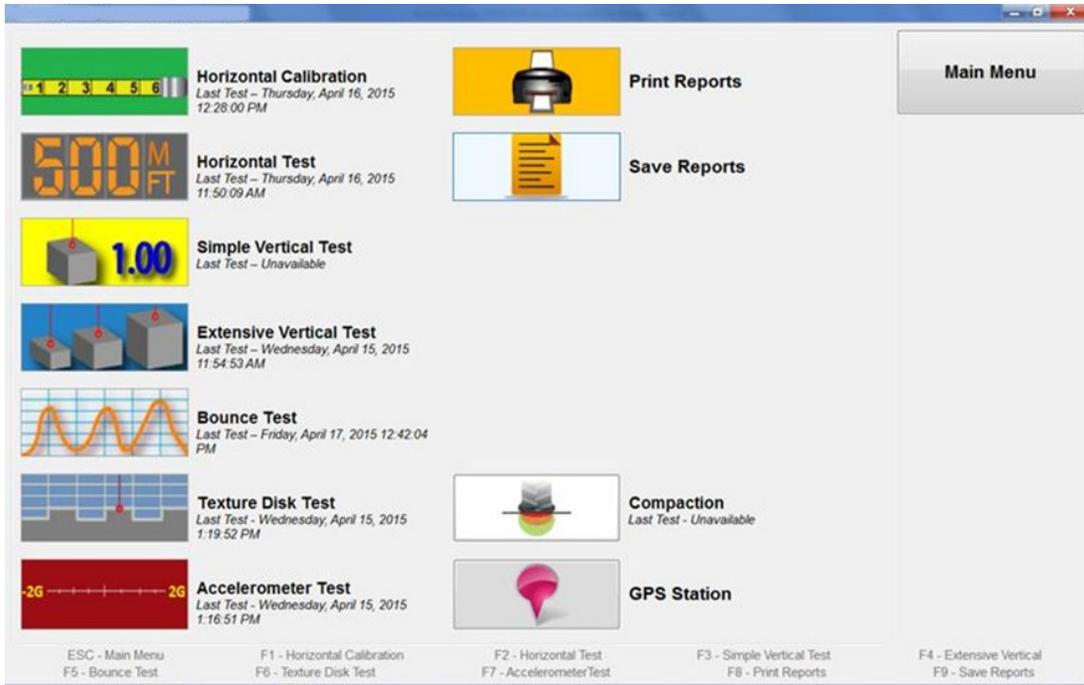
### ***2.5.9.3 Calibration Blocks***

Three sets of blocks having nominal heights of 25, 50, 75, and 100 mm are provided with each HSSV. The block number is engraved on the side of the block. The exact height of the blocks is shown in table 1. The exact height of the blocks to four decimal places must be entered into the HSSV 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 after any changes, updates, or reinstallation of the software.

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

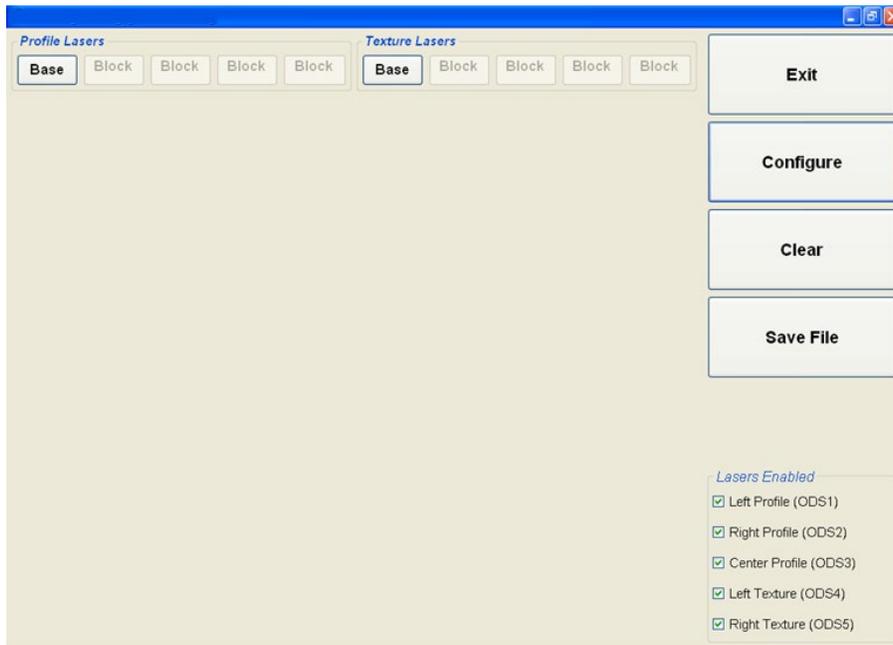
1. Boot up the laptop computer and start the HSSV software as described in section 2.8.1.
2. Press the F2 key or select “Calibrate” to bring up the Calibration menu (figure 79).
3. Press the F4 key or select “Extensive Vertical Test” and the Extensive Test menu will be displayed on the laptop computer screen (figure 80).
4. Select “Configure,” and the menu to enter the block heights will be displayed (figure 81).
5. Enter the block identifier that is engraved on the side of the block and the exact height of the block shown in table 1 into this menu. Figure 82 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 the correct block will be placed below each sensor when performing the calibration check or the full calibration check of the height sensors.



Source: FHWA.

**Figure 79. Screenshot. Calibration menu.**



Source: FHWA.

**Figure 80. Screenshot. Extensive Test menu.**

	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"/>

Source: FHWA.

**Figure 81. Screenshot. Menu for entering actual block heights.**

	Left Laser	Center Laser	Right Laser
<b>Block 1</b>	Height (mm) <input type="text" value="25.0045"/>	Height (mm) <input type="text" value="25.0039"/>	Height (mm) <input type="text" value="25.0046"/>
	Identifier <input type="text" value="A10"/>	Identifier <input type="text" value="A11"/>	Identifier <input type="text" value="A12"/>
<b>Block 2</b>	Height (mm) <input type="text" value="50.0046"/>	Height (mm) <input type="text" value="50.0046"/>	Height (mm) <input type="text" value="50.0036"/>
	Identifier <input type="text" value="A22"/>	Identifier <input type="text" value="A23"/>	Identifier <input type="text" value="A24"/>
<b>Block 3</b>	Height (mm) <input type="text" value="75.0033"/>	Height (mm) <input type="text" value="75.0031"/>	Height (mm) <input type="text" value="75.0041"/>
	Identifier <input type="text" value="A34"/>	Identifier <input type="text" value="A35"/>	Identifier <input type="text" value="A36"/>
<b>Block 4</b>	Height (mm) <input type="text" value="100.0015"/>	Height (mm) <input type="text" value="100.0043"/>	Height (mm) <input type="text" value="100.0041"/>
	Identifier <input type="text" value="A46"/>	Identifier <input type="text" value="A47"/>	Identifier <input type="text" value="A48"/>

Source: FHWA.

**Figure 82. Screenshot. Menu with actual block heights entered.**

#### 2.5.9.4 Digital Level

A digital level is provided in each HSSV to level the base plate when performing the calibration check of the height sensors (figure 83).



Source: FHWA.

**Figure 83. Photo. Digital level.**

#### 2.5.10 Auxiliary Battery

When the HSSV 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. The Lo-Battery alarm will be displayed when the main power switch is in the “On” or “Off” position.

When the engine of the vehicle 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 overestimation causes the Lo-Battery warning to appear even though the battery has not reached the Lo-Battery stage.

This Lo-Battery warning will not clear until an operator manually synchronizes the display. However, the auxiliary battery must be fully charged before this synchronization is performed. The Lo-Battery warning 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 clear the Lo-Battery warning, connect to shore power, and after charging the auxiliary battery overnight, press the two arrow keys on the battery status monitor simultaneously for 3 s. A flashing “FULL” message will appear on the display indicating it is now synchronized at full capacity, and the Lo-Battery warning will clear.

To avoid getting the Lo-Battery warning, connect to shore power when the HSSV will be parked and not used for a couple 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. Therefore, the battery status monitor will indicate the auxiliary battery is fully charged. However, it is not possible to follow this procedure unless the HSSV is parked in a garage.

If shore power cannot be connected continuously, it is recommended the battery status monitor be inspected before the HSSV goes on a trip to collect data. If the Lo-Battery status indicates “on” in the battery status display, connect to shore power and wait until the battery is fully charged by checking the display unit on the dashboard. Then, press the two arrow keys on the battery status monitor simultaneously for 3 s. The auxiliary battery will usually be fully charged in about 8 h after connecting to shore power.

The manufacturer 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.

## **2.5.11 TPMS**

The box housing the TPMS can be removed for security purposes when data collection is not being performed. After removing the TPMS, connect the dummy connectors provided in the supporting rail to cover the connections to the PSM and Ethernet cable to prevent dust or any contaminants from entering the connectors.

## **2.6 LTPP OPERATIONAL GUIDELINES**

### **2.6.1 General LTPP Procedures**

#### ***2.6.1.1 Accidents***

In the event of an accident, the operator should inform the supervisor of the incident as soon as possible. Details of the accident should be reported in writing to the supervisor. The corporate policy of the DCC should be followed in event of an accident. A police report of the accident and photographs showing damage to the vehicle should be obtained.

### ***2.6.1.2 Maintenance of Records***

The operator is responsible for preparing and forwarding the forms and records associated with calibration or calibration checks and maintenance to appropriate personnel within the company (section 2.12 and section 2.13, respectively).

### ***2.6.1.3 Safety***

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

### ***2.6.1.4 Problem Reports***

An HSSV Longitudinal Profile/Texture/Transverse Profile 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 problems 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 (GO-68 is the latest as of this printing) should be followed when profiling General Pavement Studies (GPS), SPS, and WIM sites.<sup>(9)</sup>

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

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

Form PROF-4, LTPP Major Maintenance/Repair Activity Report must be completed whenever repairs are performed on any component in the HSSV associated with data collection, such as profile height sensors, accelerometers, DMI, texture height sensors or controllers, ambient and pavement temperature sensors, GPSR, DAU, and TPMS (figure 178). This report must also be prepared if any of the referenced components are replaced due to malfunction.

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

- The DMI should be calibrated whenever repairs are made to the DMI or if the DMI is replaced.
- An accelerometer calibration check should be performed whenever repairs are made to 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 made to a profile or texture height sensor or any circuit board associated with these sensors. A full calibration check must also be performed if a profile or texture height sensor is replaced.
- A bounce test must be performed after a profile height sensor or 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 HSSV should be checked using the following procedure to ensure accurate data are collected:

1. Select a test section where longitudinal profile data has been collected recently and is close to the current location of the HSSV. When selecting the test section, review any comments made when the profile data were collected to ensure profile data available for this test section are free of errors and that no unexplained spikes are present in the data. It is recommended that GPS-3 and SPS-2 test sections be avoided, as significant variations in profile can occur on these test sections due to the effects of temperature. The DCC should use their judgment in selecting an appropriate test section to perform this comparison, taking into account the current location of the HSSV and availability of a suitable test section close to the location of the HSSV.
2. Collect profile data at the selected test section 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 visit to the test section.
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 test section. If discrepancies are still noted, the manufacturer 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. The manufacturer should be consulted on how this replacement can be accomplished. Once the repaired or replacement sensor is available, the center sensor that is now located at an outer position (i.e., 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 (i.e., left or right wheel path). A full calibration check should be performed on the repaired or replaced sensor (section 2.12.5). Thereafter, the

accelerometer check and bounce test should be performed (section 2.12.4 and section 2.9.2.4, respectively). Procedures described previously (i.e., profiling at a test section where profile data were previously collected) should be followed to ensure 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 the repaired or replaced sensor must be checked using the following procedure to ensure accurate data are collected.

1. Select an AC-surfaced test section where macrotexture data has been recently collected and is close to the current location of the HSSV. Preferably, the test section should not have visible pavement distress. The DCC should use their judgment in selecting an appropriate test section to perform this comparison, taking into account the current location of the HSSV and availability of a suitable test section close to the location of the HSSV.
2. Collect macrotexture data at the selected test section 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 replaced 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, 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 test section. If discrepancies are still noted, the manufacturer should be contacted to resolve the problem.

### **2.6.4 Data from a Previous Visit to the Test Section**

After collecting data at a test section, the HSSV operator is required to compare the longitudinal profile data and the IRI with the data collected during the previous visit to the test section, as described in section 2.9.4.5. The HSSV operator is also required to compare the current MPD values with the MPD values obtained during the previous visit to the test section, as described in section 2.9.4.3.

Before traveling to the test section, the operator must ensure the data files required to perform this comparison for the previous visit to the test section are available. The operator must also have the IRI and MPD values for the test section from the previous visit.

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

The operator should maintain a copy of the HSSV software and the ProQual software in the vehicle in case software problems occur with the software installed on the laptop computer. If the HSSV software is re-installed, the operator must go through the setup menus described in section 2.4 of this manual to ensure appropriate parameters have been set to the correct values.

Apart from HSSV 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 (e.g., extra drives or other device) to the laptop computer system before contacting the manufacturer through FHWA to determine if they will interfere with HSSV data collection and data-processing programs. Interference of programs due to additional devices may not be readily apparent.

Data files collected by the HSSV should be organized into subdirectories in the hard drive as outlined in the current version of LTPP directive I-171, *AIMS Data Storage Format Standards*.<sup>(10)</sup>

## **2.7 FIELD OPERATION GUIDELINES**

### **2.7.1 Turnarounds**

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

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

The HSSV is equipped with a light bar in the front, a directional warning light mounted on the rear, and strobe lights within the headlamps and the taillights. 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 Test Sections**

The file-naming convention to specify the name of a data file when collecting data at GPS and SPS test sections is described in this section. File-naming conventions for collecting data at WIM test sections 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:

- Characters one and two—State code in which test section is located (e.g., 27 for Minnesota).
- Characters three to six—four-digit test section number. For GPS test sections this is the four-digit LTPP identification number (e.g., 1023). For SPS test sections, the third character should be 0, A, B, and so on, depending on project code (e.g., 0300, A300, B300, and so on). The fourth character for SPS test sections is the experiment number (e.g., 2 for SPS-2 projects), while the fifth and sixth characters should be 0. However, for

SPS test sections, it is permissible to use the fifth and sixth character to indicate the first test section encountered when the SPS test section is profiled.

- Character seven—letter code defining test section type (e.g., G for GPS, S for SPS, or C for Calibration test sections).
- Character eight—sequential visit identifier code that indicates the visit code for the current data collection. This identifier indicates the number of times a set of profile runs has been collected at a test section since the test section was first profiled with the T-6600 profiler. (When the test section was first profiled with the T-6600 profiler, the letter A was used for the eighth character). Use an appropriate letter for the current profiling. For example, if a test section is being profiled for second time, use letter B; use C for the third time, H for eighth time, and so on. If a test section is being profiled for the first time, the letter A should be used for the eighth character. Thereafter, this letter should be sequentially increased (e.g., B, C, and so on) during subsequent profile data collection visits. If in the past an RSC has been using the sequential visit identifier to indicate the number of times a set of profiles has been obtained at the test section since its inception into the LTPP program, the DCC can continue to use this procedure when collecting data. In such case, the letter A is used to denote the first time the test section was profiled by the RSC, whether with the DNC690, T-6600, ICC, or HSSV. Thereafter, this letter should be sequentially increased (e.g., 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 test section is profiled the next time:

1. If the test section is a GPS test section, change character seven to H and assign the test section visit identifier to be A. For subsequent profile visits, maintain character seven as H and change the sequential visit identifier to B, C, D, and so on.
2. If the test section is an SPS test section, change character seven to T and assign the test section visit identifier to be A. For subsequent profile visits, maintain character seven as T and change the sequential visit identifier to B, C, D, and so on.

The following are examples of valid data file names:

- 171002GD—GPS test section 1002 in Illinois (State code = 17), profiled for the fourth time.
- 260200SB—SPS-2 test section in Michigan (State code = 26), profiled for the second time.
- 27A300SC—SPS-3 test section with 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 test sections, the sixth character in the 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 test 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 test 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 the maximum constant speed attainable is less than 80 km/h due to either traffic congestion or safety constraints, a lower speed—depending on prevailing conditions—should be selected. If the speed limit at test section is less than 80 km/h, the test section should be profiled at the posted speed limit. If traffic traveling at high speeds is encountered at a test section, it is permissible to increase the profiling speed to 88 km/h. If the test section is relatively flat, cruise control should be used to maintain a uniform speed. It is important to avoid changes in speed during a data collection run that may jerk the vehicle or cause it to pitch on its suspension. Change in throttle pressure or the use of brakes to correct vehicle speed should be applied slowly and smoothly.

## **2.7.5 Capturing Images at LTPP Sections**

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

For security purposes, the DCC may elect to remove the CCD camera from the mounting bracket when the vehicle is parked outside. After the camera is removed, it can be kept inside the vehicle in a location where it cannot be seen from outside to protect from possible theft.

Obtain one set of images at 10-m intervals at all LTPP test sections when collecting profile and/or macrotexture data, including GPS, SPS, and WIM test sections. At WIM test sections, 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 the camera, connect it to a USB port in the laptop computer, boot up the laptop computer, and then start the HSSV software as described in section 2.8.1. Thereafter, press the F1 key or select “Setup” to access the Setup menu and then select the “Camera” tab to access the Camera Setup menu. Use the Camera Preview to properly aim the camera. The hood of the vehicle and the guideposts 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 (section 2.2.21) if needed to obtain the best possible images.

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

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

The images captured 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 collecting images:

- Option 1—elect to have the camera “On” and capture images for all repeat runs performed at the test section. Thereafter, once 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 captured images (e.g., using Windows Explorer) after the first run. If the captured images are not satisfactory, capture images for the next run(s) until a set of satisfactory images have been obtained. If the captured images are satisfactory, close the camera window, so images will not be obtained during subsequent runs at the test section. Once the camera is closed, it is disabled. To enable the camera again, go to the Camera Setup menu and select “Photo” (section 2.4.2.1.).

For WIM test sections, the images only need to be captured when collecting data along the wheelpaths; images are not needed for non-wheelpath runs.

### ***2.7.5.2 Image Files***

The camera captures the first image when the photocell is armed. This image will have an image number of 0001. The images captured by the camera increase sequentially starting with 0001. The camera will capture the last image 152.4 m past the Stop Distance entered in the Header screen (section 2.9.3.2). The Stop Distance is always 152.4 m for a GPS test section. Hence, for a GPS test section, the camera will capture the last image approximately 152.4 m past the end of the test section.

The images captured by the camera will have the following file name assigned by the HSSV software based on the file name entered for saving the collected profile data:  
HSSAASHRPBRYYYMMDDNNNN.jpg.

Where:

HSS = high-speed survey. The first three characters of the filename will always be HSS.

AA = numeric State code (obtained from the file name).

SHRP =SHRP\_ID for a test section (obtained from the file name).

B = G for a GPS test section, W for a WIM test section, and S for data collected for an SPS project.

R = sequential visit identifier associated with the HSSV visit (section 2.7.3).

YYMMDD = profile date (year/month/date).

NNNN = number of the image in sequence starting with 1 for the first image.

For a GPS or WIM test section, the value associated with SHRP will be the SHRP\_ID of the test section. For an SPS project, the SHRP\_ID will be the SPS project number (i.e., 0200) (section 2.7.3).

All images captured from the location where the photocell was armed to the start of the test section will have the notation “Lead In” imprinted on the lower right corner of the image. All images captured from the time the photocell was triggered until the Stop Distance specified in the Header screen was reached will have the distance in meters in stations imprinted on the lower right corner of the image. The station number 0 will correspond to the location when the photocell was triggered, which is the start of the test section for a GPS or WIM test section, and the start of the first section in an SPS project. All images captured for a distance of 152.4 m after the specified Stop Distance will have “Lead Out” imprinted on the lower right corner of the image.

Example for a GPS test section: Assume images were captured at GPS test section 1018 in Arizona (State code 04) on December 9, 2014, during sequential visit identifier K. Assume that 16 images were captured before the test section, 15 images were captured within the test section, and 15 images were captured after the end of the test section. Therefore, the total number of images captured during the data collection run will be 46. The first image captured, which is when the photocell is armed, will have the following file name: HSS041018GK201412090001.jpg. The last image captured at this test section will have the following file name: HSS041018GK201412090046.jpg.

Example for an SPS test section: Assume images were captured 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 3,000 m. Assume 17 images were captured from the time photocell was armed until the start of the test section, 300 images were captured from the location where the photocell triggered to the Stop Distance that was specified, and 15 images were captured after the end of 3,000 m that was specified as the Stop Distance. Therefore, at this test section, a total of 332 images would have been obtained. The first image captured at this test section 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**

Collecting video at test sections is not required for the LTPP program. However, the DCC can collect video at the test section if desired. Video mode must be selected in the Camera Setup menu to capture video (section 2.4.2.1).

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

### **2.7.7 Event Initiation**

During longitudinal profile data collection, the data collection program uses an event mark to record the start of the test section. Event marks are generated by the photocell. The vertical photocell detects the white paint stripe or the reflective tape at the start of the 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 the

pavement is not able to trigger the vertical photocell, the horizontal photocell should be used. The cone with a reflective marker provided with the HSSV should be placed on the shoulder at the start 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 start 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 data collection run, the operator 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 the hard disk.

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

Inclement weather conditions (e.g., rain, snow, heavy crosswinds) can interfere with the acquisition of acceptable longitudinal profile, macrotexture, and transverse profile data. Therefore, data collection should only be performed on dry pavements. In some cases, it may be possible to take 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 in longitudinal profile data. When reviewing the longitudinal profile 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 (i.e., light and dark areas) may yield results inconsistent with data collected on uniformly colored (i.e., 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 the pavement is completely dry.

Electromagnetic radiation from radar or radio transmitters may affect data collected by the HSSV. If this occurs, the operator should attempt to identify the source and contact those in charge 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 survey of the test section.

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

The HSSV software allows the operator to enter comments at the end of each data collection run; these comments are hereafter referred to as end-of-run comments. These comments can be edited, if required, when the data files are imported into ProQual. The operator can also enter comments about the test section after the longitudinal profile data are imported into ProQual; these comments are hereafter referred to as operator comments (section 2.7.11.3). Both sets of comments can be up to 100 characters in length and are uploaded into the PPDB. These comments should only be related to longitudinal profile data collection, as these comments are loaded into PPDB tables related to longitudinal profile data.

End-of-run comments entered for a group of test sections profiled in one run (e.g., SPS site) are put into each individual file that is subsectioned from that profile run. Similarly, if a GPS test section is profiled in conjunction with an SPS site in one run, end-of-run comments are common

to all sections subsectioned 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 test sections in that run (e.g., weather-related comments). 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 test sections) and when a test section is profiled as an individual test section (e.g., a GPS section), end-of-run comments have been grouped into the following three categories:

- Good Profile Run—comment used to indicate that a profile run was good and that no problems were encountered. Example comment: RUN OK.
- Environment-Related Comments—data collection 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 the quality of the data, a comment should be entered. Example comment: HEAVY WINDS.
- Speed-Related Comments—the following are examples where a comment related to the speed of testing should be entered:
  - Speed limit at test section is lower than the 80 km/h specified for data collection. Example comment: SPEED LIMIT AT SITE IS 60 KM/H.
  - Heavy traffic, difficult to maintain a constant speed. Example comment: TRAFFIC CONGESTION: SPEED VARIABLE.
  - Difficult to maintain constant speed because of grade (i.e., uphill or downhill). Example comment: DIFFICULT TO MAINTAIN CONSTANT SPEED: UPGRADE.

End-of-run comments are made at the end of a run before saving the data. HSSV software offers six end-of-run comments that the operator can select at the end of a run. The operator can only select one of the comments. If none of these comments are applicable, the operator can type any desired comment. The following six end-of-run comments are available in the HSSV software:

- 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 aforementioned guidelines. If a late photocell initiation is suspected, an additional run to replace that run should be made.

### **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 comments, and operator comments.

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

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

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

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

#### ***2.7.11.2 Texture Comments***

Texture comments are entered using a dropdown menu. The operator has the option of typing a comment (maximum 100 characters) instead of using a comment from the dropdown menu. The operator also has the option of selecting a comment from the dropdown menu and then typing additional comments after that. Texture comments should be typed in capital letters. The texture comment that is entered must be the same for all runs. The following comments are available in the dropdown 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 Comments***

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

- Pavement Distress-Related Comment—a comment should be made if there are pavement distresses or features within the test section that can affect the repeatability of profile data. The 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:
  - For AC-surfaced pavements, distresses such as rutting, fatigue and alligator cracking, potholes, patches, and longitudinal and transverse cracking.  
Example comment: \_\_\_\_\_ IN SECTION (enter distress type for blank).
  - For PCC-surfaced pavements, distresses such as faulting, spalling, and longitudinal and transverse cracking.  
Example comment: \_\_\_\_\_ IN SECTION (enter distress type for blank).
  - For pavements with a chip seal, a comment should be entered if chips are missing in areas within the test section.  
Example comment: CHIP SEAL SECTION. CHIPS MISSING.
  - For pavements with dips in the test section, a comment should be made indicating such.  
Example comment: DIPS IN SECTION.
- Maintenance-Related Comments—a comment should be made if the 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 test section. The operator should specifically make a note if overband-type crack filling has been performed on the test section. (Overband-type crack filling is typically about 100 mm wide and is placed over the crack.)  
Example comment: RECENT MAINTENANCE IN SECTION, PATCHES.

- Wheel Path Tracking-Related Comments—a comment should be made if the operator encountered problems in tracking the wheel path. Such a comment should be entered if one or more of the following conditions are encountered:
  - During the profile run, the path followed was either to the left or right of the wheel path.  
Example comment: RUN RIGHT OF WHEEL PATH.
  - Difficulty in holding the wheel path due to pavement distress(es), such as rutting.  
Example comment: DIFFICULT TO HOLD WHEEL PATH, RUTTING.
  - Difficulty in holding the wheel path due to truck traffic.  
Example comment: DIFFICULT TO HOLD WHEEL PATH, TRAFFIC.
  - Difficulty in holding the wheel path due to wind.  
Example comment: DIFFICULT TO HOLD WHEEL PATH, WINDY.
  - Difficulty in holding the wheel path because of grade, either uphill or downhill.  
Example comment: DIFFICULT TO HOLD WHEEL PATH, UPHILL.
  - Difficulty in holding the wheel path because the test section is on a curve.  
Example comment: DIFFICULT TO HOLD WHEEL PATH, CURVE.
- Location of Test Section Comments—a comment should be made if the location of section has a potential impact in obtaining repeatable profile runs. Such conditions include the following:
  - Section or approach to the test section is on a curve.  
Example comment: APPROACH TO SECTION ON CURVE.
  - Section or approach to the test section is on a grade (e.g., uphill or downhill).  
Example comment: SECTION ON A DOWNHILL.
- Miscellaneous Other Comments—a comment should be made if conditions other than those not covered previously are encountered during profiling that may affect the quality of the data. Such conditions include the following:
  - Contaminants on the road, such as sand/gravel or dead animals.  
Example comment: SAND ON ROAD.
  - Traffic or WIM loops within the test section.  
Example comment: WIM LOOPS WITHIN SECTION or TRAFFIC LOOPS IN SECTION.
  - Color variability of the pavement because of salt application.  
Example comment: COLOR VARIABILITY CAUSED BY SALT.

- Excessive vehicle movements just before the test section because of pavement condition.

Example comment: CORE HOLES ON WHEEL PATH BEFORE SECTION.

- Spike-Related Comments—after ProQual has processed the data, the operator should look for the presence of spikes in the data. If spikes are present, enter a 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 the following nine comments that can be selected by the operator:

- EQUIPMENT OK
- ROUGH SURFACE TEXTURE / GRAVEL 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

The 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 and 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 previously described. 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.

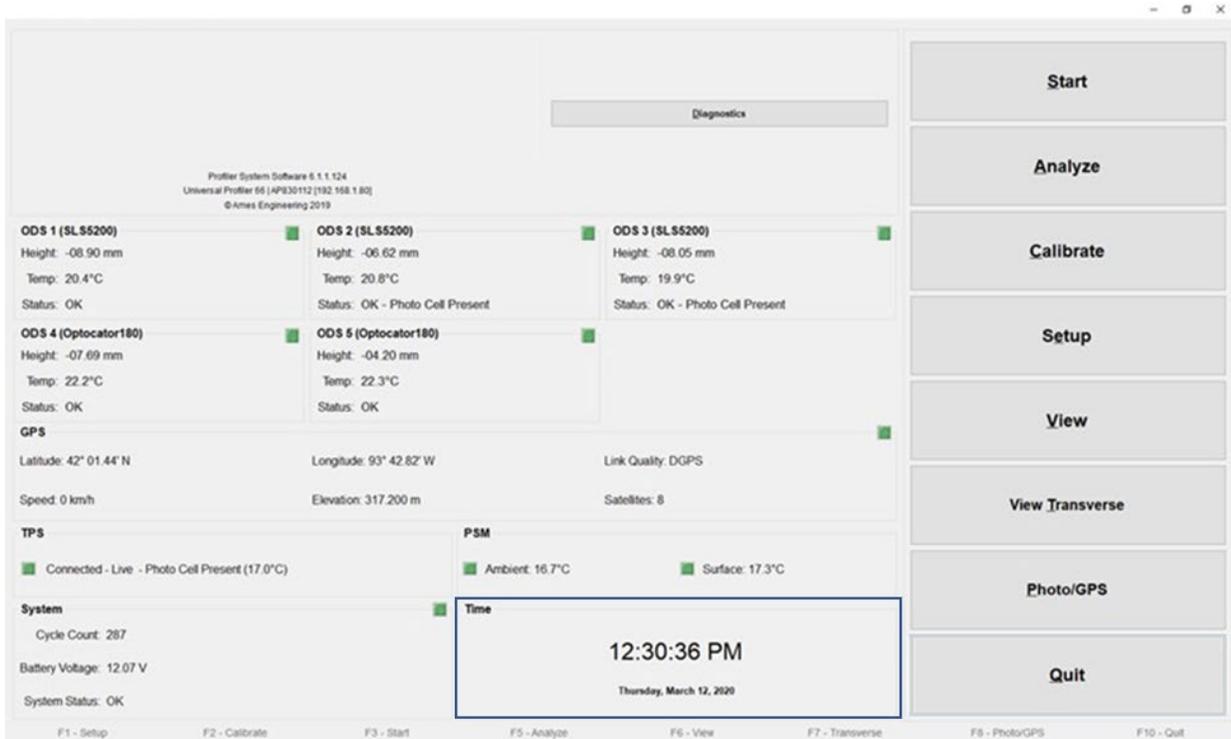
Comments are used to indicate factors that could affect the quality of data or cause variability between profile runs. Depending on conditions encountered in the field, the recommended priority order may be changed with the factor having greatest effect on quality or repeatability of profile data being 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 (figure 175). If a factor has been entered as an operator comment into ProQual, it should not be repeated in Form PROF-1.

## 2.8 POWERING UP AND SHUTTING DOWN EQUIPMENT

### 2.8.1 Power-Up Procedure

Use the following procedure to power up the equipment:

1. Attach the laptop computer to the laptop computer docking station.
2. Turn on the master power switch located on the dashboard (figure 34). The switch will show an amber color at the bottom. The master power switch can be turned on either before or after starting the vehicle.
3. Turn on the 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 accessible through the Control Panel to set the correct time.
4. Start the HSSV software, and the start-up screen shown in figure 84 will appear.
5. Check the date and time on the start-up screen to make sure they are correct.



Source: FHWA.

**Figure 84. Screenshot. HSSV software start-up screen highlighting date and time.**

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

- ODS 1, left wheel path profile height sensor.
- ODS 2, right wheel path profile height sensor.
- ODS 3, center profile height sensor.
- ODS 4, left wheel path texture height sensor.
- ODS 5, right wheel path texture height sensor.
- Photocells.
- GPSR.
- PSM.
- TPMS (under the heading TPS).

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 for ODS 1, ODS 2, ODS 3, ODS 4, and ODS 5 to show a green LED. The LED will be yellow if the sensor is not properly viewing the road surface (e.g., 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 (i.e., ODS 1, ODS 2, and ODS 3):

- Height—this indicates the height measured by the sensor. The height should be close to 0 (generally within  $\pm 15$  mm of 0) 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 “OK-Photo Cell” if a photocell is connected to that sensor. If the message “OK-Photo Cell” does not appear for the ODS 3 sensor, it means the vertical photocell was not detected, which can happen if the pavement surface below the photocell is reflective (e.g., on a PCC surface). If this occurs, and data collection is to be performed on a PCC surface, exit the software, turn down the sensitivity of the photocell, turn the main power switch off and on again, and then start up the software again and check if “OK-Photo Cell” appears under ODS 3. (Refer to the photocell documentation included in the HSSV binder on how to adjust the sensitivity of the photocell.)<sup>(5)</sup> If data collection is to be performed on an AC surface, exit the software, move the HSSV to an AC surface, and then start up the software again and check if “OK-Photo Cell” appears under ODS 3.

The start-up screen displays the following information for the texture height sensors (i.e., ODS 4 and ODS 5):

- Height—this indicates the height measured by the sensor. The height should be close to 0 (generally within  $\pm 15$  mm of 0) 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 macrotexture 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 (e.g., will indicate DGPS if a WAAS correction was made to the data).
- Speed of the vehicle in km/h.
- Elevation.
- Satellites (i.e., the number of satellites used by the GPSR).

The start-up screen shows the following information for the PSM:

- Temperature from the ambient temperature probe.
- Temperature from the surface temperature probe.

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

- Internal temperature of the sensor.
- System status.

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

- Cycle count.
- Battery voltage (i.e., voltage of the auxiliary battery).
- Time (i.e., the time set in the laptop computer).
- Date (i.e., the date set in the laptop computer).
- System status (e.g., will 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:

- Setup (F1)—to enter parameters associated with data collection.
- Calibrate (F2)—to calibrate or perform calibration checks on components.
- Start (F3)—to start data collection.
- Analyze (F5)—to analyze the collected data. This menu is not used for LTPP data collection or processing.

- View (F6)—to view and analyze the collected data.
- Transverse (F7)—to view transverse profile data and create files for upload to the PPDB.
- Quit (F10)—to exit the program.

## **2.8.2 Shut-Down Procedure**

Use the following procedure to shut down the system:

1. Go to the HSSV start-up screen (figure 84). Exit the HSSV software by pressing the F10 key or selecting “Quit” and then shut down the laptop computer. If the laptop computer will be used for other tasks, you can keep the laptop computer on and proceed to step 2 to turn power off to all components in the HSSV. The laptop computer will then be powered by the laptop computer battery.
2. Turn the master power switch located on the dashboard to the “Off” position (figure 34). Never turn the master power switch off when the HSSV software is within a menu. Always exit the HSSV 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**

The following sections describe procedures to be followed each day before and during data collection with respect to daily checks of the vehicle and equipment, start-up procedures, software setup for data collection, and using software for data collection. The procedures to be followed for testing GPS test sections are also described in this section; some of the procedures for testing SPS and WIM test sections are different than those for GPS test sections. Section 2.10 describes the procedures for SPS test sections that differ from those for GPS test sections, whereas section 2.11 describes the procedures for WIM test sections that differ from those for GPS test sections.

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

#### ***2.9.2.1 Introduction***

The operator should follow the Daily Checklist (figure 174) and perform all checks outlined at the start of the day. The Daily Checklist can be placed inside a plastic cover, and the operator can go through the items listed and ensure that everything is in proper working condition. The operator should maintain a logbook in the HSSV to note problems identified when going through the Daily Checklist. The suggested format of the logbook is shown in Form PROF-3, Profiler Log (figure 177).

To maintain the laptop computer and various associated equipment, care must be taken to either cool or warm the equipment to the operating temperature described in section 2.5.7 before

turning on the master power switch. After turning on the master power switch, wait for about 15 min for the equipment to warm up before performing daily checks.

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

- Calibration check on profile height sensors.
- Calibration check on texture height sensors.
- Bounce test.
- Visual check of the pavement surface temperature sensor.

Complete Form PROF-1 after performing the daily checks (figure 175).

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

The exact heights of the calibration blocks should have been entered into the HSSV 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 ensure the entered block heights are correct if the HSSV software is re-installed or updated.

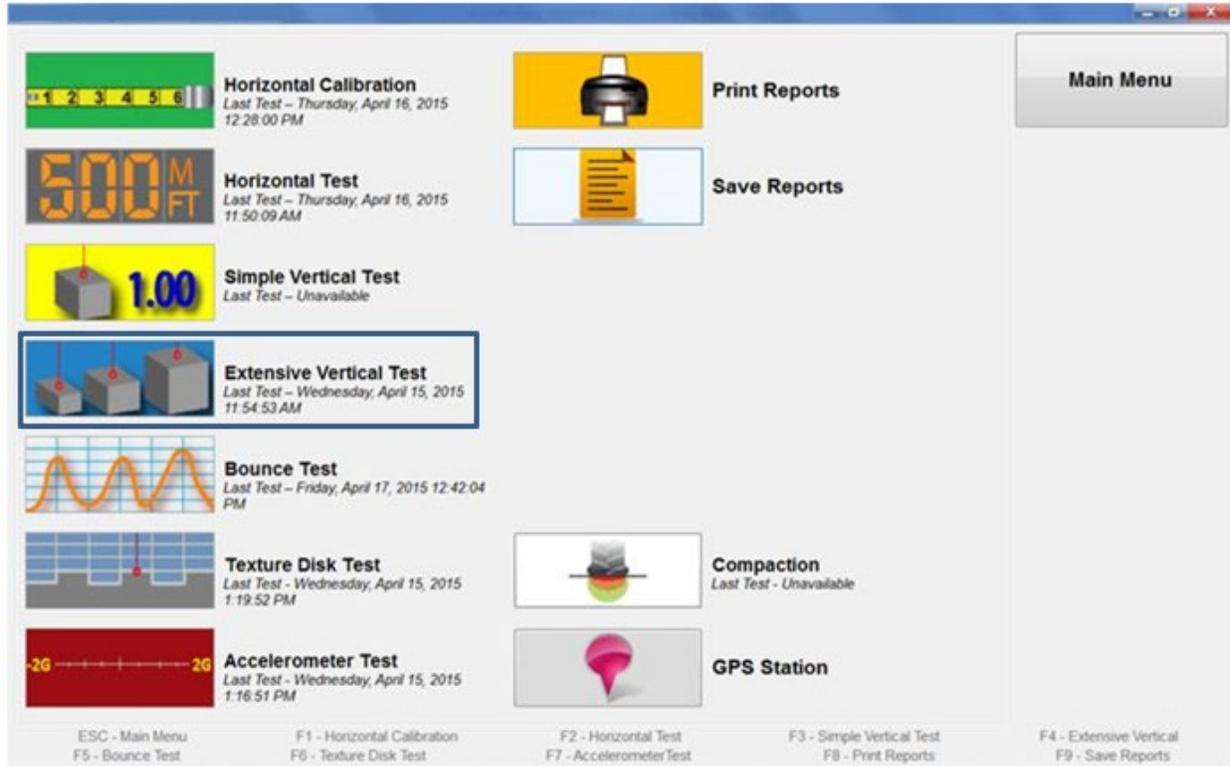
The calibration blocks must be handled with care. Surfaces of the calibration blocks are measured precisely; if they are damaged, they will not be suitable to perform the calibration check.

Do not enter, bounce, bump, or lean on the vehicle while the calibration check is performed. The operator should adjust the laptop computer so 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 when performing the calibration check:

1. Park the vehicle on a level surface.
2. Before powering up the system, open the sensor covers and inspect the glass face of the sensors. There is no need to clean the sensor glass if the glass does not appear to be dirty. If the glass appears to be dirty, clean the glass face using the procedures described in section 2.5.2.
3. Power up the system, start the laptop computer, and start the HSSV software using the procedure described in section 2.8.1. Press the F2 key or select “Calibrate” to access the Calibration Menu shown in figure 85.
4. In the Calibration Menu, press the F4 key or select “Extensive Vertical Test,” and the Extensive Test menu shown in figure 86 will be displayed. All sensors shown on the 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 the 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 (figure 87). Place the digital level parallel to the two screws that are

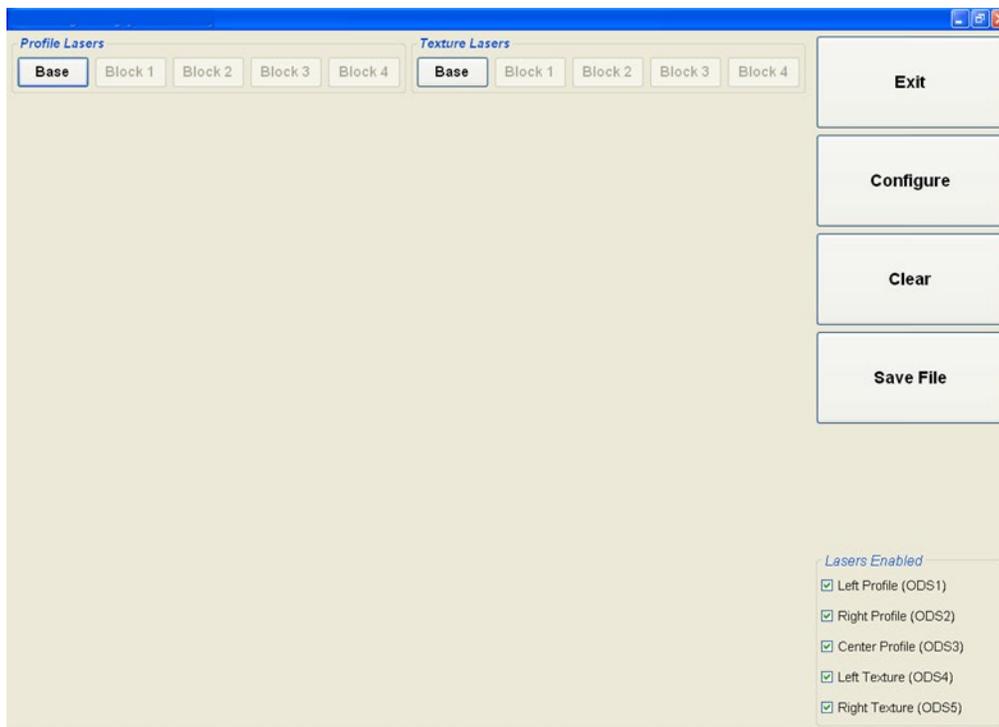
parallel to the sensor bar and level the base plate using these two screws and the digital level as a guide. Then, place the digital level perpendicular to the two screws that are parallel to the sensor bar and use the other screw to level the base plate. The base plate is considered level when the reading on the digital level is less than or equal to 0.05 degrees when placed parallel and perpendicular to the two screws that are parallel to the sensor bar.

6. Place a calibration target plate with the matte 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 (figure 88).
7. In the HSSV software, under “Profile Lasers,” select “Base” to take a measurement on top of the target placed on each base plate. Six sets of measurements are taken on each target. Figure 89 shows an example of the screen after the measurements are obtained.
8. Remove the calibration target plate from the calibration base plate, place the 25-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 on top of the block (figure 90) with the matte side facing up. Repeat this procedure for the other two sensors. Thereafter, in the software under “Profile Lasers,” select “Block 1” to take measurements on top of the target. Six sets of measurements are taken on the target. Figure 91 shows an example of the screen after the measurements are obtained.
9. Check the average bias value (i.e., Avg. Bias in figure 91). The average bias value for each sensor must be within  $\pm 0.25$  mm. If the average bias values for all three sensors meet the specified criterion, select “Save” to save the results from the calibration check. Repeat the calibration check if the average bias is outside the  $\pm 0.25$ -mm tolerance. If the average bias is still outside the specified tolerance, contact the DCC office and decide on a suitable course of action.



Source: FHWA.

**Figure 85. Screenshot. Calibration menu highlighting Extensive Vertical Test.**



Source: FHWA.

**Figure 86. Screenshot. Extensive Test menu from Extensive Vertical Test selection.**



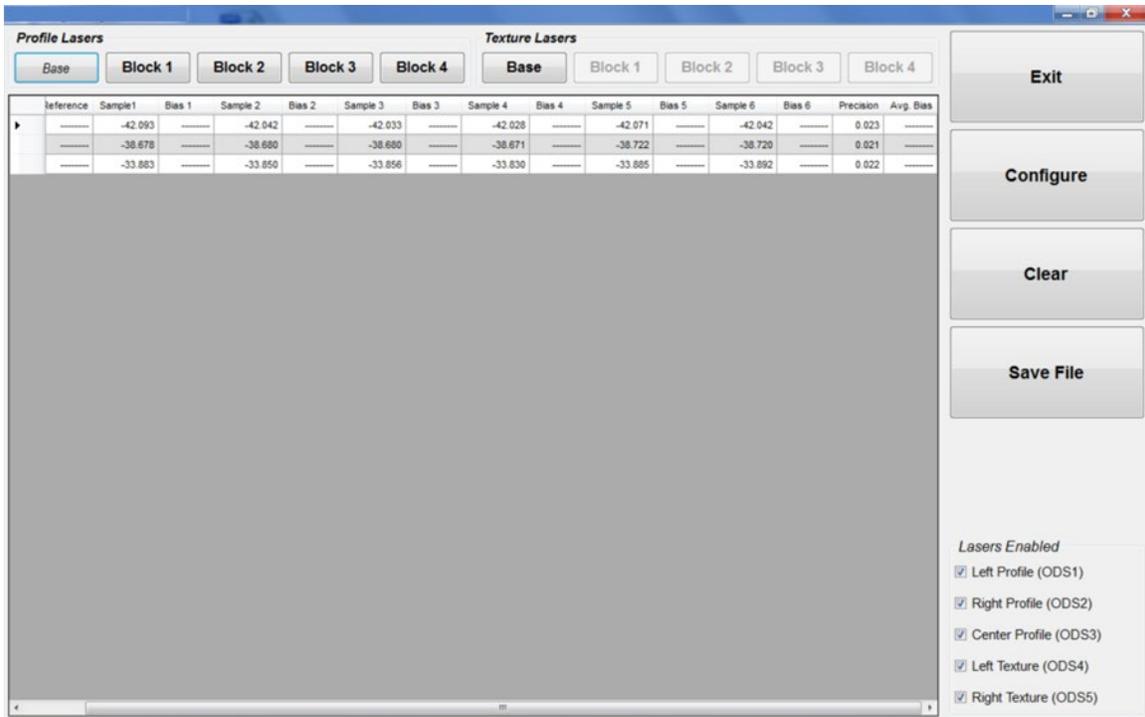
Source: FHWA.

**Figure 87. Photo. Laser dot centered on base plate.**



Source: FHWA.

**Figure 88. Photo. Target placed on base plate.**



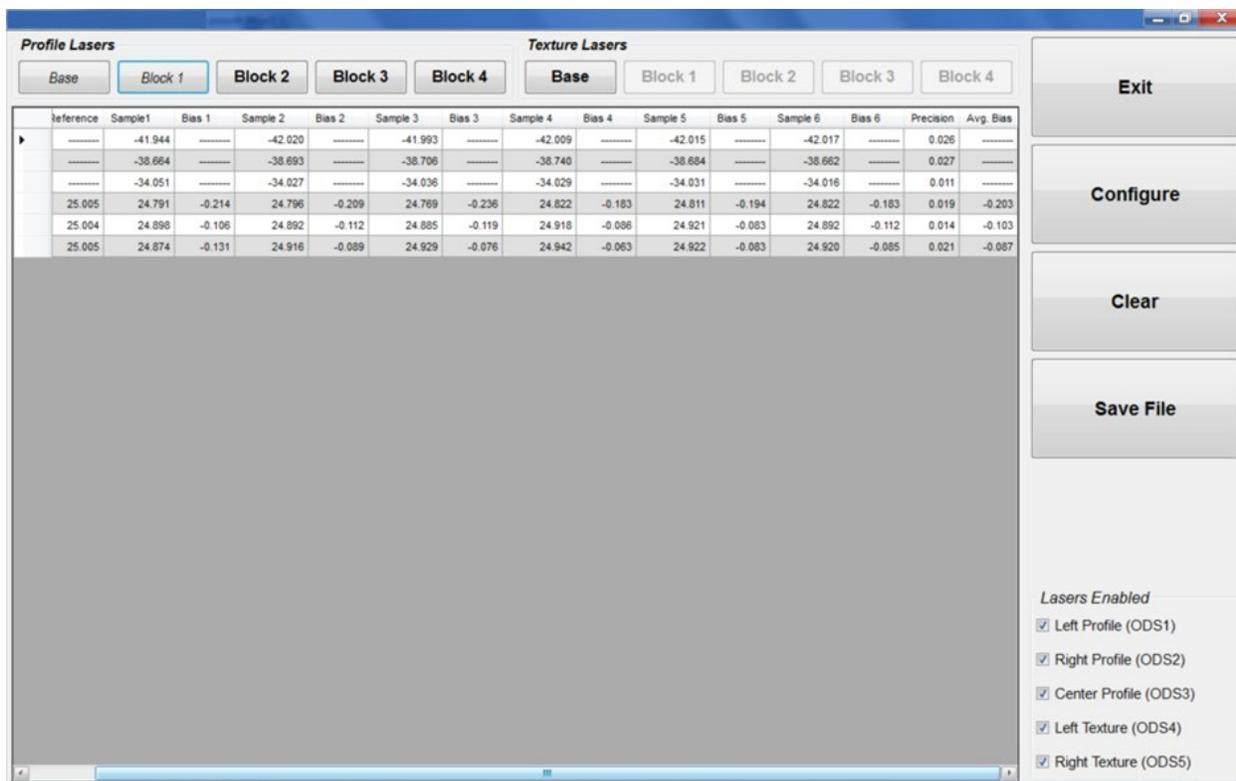
Source: FHWA.

**Figure 89. Screenshot. Display after obtaining measurements on target placed on base plate.**



Source: FHWA.

**Figure 90. Photo. Target placed on the 25-mm block.**



Source: FHWA.

**Figure 91. Screenshot. Display after obtaining measurements on the target placed on the 25-mm block.**

### 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 (figure 87). Level the base plate following the procedure described in step 5 of section 2.9.2.2.
2. Place a calibration target with the matte 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 (figure 88).
3. In the HSSV software, under “Texture Lasers,” select “Base” to take measurements on top of the target placed on each base place. Six sets of measurements are taken on each target.
4. Remove the target from the calibration base plate, place the 25-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 target with the matte side facing up on

top of the block (figure 90). Repeat this procedure for the other sensor. Thereafter, in the software under “Texture Lasers,” select “Block 1” to take measurements on top of the target. Six sets of measurements are taken on the target by each sensor.

5. Check the average bias value. The average bias value for each sensor must be within  $\pm 0.25$  mm. If the average bias values for both sensors meet the specified criterion, select “Save” to save the results from the calibration check. Repeat the calibration check if the average bias is outside the  $\pm 0.25$ -mm tolerance. If the average bias is still outside the specified tolerance, contact the DCC office 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 HSSV are functioning properly. This test must be performed immediately after performing calibration checks on the profile and texture height sensors. The vehicle’s engine may be on or off when performing the bounce 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 HSSV will collect longitudinal profile data as if it were moving at 80 km/h. Longitudinal profile data are recorded for the entire duration of the bounce test. The equipment should have been warmed up for at least for 15 min before performing the bounce test.

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

1. Park vehicle on a level surface. If the master power switch and laptop computer have been turned on and the HSSV software has been started up, go to step 2. Otherwise, power up the equipment and start the HSSV software using the procedure described in section 2.8.1.
2. In the main menu of the HSSV software (figure 84) press the F2 key or select “Calibrate” to access the Calibration menu (figure 85).
3. In the Calibration menu, press the F5 key or select the “Bounce Test” icon to enter the Bounce Test menu. The bounce test screen shown in figure 92 will appear on the laptop computer. Under “Setup,” which appears at the bottom right corner in this menu, check marks should be present in front of ODS 1, ODS 2, and ODS 3. The “Distance” field should show a value of 1,066.8 m, which means data will be collected over seven 152.4-m-long sections during the bounce test. The system will emit a beep at the start of the test and thereafter at the end of each 152.4-m-long segment for the duration of the bounce test. The IRI of each 152.4-m segment will be displayed on the top of the graph corresponding to each sensor during the bounce test.
4. Place a base plate under each profile height sensor such that the red laser dot appears at the center of the square marked on the base plate. Level the plate using the digital level as

described in step 5 of section 2.9.2.2. Place the calibration target with the matte side facing up on the square marked on the base plate.

5. Select “Begin Test” in the HSSV software (figure 92) to start the bounce test. The system will begin collecting pre-run data during the filter warm-up process, as shown in figure 93. 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 are collected during this period. Wait until two more beeps are emitted, which indicates that data have been collected over two 152.4-m-long segments (i.e., segments one and two).
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 the rear bumper for each bounce (i.e., the distance from the highest position to lowest position is 25 mm during bouncing). The bouncing motion should continue until three more beeps are emitted. Stop the bouncing motion thereafter. The system will automatically stop the bounce test after two more beeps are emitted (i.e., when the total simulated distance of 1,066.8 m is reached). The screen will display the message “Filter cool down in process” (figure 94), and thereafter will display the screen shown in figure 95 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 (i.e., segment three 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 (i.e., segment four from 457.2 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 (i.e., segment six from 762 to 914.4 m), the bouncing motion occurred only within a portion of this segment.

7. Use the IRI of segment two (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 four (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 seven (i.e., from 914.4 to 1,066.8 m) to obtain the IRI corresponding to the final static portion of the bounce test.

The IRI corresponding to segment two (i.e., from 152.4 to 304.8 m) for all three sensors must be less than or equal to 0.08 m/km. Also, for each sensor, the difference between the IRI for segment seven (i.e., from 914.4 m 1,066.8 m) and the IRI for segment one (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 aforementioned criteria are met.

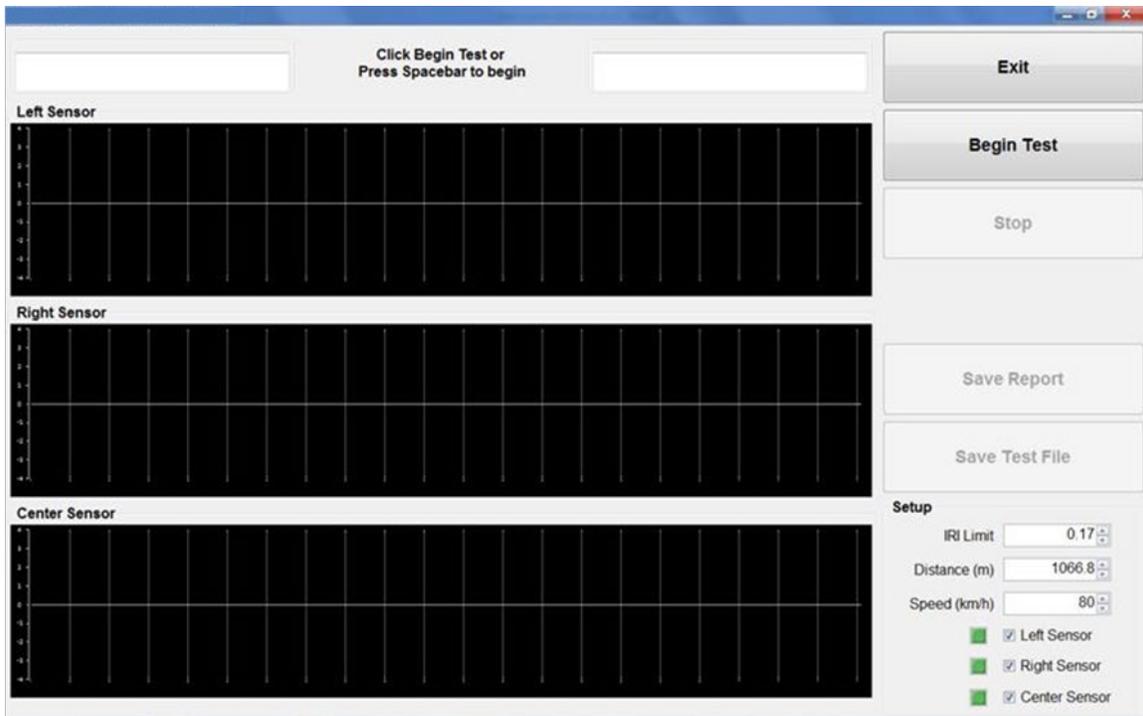
8. For each sensor (e.g., left, center, and right), compute the difference in IRI between the dynamic and initial static portions of bounce test (i.e., deduct the IRI obtained for segment two from the IRI obtained for segment four). If the difference in IRI is less than

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 bounce tests pass the criterion. If one or both of the criteria indicated in steps 8 and 9 are not satisfied for two consecutive bounce tests after repeating test several times, see section 2.9.2.4.1.

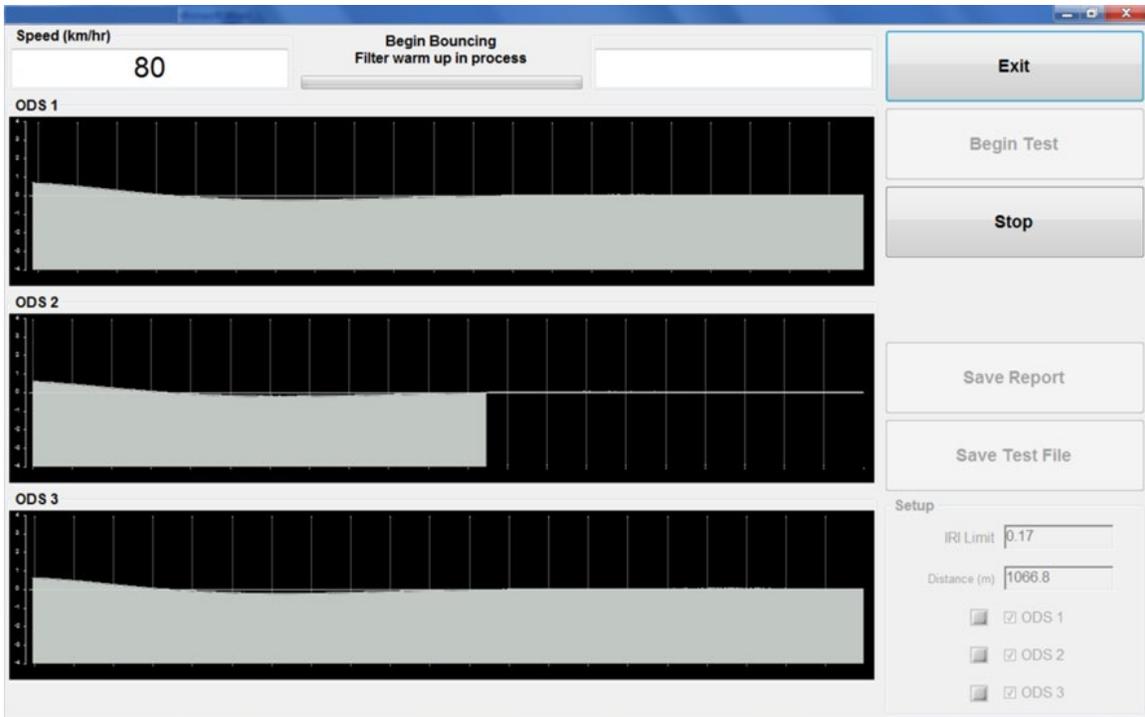
Passing the bounce test must be based on meeting the requirements indicated in steps 8 and 9 and not on the message displayed by the HSSV software indicating “Passed Bounce Test” (figure 95). The HSSV software computes the IRI for the entire duration of the bounce test (i.e., over a distance of 1,066.8 m) and then compares this IRI with the IRI 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. This procedure and result are not valid for LTPP operations, and the procedures outlined in steps 1 and 9 must be used to determine if the bounce test criterion were met.

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.



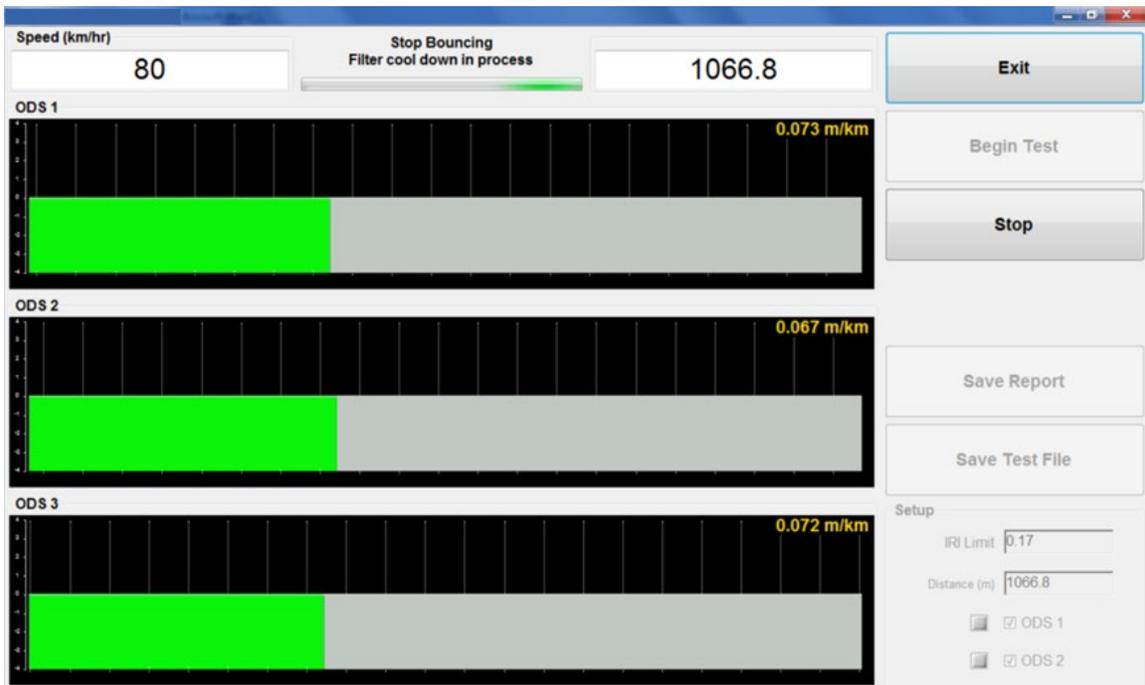
Source: FHWA.

**Figure 92. Screenshot. Bounce test start-up screen.**



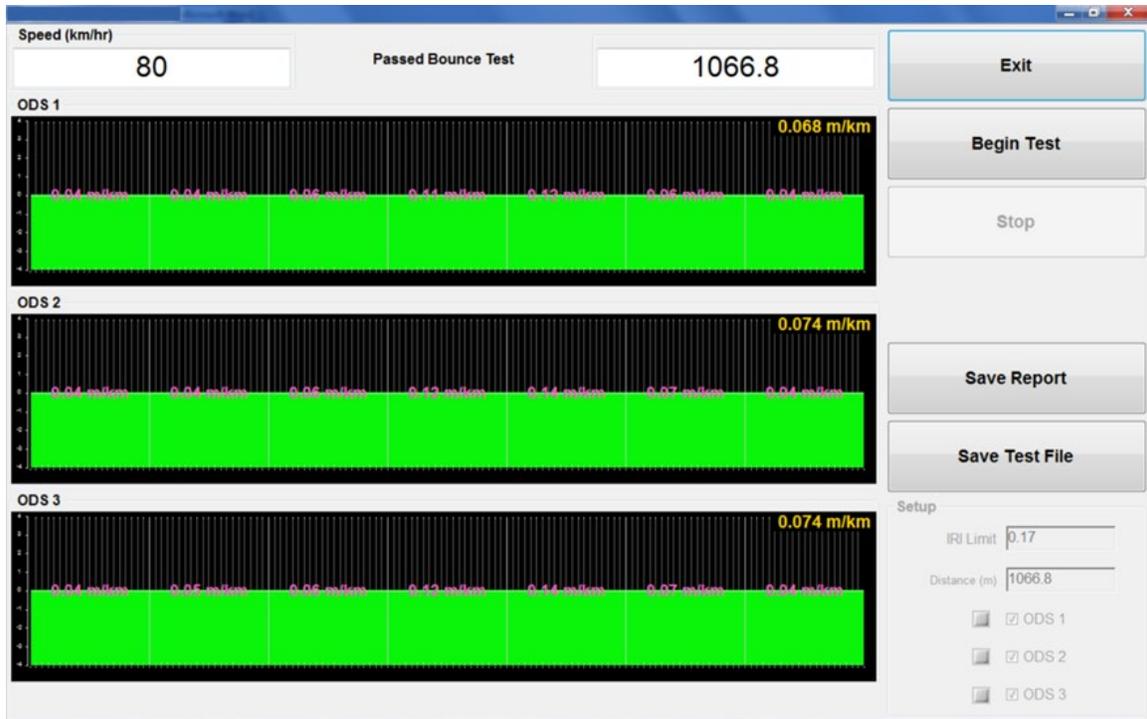
Source: FHWA.

**Figure 93. Screenshot. Filter warm up in progress during bounce test.**



Source: FHWA.

**Figure 94. Screenshot. Filter cool-down process after bounce test is terminated.**



Source: FHWA.

**Figure 95. Screenshot. Display after completing the bounce test.**

#### ***2.9.2.4.1 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 the difference in IRI between the dynamic and initial static portions of the bounce test exceeds 0.10 m/km for a sensor, the operator should contact the DCC office to decide on a course of action. If an error in the equipment is found and fixed, the operator should reevaluate the longitudinal profile data collected during the previous day. The IRI values obtained during the previous day, as well as the longitudinal profile data, should be compared with those obtained from the last visit to that test section. If data problems are suspected, such test sections should be re-profiled after equipment repairs.

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

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

## 2.9.3 Data Collection

### 2.9.3.1 Attaching Camera

Mount the camera, connect the cable from the camera to a USB port in the 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 test section, the operator must enter Header information related to the test section into the HSSV software. This section describes the procedures to enter Header information for a test section into the HSSV software and ready the system for data collection. Use the following procedures to enter Header information at a test section:

1. In the HSSV software start-up screen (figure 84), press the F3 key or select the “Start” button. The message “Make sure the door of the surface sensor is open before beginning collection” will be displayed. Ensure the protective covers over the pavement surface temperature sensor and profile and texture height sensors are open and then select “OK.” Then, the Header screen where the file name is entered and data and other Header information are saved will be displayed (figure 96).

Source: FHWA.

**Figure 96. Screenshot. Header screen.**

2. Ensure the following items on the right side of the Header screen have checkmarks:
  - ODS 1—Profile should be checked.
  - ODS 2—Profile should be checked. If using the horizontal photocell to initiate data collection, Auto Trigger should be checked.
  - ODS 3—Profile should be checked. If using the vertical photocell to initiate data collection, Auto Trigger should be checked.
  - ODS 4—Texture should be checked.
  - ODS 5—Texture should be checked.
  - PSM—Ambient, Surface, and GPS should be checked.
  - TPS—Enabled and Auto Trigger 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, while sensors that have been enabled will show a bright green status indicator.

A sensor that is not available for use will show a dark red light. If the status indicator is red, it means the DAU or laptop computer is not receiving the data collected by that sensor. If the status indicator is orange, it means there is a problem with that sensor reading data (e.g., the covers have not been removed 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 any problem present with a sensor.

The HSSV software will not allow the operator to continue data collection if any of the enabled sensors do not have a green status light 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 HSSV 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 test section during a previous test section visit, the previously created Header file can be loaded and will save 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 good practice to check all Header fields to ensure they are correct.

If a previously created Header file for the test section is not available, all Header fields must be manually entered and checked to ensure parameters that are appropriate for the current dataset are shown in the Header.

4. Select Browse next to “File name” and select the directory to store the data. If necessary, make a new directory.
5. In the File Name field, enter the file name to record the data. The default file name is the file name from the last data run. Use the file-naming conventions for GPS and SPS test

sections indicated in section 2.7.3 to determine and enter an appropriate file name. If the test section is a WIM test section, decide on an appropriate file name using the guidelines indicated in section 2.11.

6. Set the parameters and settings for the fields under Suffix 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. Always set the start method for data collection to PHOTOCELL. From the dropdown menu, select PHOTOCELL. The other option available in this field is PENDANT. If PENDANT is selected, data collection is initiated manually by pressing the F3 key. The start method PENDANT is not used for normal LTPP data collection.
8. Always set the stop method to DISTANCE. From the dropdown menu, select DISTANCE. The other options available in this field are PHOTOCELL and PENDANT. The PHOTOCELL option is used when data collection is terminated using the photocell, while the PENDANT option is used when data collection is terminated manually. If the PENDANT option is used, data collection is terminated manually by pressing the F4 key. Stop methods PHOTOCELL and PENDANT are not used for normal LTPP data collection.
9. When DISTANCE is selected as the Stop Method, the Distance field appears to the right of “Stop Method.” The distance (in meters) over which data must be collected from the start of the test section must be entered into the Distance field. For GPS test sections, the distance is always 152.4; for WIM test sections, the distance is always 305. For an SPS test section, determine the distance using the procedure described in section 2.10.2 and enter the value in the Distance field.
10. Set Units to meters.
11. Ensure “Positive” is checked in the Direction field.
12. Ensure the Header Format field shows LTPP.
13. Type the test section identification in the Site Identification field (e.g., 451024). Follow the 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 test sections, follow the procedure specified in section 2.11.
14. Ensure the Operator and Driver field is identified by a two-digit character for each, which should be the first letter of the operator’s first and last name. Operator and driver names should be separated by a backslash and typed in capital letters (e.g., CK/RS). If the HSSV is used as a one-person operation, the operator and driver name would be the same (e.g., CK/CK).

15. Enter the HSSV Vehicle Identification Number assigned to the HSSV in the Vehicle Identification field (section 1.3). 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. Type the route number where the test section is located (e.g., I-88) in the Road Description field. All letters should be capital.
17. Fill the Lane Measured field with either INSIDE or OUTSIDE. The outside lane is the lane adjacent to the shoulder at the right edge of the road. Select the appropriate lane from the dropdown menu. For nearly all LTPP sections, lane measured is OUTSIDE.
18. Select the appropriate lane direction (e.g., NORTH, EAST, SOUTH, or WEST) in the Travel Direction field by using the dropdown menu.
19. Set the value for the Horizontal Offset to 0 for all sections. The horizontal offset value has to be set only once, as the system will retain the specified value when the Header screen is brought up subsequently.
20. Enter the width of the reflective tape placed on the pavement in millimeters in the Tape Width field if data collection is initiated using the vertical photocell. Enter the width of the reflective tape on the cone in millimeters in the Tape Width field if data collection is initiated using the horizontal photocell.
21. Enter the milepost at the start of the test section in the Beginning Description field. If the milepost is not known enter NONE in this field.
22. Indicate NONE in the Ending Description field.
23. Ensure the Beginning Station field is blank.
24. Ensure the Ending Station field is blank.
25. Fill in the Road Surface Type field with either “A-CC” for AC-surfaced pavements or “P-CC” for PCC-surfaced pavements. Use the dropdown menu to select an appropriate entry.
26. Complete the Surface Condition field, which describes the surface condition of a pavement; valid entries are V. GOOD (Very Good), GOOD, FAIR, and POOR. Select an appropriate entry by using the dropdown menu. The following severity levels correspond to the definitions given in the LTPP Distress Identification Manual:<sup>(11)</sup>
  - V. GOOD—pavement does not show any distress.
  - GOOD—pavement exhibits few visible signs of surface deterioration. AC-surfaced pavements may show low-severity cracks, while PCC-surfaced pavements may show low-severity cracks and spalling.

- FAIR—typical distresses on AC-surfaced pavements 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-surfaced pavements can include the following distresses in a low to medium severity: spalling, transverse and longitudinal cracking, faulting, and patching.
  - 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 pavements can include 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. Valid entries for the Cloud Conditions field are CLEAR, P. CLOUDY (Partly Cloudy), and CLOUDY. Select an appropriate entry using the dropdown menu and the following guidelines:
- Clear—sunny sky.
  - P. Cloudy—the sun is sometimes covered by clouds.
  - Cloudy—the sun cannot be observed.
28. Fill in the the Other Weather Conditions field with CONDITIONS OK, STEADY CROSSWIND, WIND GUSTS, HOT AND HUMID, HAZY, or LOW SUN ANGLE. Select an appropriate entry using the dropdown menu.
29. Set the Filter Wavelength to 100. Once the filter wavelength value is set, it should not be changed again, as the system will retain this value.
30. Set the Spike Tolerance to 5.0.
31. Fill in the Air Temperature field, which 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. 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 ensure all fields are correct, and then select the “Save” button to save the entered Header information.

### ***2.9.3.3 Collecting Data***

After Header information has been entered and the equipment has warmed up sufficiently (allow 15 min after turning the main power switch on for equipment to warm up), the HSSV is ready to collect data. The following procedures should be followed to get an acceptable set of runs at GPS

and SPS test sections. Some of the procedures for profiling WIM test sections are different from the procedures presented in this section. See section 2.11 for the procedures for profiling WIM test sections.

1. While in the Header screen, press the 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 longitudinal profile data (i.e., ODS 1, ODS 2, and ODS 3) or macrottexture data (i.e., ODS 4 and ODS 5). 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 the start of the test section and align the vehicle along the wheel paths. As described in section 2.7.4, a speed different from 80 km/h may be used depending on test section conditions. The longitudinal profile data collected for 152.4 m before the start of the test section and the macrottexture data collected for 30 m before the start of the test section will be saved in the data file. If sufficient pre-run data are not available before the test section due to a short available lead-in distance, the HSSV software will fill the missing data with a ramp to the first point.
3. Just before sign A, which is located 150 m in advance of the start of the test section, press the F5 key or select “Enable Autotrigger.” (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 sign A or the lead-in white stripe is not present in front of the test section, press the F5 key approximately 150 m before the start of the test section.) The camera window showing the camera preview will appear as a pop-up window on the screen, and the camera will start to capture images at 10-m intervals. An orange frame will appear around the preview window when an image is captured. The photocell is now armed and will be looking for a reflective mark on the pavement surface or a cone with a reflective marking depending on the photocell that was selected to begin data collection. 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 on the pavement between the white stripe 150 m before the start of the test section and the start of the section, arm the photocell after passing this object. If at least five images cannot be captured prior to the start of a test section, use the horizontal photocell to collect data. Using the horizontal photocell will result in 15 images being captured prior to the start of the test section.

4. When the photocell detects the reflective tape, five rapid beeps will be emitted and the longitudinal profile/macrottexture plot on the screen will become a solid green color to indicate that data are now being collected and recorded (figure 97). The distance measurement value will increase as the HSSV moves forward.

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

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

The buzzer will emit five rapid beeps at the end of a test section after data have been collected for the specified distance. The buzzer will then emit a long beep once 152.4 m of post-run data have been collected after the end of the test section. Thereafter, the End of Run Summary window will appear on the screen (figure 98).

5. Bring the vehicle to a stop at a suitable location to evaluate alarms and error messages, if any; enter the End of Run comments; and save the data to the hard disk.

The following information is displayed in the End of Run Summary window for ODS 1 (left profile sensor), ODS 2 (i.e., right profile sensors), and ODS 3 (i.e., center profile sensors):

- Laser alarms—number and percentage.
- Accelerometer alarms—number.
- Temperature alarms—number.

The following information is displayed in the End of Run Summary window for ODS 4 (i.e., left texture sensor) and ODS 5 (i.e., right texture sensor):

- Laser alarms—number and percentage.
- Temperature alarms—number.

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

If error messages are present in the diagnostic log, the Diagnostic tab on the End of Run Summary window will be red (figure 99). Selecting the Diagnostic tab will display all error messages sent by any sensor in the HSSV.

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

6. Evaluate the following end-of-run comments displayed:

- 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.

If the photocell initiates late, discard that run and perform an additional run. Do not save a run with the comment "LATE PHOTOCCELL INITIATION."

7. Use the guidelines presented in section 2.7.10 to select an appropriate end-of-run comment. End-of-run comments should only be based on conditions during the data collection run. If one of the displayed comments is appropriate for the data collection run, select the appropriate comment and select "Save." If none of the displayed comments are appropriate for the data collection run and the operator wants to type in a different comment, select "Other" and type an end-of-run comment using capital letters and select "Save."

After the file is saved, the laptop computer screen will show the Header screen, with the last digit of file name incremented by 1.

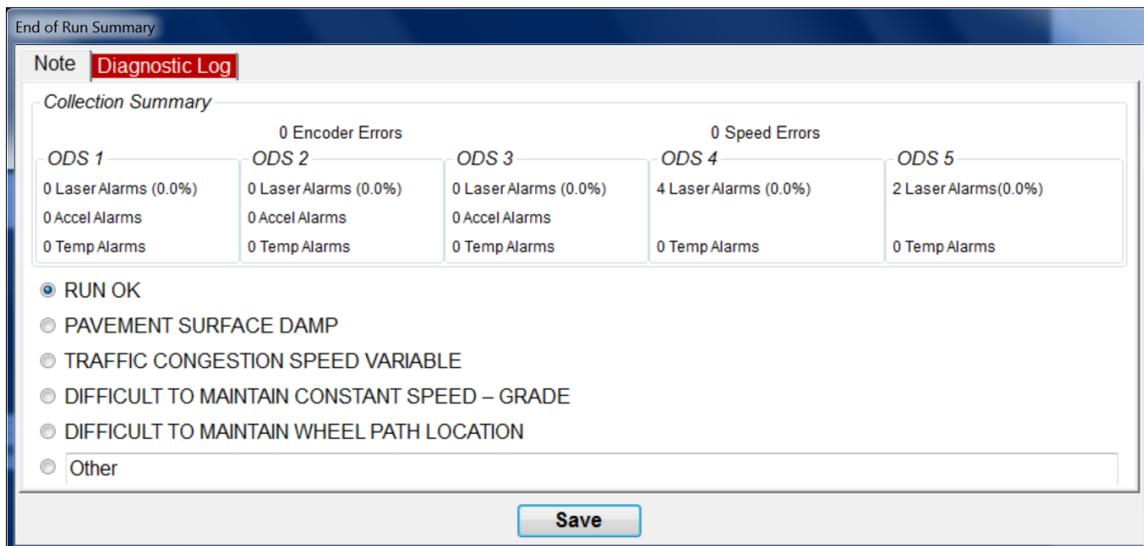
Review all captured images if the operator has elected to follow option 2 in section 2.7.5.1 for capturing images.

8. Perform four more runs at the test section using steps 2 through 7. Before starting a data collection run, look at the right side of the Header screen to ensure all sensors are enabled and showing a green status indicator. After collecting data for three runs, the operator has the option of deselecting the TPMS. This action will disable transverse profile data collection. The purpose of disabling transverse profile data collection is because files with transverse profile data are large, and as transverse profile data for only one run are loaded to the PPDB, there is no reason to collect more than three runs.
9. After performing five error-free runs for profile and macrotexture data, follow the procedures described in section 2.9.4 to use ProQual to evaluate the collected data. Review the transverse profile data using the procedures described in section 2.9.5.
10. If the collected five runs are acceptable for the longitudinal profile and macrotexture data, and the transverse profile data that were reviewed following the procedures in section 2.9.5 are acceptable, proceed to step 11. If not, perform additional runs, as described in section 2.9.4.4, and review these runs using ProQual. Complete Form PROF-1 after reviewing the data (figure 175).
11. Use Windows Explorer to back up data to a flash drive. Raw data are saved in a file with the extension ARD, and this file needs to be backed up. All files generated by ProQual when the longitudinal profile data were processed should also be backed up.
12. The operator should verify that Form PROF-2, Status of Regions Test Section, is filled before leaving the test section (figure 176).



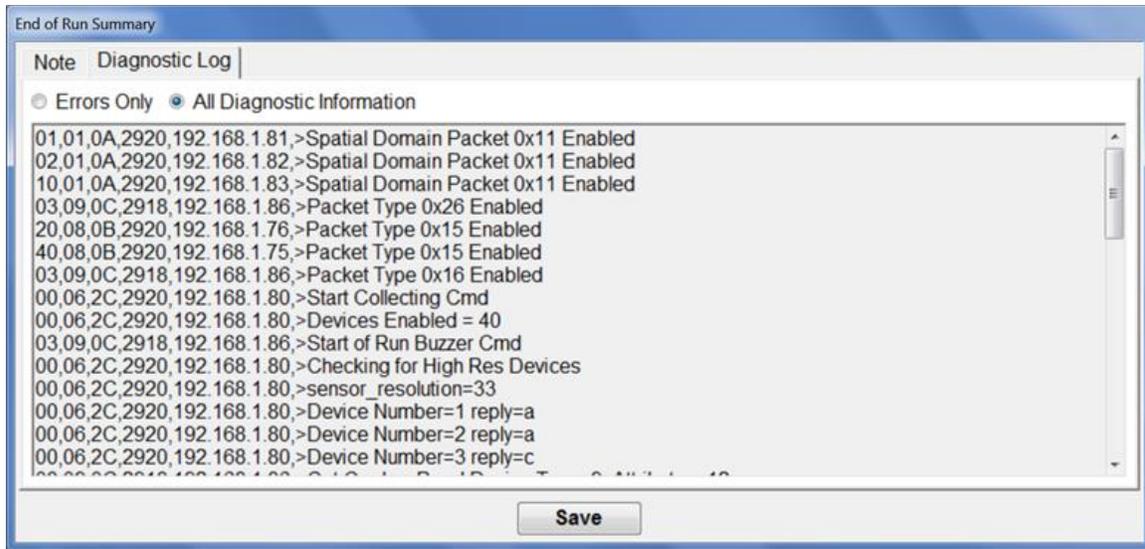
Source: FHWA.

**Figure 97. Screenshot. Screen after initiating data collection.**



Source: FHWA.

**Figure 98. Screenshot. End of Run Summary window.**



Source: FHWA.

**Figure 99. Screenshot. Diagnostic Log.**

### 2.9.3.4 Evaluating Error Messages

#### Errors Associated with Profiling Sensors

The following information is displayed in the End of Run Summary window for ODS 1 (i.e., left profile sensor), ODS 2 (i.e., right profile sensors), and ODS 3 (i.e., center profile sensors):

- Laser alarms—number and percentage.
- Accelerometer alarms—number.
- Temperature alarms—number.

Laser alarms indicate the number of data points with 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 longitudinal profile data, several measurements obtained by the height sensor are used to compute a longitudinal profile data point at 25-mm intervals. The longitudinal profile data point is tagged as having a laser alarm if one or more height sensor readings used to compute the longitudinal profile data point have an error. When computing the longitudinal 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 indicate the number of readings for which an accelerometer reading was not properly received. An accelerometer alarm occurs when the acceleration measured by the accelerometer goes outside the  $\pm 5$  g 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 emit a beep, and a warning message will appear on the screen. Accelerometer alarms should not normally occur. There is a possibility for accelerometer alarms to occur on an extremely rough pavement that will cause the accelerometers to go outside the  $\pm 5$  g range. However, such occurrences should be rare. If an accelerometer alarm occurs, and

the pavement is very rough, collect data at a lower speed to see if accelerometer alarms still occur. If the alarms persist, there may be a problem with the accelerometer.

Temperature alarms indicate the number of readings for which the temperature inside the laser box is outside the limits recommended by the manufacturer. As indicated in section 2.5.1, HSSV software monitors the temperature inside each individual sensor box that houses a profile height sensor. If a temperature alarm occurs, go to the startup screen of the HSSV software and see if the displayed temperatures are close to the upper or lower limit of the temperatures indicated by the manufacturer (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 Summary window for ODS 4 (i.e., left texture sensor) and ODS 5 (i.e., right texture sensor):

- Laser alarms—number and percentage.
- Temperature alarms—number.

Laser alarms indicate the number and percentage of data points that have invalid height sensor readings. The macrotexture data are sampled at a 62.5-kHz frequency. The number of laser alarms for a texture height sensor indicates the number of individual readings in the test 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 HSSV 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 ( $n$ ), the point before the invalid data point ( $n-1$ ), and the point after the invalid data point ( $n+1$ ) are all replaced. This procedure was adopted because of the 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 with no invalid data points, and this profile is used to compute the MPD by the HSSV software and is exported through a DLL to ProQual.

A series of invalid readings can sometimes 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 indicate the number of readings for which the temperature within the interface box for texture height sensors is outside the limits recommended by the manufacturers. As indicated in section 2.5.1, HSSV software monitors the temperature inside the interface box that processes macrotexture data. If a temperature alarm is displayed, go to the startup screen of the HSSV software and see if the displayed temperatures for the texture sensors are close to the upper or lower limit of the temperatures indicated by the manufacturer (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 allowed for the device, which is about 160 km/h.

### **Speed Errors**

A speed error is detected by the DAU and indicates that synchronization signals are not being sent out properly to the sensors and the system is lagging because the DMI signal is indicating another sample is required before the last synchronization signal was sent out. An encoder error can cause a speed error to occur, but other problems on the RS485 serial bus can 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, it 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 Summary window will be red. Selecting the Diagnostic tab will display all error messages sent by any sensor in the HSSV (figure 99).

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 include the following:

- 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 include sensor calibration and settings information from each sensor and other startup messages at the start of each run. The format for this string is as follows:

- Device address (table 2).
- Device type.
- Device attributes.

- Seconds since boot.
- Internet protocol address.
- Log string.

**Table 2. Device addresses.**

<b>Device Address</b>	<b>Module</b>
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 User Diagram Protocol Ethernet packets that were resent and have no effect on the data. A message indicating a Trigger Sequence Error means 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. A Trigger Sequence Error is not correctable 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 error 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 likely an indication of a problem with the cabling to that sensor or damage to a communications driver in the sensor. In case of such an event, contact the manufacturer to discuss the diagnostic messages.

## **2.9.4 Evaluating the Collected Longitudinal Profile and Macrotexture Data**

### ***2.9.4.1. ProQual 2014 Software***

ProQual 2014 software is used to perform quality control checks in the field on the longitudinal profile and macrotexture data collected by the HSSV.<sup>(7)</sup> 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 (section 2.7.3). The following information will be displayed in ProQual for each data collection run when the ARD files containing the data are read:

- The Header information and the End-of-Run comments that were entered into the HSSV software, which can be reviewed and corrections made if needed.
- The date, time, and average speed of the vehicle. The displayed speed is the average speed within the test section (i.e., average speed over the distance when the photocell triggers at the start of the test section and the Stop Distance value that is entered into the

HSSV software Header). The time shown is the time when “Collect Data” was selected in the HSSV software before the start of the test section (section 2.9.3.3).

- The profile count for “Pre,” “Run,” and “Post.” The ARD file contains profile data for a distance of 152.4 m before the start of the test section (i.e., pre-run), the data collected within the test section (i.e., run), and data collected for a distance of 152.4 m after the end of the test 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 test section that is profiled, the profile count for “Pre” should be 6096 if the data collection software was initiated at least 152.4 m before the start of the test 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 test section. For any test section that is profiled, the profile count for “Post” should be 6096. For a GPS test section, the profile count for “Run” will be approximately 6096. The profile count for “Run” for an SPS test section will vary depending on the length over which data were collected.
- The texture count for “Pre,” “Run,” and “Post.” The ARD file contains texture data for a distance of 30 m before the start of a test section (i.e., pre-run), data collected within the test section (i.e., run), and data collected after the end of a test section (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 test section that is profiled, the texture count for “Pre” and “Post” should be approximately 60,000. For a GPS test section, the texture count for “Run” will be approximately 304,800. The texture count for “Run” for an SPS test 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.
- The initial air temperature for each of the two ambient air temperature sensors computed from the data collected during pre-run. The number of readings 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. The number of readings 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. The readings shown include the readings obtained during pre-run, run, and post-run. The number of satellites 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.

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

The profile data collected by the HSSV are outputted at 25-mm intervals. ProQual can 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 (SV) (i.e., average of left and right wheel path).
- Average root-mean-square vertical acceleration (RMSVA) values (i.e., average of left and right wheel path) for base lengths of 0.3, 0.6, 1.2, 2.4, 4.9, 9.8, 19.5 and 39.0 m.

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

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

Under the Profile option in the Data QC menu, ProQual can 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. This feature is not currently active in version 1.5.1.37.
- The IRI distribution within the test 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 the entire run.
- Standard deviation of the mean segment depth (MSD) values.
- Dropout count.
- Dropout percentage.
- RMS value for the entire run.
- Cubic skew value based on data from the 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. This feature is not currently active in version 1.5.1.37.
- Cubic skew value.

Under the Texture option in the Data QC menu, ProQual can 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. This feature is not currently active in version 1.5.1.37.

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

#### ***2.9.4.2. Evaluating the Collected Longitudinal Profile and Macrotecture Data***

Once the operator is confident that a minimum of five error-free runs have been obtained, ProQual is used to perform quality control checks on the profile and macrotecture data. Procedures for running ProQual are described in the ProQual documentation.<sup>(12,13,14)</sup> The following is the recommended procedure to evaluate the collected data.

#### **Checks During Data Loading**

As the data are being input into ProQual, a status indicator is shown for header, texture (i.e., macrotecture data), ambient (i.e., data from the air temperature probes), profile (i.e., longitudinal 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 orange indicator does not necessarily mean there are data errors. Refer to chapter 8 of

the ProQual *User Guide* if a yellow, orange, or red status indicator is shown and take appropriate actions to correct the issue, if possible, and perform additional data collection runs if needed.<sup>(12)</sup>

### Checks on Longitudinal Profile Data

The operator should be familiar with the troubleshooting guide included in appendix C. The material presented in appendix C describes common errors that occur during longitudinal profile data collection and is a valuable tool for identifying problems when longitudinal profiles are being evaluated.

1. If data collection was performed for an SPS project, review the subsectioning 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 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 value less than 0.04 m/km is desired.

Cross-correlation was first used as a quality control tool for longitudinal profile data in the LTPP program with the implementation of ProQual 2014. The thresholds specified for the various cross-correlation parameters may change in the future based on feedback from the DCC. The 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 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. The operator should examine the 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. 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 with the graphical feature in ProQual. If the spikes for the different runs are occurring at the same location, it is likely the spike was caused by a pavement feature. If spikes are believed to be caused by operator or equipment error, the operator should correct the cause of the anomalies and perform additional runs until five profile runs free of equipment or operator errors are obtained.

6. Compare the current profile data for each path with those obtained during the previous test section 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 test section visits should be evaluated to determine if similar profile features are present in both datasets and if profile shapes are similar. If differences are observed between profiles, further comparisons should be made using the remaining runs from both the current and previous test section visit. If there are still discrepancies between profiles from the current and previous test section visits, the operator should verify that these differences are not caused by equipment problems or incorrect subsectioning of SPS test sections. The operator should also explore if differences are due to pavement maintenance activities on the test section. Version 1.5.1.37 of ProQual does not have the ability to overlay profile data collected by the HSSV with data collected by other profilers used in the past in the LTPP program to collect data (e.g., ICC). A future version of ProQual might have this capability. When HSSV data are compared to data collected with MDR profilers, differences in profile plots will be seen (figure 187 through figure 190). However, sharp upward and downward features in both profiles indicative of short wavelength features should occur at the same location. When the comparison involves only the HSSV data, both profile features and shapes should be similar.
7. Perform an IRI comparison of current versus previous test section visit data using the procedures described in section 2.9.4.3.

### **Checks on Macrotexture Data**

The following is the recommended procedure to perform checks on macrotexture data:

1. Review the left and right MPD values and the dropout percentages of the runs for consistency.
2. Review whether the average MPD value computed from all runs for each wheel path is reasonable. The ProQual *User Guide* provides typical ranges of MPD for various pavement finishes.<sup>(12)</sup>
3. Review the locations where dropouts occur for different runs using the graphical feature in ProQual. This feature is not currently active in version 1.5.1.37.
4. Perform an MPD comparison of current versus previous test section visit data using the procedures described in section 2.9.4.3.

### **Deciding If the Collected Data Are Sufficient**

If the review of the longitudinal profile and macrotexture data performed using the aforementioned procedures 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 longitudinal profile or macrotexture data) are obtained.

## **Entering Comments in ProQual**

Once the operator is confident five error-free (i.e., no errors in longitudinal profile or macrotexture data) runs have been performed at a test section, enter the Surface Finish, Texture Comments, and Operator Comments into ProQual.

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

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

### ***2.9.4.3 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. The center path IRI values for the previous visit are currently only available if the test section was tested previously with the HSSV. In the future, ProQual may be upgraded to have the ability to import ERD files from MDR and 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 obtained from the previous visit to the test section. The operator should determine if the current average IRI value along each path is higher or lower than 10 percent of the average IRI value at the test section from the previous visit. 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 the 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**

The operator should have the average MPD values obtained along the left and right wheel path for the previous visits for all test sections. The previous MPD values will only be available if the test section was tested previously with the HSSV. 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 obtained from the previous visits to the test section. The operator should determine if the current average MPD value along each path is higher or lower than 10 percent of the average MPD value at the test section from the previous visit. If the difference in MPD is greater than 10 percent, the 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.

#### **2.9.4.4 Obtaining Additional Runs**

The operator is responsible for carefully reviewing longitudinal profile and macrotexture data to determine if a high degree of run-to-run variability is indicative of bad data or 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 performed, 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, or rapid acceleration or deceleration of the vehicle could have affected the collected data.
2. Use the graphical feature in ProQual to review spike locations and determine if spikes are the result of field-related effects (e.g., potholes, transverse cracks, bumps) or due to electronic failure or interference. The cause of spikes can be determined by reviewing the runs in ProQual and observing if spikes occur at the same location in all runs. The operator should also examine longitudinal profile plots for discrepancies and features that cannot be explained by observed pavement features. ProQual provides the user with the capability to compare longitudinal profile data for all repeat runs collected at the test section. This feature should be used to compare longitudinal profile data when analyzing differences between longitudinal profile data for different runs.
3. Compare current longitudinal profile data with those collected during previous test section visits. This comparison may indicate potential equipment problems.

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

Where data anomalies are believed to be caused by pavement features rather than errors, a total of seven runs should be performed at that test section and evaluated using the ProQual software. If data from the last two runs are consistent with those from the first five runs in terms of variability and presence of pavement-related anomalies, no further runs are required. If data from the last two runs differ from those from the first five runs, the operator should reevaluate the cause of variability or the apparent spike condition. If no errors are found, perform two additional runs and terminate data collection at that test section.

Thereafter, IRI values along the left, right, and center paths should be compared with IRI values obtained during previous visits to the test section as described in section 2.9.4.3. Also, the MPD values along the left and right paths should be compared with MPD values obtained during previous visits to the test section as described in section 2.9.4.3.

#### **2.9.5 Evaluating the Collected Transverse Profile Data**

After evaluating the collected longitudinal profile and macrotexture data, use the following procedure to evaluate if acceptable transverse profile data have been collected at the test section:

1. Select “Transverse” from the main menu of the HSSV software (figure 84).
2. Go to “File Open” and load an ARD file that contains transverse profile data (figure 100).
3. After loading the data, check that the screen has the view shown in figure 101.
4. Go to “Distance Labels” on the top menu and select “Distance from the Start” so the distance from the start of the section in meters will be displayed instead of stations, as shown in figure 102. Distance = 0 corresponds to the start of the test section where the photocell triggered.

By default, the viewer will display the Intensity data. The image shown on top is called the Main View, and the image shown in the middle is called the Overview. The Overview shows a horizontally squashed view of the entire run. The main view shows a portion of the road selected in the Overview. A blue rectangle is shown in the Overview. The image shown in the Main View is the image corresponding to the box shown in the Overview.

The following are several ways to increase or decrease the distance from the start of the test section to view the image in the Main View:

- a. Using the mouse—the distances on the image shown in the Main View can be increased by placing the mouse over Main View or Overview and then moving the mouse wheel forward. The distance can be decreased by moving the mouse wheel backward.
- b. Using the arrow buttons on the Overview Menu—the user can use the arrow buttons on the left and right side of the Overview Menu to increase or decrease the distance value.
- c. Using cursors—the left and right cursor keys can be used to increase or decrease the distances in short increments. Selecting “Shift” on the keyboard plus the appropriate cursor key will increase or decrease distances in large increments.

When Overview is clicked, a box outlined by blue appears and the area highlighted by the blue box is shown in the Main View. The user can click anywhere in the Overview to show the selected portion on the Main View.

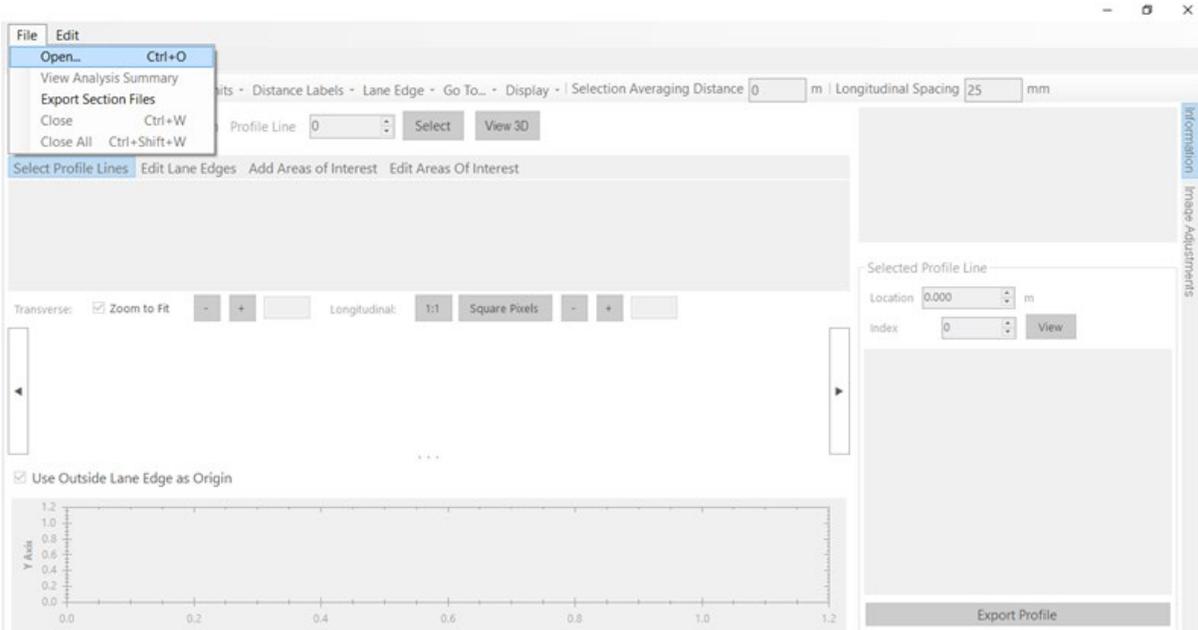
The user can enter a distance value in the Center On field and the image for a distance of 40 m centered on this station will be shown in the Main View. From the top menu under “Go To,” the user can select “Start” to go to the start of the test section or “End” to go to the end of the test section.

The contrast of the shown images can be adjusted by accessing the Image Adjustment tab on the upper right side of the screen below the Information tab.

5. Click on Distance = 0 location in the Main View and observe the intensity plot shown in the bottom graph (figure 103). The intensity graph will show a hump at the location of the lane markings. As the outside edge of the lane will always have a solid white stripe, a

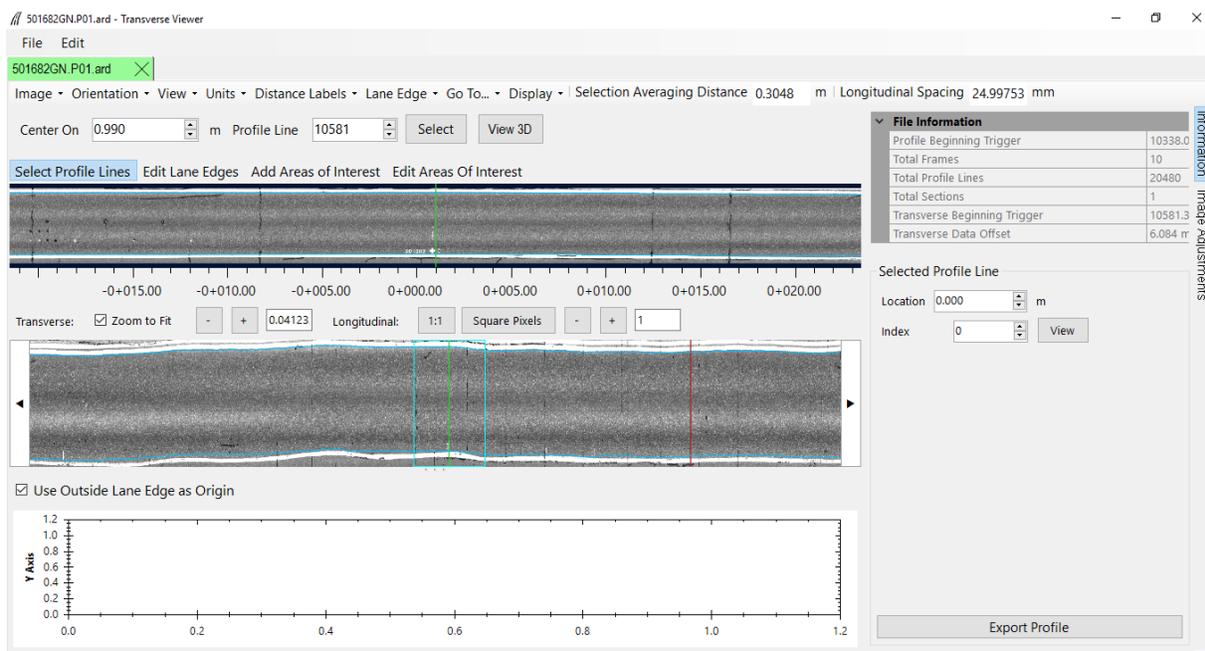
hump should be displayed on the right side of the graph. A hump may or may not appear on the left side depending on whether a lane marking was captured at that location. For a GPS test section, click on the Main View at several locations between 0 and 152.4 m to observe if the intensity will be displayed on the graph at the bottom. The operator can click on the Overview to display different distances on the Main View such that different locations can be selected on the Main View. For an SPS test section, observe if the intensity will be displayed on the graph at the bottom by selecting several locations within each test section of the SPS project. Event marks will be displayed on Overview at the start of each SPS test section.

6. Select “Range” from the top menu under “Image” (figure 104). The transverse profile at that test section will be displayed in the bottom graph (figure 105).
7. For a GPS test section, click on the Main View at several locations between 0 and 152.4 m to observe if the transverse profile at that location will be displayed on the bottom graph. The operator can click on the “Overview” to display different distances on the Main View such that different locations can be selected on the Main View. For an SPS project, observe if the transverse profile is displayed by selecting several locations within each SPS test section. Event marks will be displayed at the start of each SPS test section.
8. If acceptable data are observed for the intensity and range data in the evaluated ARD file, consider that acceptable transverse profile data have been collected at the test section. If the data appear to be erroneous, load another ARD file and evaluate if acceptable data are present in that file. If acceptable data are present in that file, assume that acceptable transverse data have been collected at the test section. If problems are detected in the data, attempt to troubleshoot the issue and, if resolved, perform additional data collection runs and evaluate the data.



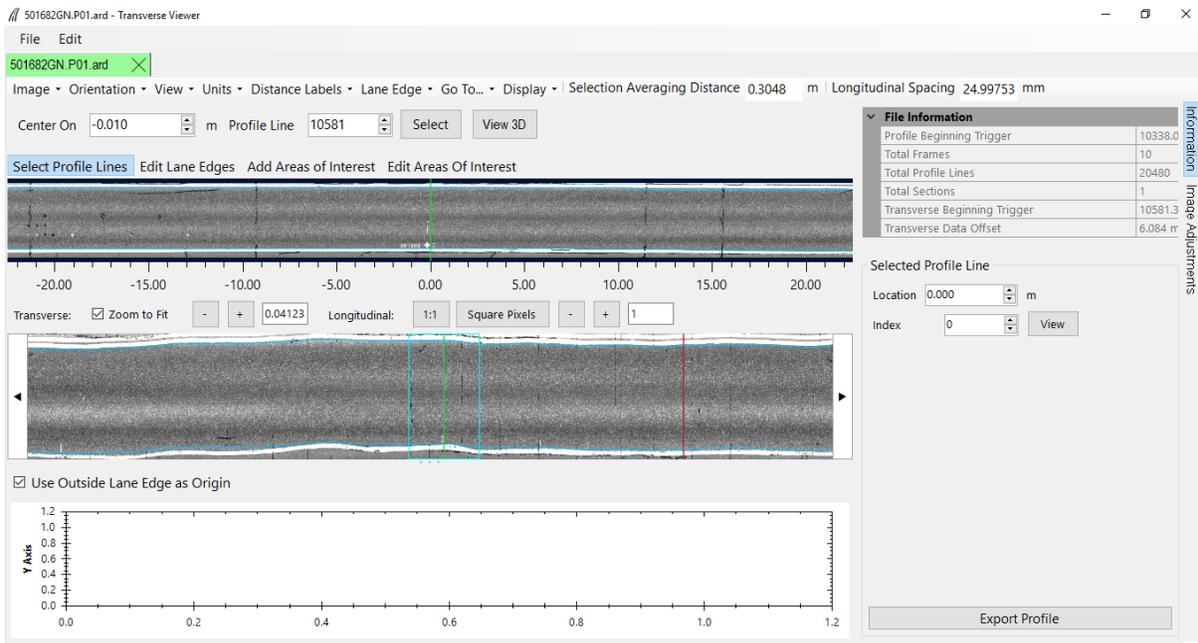
Source: FHWA.

**Figure 100. Screenshot. Loading an ARD file to view the transverse profile data.**



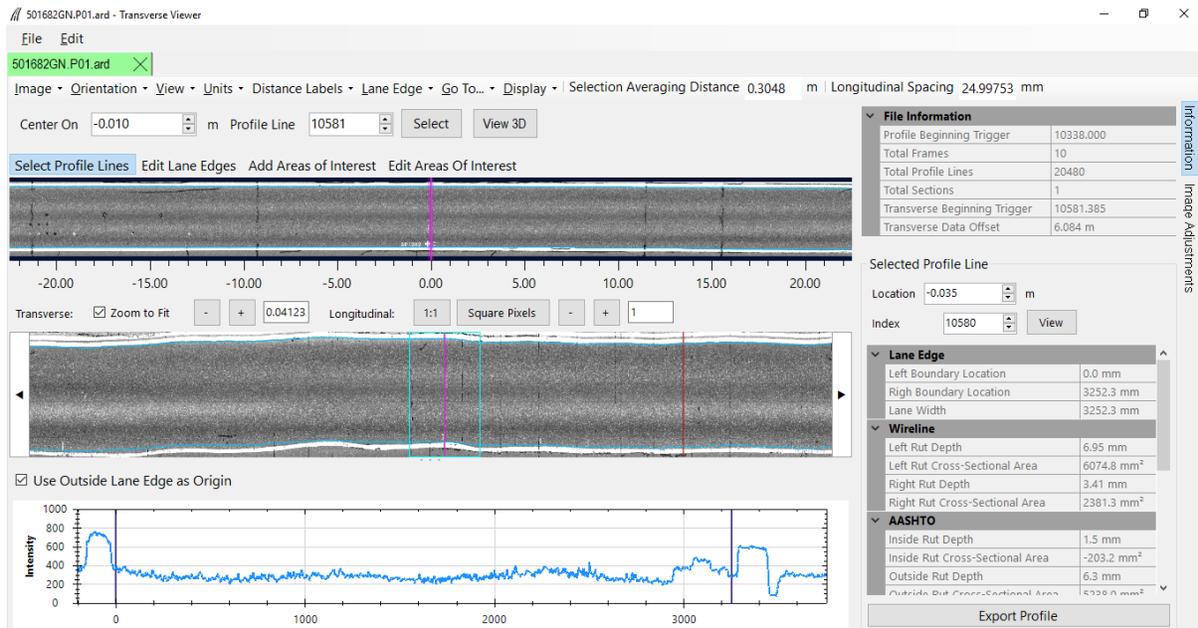
Source: FHWA.

**Figure 101. Screenshot. View of screen after loading an ARD file to view the transverse profile data.**



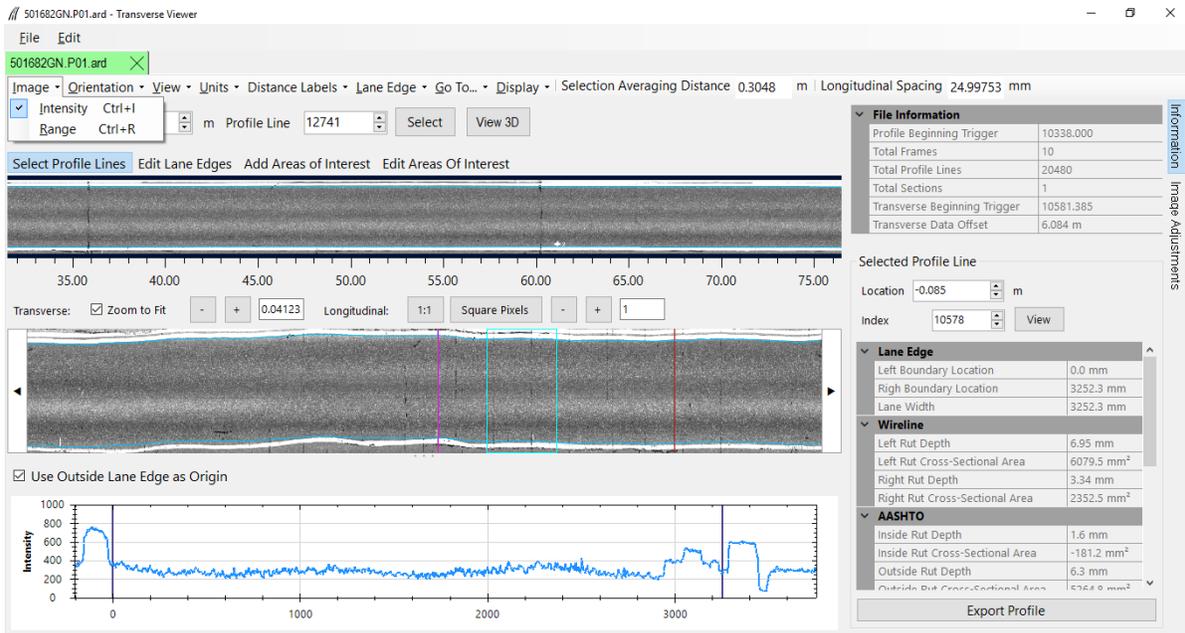
Source: FHWA.

**Figure 102. Screenshot. View of the screen with distance shown in meters.**



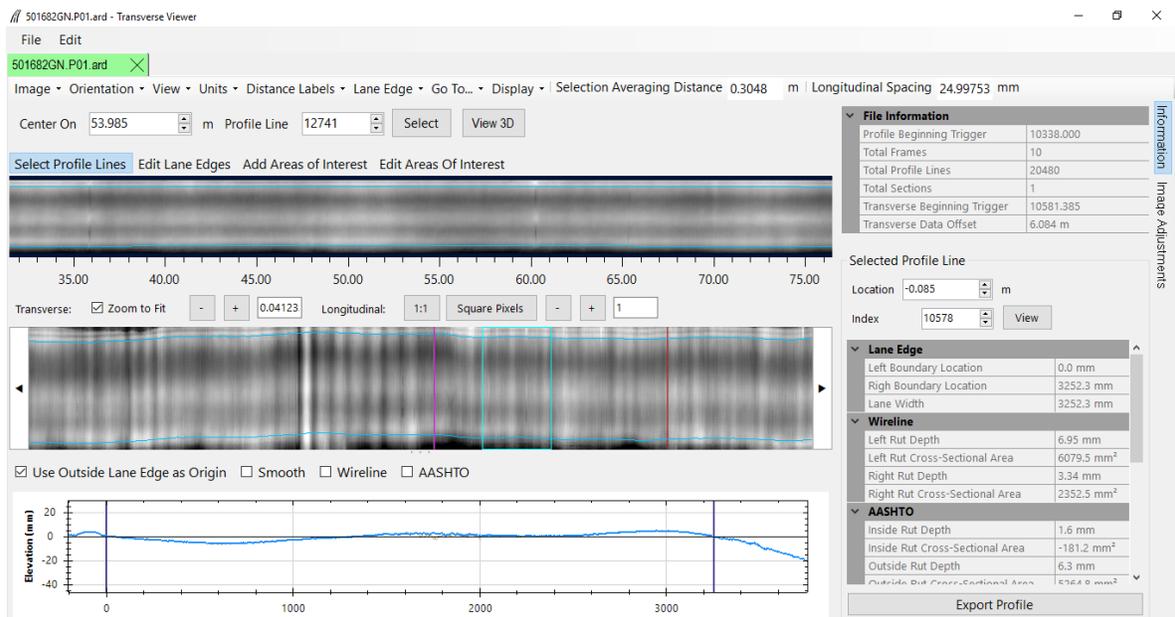
Source: FHWA.

**Figure 103. Screenshot. Example of an intensity image.**



Source: FHWA.

**Figure 104. Screenshot. Selecting range under image.**



Source: FHWA.

**Figure 105. Screenshot. Example of a range image.**

## 2.9.6 Field XML File and Data Backup

Once the operator is satisfied that an acceptable set of runs has been performed at the test section, use the Field button under the Export tab in ProQual to create the field XML file. The data collected at a test section by the HSSV (i.e., ARD files), the files generated by ProQual when the collected data were processed (i.e., Field XML), and the images captured at a test

section should be backed up to a flash drive before leaving the test section. 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 the backup of data for a test section is to create separate directories in the flash drive for each test section.

When an SPS test section is processed, the ProQual files created for all test sections in the SPS project as well as the raw longitudinal 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 containing the data collected on that day. One of these backups should be kept in the HSSV (i.e., the device copy), while the other backup (i.e., the DCC copy) should be transmitted to the DCC office. Until the DCC 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 DCC office has informed the operator that the DCC copy has been received and processed by the DCC office. The flash drive can be recycled once the DCC office informs the operator that data have been received, processed, and backed up.

Data files collected by the HSSV should be organized into subdirectories in the hard drive, as outlined in the current version of LTPP Directive I-171, AIMS Data Storage Format Standards.<sup>(10)</sup>

## **2.10 PROFILING SPS TEST SECTIONS**

### **2.10.1 General Background**

This section describes field testing procedures to be followed when testing SPS test sections, which are different than the procedures for GPS test sections. However, other than the exceptions described in this section, all other information presented in earlier sections of this manual is valid when SPS test sections are being tested. An SPS site consists of a number of test sections with a transition area between adjacent test sections. During a data collection run at an SPS site, longitudinal profile, macrotexture, and transverse profile data are collected for the entire site, which includes test sections and 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 an SPS project that includes 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 the test sections and 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 collect data at the SPS project as two groups of test sections.

### **2.10.3 Operating Speed**

Guidelines regarding the operating speed described in section 2.7.4 should be followed when collecting data at SPS test sections. When SPS test sections are tested, the transition area between test 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 test section is tested. If there is traffic in front of the HSSV, the speed of the HSSV can be initially decreased in the transition area to give more leeway with the vehicle in front. Thereafter, the HSSV 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 an SPS project is described in the ProQual *User Guide*.<sup>(12)</sup> ProQual is capable of computing the IRI value of individual test sections within an SPS project by identifying test sections using stationing and event marks. The procedure outlined in section 2.9.4 should be followed to obtain an acceptable set of runs at an 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 entered in step 9 for an SPS project is different than that entered when collecting data at GPS test sections.

The operator should refer to site layout plans and obtain the length of the SPS project encompassing all test sections. To guard against discrepancies between layout plans and as-built test 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 Stop Distance, 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 SITES**

### **2.11.1 Background**

The collection of accurate axle weight data using WIM scales is of vital importance to achieving 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 sites are not described in this manual. This section describes procedures the DCC should follow to collect longitudinal profile data at active SPS-1, -2, and -10 projects using the HSSV. The resulting longitudinal profile data will be used to determine whether a WIM site meets the LTPP pavement smoothness specifications. This manual does not contain the procedures to make this determination.

The DCC is responsible for working with the relevant highway agency to locate and correctly identify the WIM location for each SPS project.

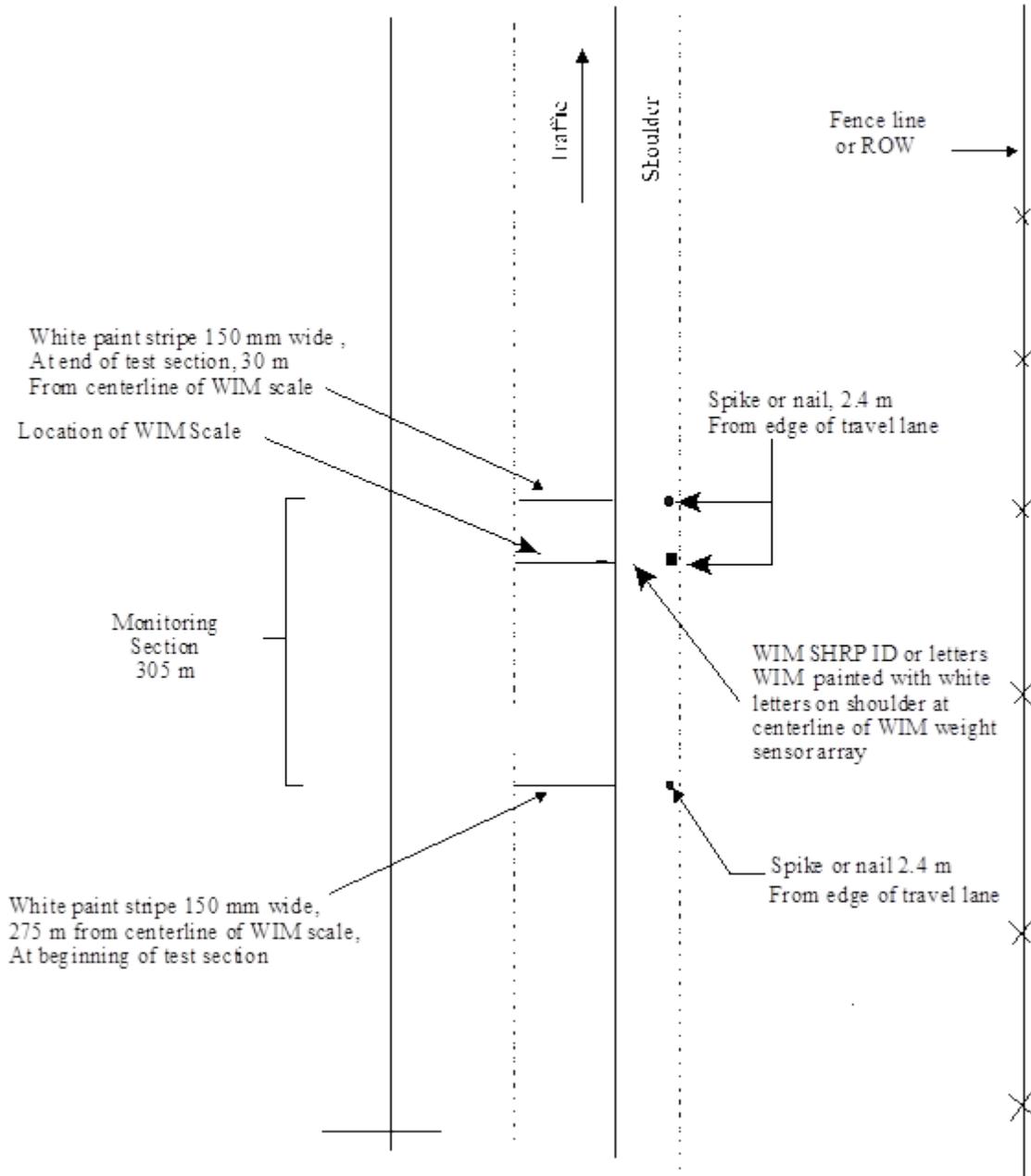
### **2.11.2 WIM Test Section**

A WIM test 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 start 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 test section should be marked as shown in figure 106. Monuments (e.g., nails, spikes, or re-bars) should be installed in the shoulders, exactly at the start and end of the test section, and at the WIM centerline as shown in figure 106. These monuments will serve as section markers in case of paint wear. The monument at the start of the test section should be 275 m before the centerline of the WIM scale. The monument at the end of the test section should be 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 test 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 start and end of the WIM test section. The leave edge of the stripes should be next to the applicable monument. If the WIM test 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 is painted near the outside shoulder for permanently marked test sections: A WIM SHRP ID of the format PP99, where PP is the Project ID (i.e., the 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



Source: FHWA.

**Figure 106. Diagram. Layout of WIM test section.**

For example, the Maryland SPS-5 project presently has a piezo system installed. The SHRP ID and appropriate marking for this WIM test 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 test section is 0598.

If permanent markings are not present at the WIM test section, reflective tape or the cone should be used to trigger the start of data collection. However, the DCC is responsible for working with the relevant highway agency to ensure their WIM test sections are permanently marked before the second visit to the test section.

### **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 test sections fall into one of the following categories:

- Verification of existing WIM test sections. Existing WIM test sections are already in operation, but will be evaluated to determine if they satisfy the specified smoothness criteria.
- Acceptance of newly constructed WIM test sections. Newly constructed WIM test sections will be evaluated to determine if they satisfy the specified smoothness criteria.
- Annual check of WIM test sections. Newly constructed WIM test sections that are accepted into the LTPP program, as well as existing WIM test sections 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.

Longitudinal 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 FHWA. Longitudinal and transverse profile measurements using a straightedge will also be taken for acceptance testing of newly constructed WIM test sections, but applicable data collection procedures are not described in this manual.

With respect to the third application, installed WIM locations on active SPS-1, -2, and -10 projects should be profiled during scheduled profile visits to their associated SPS projects. An installed test section is a location at which sensors currently exist and data are currently being collected. Said test section may or may not be located within the project limits or immediate proximity to the SPS project. Only the LTPP lane will be profiled for an installed test section. In cases where the WIM test section 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 should be taken exclusively with the HSSV; Dipstick cannot be used as a substitute for the HSSV. In addition, the profile measurements should be taken in accordance with the guidelines and procedures described in section 2.9 in this manual, except that the procedure for profiling a test section and the number of acceptable runs required at a WIM test section are different from the procedures described in section 2.9. Procedures for profiling a

WIM test section and the number of profile runs required at a WIM test 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 test sections. Transverse profile data should not be collected at WIM test sections. The following are the three lateral positions along which the HSSV is driven to collect the data:

- Along the wheel paths.
- Close to the shoulder (i.e., to the right of the wheel path).
- Close to the inner edge of the lane (i.e., to the left of the wheel path).

The following convention should be followed for naming files or errors will be produced when running ProQual that will cause problems when archiving files. The filename should consist of eight characters as follows:

SSDXLPEV

Where:

- SS = State code in which the test section is located (e.g., 27 for Minnesota).
- D = first character of the SPS project SHRP ID, which should be 0, A, B, and so on, depending on project code (e.g., 0600, A600, B600, and so on) if profiling in the same direction as the SPS project. If profiling in a different direction from an SPS test section, 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 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 test sections, this should always be W.
- V = sequential visit identifier indicating 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 test section since the test section was first profiled. Use an appropriate letter for the current profiling, with A used for the first visit, B for the second, and so on.

For example, the following are valid data filenames:

- 05A6OCWB—Arkansas SPS-6 WIM test section 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 test section 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 for the third visit.

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

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

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

- Daily checks should be performed on the equipment (e.g., laser sensor check, bounce test).
- The highway agency procedures relating to safety issues (i.e., light bar, directional warning light, strobe lights, use of turnarounds) should be strictly followed.
- 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, a lower speed—depending on prevailing conditions—should be selected. If the speed limit at the test section is less than 80 km/h, the test section should be profiled at the posted speed limit. If traffic traveling at high speeds is encountered at a test section, it is permissible to increase the profiling speed to 88 km/h.
- The photocell should always be used to initiate data collection at the start of the test section.
- When entering Header information into the software, the section number assigned to the WIM should be entered as the Site ID.
- The Stop Distance should be specified as 305 m.

The following procedure should be followed to obtain an acceptable set of profile runs at WIM test 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 left of the wheel path.

1. Ensure the end of the WIM test section is passed before terminating profile data collection.
2. Obtain at least three, but no more than five, profile runs by driving the HSSV along the wheel paths.
3. Obtain at least one, but not more than three, profile runs by driving the HSSV along a path as close as possible to the right edge of the traffic lane (i.e., the right tire of the vehicle is aligned as close as possible to the white stripe along the edge of the lane). The driver of the HSSV should judge the path to be followed based on the test section conditions such that the path followed does not cause any safety concerns.
4. Obtain at least one, but not more than three, runs by driving the HSSV along a path that is as close as possible to the left edge of the traffic lane (i.e., the left tire of the vehicle is

aligned as close as possible to the lane divider along the edge of the lane). The driver of the HSSV should judge the path to be followed based on the test section conditions such that the path followed does not cause any safety concerns.

5. Review the profile runs collected along each path after completing data collection. 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 completed at the test section, 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 completed, repeat data collection along appropriate path(s) and evaluate the profile data using the procedures described in section 2.9.4. 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, to maintain a log of the runs (figure 181).
7. Back up the data before leaving the test section following the procedures described in section 2.9.5.

## **2.12 CALIBRATION/CALIBRATION CHECKS**

### **2.12.1 General Background**

The only component in the HSSV that can be calibrated is the DMI. However, there are several components in the HSSV on which calibration checks or operational checks must be performed to ensure the components are collecting accurate data. Table 3 shows the components in the HSSV on which calibrations, calibration checks, or operational checks must be performed, as well as the maximum interval between calibration, calibration checks, or operational checks. Table 3 also shows the section in this manual that describes the calibration, calibration check, or operational check.

Power to the electronic equipment should be turned on for about 15 min before performing calibration, calibration checks, or operational checks to allow the electronic equipment to warm up and stabilize.

**Table 3. Components requiring calibration, calibration checks, or operational checks.**

<b>Component</b>	<b>Test</b>	<b>Maximum Interval Between Tests</b>	<b>Section in Manual</b>
DMI	Calibration	30 d (Note 1)	2.12.3
Accelerometer	Calibration check	30 d (Note 2)	2.12.4
Profile height sensors	Full calibration check	30 d (Note 3)	2.12.5
Texture height sensor	Full calibration check	30 d (Note 4)	2.12.5
Texture height sensor	Dynamic check	30 d (Note 4)	2.12.6
Bounce test	Dynamic check	Whenever full calibration checks of profile height sensors are performed in addition to daily check	2.12.7
Ambient temperature sensor	Calibration check	30 d (Note 5)	2.12.8
Pavement surface temperature sensor	Calibration check	30 d (Note 5)	2.12.9
GPSR	Calibration check	30 d (Note 5)	2.12.10
TPMS	Operational check	30 d (Note 5)	2.12.11
TPMS	Dynamic check	30 d (Note 5)	2.12.12
Photocells	Operational check	365 d (Note 5)	2.12.13

Note 1: The 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.

Note 2: This test must be performed whenever problems are suspected, repairs are performed on any components associated with the accelerometer, or an accelerometer is repaired or replaced.

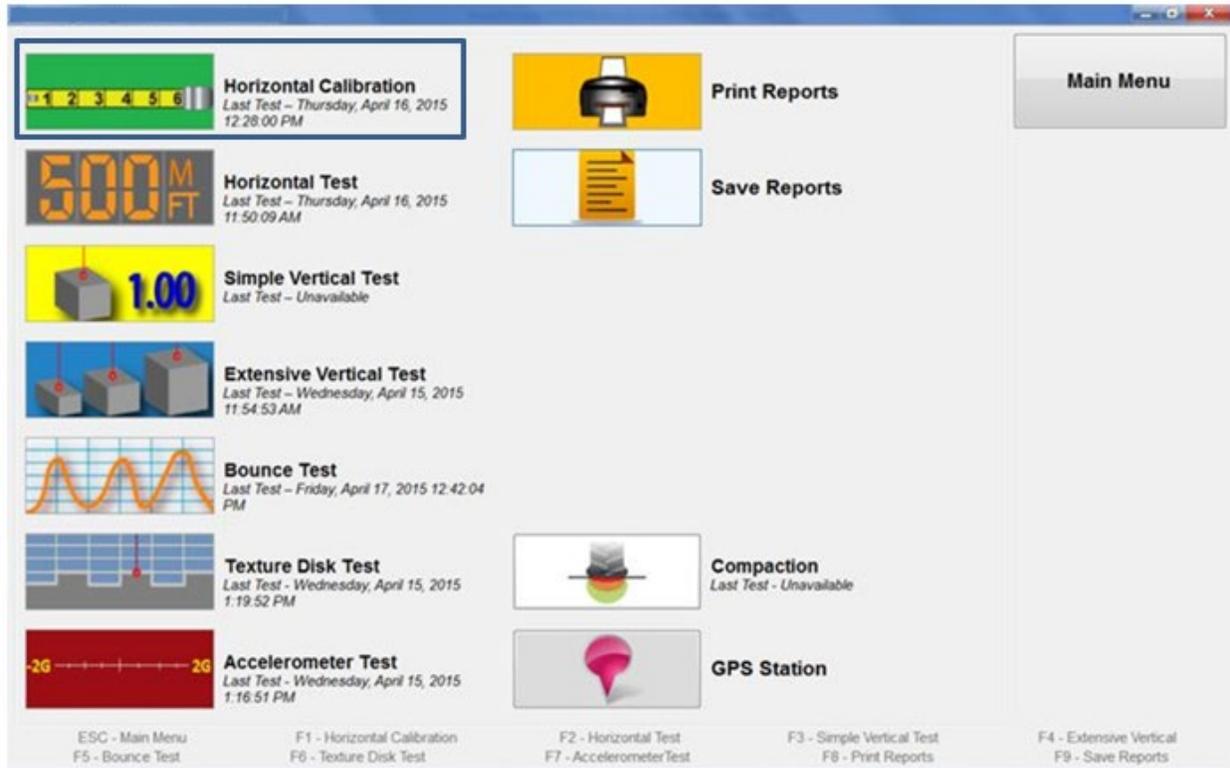
Note 3: This test must be performed whenever problems are suspected, repairs are performed on any components associated with the profile height sensor, or a profile height sensor is replaced.

Note 4: This test must be performed whenever problems are suspected, repairs are performed on any components associated with the texture height sensor, or a texture height sensor is replaced.

Note 5: This test must be performed whenever problems are suspected with the sensor or repairs are performed on any components associated with the sensor.

### **2.12.2 Calibration Menu**

The Calibration menu is accessed from the HSSV software startup screen by pressing the F2 key or by selecting “Calibration” (figure 84). The Calibration menu shown in figure 107 will then be displayed on the laptop computer screen. All of the calibration or calibration checks shown in table 3, except for the calibration checks on the ambient temperature sensor, pavement surface temperature sensor, and GPSR are performed by selecting the appropriate test from the Calibration menu.



Source: FHWA.

**Figure 107. Screenshot. Calibration menu highlighting horizontal calibration.**

### 2.12.3 Calibration of 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 test section of 300 m should be used to calibrate the DMI. This test section must be located on a straight portion of roadway that is reasonably level and has a low traffic volume.

The speed limit at a test section should be at least 80 km/h. This test section should be in an area where the vehicle can be driven at a constant speed without interruptions. The test 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 test section such that the distance between the 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 the HSSV traverses the test section.

The computed calibration factor will depend on the tire pressure of the rear driver's side tire, as the encoder is attached to the rear driver's side wheel. Before driving the vehicle in the morning, the operator should check the tire pressure to ensure the front tires are at 380 kPa and the rear tires are at 550 kPa, which are the manufacturer's recommended tire pressures. Adjust the tire pressure if needed.

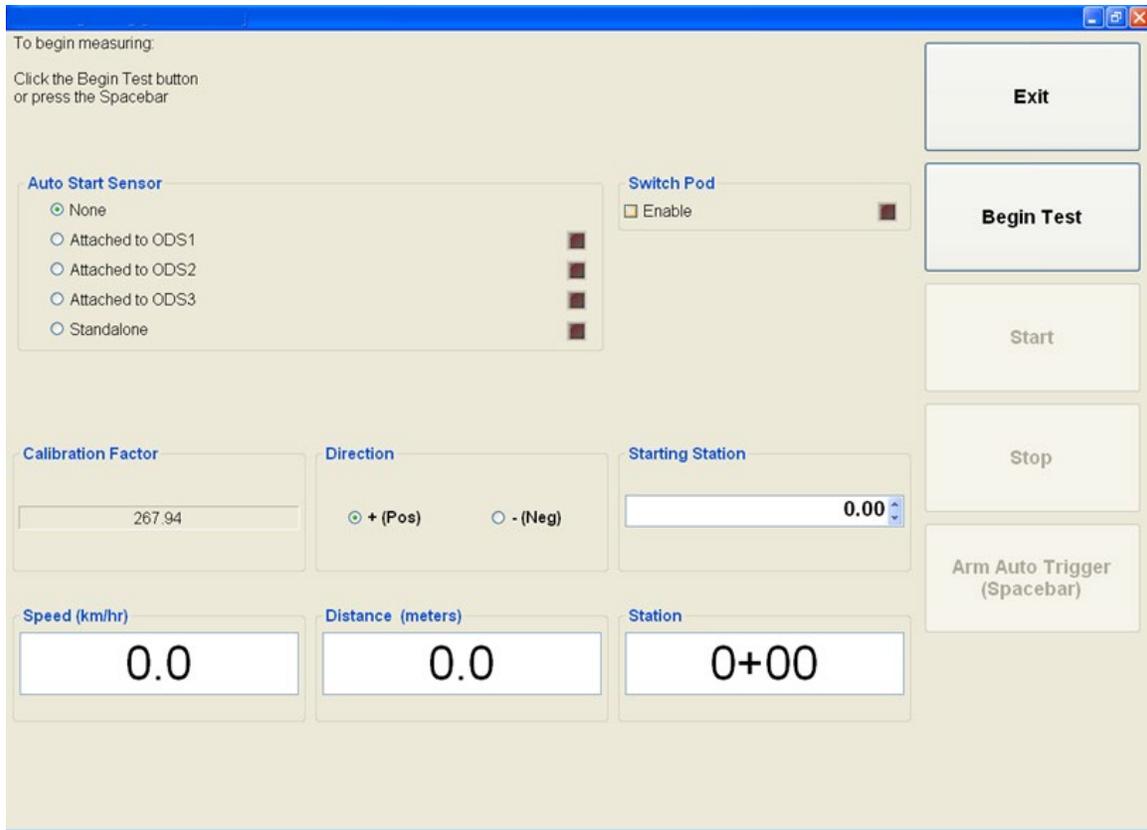
The operator should drive the vehicle for about 6 to 8 km at highway speeds before calibrating the DMI so the tires can warm up. Based on local weather conditions (e.g., cold weather) the operator may need to increase the distance driven to warm up the tires.

Before calibrating the DMI, perform a horizontal test using the “Horizontal Test” option in the Calibration menu to obtain the distance the DMI is measuring at the test section with the current calibration factor (figure 107). The horizontal test will provide information about the stability of the DMI over time. Perform the horizontal test using the following procedure:

1. Adjust the tire pressure of all tires so they match the tire pressure at the time the DMI was calibrated last.
2. Press the F2 key or select the “Horizontal Test” icon in the calibration menu (figure 107). The screen shown in figure 108 will be displayed, which shows the current calibration factor of the DMI.
3. Select “Attached to ODS3” under Auto Start Sensor to select the vertical photocell as the active photocell.
4. Select “+(Pos)” under Direction to indicate distance will be increasing.
5. Bring the vehicle up to a speed of 80 km/h about 150 m before the start of the test section and select “Begin Test.” Then, press the spacebar on the keyboard to arm the photocell.
6. Listen for a beep as the HSSV crosses the start of the test section, which indicates the photocell was triggered by the reflective tape located at the start of the test section. The Distance field will be reset to 0.
7. Press the spacebar on the keyboard to activate the photocell as the HSSV approaches the end of the test section. As the HSSV crosses the end of the test section, a beep will be emitted when the photocell is detected by the reflective tape located at the end of the test section. The Distance field will display the measured distance.

If the photocell fails to trigger at the start or end of the test 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, the operator should adjust the sensitivity control for the photocell and repeat the test. If this is not successful, the operator should use the horizontal photocell. To use the horizontal photocell, place two cones on the side of the road at start and end of the test section such that leave edge of the reflective mark on each cone is aligned with the leave edge of the mark on the pavement surface. Under “Autostart Sensor,” select “Attached to ODS2” to select the horizontal photocell and perform the test using the procedure described in steps 5 and 6 (figure 108).

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



Source: FHWA.

**Figure 108. Screenshot. Horizontal test screen.**

After performing the horizontal test, use the following procedure to calibrate the DMI:

1. Adjust the tire pressure so the front tires are between 380 and 415 kPa and the rear tires are between 550 and 585 kPa. Note the tire pressures.
2. Press the F1 key or select the “Horizontal Calibration” icon in the Calibration menu (figure 107). The Horizontal Calibration screen shown in figure 109 will be displayed on the laptop computer screen. This screen shows the calibration factor for the DMI that was saved the last time the DMI was calibrated.
3. Select “Attached to ODS3” under Auto Start Sensor to select the vertical photocell as the active photocell.
4. Enter 300 in the Calibration Length field, 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 Comments field, enter the distance that was noted in step 8 of the horizontal test.

5. Bring the vehicle up to a speed of 80 km/h, and about 150 m before the start of the test section, press “Begin Test” and then press the spacebar to arm the photocell. As the HSSV crosses the start of the test section, a beep will be emitted when the photocell is triggered by the reflective tape located at the start of the section.
6. As the HSSV approaches the end of the test section, press the spacebar to arm the photocell. As the HSSV crosses the end of the test section, a beep will be emitted when the photocell detects the reflective tape located at the end of the test section. Figure 110 shows an example of the DMI calibration screen after performing one run. The Pulses and Factor fields on the screen will automatically populate. The Pulses field indicates the pulses counted by the encoder over the calibration test section, and the Factor field indicates the calibration factor that was computed.

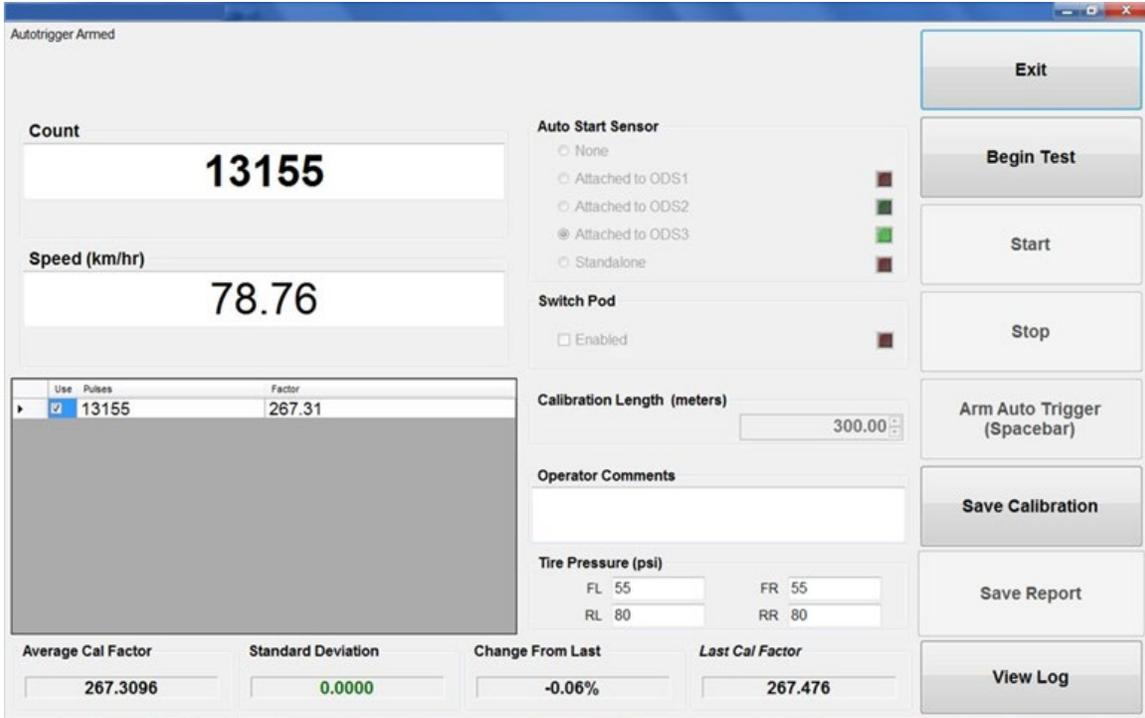
If the photocell fails to trigger at the start or end of the test section, the Stop button can be used to terminate the test. Clean the photocell and repeat the run and see if the photocell triggers. If the photocell still fails to trigger, the operator should adjust the sensitivity control for the photocell and repeat the test. If this is not successful, the operator should use the horizontal photocell. To use the horizontal photocell, place two cones on the side of the road at the start and end of the test section such that the leave edge of the reflective mark on each cone is aligned with the leave edge of the mark on the pavement surface. Under “Autostart Sensor,” select “Attached to ODS2” to select the horizontal photocell and perform the test using the procedure described in steps 5 and 6 (figure 109).

7. Repeat the calibration procedure described in steps 5 and 6 five more times so that six calibration runs are completed. At the start of each run, adjust the tire pressure to the values noted in step 1. After six calibration runs have been completed, select the six runs so 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 111 shows an example of the screen at this stage. The screen will also display the standard deviation of the calibration factor and 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 completed.
8. Complete additional runs if the standard deviation of the calibration factor is greater than 0.07. Then, select the runs to be used to compute the calibration factor. Figure 112 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 the DCC office and decide on a suitable course of action.
9. Proceed to step 10 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  $\pm 1$  percent. 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  $\pm 1$  percent, proceed to step 11.

10. Repeat the test if the tires on the vehicle are changed, because 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 the percent change is still not within  $\pm 1$  percent of the previous value, and the obtained values are similar to the previous test, select “Save Calibration” to save the computed calibration factor and select “Save Report” to save the DMI calibration report that will have details about the current calibration. Proceed 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 select “Save Report” to save the DMI calibration report that will have details about the current calibration.
12. Use the new calibration factor from this point forward until this procedure is repeated again in the future. Fill out Form PROF-5, Laser Sensor, Accelerometer, DMI Calibration/Calibration Check Form (figure 179). Press “Exit” to exit the Horizontal Calibration menu.

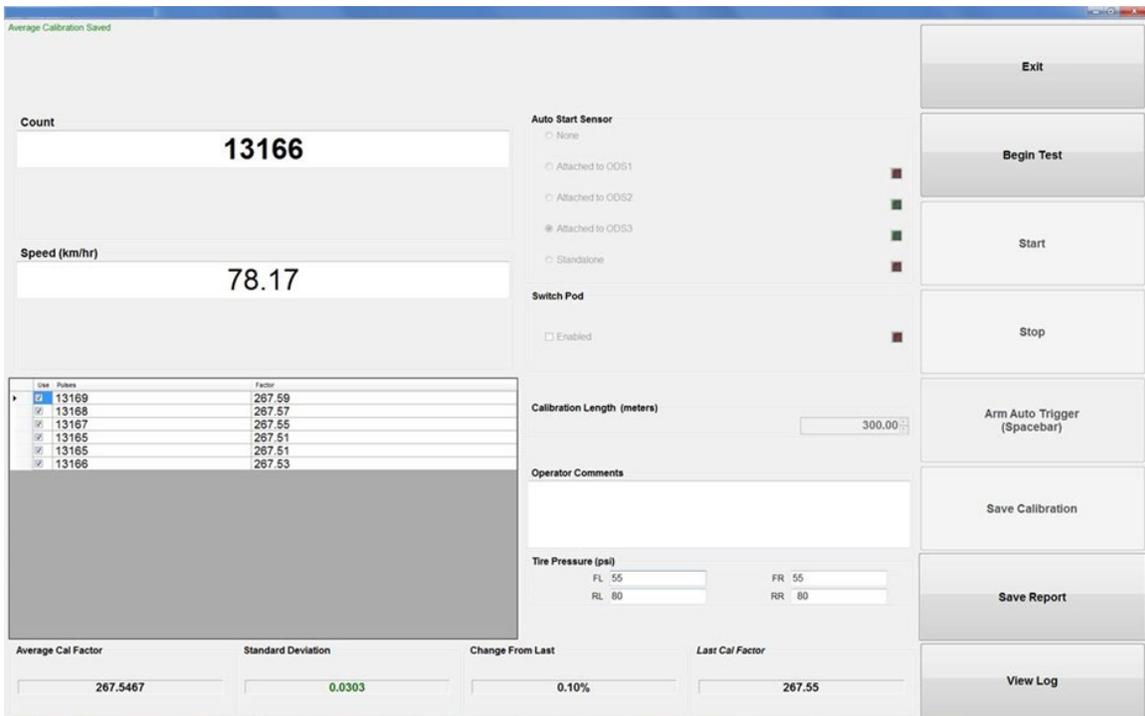
Source: FHWA.

**Figure 109. Screenshot. Horizontal Calibration screen.**



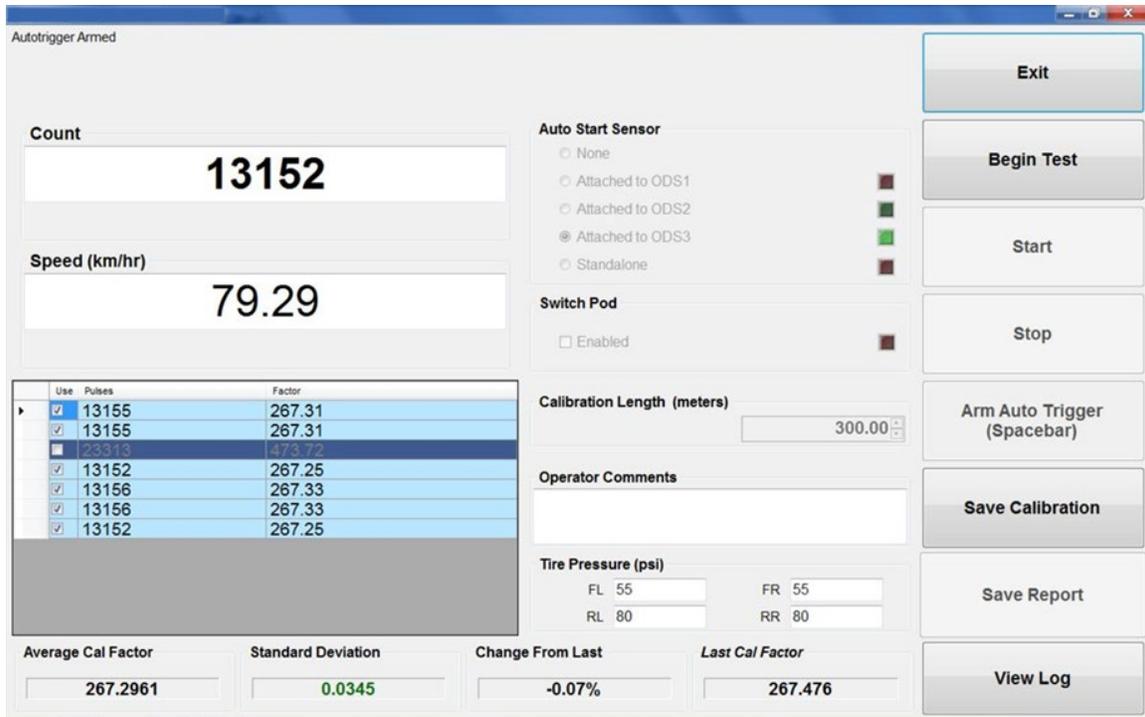
Source: FHWA.

**Figure 110. Screenshot. DMI calibration screen after performing one run.**



Source: FHWA.

**Figure 111. Screenshot. DMI calibration screen after performing six runs.**



Source: FHWA.

**Figure 112. Screenshot. DMI calibration screen showing seven runs with six selected.**

#### 2.12.4 Calibration Check of Accelerometers

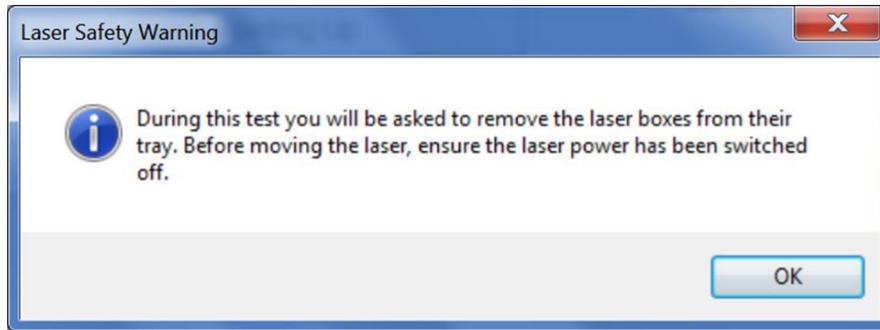
The calibration check of accelerometers checks the scaling of the accelerometers using the acceleration of the earth's gravity by flipping the accelerometers over to measure a change in acceleration of 2 g.

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

The following procedure should be followed to perform the accelerometer calibration check:

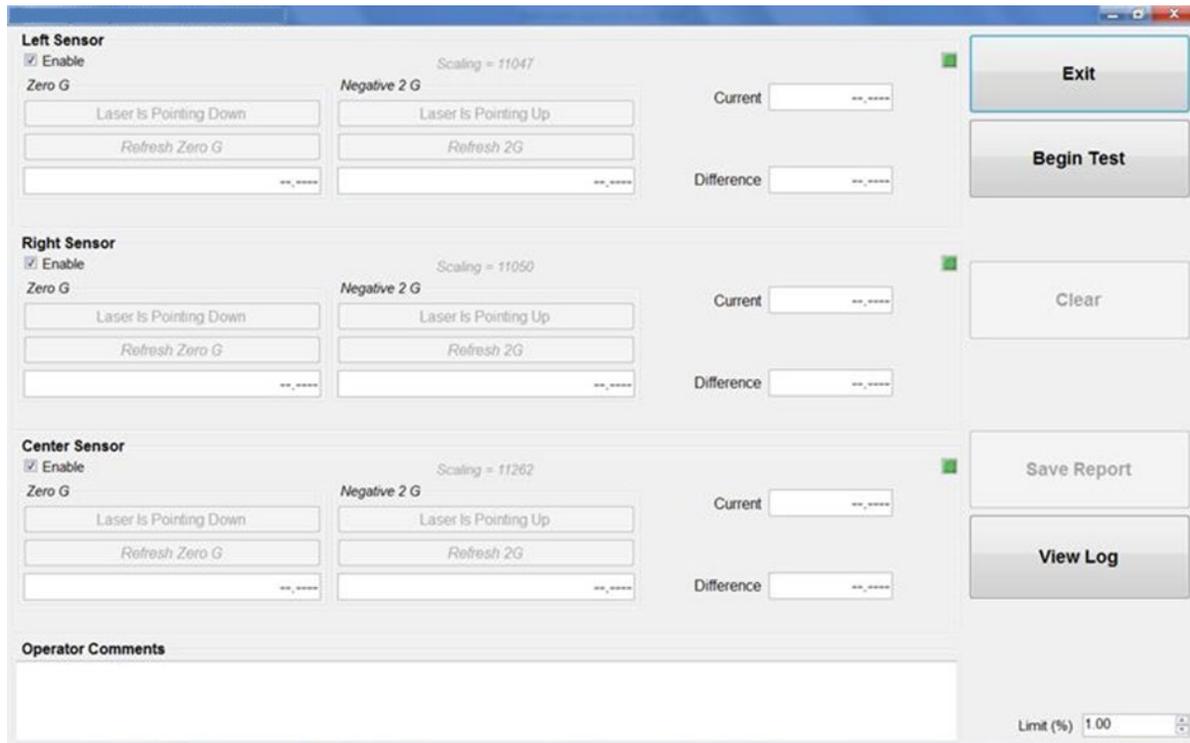
1. Open the cover of the sensor bar. Turn the key to the "Off" position in the DAU to shut off power to the laser sensors and then remove the key (section 2.2.4). The red laser dot should not be displayed on the ground. Unlatch all three laser boxes containing the profile height sensors from the mounting latches.
2. Press the F7 key or select the "Accelerometer Test" icon in the Calibration menu (figure 107). The Laser Safety Warning shown in figure 113 will be displayed.

3. Press “OK” on the Laser Safety Warning and the Accelerometer Test menu shown in figure 114 will be displayed.
4. Press “Begin Test” and the system will start displaying the current measurements in g from the accelerometers, as shown in figure 115.
5. Select “Laser Is Pointing Down” for all three accelerometers and the system will wait 20 s before storing the current value. This value is a moving average of the accelerometer over about a 20-s interval. The screen at this stage is similar to the one shown in figure 116. To refresh the current value, press “Refresh Zero G” and the current value will replace the first value that was stored after 20 s.
6. Rotate all three sensors by 180 degrees so 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 degrees and placed snugly against the DAU so it will be stable. Select “Laser Is Pointing Up” for all three accelerometers (figure 117).
7. Press “Refresh 2G” to refresh the value that was stored after 20 s. After about 20 s, the system will store the current accelerometer reading and display it in the text box (figure 118).
8. Note the difference between the two measurements (i.e., laser pointing upward and downward) for each accelerometer is displayed in the Difference window (figure 118). The value displayed in the Difference window for each accelerometer must be within  $\pm 1$  percent of 2 g (i.e., between 1.98 and 2.02 g) 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 DCC office and decide on a suitable course of action. Select “Save Report” to save the results from the accelerometer test. The results are saved in a comma-separated value (CSV) file. The results from the test are appended to the file so that results from all tests are available in one file. Fill out form PROF-5 (figure 179).
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 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 vehicle when the sensor box has been attached to the bar 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 with the part that detects the laser light. Clean the sensor glass using the procedures in section 2.5.2.



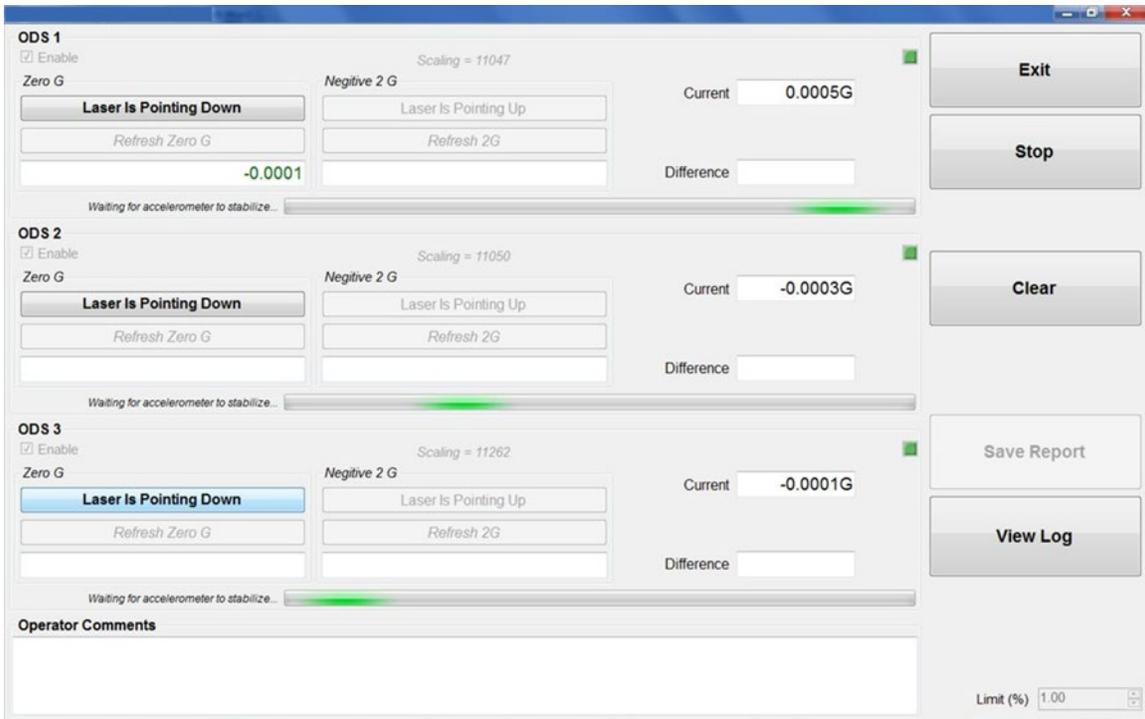
Source: FHWA.

**Figure 113. Screenshot. Laser Safety Warning during the accelerometer calibration check.**



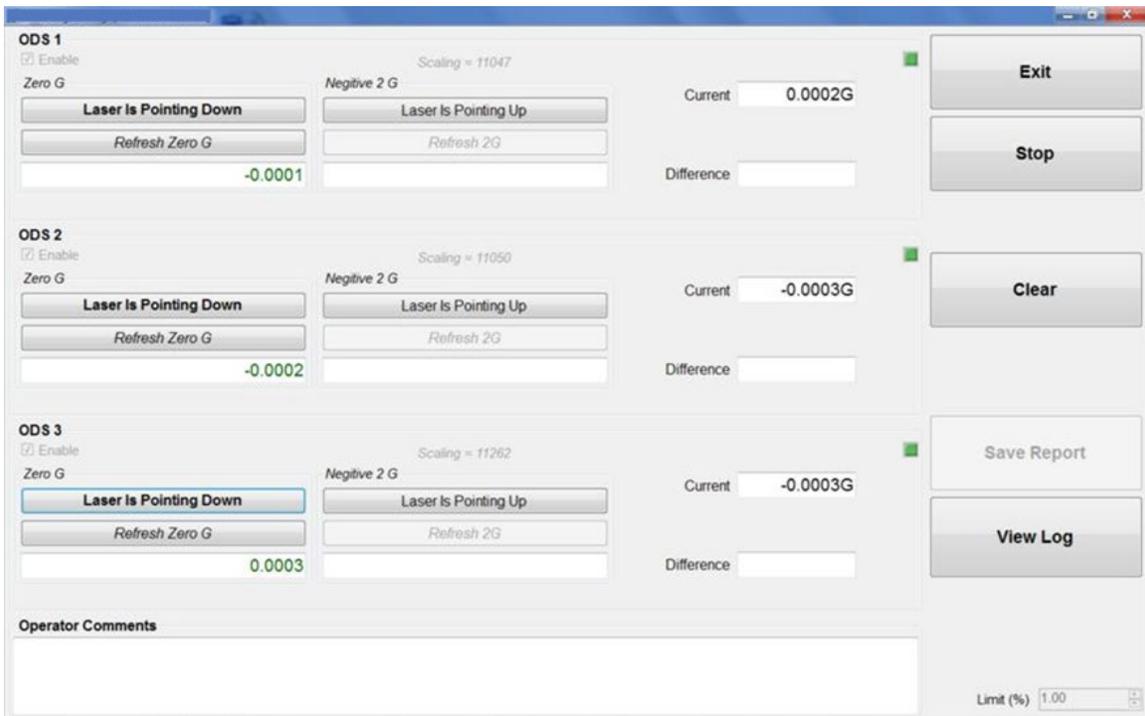
Source: FHWA.

**Figure 114. Screenshot. Accelerometer Test menu.**



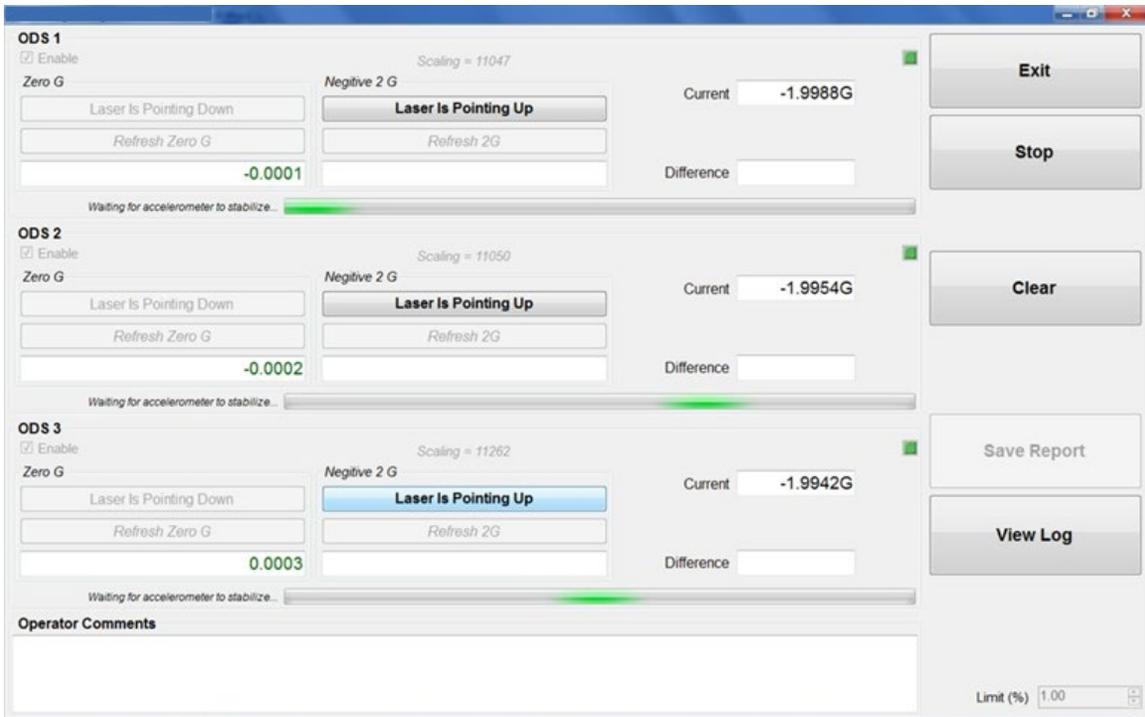
Source: FHWA.

**Figure 115. Screenshot. Screen after starting accelerometer test.**



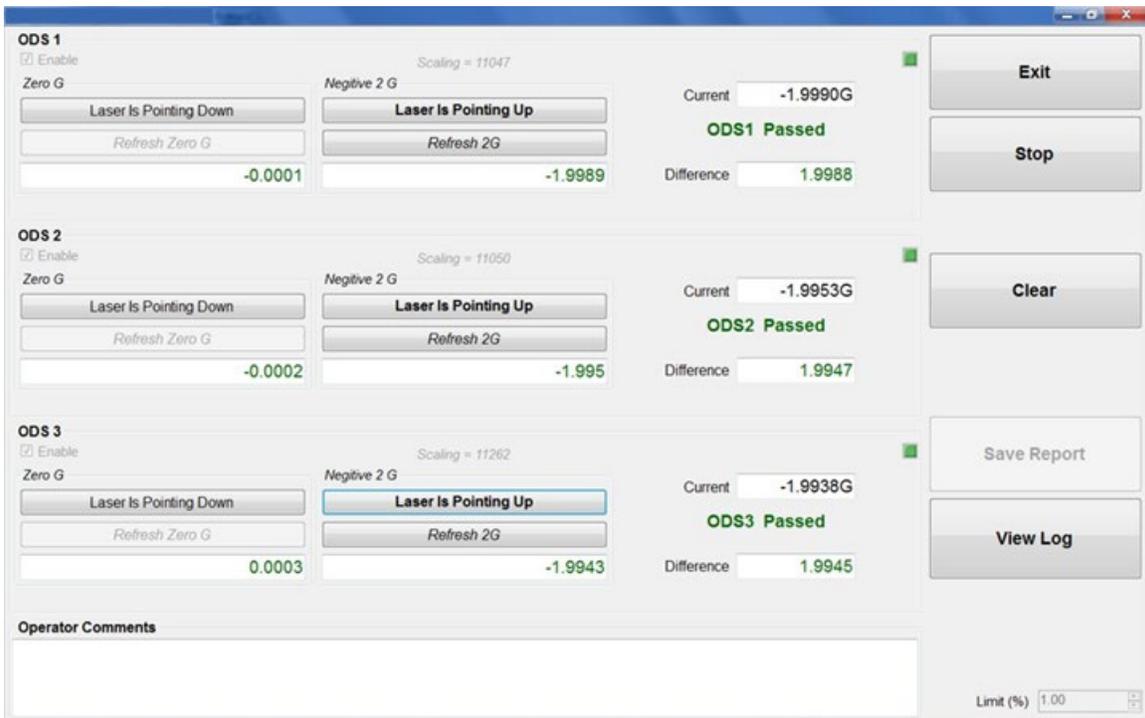
Source: FHWA.

**Figure 116. Screenshot. Screen after completion of test with lasers pointing downward.**



Source: FHWA.

**Figure 117. Screenshot. Screen after lasers are rotated with sensor glass on top.**



Source: FHWA.

**Figure 118. Screenshot. Screen after completion of test with lasers pointing upward.**

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

### ***2.12.5.1 Overview***

The profile and texture height sensors were calibrated in the factory and the operator cannot calibrate them. A calibration check on these sensors is performed before data collection in the field (section 2.9.2.2). During the calibration check, profile and texture height sensors are checked to see if they can accurately measure the height within a specified tolerance 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 d, which will check the accuracy of the profile and texture height sensors over a 100-mm distance. 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 performed before data collection in the field. The full calibration 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 (steps 9 and 10 of section 2.12.4).

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

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

The following supplies are needed to complete the calibration check:

- Vehicle support ramps—the vehicle is elevated when the full calibration check is performed. The vehicle is elevated by driving it onto ramps 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 the ramps vertically. A felt cloth is placed between the ramps to prevent them from bonding together.
- Calibration base plates—three base plates are provided with each HSSV (section 2.2.17 and section 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 HSSV (section 2.2.17 and section 2.5.9.2). Each target has a glossy and a matte side. Measurements by the height sensors should always be obtained on the matte side.
- Calibration blocks—three sets of blocks with nominal heights of 25, 50, 75, and 100 mm are provided with each HSSV (section 2.2.17 and section 2.5.9.3). A block identifier is engraved on the side of each block. The exact heights of the blocks are shown in table 1.

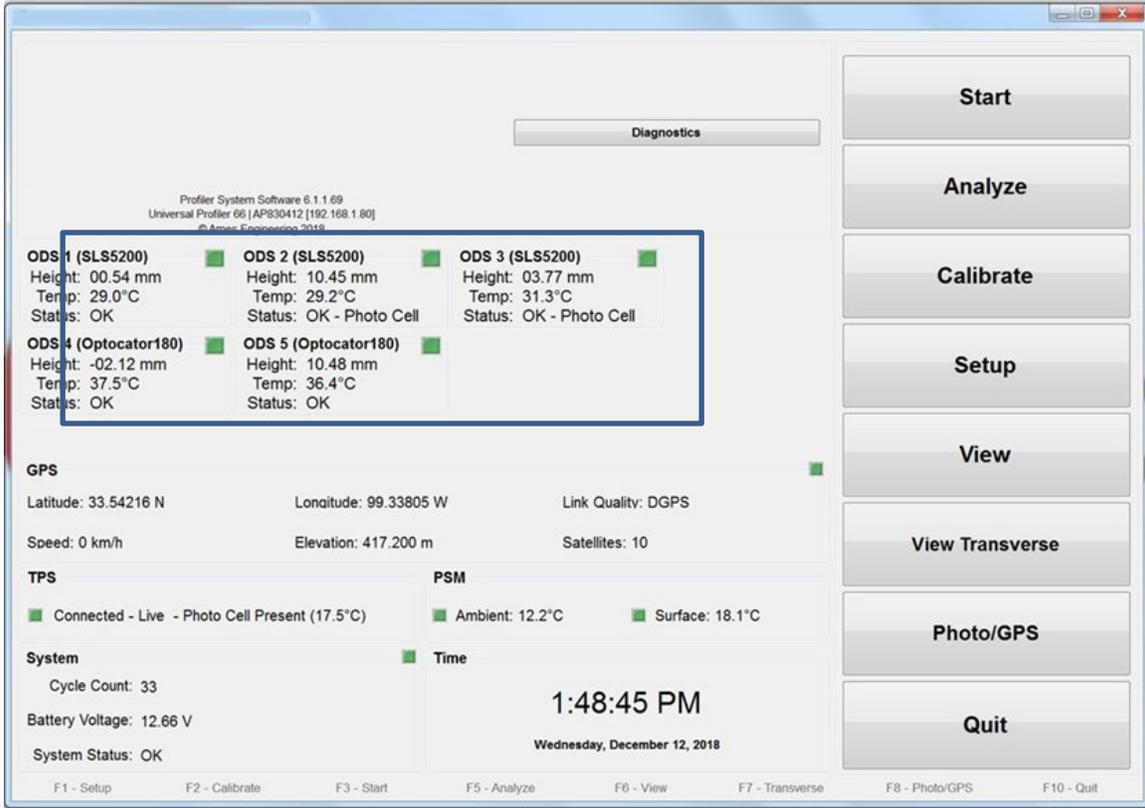
The exact height of each block should be entered into the HSSV software following the procedures described in section 2.5.9.3 before performing the full calibration check. Once entered, the block heights are saved by the software and do not need to be entered every time a check is performed.

### ***2.12.5.3 Setup HSSV***

The full calibration check of the profile and texture height sensors should be performed when the vehicle is parked on a level surface. 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 check. If the full calibration check is performed in the field, the location where the check is performed should protect the HSSV 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 the vehicle away from the sun).

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

1. Ensure the cold tire pressure of all tires is at the value specified in section 2.5.5. The tire pressure can have an effect on the results of this check, so it is important the tire pressure is correct.
2. Observe the Height values indicated below ODS 1, ODS 2, ODS 3, ODS 4, and ODS 5 in the HSSV software startup window before elevating the vehicle onto ramps with the operator outside the vehicle (figure 119). 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 midpoint of the measurement range is located exactly at the ground surface, all height values should indicate 0. However, because of variations in all these factors, the displayed Height values are unlikely to be exactly 0. Record the Height values under ODS 1, ODS 2, ODS 3, ODS 4, and ODS 5 in Form PROF-5 (figure 179). From the HSSV startup screen, record the temperature corresponding to each height sensor in Form PROF-5 (figure 119). 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 and if the sensor is properly latched at the correct position (section 2.5.3).
3. Place a ramp in front of each tire as shown in figure 120 and drive the vehicle onto the ramps such that all four tires rest on the upper part of each ramp. Figure 121 shows the HSSV in the elevated position.



Source: FHWA.

**Figure 119. Screenshot. HSSV software startup screen highlighting sensor status.**



Source: FHWA.

**Figure 120. Photo. Ramps placed in front of the tire before driving vehicle up the ramp.**



Source: FHWA.

**Figure 121. Photo. HSSV on top of ramps.**

#### ***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., an 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 sensor bar following the procedures described in section 2.5.3 and repeat the 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.

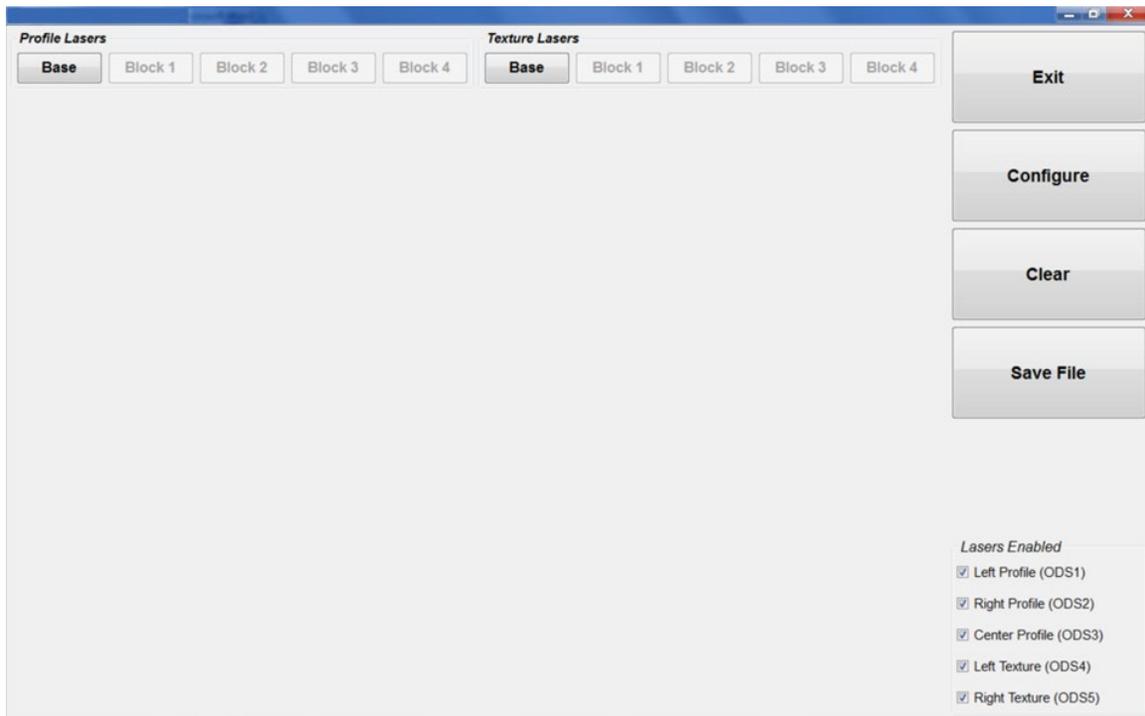
Use the following procedure to perform the full calibration check on the profile height sensors:

1. Press the F4 key or select the “Extensive Test” icon in the Calibration menu (figure 107). The Extensive Test screen shown in figure 122 will be displayed. A checkmark should appear in front of all sensors shown in the bottom right corner of the screen.
2. The operator should be outside the 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 (figure 87). 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 the plate using other screw. The plate is considered level when the reading on the digital level is less than or equal to 0.05 degree at the two positions described in step 5 of section 2.9.2.2.
4. Place a calibration target on top of each base plate within the square marked on the base plate with the matte side of the target facing up, and place the 25-mm block behind the target to provide stability to base plate (figure 88). In the software (figure 122) under “Profile Lasers” select “Base” to take a measurement on top of the target that is placed on each base plate. Six sets of measurements are taken on each target. Figure 123 shows an example of the screen after measurements have been obtained. The readings displayed are in the following order: left profile height sensor, center profile height sensor, and right profile height sensor.
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 the matte side facing up on top of the block (figure 90). Repeat procedure for the other two sensors. In the software, under “Profile Lasers,” select “Block 1” to take measurements on top of target (figure 123). 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 124. 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 the calibration target. Perform step 4. Remove the target and the 25-mm block from the calibration base plate and place the 50-mm block associated with the sensor on top of the base plate such that the 50-mm height is vertical and the block is placed within the square marked on the base plate. Place the calibration target with the matte side facing up on top of the block (figure 125). Repeat this procedure for the other two sensors. In the HSSV software, under Profile Lasers, select “Block 2” to take measurements on top of the target plate (figure 124). 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.
7. Remove the 50-mm block and the calibration target. Perform step 4. Remove the target and the 50-mm block from the calibration base plate and place the 75-mm block associated with the sensor on top of the base plate such that the 75-mm height is vertical and the block is placed within the square marked on the base plate. Place the calibration target plate with the matte side facing up on top of the block (figure 126). Repeat this procedure for the other two sensors. In the HSSV software, under Profile Lasers, select “Block 3” to take measurements on top of the target plate. Six sets of measurements are

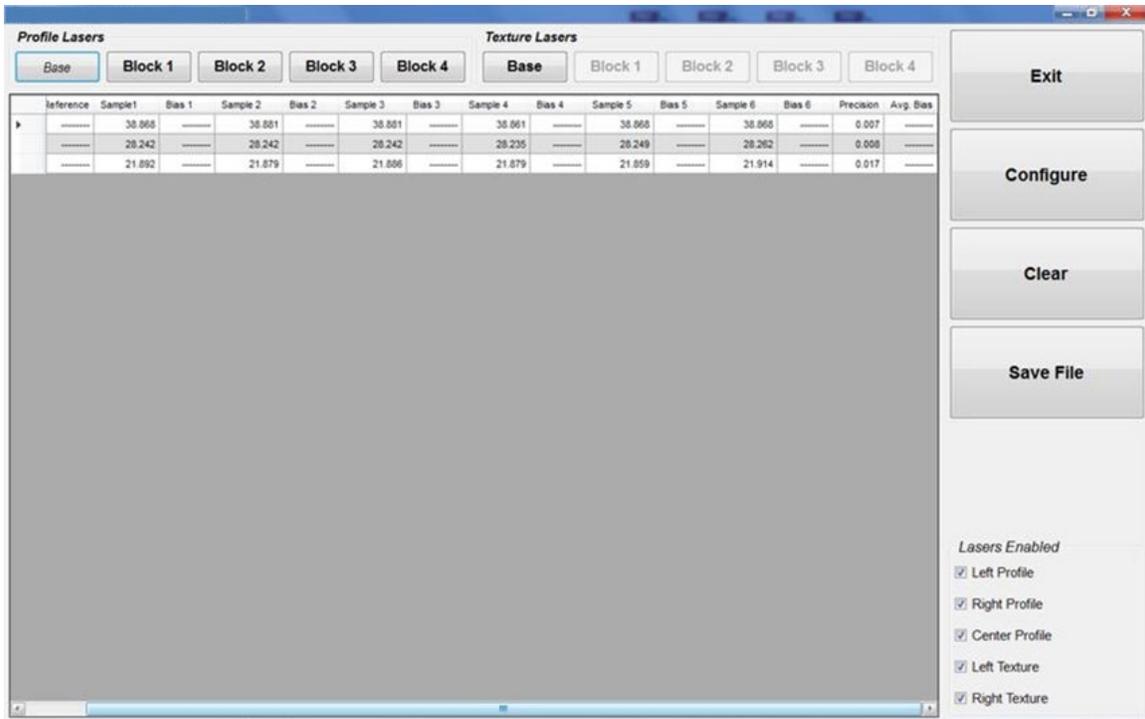
taken on the target plate. The average bias value for each sensor must be within  $\pm 0.25$  mm. If the average bias is outside this value, repeat the test until two consecutive tests meet the specified criterion.

8. Remove the 75-mm block and the calibration target. Perform step 4. Remove the target and the 25-mm block from the calibration base plate and place the 100-mm block associated with the sensor on top of the base plate such that the 100-mm height is vertical and the block is placed within the square marked on the base plate. Place the calibration target with the matte side facing up on top of the block (figure 127). Repeat this procedure for the other two sensors. In the HSSV 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.
9. Figure 128 shows the screen after the calibration check has been performed with all four blocks.



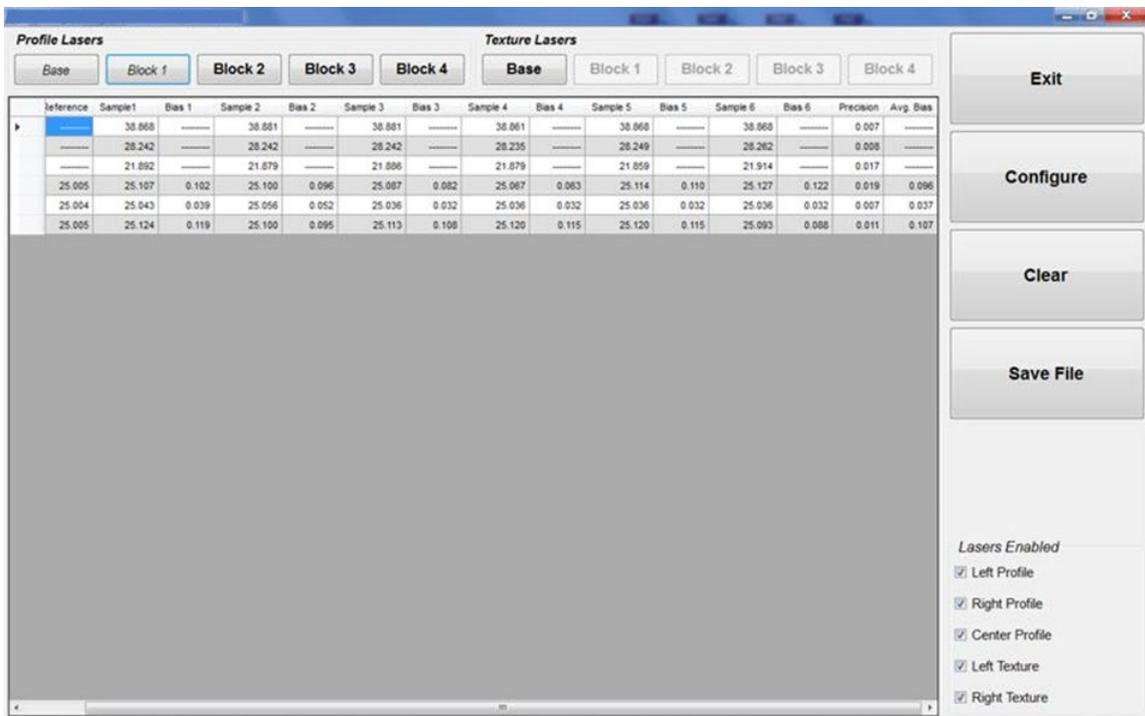
Source: FHWA.

**Figure 122. Screenshot. Extensive Test screen.**



Source: FHWA.

**Figure 123. Screenshot. Screen after obtaining readings on a target placed on the base plate.**



Source: FHWA.

**Figure 124. Screenshot. Screen after obtaining readings on the 25-mm block.**



Source: FHWA.

**Figure 125. Photo. Calibration target on top of a 50-mm block.**



Source: FHWA.

**Figure 126. Photo. Calibration target on top of a 75-mm block.**



Source: FHWA.

**Figure 127. Photo. Calibration target on top of a 100-mm block.**

Profile Lasers													Texture Lasers					
Base	Block 1	Block 2	Block 3	Block 4	Base	Block 1	Block 2	Block 3	Block 4									
Prece	Sample 1	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	24.916	-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	-----				
30.005	49.691	-0.314	49.738	-0.287	49.729	-0.276	49.729	-0.276	49.716	-0.289	49.725	-0.280	0.015	-0.283				
30.005	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				
30.004	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	-----				
30.005	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				
30.005	49.884	-0.121	49.898	-0.107	49.884	-0.121	49.891	-0.114	49.891	-0.114	49.891	-0.114	0.005	-0.115				
30.004	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	-----				
30.002	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				
30.004	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				
30.004	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				

Source: FHWA.

**Figure 128. Screenshot. Results after taking 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., an 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 sensor 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 the matte 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 the base plate (figure 88). In the HSSV software, under Texture Lasers, select “Base” to take a measurement on top of the target plate placed on each base plate (figure 122). 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 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 matte side facing up on top of the block (figure 90). Repeat this procedure for the other sensor. In the HSSV software, under Texture Lasers, select “Block 1” to take measurements on top of the target plate (figure 122). 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. Perform 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 matte side facing up on top of the block. Repeat this procedure for the other sensor. In the HSSV software, under Texture Lasers, select “Block 2” to take measurements on top of the target plate (figure 122). 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. Perform 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 matte side facing up on top of the block. Repeat this procedure for the other sensor. In the HSSV software, under Texture Lasers, select “Block 3” to take measurements on top of the target plate (figure 122). 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. Perform 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 the matte side facing up on top of the block. Repeat this procedure for the other sensor. In the HSSV software, under Texture Lasers, select “Block 4” to take measurements on top of the target plate (figure 122). 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 to save the results from this test. The results from the test on profile and 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 out Form PROF-5 (figure 179).

#### ***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 texture height sensor failed the full calibration check, compare the temperature of the lasers displayed on the HSSV software startup screen with the temperature values recorded when the height sensor last passed the check (figure 119). If there is a significant difference in temperature, it is possible that the temperature-related drift of the sensor is the cause of the sensor not passing the calibration check.

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

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

A dynamic calibration check of the texture height sensors is performed using the texture reference test device. 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, in which the results from the test provide information about the noise in the sensor and whether the sensor is scaled properly. The dynamic test checks the functioning of the sensor in the dynamic mode.

### ***2.12.6.1 Setup Procedure for Texture Reference Disk Test***

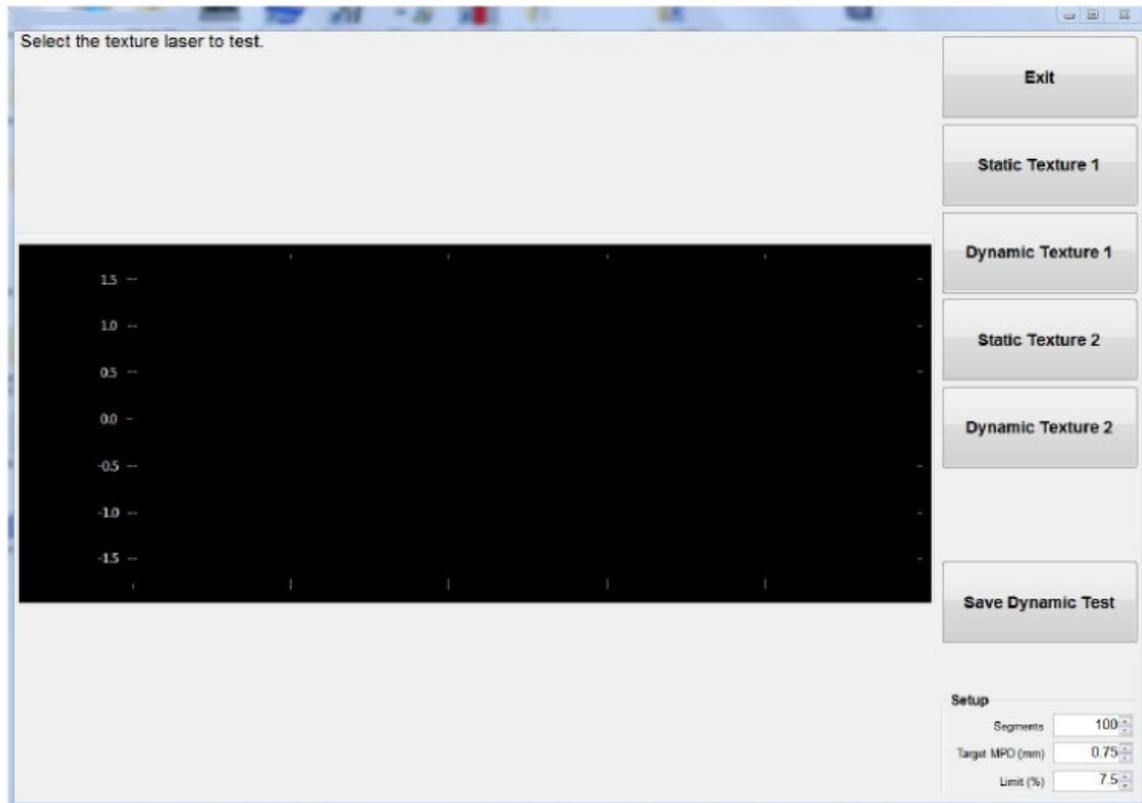
It is recommended the texture reference disk test be performed immediately after performing the full calibration check on the texture height sensors. Use the following procedure to set up this test:

1. Drive the vehicle down from the second step of the ramp to the first step and proceed to step 2 if performing the texture reference disk test after performing the full calibration check of the texture height sensors. Otherwise, place a ramp in front of each tire and drive the vehicle up the ramp to the first step (figure 120). 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. Press the F6 key or select the “Texture Disk Test” icon on the calibration screen (figure 107). This will bring up the Texture Disk Test window shown in figure 129.

The setup parameters for the texture reference disk 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:

- a. Segments—this value indicates the number of 100-mm segments averaged to compute the MPD. This parameter should be set to 100. The test will terminate once sufficient data have been collected.
- b. Target MPD—this is the theoretical MPD value for the reference disk. This parameter should be set to 0.75 mm.
- c. Limit—this value indicates the tolerance placed on the MPD computed from the data collected during the test in order to pass the test. This parameter should be set to 7.5. Therefore, to pass the test, the MPD computed from the data collected during the 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 initially set.



Source: FHWA.

**Figure 129. Screenshot. Texture disk test window.**

### ***2.12.6.2 Procedure for Performing Texture Reference Disk Test***

Use the following procedure to perform the texture reference disk test:

1. Open the sensor bar cover. Disconnect the encoder input from the DAU. Plug in the black connector attached to the reference device to the DMI input port in the DAU (figure 130). Disconnect the vertical photocell input from the center profile height sensor box. Plug in the yellow connector attached to the reference device to the photocell input port (figure 130). Power to the reference test device is provided from this port. The yellow connector can be connected to the photocell input in any laser box. However, because of the length limitation of this cable, it may not be possible to perform the texture reference 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 into the photocell input in the center sensor so 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.
2. Place the reference test device below the left texture height sensor. The reference device has a moveable cover with a target label attached to the top (figure 131). Aligning the laser dot on the target ensures the laser will strike the spinning disc in the proper spot. The static test is performed with the laser dot targeting the crosshairs (with the cover

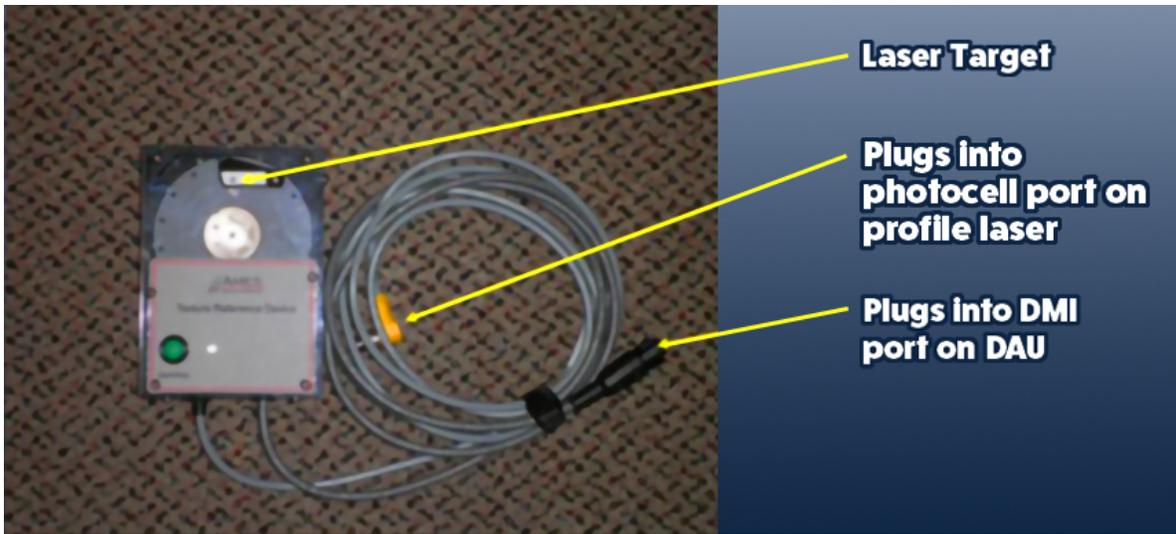
closed), and the dynamic test is performed with the laser dot targeting the spinning disk (with the cover open). With the cover closed, align the laser dot on the crosshairs of the target.

3. Select “Static Texture 1” to initiate the test (figure 129). 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 emitted. After a sufficient amount of data have been obtained, the test will terminate automatically and a single long beep will be emitted 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 waiting for it to spin down and stop automatically. This can be accomplished by pressing the green button after the beep is emitted at the end of the test. If the test was terminated this way, and a retest is desired, press the green button once.

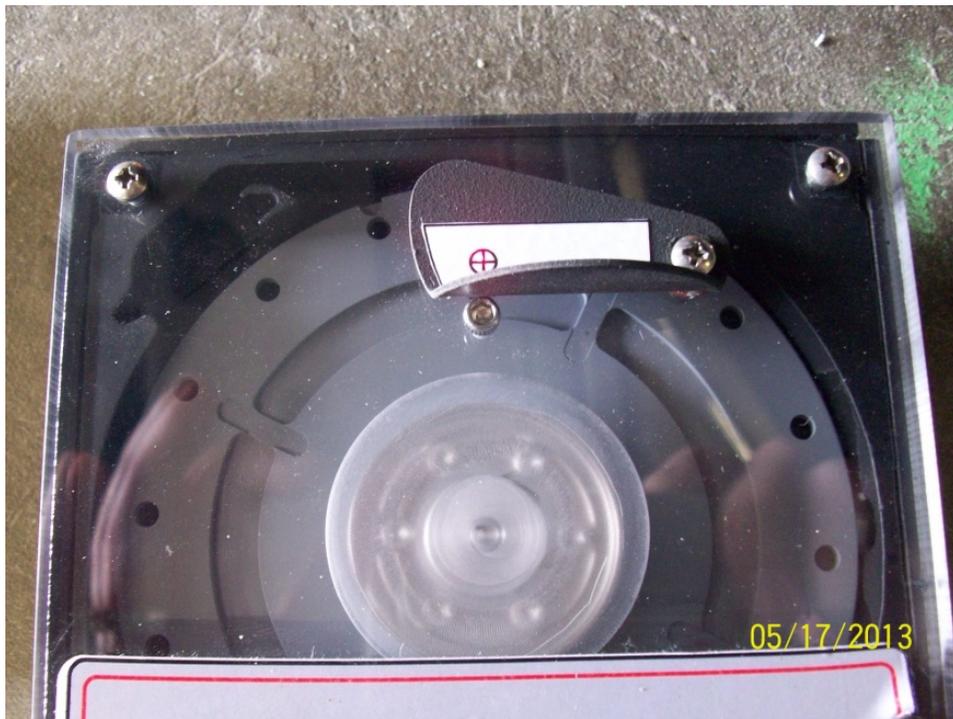
When the static test is complete, the laptop computer screen will display the average MPD for the static test (figure 132). The manufacturer established a threshold MPD of 0.33 mm for the static test. This threshold cannot be changed by the operator. If the MPD from the static test is above 0.33 mm, 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 to pass the static test. If it is not possible to obtain two consecutive tests with a value less than 0.33 mm after repeating the test several times, contact the DCC office and decide on a suitable course of action.

4. Select “Dynamic Texture 1” after the static test has been performed and if the MPD from static test is below 0.33 mm (figure 132). Align the laser on the crosshairs 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 and press the green button on the reference device to spin the disk (figure 133). After the disk is up to speed, the test will automatically start and three beeps will be emitted at the start of the test. After a sufficient amount of data have been obtained, the test will terminate automatically, and three beeps will be emitted indicating 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 (figure 134). 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 the test several times, contact the DCC office and decide on a suitable course of action.
5. 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 “Save Dynamic Test” (figure 135). This will save the file that contains the results from this test. Complete Form PROF-5 (figure 179).



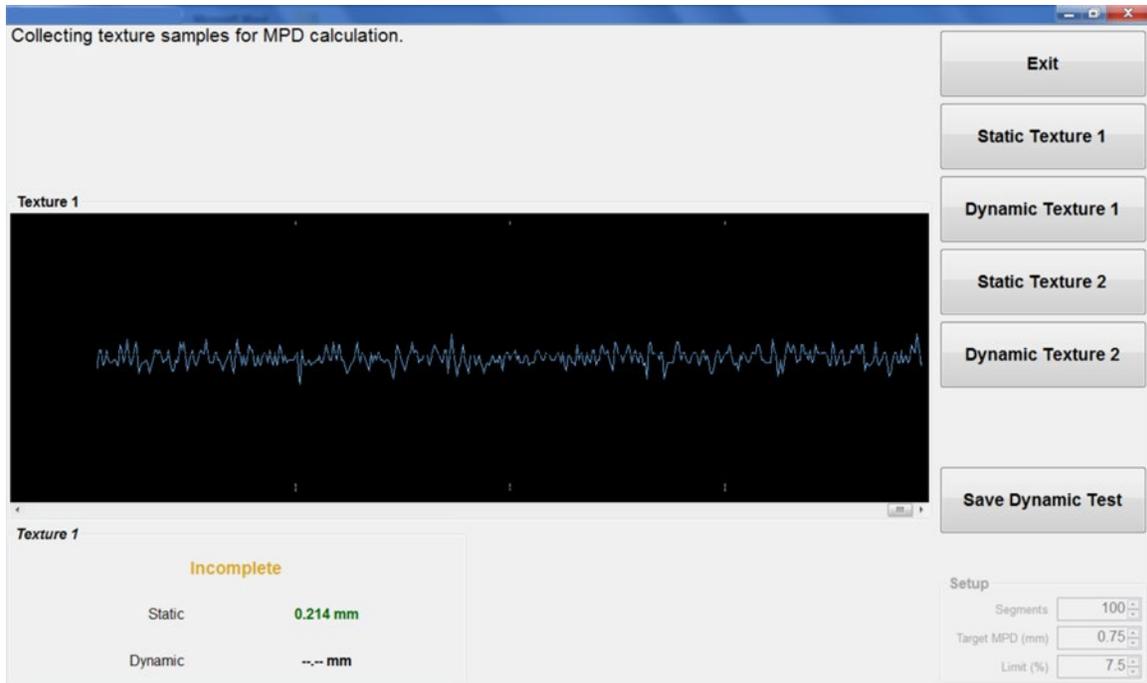
Source: FHWA.

**Figure 130. Photo. Texture reference test device.**



Source: FHWA.

**Figure 131. Photo. Target on texture reference test device.**



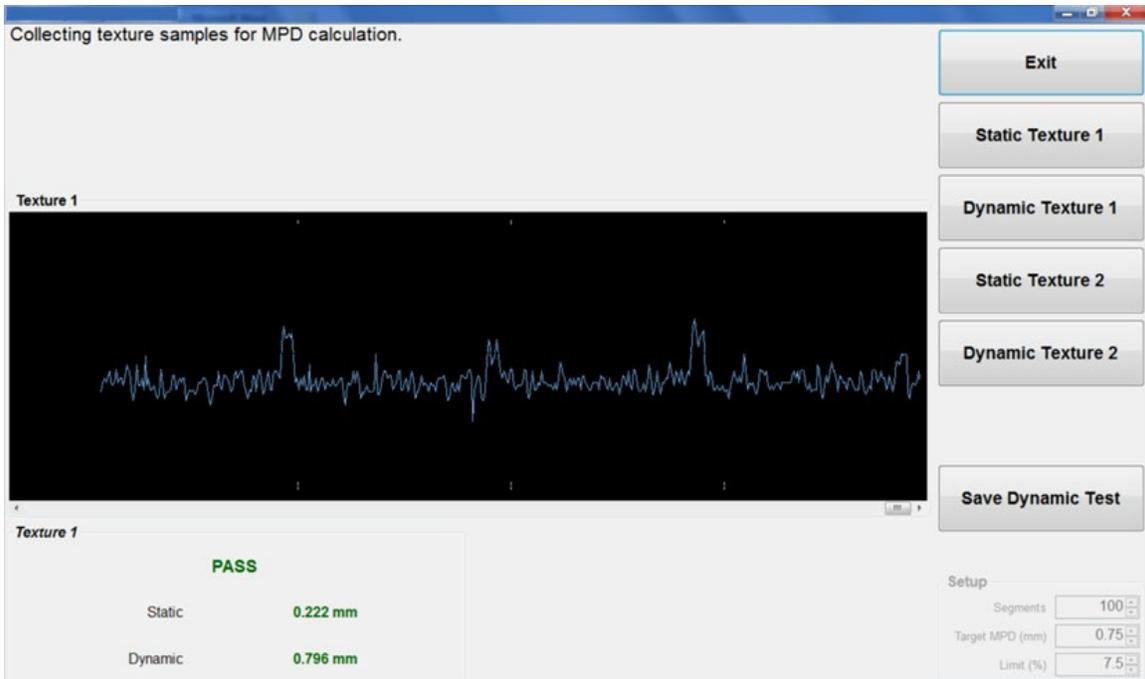
Source: FHWA.

**Figure 132. Screenshot. Texture reference test screen after static test.**



Source: FHWA.

**Figure 133. Photo. Cover open on texture reference test device.**



Source: FHWA.

**Figure 134. Screenshot. Texture reference test screen after dynamic test on left sensor.**



Source: FHWA.

**Figure 135. Screenshot. Results from a completed texture calibration check.**

### **2.12.7 Bounce Test and Ground-Level Calibration Check of Height Sensors**

After completing the full calibration check on the profile and texture height sensors, drive the vehicle off the ramps onto the ground. Perform a bounce test following the procedures indicated in section 2.9.2.4. Thereafter, perform a calibration check of the profile and texture height sensors using procedures described in section 2.9.2.2 and section 2.9.2.3, respectively. Record the results from the bounce test and the calibration check of the profile and texture height sensors in Form PROF-5 (figure 179).

### **2.12.8 Calibration Check of Ambient Temperature Sensor**

A National Institute of Standards and Technology (NIST) traceable mercury thermometer is required to perform the calibration check of the ambient temperature sensor, which should be performed in the shade using the following procedure:

1. Park the HSSV in the shade and allow some time for the vehicle to cool off if it was exposed to the sun.
2. Power up the system, start the laptop computer, and launch the HSSV software using the procedures described in section 2.8.1. Wait 15 min for the equipment to warm up.
3. The ambient temperature sensor has two temperature probes, and the temperatures measured by both probes are displayed on the display unit located on the dashboard on the driver's side (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 displayed on the display box.
6. The following two conditions must be satisfied for the ambient temperature sensor to pass the calibration check:
  - a. The difference between the two temperature readings from the two temperature probes shown on the display must be within  $\pm 2^{\circ}\text{C}$ .
  - b. The difference between each temperature probe reading 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 acceptable if the criteria indicated in step 6 are met. If one or both criteria is still not satisfied, contact the DCC office and decide on a suitable course of action.
8. Complete Form PROF-6, Ambient Temperature Sensor, Pavement Surface Temperature Sensor, GPS Receiver Calibration Check and Transverse Profile System Check Form (figure 180).

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

An NIST traceable mercury thermometer is required to perform the calibration check of the pavement surface temperature sensor, using the following procedure:

1. Power up the system, start the laptop computer, and launch the HSSV software using the procedures described in section 2.8.1. Open cover of the temperature probe (section 2.2.9). Wait 15 min for the equipment to warm up.
2. Observe the pavement surface temperature shown on the display unit located on the dashboard on the driver's side and wait for the reading to stabilize if it is changing (section 2.2.12).
3. Record the pavement-surface temperature measured by the temperature sensor shown on the display unit. Use an infrared temperature gun to record the temperature of the pavement surface at the location 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 vehicle 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°C.
5. Place the container containing the ice and water mix under the temperature sensor and allow the temperature measured by the temperature sensor displayed on the display unit to stabilize. Record the temperature shown on the display unit and the temperature of the ice and water mix measured using the thermometer.

The pavement surface temperature sensor is considered acceptable if the difference between the two temperature readings noted in step 3 and step 5 are within  $\pm 2^{\circ}\text{C}$ .

6. Repeat the appropriate test if the difference between the two temperatures is outside the  $\pm 2^{\circ}\text{C}$  tolerance for step 3, step 5, or both. If the difference between the two temperatures is still outside the specified tolerance, consider the pavement surface temperature sensor unacceptable, and contact the DCC office and decide on a suitable course of action.
7. Complete Form PROF-6 (figure 180).

### **2.12.10 Calibration Check of GPSR**

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

1. Use Google® Earth™ or an accurate handheld GPSR to obtain the latitude and longitude of a known location where the HSSV 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 HSSV will be located when parked.

2. Park the HSSV at the location that was identified. Power up the system, start the laptop computer, and launch the HSSV software using the procedures described in section 2.8.1.
3. The latitude and longitude measured by the GPSR in the HSSV is displayed on the startup screen of HSSV software (figure 119). Look at the Link Quality displayed on the screen to see if it is DGPS. If not, another location where the Link Quality is DGPS is needed to perform the calibration check of the GPSR.
4. Record the latitude and longitude values displayed on the startup screen. If the recorded values agree up to four decimal places with the latitude and longitude that was obtained from Google Earth or an accurate handheld GPSR, the GPSR on the HSSV is considered to be functioning properly. If agreement is not obtained to four decimal places, choose another location and repeat the procedure. After repeating the procedure, if agreement is still not obtained, consider the GPSR not functioning properly, and contact the DCC office and decide on a suitable course of action.
5. Complete Form PROF-6 (figure 180).

#### **2.12.11 Operational Check on TPMS**

With the HSSV parked on a level surface, measure the distance from the ground to the glass face of the camera and laser on the TPMS box. This distance must be within  $2,134 \pm 25$  mm. If the measured distance is outside the specified value, adjust the TPMS box vertically so the measured distance is within the specified limits. Inspect the sensor glass of the camera and the laser and, if required, clean the glass using the procedures described in section 2.5.2. A cloth filter is present within the fan in the TPMS box to prevent contaminants from entering the TPMS box. Remove the appropriate screws and inspect the cloth filter; if dirty, replace the filter. Complete the section related to the TPMS on Form PROF-6 (figure 180).

#### **2.12.12 Dynamic Check on TPMS**

The calibration check on the TPMS checks if the TPMS is collecting accurate data. The calibration check of the TPMS must be performed at a minimum interval of 30 d in conjunction with other calibrations/calibration checks on the components in the HSSV or when questionable transverse profile data have been identified during data processing or review.

##### ***2.12.12.1 Calibration Plate for Checking the TPMS***

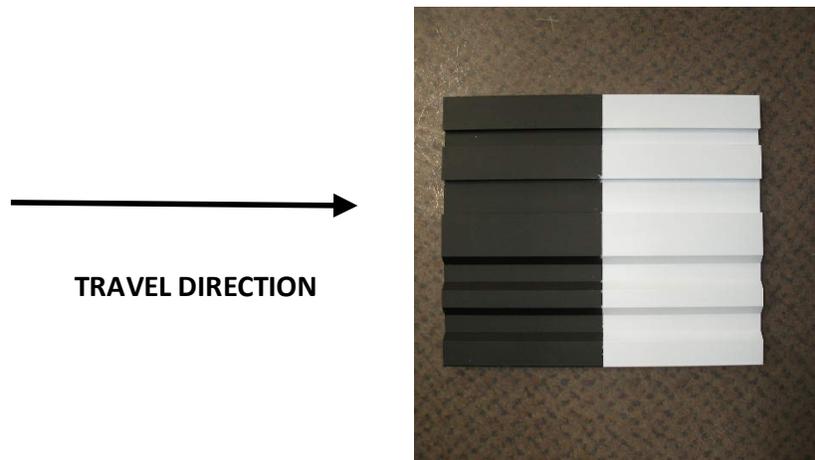
The manufacturer provided a calibration plate to check the accuracy of the TPMS. Figure 52 and figure 53, respectively, show a side and plan view of the calibration plate. The dimensions of the TPMS calibration plate are shown in figure 54 and figure 55, where figure 54 shows a plan view and figure 55 shows a side view. The two grooves with beveled edges have the same dimensions.

##### ***2.12.12.2 Data Collection***

Data collection for the TPMS calibration check involves placing the TPMS calibration plate on the ground, driving the HSSV over the plate while collecting data with the TPMS, and analyzing

the collected data with the HSSV software. Use the following procedure to collect data for the calibration check of the TPMS:

1. Select a suitable location for collecting data. As the calibration plate is placed on the ground, the location selected for performing this test must be free of other traffic. The selected location must allow for the HSSV to travel at a speed between 16 and 48 km/h when collecting data over the calibration plate. Find a safe and suitable location (e.g., a driveway, large parking lot, or shoulder of a low-volume frontage road) to perform this test.
2. Place the calibration plate on the ground at a suitable location such that data will be collected on the black surface first and orient the plate so the grooves within the plate are parallel to the direction of travel (figure 136). The calibration plate must be located at the center of the wheel paths along which the HSSV will be driven.
3. Place reflective tape on the ground to initiate data collection about 1 m before the black edge of the plate if initiating data collection with the vertical photocell. Place the cone with reflective tape about 1 m before the black edge of the plate if initiating data collection with the cone.
4. Power up the laptop computer and load the HSSV software. Set the Stop Distance to 5 m. Select an appropriate file name to store the data. It is recommended to use an appropriate file name so the HSSV and date of data collection can be identified in the future. For example, use a file name such as XXXTPMSMMDDYY, where XXX is the last three digits of the equipment identification number and MMDDYY corresponds to the date of data collection. Except for the modified Stop Distance, all other fields in the Header can be populated similarly to the values used during regular data collection.
5. Collect data on the calibration plate, ensuring that the HSSV will be travelling at a constant speed between 16 and 48 km/h when collecting data on the plate. It is preferable that data be collected at a speed of at least 32 km/h. Make sure at least 30 m of pre-run and 30 m of post-run data are collected. Performing only one run is acceptable if the operator believes error-free data were collected.
6. Remove the calibration plate from the ground and store in a suitable place inside the HSSV.



Source: FHWA.

**Figure 136. Photo. Placement of the calibration plate on the ground for data collection.**

### ***2.12.12.3 Analyzing the Collected Data***

Use the following procedure to analyze the collected data:

1. Load the HSSV software then click on View Transverse (figure 119).
2. Navigate to the location where the ARD file containing the data is located, highlight the file, and click Open. This will load the ARD file to the software, and a view similar to figure 137 will be shown on the screen.
3. Click on the Image Adjustment tab (i.e., third tab from the top) at the right edge of the screen and the Intensity Control window will appear (figure 138). Click on Analyze Current View and the image will be shown at an appropriate intensity suitable for analysis.
4. Perform the following functions:
  - a. Click on Distance and select Distance from Start in the top menu.
  - b. Click on Image and select Range in the top menu.
  - c. Enter a value of 0.05 m for Selection Averaging Distance in the top menu.
  - d. Click the down arrow next to Optimize for Rut Measurement and select None on top of the bottom graph.

The locations of these menus are highlighted in red in figure 139.

5. In the image shown in the middle of the screen, the green vertical line shows where the photocell was initiated and the dark red line shows where the data collection was terminated. When clicking any location in the image in the middle, two light blue vertical lines appear, and the image shown at the top is the zoomed image of the area bounded by the blue vertical lines. Click on the image in the middle so that the green vertical line is

approximately at the middle of the two blue lines. This will cause the calibration plate to appear on the top image approximately 1 m in front of the green vertical line (figure 140).

6. Below the top image, square pixels value appears as 1. Click on the + icon to increase the square pixels to zoom into the view of the calibration plate (figure 141). The calibration plate shown is 200 mm long.

Then, click on the calibration plate in the top menu so the magenta-colored vertical line is close to the left edge, but the entire shaded area is within the plate. The shaded magenta-colored portion around the vertical line shows the distance over which the data are averaged, which was set to a value of 0.05 m in step 4c. The vertical line is at the center of the shaded area. The entire shaded area must be on the calibration plate, so the averaged data are all obtained on the plate. If a part of the averaged data is not on the plate, this data is obtained on the ground surface, and therefore will provide erroneous data for analysis. The aim in this step is to place the vertical line such that the entire shaded area is within the black portion of the plate. The plate is 200 mm long with the white and black area having an equal length of 100 mm. The data collected over the black area of the plate will now be shown in the bottom window (figure 141).

7. To zoom in on the portion of the calibration plate in the bottom graph, use the mouse to draw a rectangle around the area of interest and let go, and a zoomed-in view of the calibration plate similar to what is shown in figure 142 will appear on the screen.

Alternatively, the size of the bottom window can be increased by placing the cursor of the mouse on top of the three dots at the bottom of the middle image and dragging the image up (figure 143).

With the calibration plate placed on the ground, as shown in figure 136, and with data being collected in the direction shown in figure 136, the four grooves that will be displayed in the graph starting from the left side are as follows:

- First groove from the left—this rectangular groove is 12.7 mm wide and 6.35 mm deep.
- Second groove from the left—this rectangular groove is 25.4 mm wide and 6.35 mm deep.
- Third groove from the left—this groove has beveled edges with a 45-degree angle at each side. The width of the groove at the bottom is 12.7 mm, while the depth of the groove is 6.35 mm.
- Fourth groove from the left—this groove has beveled edges with a 45-degree angle at each side. The width of the groove at the bottom is 12.7 mm, while the depth of the groove is 6.35 mm.

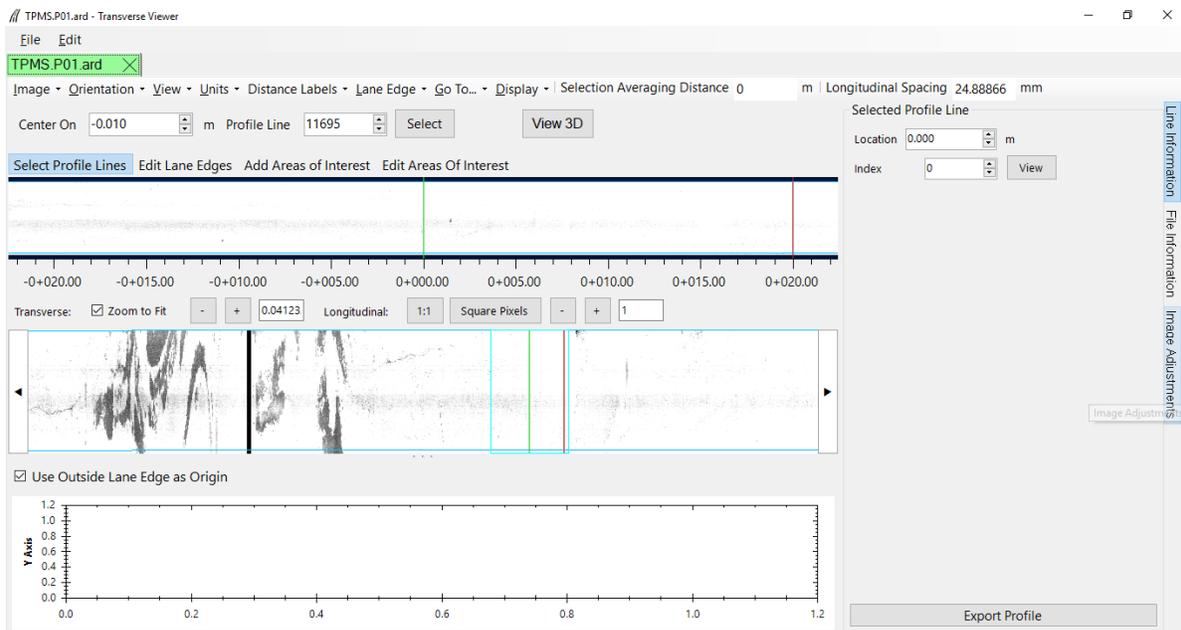
For explaining the analysis procedure, the four valleys in the calibration plate are labeled as P, Q, R, and S, as shown in figure 144. The ridges to the left of each valley are labeled as A, B, C, and D, respectively, as shown in figure 144. This naming convention will be used to explain the data analysis procedure in the following steps.

8. Locate a point on the first ridge from the left (i.e., location A) that represents the average elevation of the ridge and place the mouse so the center of the crosshairs is located at this point (figure 145).
9. Press the M key on the keyboard and this point will be locked in as the reference location, and an image similar to figure 146 will appear on the screen.

The values  $\Delta x$  and  $\Delta y$ , which are changes in the X and Y direction with respect to the reference location, will show 0. When the cursor is moved,  $\Delta x$  and  $\Delta y$  will change with respect to the locked point (i.e., reference location).

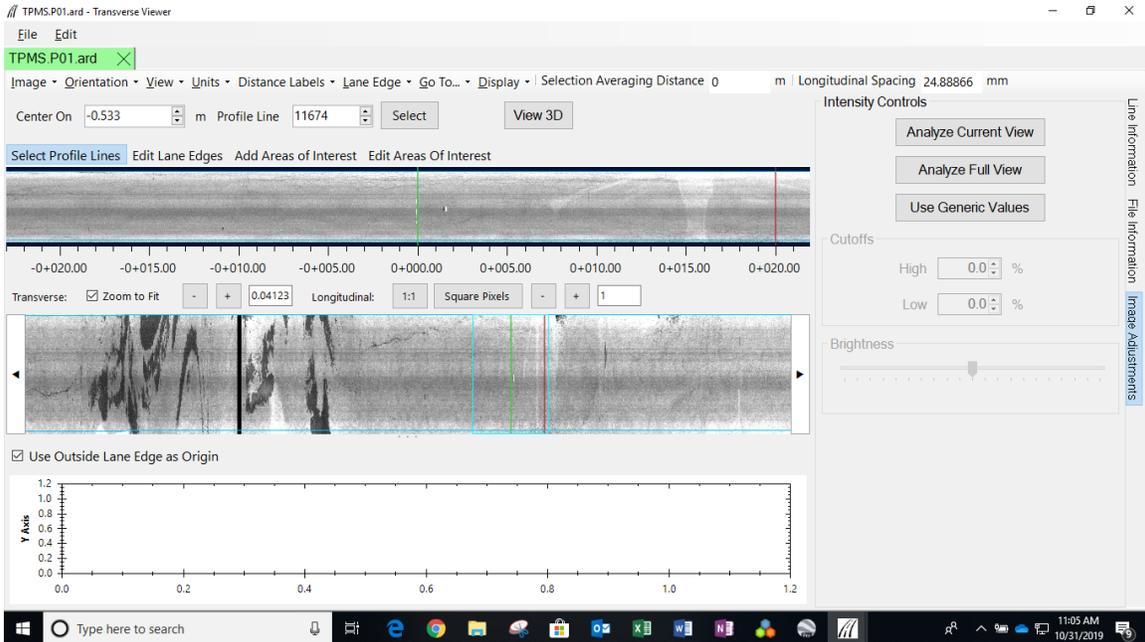
10. Select an appropriate location on the bottom of the first valley (i.e., location P) to represent an average value for the valley, place the center of the crosshairs at that location, and record the value of  $\Delta y$  (figure 147). This value is referred to as  $\Delta ypb$ , where  $p$  represents the location and  $b$  represents the black surface.
11. Move the cursor to second ridge (i.e., area B), select a location that represents the average height of the ridge for area B, place the center of the crosshairs over that location, and press the M key on the keyboard. The screen will show a view similar to that in figure 148. The values  $\Delta x$  and  $\Delta y$  will show 0. Move the cursor to the valley to the right (i.e., the area represented by Q) and select a location to represent the average value for the valley, place the center of the crosshairs at that location, and record the value shown for  $\Delta y$  (figure 149). This value is referred to as  $\Delta yqb$ , where  $q$  represents the location and  $b$  represents the black surface.
12. Repeat the procedure for the third ridge from the left and third valley from the left and record the values of  $\Delta y$ . This value is referred to as  $\Delta yrb$ , where  $r$  represents the location and  $b$  represents the black surface.
13. Repeat the procedure for the fourth ridge from the left and fourth valley from the left and record the values of  $\Delta y$ . This value is referred to as  $\Delta ysb$ , where  $s$  represents the location and  $b$  represents the black surface.
14. Perform step 6, then click on the calibration plate in the top menu so the magenta-colored vertical line is close to the right edge, but the entire shaded area is within the plate. The shaded magenta-colored portion around the vertical line shows the distance over which the data are averaged, which was set to a value of 0.05 m in step 4c. The vertical line is at the center of the shaded area. The entire shaded area must be on the calibration plate, so the averaged data are all obtained on the plate. If a part of the averaged data is not on the plate, this data is obtained on the ground surface, and therefore will provide erroneous data for analysis. The aim in this step is to place the vertical line such that the entire shaded area is within the white portion of the plate. The plate is 200 mm long with the white and black area having an equal length of 100 mm. The data collected on the white area of the plate will now be shown in the bottom window.
15. Perform steps 7 to 13. As the measurements are obtained on the white surface, the obtained  $\Delta y$  values will be  $\Delta ypw$ ,  $\Delta yqw$ ,  $\Delta yrw$ , and  $\Delta ysw$ , where the last subscript of  $\Delta y$  indicates  $w$  for the white surface.

16. Evaluate the eight recorded  $\Delta y$  values (i.e.,  $\Delta y_{pb}$ ,  $\Delta y_{qb}$ ,  $\Delta y_{rb}$ , and  $\Delta y_{sb}$  for values on the black surface and  $\Delta y_{pw}$ ,  $\Delta y_{qw}$ ,  $\Delta y_{rw}$ , and  $\Delta y_{sw}$  for values on the white surface) to see if the absolute value of all eight  $\Delta y$  values are within 4.2 and 8.5 mm. The depth of a groove is 6.35 mm, and the acceptable range was determined based on  $6.35 \pm 2.15$  mm.
17. If all eight  $\Delta y$  values satisfy the required criterion from step 16, the TPMS has passed the calibration check on both the black and white surfaces. If one or more  $\Delta y$  values did not meet the criterion, repeat the test. If, after repeating the test three times, the criterion cannot be met, call the DCC office and discuss a suitable course of action.
18. Record the eight  $\Delta y$  values (i.e.,  $\Delta y_{pb}$ ,  $\Delta y_{qb}$ ,  $\Delta y_{rb}$ , and  $\Delta y_{sb}$  for values on the black surface and  $\Delta y_{pw}$ ,  $\Delta y_{qw}$ ,  $\Delta y_{rw}$ , and  $\Delta y_{sw}$  for values on the white surface) on Form PROF-6 (figure 180).



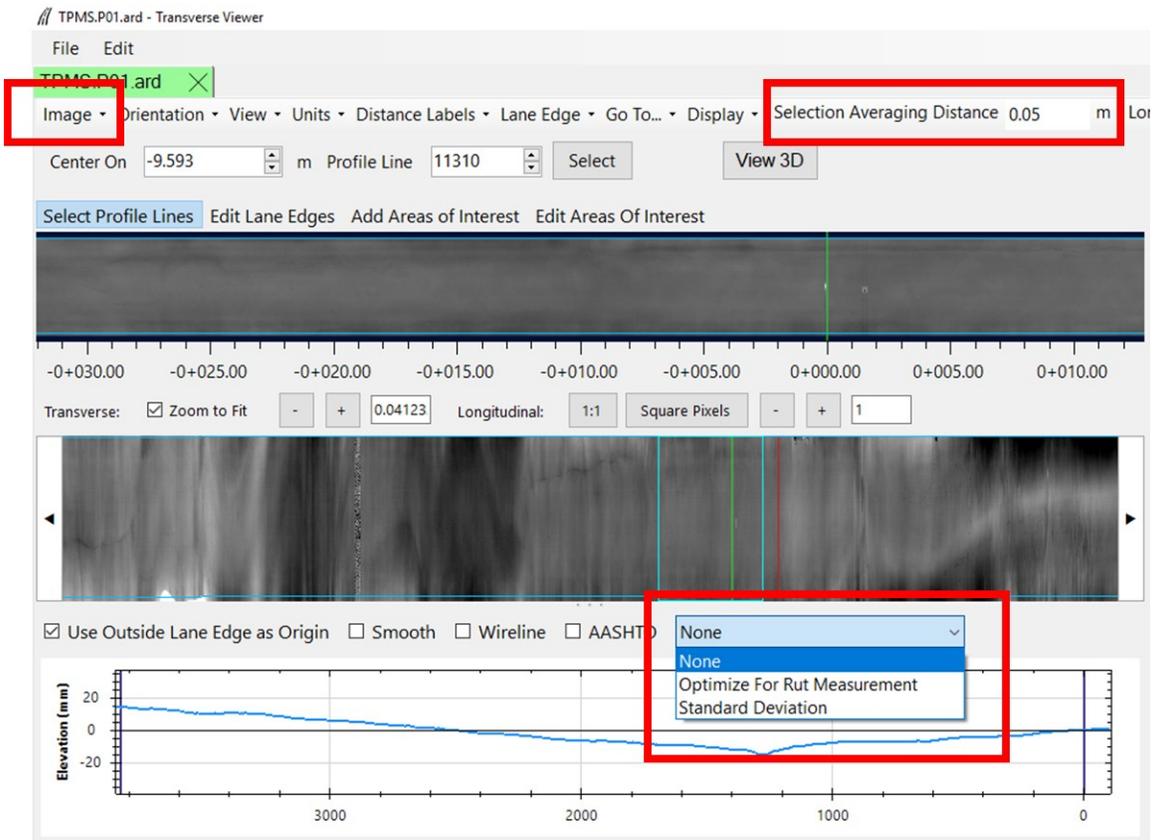
Source: FHWA.

**Figure 137. Screenshot. An ARD file with transverse profile data loaded to the HSSV software.**



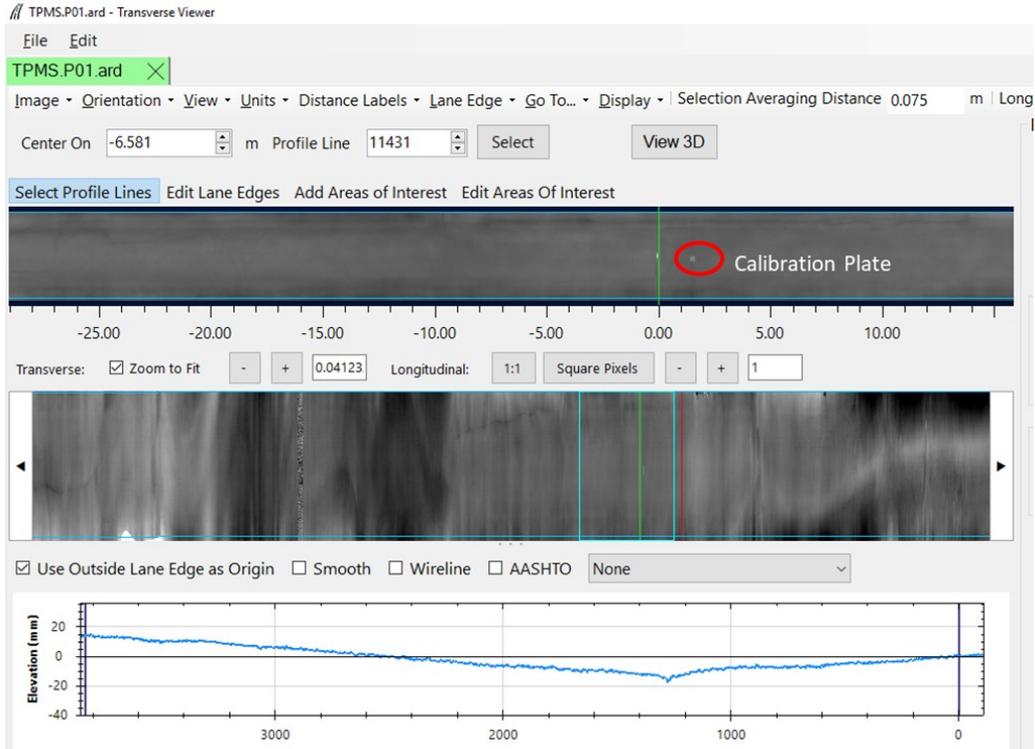
Source: FHWA.

**Figure 138. Screenshot. Intensity controls.**



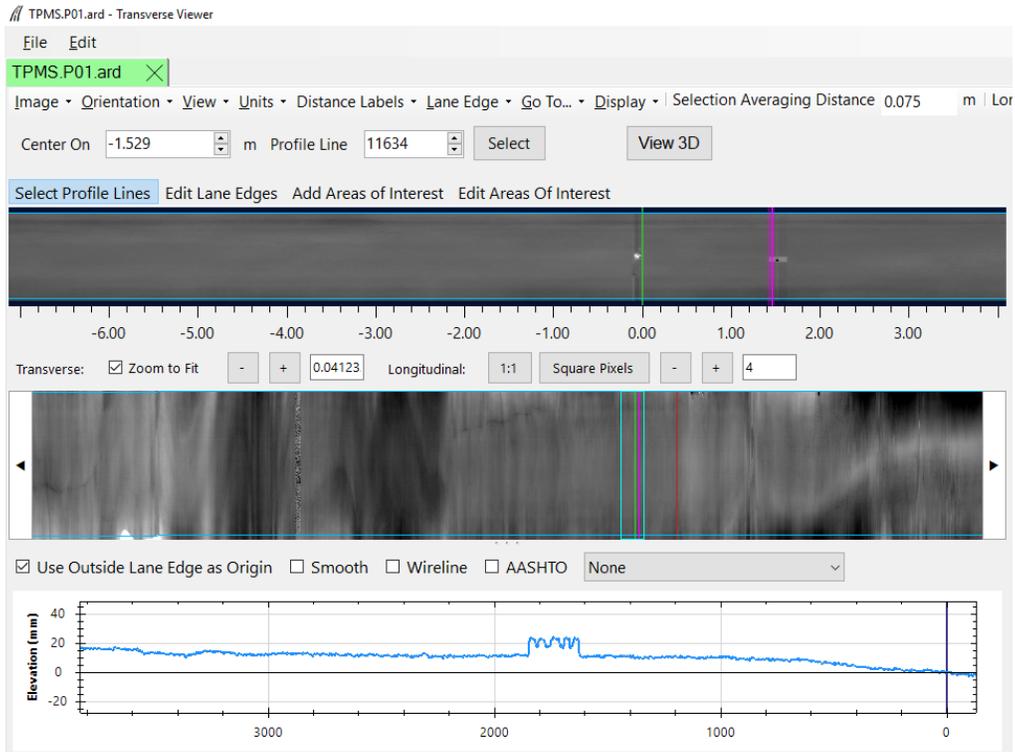
Source: FHWA.

**Figure 139. Screenshot. Location of menus requiring adjustments.**



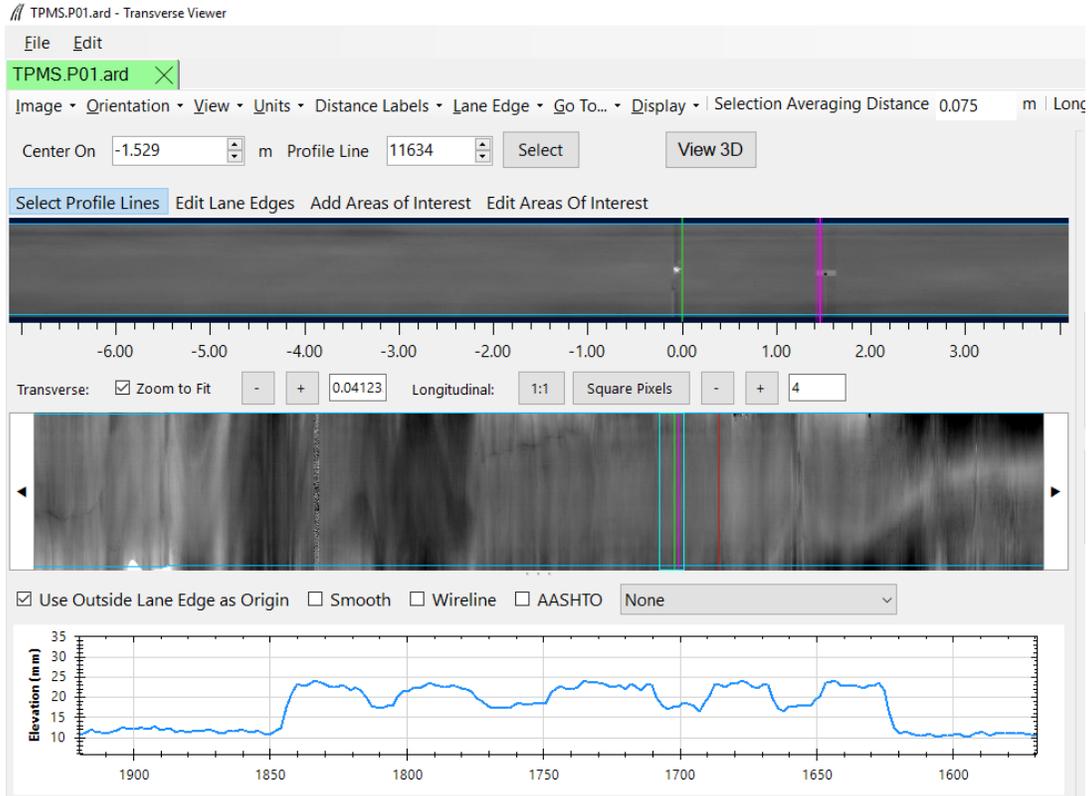
Source: FHWA.

**Figure 140. Screenshot. Calibration plate shown in the range view.**



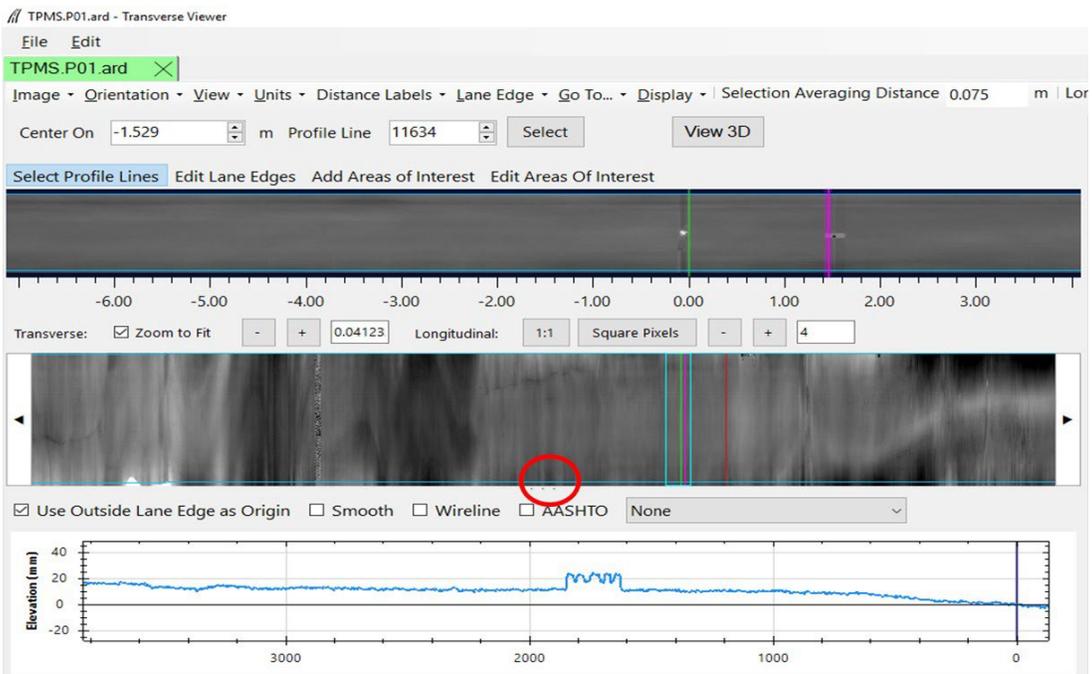
Source: FHWA.

**Figure 141. Screenshot. Elevations obtained on the calibration plate.**



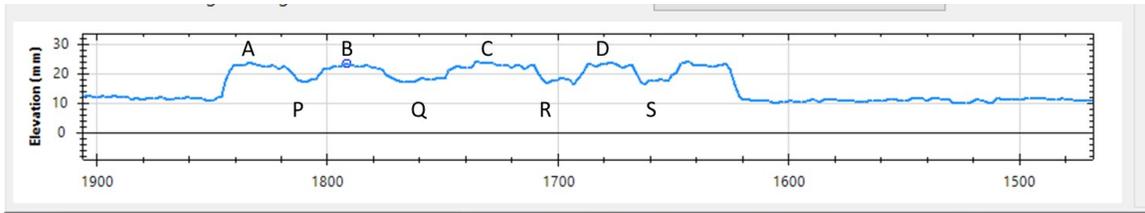
Source: FHWA.

**Figure 142. Screenshot. Zoomed-in view of the calibration plate.**



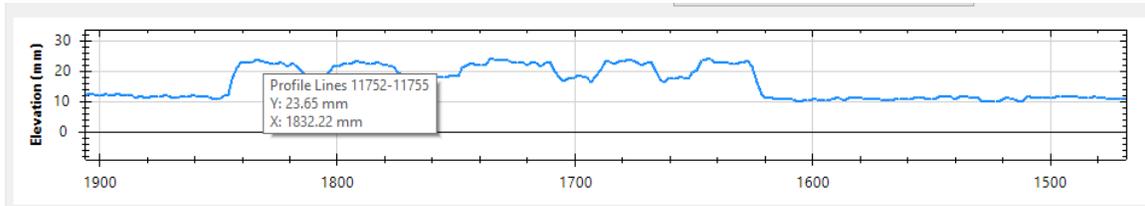
Source: FHWA.

**Figure 143. Screenshot. Three dots at the bottom of the middle window.**



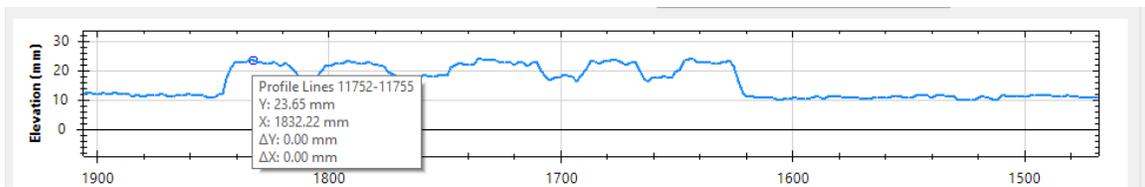
Source: FHWA.

**Figure 144. Screenshot. Naming convention for the valleys and ridges in the calibration plate.**



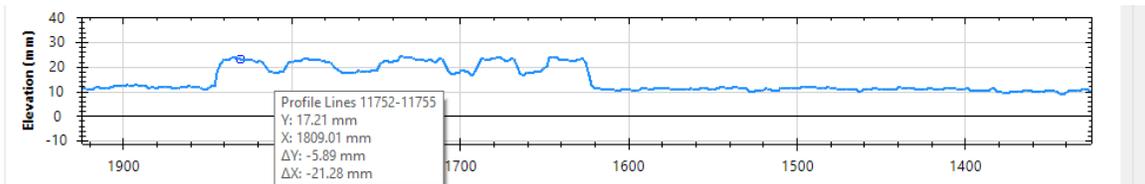
Source: FHWA.

**Figure 145. Screenshot. Selecting an average elevation for ridge A.**



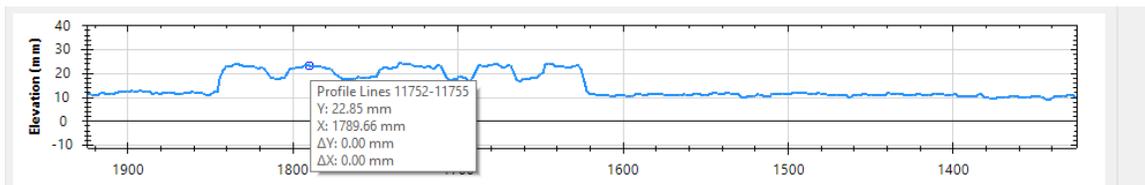
Source: FHWA.

**Figure 146. Screenshot. Locking in the reference location for ridge A.**



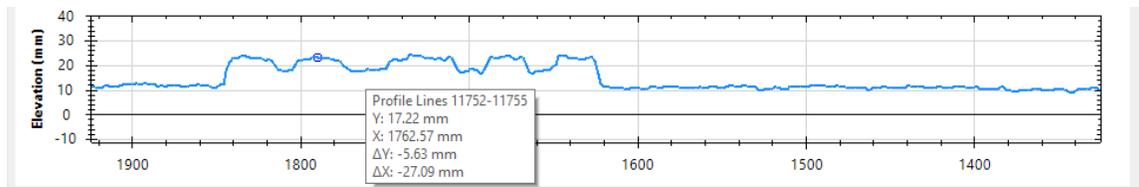
Source: FHWA.

**Figure 147. Screenshot. Reading at the bottom of the first valley.**



Source: FHWA.

**Figure 148. Screenshot. Reading at the top of the second ridge.**



Source: FHWA.

**Figure 149. Screenshot. Reading at the bottom of the second valley.**

### 2.12.13 Check on Photocell Initiation

Historically in the LTPP program, the first longitudinal profile data point recorded at a test section has been at a distance of 114 mm from the leave edge of the test section start stripe. As such, software settings in the HSSV are set so the first data point obtained at a test section is at a distance of 114 mm from the leave edge of the test section start stripe.

The DCC should annually verify if the HSSVs are 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 placed on a cone if data collection is initiated using the horizontal photocell. The DCC should maintain a log indicating the results from the photocell initiation test.

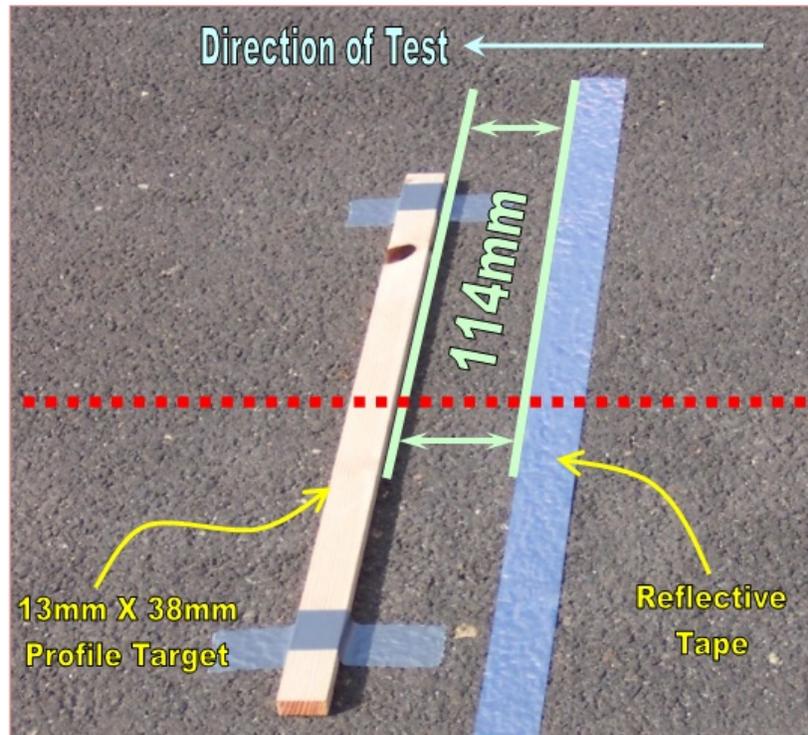
The following sections describe the field procedure for performing the check on photocell initiation and the procedure to analyze the collected data.

#### 2.12.13.1 Test Section Preparation

The photocell initiation test procedure involves attaching an artificial bump target to the pavement and then completing a series of longitudinal 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 recently overlaid pavement surface with no significant pavement distresses within 15 m of the target point. Pavements with a rough surface macrotexture, such as chip seals or severe raveling, should be avoided.

Once a location for testing has been selected, it is necessary to establish a test-section-starting mark. Place a 52- to 102-mm-wide strip of white or silver adhesive tape at the testing location on the pavement so it is perpendicular to the direction of travel and in a location that will be detected by the vertical photocell when the HSSV is driven over the location. Select a suitable bump target made of wood measuring 13 mm thick, 38 mm wide, and 750 mm long. Place the bump target on the pavement parallel to the previously established starting stripe so 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 (i.e., approximately mid-lane). The bump target should be positioned so 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 longitudinal profile data collected by the center laser. Figure 150 illustrates the positioning of the

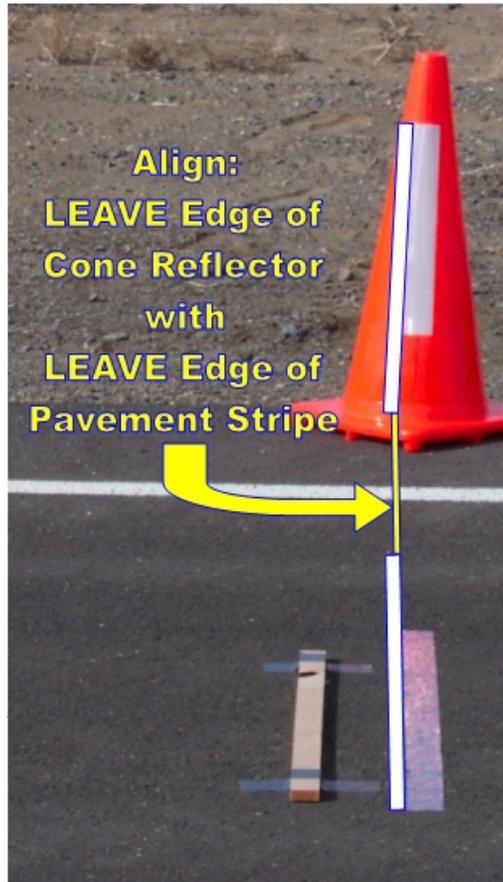
test-section-starting stripe and bump target. Thereafter, place several layers of 38-mm-wide duct tape along the left and right wheel paths so the approach edge of the duct tape is in line with the approach edge of the bump target, and the layers of duct tape are at least 8 mm high. The duct tape should be placed so the left and the right profile height sensors of the HSSV will run over the tape when collecting data.



Source: FHWA.  
1 mm = 0.04 inch.

**Figure 150. Photo. Test-section-starting stripe and bump target placed on the pavement.**

Thereafter, the horizontal photocell target has to be established in relation to the test-section-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 so the leave edge of the reflective tape 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 operations for collecting longitudinal profile data. Figure 151 illustrates the proper placement of the horizontal photocell target in relation to the starting stripe and bump target.



Source: FHWA.

**Figure 151. Photo. Placement of horizontal photocell target in relation to test section starting location.**

### ***2.12.13.2 Longitudinal Profile Data Collection***

The photocell initiation test is performed in a manner consistent with standard LTPP procedures for collecting longitudinal profile data. It is important that the DMI be calibrated beforehand in accordance with section 2.12.3 of this manual, and the tires in the HSSV be sufficiently warmed up with air pressures matching those noted during the DMI calibration. Perform the standard daily height sensor check and bounce test in accordance with section 2.9.2.2 and section 2.9.2.4 of this manual before collecting data.

For the photocell initiation test, a set of data (i.e., three runs) is collected with data collection initiated by the vertical photocell. Thereafter, a set of data (i.e., three runs) is collected with data collection initiated by the horizontal photocell. For this testing, the longitudinal profile data of concern are the data immediately after the test-section-starting stripe. Therefore, it is not necessary to collect a large amount of longitudinal profile data during each run. Only about 20 m of longitudinal profile data after the test-section-starting stripe need to be collected.

The following procedure should be followed for collecting data:

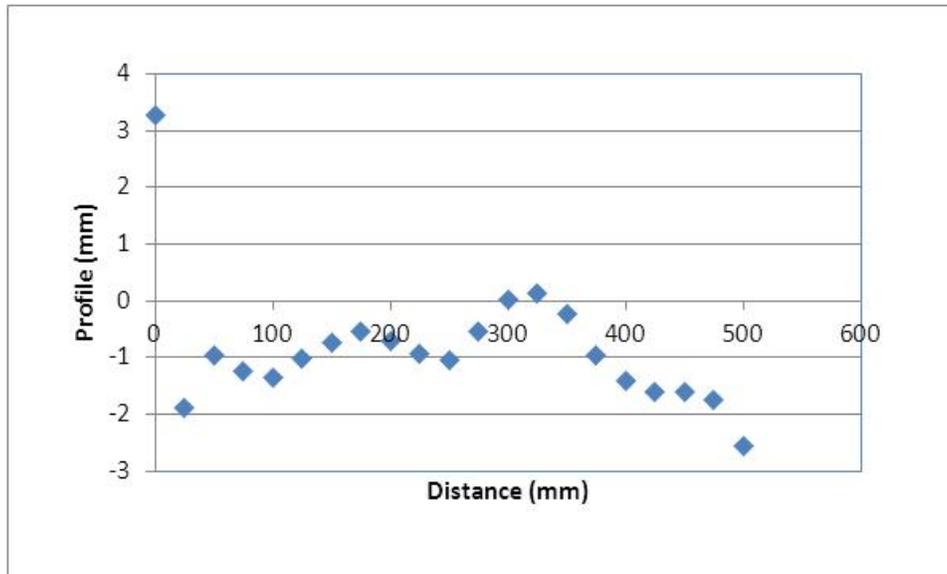
1. Set the Stop Method to “DISTANCE” and enter a value of 20 in the Distance field in the Header screen (figure 96).
2. Set the vertical photocell to be active by checking Auto Trigger under ODS 3 (figure 96). Auto Trigger under ODS 2 should not be checked. Complete three longitudinal profile runs at the test 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 Auto Trigger under ODS 2 (figure 96). Auto Trigger under ODS 3 should not be checked. Complete three longitudinal profile runs at the test section using standard LTPP data collection procedures. Data collection for these runs is initiated by the horizontal photocell.

### **2.12.13.3 Data Analysis**

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

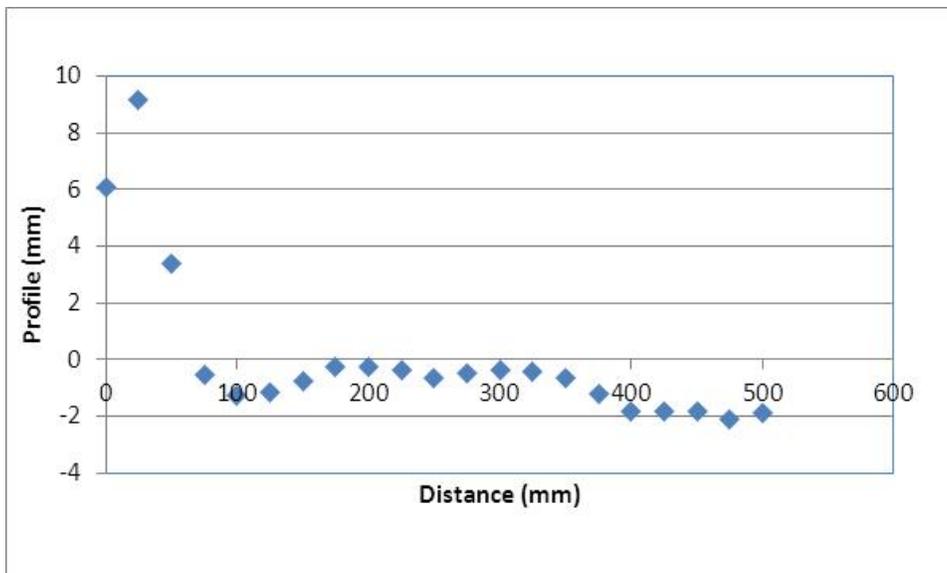
1. Create ERD files for the collected longitudinal profile and macrotexture data. The ERD file for longitudinal profile data should contain profile data at 25-mm intervals, while the ERD file for macrotexture data should contain macrotexture data at 0.5-mm intervals.
2. Import the longitudinal profile data into Excel and plot the center sensor profile data in each file versus 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. Figure 152 and figure 153 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 do not show such a feature for data collection initiated with the vertical photocell, horizontal photocell, or both, repeat the appropriate test or tests and evaluate the data. If the collected data are still not satisfactory, contact the DCC office and decide on a suitable course of action.
3. Plot the data for the left and right profile sensors versus distance for a distance of 500 mm for data in each file. Also import the collected macrotexture data into Excel and plot the data in each file for the left and right texture sensors versus 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 datapoint or the first two datapoints are at a higher elevation for data collected by the left and right profile and texture sensors, the first data point by these sensors was collected at a distance between 114 and 152 mm from the leave edge of the test-section-starting stripe. If the collected data do not show such a feature for data

collection initiated with the vertical photocell, horizontal photocell, or both, repeat the appropriate test or tests and evaluate the data. If the collected data are still not satisfactory, contact the DCC office and decide on a suitable course of action.



Source: FHWA.

**Figure 152. Graph. Example plot of data from photocell initiation test with one point on the target.**



Source: FHWA.

**Figure 153. Graph. Example plot of data from photocell initiation test with two points on the target.**

### **2.12.14 Calibration Section**

The DCC must establish a calibration test section close to the office and collect data at this test section after all calibrations, calibration checks, and operational checks have been performed. The calibration test section must be at least 152.4 m long. The longitudinal profile, macrotexture, and transverse profile data collected at this test section can be compared to previously collected data at this test section to ensure that the HSSV is collecting consistent data. In the case of the transverse profile data, the wireline rut depths computed from the transverse profile data can be used as the parameter to evaluate changes in rut depths over time. Data can be collected at the calibration test section whenever there is a question about the quality of the data collected by the HSSV. The test section used to calibrate the DMI may be used as the calibration test section.

## **2.13 EQUIPMENT MAINTENANCE AND REPAIR**

### **2.13.1 General Background**

Responsibility for equipment maintenance and repair rests with the DCC. Decisions required for proper maintenance and repair should be based on a testing schedule and expedited as necessary to prevent disruption of testing. Maintenance activities on the HSSV 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.<sup>(2,4,5)</sup> Operators must become familiar with maintenance recommendations contained in all equipment manuals. Maintenance and repair work to be performed can be classified as routine maintenance, preventive maintenance, and unscheduled maintenance.

### **2.13.2 Routine Maintenance**

Routine maintenance includes work that can be performed by the operator. The Daily Checklist includes a list of activities to be performed every day (figure 174). These include checking vehicle lights, checking under the vehicle for fluid leaks, checking fluid levels in the vehicle, and inspecting the glass face of the profile and texture height sensors. These items are the most basic and easily performed maintenance measures and should be performed every day before using the equipment. 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 the seal is broken. Cracked or chipped glass in the height sensor may cause moisture damage, which can lead to sensor failure. If any sign of physical damage is noted on the sensor glass, the manufacturer should be contacted to decide on a repair procedure.

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

Scheduled major preventive maintenance services are those performed at scheduled intervals. Scheduled preventive maintenance activities on the vehicle, which should be performed following the manufacturer's heavy-use guidelines, include oil and other fluid changes.

Checking drive belts, hoses, battery cable connections, and so on, should be performed when the oil is changed in the vehicle.

The operator must use Form PROF-4 to report the services performed, which will also serve to inform the DCC office of the condition of the HSSV on a regular basis (figure 178).

### **2.13.4 Unscheduled Maintenance**

Unscheduled maintenance includes unscheduled repairs. These repairs must be reported on Form PROF-4 as an unscheduled maintenance activity (figure 178). Form PROF-4 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 RECORDKEEPING**

The following eight types of records should be forwarded to the DCC office by the HSSV operator:

- LTPP Profiler Field Activity Report.
- Status of the Regions Test Sections.
- Profiler Log.
- LTPP Major Maintenance/Repair Form.
- Laser Sensor, Accelerometer, DMI Calibration/Calibration Check Form.
- Ambient Temperature Sensor, Pavement Surface Temperature Sensor, GPS Receiver Calibration Check and Transverse Profile System Check Form.
- Profiling of WIM Sites: Data Summary Sheet.
- ProQual outputs.

A description of each of these forms and 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 the standard operating procedures of the DCC, the completion of these forms may be omitted. It is acceptable for the DCC to use forms that have a different format if the modified form contains all 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) records all activities to and from a test section, as well as activities at the test section (figure 175). Form PROF-1 should be filled out for all travel and testing days. For travel-only days, the test section for which the operator is traveling should be noted. Entering IRI readings requested on this form is optional. However, the IRI values should be entered if the DCC keeps Form PROF-1 in the vehicle and uses IRI values as a check when the test section is profiled subsequently.

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

The Status of the Regions Test Sections Form (Form PROF-2) should be filled out at every test section (figure 176). Recent maintenance or rehabilitation activities, condition of paint marks,

missing LTPP signs and delineators, and any other comments regarding the test section should be recorded on Form PROF-2.

### **2.14.3 Profiler Log**

The operator should maintain a Profiler Log in the vehicle. The format of the log is shown in Form PROF-3 (figure 177). When the operator performs daily checks on equipment, items needing attention should be noted in Form PROF-3.

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

This form (Form PROF-4) should be filled when scheduled or unscheduled maintenance or repairs are performed on the HSSV (figure 178). Vehicle and equipment operating costs are monitored with Form PROF-4, and it should be submitted along with all receipts for maintenance activities.

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

The Laser Sensor, Accelerometer, DMI Calibration/Calibration Check Form (Form PROF-5) must be filled out when the following activities are performed at a maximum interval of 30 d (figure 179):

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

The operator should regularly back up 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, Global Positioning System Receiver Calibration Check, and Transverse Profile System Check Form**

The Ambient Temperature Sensor, Pavement Surface Temperature Sensor, Global Positioning System Receiver Calibration Check and Transverse Profile System Check Form (Form PROF-6) must be filled out when the following activities are performed at a maximum interval of 30 d (figure 180):

- Calibration check of the ambient temperature sensor.
- Calibration check of the accelerometers.
- Calibration check of the GPSR.
- Operational check on the TPMS.

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

The HSSV operator is required to fill out Form PROF-7, Profiling of WIM Sites: Data Summary Sheet, when profile data are collected at a WIM test section (figure 181).

### **2.14.8 ProQual Outputs**

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



## CHAPTER 3. PROFILE MEASUREMENTS USING DIPSTICK

### 3.1 INTRODUCTION

The Dipstick is a manually operated device for collecting precision profile measurements and can collect data at rates greater than traditional rod and level survey procedures.<sup>(15)</sup> 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 (i.e., pendulum), LCD panels, and a battery for power supply. The Dipstick sensor is mounted in such a way that its axis and the line passing through the 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 go blank. After the sensor achieves equilibrium, the difference in elevation between the two points is displayed. Swivel footpads with an approximate diameter of 32 mm should be used for all measurements.

The DCC possesses several manual (i.e., model 1500) and automated Dipsticks (i.e., model 2000 and model 2200). Both the manual and automated Dipsticks display data in millimeters. The spacing between the two feet of the Dipstick is approximately 304.8 mm for all three models. When the automated Dipstick is used for data collection, it should be used in manual mode, with data recorded manually.

Longitudinal and transverse profile measurements on GPS and SPS test sections that cannot be obtained using the HSSV 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 DCC 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 data if that person uses a voice-activated recorder to record the readings.

Detailed scheduling and traffic control at test sections must be coordinated by the DCC. Traffic control at test sections will be provided by either the State highway agency (in the United States) or provincial highway agency (in Canada). The layout of the test section should not be undertaken until all applicable traffic control equipment and devices are in place.

#### 3.2.2 LTPP Procedures

##### 3.2.2.1 Maintenance of Records

The operator is responsible for forwarding all data collected during testing to the DCC office (figure 193 through figure 202). In addition, the operator is also required to forward other records related to the Dipstick operation, which are described in section 3.6, to the DCC office.

### ***3.2.2.2 Equipment Repairs***

The DCC is responsible for ensuring that LTPP-owned equipment is properly maintained. Decisions required for proper maintenance and repair should be made based on testing schedules and expedited as necessary to prevent disruption of testing.

### ***3.2.2.3 Accidents***

In the event of an accident, the operator should inform the DCC office of the incident as soon as practical. Details of the event should subsequently be reported in writing to the DCC office. The corporate policy of the DCC should be followed in the event of an accident. A police report of the accident should be obtained.

### **3.2.3 Footpad Spacing of Dipstick**

Field studies performed with LTPP Dipsticks 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 used by the DCC can vary between 304.280 and 306.176 mm.

The DCC is required to determine the footpad spacing of all Dipsticks in their possession annually using the procedures described in appendix F. The DCC should maintain a log documenting the test date and the computed footpad spacing for each Dipstick.

The RSCs performed the test specified in appendix F in December 2003, and if the current DCC has these records, the DCC should know the footpad spacing of all Dipsticks. If longitudinal profile measurements using Dipstick are not performed routinely, it is acceptable to perform this test annually only on a Dipstick that has the footpad spacing closest to 304.8 mm. If during this test the offset at the end of the test section is not within  $\pm 25$  mm of the offset obtained from the previous year's test, the procedure described in appendix F should be used to obtain the footpad spacing of all Dipsticks in the possession of the DCC.

When performing longitudinal Dipstick measurements, the DCC should select the Dipstick in their possession with a footpad spacing 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**

- Dipstick crew (i.e., operator and recorder).
- Traffic control crew supplied by highway agency or traffic control contractor working for the highway agency.
- Other LTPP, State or provincial highway agency, and DCC personnel. (They are observers and are not required to be present.)

## **Task 2: Test Section Inspection**

- Note general pavement condition within test section limits.
- Identify wheel paths (when performing longitudinal measurements).

## **Task 3: Dipstick Measurements**

- Mark wheel paths (when performing longitudinal measurements).
- Perform operational checks on Dipstick.
- Obtain Dipstick measurements.
- Perform quality control.

## **Task 4: Form Completion**

- Form DS-1 through Form DS-7 should be completed for longitudinal profile measurements (figure 193 through figure 199).
- Form DS-7 and Form DS-8 should be completed for transverse profile measurements (figure 199 and figure 200).

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

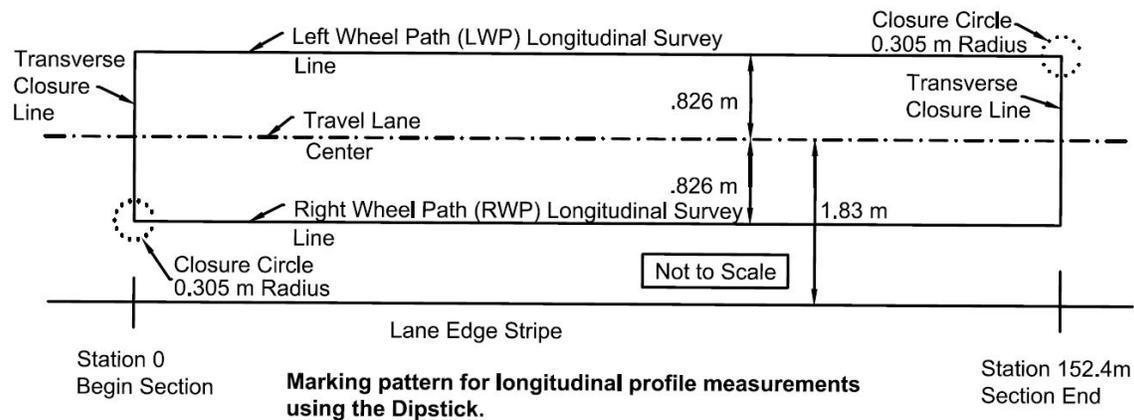
Assuming that a manual distress survey is also to be performed at the test section, traffic control typically should be available for 6 to 8 h. This period of time should provide adequate time for Dipstick measurements in both wheel paths as well as for the manual distress survey to be completed. Experienced Dipstick operators can obtain approximately 500 readings per hour.

Collecting profile data is the primary responsibility of the operator. To ensure that data collected by different operators are identical in format, the guidelines provided in section 3.3.2 through section 3.3.5 must be strictly followed.

### **3.3.2 Test Section Inspection and Layout—Longitudinal Profile Measurements**

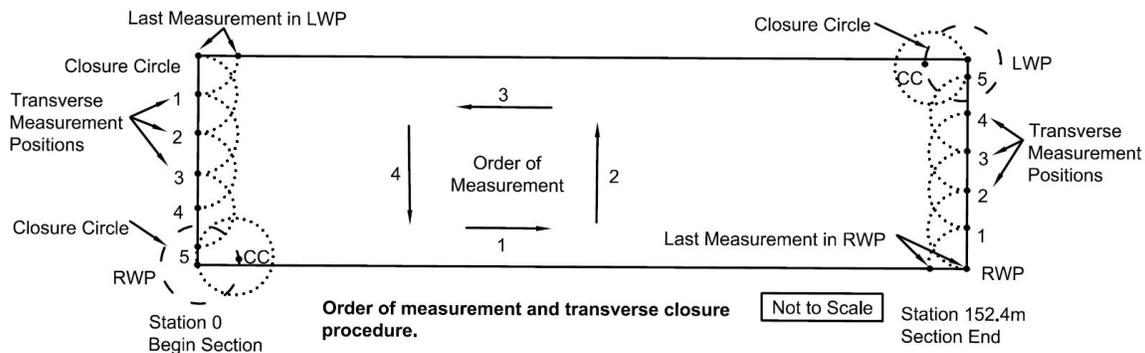
The pavement must be clear of ice, snow, and puddles of water before profile measurements can be taken with the Dipstick, as such conditions can affect profile measurements. Pools of water can cause the feet of the Dipstick to get wet, resulting in potential slippage, and can also damage the electronics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

The longitudinal Dipstick measurement procedure consists of performing an elevation survey in each wheel path and using transverse measurements at the test section ends to form a closed loop. As illustrated in figure 154 and figure 155, measurements start at station 0+00 in the right wheel path and proceed in the direction of traffic toward the end of the test section.



Source: FHWA.

**Figure 154. Diagram. Test section layout procedure for measuring longitudinal profiles with the Dipstick.**



Source: FHWA.

**Figure 155. Diagram. Measurement procedure for collecting longitudinal profiles with the Dipstick.**

At the end of the test section, transverse measurements are made to the end point of the survey line in the 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 a 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 conditions are acceptable to perform 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 test section layout is to locate the wheel paths, where each wheel path is located 0.826 m from the center of the travel lane. Use the following procedure to locate the center of the travel lane:

- Case I—where wheel paths are easily identified, the midway point between the two wheel paths should be used as the center of the lane.

- Case II—where wheel paths are not clearly identifiable, but the two lane edges are well defined, the center of the travel lane is considered to be 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.

Once the center of the travel lane has been identified, use the following procedure to layout the test section:

1. Dipstick measurements along the right wheel path will begin with the back edge of the Dipstick footpad located immediately adjacent to the leave edge of the white stripe at the beginning of the monitoring portion of the test section. If this location is not marked with a stripe, establish a transverse chalk line to define the start of the test section. At a 16-mm offset (i.e., the radius of the footpad of Dipstick) in front of the leave edge of the white stripe at the start of the test 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 starting line of the test section. This transverse line is considered to be station 0+00. Identify the location of two longitudinal elevation survey lines 0.826 m from the center of the lane. Mark these locations at intervals equal to the length of the chalk line used for marking the starting line of the test section. Use a chalk line to mark a straight line between the previously established points. Using a tape measure (measuring wheels are not acceptable), carefully measure the length of each longitudinal elevation survey line to establish end points at 152.4 m, or at a 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 the two longitudinal lines.
2. At the end of the test 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 start of the test 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 to complete the elevation survey loop.
3. On a data collection sheet or field notebook, note the method used to establish the location of the lane center and any discrepancies between the painted and measured test section end locations. This information will help operators collect consistent data in future profile measurements at that test section.

### **3.3.3 Dipstick Operation for Longitudinal Profile Measurements**

#### ***3.3.3.1 Preoperational Checks on Dipstick***

The following checks should be performed on the Dipstick before testing:

1. Check the condition of the footpads and replace them if necessary with the extra set in the Dipstick case. Clean and lubricate the ball and socket joints on the footpads to ensure smooth pivoting. When a joint is dirty, pivoting becomes difficult, and slippage of the

footpad can occur. A petroleum-based cleaning agent or a light oil for lubrication will work for the ball and socket joints.

2. Install a fresh set of rechargeable batteries if using a model 1500 Dipstick and securely close the battery compartment. The batteries in the model 1500 Dipstick have to be taken out to recharge them. The model 2000 and model 2200 Dipstick are 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 and securely close the battery compartment. Batteries in either of these units should be changed after 4 h of usage to ensure continuity of measurements. The model 1500 Dipstick is powered with 9-V batteries, while the model 2000 and model 2200 Dipsticks 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 the handle on the Dipstick.
4. Perform the zero check and calibration check, which are described in the next section. According to the manufacturer, the 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 start of data collection. The Dipstick should be fully assembled, turned on, and allowed to warm up for several min before performing these two checks.

#### ***3.3.3.1.1 Zero Check for Manual Dipstick (Model 1500)***

Form DS-7 should be filled out when the zero check is carried out (figure 199). A zero verification is performed by this test. The test should be performed on a relatively level, smooth, clean, and stable location where the Dipstick can be properly positioned. A suitable fabricated plate or wooden board that can be fitted inside the Dipstick case can be utilized to perform the zero check. After positioning the Dipstick, draw two circles around the footpads and note the reading on the display at the switch end (reading = R1). The Dipstick should then be rotated 180 degrees and the footpads placed on the two circles that were drawn earlier; note the reading obtained at the switch end (reading = R2). If readings from the two placements (i.e., R1 and R2) add up to within  $\pm 0.1$  mm, the Dipstick has passed the zero check. If the readings do not fall within these limits, a zero adjustment is necessary. The zero adjustment should be performed using the following procedure:

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

The zero adjustment is the only adjustment an operator is allowed to make on the Dipstick.

#### ***3.3.3.1.2 Calibration Check for Manual Dipstick (Model 1500)***

Calibration of the Dipstick is fixed during manufacturing and cannot be altered by the user. A user can verify the calibration against a standard calibration block that is provided with the Dipstick. After the zero check and adjustments are performed, the calibration of the Dipstick must be checked. The calibration check should be performed on a relatively level, smooth, clean, and stable location where the Dipstick can be properly positioned. A suitable fabricated plate or wooden board that can be fitted inside the Dipstick case can be used to perform the calibration check. Form DS-7 should be completed when this test is carried out (figure 199). To check the calibration, note the Dipstick reading and place the 3.2-mm calibration block under one of the footpads. The reading displayed minus 3.2 should be within  $\pm 0.1$  mm of the previous reading. If this tolerance is not obtained, Form DS-10 should be completed and the manufacturer should be contacted through the RSC office to repair the Dipstick (figure 201).

#### ***3.3.3.1.3 Zero Check for Automated Dipstick (Model 2000 and Model 2200)***

The zero check should be performed on a relatively level, smooth, clean, and stable location where the Dipstick can be properly positioned. A suitable fabricated plate or wooden board that can be fitted inside the Dipstick case can be used to perform the zero check. Circles should be drawn around the two footpads and the CAL button pressed once. The Dipstick should then be rotated 180 degrees and the two footpads placed in the circles drawn earlier. The CAL button should again be pressed once. The display will flash CAL three times, after which the error is automatically stripped out of the readings. Note the reading at the switch end. Rotate the Dipstick, place the two footpads in the circles, and note the reading at the switch end. If these two readings are within  $\pm 0.1$  mm, the Dipstick has passed the zero check. The zero check can only be performed once after the Dipstick is turned on. If the zero check is not successful, the Dipstick must be turned off and then turned on again, and the zero check repeated. A check mark should be placed on form DS-7 at the appropriate location to indicate that the zero check was performed (figure 199).

#### ***3.3.3.1.4 Calibration Check for Automated Dipstick (Model 2000 and Model 2200)***

Follow the procedure described for the manual Dipstick (i.e., model 1500) to perform the calibration check. Form DS-7 should be completed when the calibration check is carried out (figure 199).

#### ***3.3.3.2 Longitudinal Profile Measurement***

Complete the Header information on Form DS-1 (figure 193). Use the guidelines presented in section 3.3.5.2 to enter the Header information in Form DS-1, except for the air temperature. Use the guidelines presented in section 3.3.3.5 to enter the air temperature before and after profile measurements.

The following procedure should be followed to collect longitudinal profile data using the Dipstick:

1. Place the Dipstick on the marked survey line in the right wheel path with the start arrow pointed forward in the direction of traffic and the back edge of the footpad located immediately adjacent to the leave edge of the white stripe at the start of the test section. In this position, the center of the back footpad of the Dipstick will be at station 0+00.
2. Wait for the reading to stabilize and record it under the right wheel path (RWP) column on Form DS-2 on the row corresponding to Reading Number 1 (figure 194). The Dipstick should then be rotated to the next measuring point using a clockwise rotation. A clockwise rotation is specified because such motion will not loosen the handle of the Dipstick. However, if an operator has any problems using a clockwise rotation it is acceptable to use a counterclockwise rotation to advance the Dipstick. If a counterclockwise rotation is used, the operator should check the handle of the Dipstick at frequent intervals to make sure it is not loose; if the handle is loose, it should be tightened. After the reading has stabilized, it should be recorded on the next row of Form DS-2 labeled Reading Number 2 (figure 194). This procedure should be repeated for the entire length of the test section. During measurements, the following precautions and procedures should be followed:
  - a. Use a consistent motion to advance the Dipstick (either clockwise or counterclockwise).
  - b. Hold the handle of the Dipstick in a vertical position when taking measurements.
  - c. Do not apply lateral pressure to the handle during measurements.
  - d. Avoid placing the footpad of the Dipstick into a wide crack or pothole in the pavement. If such a condition is encountered, offset the placement of the footpad so it will rest on the pavement 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 the last measurement position. When restarting, return the Dipstick to the marked position and adjust it so the current measurement agrees with the measurement prior to the stoppage.
  - f. If it is not possible to mark the footpad positions prior to stoppage or successfully reposition the Dipstick in the same position, then the data must be discarded and the measurement procedure restarted from the beginning.
3. Compare the location of the transverse line that was marked at the end of the test section with the location of the back end of the front Dipstick footpad after the last measurement in the right wheel path at station 152.4 m. If the back end of the front footpad is within 275 mm of the marked transverse line, proceed with transverse closure measurements as indicated in step 4. If the front footpad is not within this interval, perform the following steps:
  - a. Draw circles around each footpad and note the direction of the start arrow.
  - b. Check data sheets for skipped or missing measurements.

- c. If no apparent anomalies are present in data, remeasure the length of the longitudinal survey line to verify the position of the end point. If the remeasured location of the end point is within 304 mm of the back end of the front footpad, remark the transverse line at this location and proceed. If the end point is not within 304 mm of the back end of the front footpad, discard the data and restart the survey from station 0+00.
4. Initiate transverse closure measurements after the location of the last measurement in the right wheel path has been verified by rotating the rear foot of the Dipstick toward the left wheel path and placing it on the pre-marked transverse closure line. Measurements along the 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 (figure 198). When the Dipstick reaches the point in which the next measurement along the transverse survey line passes the location of the left wheel path, it should be rotated so that the footpad rests at any point on the closure circle. After recording this measurement in the column labeled 5-CC, rotate the Dipstick so the footpad rests on top of the 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 154.
5. Begin measurements along the longitudinal survey line in the left wheel path, recording readings in the column labeled LWP on forms DS-2 through DS-6 (figure 194 through figure 198). These measurements will be entered in reverse order from those in the RWP.
6. Verify that the position of the back edge of the front footpad is within 275 mm of the end point when the last measurement in the left wheel path is made at station 0+00. If not, follow the procedures for end-point verification previously described for measurements in the right wheel path. If a problem is found with a missing or skipped measurement or the final location of the Dipstick in the left wheel path, measurements in the left wheel path should be discarded and the survey restarted from the starting point in the left wheel path.
7. Transverse closure measurements should be initiated after the location of the last measurement in the left wheel path has been verified by rotating the rear foot of the Dipstick toward the right wheel path and placing it on the pre-marked transverse closure line located at station 0+00. Measurements along the 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 (figure 194). When the Dipstick reaches the point in which the next measurement along the transverse survey line passes the location of the right wheel path, it should be rotated so the footpad rests at any point on the closure circle. After recording this measurement in the column labeled 5-CC, rotate the Dipstick so the footpad rests on top of the 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 154.

### **3.3.3.3. Post Data Collection Check**

After completing the survey, the operator must conduct the zero and calibration checks.

The following procedure should be followed for performing the zero check for both the manual Dipstick (i.e., model 1500) and automated Dipstick (i.e., model 2000 and model 2200). Place the Dipstick on a smooth, clean, and stable location where it can be properly positioned (i.e., on the carrying case or a flat, wooden board). Draw circles around the two footpads and note the reading at the switch end of the instrument (i.e., R1). Then, rotate the Dipstick 180 degrees and place the two footpads in the circles that were drawn earlier. Note the reading at the switch end of the Dipstick (i.e., R2). The two readings (i.e., R1 and R2) should add up to within  $\pm 0.1$  mm to pass the zero check. If the sum of the two readings is outside these limits, the Dipstick has failed the zero check.

For both the manual Dipstick (i.e., model 1500) and automated Dipstick (i.e., model 2000 and model 2200), the calibration check should be performed as described in section 3.3.3.1 for the manual Dipstick.

Results from the zero and calibration checks should be entered on form DS-7 (figure 199). Based on the results of the zero and calibration checks, one of the following procedures should be followed:

1. If the Dipstick failed the zero check, the data should be discarded and another survey performed.
2. If the Dipstick passed the zero check but failed the calibration check, the data should be discarded and the manufacturer contacted for repair, as discussed in section 3.3.3.1.
3. If the Dipstick passed both tests, the closure error computations described in section 3.3.3.4 should be performed.

If the Dipstick failed the zero check but can successfully be adjusted to pass both the zero and calibration checks, another survey should be performed.

### **3.3.3.4 Closure Error Computations**

The following procedure should be followed when performing closure error computations:

1. Perform closure error computations in the field prior to leaving the test section.
2. Sum the readings in each column on Forms DS-2 through DS-6 and record them in the last row of each column (figure 194 through figure 198). Measurements in transverse closure measurement tables on Forms DS-2 and DS-6 should be summed across each row and entered in the last column.
3. Enter column summations on Form DS-1 in the locations corresponding to the labels shown in each summation cell (figure 193).
4. Add together the elevation sums in the RWP and LWP and record them in indicated cells on Form DS-1 (figure 193).

5. Add the transverse sums to the elevation sums in the RWP and LWP and record the result in the total row at the bottom of the closure calculation table.
6. Add the two totals at the bottom of the form together and enter the result into the cell labeled closure error.
7. If closure error is not within  $\pm 76$  mm, data should be discarded and the test section re-surveyed until the 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 (figure 193). 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 pieces of equipment:

- K-type, 51-mm handheld thermocouple probe (i.e., model KHSS-18U-2).
- Microprocessor thermometer display (i.e., model HH21, model HH22, model HH33, or model HH64).

Measurements should be taken at an adequate distance from any heat source, such as the 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 d prior to air temperature measurements or whenever the operator observes suspicious temperature readings. An NIST traceable mercury thermometer is required to perform the calibration check. The check should be performed in a shaded area using the following procedure.

1. Place the thermometer close to the temperature probe, and after they have reached a stable value, observe the readings of the thermometer and probe.
2. Note the difference between the two temperature readings; if it is less than or equal to  $2^{\circ}\text{C}$ , the temperature probe is considered acceptable.
3. If the difference between the two temperatures is greater than  $2^{\circ}\text{C}$ , wait at least 5 min and repeat steps 1 and 2. If the difference is still greater than  $2^{\circ}\text{C}$ , wait at least 5 min 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 unacceptable and contact the manufacturer to resolve the problem.
4. Perform a cold temperature check on the sensor if there are any questions regarding the accuracy of the temperature probe. 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  $\pm 2^{\circ}\text{C}$  of  $0^{\circ}\text{C}$ . If not, consider the air temperature probe unacceptable and contact the manufacturer to resolve the problem.

Results of the calibration check must be recorded on form DS-11 (figure 202).

### **3.3.4 Test Section Inspection and Layout—Transverse Profile Measurements**

Transverse profile measurements should be taken when manual surveys are conducted on AC-surfaced pavements, including PCC-surfaced pavements with AC overlays. One round of transverse profile measurements should be taken on all LTPP PCC (i.e., jointed concrete and continuously reinforced concrete) test sections. The purpose of taking transverse profile measurements on PCC-surfaced test sections is to determine the transverse cross slope of the pavement.

Pavement must be clear of ice, snow, and puddles of water before profile measurements can be taken with the Dipstick, as such conditions can affect profile measurements. Pools of water can cause the feet of the Dipstick to get wet, resulting in a potential for slippage and damage to electronics. Testing under such conditions must be avoided either through adjusting the 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 the edge of the pavement and located at 15.24-m intervals, starting at station 0 and ending at station 152.4 m (or the end of the test section if the length of the test section is greater than 152.4 m). For each test section (e.g., GPS or SPS), 11 transverse lines will be present (or more if the length of the test section is greater than 152.4 m).

For AC-surfaced test 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 (figure 200).

For PCC-surfaced pavements, the location of the transverse lines should be offset to avoid joints, cracks, and any other localized anomalies, such as patches and surface defects, that would cause the measurements to be non-representative of the transverse profile as related to the effectiveness of transverse surface drainage. Unlike for AC-surfaced pavements, offsets greater than 1 m are allowed for PCC-surfaced pavements.

### **3.3.5 Dipstick Operation for Transverse Profile Measurements**

#### ***3.3.5.1 Preoperational Checks on Dipstick***

The operator should check the equipment using the procedures described in section 3.3.3.1. Checks include both the zero and calibration checks. The operator should fill out Form DS-7 (figure 199).

#### ***3.3.5.2 Entering Header Information in Transverse Profile Form***

After performing the pre-operational checks on the equipment, the operator should fill out the Header information in Form DS-8 (figure 200). Guidelines for filling this form are presented in this section. As the information in Form DS-8 is used in ProQual, it is important the operator strictly follow these guidelines. The guidelines presented in this section should also be used to fill out the Header information in Form DS-1 that is used for longitudinal profile measurements. However, the air temperature is recorded on form DS-1, whereas the pavement temperature is recorded on Form DS-8.

- State Code—code of State or Province in which the test section is located.
- LTPP Section ID—four-digit LTPP Section ID of test section.
- Date—current date.
- Time—current time in military format (e.g., 09:30, 15:30, and so on).
- Dipstick Serial #—five-digit serial number on the base or side of the Dipstick (e.g., 30021).
- Dipstick 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 test section, B for second visit, C for third visit, and so on).
- Surface Type—A-CC for AC-surfaced pavements and P-CC for PCC-surfaced pavements.
- Condition—condition of the pavement as either V. GOOD, GOOD, FAIR, or POOR (use capital letters). Use following guidelines to select condition:
  - V. GOOD—pavement does not show any distress.
  - GOOD—pavement exhibits few visible signs of surface deterioration. Pavement may show low-severity cracks.
  - 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.
  - 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, SR 31).
- Lane—circle either Outside (i.e., the outermost traffic lane) or Inside (i.e., any lane that is not an outside lane). Nearly all LTPP test sections are located in the outside lane.
- Direction—direction of traffic (i.e., NORTH, EAST, WEST, or SOUTH) in capital letters.

- Clouds—presence of clouds (i.e., CLEAR, P. CLOUDY, or CLOUDY) in capital letters. Use following guidelines to select an appropriate entry to this field:
  - CLEAR—sunny sky.
  - P. CLOUDY—the sun is sometimes covered by clouds.
  - CLOUDY—the 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 in capital letters. ProQual contains the following built-in 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.

### ***3.3.5.3 Transverse Profile Measurement***

#### ***3.3.5.3.1 AC-Surfaced Pavements***

Transverse profile measurements should be collected at the transverse lines that were laid out within the test section (section 3.3.4) starting with the transverse line marked at station 0+00. Elevations for each transverse profile should be measured from the outside edge of the pavement and should extend over the full lane width, with the actual distance depending on the lane width and pavement striping. The starting point should be the junction of the transverse measurement line and the inside edge of the white paint stripe along the outside edge of the lane. If no outside edge stripe is present, or if the outside edge stripe is on the shoulder, the beginning point for measurements should be either the shoulder-lane joint or a point approximately 0.91 m from the center of the outside wheel path. A comment should be entered in the data sheet indicating how the starting point was determined. The starting point on subsequent surveys should be the same. The initial elevation is arbitrarily established as 0, and subsequent readings are recorded relative to this benchmark. The combination of the initial measurement and subsequent measurements taken in the transverse direction provides a measure of pavement cross slope.

To begin transverse profile measurements, place the Dipstick at the outside edge of the pavement starting at station 0+00 with the start arrow pointed toward the pavement center line. Measurements should be recorded on Form DS-8 (figure 200). The operator should complete two runs per transverse profile of each LTPP test 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 Form DS-8. The comments should be entered in capital letters (e.g., ELEVEN DATA POINTS DUE TO HEAVY TRAFFIC).

### ***3.3.5.3.2 PCC-Surfaced Pavements***

Transverse profile measurements should be collected at the transverse lines that were laid out within the test section (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 (i.e., 4.3 m) of the slab measured from the shoulder joint to the centerline longitudinal joint.

The starting point for Dipstick measurements should be the shoulder joint. The initial elevation is arbitrarily established as 0, and subsequent readings are recorded relative to this benchmark. To begin transverse profile measurements, place the Dipstick at station 0+00 at the shoulder joint with the start arrow pointed toward the pavement center line. Measurements should be recorded on Form DS-8 (figure 200). The operator should complete two runs at each transverse profile location; one run up the transverse line and a return run along the 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 Form DS-8. The comments 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 the survey, the operator must conduct the zero and calibration checks.

The following guidelines should be followed for performing the zero check for both the manual Dipstick (i.e., model 1500) and automated Dipstick (i.e., model 2000 or model 2200). Place the Dipstick on a smooth, clean, and stable location where it can be properly positioned (e.g., on the carrying case or a flat, wooden board). Draw circles around the two footpads and note the reading at the switch end of the Dipstick (i.e., R1). Then, rotate the Dipstick 180 degrees and place the two footpads in the circles that were drawn earlier. Note the reading at the switch end of the Dipstick (i.e., R2). The two readings (i.e., R1 and R2) should add up to within  $\pm 0.1$  mm to pass the zero check. If the sum of the two readings is outside these limits, the Dipstick has failed the zero check.

For both the manual Dipstick (i.e., model 1500) and automated Dipstick (i.e., model 2000 or model 2200), the calibration check should be performed as described in section 3.3.3.1 for the manual Dipstick.

Results of the zero and calibration checks should be entered on form DS-7 (figure 199). Based on results of these checks, one of the following procedures should be followed:

1. If the Dipstick failed the zero check, the data should be discarded.
2. If the Dipstick passed the zero check but failed the calibration check, the data should be discarded and the manufacturer contacted for repair, as described in section 3.3.3.1.
3. If the Dipstick passed both the zero and calibration checks, the closure error computations described in section 3.3.5.5 should be performed.

If the Dipstick failed the zero check but can successfully be adjusted to pass both the zero and calibration checks, 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 used to compute this error. At each station, sum the readings for the forward and return runs separately and record the values in the Sum column of form DS-8 (figure 200). Then, at each station, add the values in the Sum column for the forward and return run and record the result in the Closure column. At each station, for each Dipstick reading, add the reading for the forward and return run and record the value in the Difference field.

To compute the allowable closure error for a transverse profile run, multiply the total number of Dipstick readings (i.e., the sum of the number of readings for the forward and return run) by 0.076 mm. The allowable closure errors for typical lane widths are presented in table 4.

**Table 4. Allowable closure errors for transverse Dipstick measurements.**

Lane Width (m)	Total Number of Dipstick Readings	Allowable Closure 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 is able to pass post data collection checks, enter a comment on why the closure error is outside the allowable value (e.g., ROUGH SURFACE TEXTURE OF CHIP SEAL MADE CLOSURE DIFFICULT). One copy of the data from the third run will be submitted to FHWA and another to the technical support services contractor (TSSC). A decision on including those data in the PPDB will be made on a case-by-case basis.

### 3.3.6 Data Backup

The importance of safeguarding Dipstick data cannot be overstated. Backup copies of Dipstick 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 DCC office, and a second copy should be retained by the operator in case the first copy fails to reach the DCC office.

## **3.4 ZERO AND CALIBRATION CHECKS**

### **3.4.1 General Background**

The zero and calibration checks described in section 3.3.3.1 are performed to ensure the Dipstick is operating properly.

The DCC should ensure that the gauge block used for the calibration check is calibrated annually to an accuracy of  $3.18 \pm 0.03$  mm using a local calibration laboratory or a calibration micrometer. The gauge block may need to be calibrated more frequently depending on the presence of oxidation, evidence of corrosion, and possible damage caused by accidental mishandling in the field. If the calibration block is not within an accuracy of  $3.18 \pm 0.03$  mm, a new block satisfying the criteria should be obtained.

If the calibration block thickness is not within  $3.18 \pm 0.03$  mm, all data collected since the last calibration check of block are suspect and may have to be discarded. The person at DCC in charge of data collection should make this decision.

### **3.4.2 Frequency of Checks**

The zero and calibration checks should be conducted by the operator prior to and after Dipstick measurements. Procedures for performing the pre-operational zero and calibration checks are described in section 3.3.3.1. Procedures for performing the post-operational zero and calibration checks are described in section 3.3.3.3. If the Dipstick fails the calibration check, approval from a DCC engineer is required before shipping any equipment to the manufacturer.

## **3.5 EQUIPMENT MAINTENANCE AND REPAIR**

### **3.5.1 General Background**

Scheduled preventive maintenance ensures proper operation of equipment and helps in identifying potential problems. Timely identification of problems helps avoid costly delays or incomplete data that could result from on-site equipment malfunction. Time constraints on the profile testing program require maintenance activities be performed prior to mobilization for testing. During testing, the operator must be constantly aware of the proper functioning of equipment. There will be little time to accomplish more than the required initial checks at a test section in preparation for a test day. Therefore, preventive maintenance must be performed on the Dipstick as a routine function at the end of each test day.

Minimizing the rate of equipment deterioration is the responsibility of the DCC and individual operators. Detailed maintenance procedures are contained in the equipment manuals, and the 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 manual and the manufacturers' instructions, the more stringent requirements should be followed.

### **3.5.2 Routine Maintenance**

Routine maintenance includes functions that can be easily performed by the operator with minimal disassembly of the device. Routine maintenance for the Dipstick includes cleaning and lubricating the ball and socket joints of the footpads, replacing batteries, and cleaning the battery contacts. These items can be performed easily and should always be completed prior to and after operating the 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 the general appearance, glass display (should be clean), and ball and socket joints of footpads (should be properly lubricated).
2. Accessories—ensure adequate supplies of consumables are on hand (e.g., batteries, petroleum-based lubricants).

### **3.5.3 Scheduled Major Preventive Maintenance**

Scheduled major preventive maintenance should include more than routine checks and will require some disassembly of equipment by personnel with technical capabilities beyond the skill of operators or DCC staff. Form DS-10 should be used by the operator to report repairs that are performed (figure 201). Form DS-10 will also serve to inform the DCC office of the condition of the Dipsticks on a regular basis. Items such as replacing the battery connector 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 maintenance program, equipment failures are inevitable. When equipment failures occur, it is important repairs or replacements be accomplished in a timely fashion. Equipment failures 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 the impact of problems with equipment, it is essential that the operator immediately notify the DCC office and any other agencies or individuals about such problems.

Responsibility for equipment maintenance and repair activities rests with the DCC. However, the DCC should keep LTPP staff informed of any major problems concerning equipment. When repairs are necessary and must be performed by an outside agency, the operator should report this information on Form DS-10 as an unscheduled maintenance activity (figure 201).

## **3.6 RECORDKEEPING**

The Dipstick operator will be responsible for maintaining the following forms:

- For longitudinal profile measurements—Longitudinal Profile Forms DS-1 through DS-6 (figure 193 through figure 198).

- For transverse profile measurements—Dipstick Data Collection Form - Transverse Profile, form DS-8 (figure 200).
- Zero and Calibration Check Records (Form DS-7) for both longitudinal and transverse profile measurements (figure 199).
- Major Maintenance/Repair Form, Form DS-10 (figure 201).
- Air Temperature Probe Calibration Check Form, Form DS-11 (figure 202).

Each of these forms must be kept on file by the DCC. The following sections describe each of these forms.

### **3.6.1 Longitudinal Profile Measurements**

Form DS-1 through Form DS-6 should be filled out at every test section where longitudinal profile measurements are performed with a Dipstick. Follow the guidelines presented in section 3.3.5.2 to fill out the Header fields in form DS-1. Pavement temperature is not recorded for longitudinal profile measurements. However, air temperature is recorded. Follow the guidelines in section 3.3.3.5 to record air temperature. The comments section in Form DS-1 should include any downtime and factors that might affect collected data. Names and organizations of other personnel present at the test section should be included in this form. The names of these personnel will be invaluable if an accident occurs at a test section. The operator should keep the original copy of Form DS-1 through Form DS-6 and forward copies to the DCC office.

### **3.6.2 Transverse Profile Measurements**

Form DS-8 should be filled out at every test section where transverse profile measurements are performed. Follow the guidelines presented in section 3.3.5.2 to fill the Header fields in Form DS-8. The operator should keep the original copy of Form DS-8 and forward a copy to the DCC office.

### **3.6.3 Zero and Calibration Checks Form**

Form DS-7 should be completed whenever the zero and calibration checks are performed.

### **3.6.4 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**

Form DS-11 must be filled out when a calibration check is performed on the temperature probe used to measure the air temperature when longitudinal profile measurements are performed with Dipstick.



## CHAPTER 4. PROFILE MEASUREMENTS USING THE ROD AND LEVEL

### 4.1 INTRODUCTION

The rod and level can be used to accurately measure the longitudinal 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—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 capable of automatically storing the measured data.

### 4.2 OPERATIONAL GUIDELINES

#### 4.2.1 General Procedures

Detailed scheduling and traffic control at test sections must be coordinated by the DCC. However, all traffic control activities at the test sections will be performed by personnel from either the State or provincial highway agency. The test section should not be laid out until all applicable traffic control devices are in place.

#### 4.2.2 Equipment Requirements

Precision leveling instruments are required for pavement-profile measurements, and the rod and level used in routine surveying and road construction will generally not have the required resolution. Instruments used for profile measurement should satisfy the resolution criterion in table 5, which was obtained from ASTM E1364, *Standard Test Method for Measuring Road Roughness by Static Level Method*.<sup>(16)</sup>

**Table 5. Resolution requirement for rod and level measurements.**

<b>IRI Range (m/km)</b>	<b>Resolution (mm)</b>
$0 \leq \text{IRI} < 0.5$	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 it can be accurately held vertically. A suitable base may be selected for the rod 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>(16)</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**

The operator is responsible for maintaining records by forwarding all data collected during testing to the DCC office.

In event of an accident, the operator should inform the DCC office of the incident as soon as possible. Details of the event should subsequently be reported in writing to the DCC office. The corporate policy of the DCC 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**

- Personnel for rod and level survey.
- Traffic control crew supplied by the highway agency or traffic control contractor working for the highway agency.
- Other LTPP, State or provincial highway agency, and DCC personnel (they are observers and are not required to be present).

#### **Task 2: Test Section Inspection**

- Identify general pavement condition within the test section limits.
- Identify wheel paths.

#### **Task 3: Rod and Level Measurements**

- Mark wheel paths.
- 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 (i.e., the rod person) and another is needed to operate the level and take readings (i.e., the instrument operator). If the level is not capable of automatically recording readings, having an additional person to record the readings (i.e., a recordkeeper) will speed up the process.

According to the ASTM E1364, an experienced crew of three would require less than 10 s to obtain one reading.<sup>(16)</sup> This involves positioning the rod by the rod person, reading the level by the instrument operator, and recording the measurements by the recordkeeper.

### 4.3.2 Test Section Inspection and Preparation

The two wheel paths in the outside travel lane should be marked using the following procedure:

1. Clean the 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 the center of the lane from one of the following cases:
  - a. Case I—If wheel paths are easily identified, the midway point between the two wheel paths should be used as the center of the lane.
  - b. 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.
  - c. Case III—if 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 the length of the chalk line used for marking. Use the chalk line to mark a straight line between the previously established points.

The method by which the wheel paths were located should be noted in the Comments field of Forms RL-1 through RL-5 (figure 208 through figure 212). This will help in locating the wheel paths used for profile measurements at a future date.

Measurements must 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:

- 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 the pavement at 0.3-m intervals using a suitable marker. Markings have to be made along the entire length of the test section on both wheel paths.
- 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 test 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 set up is referred to as a backsight, whereas 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 foresight are referred to as intermediate sights. Use the following procedure to measure the longitudinal profile:

1. Complete the required Header information in Forms RL-1 through RL-5 (figure 208 through figure 212).
2. Set up 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 located near the center of the test section. The level should be set up at a position where it will not be disturbed by passing traffic. In addition, the level should be set up 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. Place the rod at the zero position of the section, and using the bubble level attached to the rod as a reference, hold the rod vertically. Once the rod is held vertically, the rod person should signal to the instrument operator to take a reading. If readings are recorded manually by a third crewmember, the instrument operator should call out the reading to the recordkeeper. Readings should be recorded in Forms RL-1 through RL-5 (figure 208 through figure 212). If an automated system is being used, the instrument operator should ensure the reading is saved.
4. Place the rod 0.3 m away from the initial reading and record a new reading. This process should be continued until either the entire test section is surveyed or the horizontal or 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 properly focus. 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. Relocate the level if the range of the level is exceeded during measurements. 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 taken at this location. If the readings do not agree within the resolution of the instrument, all readings taken from the current position of the level 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 (i.e., the foresight). Then, set up the instrument at the new location. Place the rod at the pivot point and take the reading (i.e., the 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 the zero position (i.e., the point from which the 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, the profile has to be measured again from the last pivot point to the end of the test section.

Measuring 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. The accuracy can be checked by establishing a set of control points along the wheel path (e.g., at 30-m intervals) starting from the beginning of the test 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 aforementioned 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:

- If the level is sensitive to temperature variations, it might need to be covered with an umbrella to protect it from direct sunlight.
- During windy conditions, profile measurements should be avoided, as movement of the level could occur.
- If the level has to be set up at more than one position during profile measurements, make the length to backsights and foresights equal. This will eliminate errors due to curvature and refraction at turning points.
- To reduce the error caused by the rod not being exactly vertical, set up the level as low as possible.

#### **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 are used to obtain the longitudinal profile of the pavement.

For profile computations, the elevation of the location where the first reading (i.e., the first backsight) was measured is needed. However, as only relative elevations are needed to compute roughness indices (e.g., 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.

$$IS = BM + RR1 \quad (1)$$

Where:

$IS$  = initial instrument height.

$BM$  = elevation of a point where the first backsight was taken (assume any value [e.g., 30 m]).

$RR1$  = rod reading at the first backsight.

$$\text{Relative Elevation of a Point} = IS - RR \quad (2)$$

Where:

$IS$  = initial instrument height.

$RR$  = rod reading at any point from the 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.

$$Nht = Oht + BS - FS \quad (3)$$

Where:

$Nht$  = new instrument height.

$Oht$  = old instrument height.

$BS$  = backsight at the pivot point.

$FS$  = foresight at the pivot point.

The relative elevation of points measured from this new instrument location can be determined by using equation 4.2 and using  $Nht$  instead of  $IS$ .

#### 4.3.6 Quality Control

A quality control check must be performed in the field to ensure that no movement of the level occurred 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 and 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 level. Different makes and models of levels require different adjustments. The following are some common adjustments that are required to obtain accurate measurements from levels. 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:

- Make the axis of the level bubble perpendicular to the 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.
- Adjust the horizontal crosshairs: This adjustment will ensure the horizontal cross hairs are truly horizontal when the rod and level is leveled.
- Adjust the 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.
- Check the rod 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 rod and level. Always clean the rod and level after measurements are completed. Before cleaning the lenses, blow any dust off the lenses, then clean the lenses using a soft cloth. Lenses should not be touched with fingers. If the rod and level becomes wet in the field, make sure it is completely dry before packing. The tripod should be inspected regularly to ensure connections are not loose.

## **4.6 RECORDKEEPING**

Forms RL-1 through RL-5 (figure 208 through figure 212) should be used to record readings when profile measurements are performed using the rod and level. A comment should be made on these forms as to how the wheel paths were located. All items in this form should be completed by the instrument operator or the recordkeeper. 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 DCC office, while the second copy should be retained by the operator in case the first copy fails to reach the DCC office.



## CHAPTER 5. PROCESSING COLLECTED DATA IN THE OFFICE

### 5.1 INTRODUCTION

All data collected by the HSSV and longitudinal and transverse profile data collected with the Dipstick are sent to the DCC office for processing.

In the LTPP program, the ProQual 2014 software is used in the Office Mode to process the longitudinal profile and macrotexture data collected by the HSSV and to perform quality assurance checks on the data.<sup>(7)</sup> The HSSV software is used to process the transverse profile data collected by the HSSV and to perform quality assurance checks on the data. The longitudinal and transverse profile data collected by the Dipstick are processed and quality assurance checks are performed using ProQual 2014. After the data are processed and quality assurance checks have been performed, data files for upload to the PPDB are created by ProQual, except for the transverse profile data collected by the HSSV. The transverse profile data files collected by the HSSV that are uploaded to the PPDB are created using the HSSV software. The data files to be saved in AIMS, except for transverse profile data collected by the HSSV, are also created by ProQual. This chapter presents guidelines for processing, performing quality assurance checks, and creating data files for upload to the PPDB for all data types described previously to ensure consistency and uniformity.

These guidelines should be viewed as the minimum required amount of data checking to be performed by the DCC. The DCC may already have procedures in place that exceed the minimum requirements described in this chapter. In such circumstances, the DCC should continue to use those procedures in addition to the procedures presented in this chapter. The guidelines for processing data and performing quality assurance checks are presented separately for each data type. Processing and evaluating longitudinal profile and macrotexture data collected by the HSSV and longitudinal and transverse profile data collected with the Dipstick are performed using ProQual. For each of these data types, general guidelines on data processing and quality assurance checks to be performed using ProQual are described. Detailed information on the operation of the ProQual 2014 software is presented in reference 7, while detailed information on the operation of the ProQual 2012 software is presented in references 12 and 13.

The DCC is not required to process profile data collected at WIM test sections except to perform quality assurance checks, if needed, to make sure data are error free. However, the DCC is required to store the profile data at WIM test sections according to the procedures described in section 5.7.

The DCC is required to name the image files captured by the camera in the HSSV using the file-naming convention described in section 5.8 and store the image files according to the procedures described in section 5.8.

### 5.2 LONGITUDINAL PROFILE AND MACROTEXTURE DATA COLLECTED BY THE HSSV

The following are the recommended procedures for processing and performing quality assurance checks on the data collected by the HSSV, except for the transverse profile data. Procedures for

processing and performing quality assurance checks on the transverse profile data collected by the HSSV are described in section 5.3. 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 the “Read XML” button in ProQual. All ARD files indicated in the XML file that are found in C:\profiles will be read into ProQual. Evaluate the data collected at each test section by using the following procedures:
  - a. Review the information shown in the Header screen and in the 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” tab in ProQual.
  - b. Correct any errors in any of the Headers that can be corrected. If there are errors that cannot be corrected (e.g., not using the photocell to initiate data collection) discard the data; profile data will have to be re-collected.

The following fields need to be reviewed after a set of data has been read into ProQual:

- Sequence—the sequence identifier for the visit. If the sequence identifier is incorrect, rename the raw data files and import the data files into ProQual.
- Time—the time when the data collection program in the HSSV software is activated before the start of the test section. Review the time to see if it is reasonable. If unreasonable, the time shown on the laptop computer of the HSSV should be checked for possible errors. If errors are detected, check with the operator to obtain the correct time when profile data were collected.
- Start Method—the start method for profile data collection is always PHOTOCCELL. If a method other than PHOTOCCELL 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—the route number where section is located (e.g., I-88). Check if this information is correct.
- Begin—the entry made for the Beginning Description field in the HSSV software. Check to see if the milepost has been entered in this field. If not, this field should show NONE.
- End—the entry made for the Ending Description field in the HSSV software. This field should show NONE.
- Lane—the lane where data were collected. Valid entries are INSIDE or OUTSIDE. Check if the entry in this field is correct.

- Direction—the travel direction when collecting data at the test section. Valid entries for this field are NORTH, EAST, SOUTH, or WEST. Check if the travel direction is correct.
- Stop Distance—the stop distance for GPS test sections is 152.4 m; verify the value is correct. For SPS projects, see if the value appears reasonable; the stop distance shown for SPS projects is the length of entire profile run.
- Average Speed—average speed during data collection, 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—operator and driver initials. Check for correctness. The operator and the driver should be identified by two characters each (i.e., the 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 data collection is performed as a one-person operation, the operator and driver name should be the same (e.g., CK/CK).
- Surface Type—the surface type. Should be “A-CC” for AC-surfaced pavements or “P-CC” for PCC-surfaced pavements. Check if the entered surface type is correct.
- Surface—the surface condition of the road. Valid entries are V. GOOD, GOOD, FAIR, and POOR. As this field is selected in the HSSV 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 test section during the previous test section visit be reviewed when checking this field. Otherwise, there could be variability in the value assigned to this field from 1 yr to another (e.g., V. GOOD during the latest visit, but the value for the previous visit was GOOD).
- Clouds—the cloud condition at the time of data collection. Valid entries are CLEAR, P. CLOUDY (Partly Cloudy), or CLOUDY. As this field is selected in the HSSV 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—the value in this field should always be Positive. The available options for this field are Positive or Negative.
- Units—the value in this field should show mm.
- Weather—the value in this field corresponds to the “Other Weather Conditions” field that was entered into the HSSV software. In the HSSV 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 HSSV operator to verify the entry is correct. The information in this field may be used when evaluating longitudinal profile data.

- Run End Comment—the entry made in the field by an operator at the end of a data collection 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 PHOTOCELL 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 data collection runs. There should not be runs with the comment “LATE PHOTOCELL INITIATION,” as the operator is required to complete additional runs if this condition is encountered. If there are runs with the comment “LATE PHOTOCELL INITIATION,” discard those runs.
- Profile Counts—the number of 25-mm interval datapoints. The “Pre,” “Run,” and “Post” counts for the left, right, and center sensor are shown. The ARD file contains longitudinal profile data for a distance of 152.4 m before the start of the test section (i.e., pre-run), the data collected within the section (i.e., run), and the data collected for a distance of 152.4 m after the end of the test section (i.e., post-run). The HSSV 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 test section, the profile count for “Pre” should be 6,096 if the data collection software was initiated at least 152.4 m before the start of the test section; this value could be less if the data collection software was initiated at a distance less than 152.4 m before the start of the test section. For any test section, the profile count for “Post” should be 6,096. For a GPS test section, the profile count for “Run” will be approximately 6,096. The profile count for “Run” for an SPS test section will vary depending on the length over which data were collected. Evaluate if the shown count values are satisfactory.
- Texture Counts—the number of 0.5-mm interval datapoints. The “Pre,” “Run,” and “Post” counts for the left and the right sensor are shown. The ARD file contains texture data for a distance of 30 m before the run (i.e., pre-run), data collected within the test section (i.e., run), and data collected after the run (i.e., post-run). The HSSV software displays the texture count for each sensor (i.e., left and right) for the pre-run, run, and post-run. For any test section, the texture count for “Pre” and “Post” should be approximately 60,000. For a GPS test section, the texture count for “Run” will be approximately 304,800. The texture count for “Run” for an SPS test 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 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 reasonable based on date and month of testing. If the temperatures appear 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 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 values appear reasonable based on the time and date of testing. If the surface temperatures appear questionable, check with operator who collected the data.
  - Global Positioning System—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.
2. Review the subsectioning information shown in the “Section” tab for data collected at SPS test sections to verify the test sections have been subsectioned properly. If errors are detected, perform subsectioning using the correct values.
  3. Review the longitudinal profile data and the indices computed from the longitudinal profile data. Use the following procedures to review the longitudinal profile data and the indices computed from the longitudinal profile data. This review is performed in the “Profile” secondary tab under the “Data QC” 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 the following items should be reviewed:
    - a. Computed indices—review the IRI values of the runs for the left, right, and center sensors for consistency. Also review the displayed SV and RMSVA values, which are average values for the left and right sensor data.
    - b. 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 evaluating the IRI values.
    - c. Computed indices for the test 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 value less than 0.04 m/km is desired.

Cross-correlation is being used as a quality control and 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 the DCC. The 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. 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. The operator should examine the 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, Form PROF-1 should be reviewed to see if the operator made any additional comments related to data collection runs in that report (figure 175). If variations between the data collection 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. Spikes in profiles—review the spike count for each run. If spikes are present, review the spike locations using the graphical feature in ProQual. If present, it should be determined 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 step 3f 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. Profile data and previous data—compare the current profile data for each path with data obtained during the previous test section 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 test section visits should be evaluated to determine if similar profile features are present in both datasets and 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 visits. If there are still discrepancies between profiles from the current and previous visits, verify that these differences are not caused by equipment problems or due to incorrect sub-sectioning of SPS test sections. If the horizontal offset of profile features is noted between visits, it may indicate a problem with sub-sectioning. Based on feedback provided by the DCC 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 the two previous test section visits and perform a comparison. If no explanation for the differences in profiles is found, submit the data to the appropriate DCC personnel for review.

Version 1.5.1.37 of ProQual does not have the ability to overlay profile data collected by the HSSV with data collected previously by other profilers used in the past to collect data at LTPP sections (e.g., ICC). A future version of ProQual might have the ability to overlay longitudinal profile data from the current visit with past data collected by any profiler that was used previously in the LTPP program.

When longitudinal profile data from the HSSV are compared to data collected with ICC profilers, differences in profile plots will be seen (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 HSSV data, both profile features and profile shapes should be similar.

- g. IRI values and previous IRI values—perform an IRI comparison of current versus previous test section visit data for each path (i.e., left, right, and center). If the difference in IRI values for a path exceeds 10 percent, check to see if the cause of the IRI change can be identified. If a cause for the change cannot be identified, submit the data to the appropriate DCC personnel for review to verify that the change in IRI was not caused by an equipment issue.
4. Review macrotexture data. Use the following procedures to review the macrotexture data and the indices computed from the macrotexture data. This review is performed in the “Texture” secondary tab that is under “Data QC” 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 the items described below should be reviewed.
    - a. Surface Finish—evaluate the Surface Finish entered by the operator and modify if needed. If data have been collected previously at the test section, 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's entry is correct.

- b. Texture Comment—evaluate the Texture Comment entered by the operator and modify if needed. If data have been collected previously at the test section, 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's 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. This feature is not currently active in version 1.5.1.37.
  - e. Section averages—review if the average MPD value that is computed from all runs for each wheel path is reasonable. The ProQual *User Guide* provides typical ranges of MPD for various pavement finishes.<sup>(12)</sup>
  - f. MPD and previous MPD—compare the MPD from the current visit with data from previous test section visits for each path (i.e., left and right). If the difference in MPD for a wheel path exceeds 10 percent, check to see if the cause for the MPD change can be identified. If a cause for the change cannot be identified, submit the data to the appropriate DCC personnel for review to verify that the change in MPD was not caused by an equipment issue.
5. Assign an RCO Code and RCO Note. These activities are performed in the “Header” secondary tab under the “Data QC” tab.

An RCO Code must be assigned to each profile run after quality assurance checks are performed on the data. Quality assurance checks include: reviewing operator comments; comparing IRI values and reviewing the standard deviation of IRI for each path (i.e., left, right, and center); comparing the profile data of replicate runs collected along each path (i.e., left, right, and center) during the test section visit; reviewing spikes in profile data and reviewing operator comments regarding spikes; comparing profile data with those collected during previous test section visits; and reviewing distress maps to investigate spikes in the data, if required.

Once these tasks have been completed, assign an RCO Code in ProQual for each profile run using the guidelines presented in section 5.5.

An RCO Note must be made for each profile run in ProQual. A dropdown 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 or selecting a comment from the dropdown list and typing in additional comments.

The following are reasons for making an entry in the RCO Note field: indicating improper DMI calibration, indicating if spikes are pavement-related, and indicating the cause(s) for variability in profiles.

The following comments are available in the dropdown 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. ProQual version 1.5.1.37 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 regarding a data collection run, the comment PROFILE DATA OK must be selected from the dropdown list in the RCO Note field.

6. Select runs for upload to the PPDB and create upload files. From all available longitudinal profile runs, select five profile runs for upload. In the past when the RSC collected data, there may have been differences in the way each selected the five runs for upload. Use the procedure the DCC has used in the past 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 the appropriate DCC personnel for review and upload to the PPDB. If any problems are encountered during upload, they should be resolved and the corrected data should be uploaded to the PPDB.
7. Store data. Use ProQual to create data files that are to be stored in AIMS. The menus for creating XML files that are to be stored in AIMS are located in the “Data QC” tab. To create AIMS FRD Export XML files, select the AIMS FRD button. To create Section Export XML Files, select AIMS Section. Use the procedures indicated in the current version of LTPP Directive I-171 to store these data files and the raw data collected by the HSSV (i.e., ARD files).<sup>(10)</sup>

## **5.3 TRANSVERSE PROFILE DATA COLLECTED BY THE HSSV**

### **5.3.1 Transverse Profile Data Uploaded to the PPDB**

The transverse profile data collected by the HSSV at LTPP test sections are processed in the office to perform quality assurance checks on the data and generate XML files containing the transverse profile data for upload to the PPDB. Intensity and range images are also generated at 1-m intervals for upload to the PPDB. For each test section visit, transverse profile data collected for one data collection run and the associated intensity and range images are uploaded to the PPDB.

The following are descriptions of the transverse profile data contained in the XML file that is created for upload to the PPDB:

- Longitudinal spacing of transverse profile data—transverse profile data at 0.3048-m intervals are contained in the XML file. The TPMS obtains data at approximately 25-mm

intervals. At each 0.3048-m interval, the transverse profile data obtained at approximately 25-mm intervals are averaged over a distance of 0.3048 m centered at each 0.3048-m interval to produce an averaged transverse profile (i.e., at each data-reporting location, data for either 13 or 14 transverse profiles are averaged). Thereafter, a 50.8-mm moving average is applied to the averaged transverse profile. The values of 0.3048 and 50.8 mm are specified in the Transverse Analysis menu of the HSSV software (section 2.4.2.2.2).

- Location of the start and end of transverse data—the TPMS obtains transverse profile data over a length of 3.96 m, with 2,048 data points obtained for each transverse profile. The limits for the start and end of the transverse profile data within the lane is determined based on the lane markings. For each transverse profile, the first data point (i.e.,  $X = 0$ ) will be located 12.5 mm from the inside edge of the lane stripe at the edge of the lane. The value of 12.5 mm is specified in the Transverse Analysis menu of the HSSV software (section 2.4.2.2.2). The location of the last data point is determined based on the minimum width of the lane within the test section.
- Data interval in the transverse profile—the interval between data points in a transverse profile is 1.93 mm. This value cannot be changed by a user.
- Normalization of transverse profile data—each transverse profile included in the XML file is a normalized profile (i.e., the elevation of the start and end location of each transverse profile is set to 0).

Only the transverse profile data are uploaded to the PPDB. The rut depths are computed by the TSSC from the uploaded transverse profile data using a specialized program.

### **5.3.2 Settings in the HSSV Software**

Proper settings must be specified in Analysis Options, Transverse Analysis, and Report Options menus of the HSSV software to process the transverse profile data. The required settings for these three menus are described in section 2.4.2.2. All computers used by the DCC to process transverse profile data must have these settings specified in the HSSV software.

### **5.3.3 Processing Data Collected at GPS Test Sections**

For GPS test sections, use the following procedures to perform quality assurance checks on the transverse profile data and create XML files that contain the transverse profile data for upload to the PPDB.

1. Load the HSSV software and select “View Transverse” (figure 156).
2. Go to “File,” select “Open,” and load the desired ARD file (figure 157).

After the ARD file is loaded, the screen will appear as shown in figure 158. Multiple files can be opened at once, and each opened file will have a separate tab on the main bar.

3. Go to “Distance Labels” on the top menu and select “Distance from the Start” so the distance in meters from the start of the test section will be displayed instead of stations, as shown in figure 159. Distance = 0 corresponds to the start of the test section.

By default, the viewer will display the intensity data. The image shown on top of the screen is called the Main View, and the image shown on the middle of the screen is called the Overview. The Overview shows a horizontally flattened view of the entire run. The Main View shows a portion of the roadway selected in the Overview.

The following are ways to increase or decrease the distance from the start to view the image in the Main View:

- a. Using the mouse—the distances on the image shown on the Main View can be increased by placing the mouse over Main View or Overview and then moving the mouse wheel forward. The distance can be decreased by moving the mouse wheel backward.
- b. Using arrow buttons on the Overview menu—the user can use the arrow buttons on the left and right side of the Overview menu to increase or decrease the distance value.
- c. Using cursors—the left and right cursor keys can be used to increase or decrease the distances, respectively, in short increments. Pressing the Shift key on the keyboard plus the appropriate cursor key can increase or decrease distances in large increments.

When the Overview is clicked, a box outlined by blue appears and the area highlighted by the blue box is shown in the Main View. The user can click anywhere in the Overview to show the selected portion on the Main View.

The user can also enter a distance value in the Center On field, and the image for a distance of 40 m centered on this distance will be shown in the Main View. From the top menu, under “Go To,” the user can select Start to go to the start of the test section or End to go to the end of the test section.

The default orientation of the images for the Main View and the Overview is Horizontal. The orientation can be changed to vertical by going to the top menu and selecting Orientation and then selecting Vertical. The Overview is now shown on the right and the Main View is now shown on the left.

The navigation panel, graph at the bottom, and right panel are displayed by default. The user has the option to disable any of these items by going to Display in the top menu.

The contrast of the shown images can be adjusted by accessing the Image Adjustment tab on the upper right side of the screen below the Information tab.

4. Review the lane edges detected by the HSSV software. When the file is loaded, the viewer attempts to find lane edges by detecting lane markings. With the “Image” selected as “Intensity,” the blue line in the Intensity image shows the lane edges that are detected

by the HSSV software (figure 160). The HSSV software first detects the right edge of the lane. Then, based on the minimum width of the test section, the HSSV software detects the left edge of the lane.

The intensity at the two edges of the lane at any transverse profile location can be viewed by clicking on the Main View. When the Main View is clicked, a magenta-colored line will be shown on the Main View and the Overview. The graph at the bottom will show the intensity levels at the edges of the transverse profile as shown in figure 160. “Use Outside Lane as Origin” is checked as default. In the LTPP program, the transverse profile at the outside lane edge is treated as the  $X = 0$  location.

Use any of the methods described in steps 3a through 3c to scroll through the test section to view the lane edges detected by the HSSV software.

5. Select “Edit Lane Edges” from the menu on top of the Main View and the image shown in figure 161 will be displayed. The blue dots show the lane edges detected by the HSSV software. Points calculated from lane markings show up as thick circles; points that are interpolated from other points show up as thin circles. These points can be moved if desired. Scroll through the test section to review the circles corresponding to lane edges detected by the HSSV software by comparing them to the actual lane markings; the lane edge at the right side of the lane is shown by the solid white stripe at the edge of the lane. If needed, adjust the blue dots at specific locations to change the lane edges detected by the HSSV software. Moving a circle will change the pavement width at that location. Therefore, if the circle at the outer edge is moved, the corresponding circle at the inner edge will also need to be moved to keep the pavement width at the desired value. If numerous circles require adjustment, it is better to do a global adjustment (via Menu - Lane Edge/Recalculate from Opposite Edge and Lane Width/Left Edge). Select “File” from the top menu and then save for the changes to be saved in the ARD file.
6. Review the transverse profile data. Go to “Image” on the top menu and then select “Range.” Then, check “Wireline” on the field on top of the graph at the bottom. The screen will appear as shown in figure 162. The transverse profile graph at the bottom will show the wireline fitted to the data. Click on the Main View at selected locations (i.e., every 3 to 5 m) from start of the test section until 152 m is reached and view the transverse profile displayed at the bottom. The main view displays 45 m of data. Use one of the methods described in step 3a through 3c to advance when the end of the Main View is reached. Observe if the transverse profile contains spikes, humps, or any strange features. If spikes are noted, determine if they were caused by pavement features. Longitudinal profile and distress data from the test section can be used to determine if spikes are pavement-related.)

If spikes or any anomalous features are noted, click just beyond that location on the Main View so that the magenta line is shown. Then, click “View 3D” on top of the Range data at the right. A three-dimensional view of the data up to a distance of 5 m before the magenta line will be displayed, as shown in figure 163. This image can be zoomed in or rotated if needed to get a closer look at the spikes or anomalous features.

The following information about the profile line that is selected (i.e., the magenta-colored line) is shown on the panel on the right side, as shown in figure 164:

- Lane edge—left boundary location, right boundary location, and lane width.
- Wireline rut parameters—left rut depth, right rut depth, left rut cross-sectional area, and right rut cross-sectional area.
- AASHTO rut parameters—left rut depth, right rut depth, left rut cross-sectional area, and right rut cross-sectional area.

This information can be reviewed if needed for different transverse profiles within the test section. The information shown for a particular distance is that for an averaged transverse profile. Transverse profiles located within a distance of 0.3048 m centered at that distance are averaged to produce the averaged transverse profile (i.e., transverse profiles located  $\pm 0.1524$  m from each side of the line in question are averaged to produce the average transverse profile).

7. Look for the presence of anomalous features. If spikes or anomalous features are detected in the transverse profile that cannot be explained by pavement features (through a review of longitudinal profile and distress data), load the transverse profile data collected for another run at the test section and review the data using the procedures described in step 2 through step 6. If this transverse profile does not have anomalous features, discard the previously reviewed profile and use the profile for further analysis. If this transverse profile also has the same anomalous features noted in the previous transverse profile, use one of the transverse profiles for further analysis.
8. Select “File” and then “View Analysis Summary” from the top menu (figure 165).

A summary of the rut parameters at the test section at 3-m intervals will be displayed, as shown in figure 166. Rut depths are computed for averaged transverse profiles at 0.3048-m intervals and then averaged. At each 0.3048-m interval, transverse profiles obtained over a distance of 0.3048 m centered at that location are averaged to obtain an averaged transverse profile (i.e., transverse profiles located  $\pm 0.1524$  m from each side of the line in question are averaged to produce the average transverse profile).

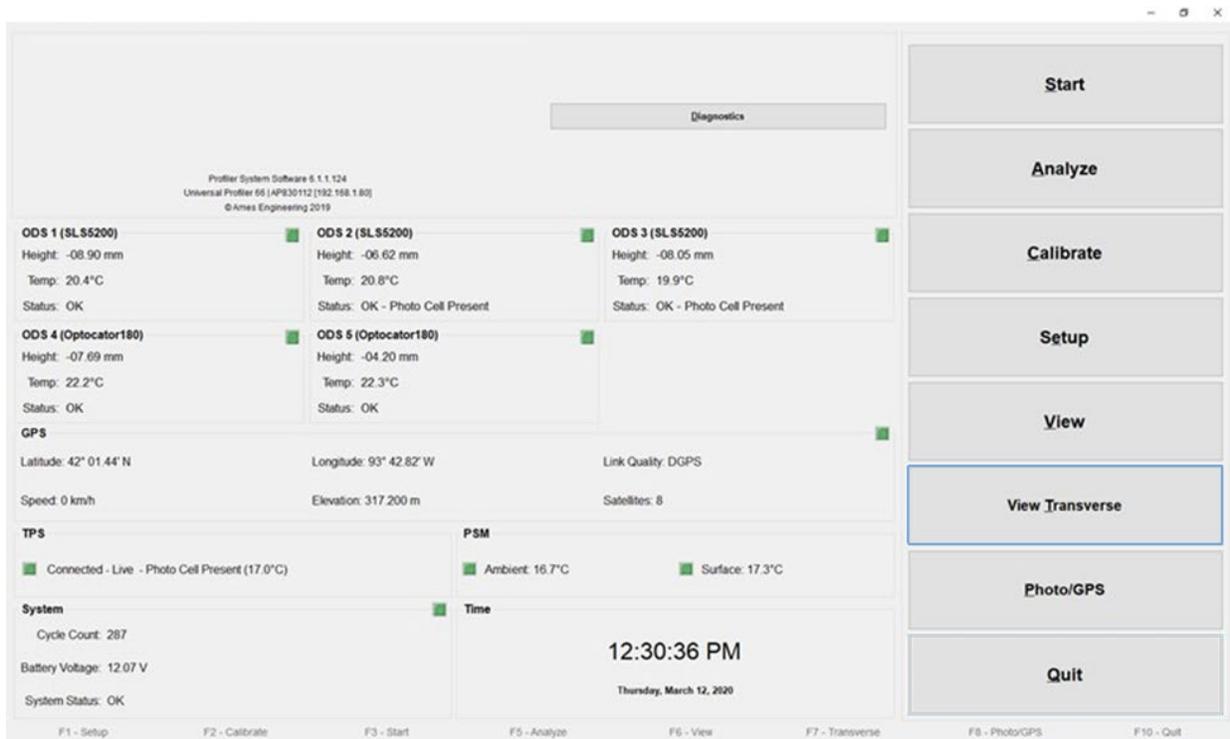
Highlight this sheet and copy the table to an Excel file. Name the Excel file using the test section number, run number, and the date of testing. Review the left and right rut depths using the wireline method to detect any anomalies. If transverse profile data have been collected at the test section previously, compare the rut depths from the current data collection with the rut depths computed for the previous visit to the test section. If significant differences are noted for rut depths between the two datasets, investigate to identify the reason for the difference.

9. If no issues are found with the data, go to “File” in the top menu and select “Export Section Files” (figure 167).

The screen will show a window similar to that shown in figure 168. This window shows the Site ID and Start and End distances, which should be 0 and 152.4 m, respectively.

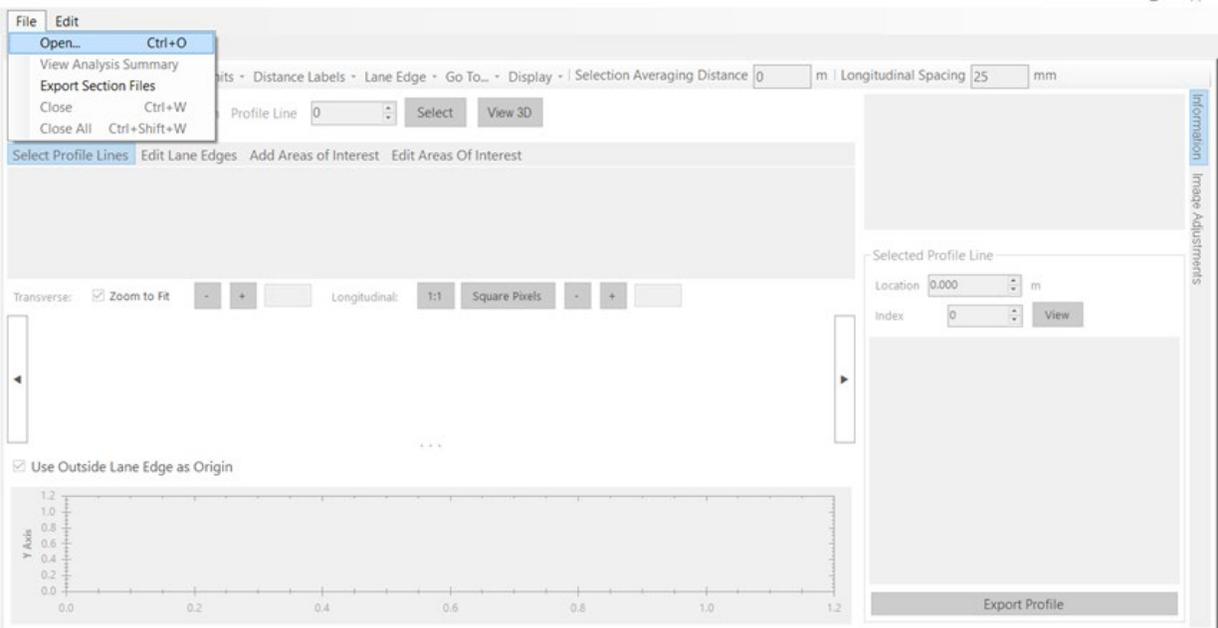
The “Write XML” and “Write Images” boxes are checked by default. Add any desired comments in the Comments field and click on “Export” to create an XML file containing the transverse profile data. The comments are not imported into the PPDB. The DCC can elect to enter any comments (e.g., if lane edges were adjusted, a comment can be made regarding lane adjustment) that may be useful when the XML file is viewed in the future and questions arise about the exported data.

10. If any anomalous data were noted within the test section, edit the created XML file to eliminate the locations where anomalous data were present. If any data are to be eliminated, a comment can be made regarding this before exporting the data.
11. Store the ARD file containing the transverse profile data used to create the XML file for upload to the PPDB in the AIMS. The transverse profile data from other ARD files at this test section can be removed prior to storing the ARD files in AIMS by using the HSSV software tool provided by the manufacturer. This tool removes the transverse profile data from the ARD file while keeping all other data intact. The reason for removing the transverse profile data from an ARD file is to reduce the file size.



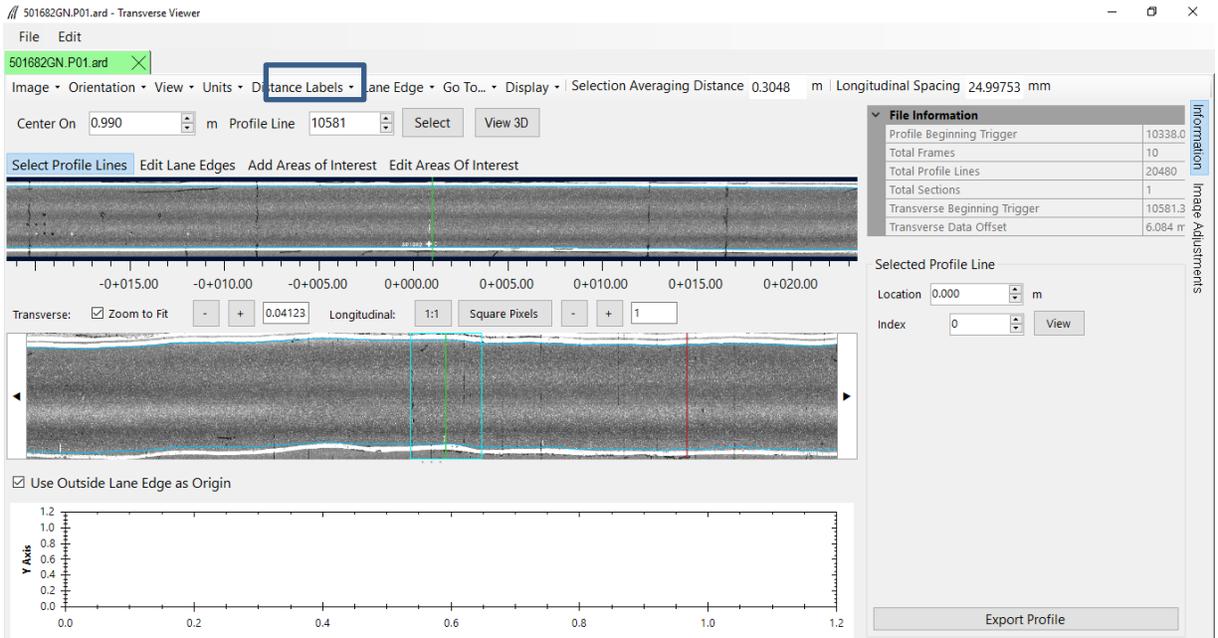
Source: FHWA.

**Figure 156. Screenshot. HSSV software with View Transverse highlighted.**



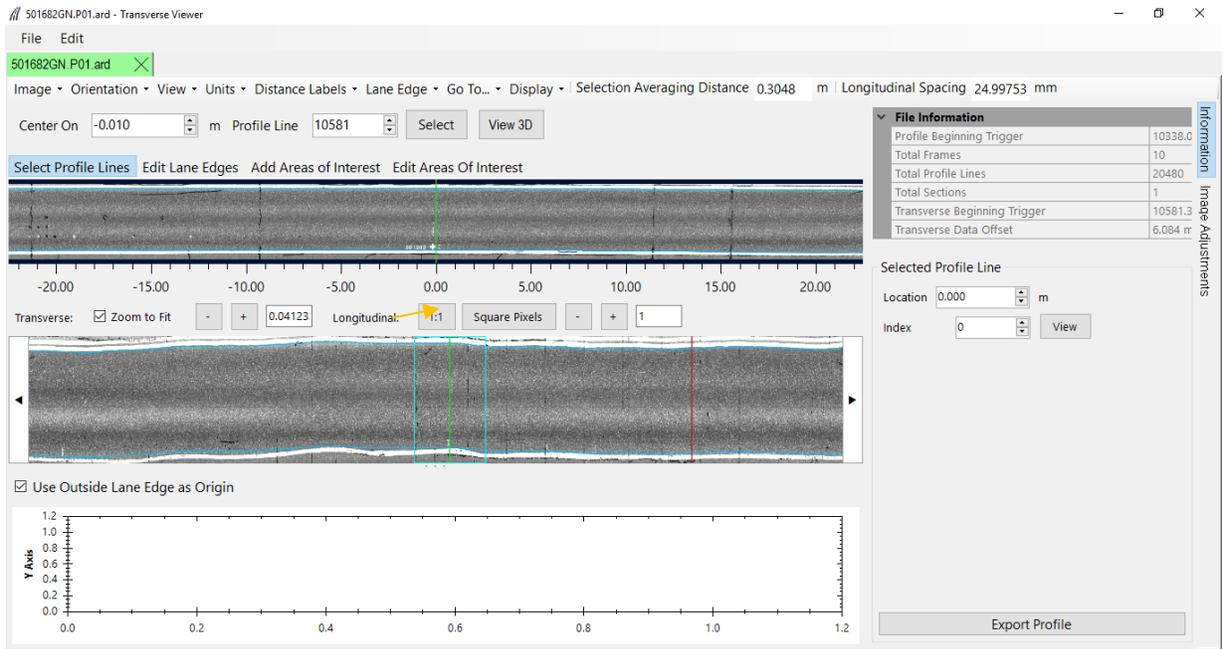
Source: FHWA.

**Figure 157. Screenshot. Loading an ARD file.**



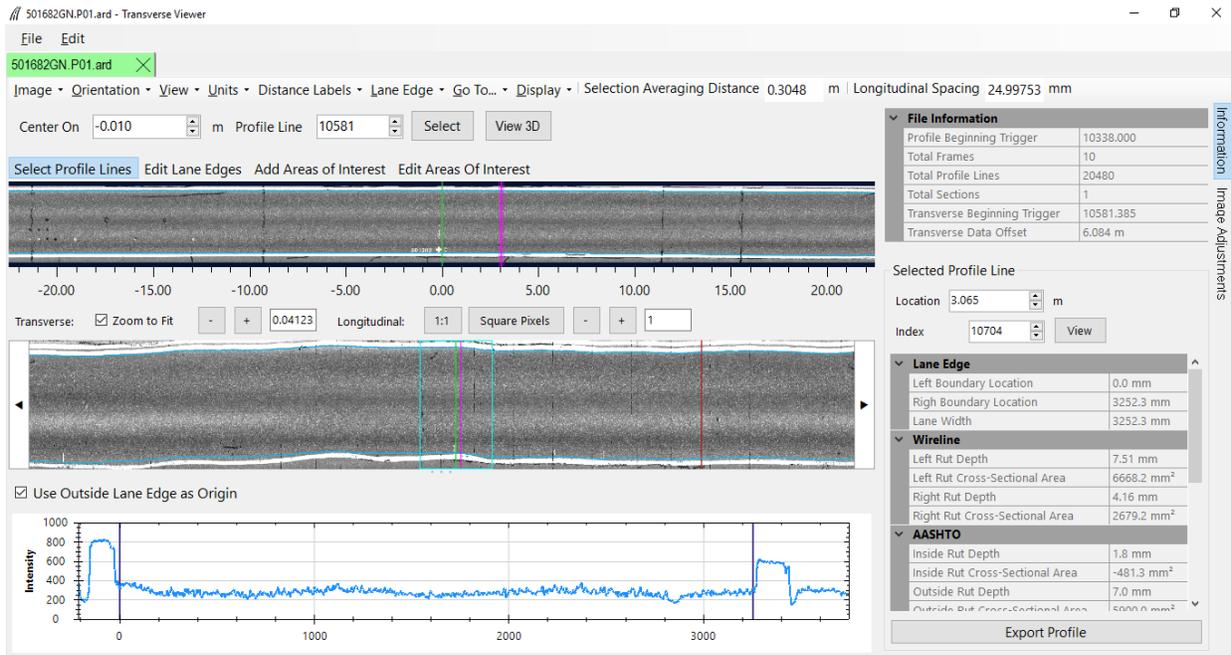
Source: FHWA.

**Figure 158. Screenshot. View of the screen after loading the ARD file.**



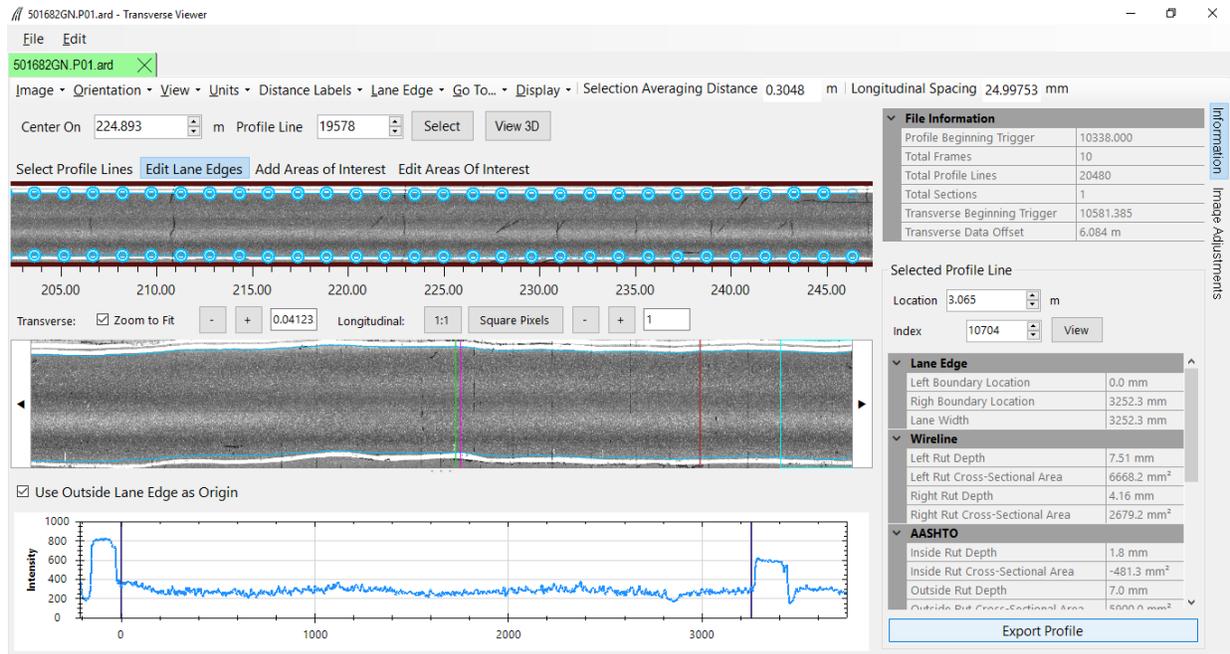
Source: FHWA.

**Figure 159. Screenshot. View of the screen with distance shown in meters.**



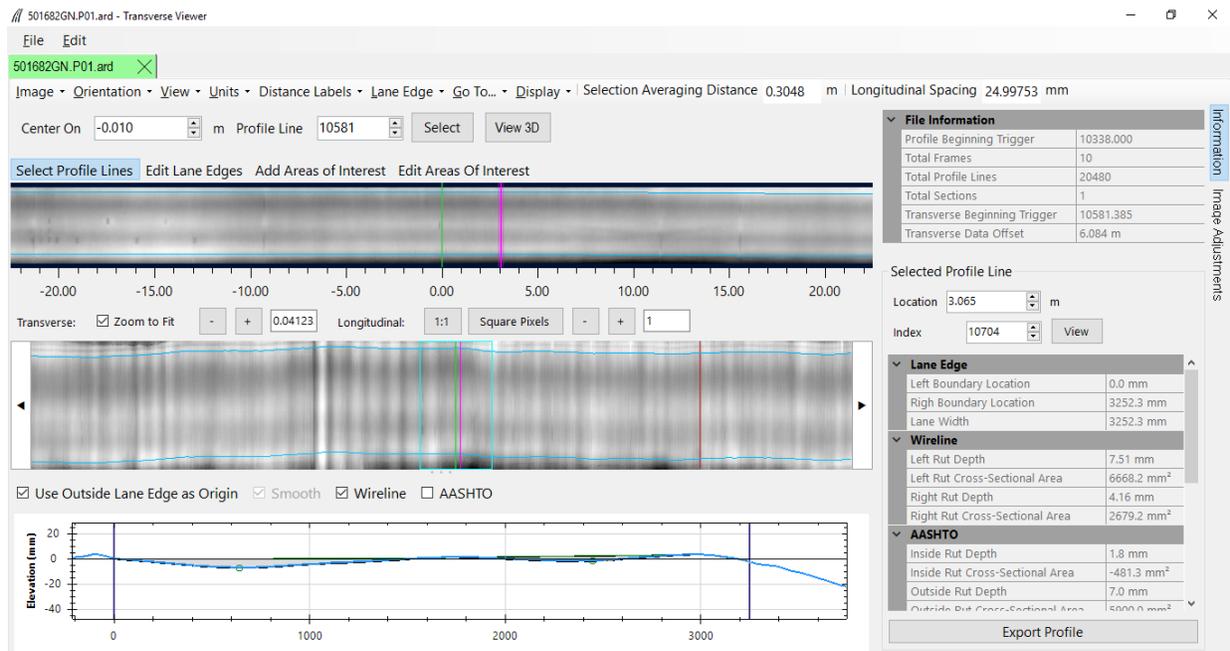
Source: FHWA.

**Figure 160. Screenshot. Graph of intensity shown at the bottom.**



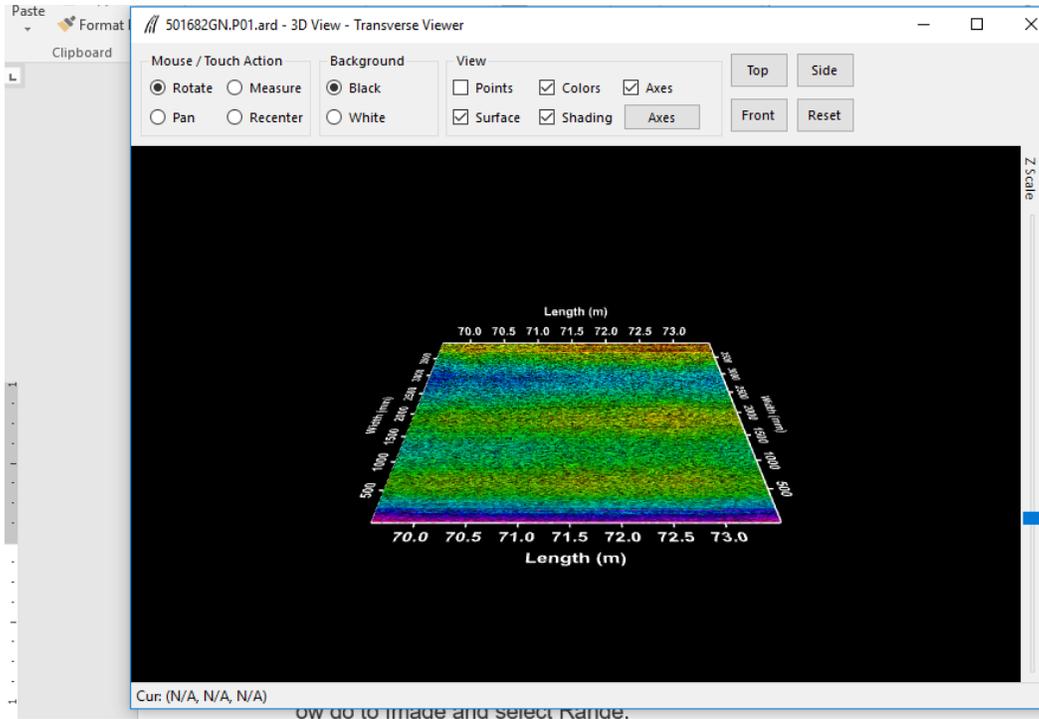
Source: FHWA.

**Figure 161. Screenshot. View when Edit Lane Edges is selected.**



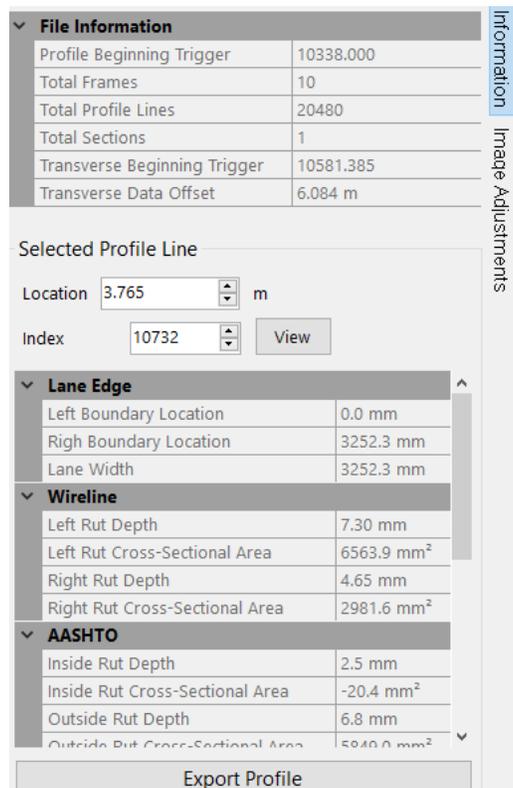
Source: FHWA.

**Figure 162. Screenshot. View of range data.**



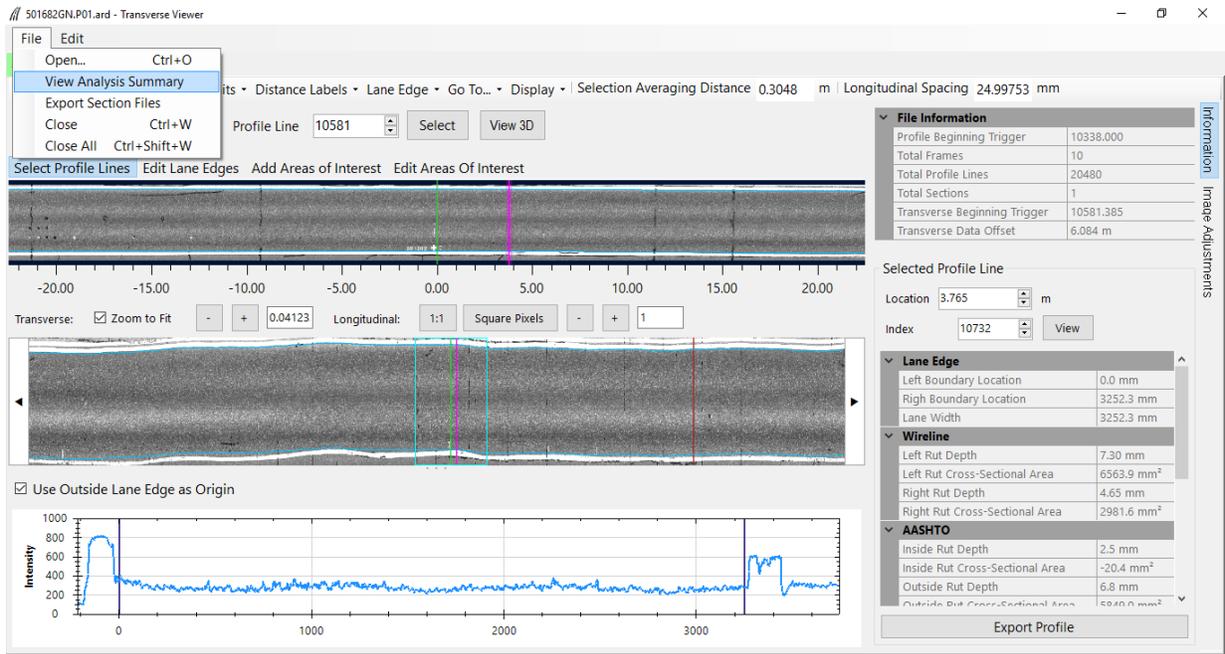
Source: FHWA.

**Figure 163. Screenshot. Three-dimensional view of the range data.**



Source: FHWA.

**Figure 164. Screenshot. Information about the selected transverse profile.**



Source: FHWA.

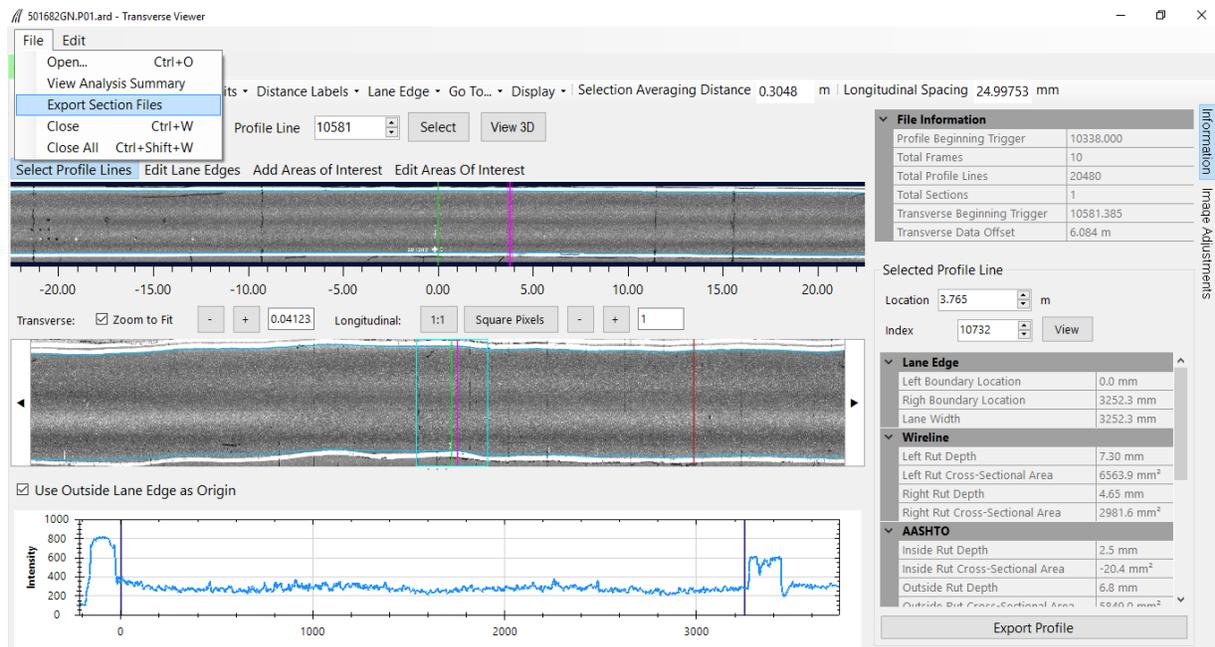
Figure 165. Screenshot. Selecting View Analysis Summary.

Analysis (501682GN.P01.ard)

Distance (m)	Left Rut Depth, AASHTO (mm)	Center Rut Depth, AASHTO (mm)	Right Rut Depth, AASHTO (mm)	Left Rut Cross Sectional Area, AASHTO (mm <sup>2</sup> )	Center Rut Cross Sectional Area, AASHTO (mm <sup>2</sup> )	Right Rut Cross Sectional Area, AASHTO (mm <sup>2</sup> )	Left Rut Depth, Wireline (mm)	Right Rut Depth, Wireline (mm)	Left Rut Cross Sectional Area, Wireline (mm <sup>2</sup> )	Right Rut Cross Sectional Area, Wireline (mm <sup>2</sup> )
0.00	-7.00	0.00	-1.89	6068.40	0.00	-340.14	7.72	4.06	7000.96	2705.14
3.00	-6.72	0.00	-1.74	5647.17	0.00	-804.53	7.37	4.25	6477.76	2664.01
6.00	-6.90	0.00	-1.35	5921.10	0.00	-1028.87	7.58	3.76	6808.84	2359.62
9.00	-7.25	0.00	-2.02	6218.08	0.00	-551.20	8.05	4.06	7226.75	2474.00
12.00	-6.43	0.00	-1.13	5358.78	0.00	-818.38	6.93	3.05	6018.11	1978.60
15.00	-6.85	0.00	-1.25	5661.56	0.00	-1033.55	7.29	3.59	6299.91	2071.96
18.00	-6.27	0.00	-1.70	5150.24	0.00	-454.07	6.58	3.69	5605.32	2220.36
21.00	-6.60	0.00	-1.93	5580.02	0.00	-203.71	7.01	3.79	6289.64	2280.61
24.00	-6.61	0.00	-1.99	5694.68	0.00	-24.05	6.87	3.63	6133.48	2185.52
27.00	-6.59	0.00	-2.21	5739.14	0.00	61.26	6.92	4.03	6202.78	2591.13
30.00	-6.52	0.00	-2.66	5470.05	0.00	380.52	6.78	4.49	5870.75	2890.74
33.00	-7.04	0.00	-2.39	5878.82	0.00	193.38	7.30	4.23	6326.21	2699.82
36.00	-6.47	0.00	-1.96	5493.70	0.00	-165.26	6.75	3.81	5920.09	2300.28
39.00	-6.50	0.00	-2.09	5387.25	0.00	6.92	6.77	3.89	5851.41	2401.51
42.00	-6.54	0.00	-2.01	5531.59	0.00	-185.03	6.79	3.91	5923.88	2355.37
45.00	-6.26	0.00	-1.79	5228.68	0.00	-311.81	6.45	3.73	5600.16	2167.68
48.00	-6.65	0.00	-2.42	5341.49	0.00	420.35	6.89	4.01	5788.37	2506.67
51.00	-6.48	0.00	-2.36	5297.90	0.00	390.57	6.72	3.87	5756.43	2346.09
54.00	-6.14	0.00	-2.26	5128.21	0.00	423.66	6.42	3.64	5605.74	2128.05
57.00	-6.35	0.00	-1.94	5298.94	0.00	202.32	6.61	3.27	5702.07	1872.53
60.00	-6.55	0.00	-1.95	5516.23	0.00	231.10	6.83	3.37	5971.03	2042.59
63.00	-6.29	0.00	-2.01	5309.74	0.00	409.33	6.53	3.39	5687.53	2187.31
66.00	-6.20	0.00	-2.28	5122.76	0.00	612.52	6.42	3.68	5573.92	2374.54
69.00	-6.66	0.00	-2.58	5556.96	0.00	950.43	6.88	3.83	6035.25	2529.24
72.00	-6.99	0.00	-2.23	5960.27	0.00	821.36	7.21	3.46	6418.98	2319.91
75.00	-6.46	0.00	-1.25	5494.49	0.00	-194.20	6.71	2.89	5951.12	1766.07
78.00	-6.53	0.00	-1.55	5450.11	0.00	197.86	6.81	2.90	6000.91	1837.63
81.00	-7.07	0.00	-1.95	6033.84	0.00	729.73	7.44	3.03	6702.25	2061.36

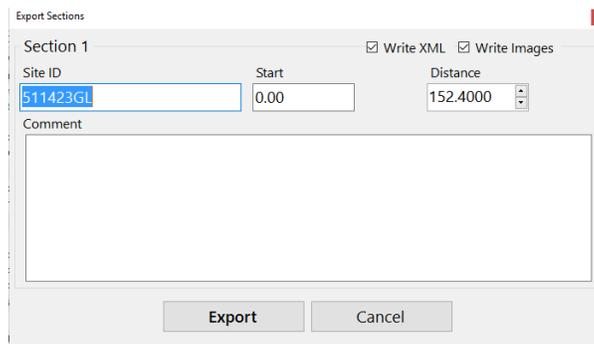
Source: FHWA.

Figure 166. Screenshot. Rut depths computed by the HSSV software.



Source: FHWA.

**Figure 167. Screenshot. Exporting transverse profile data.**



Source: FHWA.

**Figure 168. Screenshot. Exporting data to a file.**

### 5.3.4 Processing Data Collected at SPS Test Sections

For SPS test sections, use the following procedures to perform quality assurance checks on the transverse profile data and create XML files that contain the transverse profile data for upload to the PPDB:

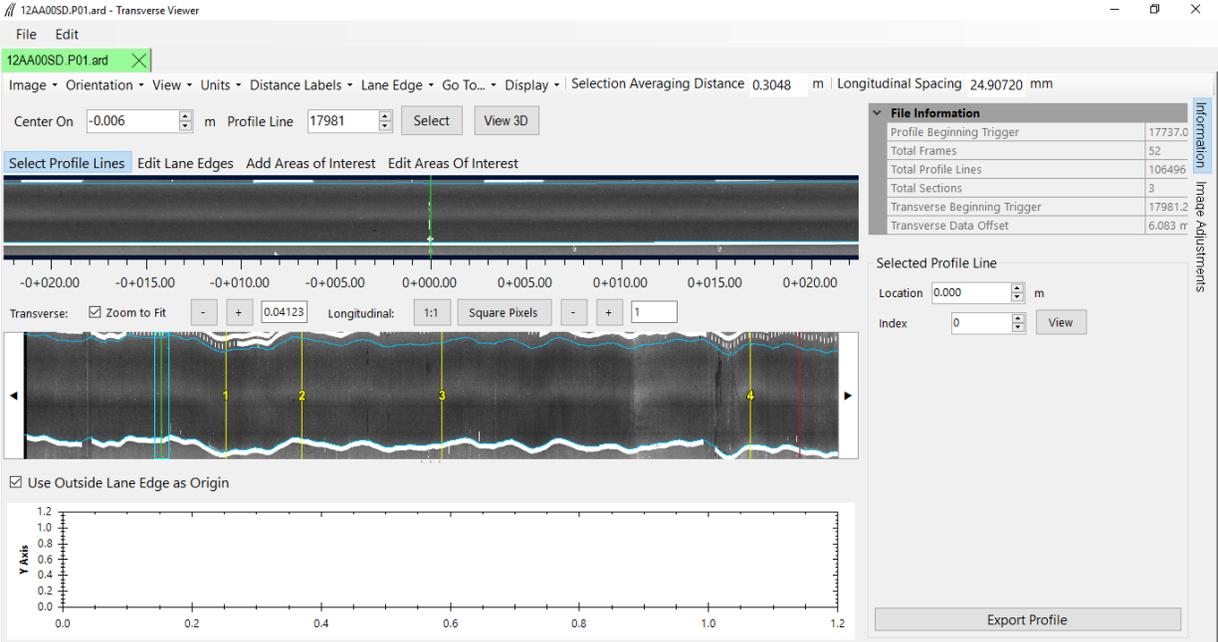
1. Load the HSSV software and select “View Transverse” (step 1 of section 5.3.3).
2. Go to “File,” select “Open,” and load the desired ARD File (step 2 of section 5.3.3). Figure 169 shows an example of an ARD file that contains data collected at an SPS project loaded into the HSSV software. The yellow vertical lines in the Overview show the detected event marks after the start of the test section. These event marks correspond

to the start location of the SPS test sections within the project detected after the end of the first test section (i.e., the first test section in the project is at Distance = 0).

3. Go to “Distance Labels” on the top menu and select “Distance from the Start” so the distance from the start of the test section in meters will be displayed instead of stations. Distance = 0 corresponds to the start of the test section.
4. Go to “File” on the top menu and select “Export Section Files” (figure 170). A screen similar to that shown in figure 171 will be displayed. This screen shows the start and end distance of each SPS test section based on the event marks detected by the photocell. However, the Site ID displayed for all test sections is the same and reflects the file name of the loaded file. There is a possibility for the photocell to be triggered by reflective features or other marks apart from the reflective marks at the start of each SPS test section. Review the start and end locations of the test sections with the site layout of the SPS project and identify any false event locations that do not correspond to the start of an SPS test section.
5. Scroll through the data corresponding to each SPS test section (i.e., from 0 to 152.4 m for the first section and from the start of the test section for a distance of 152.4 m for the other test sections) to view the lane edges that were detected by the software as described in step 4 of section 5.3.3.
6. Select “Edit Lane Edges” from the menu on the top of the Main View. As described in step 5 of section 5.3.3, scroll through the data corresponding to each SPS test section (i.e., from 0 to 152.4 m for first test section and from the start of the test section for a distance of 152.4 m for the other test sections). Review the circles corresponding to the lane edges that were detected by the HSSV software by comparing them to the actual lane markings; the lane edge at the right side of the lane is shown by the solid white stripe at the edge of the lane. If needed, adjust the blue dots at specific locations to change the lane edges that were detected by the HSSV software. Moving a circle will change the pavement width at that location. Therefore, if the circle at the outside edge is moved, the corresponding circle at the inner edge will also need to be moved to keep the pavement width at the desired value. If numerous circles require adjustment, it is better to do a global adjustment (via Menu - Lane Edge/Recalculate from Opposite Edge and Lane Width/Left Edge). Select “File” from the top menu and then “Save” for the changes to be saved in the ARD file.
7. Review the transverse profile data. Follow the procedure described in step 6 of section 5.3.3 to review the transverse profile data within each SPS test section.
8. Look for the presence of anomalous features. If spikes or anomalous features are detected in the transverse profile within any SPS test section that cannot be explained by pavement features (through a review of longitudinal profile and distress data), load the transverse profile data collected for another run at the test section and review the data using the procedures described in step 2 through step 7. If this transverse profile does not have anomalous features, discard the previously reviewed profile and use the profile for further

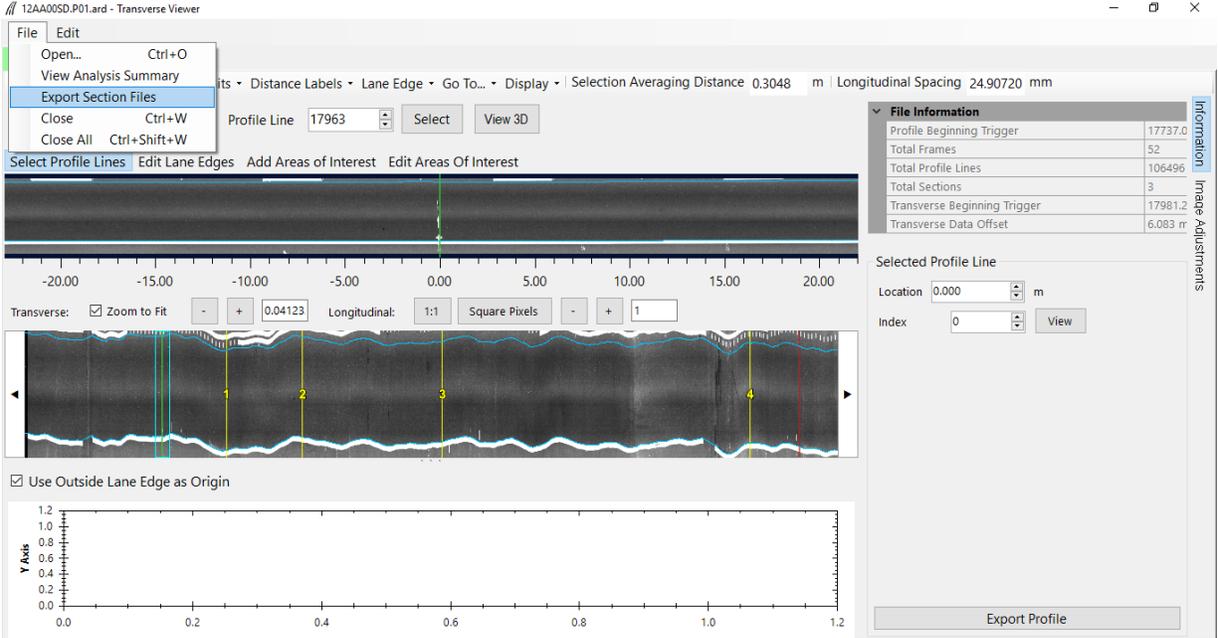
analysis. If this transverse profile also has the same anomalous features that were noted in the previous transverse profile, use one of the transverse profiles for further analysis.

9. Use the procedures described in step 8 of section 5.3.3 to view the Analysis Summary. Highlight this sheet and copy the table into an Excel file. Name the Excel file using the SPS test section number, run number, and the date of testing. Review the left and right rut depths using the wireline method for data corresponding to each SPS test section to detect any anomalies. Data in this file can be used the next time data are collected at the test section to compare the rut depths.
10. Go to “File” in the top menu and select “Export Section Files” as described in step 4. The screen will show a window similar to that shown in figure 172. The Site ID values shown will be the same for all test sections in the SPS project. Type the appropriate Site ID in each field. When the Site ID is typed, a check mark appears in the box next to Write XML and Write Images. This means an XML file containing the exported transverse profile data and intensity and range images will be created for the test section. If any false event locations that do not correspond to the start of an SPS test section were identified, ignore such locations. As Write XML and Write Images are not checked for such test sections, an XML file or images will not be created for such test sections. Then, add any desired comments in the Comments field and click Export to create XML files containing the transverse profile data and intensity and range images. The comments are not imported into the PPDB. The DCC can elect to enter any comments (e.g., if lane edges were adjusted, a comment can be made regarding lane adjustment) that may be useful when the XML file is viewed in the future if any questions arise about the exported data.
11. If any anomalous data were noted within a test section, edit the created XML file corresponding to the test section to eliminate the locations where anomalous data were present. If any data are to be eliminated, a comment can be made regarding this before exporting the data.
12. Store the ARD file containing the transverse profile data that was used to create the XML file for upload to the PPDB in the AIMS. The transverse profile data from other ARD files at this test section can be removed prior to storing the ARD files in AIMS by using the HSSV software tool provided by the manufacturer. This tool removes the transverse profile data from the ARD file while keeping all other data intact. The reason for removing the transverse profile data from an ARD file is to reduce the file size.



Source: FHWA.

**Figure 169. Screenshot. Example of an ARD file at an SPS project loaded to the HSSV software.**



Source: FHWA.

**Figure 170. Screenshot. Selecting Export Section Files.**

Export Sections ✕

**Section 1**  Write XML  Write Images

Site ID: 12AA00SD      Start: 0.00      Distance: 152.4000

Comment:

**Section 2**  Write XML  Write Images

Site ID: 12AA00SD      Start: 207.55      Distance: 152.4000

Comment:

**Section 3**  Write XML  Write Images

Site ID: 12AA00SD      Start: 456.30      Distance: 152.4000

Comment:

**Section 4**  Write XML  Write Images

Site ID: 12AA00SD      Start: 912.85      Distance: 152.4000

Comment:

**Section 5**  Write XML  Write Images

Site ID: 12AA00SD      Start: 1,917.26      Distance: 152.4000

Comment:

Source: FHWA.

**Figure 171. Screenshot. Start and end locations of SPS test sections.**

Export Sections ✕

**Section 1**  Write XML  Write Images

Site ID:       Start:       Distance:  ▲▼

Comment:

**Section 2**  Write XML  Write Images

Site ID:       Start:       Distance:  ▲▼

Comment:

**Section 3**  Write XML  Write Images

Site ID:       Start:       Distance:  ▲▼

Comment:

**Section 4**  Write XML  Write Images

Site ID:       Start:       Distance:  ▲▼

Comment:

**Section 5**  Write XML  Write Images

Site ID:       Start:       Distance:  ▲▼

Comment:

Source: FHWA.

**Figure 172. Screenshot. Screen for exporting data to a file.**

## 5.4 LONGITUDINAL DIPSTICK DATA

Version 1.5.1.37 of ProQual 2014 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 for processing and performing quality assurance checks on longitudinal profile data collected with a Dipstick:

1. Check if Dipstick passed the pre- and post-measurement checks and if data met the closure error. Check Form DS-7 to verify that Dipstick passed the zero and calibration checks prior to and after data collection (figure 199). Check Form DS-1 to verify the closure error was within the acceptable value (figure 193).
2. Enter the Header information. This section presents general procedures for navigating through the different ProQual menus and specifies the information that should be present in the Header fields. Details on the procedures for navigating between menus are presented in the ProQual user manuals.<sup>(12,13,14)</sup>

Appropriate parameters that have to be entered into ProQual to process Dipstick data must be entered using the guidelines presented in the ProQual user manuals.<sup>(12,13,14)</sup>

To enter the Header information of a test section into ProQual, select “Manual” from the main menu, then select the “Longitudinal” option. Thereafter, select “Site” from the left side of the screen. If the site has not been created in ProQual, create the site by selecting “System” in the main menu and then selecting the “Sites” option. Select the “Insert Data Set” icon (i.e., the + icon) and edit or enter the information in the following fields in the Manual Data Set part of the screen:

- Name—the default entry 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 in this field will be 261000 Manual Data Set: 13/May/2003 1:36:10 PM. Edit the date and time to show the date and time at which data collection was started. This information is contained in Form DS-1.
- Sample Interval—the default value in this field is 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 for this field.
- Date—the date of data collection from Form DS-1.
- Time—the time data collection started from Form DS-1.
- Equipment—the appropriate Dipstick model number from the dropdown menu such that Model Number and Equipment # corresponds to the Serial Number and Model Number shown in Form DS-1. If the required Dipstick Model Number and Serial Number is not available in the dropdown menu, the appropriate Dipstick 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 will 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 dropdown 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, and so on). 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® used in the LTPP program show readings in millimeters. Therefore, no change is required to the value shown in this field.
- **Lane:** Use the dropdown list and enter lane, which can be either OUTSIDE or INSIDE.
- **Direction:** This is the traffic direction of test section. Use the dropdown 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 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 PCC 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 test section visit be reviewed when checking this field. Otherwise, there could be variability in the value assigned to this field from 1 yr 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 Form DS-2 through Form DS-6 into the Profiles sheet in ProQual (figure 194 through figure 198). The exact sign convention used in the datasheets should be followed when entering the data (i.e., a negative value in datasheet should be entered as a negative value in ProQual). Once data have been entered for the left and the right wheel paths, print the data by selecting the Printer icon. Check the Dipstick data values along the left and right wheel paths in the printout with the values in Form DS-2 through Form DS-6 to ensure all data have been entered correctly.
4. Sum the Dipstick data and filter profile using the Surface Dynamics filter. After checking the data and making corrections as needed, select the sum button to obtain the 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. The Surface Dynamics filter included with the ProQual software was used in the T-6600 profilers as the upper wavelength cutoff filter. Thereafter, select the Update Main Tables icon to update the main tables with the filtered profile data. ProQual provides the option of filtering the Dipstick elevation profile with either the Surface Dynamics or ICC filter. Longitudinal Dipstick data are collected on a regular basis at test sections in Alaska, Hawaii, and Puerto Rico.

To provide consistency in data collected at these test sections, the Surface Dynamics filter must be used to filter Dipstick profiles.

5. Compute the ride indices and review the data. The dataset can now be treated as a profiler run that was obtained using an inertial profiler by selecting the Profiles menu from the main menu of ProQual, and then selecting the Data submenu. Select the dataset to be analyzed, and in the Analysis submenu of the Data Sets menu, select All to compute all roughness indices (i.e., IRI, RMSVA, SV). Review to see if spikes are present in the profile. If spikes are present, check to ensure that spikes were not caused by errors during data entry. Print the Site Summary Report to review the values computed for IRI, Spike Count, RMSVAs, Mays Output, and SV. Plot the profiles along left and right wheel paths and review the profile plots to see if they are reasonable.
6. Compare current data with data from the previous visit. Compare IRI values obtained along each wheel path with those obtained during the previous test section visit. If the difference is greater than 10 percent for a wheel path, investigate the reason for the difference. Graphically compare profiles along each wheel path with those generated from the previous test section visit. If major differences are noted between the two datasets and no explanation for the differences is found, paper copies of the profiles should be submitted to the appropriate RSC personnel for review.
7. Review Operator and Run End Comments. The Operator and Run End Comments were entered into the Header screen in step 2. If needed, make changes to the Operator or Run End Comments based on the review of profile data.
8. Assign an RCO Code and RCO Note.

An RCO Code must be assigned to the profile data after quality assurance checks have been performed on the data. Those checks include: reviewing operator comments, comparing IRI values along each wheel path with those obtained during the previous test section visit, reviewing spikes in profile data and reviewing operator comments (if any) regarding the spikes, comparing profile data with those collected during previous test section visits, and reviewing distress maps to investigate spikes in the data if required.

Once these tasks are completed, assign the RCO Code to the profile runs using the guidelines presented in section 5.5. The RCO Code is assigned in the Results and Status tab of the Run Details sheet in ProQual.

An 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 dropdown menu is available in this field to select an appropriate comment. The operator also has the option to type in a comment or select a comment from the dropdown menu 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 dropdown menu: 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 dropdown menu in the RCO Note field.

9. Create LTPP PPDB upload files. Select the longitudinal Dipstick profile file for upload and create the RIMS upload file. Check the ProQual Export Review Summary Report for errors and exceptions, and if any are found, resolve them and recreate the RIMS upload files.
10. Submit the RIMS files to the appropriate RSC personnel for review and upload. If any problems are encountered during the upload of RIMS data to the PPDB, resolve the problems and upload the corrected data to the PPDB.
11. Store the data. Store all files related to the test section that were created by ProQual. Use the file structure described in the current version of LTPP Directive I-171.<sup>(10)</sup>

## **5.5 ASSIGNING AN RCO CODE**

An RCO Code must be assigned to the longitudinal profile data collected by the profiler as well as by Dipstick after quality assurance checks have been performed on the data. The quality assurance tests that must be completed before the assignment of an RCO Code to profiler data and Dipstick data were described in sections 5.2 and 5.4, respectively.

The assignment of an 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.

An 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 the data because of pavement features, the operator comments document that they are pavement-related.
- Profile data plots are in good agreement with those collected during previous test section visits. This procedure provides a check on errors caused by incorrect sub-sectioning of SPS test sections, incorrect labeling of test sections, and incorrect start locations for profile data collection.

An RCO Code of 2 should be assigned to a profile run if any of the following features are identified in the data:

- If there is poor repeatability between the multiple profile runs, and operator comments do not indicate that this variability was caused by pavement features. Sometimes profilers have poor repeatability on rough test sections and on sections where the approach to the test section is rough (e.g., patched core holes prior to the test section). On such test sections, the data from multiple profiler runs are generally different from each other, with the operator having no comments regarding problems with wheel path tracking. Although there are large differences in profile data, the IRI values from these runs are generally in good agreement with each other. 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 an RCO Code of 2.
- If there are spikes in the profile data, and the operator comments indicate that the spikes are not pavement-related, such data points should be logically marked and the profile run should be assigned an RCO Code of 2. It is not possible to logically mark profile data points in ProQual 2014 version 1.5.1.37. 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 and crosses at 30-m intervals 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 the operator indicates that these spikes are not explained by pavement features, such profile data points should be logically marked and the profile run assigned an RCO Code of 2.

An 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 the test section 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 test section visit, but the differences cannot be explained by operator.
- Profiler runs collected during the test section visit are repeatable but different from those collected during previous test section visits, and the differences are caused by conditions at the time of testing (e.g., damp pavement). While data collection at LTPP test sections should be performed on dry pavements, there could be cases where data were collected on a damp surface due to existing circumstances.

## **5.6 TRANSVERSE DIPSTICK DATA**

The current version of ProQual 2014 (i.e., version 1.5.1.37) cannot process longitudinal Dipstick data. Future versions of ProQual 2014 may have the ability to process transverse Dipstick data. The latest version of ProQual that can process transverse Dipstick data is ProQual 2012 (i.e., version 6.3.1.2).

The following are the recommended procedures for processing and performing quality assurance checks on transverse profile data collected with a Dipstick.

1. Check if Dipstick passed the pre- and post-measurement checks. Check Form DS-7 to verify that Dipstick passed the zero and calibration checks prior to and after data collection (figure 199).
2. Enter the Header information. This section presents general procedures for navigating through the different ProQual menus and specifies the information that needs to be entered into the Header fields. Details on the procedures for navigating between menus are presented in the ProQual user manuals.<sup>(12,13,14)</sup> 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 test section into ProQual, select “Manual” from the main menu, and then select the “Transverse” option. Thereafter, select the site from the left side of the screen. If the site has not been created in ProQual, create the site by selecting “System” in the main menu and then selecting the “Sites” option. Select the “Insert Data Set” icon (i.e., the + icon) and edit or enter the 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 the date and time to show the date and time at which data collection was started. This information is contained in Form DS-8.
- Station Interval—the default value in this field is 15.24 m. This is the station interval at which transverse data were collected at LTPP test sections. No change is required for this field.
- Tests—the number of readings taken for a transverse profile. Enter the number of readings by reviewing the data on Form DS-8.
- Date—the date of data collection from Form DS-8.
- Time—the time data collection started from Form DS-8.
- Equipment—the appropriate Dipstick model number from the dropdown menu such that Model Number and Equipment # corresponds to the Serial Number and Model Number shown in Form DS-8. If the required Dipstick Model Number and Serial Number is not available in the dropdown menu, the appropriate Dipstick information should be entered in the Equipment 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 test section, B for second visit, C for third visit, and so on). 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 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 PCC 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 test section visit be reviewed when checking this field. Otherwise, there could be variability in the value assigned to this field from 1 yr 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 screen: Operator Comment, Run End Comment, and RCO Comment. It is recommended that these three fields be completed after the transverse Dipstick data has been entered and evaluated.

Once all Header entries have been made and checked, save the Header information.

3. Enter transverse Dipstick data. The transverse Dipstick data collected in the field and recorded on Form DS-8 are entered into ProQual through the Profiles tab. The readings taken from the edge of the pavement to the centerline should be entered in the left column. The data for the return run (i.e., the center of the pavement to the edge of the 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 the elevations are displayed for runs from the edge of the pavement to the centerline, from the centerline to the edge of the pavement, and for the sum of the two elevation measurements.

Once the data have been entered, review and see if the 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 the data have been entered correctly.

After data have been checked for accuracy, select Verify Profiles. Confirm the closure error limit has been met. If not, recheck the data entry. If the data do not meet the closure error limit, a copy of the data from that run should be submitted to the FHWA and another copy to the LTPP TSSC.

Enter the data for other transverse locations. Follow the procedures outlined above to check those data.

4. Use the graphic profile option to check profiles. After data for all transverse profile runs have been entered, use the 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 the 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 a rut analysis. Select the Rut Analysis icon to compute the rut depths and then print the Rut Report using the Rut Report icon. Review the 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 a record of the rut depths computed by ProQual for the previous test section visit, compare the current rut depths with those from the previous visit. The comparison should be made at each transverse location for each wheel path. If there are large differences, check if the 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 the 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 the data. Store all files related to the test section that were created by ProQual. Use the guidelines in the current version of LTPP Directive I-171 to store the data.<sup>(10)</sup>

## 5.7 STORING WIM DATA

Profile data collected at WIM test sections should be stored at the DCC office in external hard disk-based media with a USB interface. The DCC should maintain a file with the completed Form PROF-7 for each occasion a WIM test section has been profiled (figure 181).

The DCC should store the WIM data using the procedures described in the current version of LTPP Directive I-171.<sup>(10)</sup>

For the ICC profiler, store the raw profile data files with extensions of p, e, and v. For the HSSV, store the files with file extension ARD that contain the raw data. All files generated by ProQual for each test section should be stored in conjunction with the raw profile data files.

## 5.8 NAMING AND STORING IMAGE FILES

The image files captured by the camera in the HSSV must be named according to the procedures described in this section. The DCC should store the image files using the procedures described in the current version of LTPP Directive I-171.<sup>(10)</sup>

### 5.8.1 File Names for Images Collected at GPS and WIM Test Sections

Use the following file-naming convention to name images captured at GPS and WIM test sections: HSSAASHRPBrYYYYMMDDNNNN.jpg.

Where:

HSS = high-speed survey. The first three characters of the filename will always be HSS.

AA = Numeric State code.

SHRP = SHRP\_ID for the test section.

B = G for a GPS test section and W for a WIM test section. After sequential visit identifier Z has been reached at a GPS test section, change G to H; after sequential visit identifier Z has been reached at a WIM test section, change W to X.

r = sequential visit identifier associated with the profiler visit (section 2.7.3). After sequential visit identifier Z has been reached, restart with A.

YYYYMMDD = profile date (year/month/date).

NNNN = Number of the image in sequence starting with 1 for the first image.

For images captured with HSSV software version 6.0.1.69, the first image was captured when the photocell was triggered at the start of the test section. Hence, the number for this image will be 0001. With HSSV software version 6.0.1.69, the last image was captured at the end of the test section.

For images captured with HSSV software version 6.0.1.116 and later versions of the software, the first image is captured when the photocell is armed. The operator should arm the photocell just before Sign A, which is located 152 m before the start of the test section. A white paint stripe is located across the lane at this location. The first image captured with the camera, which is when the photocell is armed at approximately 152 m before the start of the test section, will be numbered 0001. The camera continues to capture images for a distance of 152.4 m past the end of the test section.

Starting HSSV software version 6.0.4.18, the HSSV software will automatically name files according to the convention described in the previous paragraphs. All image files captured before HSSV software version 6.0.4.18 will have to be renamed manually to meet the file-naming convention described in the previous paragraphs.

The following example only applies to images captured with HSSV software version 6.0.1.116 and later, because images were not captured before the start and after the end of the test section with version 6.0.1.69. Assume images were obtained at GPS test section 1018 in Arizona (State code 04) on December 9, 2014, during sequential visit identifier K. Assume that 16 images were captured before, 15 images were captured within the test section, and 15 images were captured after the end of the test section. The first image captured at this test section, which is when the photocell was armed, will have the following file name:

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

### 5.8.2 File Names for Images Collected at SPS Test Sections

Use the following file-naming convention for images captured at SPS test sections:  
HSSAASHRPSRYYYYMMDDNNNN.jpg.

Where:

HSS = high-speed survey. The first three characters of the filename will always be HSS.

AA = numeric State code.

SHRP = SHRP\_ID for the test section.

S = this digit will always be S to indicate the image was captured at an SPS test section.

However, after sequential visit identifier Z, change this digit to T.

R = sequential visit identifier associated with the profiler visit. After sequential visit identifier Z has been reached, restart with A.

YYYYMMDD = profile date (year/month/date).

NNNN = number of the image in sequence starting with 1 for the first image.

Name the image files according to the convention described above for each test section. The files will have to be named manually.

Use the following rules to treat images captured within transition areas between test sections:

- If more than 30 images were captured in the transition area between test sections, assign the first 15 images to the lead-out area of the first test section and the last 15 images to the lead-in area of the second test section. Discard the other images.
- If fewer than 30 images were captured in the transition area between test sections, assign half of the images to the lead-out area of first test section and the other half to the lead-in area of the second test section. If the number of images captured in the transition area is an odd number, assign the extra image to the lead-in area of the second test section.

For images captured with HSSV software version 6.0.1.69, the camera captures the first image when the photocell is triggered at the start of the first test section in the SPS project. Therefore, no images are captured before the start of the first test section. The camera captures the last image at the Stop Distance specified in the Header screen in the HSSV software (section 2.9.3).

In HSSV software version 6.0.1.116 and other software versions released after that date, the first image is captured when the photocell is armed. The photocell should be armed just before Sign A located 152 m before the start of the first test section in an SPS project. A white paint stripe is located across the lane at this location. Hence, the first image obtained in an SPS project is located approximately 152 m before the start of the first test section in the SPS project. Hence, for HSSV software version 6.0.1.116 and later, images are available before the start of the test section. The camera continues to capture images for a distance of 152.4 m past the Stop Distance specified in the Header screen of the HSSV software (section 2.9.3).

If the photocell was armed before Sign A and resulted in more than 15 images captured before the start of the first test section of the SPS project, keep only the 15 images captured immediately before the start of the test section and discard the extras. The first image should have the sequence number 0001. Keep only the 15 images immediately past the end of the last test section in the SPS project and discard the extras.

The following example applies to images obtained with HSSV software version 6.0.1.116 and later because images were not obtained before the start of the first test section in an SPS project with version 6.0.1.69. Assume images were captured at the SPS-1 project in Delaware (State code 10). The first test section encountered during profiling is test section 0160, and the second test section encountered during profiling is test section 0107. The transition area between these two test sections is 60 m. Assume this test section was profiled on February 7, 2015, during sequential visit identifier H. Assume that 15 images were captured before test section 0160, 15 images were captured within test sections 0160 and 0107, and 6 images were captured within the transition area between the test sections. Six images were captured within the transition area; three will be assigned as lead-out images for test section 0160, and three images be assigned as lead-in images for test section 0107.

The first image captured at test section 0160, which is when the photocell was armed, will have the following file name: HSS100160SH201502070001.jpg. The last image assigned to test section 0160 will be the third picture after the end of the test section, which will have the following file name: HSS100160SH201502070033.jpg.

The first image assigned to test section 0107 was captured in the lead-in area and will have the following file name: HSS100107SH201502070001.jpg.

## **CHAPTER 6. COMPARISON TESTING AMONG THE ENGINEERING HIGH-SPEED SURVEY VEHICLES**

### **6.1 INTRODUCTION**

This chapter describes a plan for periodic comparison of the data collected by the HSSVs used in the LTPP program. This comparison is usually performed on an annual basis at a date and location determined by FHWA. The DCC will be responsible for coordinating logistical arrangements (e.g., hotels, maps, traffic control, meeting places); selecting and marking test sections; and measuring the longitudinal profile on those test sections using a suitable reference device. After completing the preparatory activities, but within 14 d of reference profile measurements, data collection at the established test sections will commence with the HSSVs.

The Dipstick has been traditionally used to collect the longitudinal reference data at test sections. The Dipstick collects data at 304.8-mm intervals. Currently, rolling profilers, such as the SurPRO, can collect longitudinal profile data at 25-mm intervals. As the HSSVs collect longitudinal profile data at 25-mm intervals, the Dipstick is not the best device to use to collect reference profile data. A rolling profiler, such as the SurPRO, is ideal for collecting longitudinal reference profile data, as its data-recording interval matches the longitudinal profile data recording interval of the HSSVs. However, the LTPP program currently does not have a SurPRO in its possession.

One copy of a report summarizing the results of the comparison tests for each HSSV and the associated data must be submitted by the DCC to the FHWA LTPP office and another copy submitted to the LTPP TSSC within 21 d of completing the comparison tests. An analysis of the data collected by all four HSSVs will be performed by the TSSC, who will produce and submit to the FHWA LTPP office a report of the results within 45 d after receipt of the report from the DCC.

### **6.2 PREPARATORY ACTIVITIES**

The DCC will be responsible for the following activities:

- Selecting dates for comparison testing of HSSVs in coordination with FHWA and the TSSC.
- Selecting test sections.
- Logistical arrangements (e.g., reserving hotel rooms, meals, traffic control).
- Communicating the final logistical arrangements to FHWA and the TSSC.
- Measuring longitudinal profiles at the test sections using a suitable reference device.

### **6.3 TEST SECTIONS**

The DCC will be responsible for selecting and marking the test sections to be used for the comparison test of HSSVs. Five test sections for longitudinal profile, macrotexture, and transverse profile data collection and one test section for DMI testing should be established. The five test sections 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 data collection should meet the following criteria:

- The AC pavement test sections should not be PCC test 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 test sections with sufficient length at each end to allow for acceleration to a constant speed before the test 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.
- Test sections should be located within a centralized locale with short travel distances between each test section to reduce travel time, where possible.
- 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 test section should be established as the DMI test 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, safe for operators).

#### **6.4 REFERENCE DATA COLLECTION AT TEST SECTIONS**

A suitable reference device (e.g., SurPRO, Dipstick) approved by FHWA should be used to obtain longitudinal reference measurements along both wheel paths and the center of the lane at all test sections. If a Dipstick 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 d of the comparison tests. On PCC test sections, the reference data collection should be performed after 12 p.m., at the same approximate time of day as expected for the collection of data by the HSSVs. If sufficient resources are not available for reference data collection at all test sections, with approval from FHWA, the DCC should collect data only at the smooth AC test section.

## **6.5 COMPARISON TESTING OF DEVICES**

The following sequence should be followed 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 the DMI and collecting data to check the bias and precision of the DMI.
5. Dynamic calibration check on the TPMS.
6. Collection of longitudinal, macrotexture, and transverse profile data at the test sections.
7. Verification of the DMI.

Details on each of these tests and 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.

### **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.

### **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. Then, perform a bounce test following the procedure described in section 2.9.2.4.

### **6.5.4 DMI Test**

Calibrate the DMI following the procedures described in section 2.12.3. Then, perform a horizontal test using the Horizontal Test option in the HSSV software to obtain the distance between the reflective marks on the DMI test section (section 2.12.3). Record the displayed distance. Repeat this procedure five more times. Check and adjust the tire pressure if necessary before each run so it matches the tire pressure during the DMI calibration. Compute the average and standard deviation of the six recorded distances.

### **6.5.5 Dynamic Calibration Check of the TPMS**

A dynamic calibration check of the TPMS should be performed using the procedures described in section 2.12.12. Obtain three repeat runs with each HSSV.

### **6.5.6 Data Collection**

Longitudinal profile, macrotexture, and transverse profile data collection at each test section should be performed following the procedures used when collecting data at GPS test sections as

described in section 2.9 of this manual. Testing should be performed at a speed of 80 km/h. The PCC test sections should be profiled at approximately the same time as when reference data were collected at the test sections.

### **6.5.7 Verification of the DMI**

The purpose of this test is to evaluate the stability of the DMI over time. This test should be performed after collecting data at all five test sections. The DMI should not be calibrated before performing the verification testing. Warm up the tires following the procedures used when the tires were warmed up before calibrating the DMI. Then, perform a horizontal test using the Horizontal Test option in the HSSV software to obtain the distance between the reflective marks on the DMI test section (section 2.12.3). Record the displayed distance. Repeat this procedure five more times. Check and adjust the tire pressure if necessary before each run so it matches the tire pressure during the DMI calibration.

## **6.6 REPORTS**

### **6.6.1 Submission of Reports and Data by the DCC**

Within 21-d of the completion of the comparison testing, the DCC should submit a copy of the report and data collected during the comparison test to the FHWA LTPP office and submit another 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:

- Form COMP-1, Profile Height Sensors—Static Height Sensor Measurements Form (Figure 213).
- Form COMP-2, Texture Height Sensors—Static Height Sensor Measurements Form (figure 214).
- Form COMP-3, Accelerometer Calibration Check, Bounce Test, and Texture Dynamic Check Form (figure 215). Report the results from the bounce test immediately after the full calibration check of the height sensors.
- Form COMP-4, DMI Measurement Form (figure 216).
- Form COMP-5, DMI Verification Form (figure 217).
- Form COMP-6, IRI Values Form (figure 218). Compute the IRI of the five runs at each test section that would have been selected for upload to the PPDB using the current version of ProQual. Enter the IRI values into figure 218. Compute the average and standard deviation of the IRI for each wheel path at each test section.

- Form COMP-7, MPD Values Form (figure 219). Compute the MPD values for the five runs that were included in Form COMP-6 (figure 218). Enter the MPD values into the MPD Values table. Compute the average and standard deviation of the MPD for each wheel path at each test section.
- Rut Depth Table. Compute the average rut depth for the left and right wheel paths at each test section for the five runs that were included in Form COMP-6 (figure 218). Enter the rut depths into a table similar to that used for MPD values (i.e., figure 219). Compute the average and standard deviation of the rut depths for each wheel path at each test section.
- Profile Plots. Overlay the five selected runs at each test section using ProQual. Create the following graphs separately for each test section and cut and paste them into the report:
  - Five overlaid runs for left wheel path.
  - Five overlaid runs for the right wheel path.
  - Five overlaid runs for the center path.
  - Two overlaid runs showing the left, right, and center profiles on same graph.

Create these graphs for all five test sections. Indicate the test section, surface type, and date of testing for each set of graphs.

- Discuss the possible causes for 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, rut depths at a test section, or repeatability of the profile plots.

The DCC should also include the following items in the report:

- 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 longitudinal profile, macrotexture, or transverse profile measurements, such as meandering cracks in the wheel paths, highly variable transverse profile, and so on. Detailed measurements are not required, and subjective-based descriptions are satisfactory. Include photographs of the test sections in the report.
- A table showing the IRI values computed from reference device measurements. Indicate the date, start time, and end time for reference data collection.

### **6.6.3 Data Submission**

The following data should be organized in a logical manner and submitted on a USB drive:

- Results from the full calibration check of the profile and texture height sensors.
- The accelerometer calibration check log.
- The ARD files from the dynamic check on the texture height sensors.
- The DMI calibration report.

- The ERD files for the bounce test that was performed immediately after the full calibration check on the height sensors.
- The ARD files collected for the dynamic calibration check of the TPMS.
- The ARD files containing the data collected at the five test sections.
- The ERD files containing longitudinal profile data collected at the five test sections at 25-mm intervals and the ERD files containing the macrotexture data collected at the five test sections at 0.5-mm intervals.
- An Excel file with separate sheets in the file for each of the following items:
  - Form COMP-1 (figure 213).
  - Form COMP-2 (figure 214).
  - Form COMP-3 (figure 215).
  - Form COM-4 (figure 216).
  - Form COMP-5 (figure 217).
  - Form COMP-6 (figure 218).
  - Form COMP-7 (figure 219), and a form containing the rut depths (use similar form as Form COMP-7).
- The data files containing the reference profile data.

#### **6.6.4 Preparation of Report by TSSC**

Upon receipt of the DCC report and data, the TSSC will compare the results obtained for the four HSSVs and submit a report to the FHWA LTPP office within 45 d after receipt of the report from the DCC.

The report will document the results of the following analyses:

- 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.
- Results from the accelerometer check—the results from the accelerometer check will be evaluated to determine if they meet the criteria specified in this manual.
- 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.
- Results from the dynamic check of the texture height sensors—the MPD values obtained from the the dynamic check of the texture height sensors will be evaluated to determine if they meet the criteria specified in this manual.

- Accuracy and stability of the DMI—the results obtained from the DMI tests will be evaluated to determine if the bias of the DMI is within 0.15 m (i.e., 0.05 percent of the length of the test section), and 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.
- Results from the dynamic calibration of the TPMS for the four HSSVs will be compared.
- IRI values obtained by the HSSVs—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 the following:
  - If the precision of the IRI along a profiled path is less than 0.04 m/km.
  - If the difference in IRI for a profiled path between the reference device IRI and average HSSV IRI obtained from the five runs is within 0.10 m/km for paths with an IRI less than 1.6 m/km and within 0.15 m/km for paths with an IRI greater than 2.2 m/km.
- Repeatability of the HSSVs using cross-correlation—the IRI-filtered cross-correlation for all possible longitudinal profile pairs for each profiled path at each test section will be computed; these values will then be used to compute the average IRI-filtered cross-correlation value. The average IRI-filtered cross-correlation for each profiled path at all test sections must be greater than or equal to 0.92.
- Accuracy of the HSSVs 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 data collection run for each profiled path will be computed; these values will then 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.
- Repeatability of profile data using profile plots—the profile data collected by each HSSV along each profiled path at all test sections will be visually evaluated by examining overlaid profile plots.
- Comparison of profile data obtained by the HSSVs—the profile data collected by the four HSSVs will be visually evaluated by preparing overlaid profile plots for each path at each test section and then selecting one representative profile run for each HSSV at each test section.
- Comparison of MPD values obtained by the HSSVs—the average MPD values obtained along each wheel path at each test section will be compared among the HSSVs.
- Comparison of rut depths obtained by the HSSVs—the average rut depth values computed from the HSSV software along each wheel path at each test section will be compared among the HSSVs.



## **APPENDIX A. LONGITUDINAL PROFILE/TEXTURE/TRANSVERSE PROFILE PROBLEM REPORT FORM**

To provide for a more uniform way of reporting, handling, and tracking problems associated with LTPP longitudinal profile, macrotexture, and transverse profile data collection and processing, the FHWA LTPP team designed the Longitudinal Profile/Texture/Transverse Profile Problem Report (PROFPR) Form for use by the DCC (figure 173).

The PROFPR Form provides several benefits, including a standard format for submitting problems associated with the longitudinal profile/macrotexture/transverse profile monitoring activities; an easy means of tracking when a problem was submitted; who is responsible for resolving the problem; whether or not the problem has been resolved; and how and when the problem was resolved, which reduces the probability of problems being forgotten and left unresolved.

A PROFPR Form must be submitted whenever there are equipment problems in the HSSV; problems with data collection or data-processing software; problems with data collection guidelines; other problems related to HSSV activities; or problems with longitudinal profile, macrotexture, or transverse profile data. If a problem was encountered and was resolved, and the profiler operator/coordinator feels this information would be useful to the other DCC personnel, TSSC, and FHWA, an informational PROFPR Form should be submitted. When submitting an informational PROFPR Form, indicate that the form is being submitted for informational purposes in the description part of the form.

The PROFPR Form is self-explanatory except for the PROFPR number. The number consists of the following two parts:

- A letter code representing the agency submitting the problem (e.g., F for FHWA LTPP Division, DC for data collection contractor, TSSC for technical support services contractor, and O for others).
- A sequential number code representing the PROFPR number for the submitting agency starting from 1 (e.g., F-07 represents the seventh problem reported by the FHWA LTPP team, and DC-23 represents the twenty-third problem reported by the DCC).

Completed PROFPR Forms must be submitted to the FHWA LTPP team, with a copy sent to the TSSC. Forms must be transmitted electronically by an attachment to an email. A complete set of PROFPR Form 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 DCC for their information and action as appropriate after the reported problem has been reviewed and/or resolved by FHWA and the TSSC.

Agency: \_\_\_\_\_  
PROFPR #: \_\_\_\_\_

**LTPP LONGITUDINAL PROFPR**

Attention: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Type of Problem	Reported by: _____
Guidelines _____	Agency: _____
Equipment _____	Date: _____
Software _____	Urgent (Y/N) _____
Name _____	Page ____ of ____
Version _____	
Other _____	
Description:	

<i>THIS SECTION FOR USE BY FHWA AND TSSC</i>	
Received by: _____	Date Received: _____
Referred to: _____	Approved by: _____
Date Referred: _____	Date Approved: _____
Resolution:	
Notes:	

Source: FHWA.

**Figure 173. Form. LTPP Longitudinal PROFPR Form.**

## **APPENDIX B. STANDARD FORMS FOR HSSV OPERATIONS**

Figure 174 through figure 181 show the standard forms for HSSV operations. The relevant forms are used by DCC personnel to:

- Perform a daily checklist on the HSSV before commencing data collection.
- Document the daily data collection activities of the HSSV.
- Note the condition of markings and signs at test sections where data are collected.
- Note HSSV equipment problems and the actions taken to remedy the issues.
- Document major maintenance and repair activities performed on the HSSV.
- Document the calibration or calibration checks that are performed on the HSSV.
- Document data collection at WIM sections.

### DAILY CHECKLIST

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

Source: FHWA.

**Figure 174. Form. Daily Checklist.**

<b>LTPP PROFILER OPERATIONS LTPP PROFILER FIELD ACTIVITY REPORT FORM PROF-1</b>	<b>REGION</b> <b>STATE CODE</b> <b>LTPP SECTION ID</b> <b>TESTING DATE</b> <b>TESTING START TIME</b>								
<b>HEADER INFORMATION</b>									
FILE NAME: <input style="width:100px;" type="text"/>	EXPERIMENT CODE: <input style="width:100px;" type="text"/>	PROFILER: <input style="width:100px;" type="text"/>							
SURFACE: <input style="width:100px;" type="text"/>	TIME ZONE: <input style="width:100px;" type="text"/>	<input style="width:100px;" type="text"/>							
ROUTE/HIGHWAY NUMBER: <input style="width:150px;" type="text"/>	DIRECTION: <input style="width:100px;" type="text"/>								
<b>EQUIPMENT / OPERATION CHECKS:</b>									
Comments / Issues: <input style="width:300px;" type="text"/>		EQUIPMENT OK? <input style="width:50px;" type="text"/> (Initials) <input style="width:50px;" type="text"/>							
		Downtime (hrs): <input style="width:50px;" type="text"/>							
<b>DAILY LASER SENSOR CHECK</b>		<b>DAILY BOUNCE TEST</b>							
<i>Profile</i>	<i>Identifier</i>	<i>Label</i>	<i>Reference</i>	<i>Bias</i>		<i>Left (1)</i>	<i>Center (3)</i>	<i>Right (2)</i>	<i>Pass (Y/N)</i>
LEFT (1)	ODS 1					Static (Seg 2)			
CENTER (3)	ODS 3					Dynamic (Seg 4)			
RIGHT (2)	ODS 2					Difference			
<i>Texture</i>	<i>Identifier</i>	<i>Label</i>	<i>Reference</i>	<i>Bias</i>		Seg. 2 - Seg. 7			
LEFT (1)	ODS 4					<i>Static IRI ≤ 0.08 / IRI difference ≤ 0.10 / Seg.2 - Seg. 7 ≤ 0.01</i>			
RIGHT (2)	ODS 5					<b>TIRE PRESSURE MONITORING</b>			
<b>PASSED?</b>						<i>Tire</i>	<i>Left</i>	<i>Right</i>	<i>Comments</i>
						Front (50 psi)			
						Rear (80 psi)			
<b>TRANSVERSE PROFILE DATA SUMMARY</b>									
Review Transverse Profile Data:					Check imagery for complete coverage of section: <input style="width:100px;" type="text"/>				
					Check imagery for calculated lane width issues: <input style="width:100px;" type="text"/>				
Outside lane paint stripe condition: <input style="width:200px;" type="text"/>									
Check Rut Depth values. Comment for ruts greater than 0.5in.. <input style="width:200px;" type="text"/>									
<b>PROFILE AND TEXTURE DATA SUMMARY</b>									
<i>10% Check:</i>	<b>DATE</b>	<b>LEFT (IRI)</b>	<b>RIGHT (IRI)</b>	<b>CENTER (IRI)</b>	<b>LEFT (MPD)</b>	<b>RIGHT (MPD)</b>			
<b>CURRENT</b>									
<b>OLD VISIT</b>									
<b>% CHANGE</b>									
TEXTURE COMMENT: <input style="width:600px;" type="text"/>									
ARE THERE SPIKES PRESENT? <input style="width:50px;" type="text"/> IF YES, SUMMARIZE DISTRESS BELOW									
<b>ISSUES / COMMENTS / DISTRESS SUMMARY</b>									
PROFILER CREW: <input style="width:100px;" type="text"/>			DRIVER: <input style="width:50px;" type="text"/> (Initials)			OPERATOR: <input style="width:50px;" type="text"/> (Initials)			

Source: FHWA.

Figure 175. Form. LTPP Profiler Field Activity Report Form PROF-1.



**LTPP Profiler Operations**  
**Profiler Log**  
**Form PROF-3**

Date	Noted Problem	Action Taken and Date

Source: FHWA.

**Figure 177. Form. Profiler Log Form PROF-3.**

<b>LTPP Profiler Operations</b> <b>LTPP Major Maintenance/Repair</b> <b>Work Order</b> <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>  Equipment: _____ Description: _____ _____ _____ _____	Performed By: _____ Date: _____ Start Time: _____ End Time: _____
<b>Troubleshooting</b>  Description: _____ _____ _____ _____	Performed By: _____ Date: _____ Start Time: _____ End Time: _____ Hours: _____
<b>Reporting</b>  Referred to: _____ _____  Actions (Return/Order Parts): _____ _____ _____	Date: _____ Time: _____  Date: _____ Time: _____
<b>Service</b>  Description (Repairs Performed/Replacement Part Information): _____ _____ _____ _____  Agency Performing Maintenance: _____ _____ _____	Performed By: _____ Date: _____ Start Time: _____ End Time: _____ Hours: _____ Total Cost: _____
<b>Verification</b>  Description (Check/Calibration): _____ _____ _____ _____	Performed By: _____ Date: _____ Start Time: _____ End Time: _____ Hours: _____
<b>Return to Service</b>  Status: _____ _____	Performed By: _____ Date: _____

Source: FHWA.

**Figure 178. Form. LTPP Major Maintenance/Repair Work Order Form PROF-4.**

LASER SENSOR, ACCELEROMETER, DMI CALIBRATION/CALIBRATION CHECK FORM							Form PROF-5			
HIGH SPEED SURVEY VEHICLE							DATE (DD/MMM/YYYY)			
AMES PRO SOFTWARE VERSION							TIME			
OPERATOR(S)							MILEAGE			
SENSOR CALIBRATION CHECK (TEST IS PERFORMED WITH TRUCK ON SECOND STEP OF RAMP)										
IRI SENSORS	Block Height (mm)	25 mm Bias	50 mm Bias	75 mm Bias	100 mm Bias	GROUND LEVEL CHECK		Pass (Yes / No)		
						25 mm Block	Bias			
<b>LEFT (ODS 1)</b>										
Internal Temp.										
Laser Height (mm):										
Truck on Ground										
<b>CENTER (ODS 3)</b>										
Internal Temp.										
Laser Height (mm):										
Truck on Ground										
<b>RIGHT (ODS 2)</b>										
Internal Temp.										
Laser Height (mm):										
Truck on Ground										
TEXTURE SENSORS										
<b>LEFT (ODS 4)</b>										
Internal Temp.										
Laser Height (mm):										
Truck on Ground										
<b>RIGHT (ODS 5)</b>										
Internal Temp.										
Laser Height (mm):										
Truck on Ground										
Laser Height allowable range: -15mm to 15mm		COMMENTS:							tolerance ±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 ≤ 0.08 Pass (Y/N)	IRI (m/km)	Difference Pass (Y/N)	IRI (m/km)	Difference	Pass (Y/N)	
LEFT (ODS 1)					0.00		0.00			
RIGHT (ODS 2)					0.00		0.00			
CENTER (ODS 3)					0.00		0.00			
Segment 2 must be ≤ 0.08 m/km   Segment 2 - Segment 7 must be ±0.01 m/km   Segment 4 - Segment 2 must be ≤ 0.1 m/km										
COMMENTS:										
DISTANCE MEASURING INSTRUMENT (DMI) CALIBRATION										
Photocell Used:			DMI Encoder used:			DMI calibration				
Distance from Horizontal Test (m):			Calibration Length (m):			Date Performed:				
<i>Horizontal test must be performed BEFORE calibration runs</i>					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)		NEW CALIBRATION FACTOR:					
LEFT	psi		psi		% CHANGE FROM LAST:					
RIGHT	psi		psi		STD DEV OF CAL FACTOR (must be ≤0.07)					
ACCELEROMETER CALIBRATION					TEXTURE SENSOR CALIBRATION CHECK					
ACCELEROMETER	ZERO G	NEG. 2 G	DIFFERENCE	PASS (Y/N)	<i>Performed with van on first step of cal blocks</i>					
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)					
<i>To pass difference must be between 1.98 and 2.02</i>					<i>To Pass: MPD less than 0.33</i>					
ADDITIONAL COMMENTS					Dynamic Texture Test		MPD VALUE	PASS (Y/N)		
					Left - Texture 1 (ODS 4)					
					Right - Texture 2 (ODS 5)					
					<i>To Pass: Range for MPD (.694 - .806)</i>					

Source: FHWA.

Figure 179. Form. Laser Sensor, Accelerometer, and DMI Calibration/Calibration Check Form PROF-5.

AMBIENT TEMPERATURE SENSOR, PAVEMENT SURFACE TEMPERATURE SENSOR, GPS RECEIVER CALIBRATION CHECK AND TRANSVERSE PROFILE SYSTEM CHECK						Form PROF-6	
HIGH SPEED SURVEY VEHICLE				DATE (DD/MMM/YYYY)			
AMES PRO SOFTWARE VERSION				TIME			
OPERATOR(S)				MILEAGE			
AMBIENT TEMPERATURE SENSOR CALIBRATION CHECK							
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 Temperature Probe 1 and Thermometer Temperature must be within $\pm 2$ °C							
Difference between Temperature Probe 2 and Thermometer Temperature must be within $\pm 2$ °C							
Difference between Temperature Probe 1 and Temperature Probe 2 must be within $\pm 2$ °C							
COMMENTS							
PAVEMENT SURFACE TEMPERATURE SENSOR CALIBRATION CHECK							
<b>Readings Taken on Ground Surface</b>							
Reading from Pavement Temperature Sensor (°C)							
Reading from Temperature Gun (°C)							
Difference (°C)				Pass (Y/N)			
<b>Reading Taken on Ice and Water Mix</b>							
Reading from Pavement Temperature Sensor (°C)							
Reading from Thermometer (°C)							
Difference (°C)				Pass (Y/N)			
<i>Difference in temperature must be within <math>\pm 2</math> °C for both cases</i>							
COMMENTS							
GPS RECEIVER CHECK							
				Latitude	Longitude	Location performed	
Latitude and Longitude from Google Earth or Portable GPS device							
Latitude and Longitude from GPS Receiver							
Difference between Google Earth and GPS Receiver				0.0000	0.0000		
Latitude/Longitude Agree to Four Decimal Places (Y/N)?							
<i>Latitude and Longitude must agree to four decimal places</i>							
COMMENTS							
TRANSVERSE PROFILE MEASUREMENT SYSTEM (TPMS) CHECK							
Vertical Height measurement from floor to face of TPMS unit (Must be = 84" $\pm$ 1") *							
<i>If measurement is out of the 1" tolerance, adjust TPMS sensor mounting position to 84"</i>							
Transverse Profile unit cooling fan filter inspection (Select Filter OK or Filter Replaced from Dropdown list)							
TPMS Cal	Black	$\Delta y_{pb}$		$\Delta y_{qb}$		$\Delta y_{rb}$	
$\Delta y$ values	White	$\Delta y_{pw}$		$\Delta y_{qw}$		$\Delta y_{rw}$	
<b>Acceptable range for <math>\Delta y</math> results: Absolute value between 4.2 and 8.5mm</b>							
<b>* Note: If monthly cal is performed in the field, locate the best level surface available to perform this measurement.</b>							
COMMENTS							

Source: FHWA.

**Figure 180. Form. Ambient Temperature Sensor, Pavement Surface Temperature Sensor, Global Positioning System Receiver Calibration Check, and Transverse Profile System Check Form PROF-6.**

**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 Number	Location (Note 1)	Offset Reference and Distance (Note 2)	Time at Start of Run	File Name	Error 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).

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Other information related to WIM site that may have influenced data collection (e.g., length of sensor array for multiple sensor configuration).

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Source: FHWA.

**Figure 181. Form. Profiling of WIM Sections Data Summary Sheet Form PROF-7.**



## APPENDIX C. PROFILE TROUBLESHOOTING GUIDE

This appendix contains a catalog of problems commonly encountered by LTPP operators when collecting and reviewing longitudinal profile data. Knowledge of these problems will help operators collect more accurate and valid longitudinal profile data for the LTPP program. These commonly encountered problems can be grouped into the following four categories:

- Spikes in longitudinal profile data.
- Miscalibrated DMI, incorrect tire pressure, or tires not properly warmed up.
- Early start of data collection.
- Different profiles.

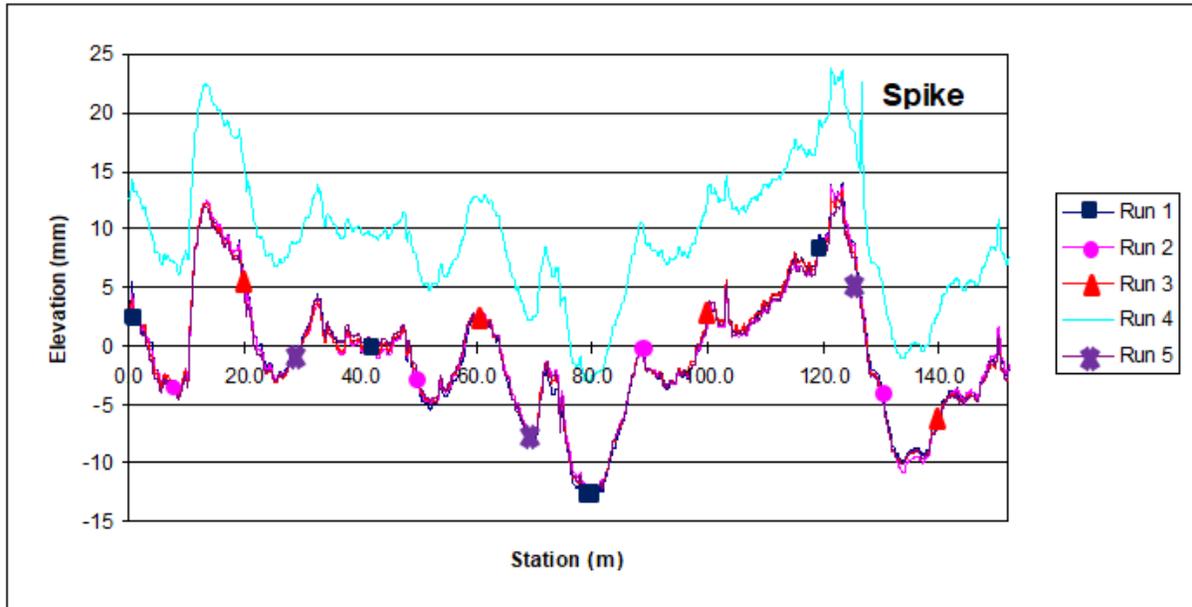
To detect an early start of data collection or different profiles, the longitudinal profile data in question must be compared to those collected during the previous test section visit. However, an early start of data collection can also be detected when comparing repeat runs obtained at a test section. Longitudinal profile data from the previous test section visit 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. To perform an accurate and valid comparison with longitudinal profile data from the previous test section visit, the previous test section visit data must be error free. Descriptions and references to the longitudinal profile data comparisons made later in this appendix assume that data from the previous test section visit are error free.

### SPIKES IN LONGITUDINAL PROFILE DATA

Spikes can be introduced in the longitudinal profile data by pavement features, equipment problems, debris on the road (e.g., paper, leaves, tire pieces), or objects passing below the sensor (e.g., paper, leaves, weeds, insects). The spikes can be identified by comparing multiple profile runs at a test section. Accordingly, once a set of longitudinal 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 182 shows five profile runs collected on the left wheel path and illustrates the presence of a spike in the longitudinal profile data. The longitudinal profile data for run 4 indicates a spike that is not present in the other four runs. The longitudinal profile data for run 4 has been offset for clarity. In ProQual, the repeat profile runs are color-coded (i.e., there is a different color for each run). Since the spike only occurs in one run of the dataset, 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 passing below the sensor, or 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 passing below the sensor unless the operator noted such a situation when collecting data. If the spike was caused by debris, the location of the debris may have shifted or blown off the pavement by passing traffic. If multiple upward spikes

are noted on a run and no pavement feature or debris on the road can explain the cause of the spikes, equipment problems can be suspected.

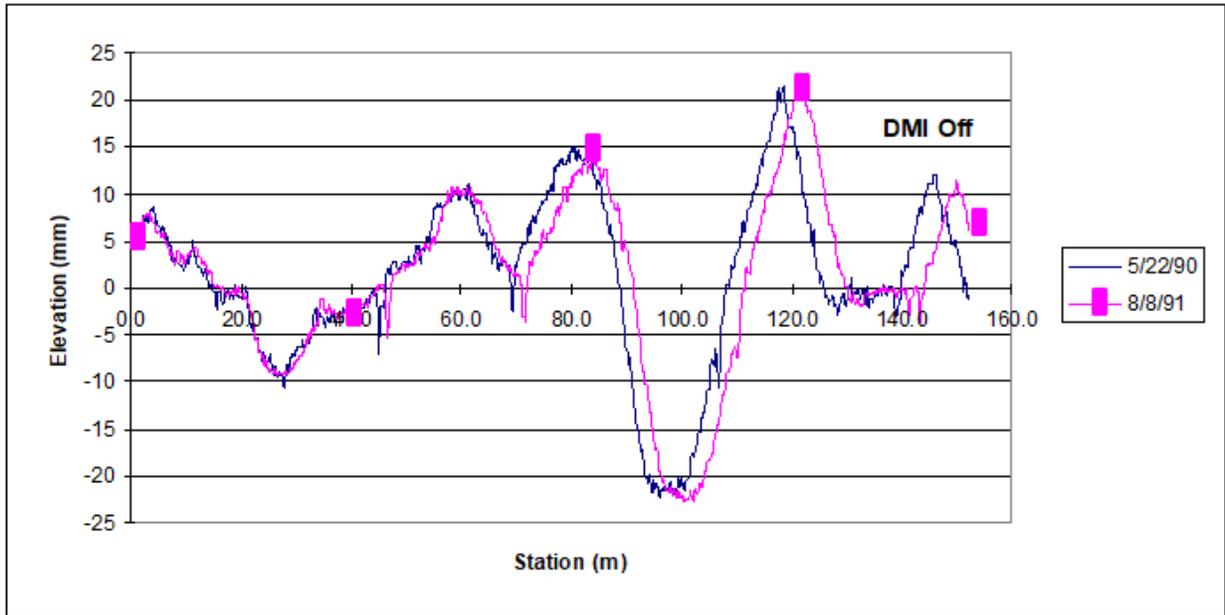


Source: FHWA.

**Figure 182. Graph. Spike in profile data (profile data for run 4 have been offset for clarity).**

### **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 longitudinal profile runs obtained during a test section visit. However, when those runs are compared with the longitudinal profile runs collected during the previous test section visit, the profile (i.e., elevation versus distance) plot for the more recently collected data will appear squeezed or stretched in the  $x$  (i.e., distance) direction if the vehicle has a miscalibrated DMI or if tires have been set to an incorrect tire pressure. The current and previous longitudinal profile data should be compared using ProQual. An example of profile data associated with a miscalibrated DMI is shown in figure 183; data for May 22, 1990, were collected using a miscalibrated DMI.



Source: FHWA.

**Figure 183. Graph. Data collected with a correctly calibrated and a miscalibrated DMI.**

When this problem is encountered, the operator should check the tire pressure of vehicle to ensure it is at the values at which the DMI was calibrated. If the current tire pressure is different, the operator should adjust tire pressure, so it matches tire pressure when DMI was calibrated and obtain a new set of measurements at the test section. If the difference in the distance between the current and previous data at the end of the test section is less than or equal to 0.5 m for a GPS test section, the current dataset is considered 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:

1. The operator can determine if the DMI is calibrated correctly by running the test section using the photocell as the stop option and noting the length over which data were collected. If the length of the test section obtained when the test 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 test section is not 152.4 m. 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 step 2.
2. It is expected that all test sections would have at least two previous longitudinal profile datasets. The operator can check the accuracy of the DMI for the previous visit by calling the office and asking the office personnel to compare the previous data with other data available for the test section. The purpose of this comparison is to determine if there is any error in the DMI associated with the data from the previous visit. The office personnel should compare the relative position of the longitudinal profile at the end of the

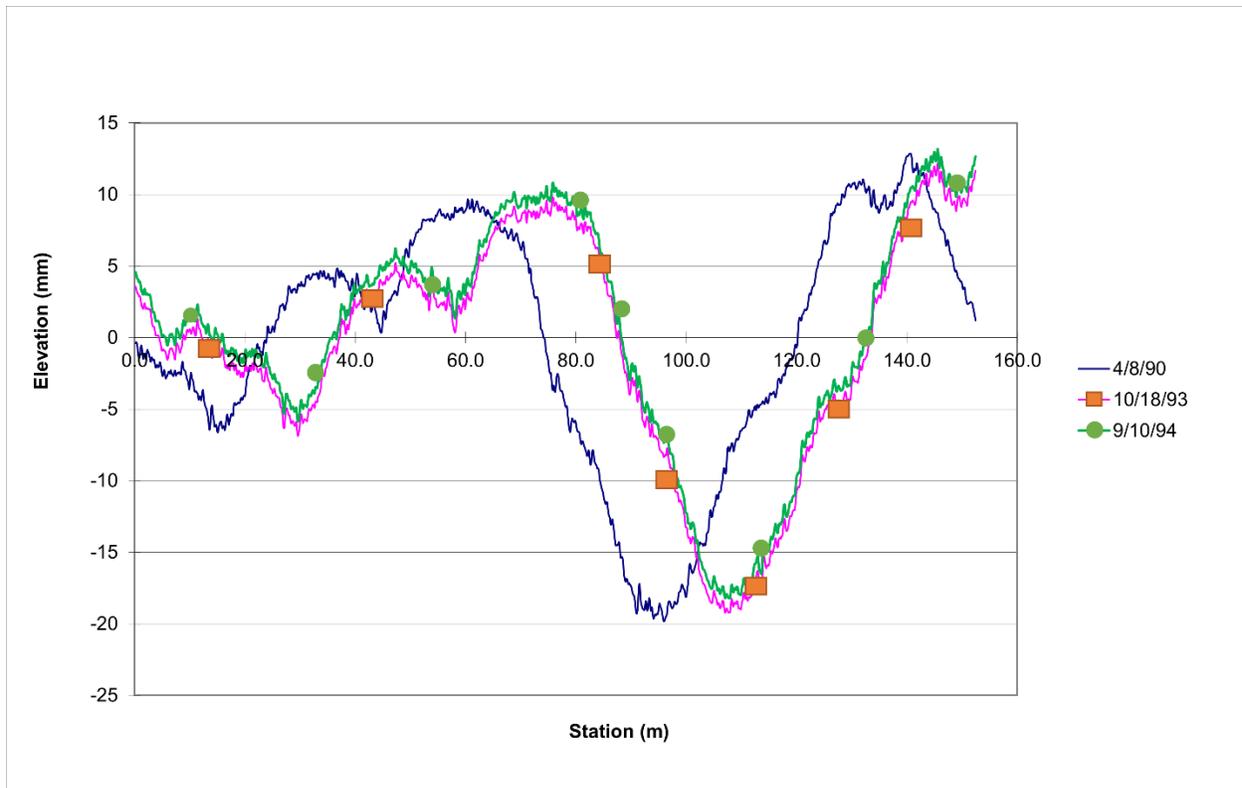
test section for previous visits and convey that information to the operator. The office personnel and the operator can then use the available information to judge the accuracy of the DMI for the current data. If all available data indicates that the DMI for the previous visit is accurate, the indications are that the DMI in the HSSV is out of calibration. The operator should proceed to another test section and compare the longitudinal profile plots following the procedures described at the beginning of this section. If the data at that test section also indicate the DMI is out of calibration, the DMI should be calibrated before further longitudinal 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 test sections located toward the end of the SPS site. When comparing longitudinal profile data between two site visits at SPS test sections, close attention should be paid to the first two test sections in the SPS site. If the longitudinal profile data for the current and previous site visit satisfy the criteria described at the beginning of this section at the first two test sections, 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 acceptable for the other test sections in the SPS project.

If a profile plot similar to that shown in figure 183 is observed when repeat runs collected by the HSSV at the test section are compared, this means the tires in the HSSV have not been warmed up sufficiently.

#### **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 data collection runs during a test section 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 longitudinal profile data are compared with those collected during the previous test section visit, the early start problem can be easily identified by a clear shift in the two longitudinal profile datasets. The longitudinal profile data should be compared using ProQual. The early start problem is illustrated in figure 184, which shows the profile plot for a single run along the left wheel path conducted on three different dates. The longitudinal profile plot for the last two dates have similar start locations, but that for the earlier date (i.e., 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 located before the start of the test section, the operator can use the horizontal photocell to initiate data collection.



Source: FHWA.

**Figure 184. Graph. Example of early profile start.**

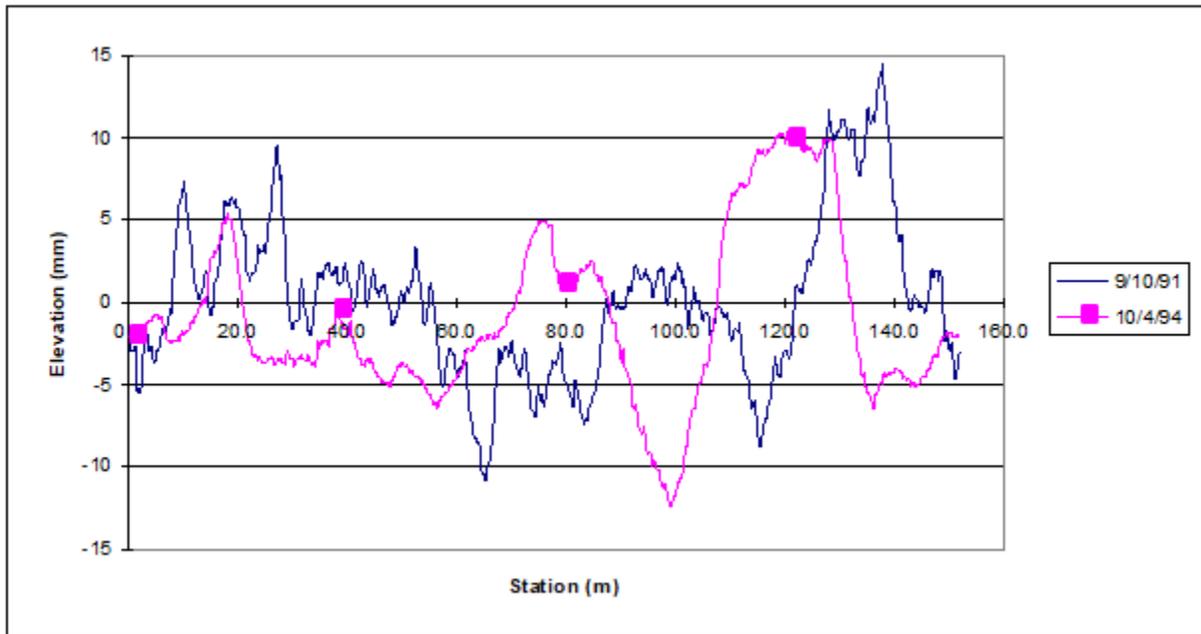
The early start problem can also occur in one or more runs within a longitudinal profile dataset collected during a single test section visit. This problem can be easily identified by comparing the repeat runs using ProQual; one or more runs will be shifted to the left of the others if there is an early 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 184. If an early start is detected in one or more profile runs, the operator should complete additional profile runs until a set of error-free data (i.e., meeting the criteria described in section 2.9.4) is obtained. If the early start problem is caused by a mark on the pavement located before the start of the test section, the operator can use the horizontal photocell to initiate data collection.

## DIFFERENT PROFILES

“Different profiles” describes when (a) the operator compares repeat profile runs collected during a single test section visit and no problems are observed in the data (i.e., data are error free) and (b) the operator compares current data with that from the previous test section visit (also error-free), and the two sets of profiles appear to be different.

Such a condition can be caused by rehabilitation or maintenance activities to the test section between visits. Different profiles can also occur when the location of test section is incorrectly selected during one of the test section visits.

Figure 185 illustrates the case where rehabilitation has been performed on a test section between visits. Figure 185 shows a plot of the left wheel path longitudinal profile data obtained on two separate test section visits—September 10, 1991, and October 4, 1994. The two longitudinal profiles shown in this plot are completely different. In figure 185, the differences in longitudinal profile were caused by an overlay that was placed on the test section sometime between the two visits. When the location of the test section has been incorrectly selected during one of the visits, differences in longitudinal profile similar to those shown in figure 185 will also be seen.

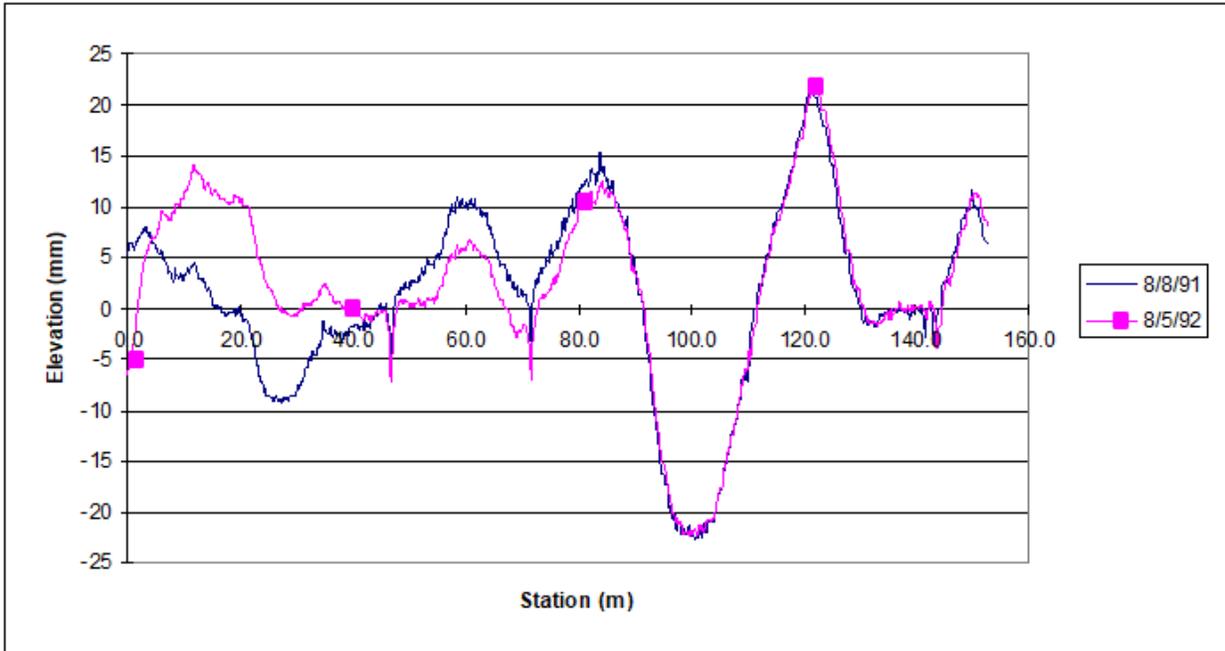


Source: FHWA.

**Figure 185. Graph. Differences in profile due to rehabilitation of a test section.**

If a case such as that shown in figure 185 is encountered, the operator should first verify that the test section location is correct. If such a condition is encountered at an SPS or GPS test section where data were collected in conjunction with an SPS test section, the operator should verify that the stationing used for subsectioning is correct. If evidence of rehabilitation is noted at the test section, it should be entered in the Operator Comments field and noted in Form PROF-2 (figure 176).

An example where maintenance has occurred on a portion of the test section between visits is illustrated in figure 186. Figure 186 shows a plot of the left wheel path profile obtained on two separate test section visits—August 8, 1991, and August 5, 1992. This plot shows that the longitudinal profile at the beginning of the test section for the two visits are different, indicating possible maintenance at the test section. If a case such as that shown in figure 186 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 Comments field (e.g., POSSIBLE MAINTENANCE IN SECTION) and note it in Form PROF-2 (figure 176).



Source: FHWA.

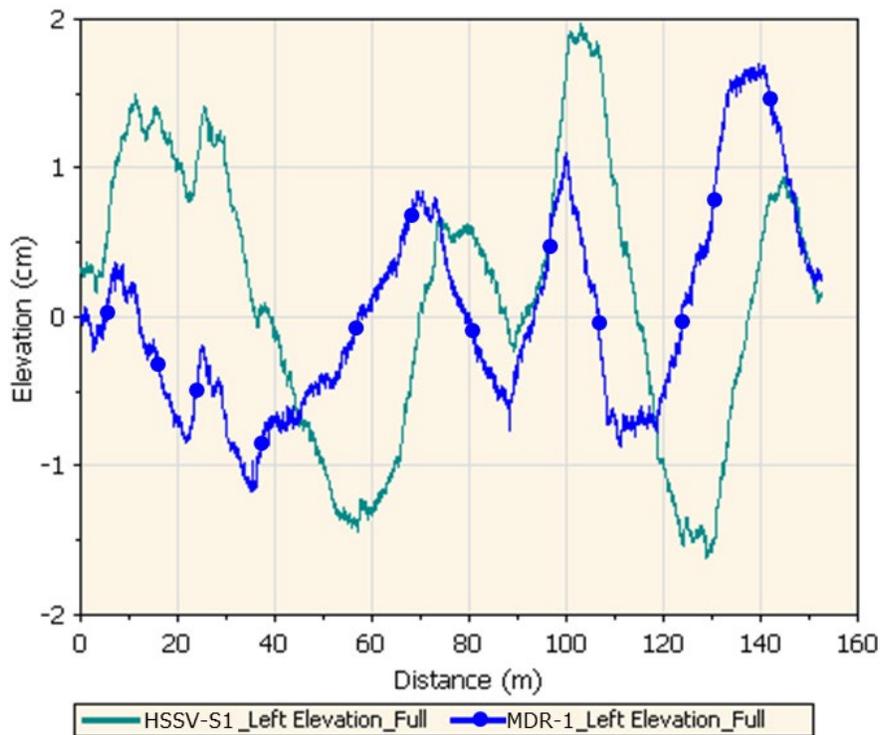
**Figure 186. Graph. Differences in profile due to maintenance within a test section.**



## APPENDIX D. DIFFERENCES BETWEEN MDR AND HSSV PROFILE DATA

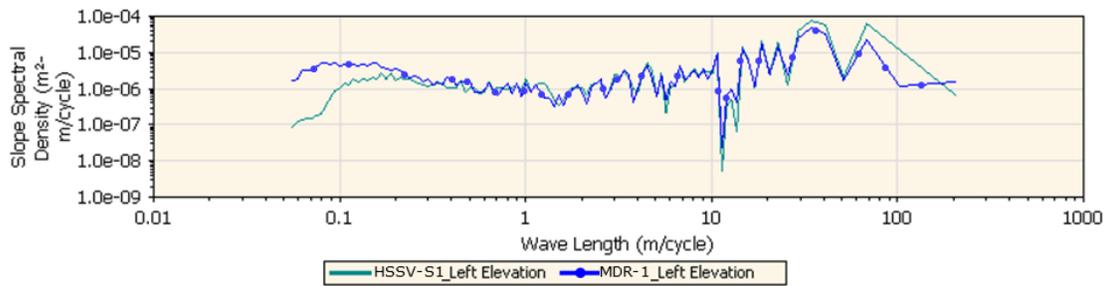
When longitudinal profile data are plotted, differences between profile data collected by MDR devices and HSSVs can be observed. These differences occur because of differences in the upper wavelength cut-off filter applied to the data by the two devices. Although both devices apply a 100-m upper wavelength cutoff filter to the longitudinal profile data, there are differences in the upper wavelength cut-off filter that is used by each device.

Figure 187 shows the left wheel path profile data collected by the MDR and HSSV at a test section (i.e., section 1). The profile data collected at this test section by the two devices look very different. Figure 188 shows the power spectral density (PSD) plot of the profile data shown in figure 187, and this plot shows the two devices collected similar spectral content at this section with some differences for wavelengths after about 90 m, which is close to the 80-m upper wavelength cut-off used for both datasets. Differences in data are also seen for wavelengths below 0.2 m, which occurs because of a low-pass filter applied to the HSSV data.



Source: FHWA.

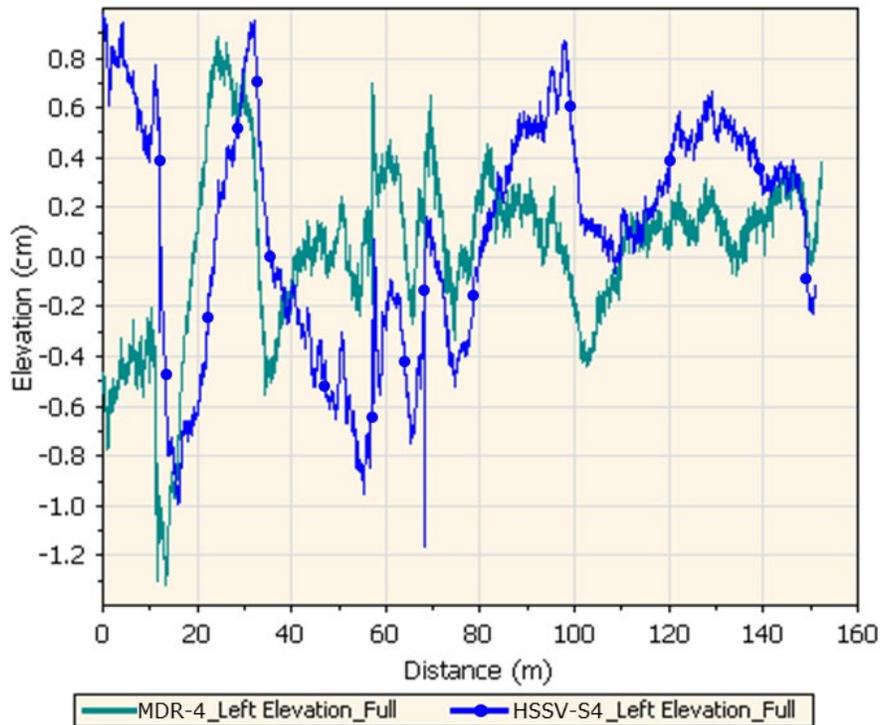
**Figure 187. Graph. MDR and HSSV longitudinal profile data collected at section 1.**



Source: FHWA.

**Figure 188. Graph. PSD plot of longitudinal profile data collected by MDR and HSSV at section 1.**

Figure 189 shows the left wheel path longitudinal profile data collected by the MDR profiler and HSSV at another test section (i.e., section 4). In figure 187, the longitudinal profile data collected at this test section by the two devices look very different. However, some of the sharp upward and downward features in the two longitudinal profiles occur at the same distance. Figure 190 shows the PSD plot of the profile data shown in figure 189, and the PSD plot shows the two devices collected similar spectral content at this test section, except some content had higher wavelengths and some had a wavelength less than 0.2 m.



Source: FHWA.

**Figure 189. Graph. MDR and HSSV profile data collected at section 4.**



Source: FHWA.

**Figure 190. Graph. PSD plot of profile data collected by MDR and HSSV devices at section 4.**

Section 2.9.4.2 of this manual indicates that operators should compare longitudinal profile data collected during a test section visit with previous data collected at the test section as a quality control measure. However, as shown by the two examples in this appendix, comparing longitudinal profile data collected by the HSSV with longitudinal profile data collected by the MDR at the same test section can be problematic, as profile plots of the two datasets 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 software provided by the manufacturer. This appendix presents the procedure to be followed for re-linearizing a sensor.

The sensor configuration software must be installed on the HSSV laptop computer. Use the following steps to re-linearize each sensor using the HSSV linearization software:

1. Power up the height sensors and wait until the height sensor temperatures shown on the main screen of the HSSV software has stabilized. Before performing the re-linearization, it is recommended that the temperature indicated on the screen be between 35 and 40°C in 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 important that the appropriate sensor is selected before clicking any other buttons. Pressing another button while the setting is at Global can make changes to the system that is very difficult to correct. Select the sensor that requires relinearization (i.e., ODS 1, ODS 2, ODS 3, ODS 4, or ODS 5) from the Main tab using the appropriate radio button (figure 191). 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 click 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.
3. Click “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.

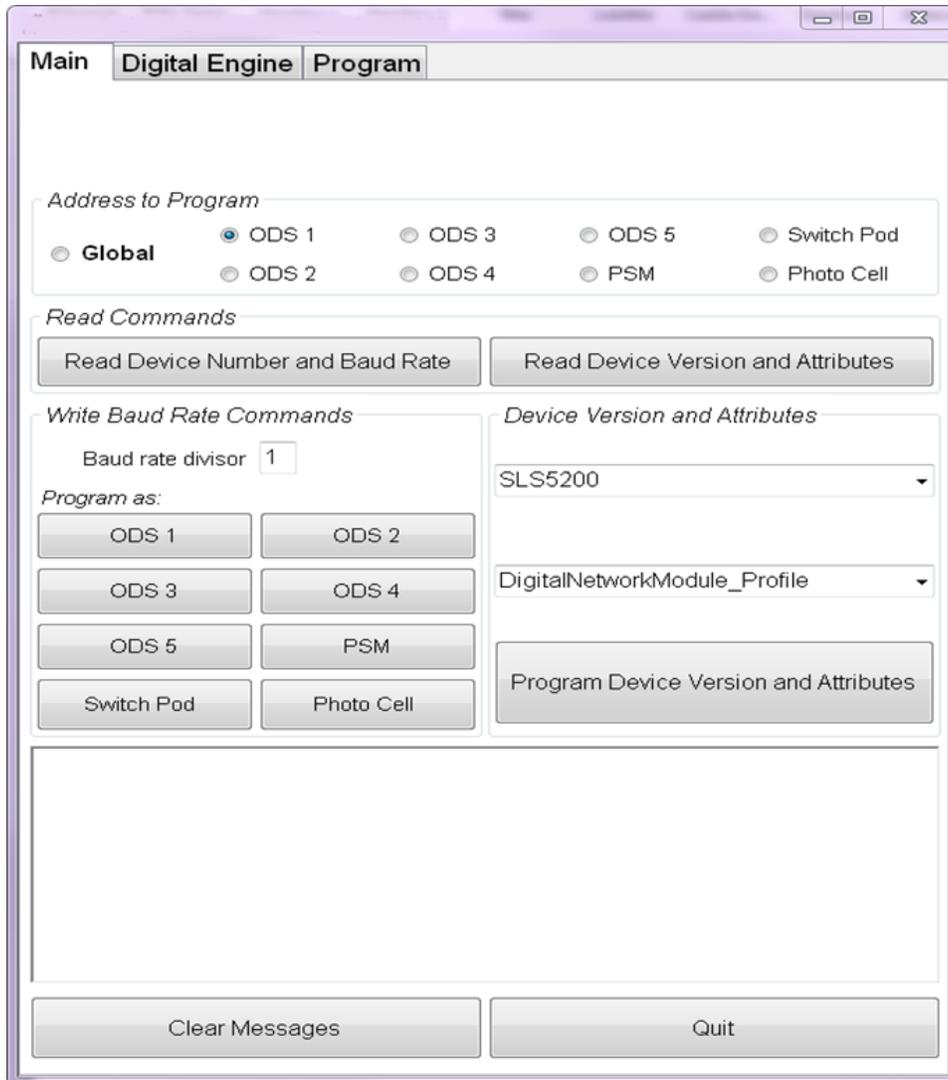
The device number is the same as the address for that device. If the value appropriate for the sensor is not displayed, contact the manufacturer for assistance.

4. Click “Read Device Version and Attributes.” The following information should be displayed in the dialogue box and in the two dropdown menus on the right-hand side:

- ODS 1, ODS 2, and ODS 3—Device Type should show up as SLS5200, with attributes of DigitalNetworkModule\_Profile.
- ODS 4 and ODS 5—Device Type should show up as Optocator180, with attributes of DigitalNetworkModule\_Texture.

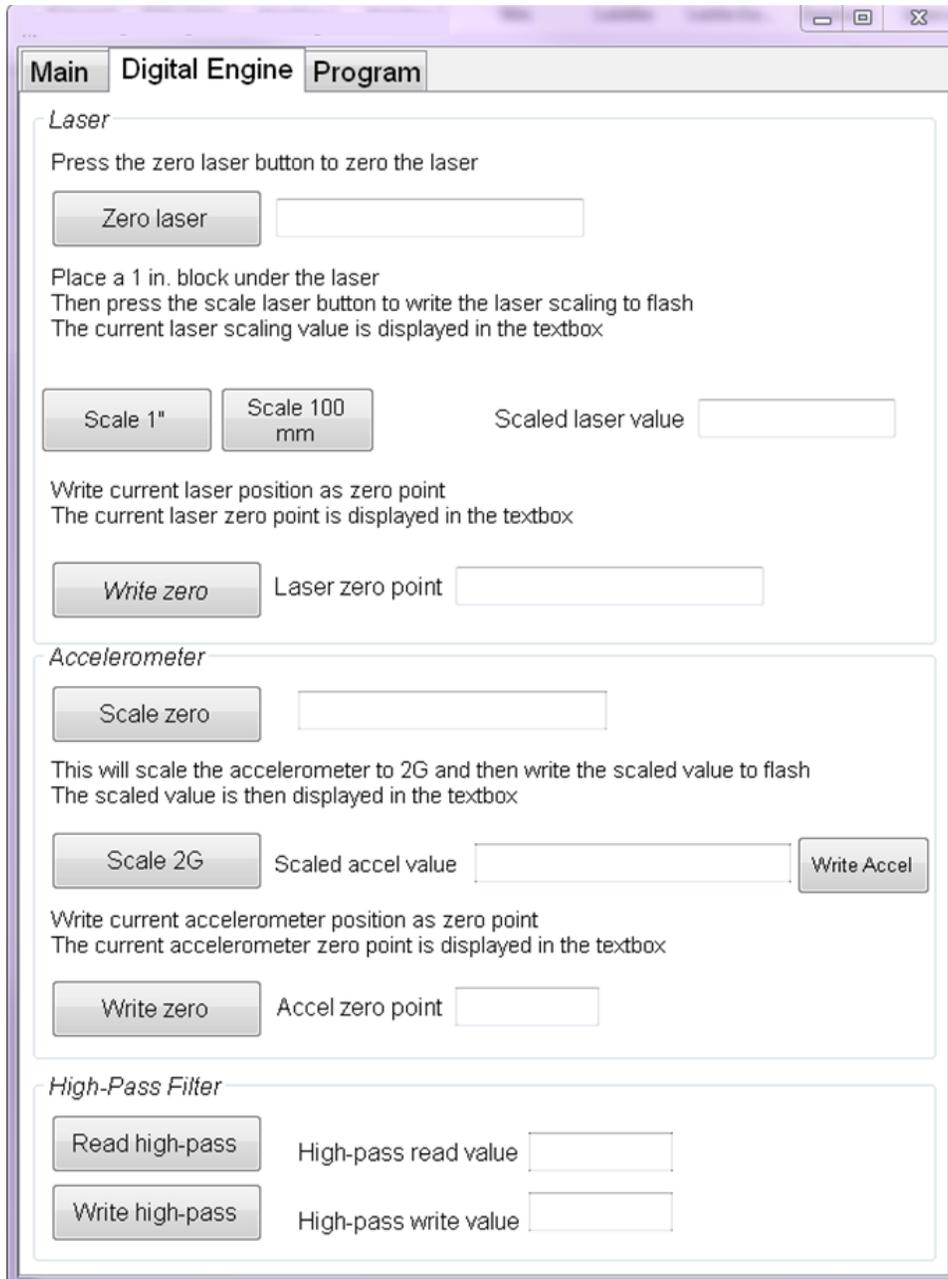
If these values are not displayed, contact the manufacturer for assistance.

5. Place the 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 the calibration checks are performed. 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 marked on the base plate. Place the target on the base plate within the marked square with the matte side facing up. The 100-mm block should be placed behind the target to provide further stability to the base plate.
6. Click on Zero Laser from the Digital Engine tab (figure 192). A statement indicating that the laser has been zeroed will appear 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 matte side facing up. Make sure the laser dot is at the center of the target plate.
8. Click Scale 100 mm. A Scaled Laser Value will be displayed in the dialogue box next to this field. 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  $2,000 \pm 15$ , while the value for the texture laser should be  $2,222 \pm 15$ . If the displayed value is outside this range, this procedure (step 8) should be repeated. If results outside of the required range are obtained after several attempts, the sensor should be sent to the manufacturer for service.
9. Repeat the procedure if another sensor is to be linearized. Otherwise, proceed to step 10.
10. Select Quit from the Main menu to exit 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 on procedure is required to load the new calibration factors into the system. From this point forward, the new calibration factors will be used for data collection.
12. File the Scaled Laser Values from step 8 in an appropriate folder with the date and time of the calibration recorded on the sheet.



Source: FHWA.

**Figure 191. Screenshot. Re-linearization software Main menu.**



Source: FHWA.

**Figure 192. Screenshot. Digital Engine tab of re-linearization software.**

## APPENDIX F. DIPSTICK DATA COLLECTION FORMS

Figure 193 to figure 202 provide the forms for data collection using the Dipstick. The description of how these forms are used is provided in chapter 3.

LTPP Dipstick Data Collection Form Longitudinal Profile Form DS-1 Measurement Information and Closure Computation	State Code [__ __] LTPP Section [__ __ __] Date (dd/mmm/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		<b>Traffic Control Crew:</b>
O4		I4		
O5		I5		
O6		I6		
O7		I7		
O8		I8		
O9		I9		
O10		I10		
O11		I11		
O12		I12		
O13		I13		<b>Other Personnel At Site:</b>
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

Source: FHWA.

**Figure 193. Form. Longitudinal Profile Form DS-1.**

LTPP Dipstick Data Collection Form Longitudinal Profile Form DS-2 Reading 1 to 100	State Code [    ] LTPP Section ID [    ] Date (dd/mmm/yy) [    /    /    ]
--	--

Reading No.	Reading (mm)										
	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

Source: FHWA.

**Figure 194. Form. Longitudinal Profile Form DS-2.**

LTPP Dipstick Data Collection Form Longitudinal Profile Form DS-3 Reading 101 to 200	State Code [____] LTPP Section ID [____] Date (dd/mmm/yy) [____/____/____]
--	--

Reading No	Reading (mm)										
	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	05	15		06	16		07	17		08	18

Source: FHWA.

**Figure 195. Form. Longitudinal Profile Form DS-3.**

LTPP Dipstick Data Collection Form Longitudinal Profile Form DS-4 Readings 201 to 300	State Code [    ] LTPP Section ID [    ] Date (dd/mmm/yy) [    /    /    ]
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Reading No.	Reading (mm)										
	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	09	19		010	110		011	111		012	112

Source: FHWA.

**Figure 196. Form. Longitudinal Profile Form DS-4.**

LTPP Dipstick Data Collection Form Longitudinal Profile Form DS-5 Readings 301 to 400	State Code [____] LTPP Section ID [____] Date (dd/mmm/yy) [__/__/__]
---	--

Reading No.	Reading (mm)										
	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		
<b>Sum</b>	013	113		014	114		015	115		016	116

Source: FHWA.

**Figure 197. Form. Longitudinal Profile Form DS-5.**

LTPP Manual Dipstick Data Collection Form Longitudinal Profile Form DS-6 Station 401 to 500	State Code [____] LTPP Section ID [____] Date (dd/mmm/yy) [__/__/__]
---	--

Reading No	Reading (mm)										
	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

Source: FHWA.

**Figure 198. Form. Longitudinal Profile Form DS-6.**

LTPP Dipstick Data Collection Form Longitudinal Profile Form DS-7 Pre/Post Measurement Zero and Calibration Checks	State Code [____] LTPP Section ID [____] 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	A	Second Reading - 3.2 - First Reading	B

Notes:  
A. First + Second Reading must be less than ± 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 ± 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	A	Second Reading - 3.2 - First Reading	B

Notes:  
A. First + Second Reading must be less than ± 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 ± 0.1. If not, notify the RSC office and contact Face Company for repair.  
Comments: \_\_\_\_\_

Source: FHWA.

**Figure 199. Form. Longitudinal Profile Form DS-7.**

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: \_\_\_\_\_

Source: FHWA.

**Figure 200. Form. Transverse Profile Form DS-8.**

There is no Form DS-9.

<b>LTPP Dipstick Operations</b> <b>LTPP Major Maintenance/Repair</b>  <b>Form DS-10</b>	<b>Region</b> [        ] <b>Serial Number</b> [        ]  <b>Scheduled</b> [ YES / NO ]
--	--

<b>Problem Identification / Scheduled Maintenance</b>  Equipment: _____ Description: _____ _____ _____	Performed By: _____ Date: [    /    /    ] Start Time: [    :    ] End Time: [    :    ]
<b>Troubleshooting</b>  Description: _____ _____ _____ _____	Performed By: _____ Date: [    /    /    ] Start Time: [    :    ] End Time: [    :    ] Hours: _____
<b>Reporting</b>  Referred to: _____ _____  Actions (Return/Order Parts): _____ _____ _____	Date: [    /    /    ] Time: [    :    ]  Date: [    /    /    ] Time: [    :    ]
<b>Service</b>  Description (Repairs Performed/Replacement Part Information): _____ _____ _____ _____  Agency Performing Maintenance: _____ _____ _____	Performed By: _____ Date: [    /    /    ] Start Time: [    :    ] End Time: [    :    ] Hours: _____ Total Cost: [ \$        .    ]
<b>Verification</b>  Description (Check/Calibration): _____ _____ _____ _____	Performed By: _____ Date: [    /    /    ] Start Time: [    :    ] End Time: [    :    ] Hours: _____
<b>Return to Service</b>  Status: _____ _____	Performed By: _____ Date: [    /    /    ]

Source: FHWA.

**Figure 201. Form. LTPP Major Maintenance/Repair Form DS-10.**

<b>LTPP Dipstick Operations</b> <b>Air Temperature Probe Calibration Check</b>  <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 ]

Ambient Temperature Check - Trial # 1	
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.	

Ambient Temperature Check - Trial # 2	
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.	

Ambient Temperature Check - Trial # 3	
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.	

Cold Temperature Check	
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: \_\_\_\_\_  
Source: FHWA.

**Figure 202. Form. Longitudinal Profile Form DS-11.**



## APPENDIX G. PROCEDURE TO DETERMINE DIPSTICK FOOTPAD SPACING

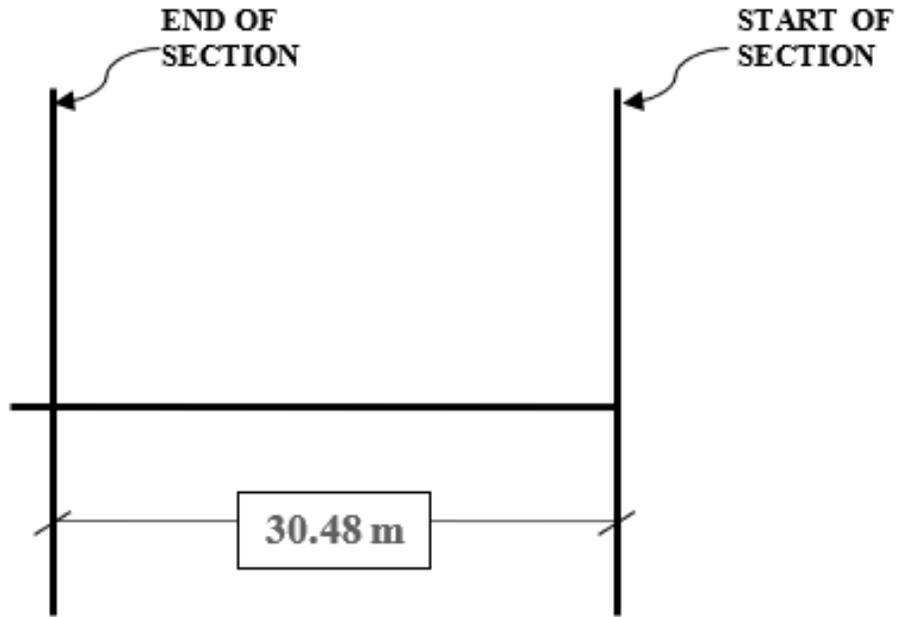
### BACKGROUND

Testing performed in the field has indicated that the spacing between the centerline of the footpads in various Dipsticks used in the LTPP program is not exactly 304.8 mm. Therefore, the DCC 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 computing the footpad spacing of the Dipstick from those data.

### TEST PLAN

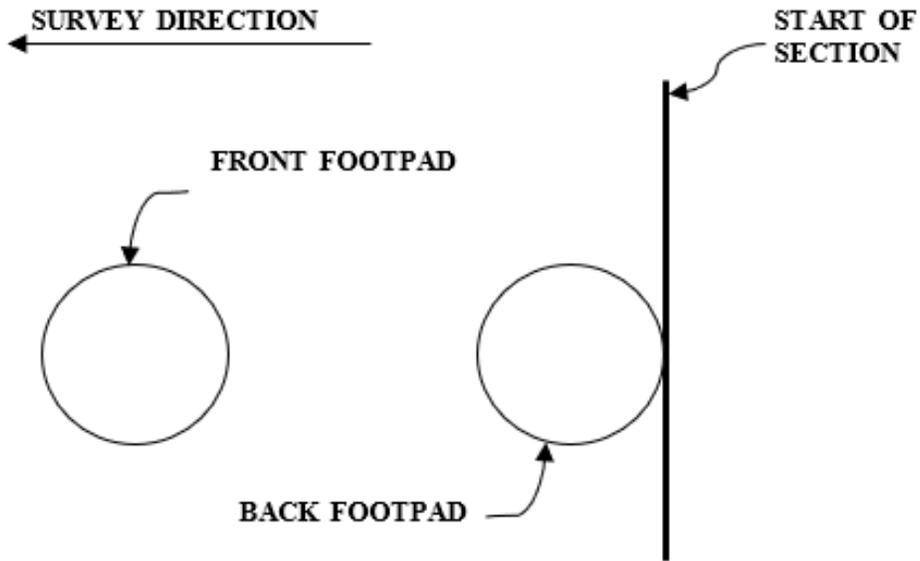
This test should be performed on a smooth AC or PCC pavement that is free of distress. Use the following procedure to lay out the test section and perform the test:

1. Lay out a 30.48-m-long test section using a tape measure that is in a good condition. A longitudinal chalk line should be marked on the test 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 (i.e., 0 m) and end (i.e., 30.48 m) of the test section. Figure 203 shows the layout of the test section.
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 (figure 204).
4. Walk the Dipstick along the test section following the procedures outlined in section 3.3.3 of this manual. After taking the one-hundredth reading, measure the distance (in mm) from the back end of the front footpad of the Dipstick to the transverse line marked at the end of the test 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 (figure 205). The distance to be measured is the distance X indicated in figure 205. Measure this distance (in mm).
  - b. The back end of the front footpad is before the transverse line at the end of the test section (figure 206). The distance to be measured is the distance X indicated in figure 206. Measure this distance (in mm).
  - c. The back end of the front footpad is exactly on the transverse line at the end of the test section, in which case the offset X is 0.
5. Repeat steps 3 and 4 two additional times.



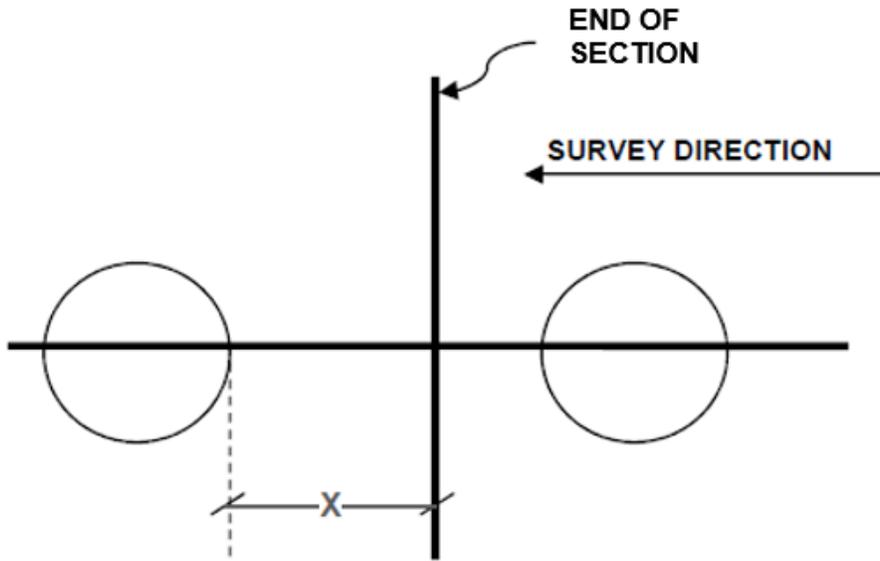
Source: FHWA.

**Figure 203. Diagram. Test section layout.**



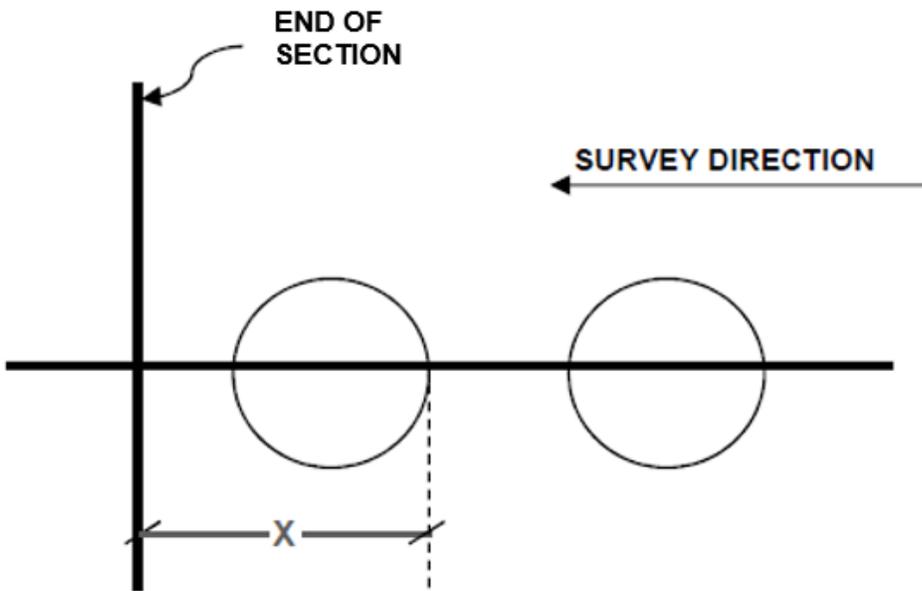
Source: FHWA.

**Figure 204. Diagram. Location of the back footpad of Dipstick at the start of the test section.**



Source: FHWA.

**Figure 205. Diagram. Back end of front footpad is past the end of the test section when the last reading is obtained.**



Source: FHWA.

**Figure 206. Diagram. Back end of the front footpad is before the end of the test section when the last reading is obtained.**

## COMPUTING DIPSTICK FOOTPAD SPACING

1. Compute the footpad spacing for the Dipstick for each run using one of the following procedures:

If back edge of the front footpad was past the end of the test section when the last reading was obtained, use the following formula to compute the footpad spacing (figure 205):

$$\text{Footpad spacing (mm)} = (30,480 + X)/100, \text{ where } X \text{ is in mm.}$$

If back edge of the front footpad was before the end of the test section when the last reading was obtained, use the following formula to compute the footpad spacing (figure 206):

$$\text{Footpad spacing (mm)} = (30,480 - X)/100, \text{ where } X \text{ is in mm.}$$

If the back edge of the front footpad is exactly in line with the end of the test section, the footpad spacing of the Dipstick is 304.8 mm.

Compute the average footpad spacing for each Dipstick by averaging the values obtained for the three runs to two decimal places.

2. Maintain a log in the DCC office that indicates the following information: date when testing was performed, Dipstick model number, diameter of the Dipstick footpads, results from the field tests, computed footpad spacing for each run, and average footpad spacing. The suggested format of the log is shown in figure 207.
3. Write the average Dipstick footpad spacing and date when testing was performed on a sheet of paper and securely tape it to the inside of the Dipstick carrying case.

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			

<sup>1</sup>Offset is positive if the back end of the front footpad is past the end of the test section at the last reading, whereas offset is negative if the back end of the front footpad is before the end of the test section when the last reading is obtained.

Source: FHWA.

**Figure 207. Form. Dipstick footpad spacing log.**

## **APPENDIX H. DATA COLLECTION FORMS FOR ROD AND LEVEL PROFILE MEASUREMENTS**

Figure 208 through figure 212 show forms for collecting profile data with the rod and level.

LTPP Rod and Level Data Collection Form  
 Longitudinal Profile Measurements  
 Form RL-1

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.
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							

B.S. = Back Sight, F.S. = Foresight

Comments: \_\_\_\_\_

Source: FHWA.

**Figure 208. Form. Longitudinal Profile Measurements Form RL-1.**

LTPP Rod and Level Data Collection Form  
 Longitudinal Profile Measurements  
 Form RL-2

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.
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							

B.S. = Back Sight, F.S. = Foresight

Comments: \_\_\_\_\_

Source: FHWA.

**Figure 209. Form. Longitudinal Profile Measurements Form RL-2.**

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							

B.S. = Back Sight, F.S. = Foresight

Comments: \_\_\_\_\_

Source: FHWA.

**Figure 210. Form. Longitudinal Profile Measurements Form RL-3.**

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							

B.S. = Back Sight, F.S. = Foresight

Comments: \_\_\_\_\_

Source: FHWA.

**Figure 211. Form. Longitudinal Profile Measurements Form RL-4.**

LTPP Rod and Level Data Collection Form  
 Longitudinal Profile Measurements  
 Form RL-5

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.
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			

B.S. = Back Sight, F.S. = Foresight

Comments: \_\_\_\_\_

Source: FHWA.

**Figure 212. Form. Longitudinal Profile Measurements Form RL-5.**

## **APPENDIX I. FORMS FOR HSSV COMPARISON TESTS**

Figure 213 through figure 219 show the forms used for HSSV comparison tests.

**PROFILE HEIGHT SENSORS - STATIC HEIGHT SENSOR MEASUREMENTS**

**FORM COMP-1**

RSC: \_\_\_\_\_

Date: \_\_\_\_\_

Value of Height (mm) when Device is on Ground  
on a Level Surface:

ODS1: \_\_\_\_\_ ODS2: \_\_\_\_\_ ODS3: \_\_\_\_\_

**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**

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 STDEVP function in Excel

Source: FHWA.

**Figure 213. Form. Profile Height Sensors—Static Height Sensor Measurements Form COMP-1.**

**TEXTURE HEIGHT SENSORS - STATIC HEIGHT SENSOR MEASUREMENTS**

**FORM COMP-2**

RSC: \_\_\_\_\_

Date: \_\_\_\_\_

Value of Height (mm) when Device is on Ground  
on a Level Surface:

ODS4: \_\_\_\_\_ ODS5: \_\_\_\_\_

**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 function in Excel

Source: FHWA.

**Figure 214. Form. Texture Height Sensors—Static Height Sensor Measurements Form COMP-2.**

ACCELEROMETER CALIBRATION CHECK, BOUNCE TEST, AND TEXTURE DYNAMIC CHECK FORM						FORM COMP-3	
Region							
STATIC AND DYNAMIC BOUNCE CHECK							
	Initial Static Segment 2 IRI (m/km)	Dynamic Segment 4 IRI (m/km)	Final Static Segment 7 IRI (m/km)	IRI Seg. 4 - Seg. 2 (m/km)	Pass (Y/N)	IRI Seg. 7 - Seg. 2 (m/km)	Pass (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)							

Source: FHWA.

**Figure 215. Form. Accelerometer Calibration Check, Bounce Test, and Texture Dynamic Check Form COMP-3.**

<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		
Standard deviation		

Note: Use the STDEV function in Excel to calculate standard deviation.

Source: FHWA.  
 1 psi = 6.895 kPa.

**Figure 216. Form. DMI Measurements Form COMP-4.**

<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		
Standard deviation		

Note: Use the STDEVP function in Excel to calculate standard deviation.

Source: FHWA.  
 1 psi = 6.895 kPa.

**Figure 217. Form. DMI Verification Form COMP-5.**

<b>IRI VALUES</b>	<b>FORM COMP-6</b>
-------------------	--------------------

**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)							

Source: FHWA.

**Figure 218. Form. IRI Values Form COMP-6.**

<b>MPD VALUES</b>	<b>FORM COMP-7</b>
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**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)							

Source: FHWA.

**Figure 219. Form. MPD Values Form COMP-7.**

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