FHWA LTPP Guidelines for Measuring Bridge Approach Transitions Using Inertial Profilers

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U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
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McLean, VA 22101-2296

FOREWORD

This document presents guidelines to measure bridge approach transitions using inertial profilers. The guidelines were developed by the Long-Term Pavement Performance (LTPP) Program and the Office of Infrastructure Research and Development Bridge and Foundation Engineering Team. The bump at the end of the bridge has long been studied for highways and railways, yet experts from across the transportation industry continue to identify it as one of the most prevalent substructure factors affecting bridge performance. Often, rideability is a subjective measurement used by State transportation departments to define the presence of a bump. User complaints typically drive maintenance schedules. However, the bump is not just an annoyance on the traveling public; the dynamic impact of vehicles resulting from the bump causes distress, fatigue, and long-term damage to the bridge deck. In addition, the bump also causes damage to vehicles and potentially creates an unsafe condition for drivers when this issue is not maintained in a timely manner. This guideline describes the methodology for measuring bridge approach transitions using inertial profilers. Details include bridge sectioning and site information, data collection procedures, and data analysis and reporting approaches. The intended audience for this report is pavement and bridge engineering professionals and researchers.

The LTPP Program is an ongoing and active program. To obtain current information and to access other technical references, LTPP data users should visit the LTPP Web site at http://www.tfhrc.gov/pavement/ltpp/ltpp.htm. LTPP data requests, technical questions, and data user feedback can be submitted to LTPP customer service via e-mail at ltppinfo@fhwa.dot.gov.

Cheryl Richter
Director, Office of Infrastructure
Research and Development

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The bump at the end of the bridge has long been studied for highways and railways, yet experts from across the transportation industry continue to identify it as one of the most prevalent substructure factors affecting bridge performance. Often, rideability is a subjective measurement used by transportation departments to define the presence of a bump. User complaints typically drive maintenance schedules. However, the bump is not just an annoyance on the traveling public; the dynamic impact of vehicles resulting from the bump causes distress, fatigue, and long-term damage to the bridge deck. In addition, the bump also causes damage to vehicles and potentially creates an unsafe condition for drivers when this issue is not maintained in a timely manner. This guideline describes the methodology for measuring bridge approach transitions using inertial profilers. Details include bridge sectioning and site information, data collection procedures and data analysis, and reporting approaches.</td></tr>
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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the 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 ABBREVIATIONS

DMI	distance-measuring instrument
ERD	Engineering Research Division
FHWA	Federal Highway Administration
GPS	Global Positioning System
GRS	geosynthetic reinforced soil
IBS	Integrated Bridge System
ID	identification
IRI	International Roughness Index
LTPP	Long-Term Pavement Performance
PCC	portland cement concrete
PI	Profile Index
PPF	pavement profile format
RSE	rolling straight edge
WIM	weigh-in-motion

CHAPTER 1. PROFILING BRIDGE SECTIONS

BACKGROUND

The bump at the end of the bridge has long been studied for highways and railways, yet experts from across the transportation industry continue to identify it as one of the most prevalent substructure factors affecting bridge performance. Often, rideability is a subjective measurement used by State transportation departments to define the presence of a bump. User complaints typically drive maintenance schedules. However, the bump is not just an annoyance on the traveling public; the dynamic impact of vehicles resulting from the bump causes distress, fatigue, and long-term damage to the bridge deck. In addition, the bump also causes damage to vehicles and potentially creates an unsafe condition for drivers if this issue is not addressed in a timely manner. To ensure that the bump is within tolerable limits based on safety, rideability, and effects to long-term bridge performance for State transportation departments, tools are necessary to measure and assess the bridge approach transition. These products can ultimately be used to help State transportation departments manage and preserve their bridge inventory.

PROFILE DATA COLLECTION CONSIDERATIONS FOR BRIDGE APPROACH TRANSITIONS

The high-speed inertial profiler is an excellent tool to determine the smoothness or lack thereof as the result of differential differences between pavements, bridge approaches, and bridge structure. These devices can collect profile data without interruption to the travelling public, have sample rates of 1 inch or less, produce profiles that are consistent and repeatable, and provide datasets that are useable for producing numerous indices for riding comfort and pavement profile. The International Roughness Index (IRI), rolling straight edge (RSE) simulation, and diamond grinding simulation analysis have all been used to evaluate and provide solutions for issues with bridge approach transitions.(1) Profiling devices such as the Face Dipstick® or walking profiler (e.g., International Cybernetics' SurPRO) could also be considered if only a few bridges were to be considered for testing. Testing with these devices requires a greater level of coordination because there is a need for lane closures and site preparation, which would most likely limit production to one site per test day. Of these two devices, the walking profiler would be the better alternative because a sample rate of less than 1 inch is possible. The elevations from these devices are generated without extensive filtering, which results in a product that is more representative of the true profile. A high-speed inertial profiler will detect a bump or dip at bridge approach transitions to a similar level of accuracy, but the longwave profile shape will not match that of the true profile. For profile data collection at bridge approach transitions, the high-speed inertial profiler can provide all of the information needed to detect bump or dip locations and produce statistics (e.g., IRI and RSE) to evaluate and compare bridge transition performance. Bump height can be obtained, but it will be a representative value. A comparison of testing devices is shown in table 1.

Table 1. Comparison of testing devices.

Device	Pros	Cons
Inertial profiler	· 1-inch (25.4-mm) or less sample rate. · Quick (multiple sites per day). · No lane closure required. · No site preparation.	High wavelengths filtered out.
Dipstick®	True profile.	· Lane closure. · Necessary site preparation. · Slow speed (approximately 1 site per day). · 1-ft (0.305-m) sample rate.
Walking profiler	· 1-inch (25.4-mm) or less sample rate. · True profile.	· Lane closure. · Site preparation necessary. · Slow pace of measurement (approximately 1 site per day).

The bridge profile data collection procedure was developed using the Federal Highway Administration's (FHWA) Long Term Pavement Performance (LTPP) high-speed inertial profiler. Survey units (see figure 1) contained three pavement profiling sensors located in the left and right wheelpaths and midlane, two 62.5-kHz texture-sensing lasers located in the left and right wheelpaths, ambient and surface temperature sensors, a Global Positioning System (GPS), and a forward direction photo logger.

Figure 1. Photo. Survey unit.

Although 25 ft (8 m) of pavement before and after the approach area is considered sufficient for bridge ride specifications, collecting data over a longer length provides a better understanding of bridge performance relative to localized pavement condition.(2) These guidelines are based primarily on measurement procedures used within the LTPP Program for profiling weigh-in-motion (WIM) sites. The WIM data collection started 902 ft (275 m) prior to the WIM sensor and continued 97 ft (30 m) past it. This length was selected to measure how the bumps in the road affected truck movement and the resulting variability in dynamic loads that would affect the WIM sensing device. The primary concern for selection and calibration of WIM locations was to ensure that the location selected did not have a pavement profile that would induce unacceptable amounts of truck bounce as the truck approached the WIM scale. By collecting longer pavement lengths prior to the bridge interface, useful information could be used to model the dynamic effects of truck loads on the bridges. For many small, local bridges within the study group, which were primarily on rural roads, it would have been difficult to set up and collect profile data for lengths longer than 200 ft (61 m) prior to and past bridges. Based on this knowledge, the decision was made to use a distance from the bridge deck to the beginning of the test section of 200 ft (61 m) with the distance from the end of the bridge deck to the end of the test section also being 200 ft (61 m). This length should be sufficient enough to monitor the long-term changes that occur at the bridge location using inertial profilers.

For some of the bridge locations, it may be possible to collect profile data with a longer approach to the bridge location. This could be established as a pilot within the data collection if there is interest in modelling the dynamic effects of truck loads on bridges.

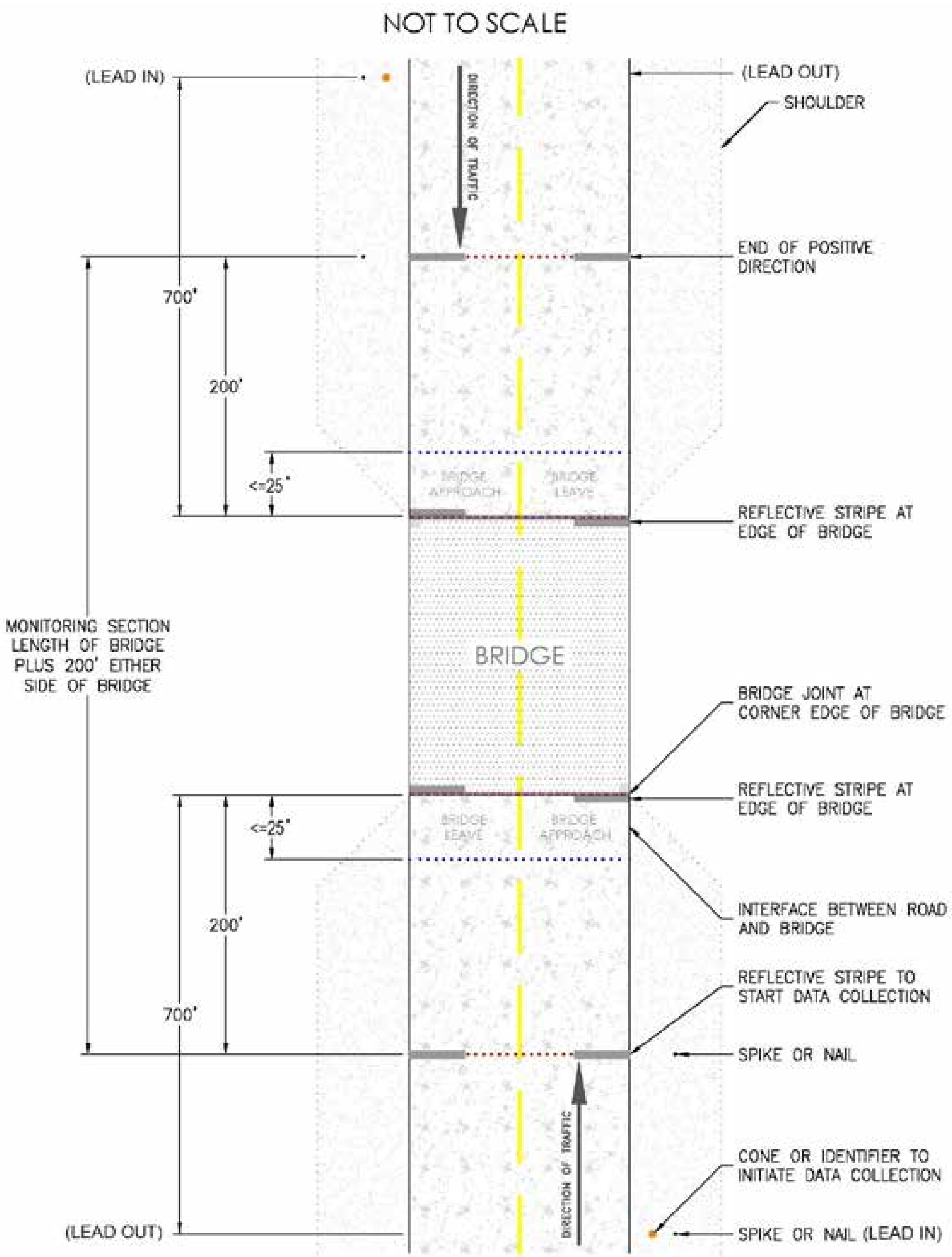
ProVAL is a profile viewing and analysis software used by many State transportation departments and consulting firms as a tool for calibrating inertial profilers and analyzing profile data.[3] This software can use profile data from numerous profilers that are available within the North American market. ProVAL 3.5 has been recently updated to handle the .ARD file that is the current profile file generated from the LTPP profilers. Due to these added features within ProVAL, the use of this software for the processing of the bridge profile data is suggested. Some manipulation of the data may, however, be required for processing and presentation, but for the most part, ProVAL generates the reports for the bridge surveys.

Two 62.5-KHz texture-sensing lasers located in the left and right wheelpaths collected profile data at 0.012-inch (0.5-mm) intervals. The texture laser sensor output is a point-to-point measurement with a greater accuracy than that of the 16 kHz profile lasers. Unlike the profile laser sensors, which are integrated with the accelerometer output to generate a pavement profile, the output from these lasers is simply the step difference between samples. Some of the limitations of the texture laser are that there are spikes that are not part of the sampling within the profile data. Algorithms have been developed to remove these spikes, but at this time, there does not seem to be any consensus about the validity of the spike removal process. While options for spike removal exist, they are not currently used in the data collection and processing of LTPP profile data. The tight interval sampling provides an opportunity to identify discreet changes within the pavement surface with a greater level of accuracy than is available from the profile sensors because of the tighter sample rate and minimal filtering. Procedures are in place to use this information for determining pavement texture and are under consideration for determining faulting in portland cement concrete (PCC) pavements. It is possible to use this information to locate and measure the step at the transition between the pavement, approach structure, and bridge, but at this time, there is no widely available software that could be used for this purpose. As development in this area continues, the data collected could be useful in future analysis.

BRIDGE SECTIONING AND SITE INFORMATION

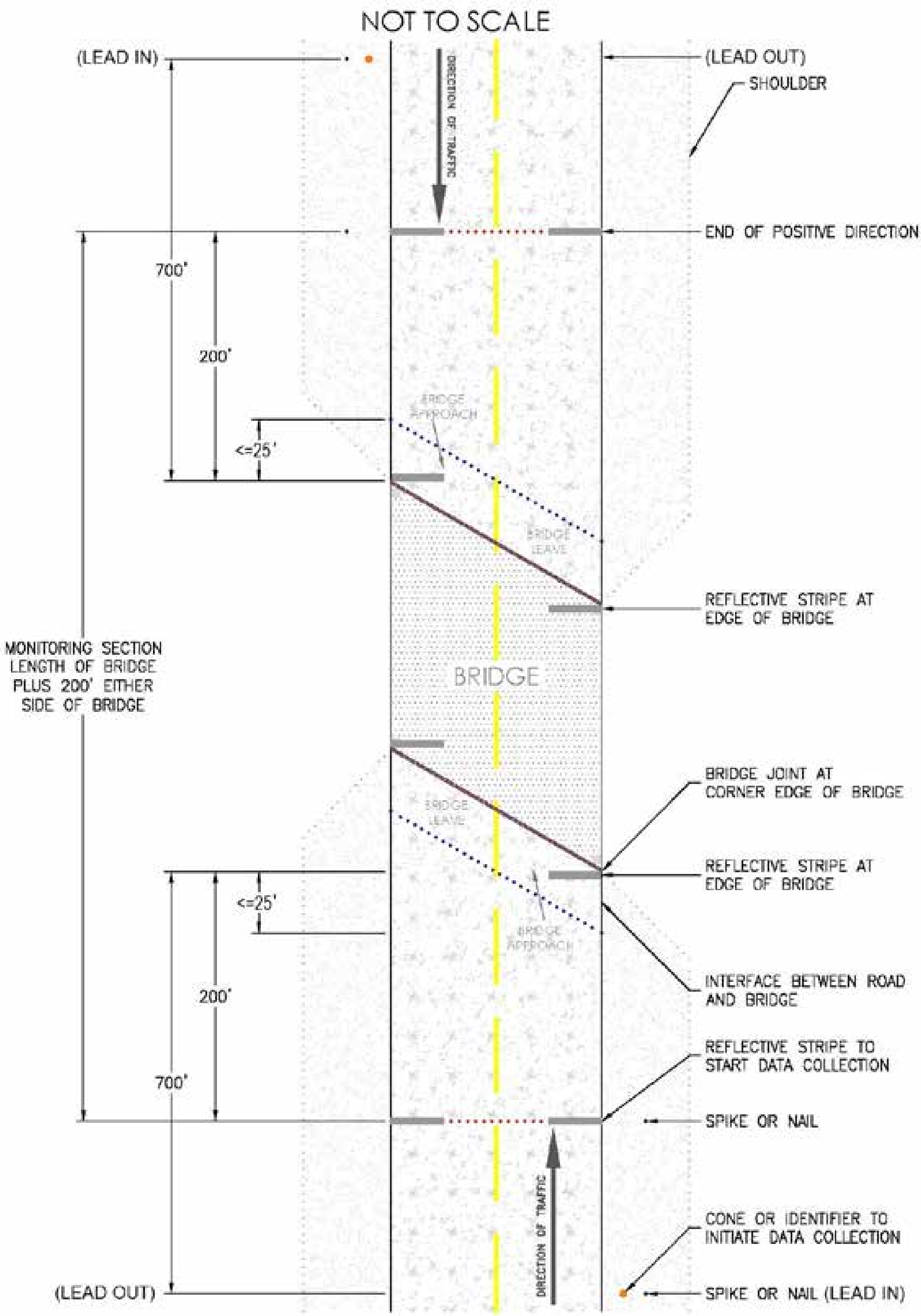
A *bridge profile section* for purposes of this survey is defined as a section that includes a portion of pavement prior to the approach structure, bridge deck, and portion of pavement after the bridge. The length of the section will vary depending on the span length of the bridge deck. For some types of bridges, it may not be possible to visually determine the interface location of the approaches from the bridge. In general, the transition distance is within 25 ft (8 m) of the bridge structure. It is about 3 to 5 ft (0.9 to 1.5 m) from the face of the abutment wall to the end of the beams. The distance from the bridge deck to the beginning of the test section should be 200 ft (61 m), and the distance from the end of the bridge deck to the end of the test section should also be 200 ft (61 m). This distance may be modified at the discretion of the profile operator if any safety issues related to location conditions exist (e.g., stop signs within the profile area).

The bridge section should be marked as shown in figure 2 for bridge decks that are perpendicular to the paved roadway. Marking for bridge decks that are on a skew are shown in figure 3. Bridges that have both a perpendicular and skewed deck interface will require markings based on information provided from both figures. Monuments (in the form of nails or spikes) should be installed in the shoulders at the beginning and end of the test section as shown in the figures. These monuments will serve as section markers for future surveys. The monument at the beginning of the section should be located 200 ft (61 m) before the leading edge of the bridge deck. The monument at the end of the section should be located 200 ft (61 m) after the end of the deck, in the shoulder of the opposite lane. The distances measured should be accurate to within ±1 ft (0.305 m). Profile surveys should be done for all lanes in both directions.



1 ft = 0.305 m.

Figure 2. Drawing. Layout of bridge site with perpendicular joints.



1 ft = 0.305 m.

Figure 3. Drawing. Layout of bridge site with skewed joints.

A fourth-order Butterworth high-pass filter was used to determine profile elevations for these surveys with a cutoff wavelength of 300 ft (91 m). For the filter to have sufficient length to normalize the profile elevations, a minimum of 450 ft (137 m) of lead-in and lead-out were required (1.5 times the filter wavelength). For bridges on a curve, the minimum lead-in and lead-out required should be based on the lane with the shortest curve length. The survey unit had a default setting of 500 ft (152 m). To ensure the proper lead-in length and consistency in profile data collection, it is recommended that a cone or marker be placed as a reference for the profile operator to initiate the profile data collection. A permanent monument (in the form of nails or spikes) should be considered at these locations for ease of reference in future surveys. The speed of the profiler during the lead-in and lead-out should be consistent with that of the profile data collection. In other words, there should be no acceleration or deceleration in the lead-in or lead-out area.

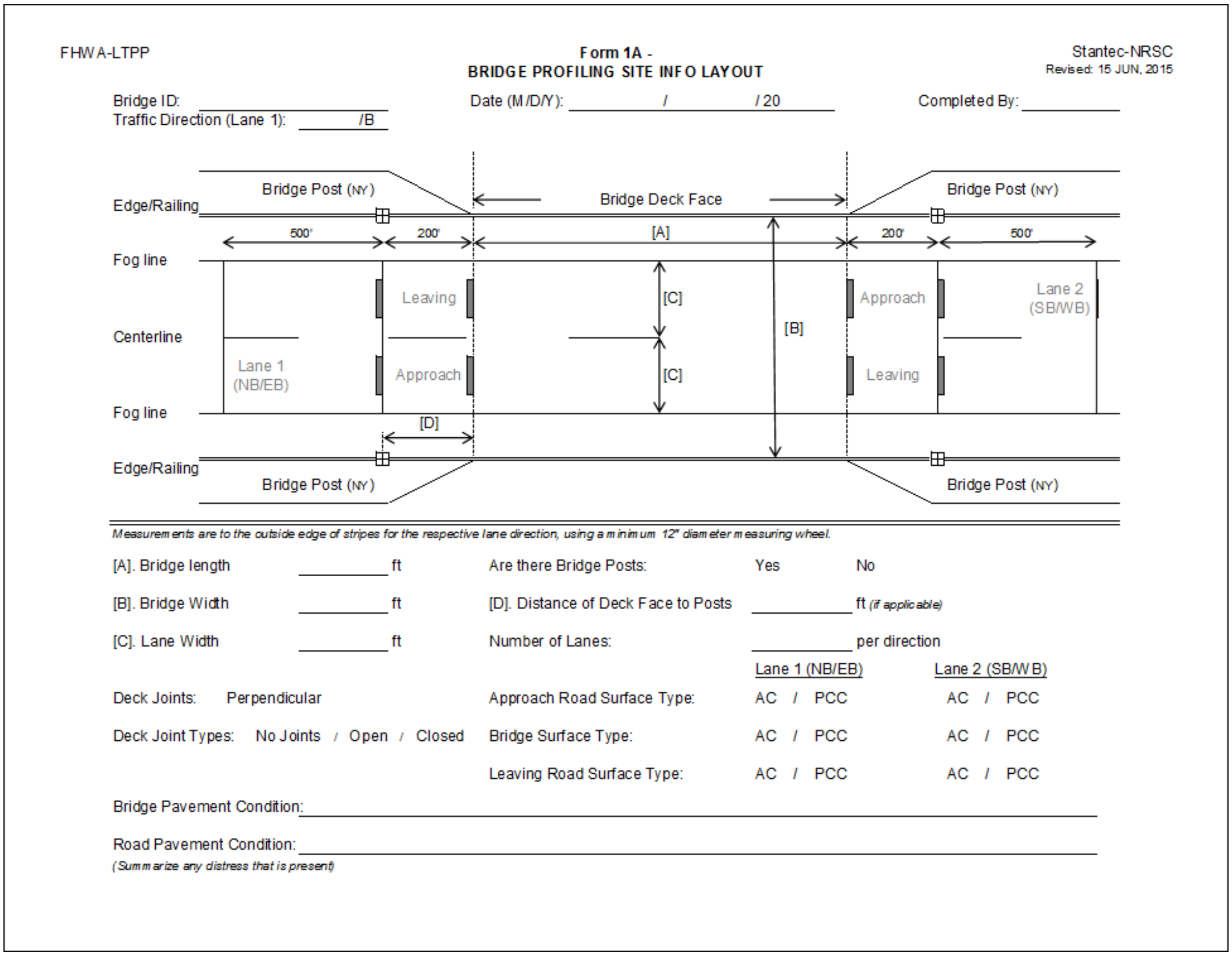
To initiate the profile data collection and identify the start and end of the bridge deck, reflective stripes or cones should be placed at the start and end of the section and at the start and end of the bridge deck. The leave edge of the stripes should be next to the applicable monument. There are a number of options available to provide a reflective surface for the profiler photocell to initiate data collection. If no permanent or semipermanent reflective stripe is evident at the defined locations, the profiler crew can place cones with reflective tape near the edge of pavement and bridge deck. Alternatively, a reflective stripe (typically 2 inches (51 mm) in width) needs to be placed in the lane located perpendicular to the edge of pavement.

For State transportation departments willing to permanently mark the test location, preparations should be coordinated at the time of the first profile data collection to ensure that bridge section markings are consistent. This will allow for subsequent surveys to be repeated at the same locations. Alternatively, the profiler crew will be required to locate, measure, mark, and install the permanent monuments prior to the first survey.

Section location information can be painted near the outside shoulder for permanently marked sites at the discretion of the State transportation department. To locate a bridge, the profiler crew relies on the GPS longitude and latitude coordinates provided by the department or from a previous survey.

The profiler crew collects and records information regarding the roadway, bridge approach, and bridge structure on form 1A, as shown in figure 4. The following information would be useful in identifying test locations:

- The length and width of the bridge.
- The type and length of the approach.
- Pavement type (e.g., asphalt concrete or PCC).
- Pavement condition (e.g., cracking, deformations, and texture (with particular attention to the transition zones)).
- Landmarks or benchmarks (e.g., bridge posts).



FHWA-LTPP

Form 1A -
BRIDGE PROFILING SITE INFO LAYOUT

Stantec-NRSC
Revised: 15 JUN, 2015

Bridge ID: ____________
Traffic Direction (Lane 1): ______ /B

Date (M/D/Y): ______ / ______ / 20______

Completed By: ____________

Measurements are to the outside edge of stripes for the respective lane direction, using a minimum 12" diameter measuring wheel.

[A]. Bridge length ________ ft

[B]. Bridge Width ________ ft

[C]. Lane Width ________ ft

Are there Bridge Posts: Yes No

[D]. Distance of Deck Face to Posts ________ ft *(if applicable)*

Number of Lanes: ________ per direction

	Lane 1 (NB/EB)	Lane 2 (SB/WB)
Approach Road Surface Type:	AC / PCC	AC / PCC
Bridge Surface Type:	AC / PCC	AC / PCC
Leaving Road Surface Type:	AC / PCC	AC / PCC

Deck Joints: Perpendicular

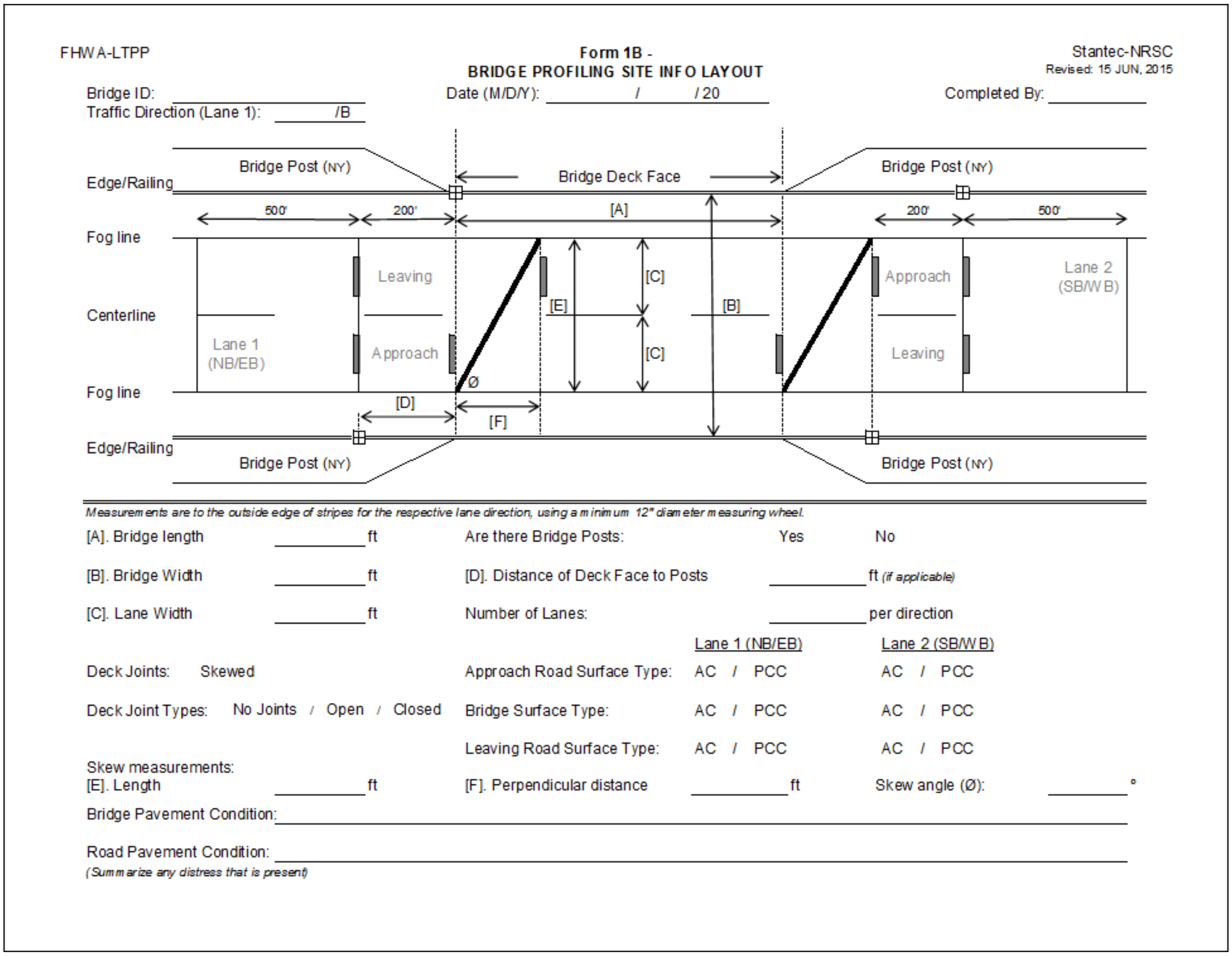
Deck Joint Types: No Joints / Open / Closed

Bridge Pavement Condition: ____________________________

Road Pavement Condition: ____________________________
(Summarize any distress that is present)

Figure 4. Form. Perpendicular joint site layout (form 1A).

For bridges having a skewed interface with the roadway, the profile crew should use form 1B (see figure 5) and also provide the length of the skew and the distance between the start and end portion of the skew. Measurement procedures, measurement tools, and dimensional information (including all length and width information relevant to the survey) should be incorporated into the diagram as outlined in the corresponding form (1A or 1B).(4) Comments specific to the site conditions and location should also be included.


FHWA-LTPP

Form 1B -
BRIDGE PROFILING SITE INFO LAYOUT

Stantec-NRSC
Revised: 15 JUN, 2015

Bridge ID: ______
Traffic Direction (Lane 1): ____ /B
Date (M/D/Y): ____ / ____ / 20____
Completed By: ______

Measurements are to the outside edge of stripes for the respective lane direction, using a minimum 12" diameter measuring wheel.

[A]. Bridge length ______ ft
Are there Bridge Posts: Yes No
[B]. Bridge Width ______ ft
[D]. Distance of Deck Face to Posts ______ ft *(if applicable)*
[C]. Lane Width ______ ft
Number of Lanes: ______ per direction

		Lane 1 (NB/EB)	Lane 2 (SB/WB)
Deck Joints: Skewed	Approach Road Surface Type:	AC / PCC	AC / PCC
Deck Joint Types: No Joints / Open / Closed	Bridge Surface Type:	AC / PCC	AC / PCC
	Leaving Road Surface Type:	AC / PCC	AC / PCC

Skew measurements:
[E]. Length ______ ft
[F]. Perpendicular distance ______ ft
Skew angle (Ø): ______ °

Bridge Pavement Condition: ______

Road Pavement Condition: ______
(Summarize any distress that is present)

Figure 5. Form. Skewed joint site layout (form 1B).

Pictures of the bridge, the bridge superstructure, pavement section, unique features (i.e., cracks in the pavement, vertical offsets, etc.), and location landmarks should be taken at the time of survey. Form 2A, as shown in figure 6, should be used to record the number and type of each picture. Form 2B (see figure 7) shows an overhead view of the photo locations. Pictures should not include any individual or vehicle license. In the event that these details are captured in any of the photos, either the photo should be deleted or the image blurred.

FHWA-LTPP

Form 2A -
BRIDGE PROFILING PHOTO LOG

Stantec-NRO
Revised: 02 FEB 2015

Date (yyyy/mm/dd): 20 / /

Bridge Type: GRS-IBS / Conventional

Weather: Sunny / P. Cloudy / Cloudy

Bridge Name:

Vehicle: AESU 830112 / AESU 830412 / others

City/County:

Bridge Surface Type: AC / PCC

State: (2 alphabets)

Bridge ID: (G or S + 3 digits)

Road Surface Type: AC / PCC

Prepared by:

Highway #:

Dir.: /B (+ve, Lane 1)

Photo #	Standard or Non-standard	Detail	Direction (N, E, S, W)	Filename BPPaatnnnsyyyy##.jpg
1	Standard, +ve	Bridge ID Tag on the face of structure wall		BPP 201 01.jpg
2	Standard, +ve	Bridge approach interface & beginning stripe, looking with traffic		BPP 201 02.jpg
3	Standard, +ve	Bridge approach interface & beginning stripe, looking against traffic		BPP 201 03.jpg
4	Standard, +ve	Bridge outside edge & support structure at beginning of bridge, looking against traffic (45°)		BPP 201 04.jpg
5	Standard, +ve	Bridge outside edge & bridge span at beginning of bridge, looking with traffic (45°)		BPP 201 05.jpg
6	Standard, +ve	Bridge approach interface & ending stripe, looking with traffic		BPP 201 06.jpg
7	Standard, +ve	Bridge approach interface & ending stripe, looking against traffic		BPP 201 07.jpg
8	Standard, +ve	Bridge outside edge & bridge span at ending of bridge, looking against traffic (45°)		BPP 201 08.jpg
9	Standard, +ve	Bridge outside edge & support structure at ending of bridge, looking with traffic (45°)		BPP 201 09.jpg
10	Standard, -ve	Bridge approach interface & beginning stripe, looking with traffic		BPP 201 10.jpg
11	Standard, -ve	Bridge approach interface & beginning stripe, looking against traffic		BPP 201 11.jpg
12	Standard, -ve	Bridge outside edge & support structure at beginning of bridge, looking against traffic (45°)		BPP 201 12.jpg
13	Standard, -ve	Bridge outside edge & bridge span at beginning of bridge, looking with traffic (45°)		BPP 201 13.jpg
14	Standard, -ve	Bridge approach interface & ending stripe, looking with traffic		BPP 201 14.jpg
15	Standard, -ve	Bridge approach interface & ending stripe, looking against traffic		BPP 201 15.jpg
16	Standard, -ve	Bridge outside edge & bridge span at ending of bridge, looking against traffic (45°)		BPP 201 16.jpg
17	Standard, -ve	Bridge outside edge & support structure at ending of bridge, looking with traffic (45°)		BPP 201 17.jpg
18	Non-standard			BPP 201 18.jpg
19	Non-standard			BPP 201 19.jpg
20	Non-standard			BPP 201 25.jpg

Comments:

☐ Yes, checked GPS Coordinates matching the Statement of Work provided.

Filenaming:
BPP = Bridge Profiling Photo; aa = State Code; t = G for GRS-IBS, C for Conventional
nnn = Bridge ID number; 001, 002, etc.; s = annual survey sequence letter; A is 1st, B is 2nd, etc.
yyyy = year of survey; ## = photo sequence # on survey day; 01,02,03, etc.; jpg = jpeg file format extension

Note:
1. **Each photo must be framed within the area outlined by the center line and the edge of pavement or fog line;**
2. **For 45° angle photo, it should capture the location of the bridge support structure, bearings, and earth fill or concrete wall;**
3. **For non-standard photo, it should capture unique features, cracks in the road pavement & bridge deck, vertical offsets, and location landmarks.**
4. **For Chinage, North and East are +ve (Lane 1, 3, 5, etc); while South and West are -ve (Lane 2, 4, 6, etc).**

Figure 6. Log. Form 2A—photo log.

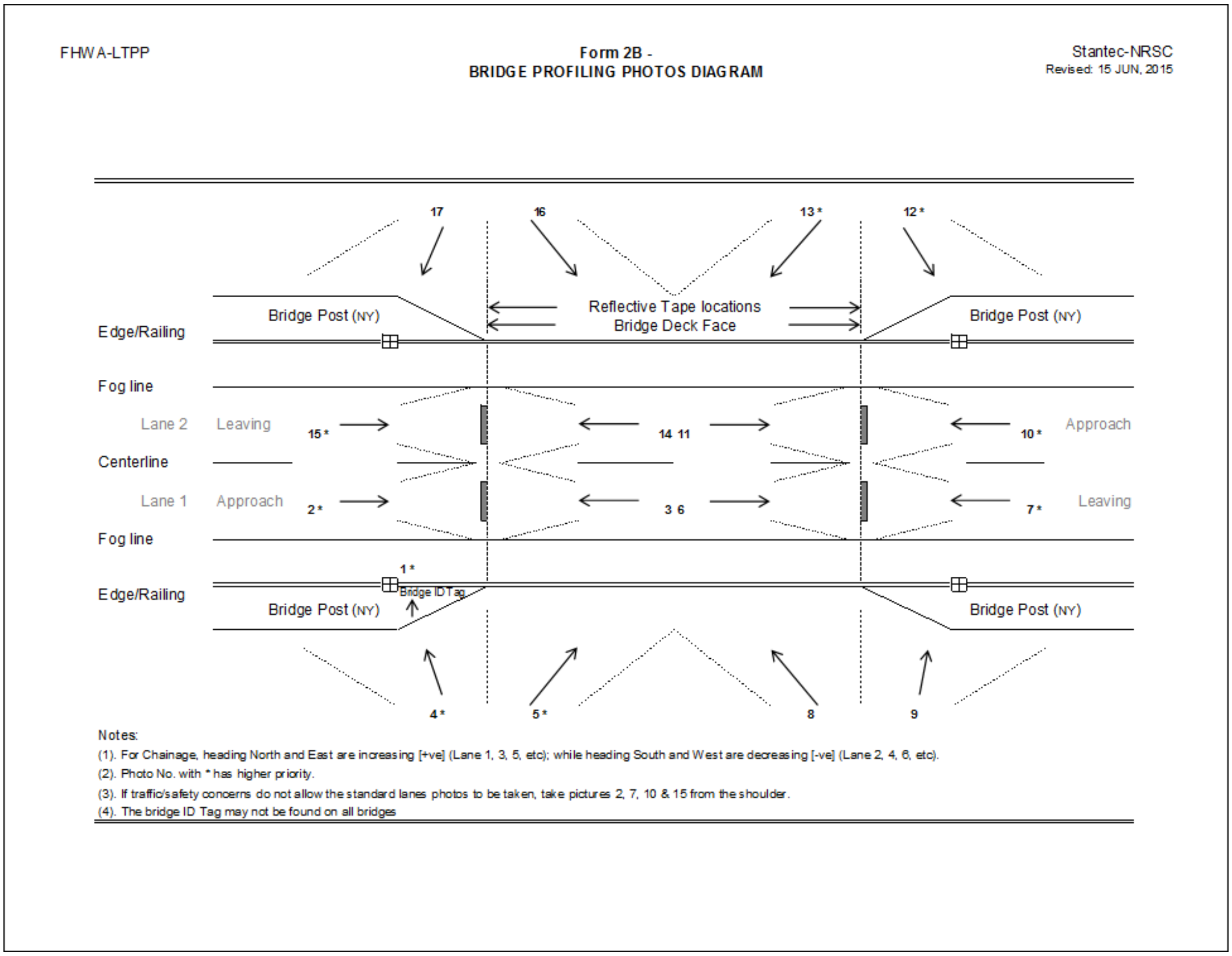


Figure 7. Log. Form 2B—photo diagram.

CHAPTER 2. PROFILE MEASUREMENTS

Profile measurements should be performed with the LTPP inertial profilers survey units in accordance with the data collection and processing guidelines and procedures described in the draft *LTPP Manual for Profile Measurements and Processing* or any subsequent updates or replacements that occur for this manual.(5) The exception is that the setup options are modified for Long-Term Bridge Performance data collection as identified in these guidelines, which outline the procedure for profiling a bridge section and the number of acceptable runs that are required.

INERTIAL PROFILER SETUP

The FHWA LTPP profilers are set up for data collection for the LTPP Program as defined in the draft *LTPP Manual for Profile Measurements and Process* using the LTPP header format.(5) This header format has some limitation for use in collecting profiles for measuring bridge approach transitions. The main limitations are the ability to increment in both the positive and negative direction, input a start location other than zero, and add custom comments for all header information inputs. The long header format will accommodate the input information that is required for the bridge transition profile data collection with some interpretation of the header descriptions. This header format is compatible with the ProVAL software with output format in both the Engineering Research Division (ERD) and pavement profile format (PPF).

The profiler setup procedure for the bridge profile is as follows:

1. Enter the Setup screen from the main menu and select the Analysis Options tab and make the following key changes:

    - English Units—check "feet."

    It is not necessary to update or modify any of the analysis parameters. Figure 8 shows an example of a screen capture of the Analysis setting in the software program.

2. Select the Report Options tab and make the following key changes:

    - Header Format—long.
    - Profile Data Output Files—ERD, ProVAL PPF.

    Figure 9 shows an example of a screen capture of the Report setting in the program.

3. Select the Profile Analysis tab and make the following key changes:

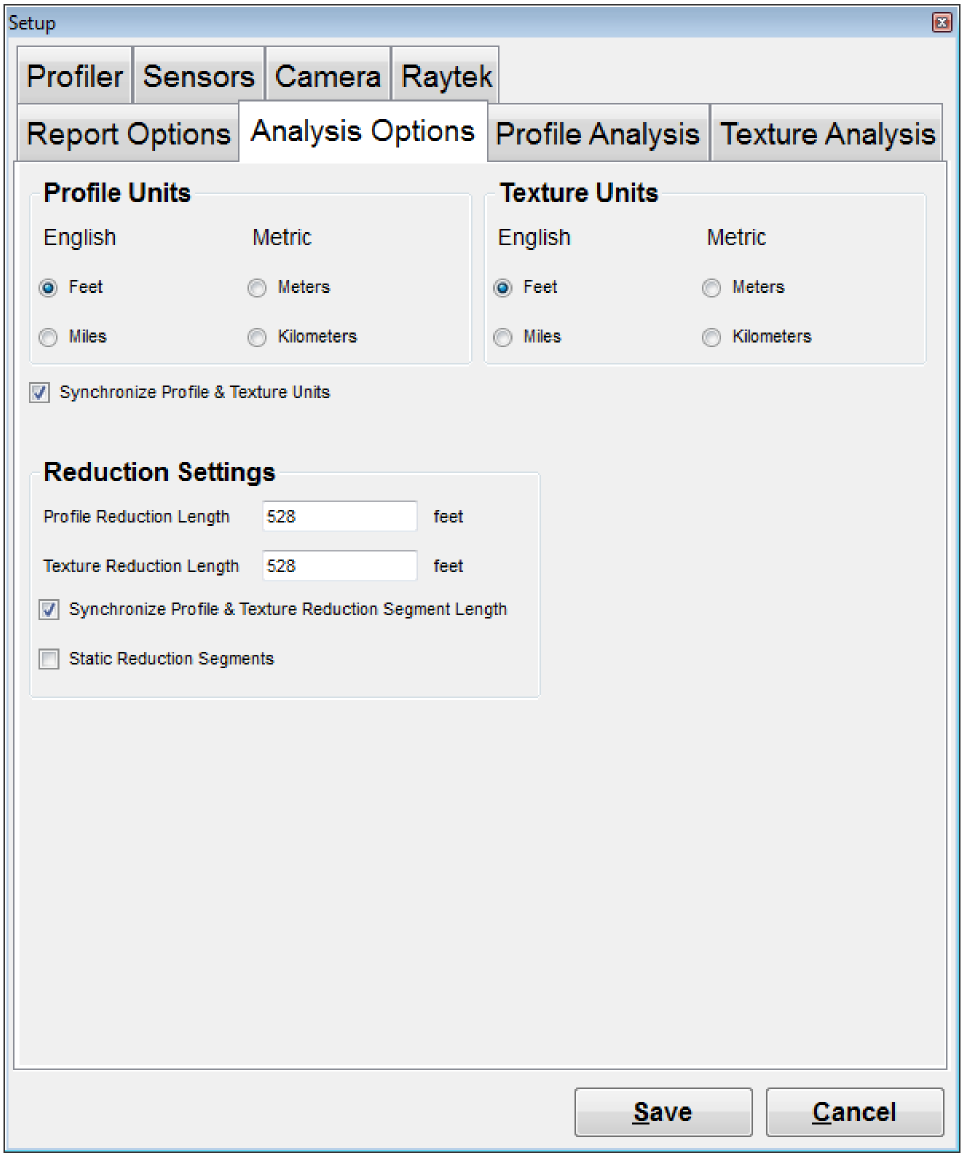
    - Profile Filter Setting—set high pass filter to 300 ft.
    - Profile Filter Setting—set low pass filter to 0 ft.

    Figure 10 shows an example of a screen capture of the Report setting in the program.

4. Select the Texture Analysis tab and make the following key change:

    - Texture Indices Produced—mean profile depth, ASTM 1845.[6] "Spike removal" should be unchecked.

Figure 11 shows an example of a screen capture of the Report setting in the program.



1 ft = 0.305 m.

Figure 8. Screen capture. Analysis options.

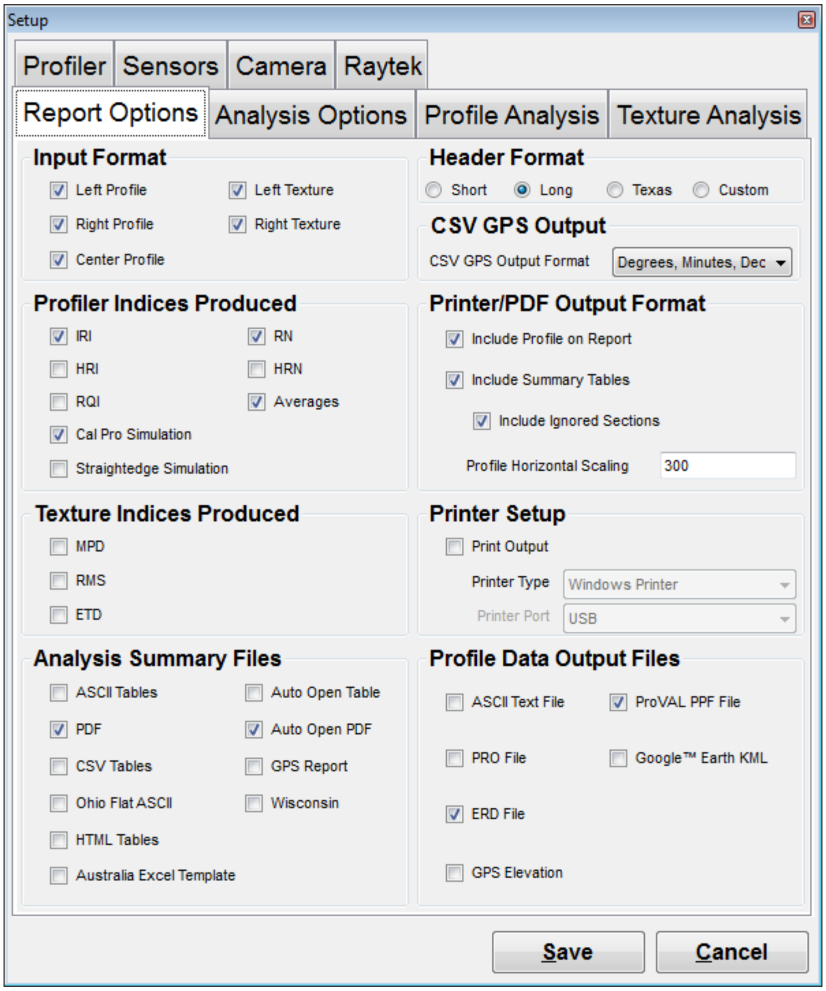
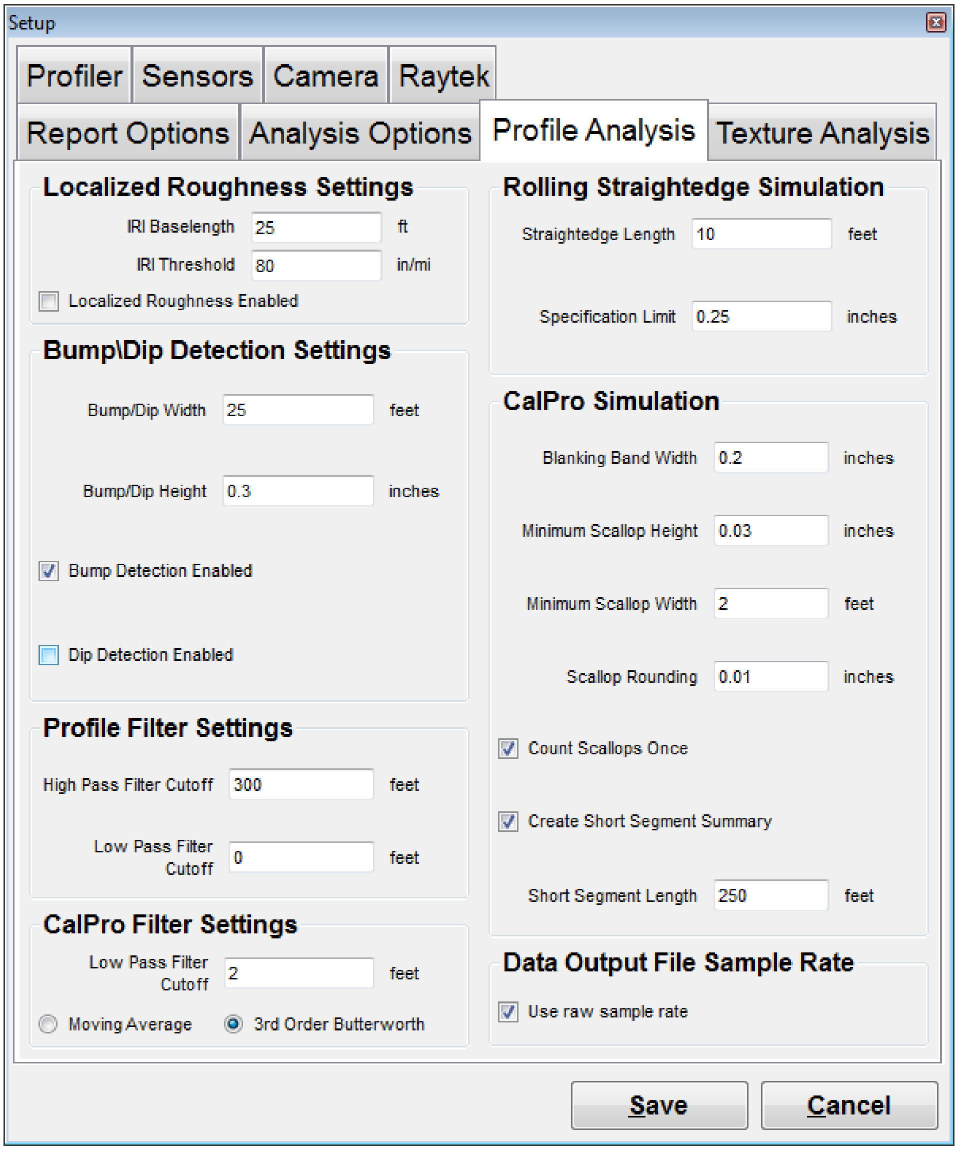
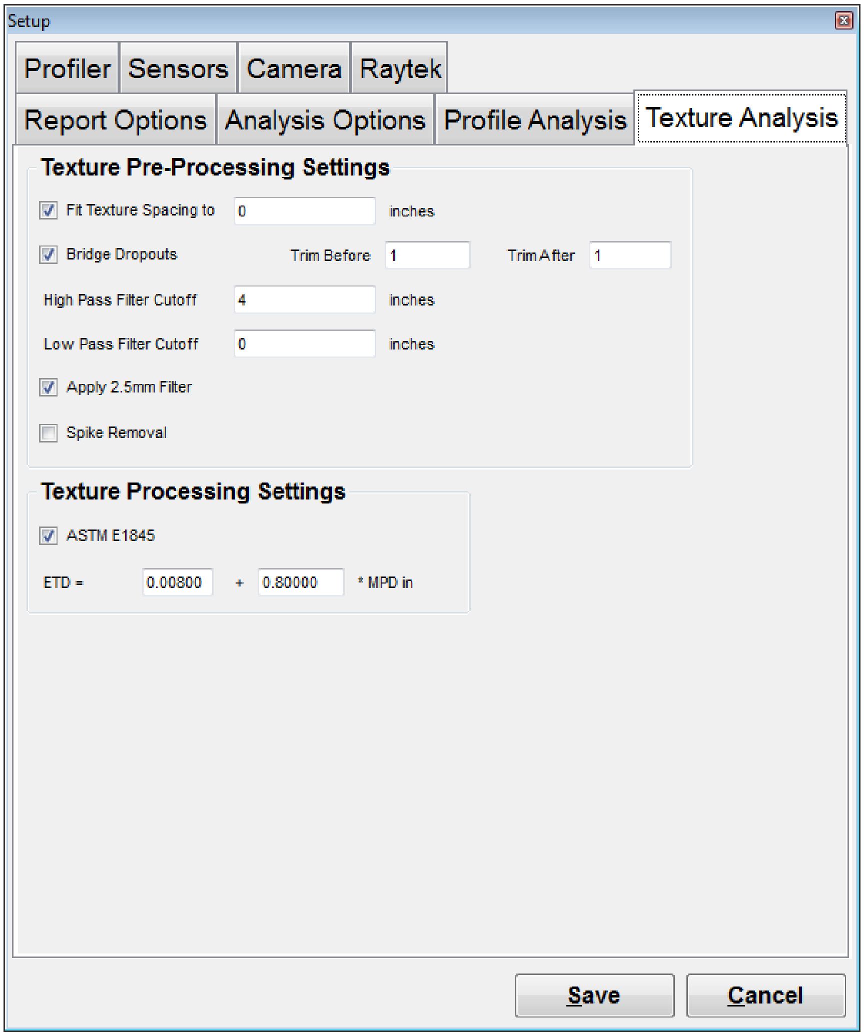


Figure 9. Screen capture. Report options.



1 ft = 0.305 m.
1 inch = 25.4 mm.
1 inch/mi = 15.8 mm/km.

Figure 10. Screen capture. Profile analysis.



1 inch = 25.4 mm.

Figure 11. Screen capture. Texture analysis.

PROFILER SURVEY PROCEDURE

Profile surveys should be done in both directions using the following conventions:

- Positive direction from south to north or west to east.
- Negative direction from north to south and east to west.
- Distance should increase in the positive direction.
- Distance should decrease in the negative direction. The ending station for the positive direction will be the starting station for the negative direction and will end at zero.

The above instructions are based on general industry practice to increment stations from south to north and west to east. Site location and conditions may indicate that an alternative approach may be more practical, and this decision should be made at the discretion of the profiler crew.

The road signage may not always be consistent with the direction of travel. For example, it is possible to be travelling in an easterly direction with the route signs indicating north. Because the profile data will be geo-tagged, it is not necessary to record the test direction information. The operator should indicate the direction from the route sign or general direction if there is no route signage. This information is included in the profile header and on the site information form.

Procedures for profiling a bridge section and the number of profile runs that are required at a bridge section are described in the next section.

PROFILING PATHS AND FILE NAMING CONVENTION

The profile data should be collected with the profiler centered in the wheelpaths. If no defined wheelpath is visible, then the profiler will be centered between the centerline of the road and edge of the pavement. The operator should follow the same path when traversing the bridge.

The SSNNNDLV convention should be followed for naming files. The acronym is defined as follows:

- **SS:** State in which site is located. LTPP standard agency codes are used (e.g., 36 for New York).
- **NNN:** Bridge identification (ID). This is a numeric character to identify the bridge as tested in sequence. This number can be tied to a specific bridge type (e.g., steel stringers or timber), type of approach (e.g., geosynthetic reinforced soil (GRS), approach slab or roadbase), or type of foundation (GRS, spread footing, piles, or drilled shafts).
- **D:** Letter code defining direction of travel (e.g., N for north, S for south, W for west, or E for east).
- **L:** Profile lane (i.e., lane 1, 3, 5, 7, 9, etc., in the positive direction and 2, 4, 6, 8, etc., in the negative direction taken from the median or centerline).
- **V:** Sequential visit identifier that indicates the visit code for the current profile data collection. This identifier indicates the number of times a set of profile runs has been collected at a site since the site was first profiled. An appropriate letter should be used for the current profiling (i.e., A used for the first visit, B for the second, etc.).

For example, the following data file names would be valid:

- **36001N1A**: The profile data was collected in New York with this being the first bridge profiled in the northbound positive outer lane during the first visit.
- **36003W2B**: The profile data was collected in New York with this being the third bridge profiled in the westbound negative outer lane during the second visit.

Information on the roadway for which the bridge is located, the bridge name, ID number, start location, and end length should be contained within the header discussed in the Inertial Profiler Setup subsection. An end of run comment should be completed by the operator for each run that will identify the run status or any conditions that could have an effect on the profile data. The operator comment field should be used for any additional comments regarding site conditions or pavement features. As previously noted, the information regarding the bridge is recorded on form 1A (see figure 4) or 1B (see figure 5) along with photos as recorded on form 2A (see figure 6).

DATA COLLECTION PROCEDURE

Before collecting data at bridge sections, the operator should either perform or take steps to ensure the following conditions are met:

- Daily checks should be performed on the equipment (i.e., laser sensor check and bounce test).
- State transportation department procedures relating to safety issues should be strictly followed (i.e., light bar, directional warning light, strobe lights, use of turnarounds, etc.).
- Operating speed for collecting profile data should be 50 mi/h (80 km/h). If the maximum constant speed attainable is less than 50 mi/h (80 km/h) because of either traffic congestion or safety constraints, then a lower speed should be selected depending on the prevailing conditions. If the speed limit at the site is less than 50 mi/h (80 km/h), then the site should be profiled at the posted speed limit. If traffic traveling at high speeds is encountered at a test site, it is permissible to increase the profiling speed to 55 mi/h (89 km/h). Deviation from the expected speed should be noted. Hardware limitations, primarily as the result of the quality and configuration of the inertial profiler's accelerometer, affects low-speed pavement longitudinal profile collection at less than 15 mi/h (25 km/h), causing the calculation of abnormally high and often invalid IRI data at these points.[7]
- The photocell should always be used to initiate data collection at the beginning of the test section.
- When entering header information into the software, the section number and direction of travel (four digits combined) assigned to the bridge should be entered as the site ID.
- The software's stop distance should be established by taking a preliminary run using the start and end tapes to identify the beginning and end of the section. The horizontal test within the Calibration menu can be used to establish the distance between the two reflective stripes. Subsequent runs will use the photocell to start profiling and distance to end profiling.
- Digital forward-looking images should be collected in each direction following the procedures outlined in the draft *LTPP Manual for Profile Measurements and Process*.[5]

- The profile survey crew is responsible for working with FHWA and the relevant State transportation department to locate and correctly identify the bridge location for each project.

By selecting Start within the main menu, access to the header menu is obtained. Before starting the profile data collection, the header information needs to be entered or modified to represent the run data that will be collected. The following list outlines the required inputs for the header file:

- **File name**: The user enters the file name using the format as defined for the bridge profile data collection.

- **Number**: The user starts with run 1 and increases by increments of 1 in each direction.

- **Start/stop method**: The start method will always be photocell, and the stop method will always be distance. The distance input value is established from the trial run using the horizontal test from the Calibration menu.

- **Units**: The units will always be feet.

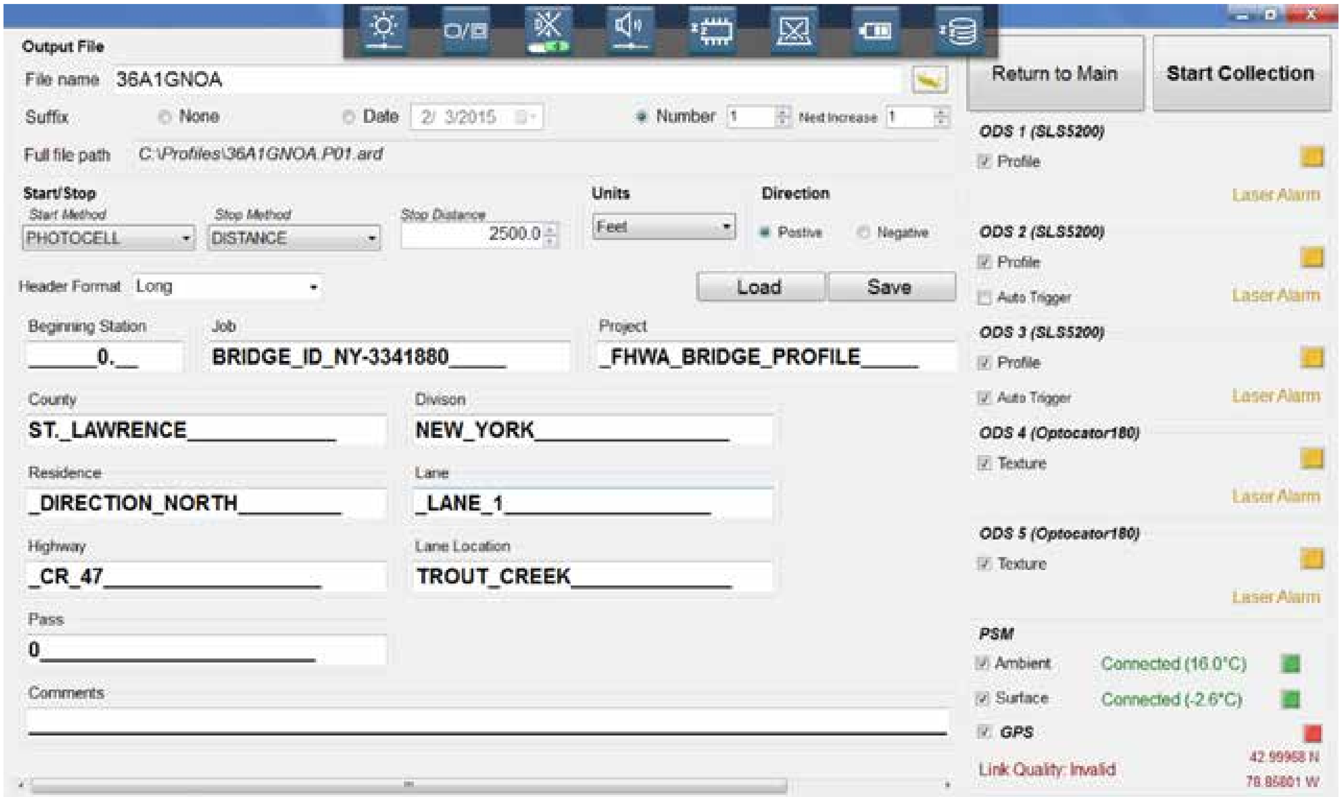
- **Direction**: The direction is positive or negative, which is updated with file name changes.

- **Beginning station**: The user enters "zero" in the positive direction and "length" as input for distance in the negative direction.

- **Header fields**: These fields describe the test location, lane, and direction. The bridge sequential number, bridge name and/or identifier, route, city/county, and State provided for locating the bridge should be input to the header file along with the lane designation and route direction.

- **Comments**: Comments that will explain or help with the interpretation of the profile data should be included here. If there are no comments, put "none" in the comment field.

Figure 12 shows an example of a screen capture of the header inputs. With the header information input, the user should initiate profile data using the procedures as outlined in the draft *LTPP Manual for Profile Measurements and Processing*.[5]



1 ft = 0.305 m.

Figure 12. Screen capture. Profiler system software header fields.

On completion of the previously mentioned steps, the following procedure should be followed to obtain an acceptable set of profile runs at bridge sections:

1. Profile data should only be collected when traffic, weather, and pavement conditions (i.e., pavement surface is dry and clear of debris) will not hamper or affect the profile data. If conditions are not acceptable, the profile crew will be required to adjust or reschedule the profile data collection.

2. The operator should ensure that the end of the bridge section length (i.e., 700 ft (213 m) from the end of the bridge interface) is passed before terminating profile data collection.

3. The operator should obtain at least three runs by driving the profiler along the wheelpaths.

4. After completing the data collection, the operator should review the profile runs that were collected. The operator should evaluate the profiles for equipment-related spikes by following the procedures described in section 2.9.4 of the draft *LTPP Manual for Profile Measurements and Processing*.[5] If the operator determines that at least three error-free runs along the wheelpaths have been obtained at the site, data collection should be terminated. Runs are considered error free if there are none of the following:

   - Sensor issues.
   - Distance-measuring instrument (DMI) issues, including DMI shift.

- Other equipment issues.
- Operator issues, including testing out of the wheelpath.
- Variability that is not pavement related.
- Unexplained run-to-run variability of profiles and/or IRI.

If the operator believes that three error-free runs along the wheelpaths have not been obtained, the operator should repeat the data collection and evaluate the profile data using the procedures described previously. A maximum of five runs along the wheelpaths can be performed. If the additional runs do not satisfy the criteria established for profile acceptance (defined in the LTPP manual), then the profile operator needs to provide an explanation for why the profile data is suspect. If the issue is equipment-related, then the operator should terminate the data collection and have the equipment serviced or repaired and calibrated before collecting any further profile data. The profile data can be retained or discarded at the discretion of the profile analyst.

5. The profile sensors in the left wheel and right wheelpath and midlane along with two texture lasers located in the left and right wheelpath should be checked for operation and accuracy prior to profiling. The profile acceptance criteria are based on the profile sensors in the left and right wheelpath. The profile operator should perform a visual observation of the profiles in the midlane and those collected by the texture lasers by reviewing the profile graphs. In general, if the left and right profiles are of acceptable quality, then the texture lasers will also produce acceptable results.

   Note that fewer than three runs can be accepted if conditions at the site result in excessive delay in the schedule. This may occur if it starts to rain during the data collection or if there are other local interruptions such as accidents or farm machinery using the roadway.

6. The operator should generate ERD and PPF files from the .ARD data following the instructions in the user manual.(8)

7. The operator is encouraged to use ProVAL cross-correlation analysis to determine run-to-run acceptability, time permitting. A correlation of 92 percent for three runs would be the target for acceptable repeatability between runs. It is possible that three error-free runs may not meet the criteria because of transverse variability within the section limits. In this instance, a comment on either form 1A or 1B would be sufficient to explain the variability.

8. The operator should maintain a log of the runs on the daily progress report.

9. The operator should back up the data before leaving the site following procedures described in section 2.9.6 of the draft *LTPP Manual for Profile Measurements and Processing*.(5)

An acceptable set of profile runs is three error-free runs in the wheelpaths.

CHAPTER 3. DATA ANALYSIS AND REPORTING

The profile data collected with the LTPP inertial profiler is used to evaluate the smoothness of the transition between the pavement, approaches, and bridge deck. The profile data is also used to determine whether settlement has occurred at the deck approaches, which may or may not be evident through cracking or steps/faulting at the interface between the different structures. In addition, the profile data is used to evaluate various bridge systems to determine factors and recommendations that will lead to the meeting of smoothness specifications from initial construction and over time.

Three profile passes are collected in each direction at all bridge locations. Unless there are issues identified with certain profile runs by the data analyst, the profiles from run 2 will be analyzed and presented as part of the reporting.

PROFILE GRAPHS

As part of the pilot project, procedures were developed to graphically present the profiles from the bridge survey that showed the elevation profile for the length of the survey section (the bridge plus 200 ft (61 m) either side of the bridge). The procedure used is as follows:

1. Load raw (.ARD) data into ProQual 2012 software.

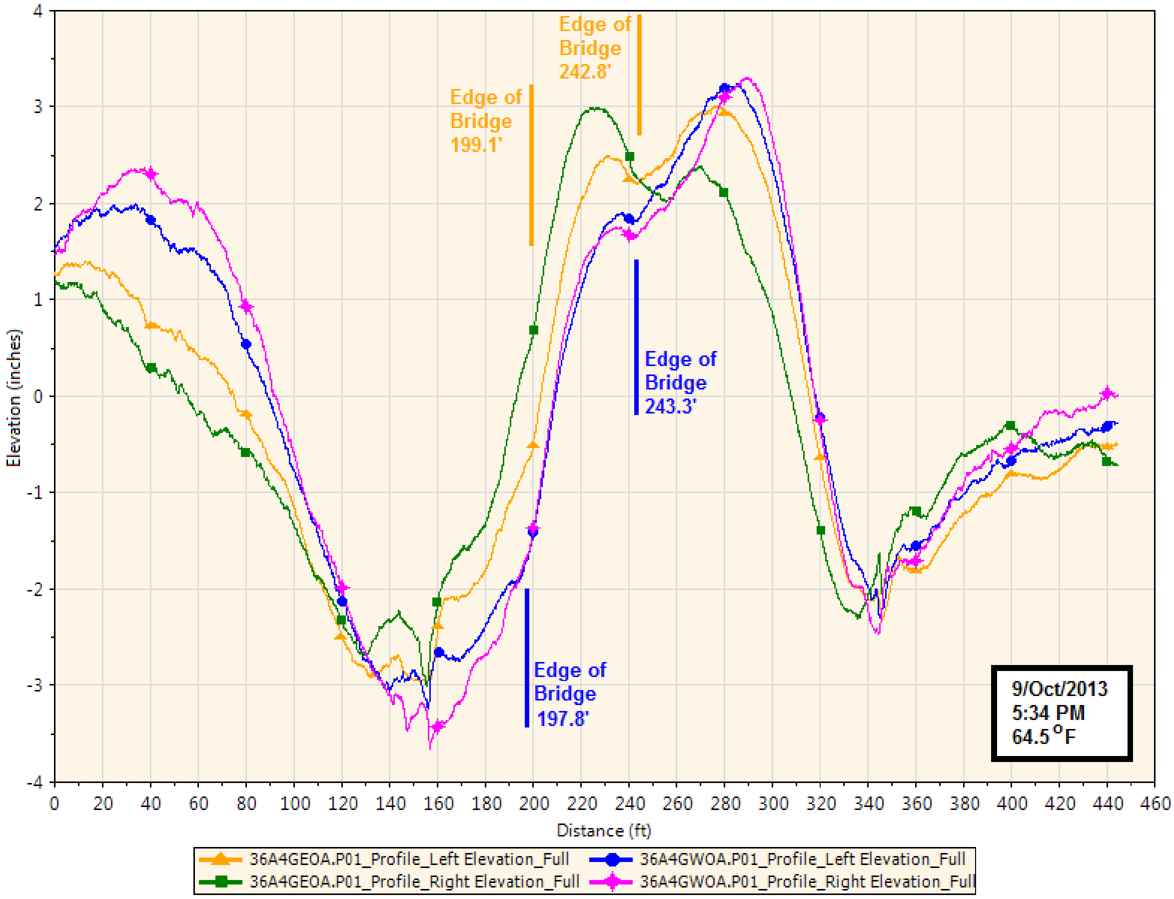
2. Generate ERD files using ProXport software using .ARD data and ProQual 2012 sectioning information.

3. Reverse elevations for opposite lane. (Microsoft® Excel was used.)

4. Load ERD files into ProVAL software.

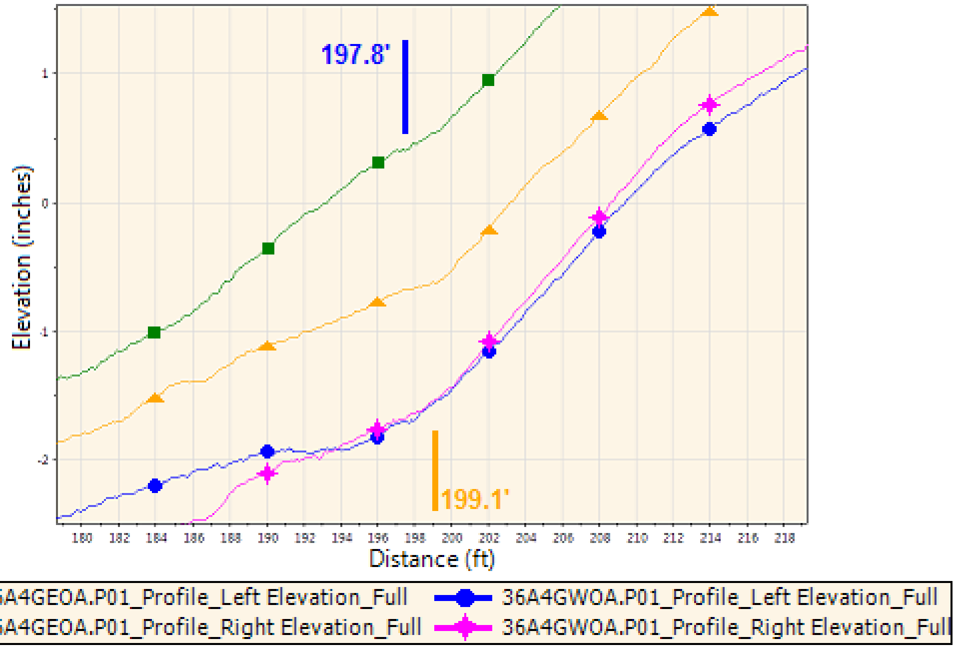
Since the pilot project, the ability to load .ARD files has been developed into ProVAL, so it is expected that steps 1 through 4 can be combined into a single step.

Photocell events are used to identify the start and end of the bridge. Using these events, it is possible to isolate the location of the bridge approach structures to determine whether there are bumps, dips, or settlement associated with the bridge approach. Figure 13 through figure 18 are examples of the graphical presentation for a GRS-Integrated Bridge System (IBS) bridge and conventional bridge structure, respectively. These were collected as part of a pilot project in St. Lawrence County, NY. Other than the application of a 300-ft (91-m) upper wavelength filter, no corrections have been made. Applying normalization at various spans yielded insignificant results. As mentioned previously, the opposite direction data have been reversed in order to line up the data. The edge-of-bridge locations in figure 13 vary because the bridge is on a curve. A photo of this bridge is shown in figure 19. A photo of the conventional bridge is also shown in figure 20. The procedure developed and presented in these figures will be produced for all bridge profile sections as part of the bridge profile study.



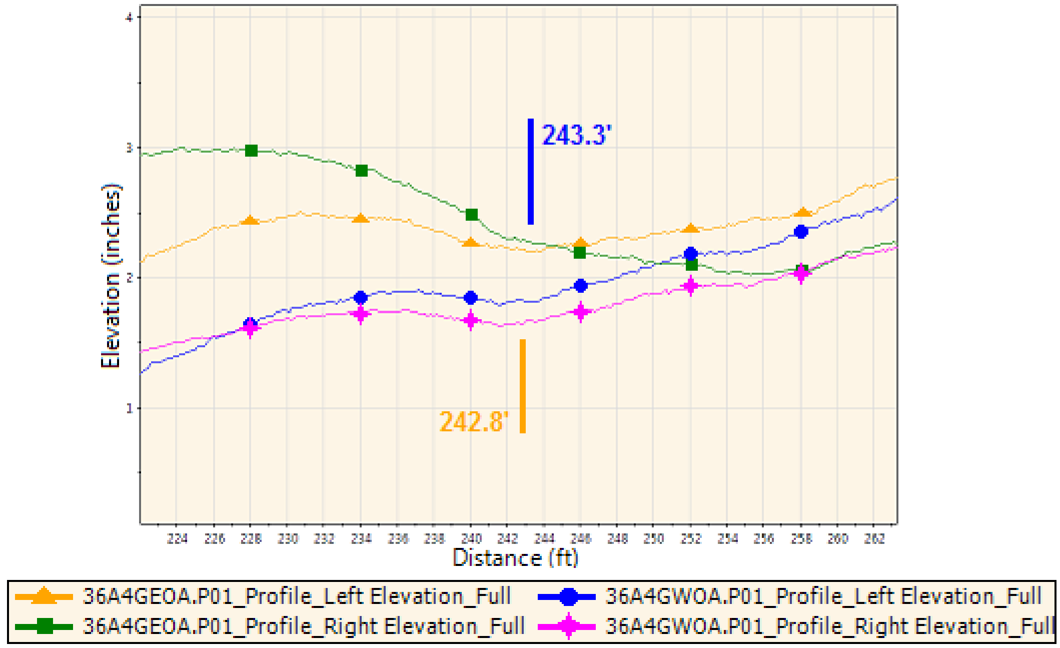
1 inch = 25.4 mm.
1 ft = 0.305 m.
1 °F = 1.8° C +32.

Figure 13. Chart. Example of a GRS-IBS bridge profile in St. Lawrence County, NY (eastbound direction).



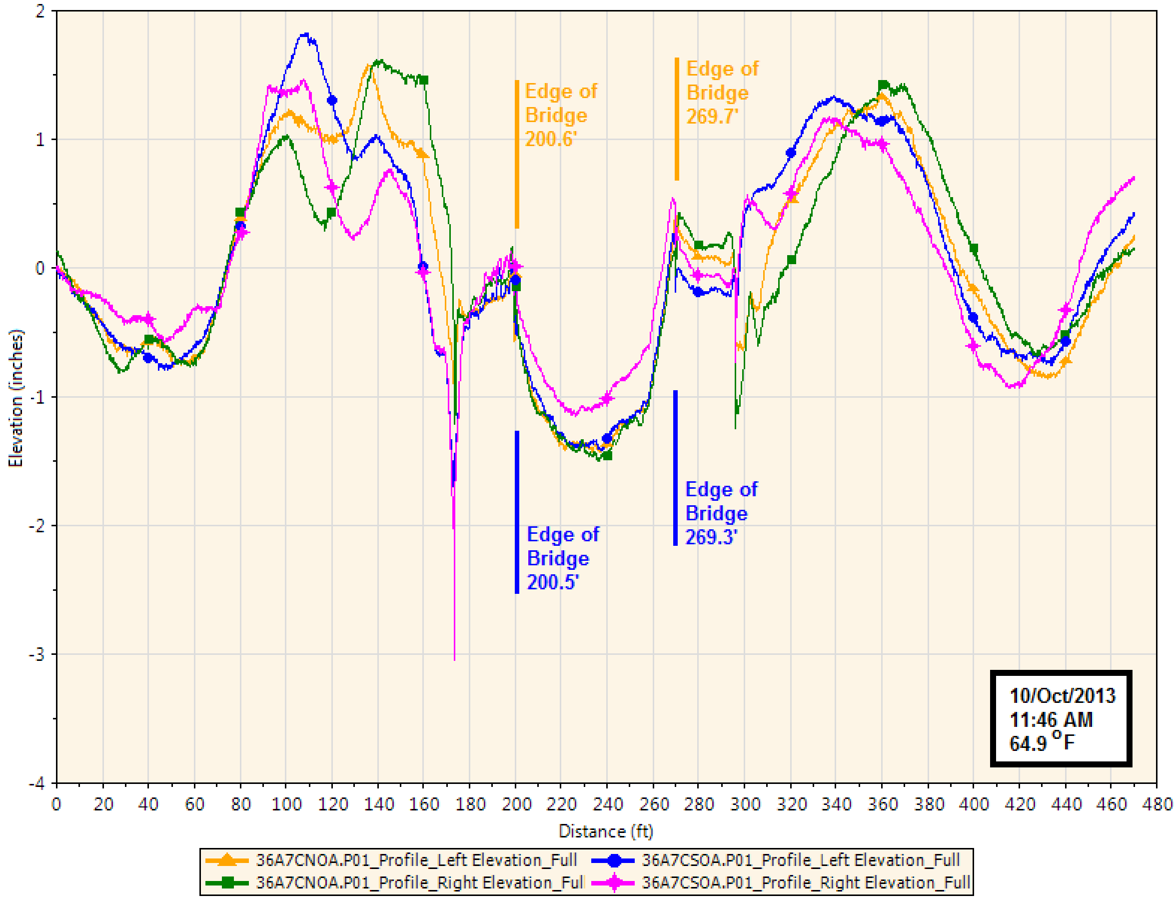
1 inch = 25.4 mm.
1 ft = 0.305 m.

Figure 14. Chart. Example of a GRS-IBS bridge profile in St. Lawrence County, NY, at first interface (eastbound direction).



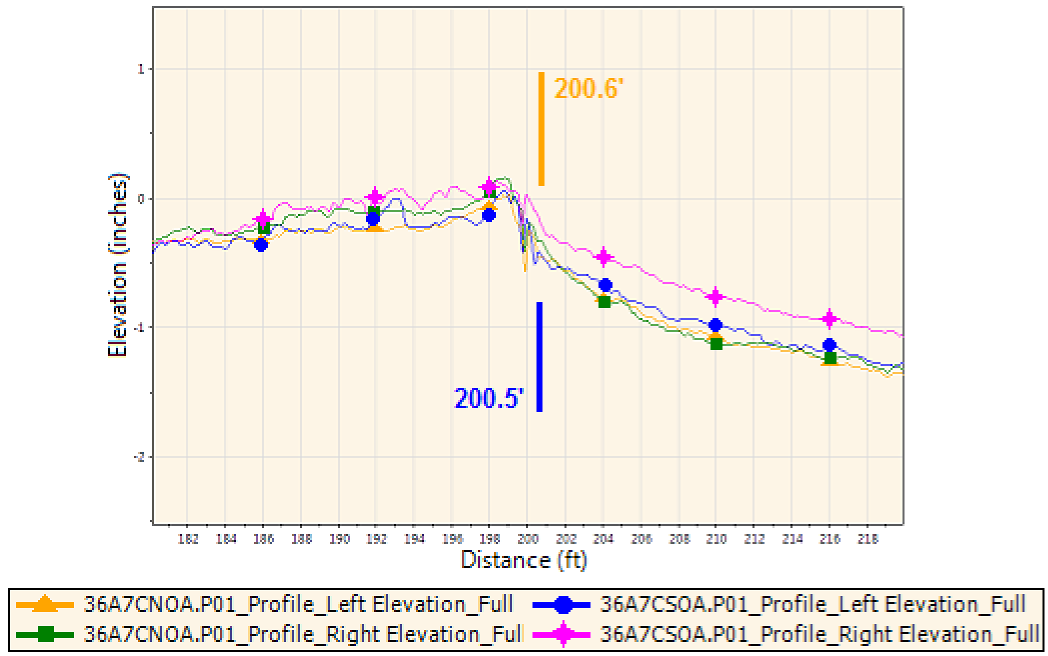
1 inch = 25.4 mm.
1 ft = 0.305 m.

Figure 15. Chart. Example of a GRS-IBS bridge profile in St. Lawrence County, NY, at second interface (eastbound direction).



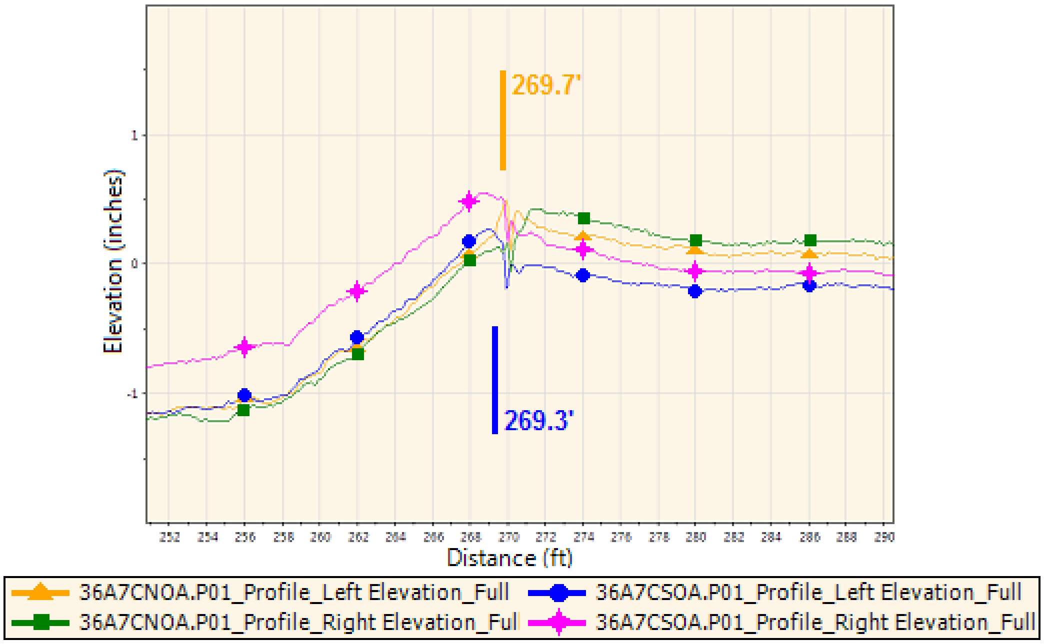
1 inch = 25.4 mm.
1 ft = 0.305 m.
1 °F = 1.8° C +32.

Figure 16. Chart. Example of a conventional bridge profile in St. Lawrence County, NY (northbound direction).



1 inch = 25.4 mm.
1 ft = 0.305 m.

Figure 17. Chart. Example of a conventional bridge profile in St. Lawrence County, NY, at first interface (northbound direction).



1 inch = 25.4 mm.
1 ft = 0.305 m.

Figure 18. Chart. Example of a conventional bridge profile in St. Lawrence County, NY, at second interface (northbound direction).

Figure 19. Photo. A GRS-IBS bridge in St. Lawrence County, NY (eastbound direction).

Figure 20. Photo. A conventional bridge in St. Lawrence County, NY (northbound direction).

IRI

IRI is a statistic used to estimate the amount of roughness in a measured longitudinal profile. IRI is computed from a single longitudinal profile using a quarter-car simulation as described in the report “On the Calculation of IRI from Longitudinal Road Profile.”[9] The standard for most State transportation departments is to collect two profiles (one in each wheelpath) and average the IRI calculated for each wheelpath to represent the roughness for a section of roadway. Appendix E in the *Highway Performance Monitoring System Field Manual* lists the following advantages of using IRI to document pavement performance:[10]

- It is a time-stable, reproducible mathematical processing of the known profile.
- It is broadly representative of the effects of roughness on vehicle response and users’ perception over the range of wavelengths of interest and is thus relevant to the definition of roughness.
- It is a zero-origin scale consistent with the roughness definition.
- It is compatible with profile-measuring equipment available in the U.S. market.
- It is independent of section length and amenable to simple averaging.
- It is consistent with established international standards and able to be related to other roughness measures.

FHWA has determined ranges of IRI that fit particular categories (from very good to very poor) of road roughness. Those ranges are as follows:

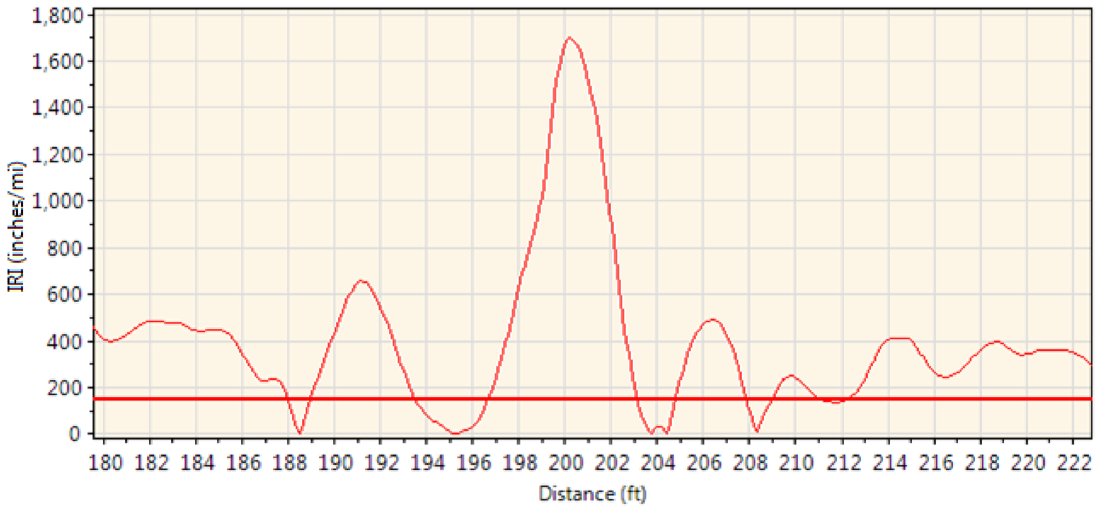
- **Very good**: IRI below 60 inches/mi (0.95 m/km).
- **Good**: IRI up to 95 inches/mi (1.50 m/km).
- **Fair**: IRI up to 170 inches/mi (2.68 m/km).
- **Poor**: IRI up to 220 inches/mile (3.47 m/km).
- **Very poor**: IRI exceeding 220 inches/mi (3.47 m/km).

Many State transportation departments have replaced the Profile Index (PI) collected from RSE with IRI from lightweight or high-speed inertial profilers as part of pavement smoothness specification for construction quality control. IRI has proven to be a better indicator of pavement smoothness than PI and also provides an advantage in that the initial profiles are relevant in monitoring long-term performance. IRI is the standard by which most State transportation departments manage pavements and determine the time frame for maintenance or rehabilitation interventions.

For most State transportation departments, the smoothness of the pavement excludes the area of the bridge approach and bridge. Departments have monitored smoothness at bridge locations using IRI, but there does not appear to be a widely accepted standard based on IRI covering the bridge area.(11) In general, it can be expected that the roughness at a bridge will be greater than the road surface as a result of the transition zones and variance in construction. This does not appear to be the situation for the GRS-IBS structures because the travelling public response has been that the bridge area is undetectable from the roadway pavement. When evaluating the bridge location performance based on IRI, a tolerance limit of 80 inches/mi (1,263 mm/km) would apply for postconstruction surveys, and a value of 170 inches/mi (2,683 mm/km) would separate smooth from rough bridge locations.

The Smoothness Assurance Module within ProVAL can be used to plot IRI profiles and identify locations where the IRI exceeds a tolerable limit. This process can be used to identify a location where grinding could be considered to correct a portion of pavement that does not meet an acceptance criteria. The grinding module within ProVAL can also be used to determine the improvement that can result from the grinding process. For the bridge study plotting, the IRI locations based on a tolerable limit would allow identifying any smoothness issues that could be associated with the bridge transition zones.

An IRI graph (showing areas that are acceptable and out of tolerance for an approach structure) is shown in figure 21. The plot range is 20 ft (6 m) before and after the bump. By plotting IRI in this manner, it is easy to determine whether there are smoothness issues at the approach structure. The graph should be produced based on an IRI tolerance limit of 170 inches/mi (2,683 mm/km) for both the approach and exit from the bridge. For the newly constructed bridges, a tighter tolerance limit of 80 inches/mi (1,263 mm/km) should also be generated. The results can also be tabulated and presented in a histogram.



1 inch/mi = 15.8 mm/km.
1 ft = 0.305 m.

Figure 21. Chart. IRI plot using ProVAL software of conventional bridge profile in St. Lawrence County, NY.

RSE

Traditional smoothness specifications for newly constructed pavements for most State transportation departments have been based on the output from an RSE. The process requires pushing a rubber tire wheeled device of that is 10 ft (3.1 m) long along the wheelpath of the pavement to obtain the deviation at the midpoint of the profiling device. An acceptable tolerance for this deviation, which varies from department to department, is used to calculate the percentage of defective length and located areas that require improvement.

Profiles collected using inertial profilers can be used to simulate the RSE measurement by determining the vertical deviation between the center of the straight edge and the profile for every increment in the profile data. To simulate the straight edge, the length of the straight edge and the deviation threshold value is required to determine out-of-spec locations. For this study, it was suggested to use a specification of 0.125 inch (3.2 mm) in 10 ft (3.1 m) RSE requirement.(2)

A module in ProVAL allows for the processing and reporting of the RSE results from inertial profile data. The outputs can include a plot of the surface deviations (see figure 22), surface deviations with shaded thresholds, and a defective segments table (i.e., hot spots or out-of-spec areas and maximum surface deviations). The peak deformation value can be used to quantify the bump/dip height at the approach transition.

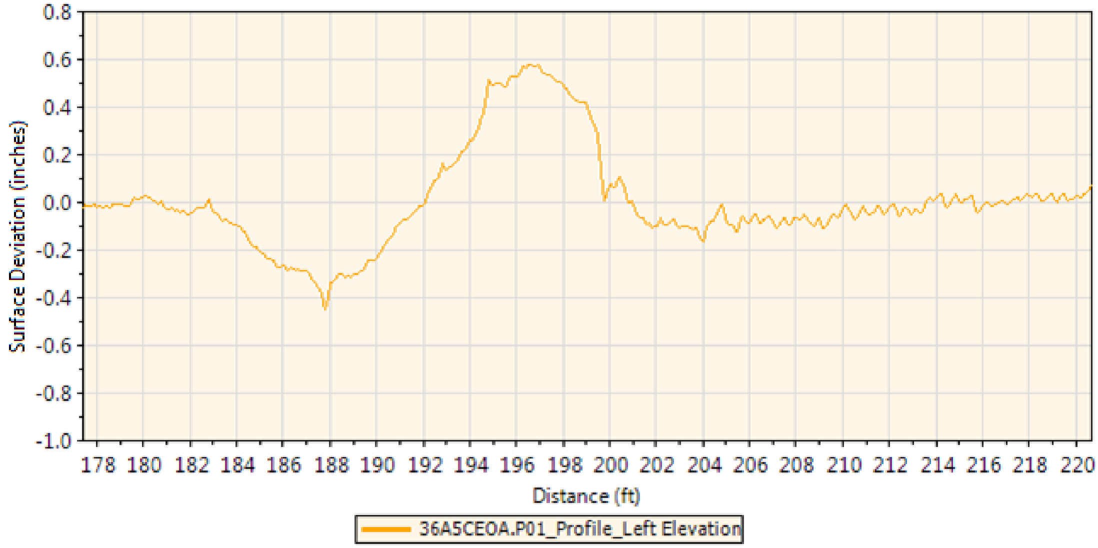


Figure 22. Chart. RSE surface deviations plot using ProVAL software of conventional bridge profile in St. Lawrence County, NY.

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