SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

SHRP2 Technologies to Enhance Quality Control on Asphalt Pavements
Infrared (IR) Scanner

Hosted by:
Alabama DOT
August 30, 2017

U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

Welcome & Introductions

1. ALABAMA DOT
2. AASHTO
3. FHWA

Remote Locations:
Please have all attendees complete the attendance list and return to Lyndi Blackburn.

Infrared Scanner Workshop

AGENDA:

Time	Topic/Presentation	Speaker
8:00	**Doors Open / Sign In**	
8:30	**Call to Order**	Blackburn, Alabama DOT; Moderator
8:30 to 8:50	**Welcome and Introductions**	Blackburn (ALDOT) and Cooper (FHWA)
8:50 to 9:30	**Introduction to Infrared Technology: What is it and Why is it Needed?**	Dalbey (ARA)
9:30 to 10:10	**Equipment and Software: How to use it?** Getting Real Time Information for Decision Making	Dalbey (ARA)
10:10 to 10:50	**Data Analyses and Findings**: What was learned from the Demonstration Project; Outcome and Lessons Learned from the Field Demonstration Projects	Reiter (ARA)
10:50 to 11:00	Break	
11:00 to 11:30	**Contractor and Agency Perspectives as a QA/ QC Tool:** • Agency overview of the technology in ensuring a higher uniformity of the mat, as well as potential implementation strategies • Contractor overview of the advantages of the technology in minimizing deficiencies and any associated pay reduction.	Blackburn (ALDOT) and Doss (Contractor)
11:30 to 12:00	**Implementation Strategies (focus on Contractor use):** • Products and Application of Products o Case Studies from Demonstration Projects o Updated Specification: Improving the Mat • Trouble Shooting Guide Lead Agency Strategies/Specifications Lessons Learned	Reiter (ARA)
12:00 to 12:30	**IR Workshop Wrap-Up - Questions/Answers and Closing Comments**	Blackburn, Alabama DOT; Moderator

Our Focus for Today

Workshop Objectives …

1. Describe use of the Infrared Technology.

2. Understand the installation and use of the IR equipment & software.

3. Discuss results/findings from the field demonstration project on AL 202.

4. List contractor's and agency's opinions and/or perspective of IR as a QC or QA tool.

5. Know the implementation strategies used by the lead agencies.

6. Products of the field demonstration projects

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Infrared Technology (IR)

Part 1: What is it and why use it?

August 30, 2017

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Introduction to IR Technology

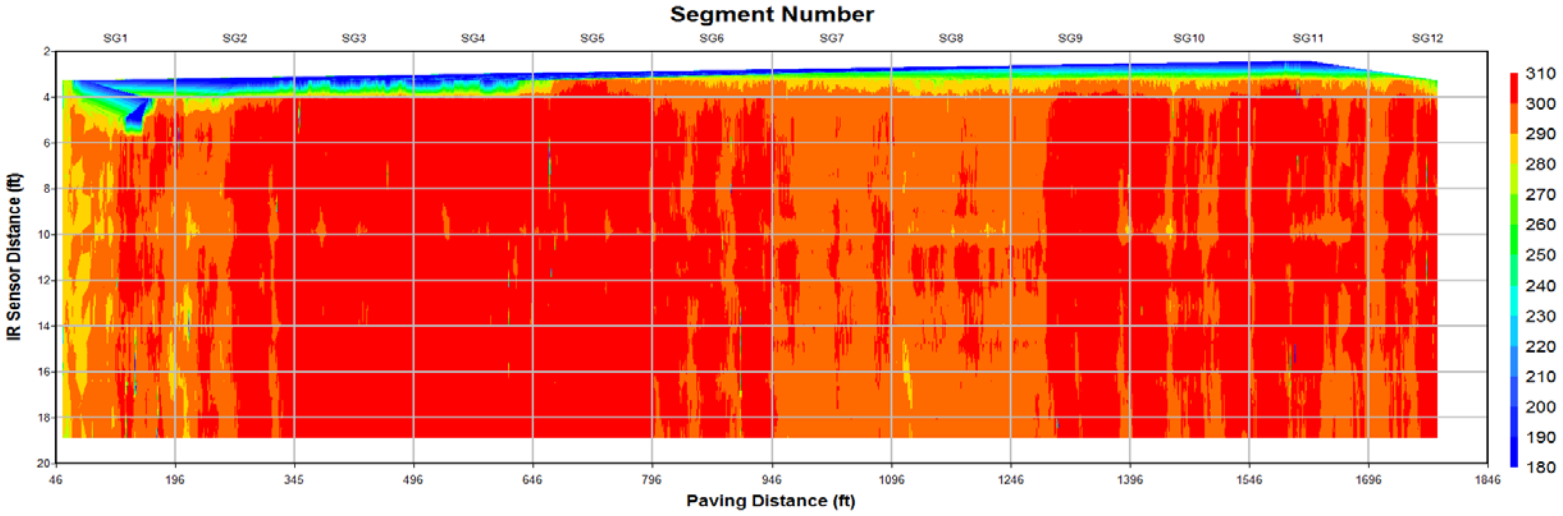
Part 1: What is it and why use it?

1. IR - Defined.
2. How is it measured?
3. Why is it important?

IR Defined

Infrared Thermography Defined:

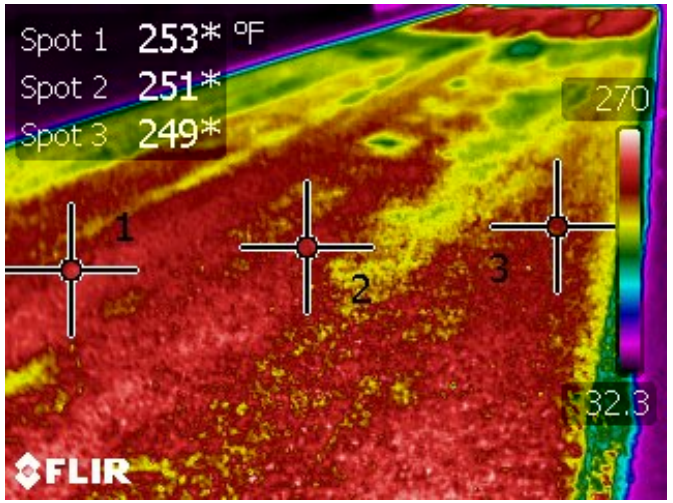
- The mapping of temperature contours (equal temperature) over the surface of a material.
- Contours are used to evaluate materials by measurement of their surface temperature and its variation.

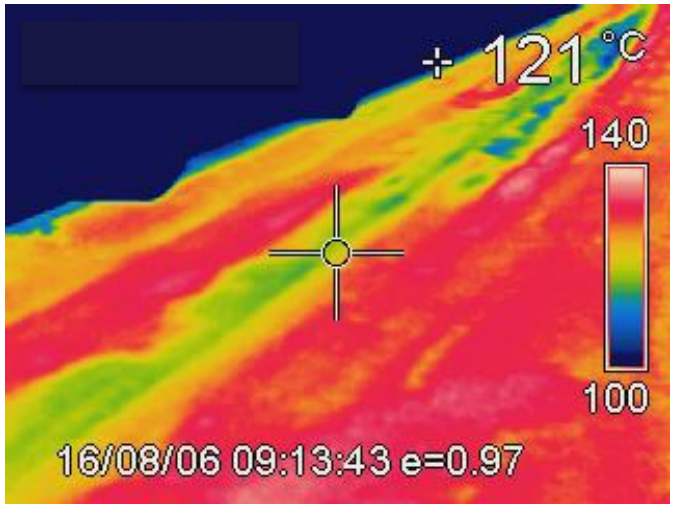


IR Defined

Types of Temperature Differences:

1. Cold spots
   - Truck to truck temperature differences
   - Improper loading and unloading of trucks
2. Thermal streaks
   - Longitudinal segregation
   - Inadequate or non-uniform amount of material across the mat





Introduction to IR Technology

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IR Measurements

History; Mat Temperature Measurements

- Temperature guns
  - Point readings
- Temperature cameras
  - Time specific to identify areas with cold spots or thermal streaks

IR Measurements

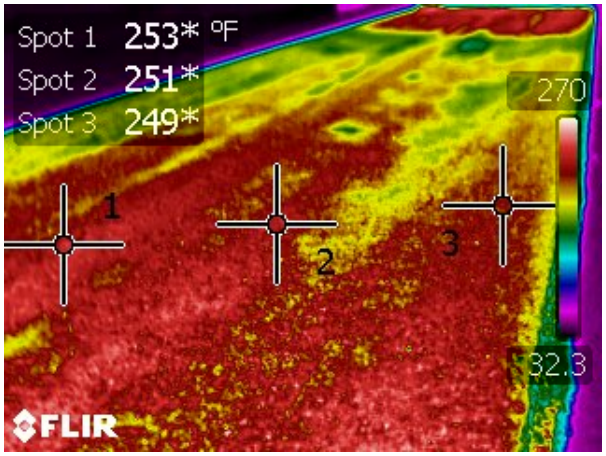
History; Mat Temperature Measurements:

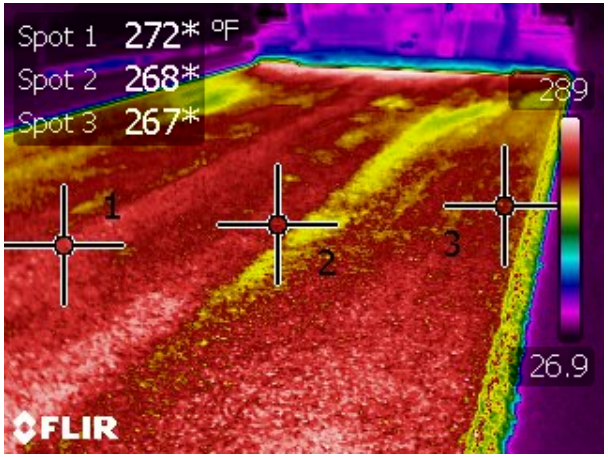
- **IR sensors, IR-Bar**; first device for continuous readings.
- **Pave-IR Scanner**; second generation device for continuous readings.

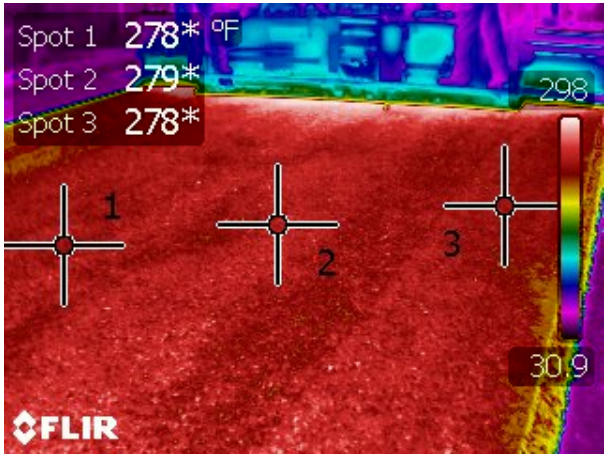
IR Measurements

Application & use of IR cameras:

- Identify areas with cold spots for biased sampling in density specification.
- Identify thermal streaks.



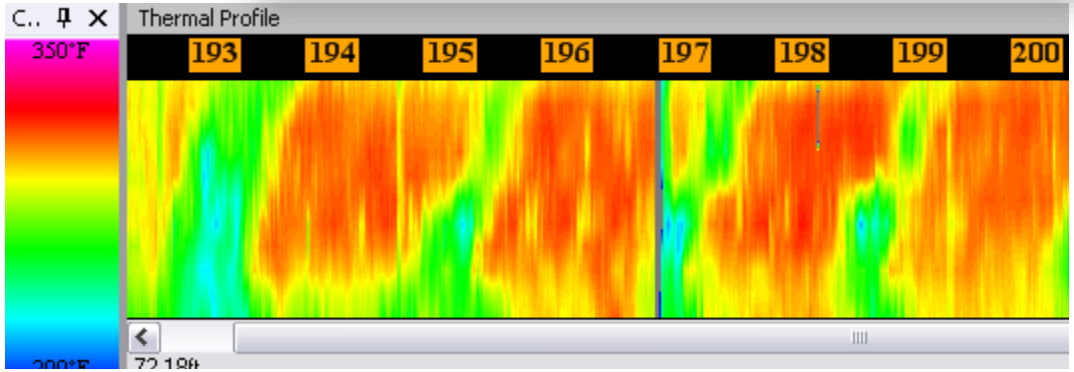




IR Measurements

Application & use of IR-Bar and Scanner:

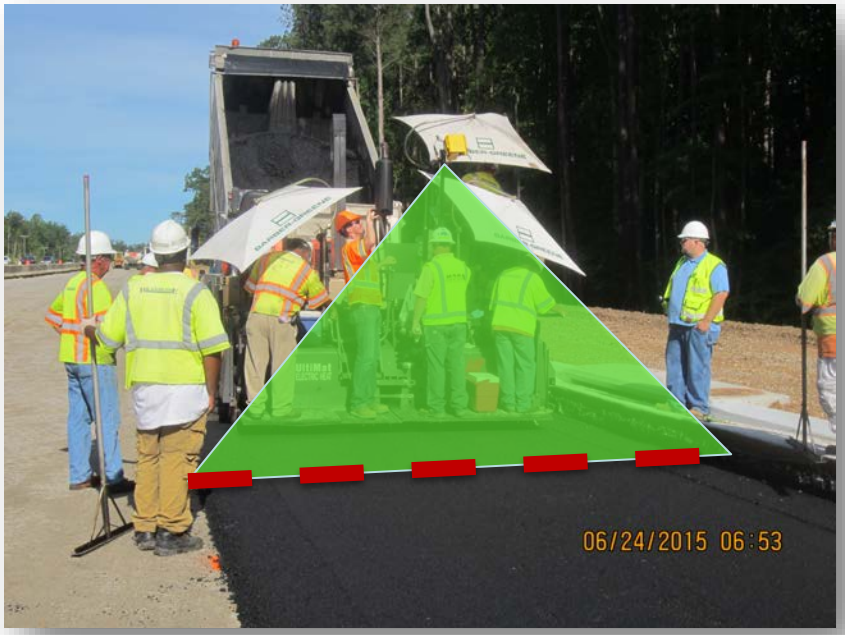
- Continuous readings to evaluate mat uniformity through temperature uniformity.
- Non-uniform temperatures usually mean, non-uniform densities.

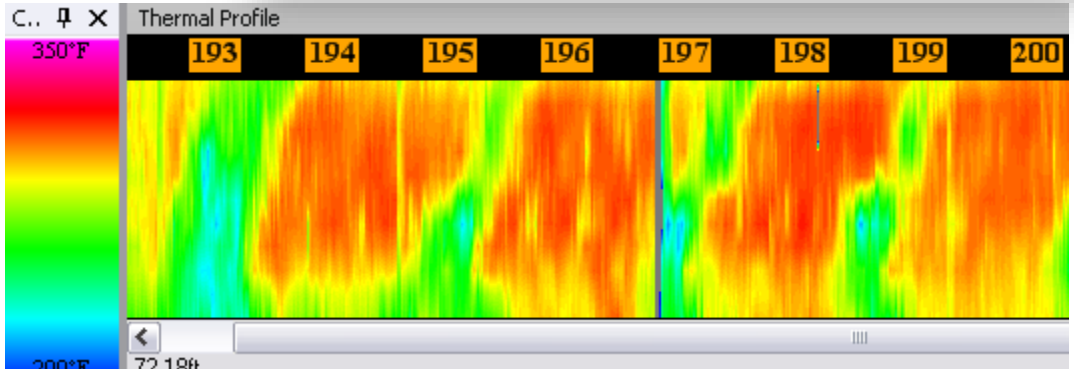


IR Measurements

IR-Scanner:

- Sensor—detects infrared radiation emitted from the mat.
- Scans the mat 6 to 10 ft. behind the screed.
- Creates thermal profile of the mat surface.





Introduction to IR Technology

Part 1: What is it and why use it?

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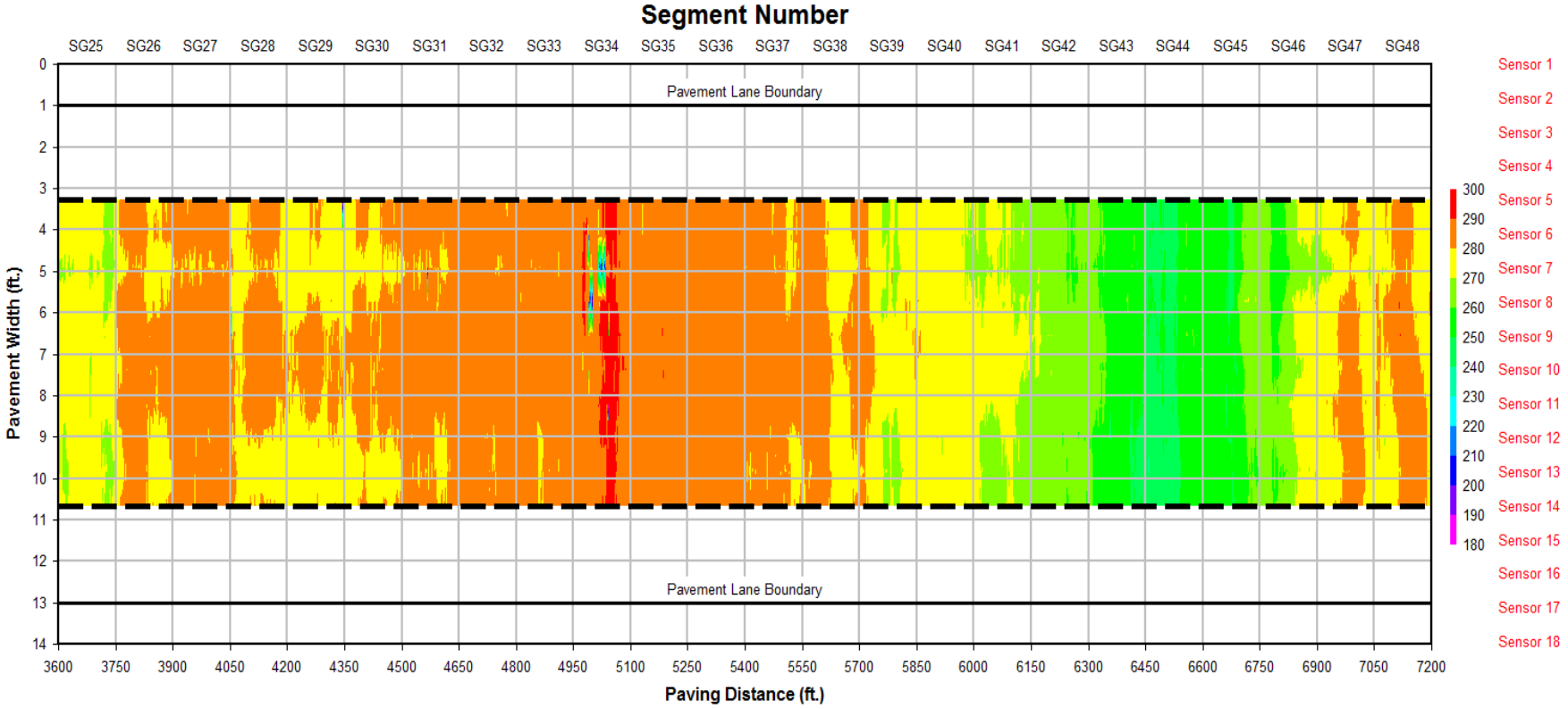
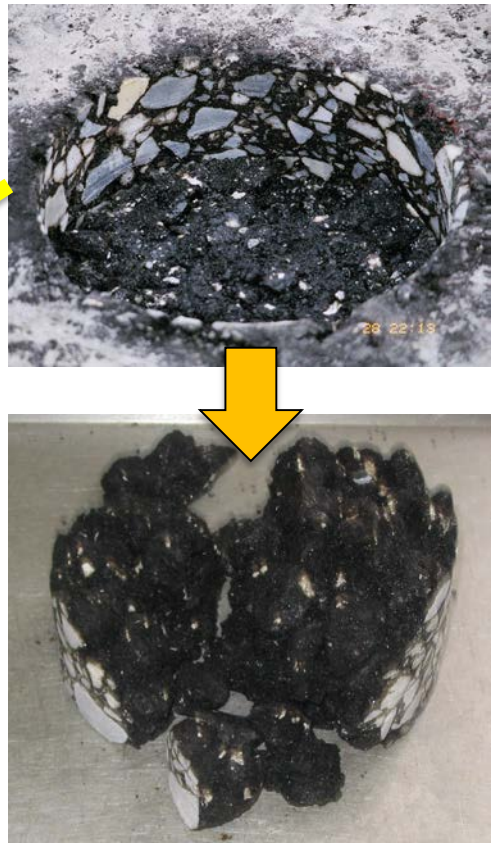
IR Importance

- Aggregate segregation in mat = temperature differentials
- Non-uniform temperatures = non-uniform densities



IR Importance

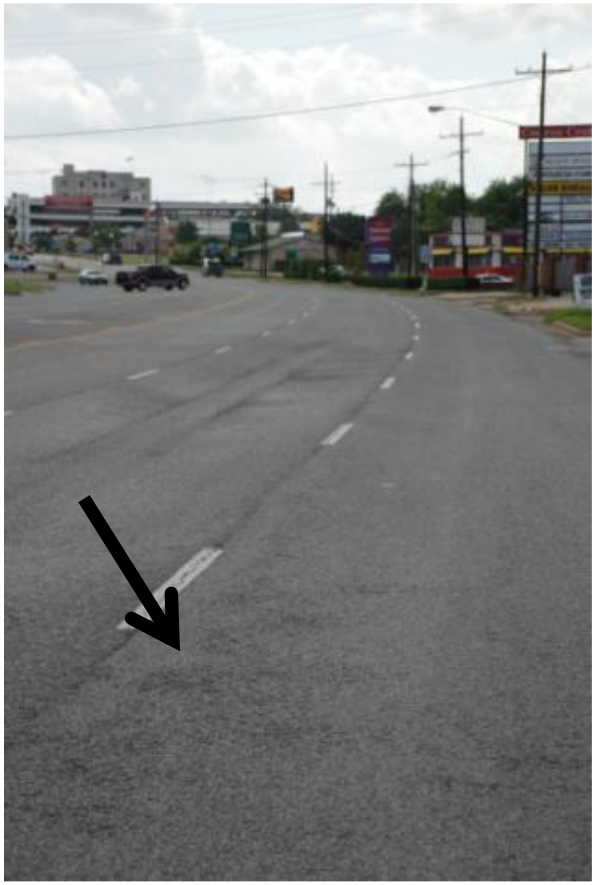
Segregation – A difficult issue to resolve, when it is difficult to identify or confirm.



IR Importance

Cold spots; areas with increased potential for:

- Fatigue cracks
- Raveling
- Pot holes



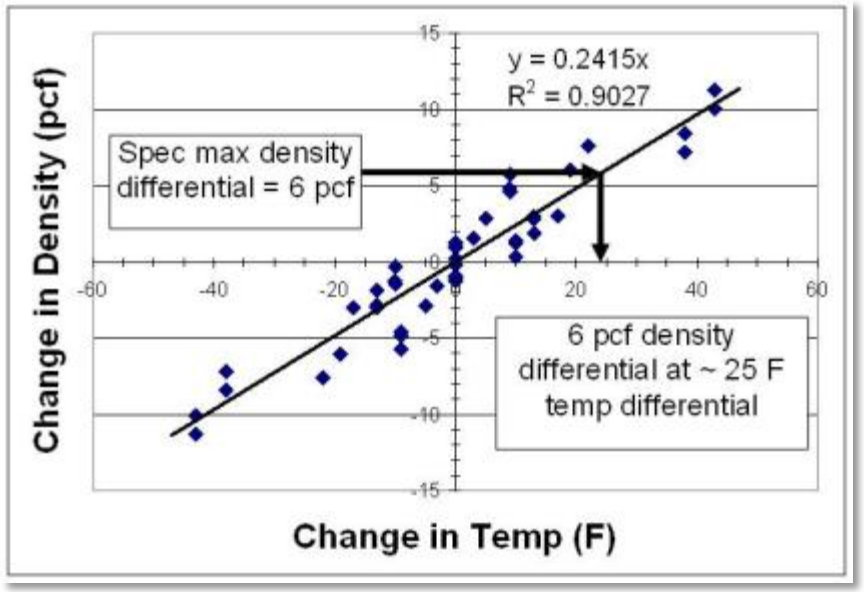
IR Importance

Impact of temperature differences or areas with low temperatures.

IR Importance

Background

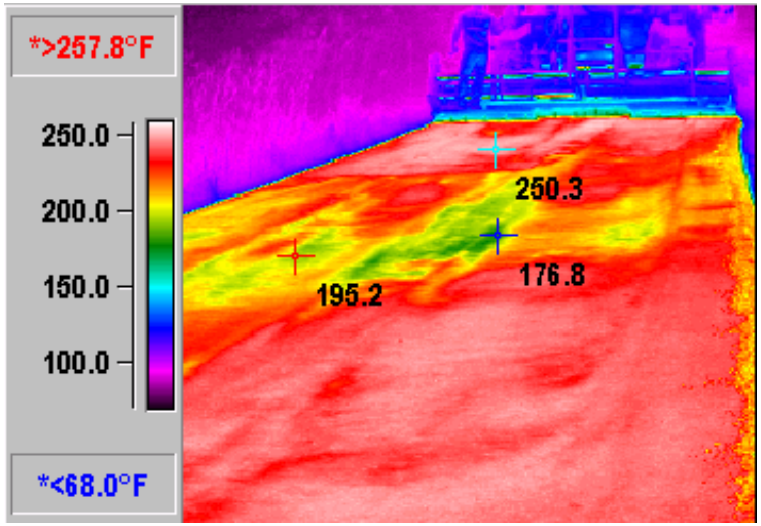
- 1996 through 2000s – field work concluded temperature differences could be accurately detected and quantified:
  - Low temperatures result in low density zones in mat.
  - A few States adopt temperature uniformity specification.



Temperature profile criteria based on desired density uniformity.

IR Importance

- Cold spots
  - Temperature difference of mat between truck exchanges – common.
  - Areas with higher air voids
- Focused testing have validated higher air voids
  - Coring
  - Radar (full coverage)
  - Nuclear gauge

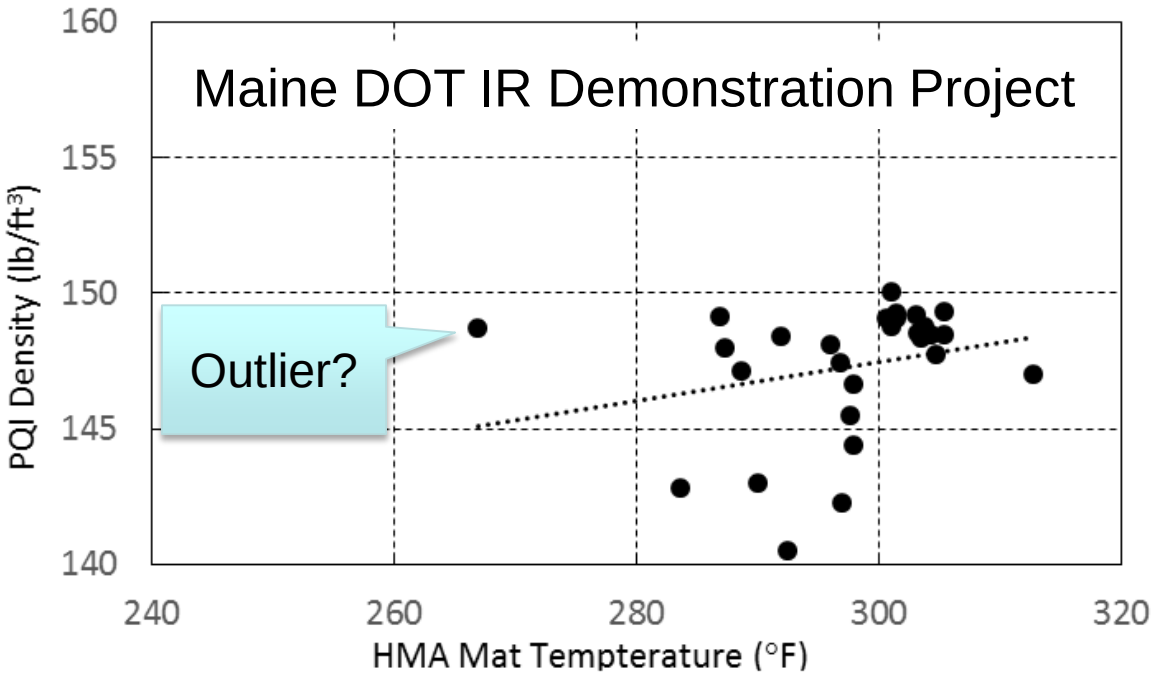


IR Importance

- Effect of cold spots, low mat temperatures on percent compaction; densities are:
  - Lower
  - More variable

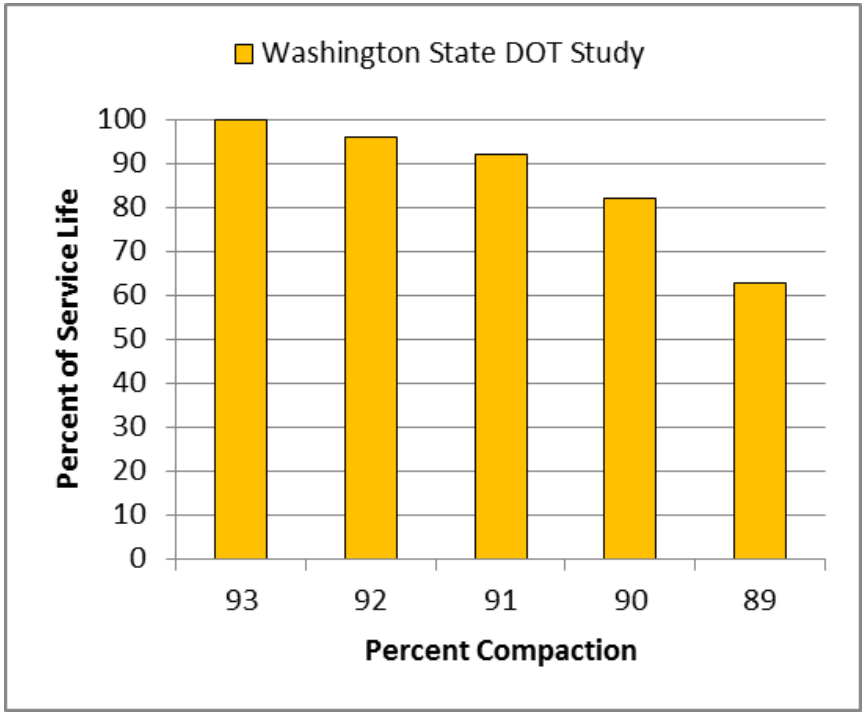
TTI Study:
Δ25 ºF ~ Δ6 pcf

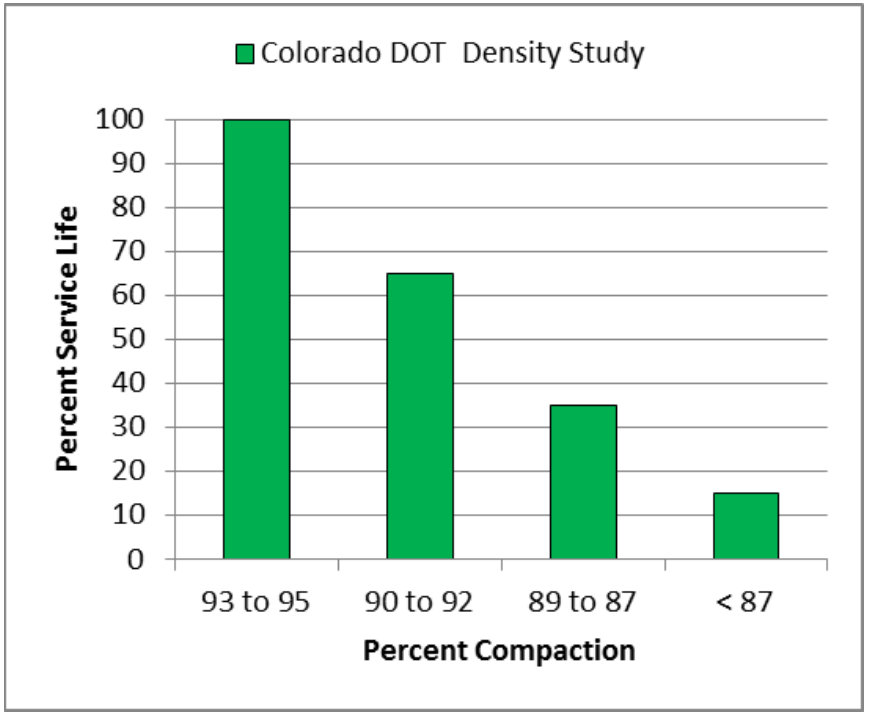
Maine DOT:
Δ20 ºF ~ Δ4 pcf



IR Importance

- Effect of reduced compaction because of lower mat temperatures or inadequate rolling.





Questions?

NEXT:

- Part 2: Equipment and Software – Installation and Use

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Infrared Technology Workshop

Part 2: Equipment & Software – Installation and Use

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Equipment and Software

Part 2: Equipment and Software – Installation and Use

1. Equipment and Its Installation
2. Software Features and Parameters
3. Data Collection and Reports

Equipment and Its Installation

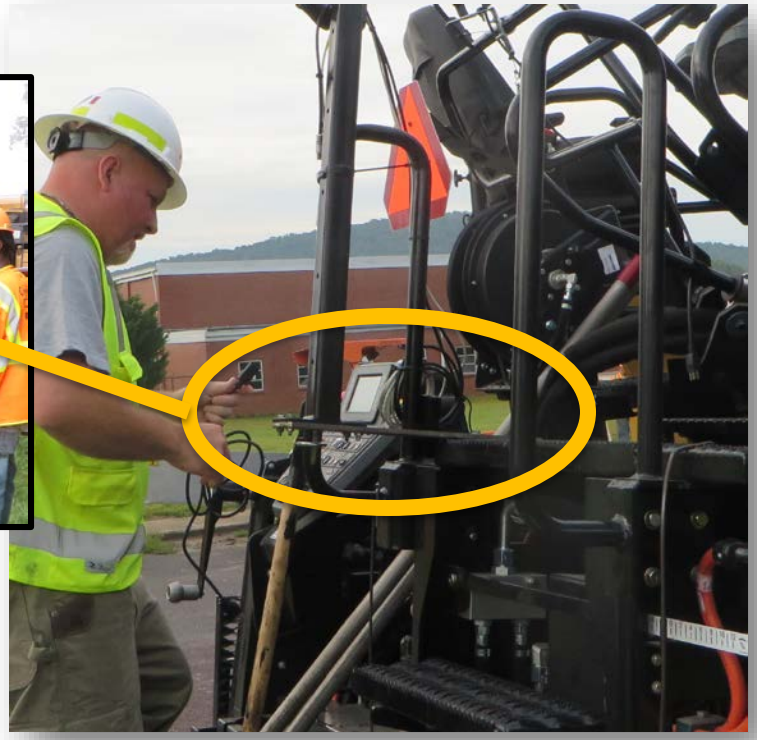
Equipment

- Mast Base
- Mast Extension
- Mast Arm
- IR Scanner
- DMI
- GPS Unit
- Wiring
- Connection bolts & materials

Equipment and Its Installation

IR mast base and extension attached to paver.

Mounted Directly to Screed



Mounted to a Steel Plate Attached to Work Platform

Equipment and Its Installation

- IR Scanner attached to paver; scans mat behind screed in one direction.
- GPS attached to the mast arm.

Equipment and Its Installation

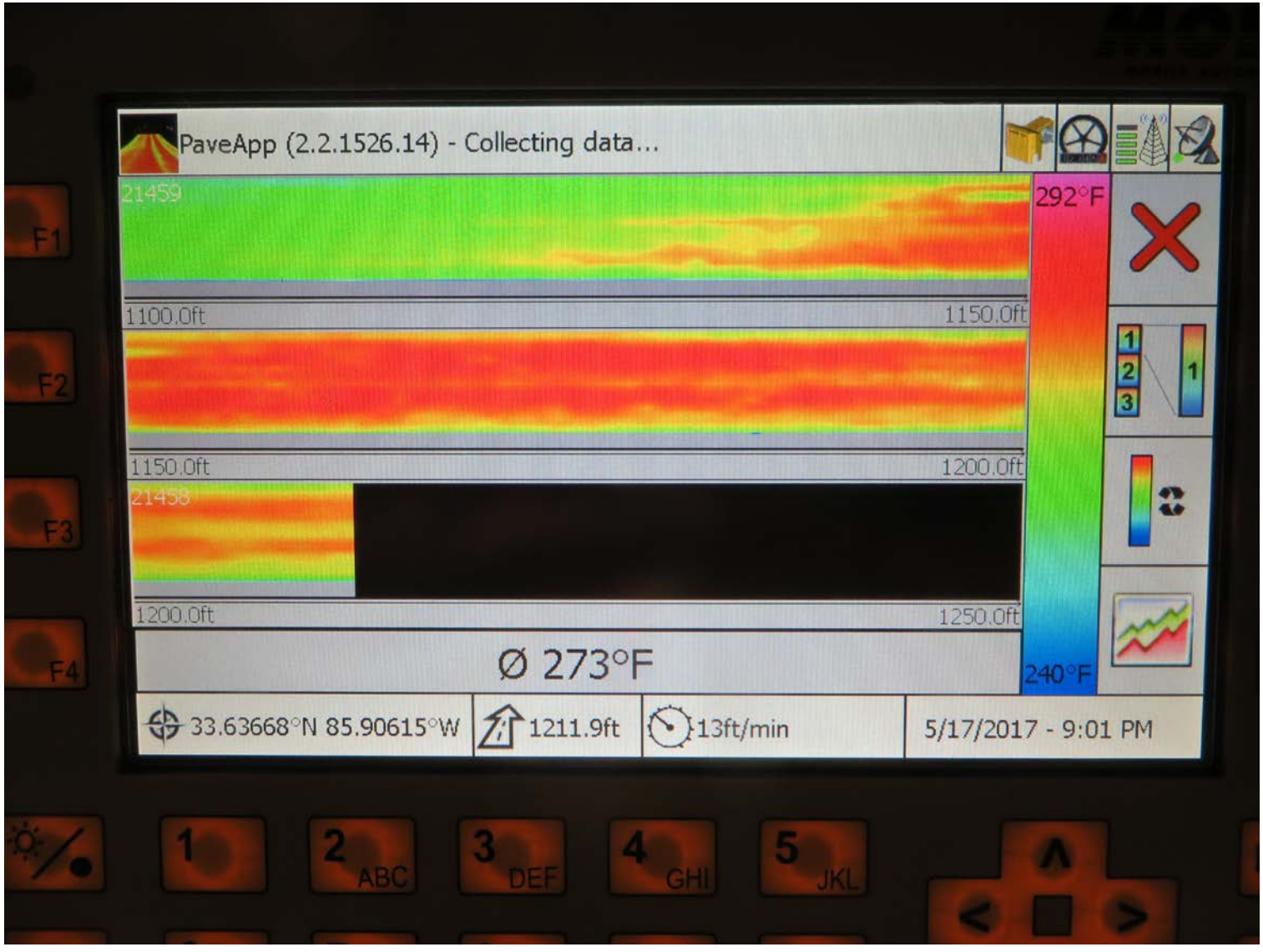
DMI placed on wheel hub to measure distance during paving operation.

Equipment and Its Installation

IR scan screen used to see/monitor mat temperatures in real time; attached to the mast post or extension.

Equipment and Its Installation

Equipment and Its Installation



Equipment and Its Installation

Two models of data transfer and extraction

1. Automated; GPS
2. Manual; Memory stick

Equipment and Software

Part 2: Equipment and Software – Installation and Use

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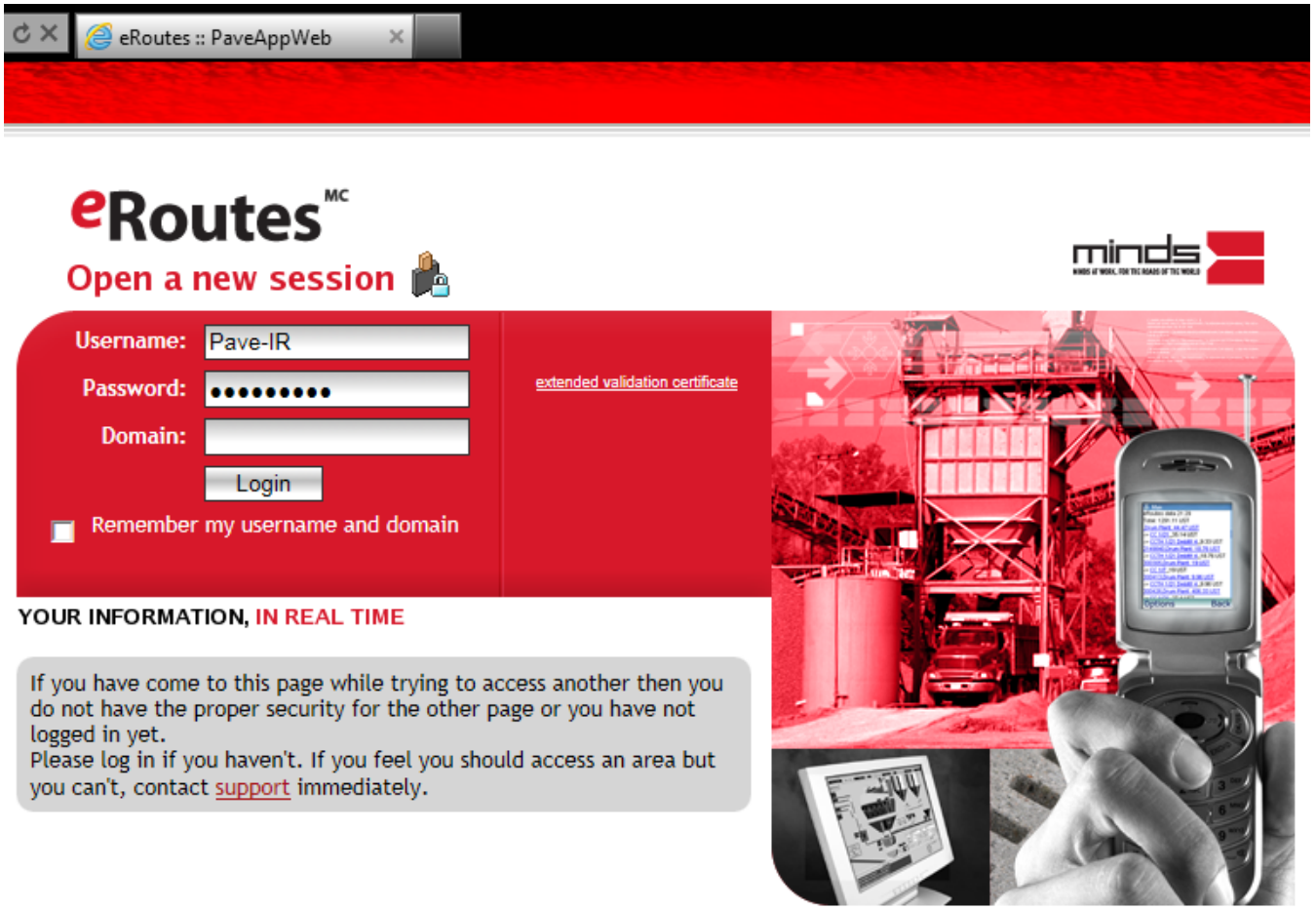
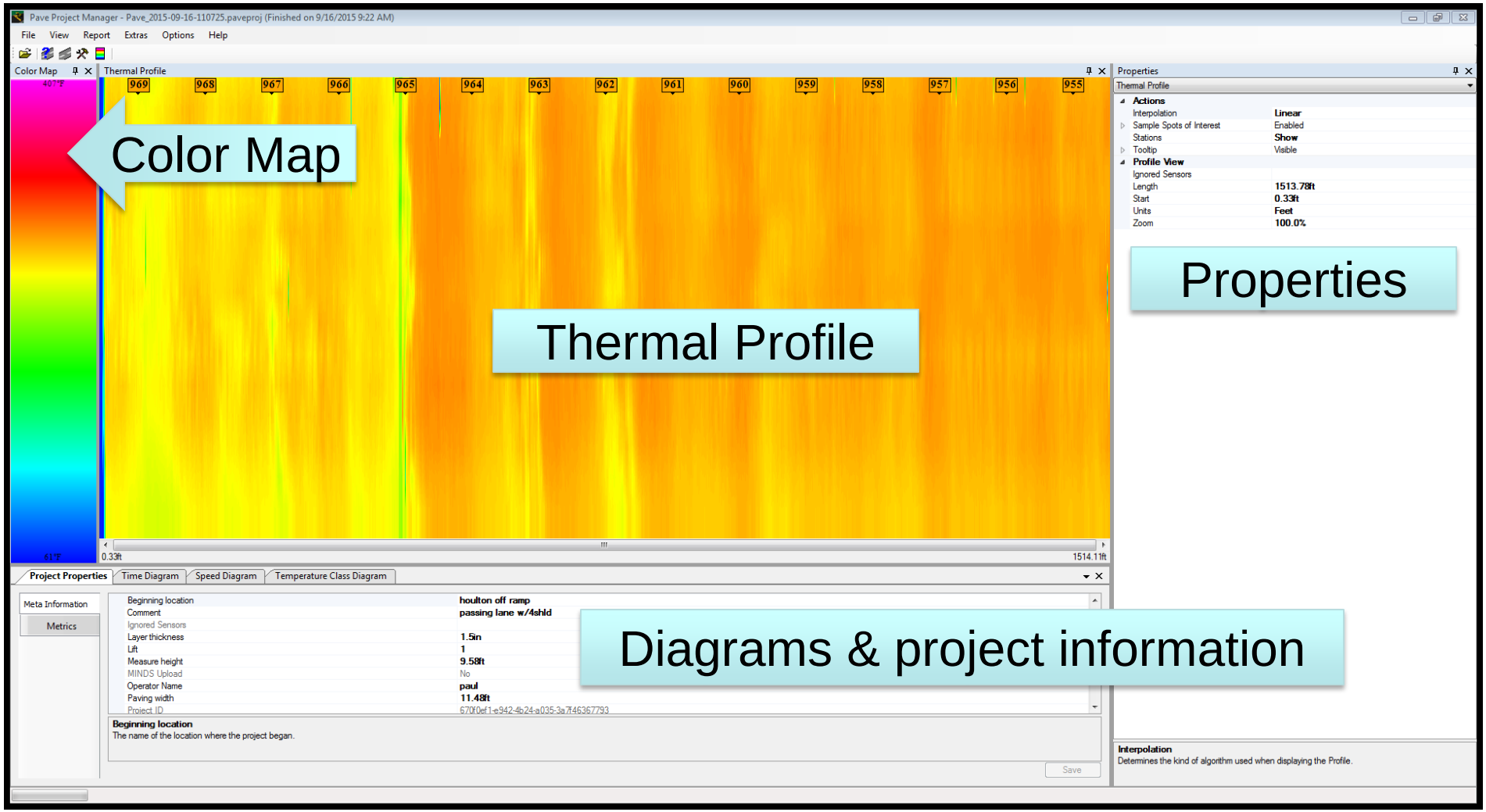
Software Features

- Online Web App: https://eroutes.info/paveappweb/
- Login is user specific



Software Features

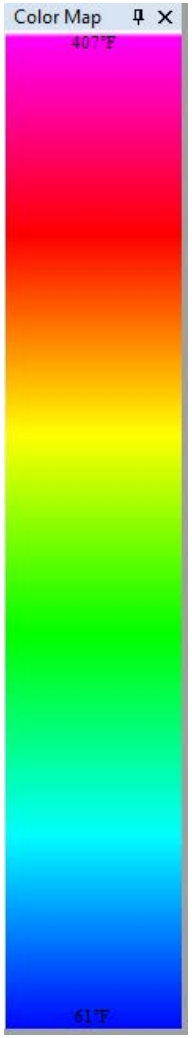
Explore Data: MOBA Pave Project Manager Main Screen



Software Features

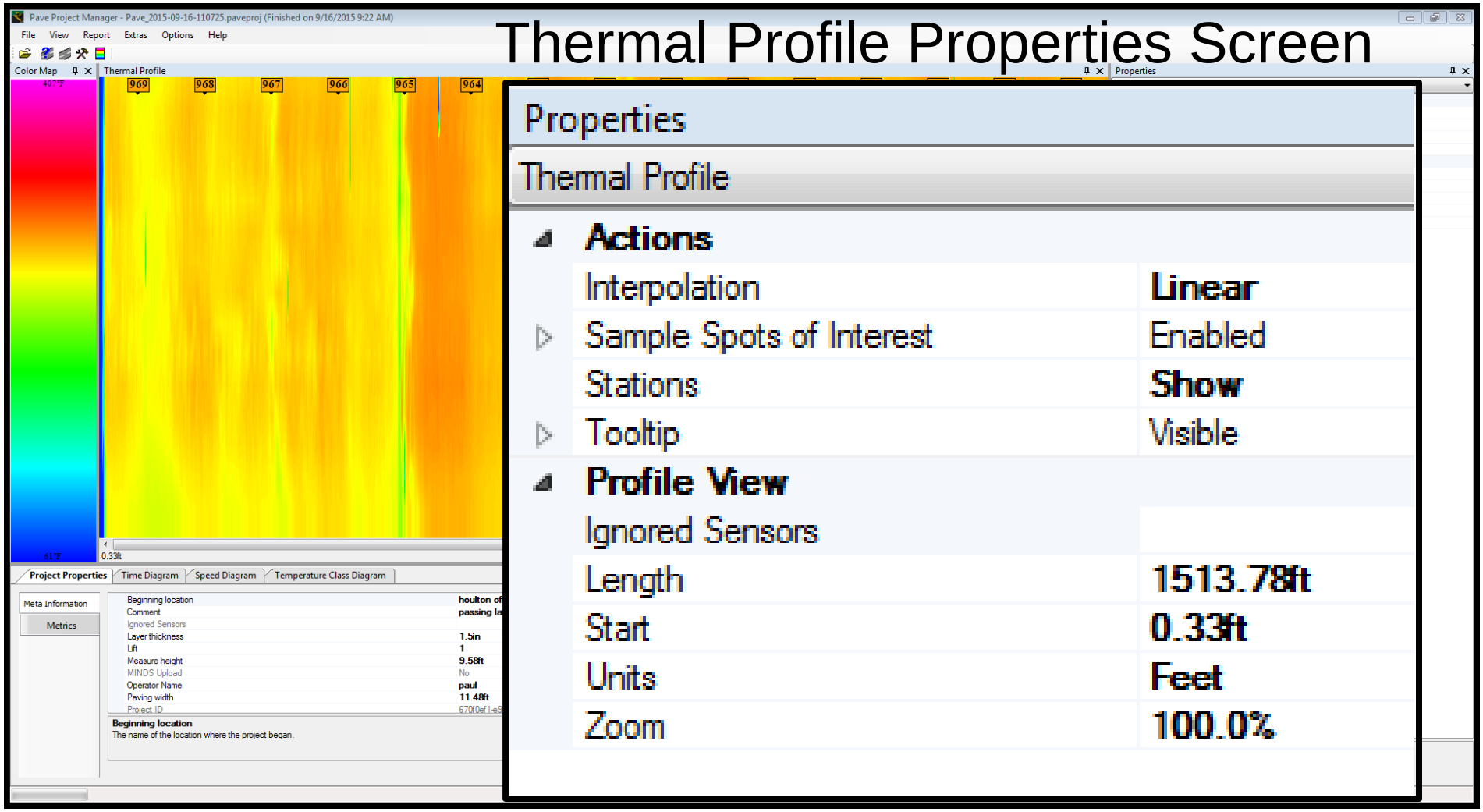
Color Map and Properties for Screen

Properties	
Color Map	
Temperature range	
Max	407°F
Min	61°F



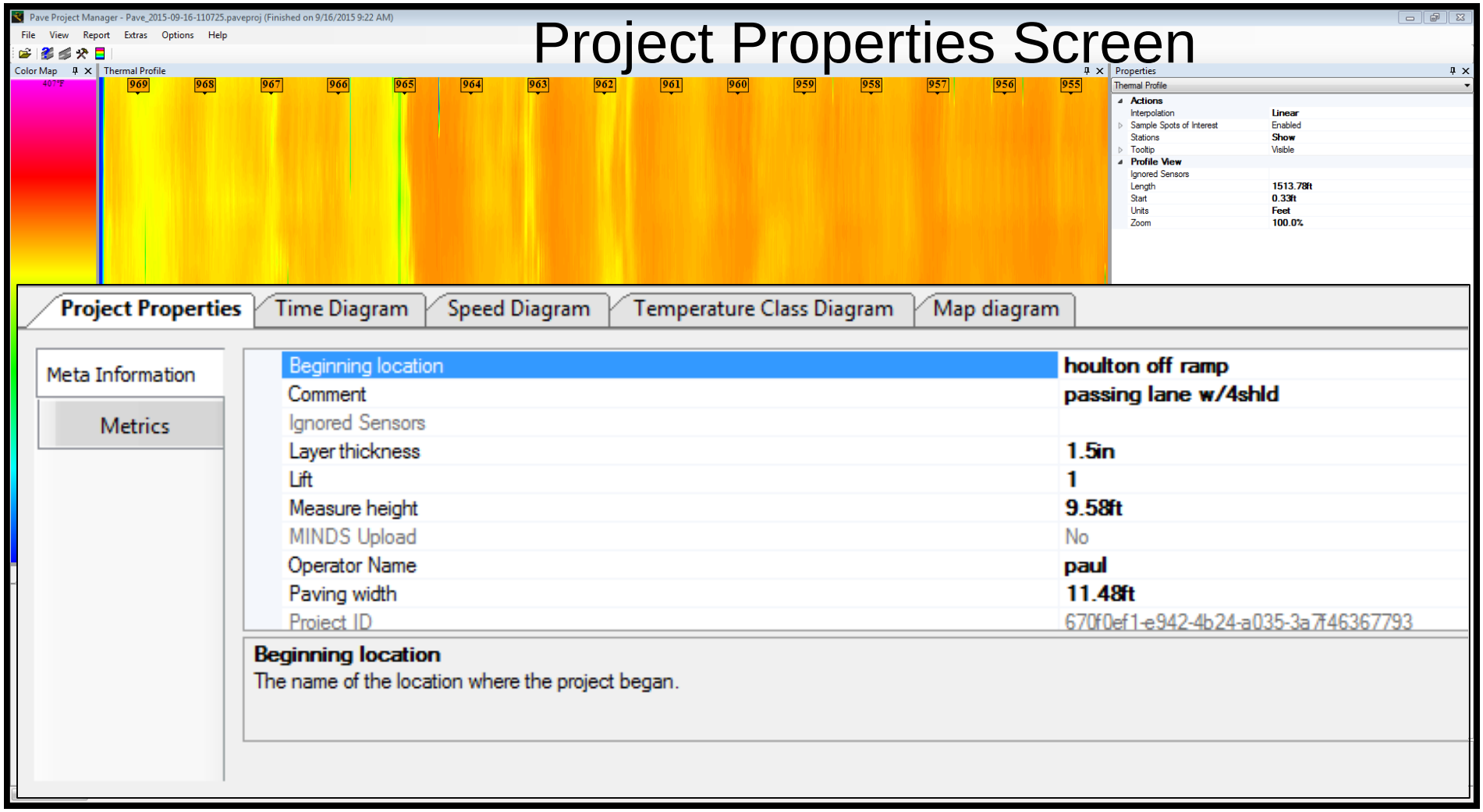
Software Features

Thermal Profile Properties Screen

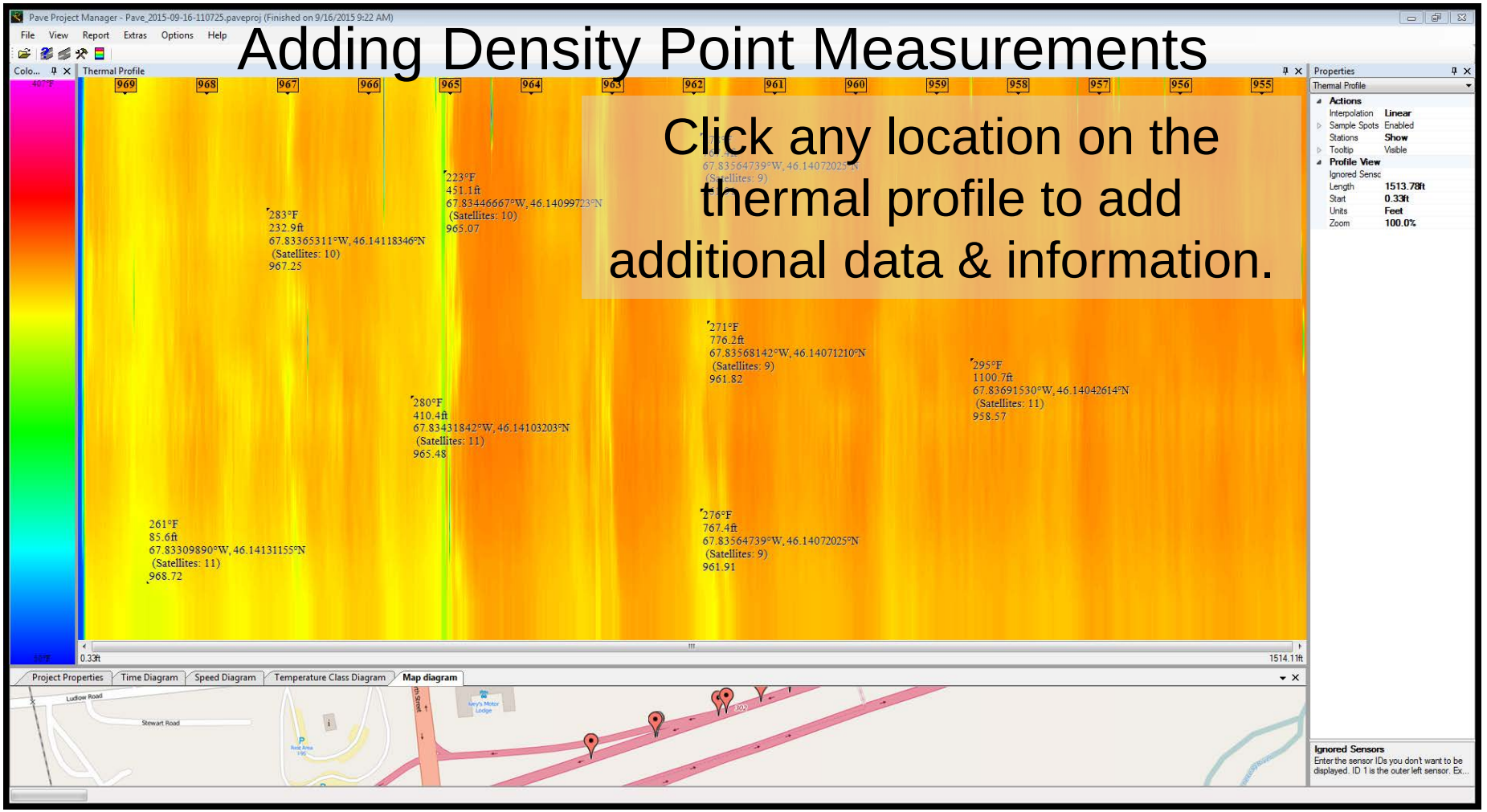


Software Features

Project Properties Screen



Software Features

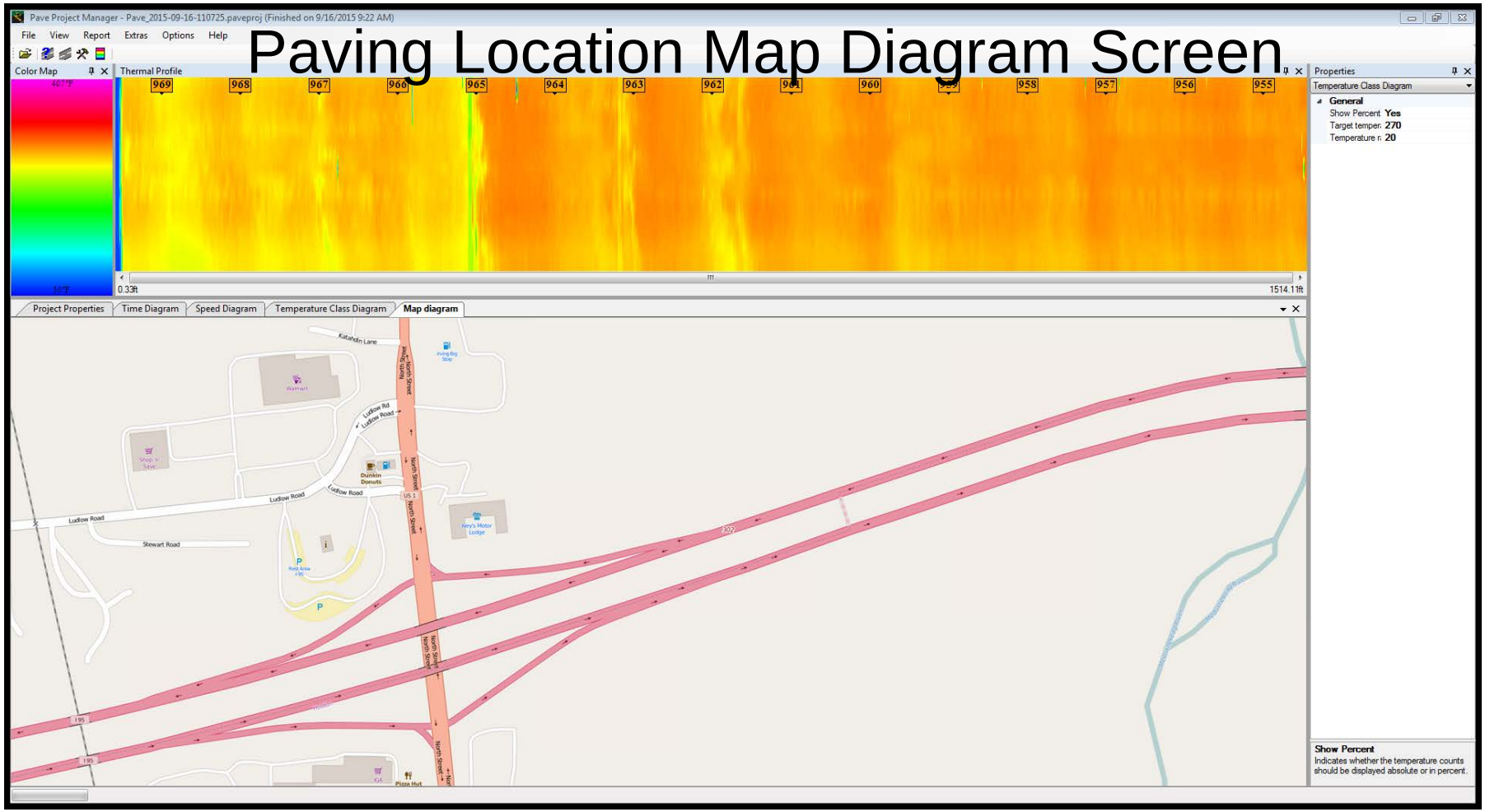


Software Features

Data diagrams reviewed during production:

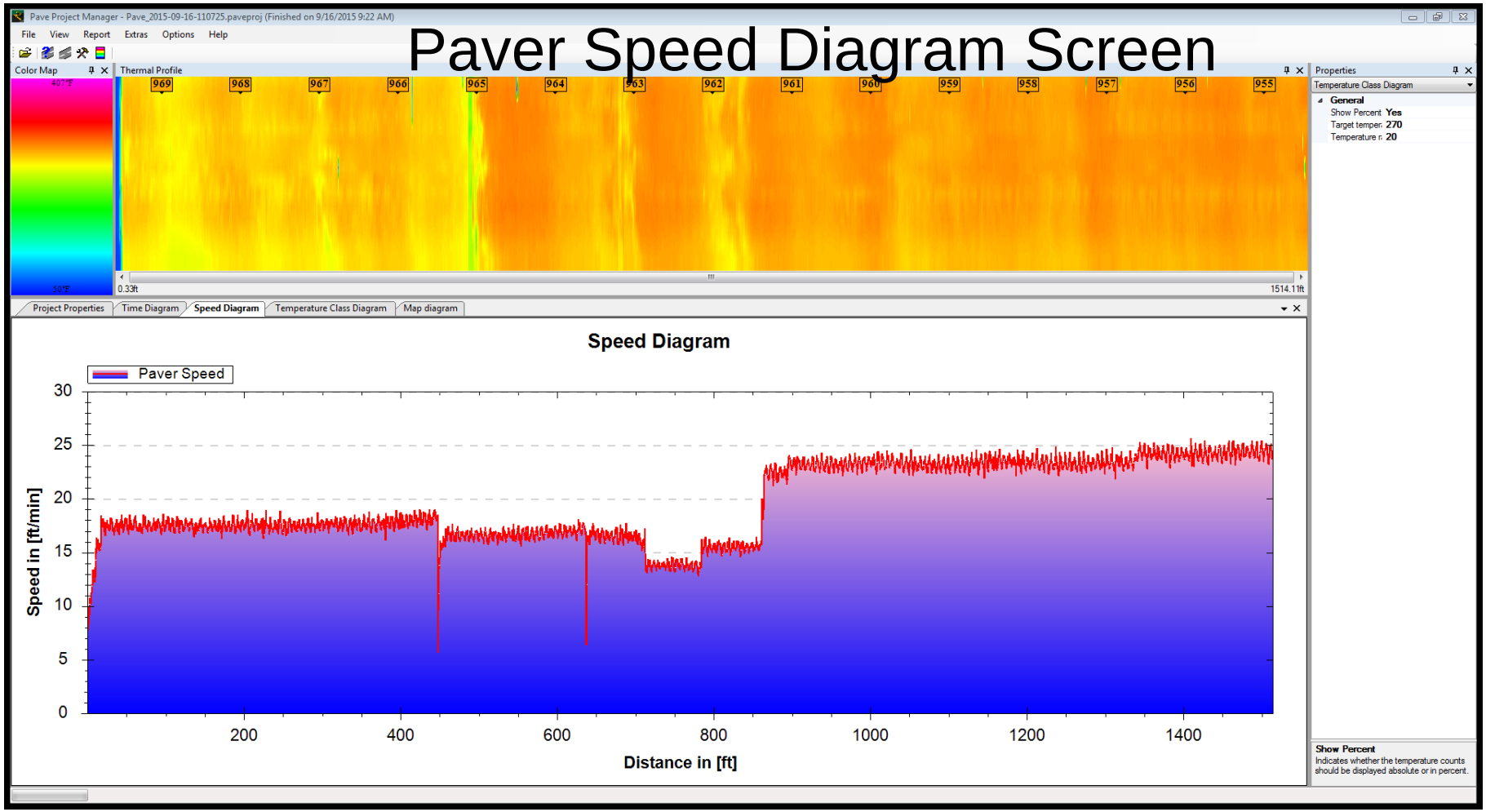
1. Paving Location Map
2. Paver speed diagram
3. Time plot
4. Average temperature plot

Software Features



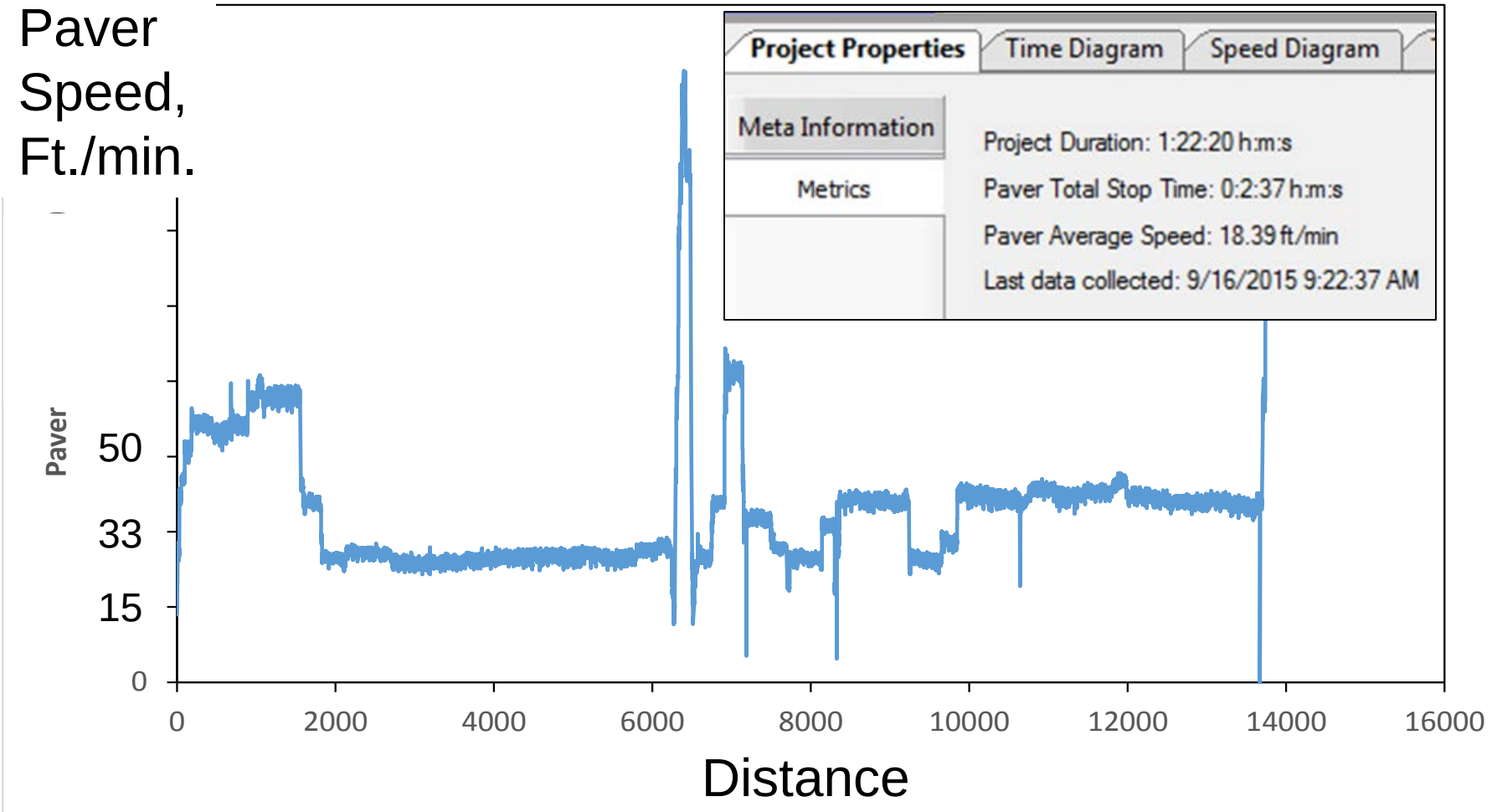
Software Features

Paver Speed Diagram Screen

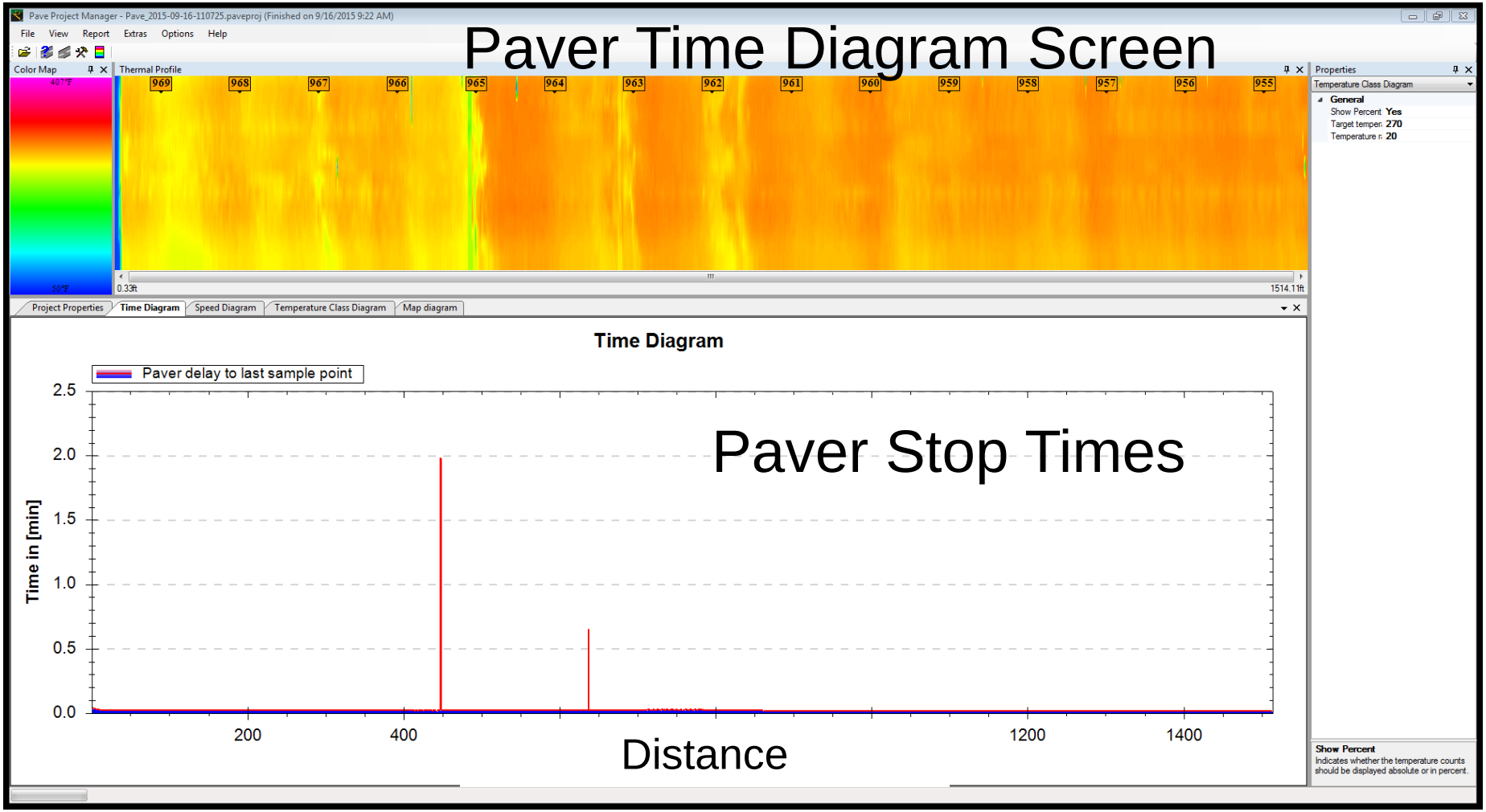


Software Features

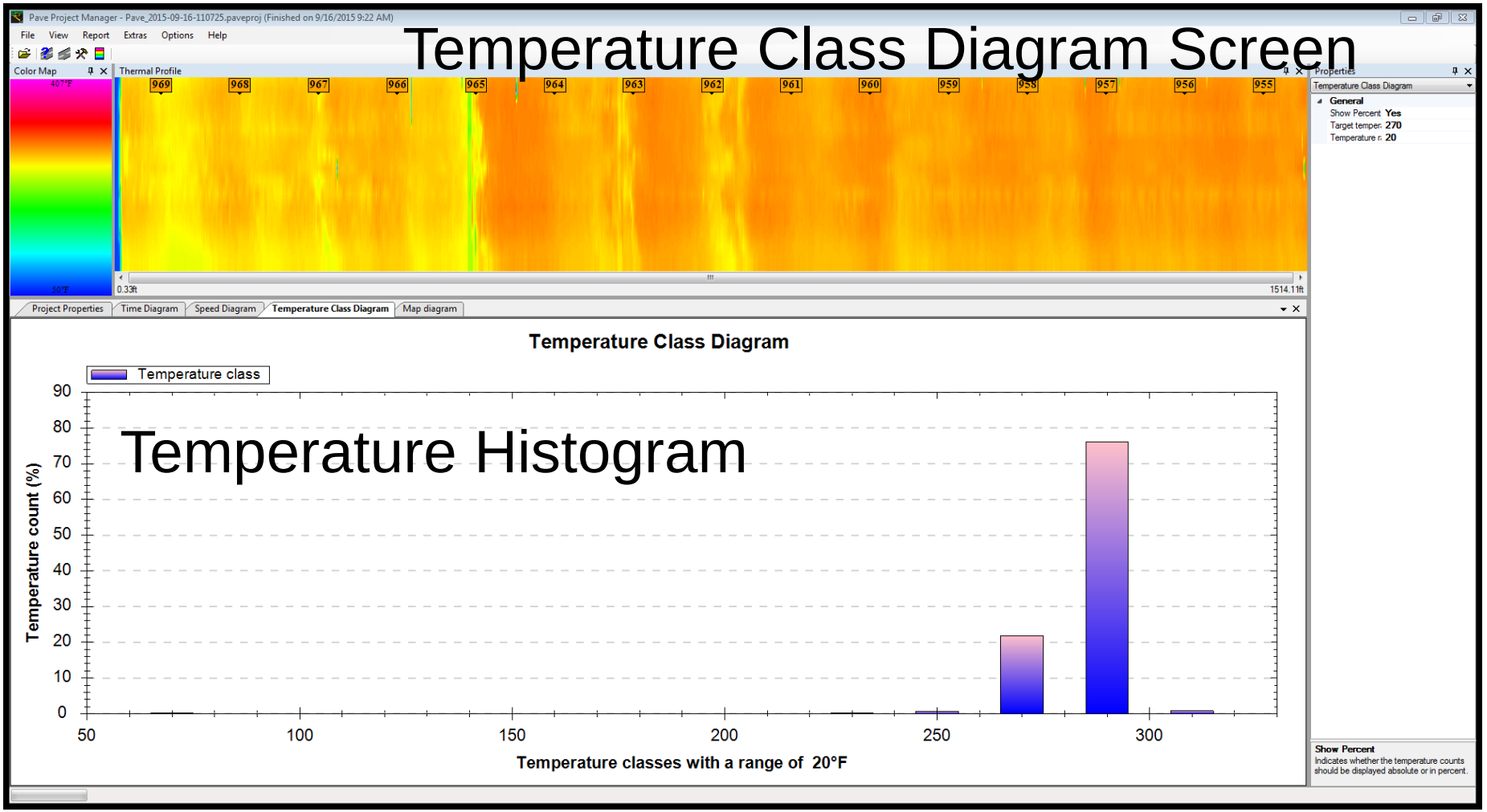
Paver Speed Diagram



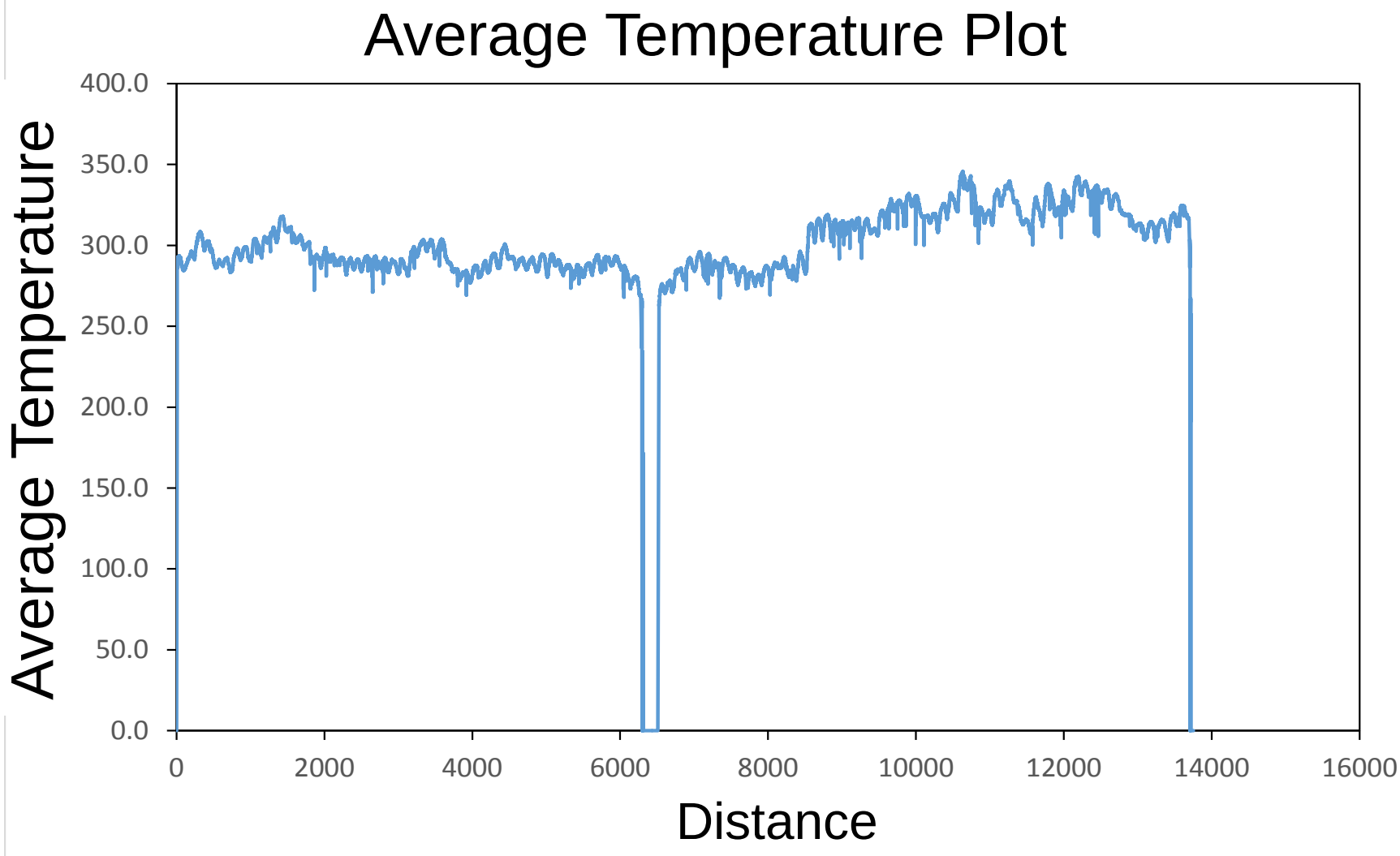
Software Features



Software Features



Software Features



Equipment and Software

Part 2: Equipment and Software – Installation and Use

1. Equipment and Its Installation
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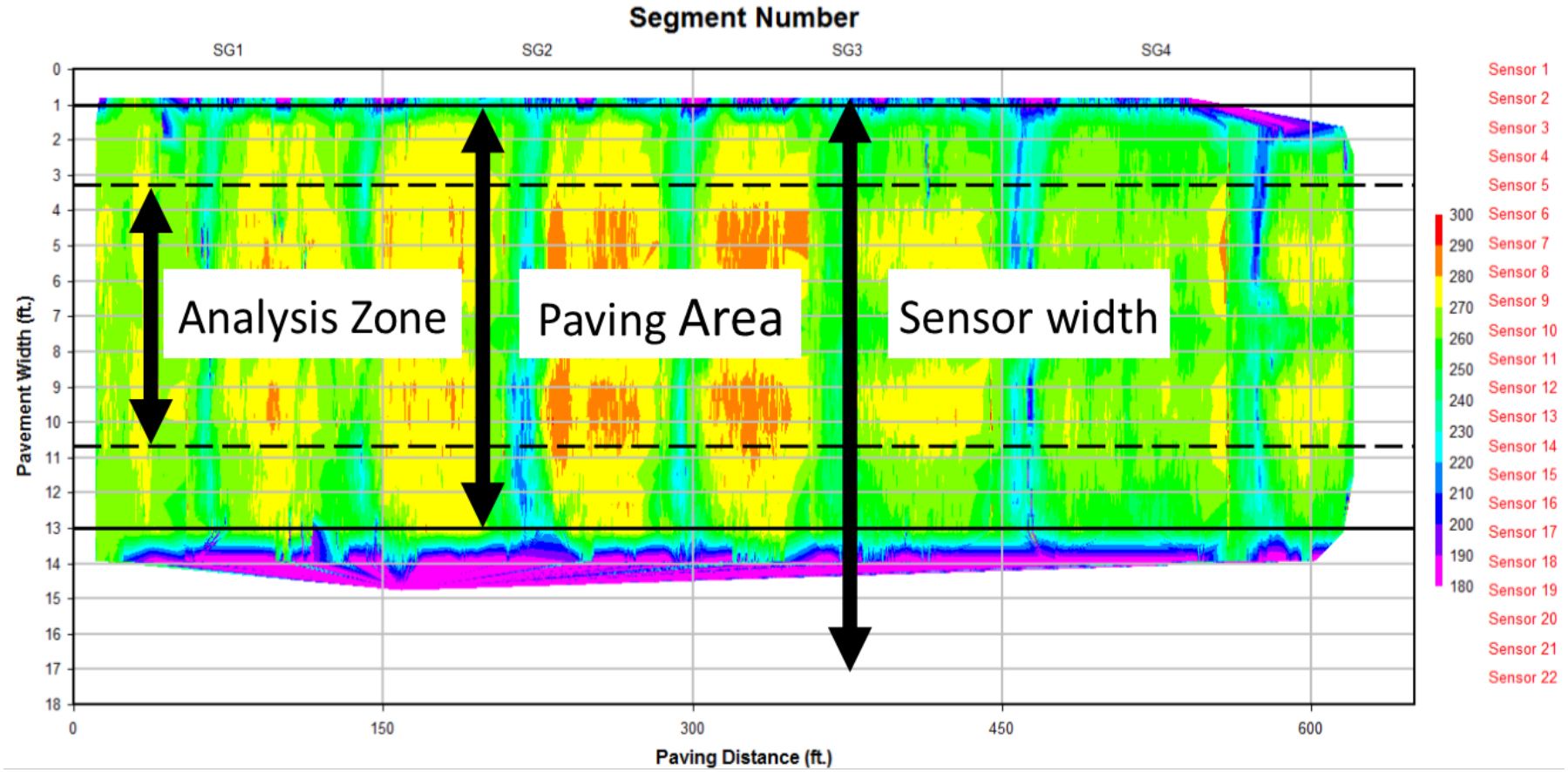
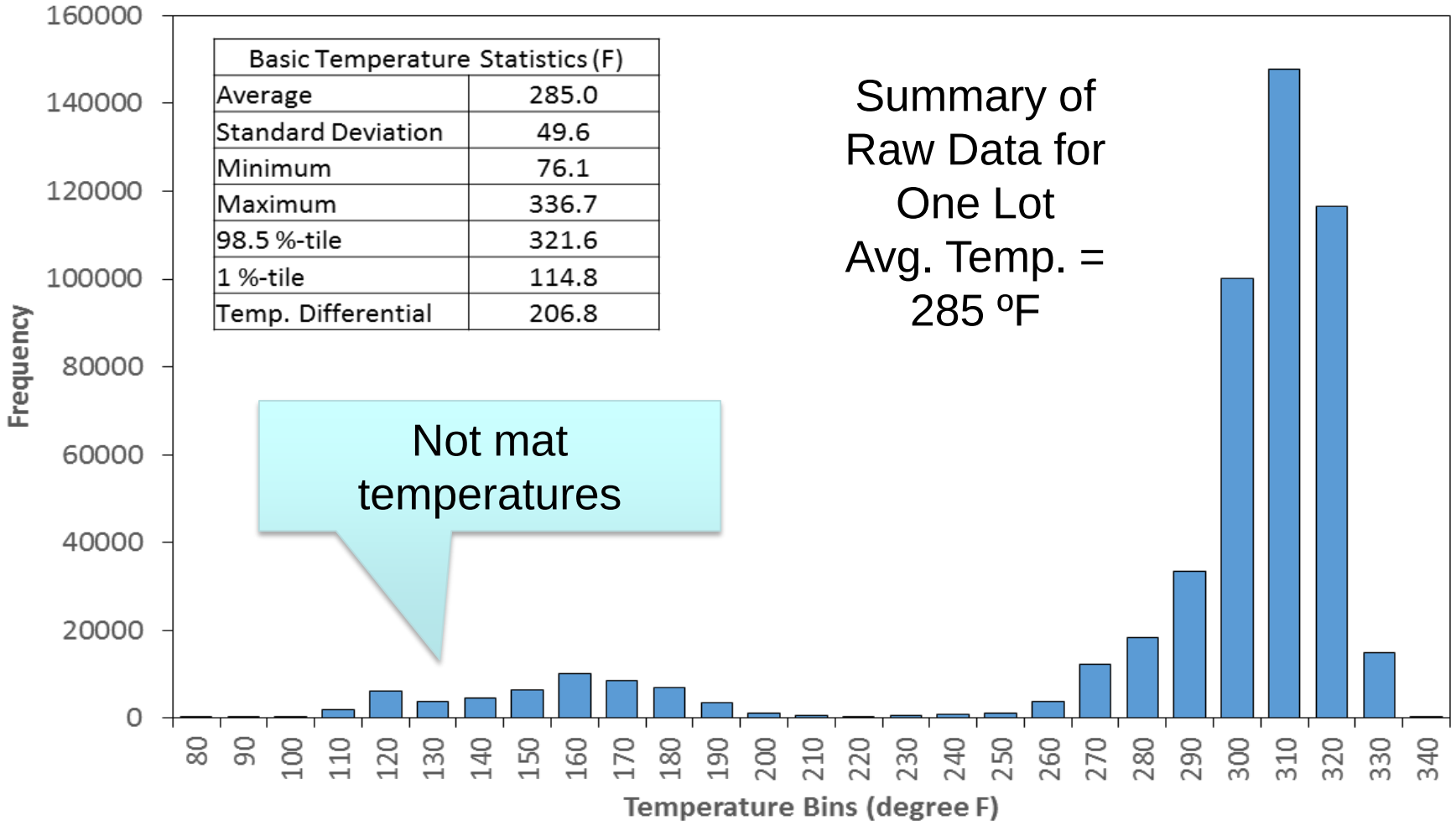
Data Processing and Reports

Raw Temperature Profile; all data collected and retained in the data file.



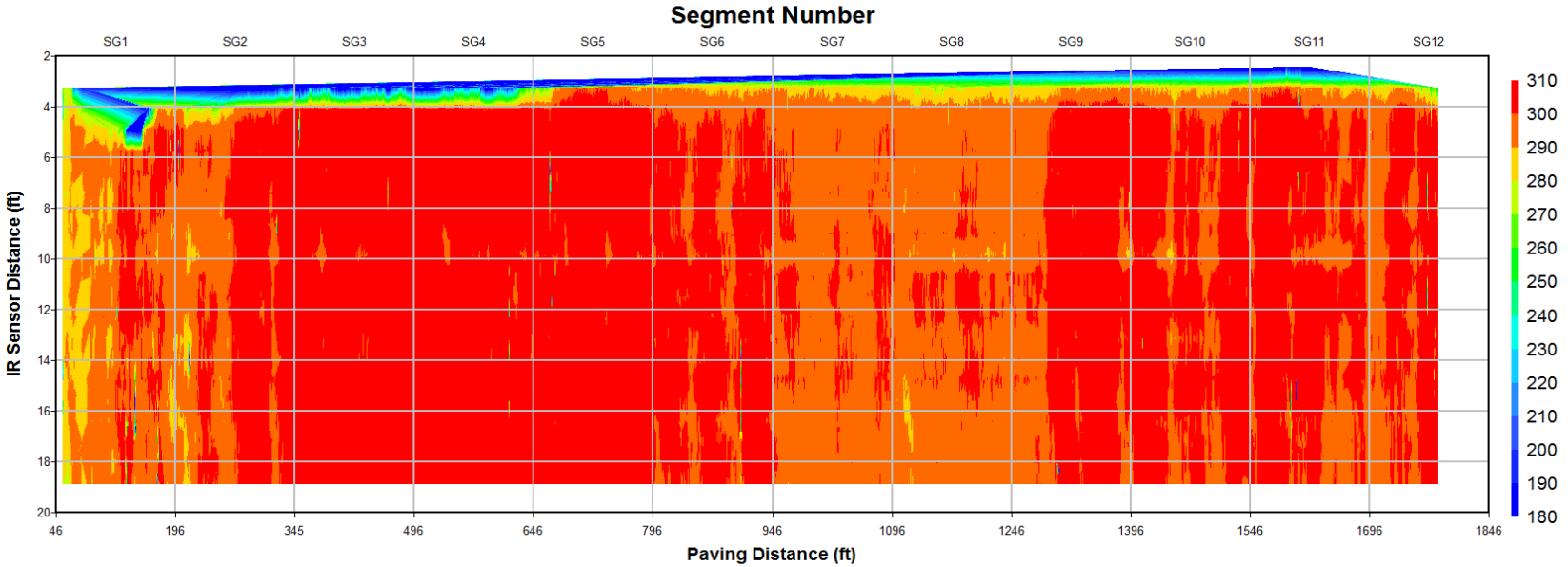
Data Processing and Reports



Data Processing and Reports

Data Processing—eliminate invalid temperature measurements, 3 steps:

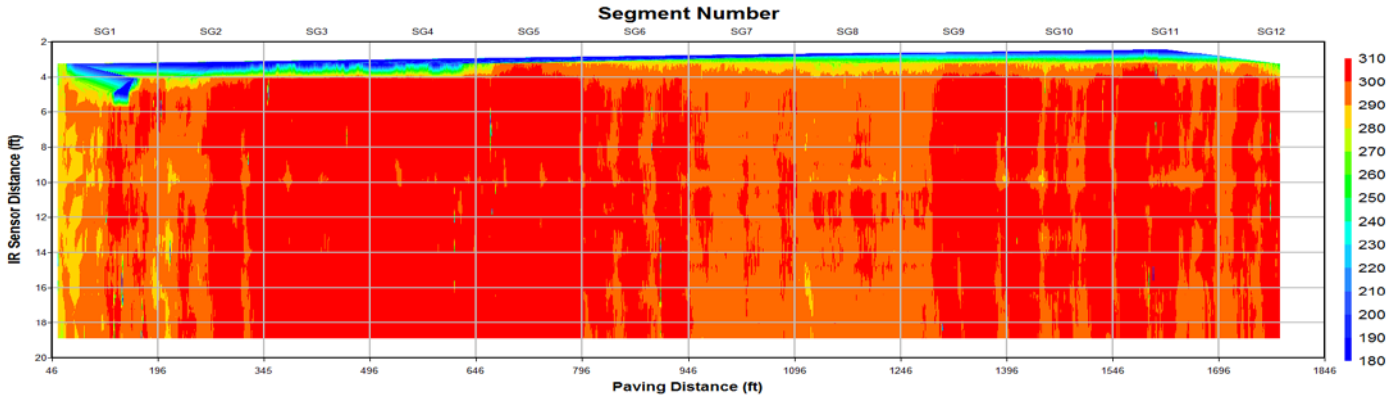
1. Eliminate measurement locations within 2 feet of the mat's edge.



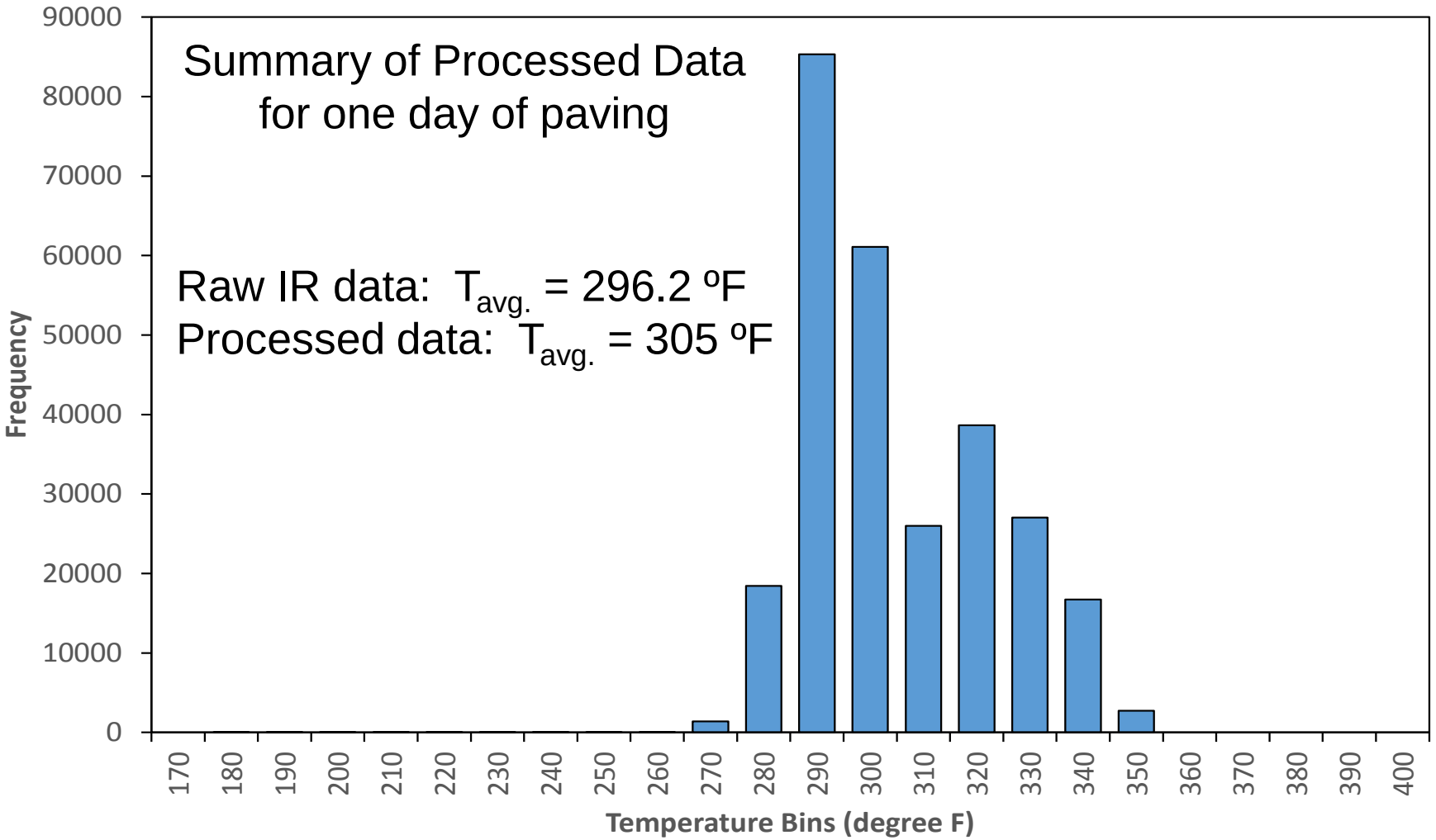
Data Processing and Reports

Data Processing—eliminate invalid temperature measurements, 3 steps:

2. Eliminate temperature readings < 170 ºF and > 400 ºF.
3. Eliminate data with paver stops greater than 60 seconds, between locations:
   - 2 feet behind measurement location of stop
   - 8 feet in front of measurement location of stop



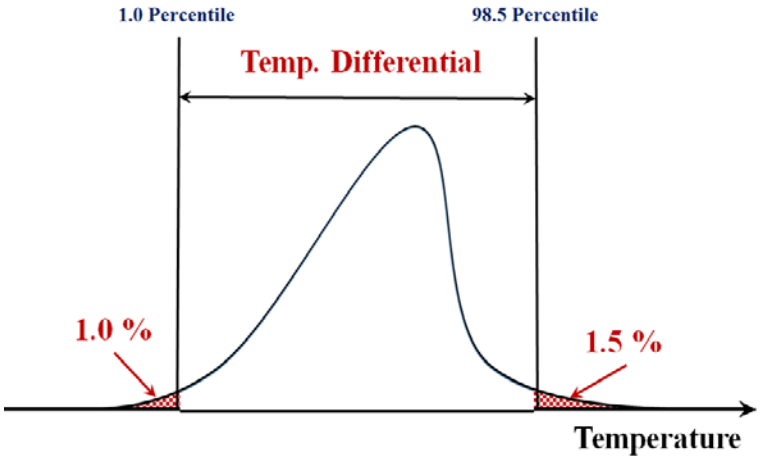
Data Processing and Reports



Data Processing and Reports

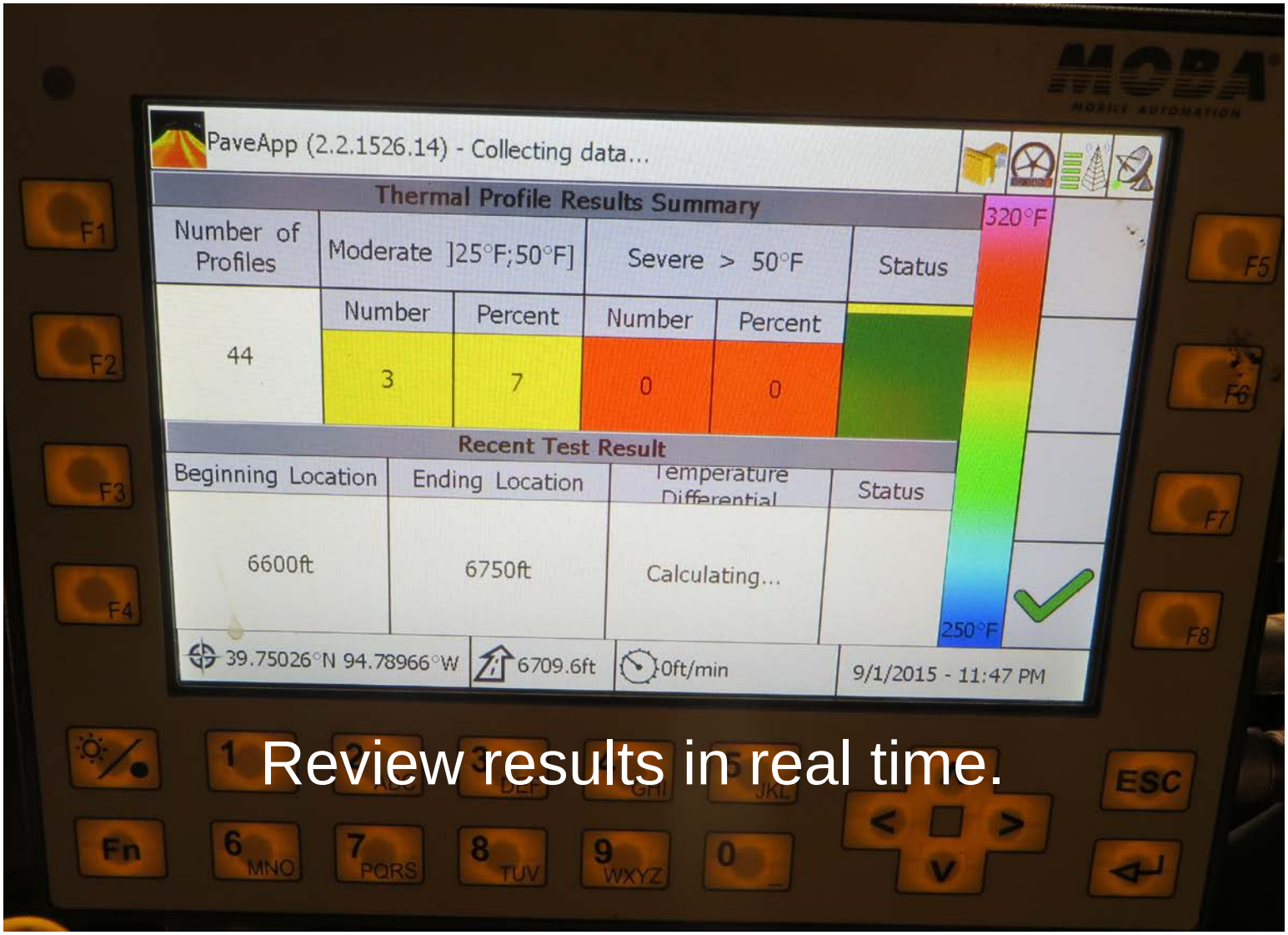
- Temperature Differential Criteria, each 150 foot segment:

$$T_{Diff} = T_{98.5} - T_{1.0}$$



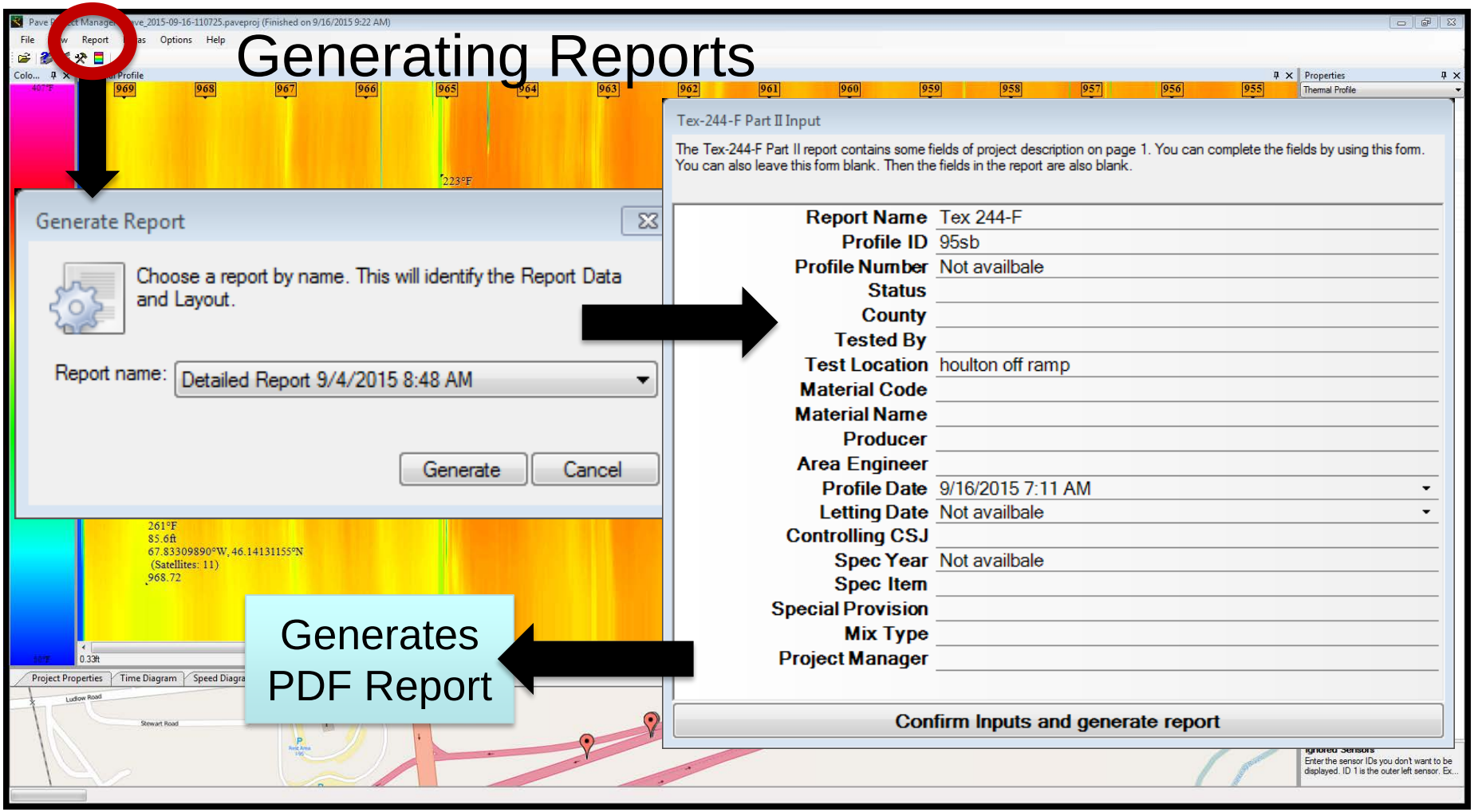
- **$T_{diff} \leq 25$ ºF** — **Minor temperature difference**
- 25 ºF < $T_{diff} \leq 50$ ºF — Moderate temperature difference
- **$T_{diff} > 50$ ºF** — **Severe temperature difference**

Data Processing and Reports



Data Processing and Reports

Generating Reports



Data Processing and Reports

Report; Tex 244-F

Tex 244-F

Thermal Profile Summary Report

Profile ID:	95sb	Profile Date:	9/24/2015 9:18:13 AM
Profile Number:		Letting Date:	
Status:		Controlling CSJ:	
County:		Spec Year:	
Tested By:		Spec Item:	
Test Location:	194	Special Provision:	
Material Code:		Mix Type:	
Material Name:			
Producer:			
Area Engineer:		Project Manager:	

Course/Lift:	3	Temperature Differential Threshold:	25.0
Segment Length (ft):	150	Sensors Ignored:	-

Thermal profile summary.

Number of Profiles	Moderate 25.0°F < differential <= 50.0°F		Severe differential > 50.0°F	
	Number	Percent	Number	Percent
28	0	0	0	0

Locations without thermal segregation.

1	194.49	68.12363437 W, 46.11892049 N	193.00	68.12419593 W, 46.11879052 N	303.4	287.8	15.7
2	192.99	68.12419985 W, 46.11878960 N	191.50	68.12476079 W, 46.11866149 N	304.9	289.6	15.3
3	191.49	68.12476285 W, 46.11866104 N	190.00	68.12532427 W, 46.11853654 N	301.1	286.3	14.8
4	189.99	68.12533012 W, 46.11853523 N	188.50	68.12589203 W, 46.11840836 N	299.3	285.8	13.5
5	188.49	68.12589363 W, 46.11840800 N	187.00	68.12645526 W, 46.11828259 N	297.7	285.4	12.2
6	186.99	68.12645906 W, 46.11828176 N	185.49	68.12702186 W, 46.11815402 N	298.9	283.5	15.5
7	185.49	68.12702379 W, 46.11815360 N	183.99	68.12758506 W, 46.11802607 N	302.2	283.8	18.4
8	183.98	68.1275889 W, 46.11802512 N	182.49	68.12815126 W, 46.11789818 N	303.1	292.6	10.4
9	182.49	68.12815319 W, 46.11789773 N	181.00	68.12871395 W, 46.11777111 N	306.1	288.1	18.0
10	180.99	68.12871621 W, 46.11777052 N	179.50	68.12928274 W, 46.11764036 N	302.2	284.4	17.8
11	179.49	68.12928577 W, 46.11763966 N	178.00	68.12985205 W, 46.11751058 N	302.9	287.6	15.3
12	177.99	68.12985387 W, 46.11751020 N	176.50	68.13042113 W, 46.11738235 N	302.0	288.0	14.0
13	176.49	68.13042482 W, 46.11738148 N	175.00	68.13099093 W, 46.11725309 N	301.8	289.2	12.6
14	174.99	68.13099275 W, 46.11725265 N	173.50	68.13155886 W, 46.11712703 N	302.2	288.0	14.2
15	173.49	68.13156263 W, 46.11712618 N	171.99	68.13212684 W, 46.11699931 N	303.6	286.3	17.3
16	171.99	68.13212971 W, 46.11699866 N	170.49	68.13269254 W, 46.11687031 N	302.9	286.5	16.4
17	170.48	68.1326963 W, 46.11686947 N	169.00	68.13325913 W, 46.11674378 N	305.8	288.9	16.9
18	168.99	68.13326314 W, 46.11674285 N	167.50	68.13382973 W, 46.11661558 N	302.0	286.0	16.0
19	167.49	68.13383168 W, 46.11661512 N	166.00	68.1343973 W, 46.11648481 N	298.6	284.2	14.4
20	165.99	68.13440119 W, 46.11648392 N	164.50	68.13497078 W, 46.11635549 N	298.4	282.9	15.5
21	164.49	68.13497271 W, 46.11635503 N	163.00	68.13554162 W, 46.11622699 N	297.5	282.4	15.1
22	162.99	68.13554551 W, 46.11622616 N	161.49	68.13611883 W, 46.11609795 N	296.1	283.6	12.4
23	161.49	68.13612069 W, 46.11609752 N	160.00	68.13668796 W, 46.11596968 N	301.6	277.2	24.5
24	159.99	68.13669173 W, 46.11596883 N	158.49	68.13725615 W, 46.11584140 N	299.7	281.1	18.5
25	158.49	68.13725879 W, 46.11584082 N	157.00	68.1378221 W, 46.11571525 N	301.6	287.4	14.2
26	156.99	68.13782589 W, 46.11571440 N	155.50	68.13839327 W, 46.11558715 N	302.2	288.5	13.7
27	155.49	68.13839721 W, 46.11558631 N	154.00	68.1389655 W, 46.11545741 N	302.2	289.8	12.4

Data Processing and Reports

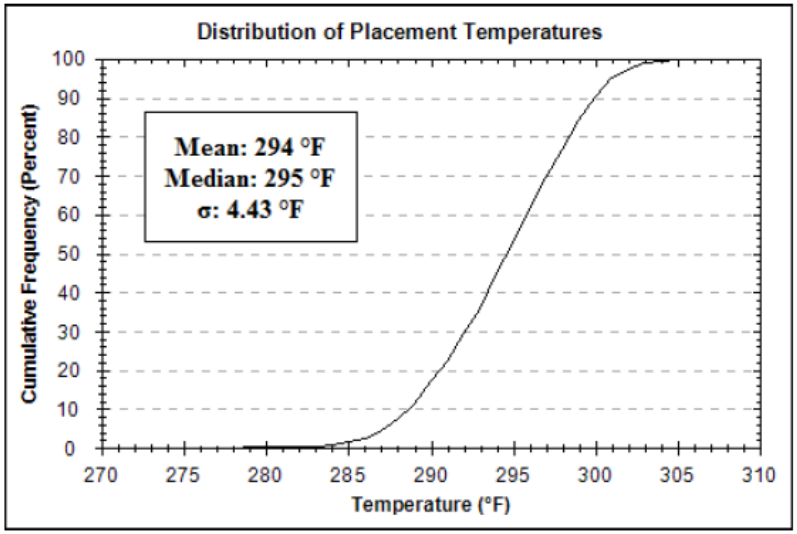
Report; Tex 244-F

Distribution of mat temperatures.

Location of paver stops.

Summary of Locations Without Thermal Segregation

Profile Nr	Beginning Location		Ending Location		Max Temp	Min Temp	Temperature Differential
	Station	GPS in °	Station	GPS in °			
28	153.99	68.13896866 W, 46.11545670 N	153.24	68.13925736 W, 46.11538960 N	299.1	287.2	11.9



Location of Paver Stops greater than One Minute

Location (stations)	Duration (h:min:sec)
185.89	0:2:0
172.06	0:4:22
168.59	0:4:25

Questions?

NEXT:

- Part 3: IR Field Demonstration Projects—Findings

SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Infrared Technology Workshop

Part 3: IR Field Demonstration Project – AL 202

U.S. Department of Transportation
Federal Highway Administration

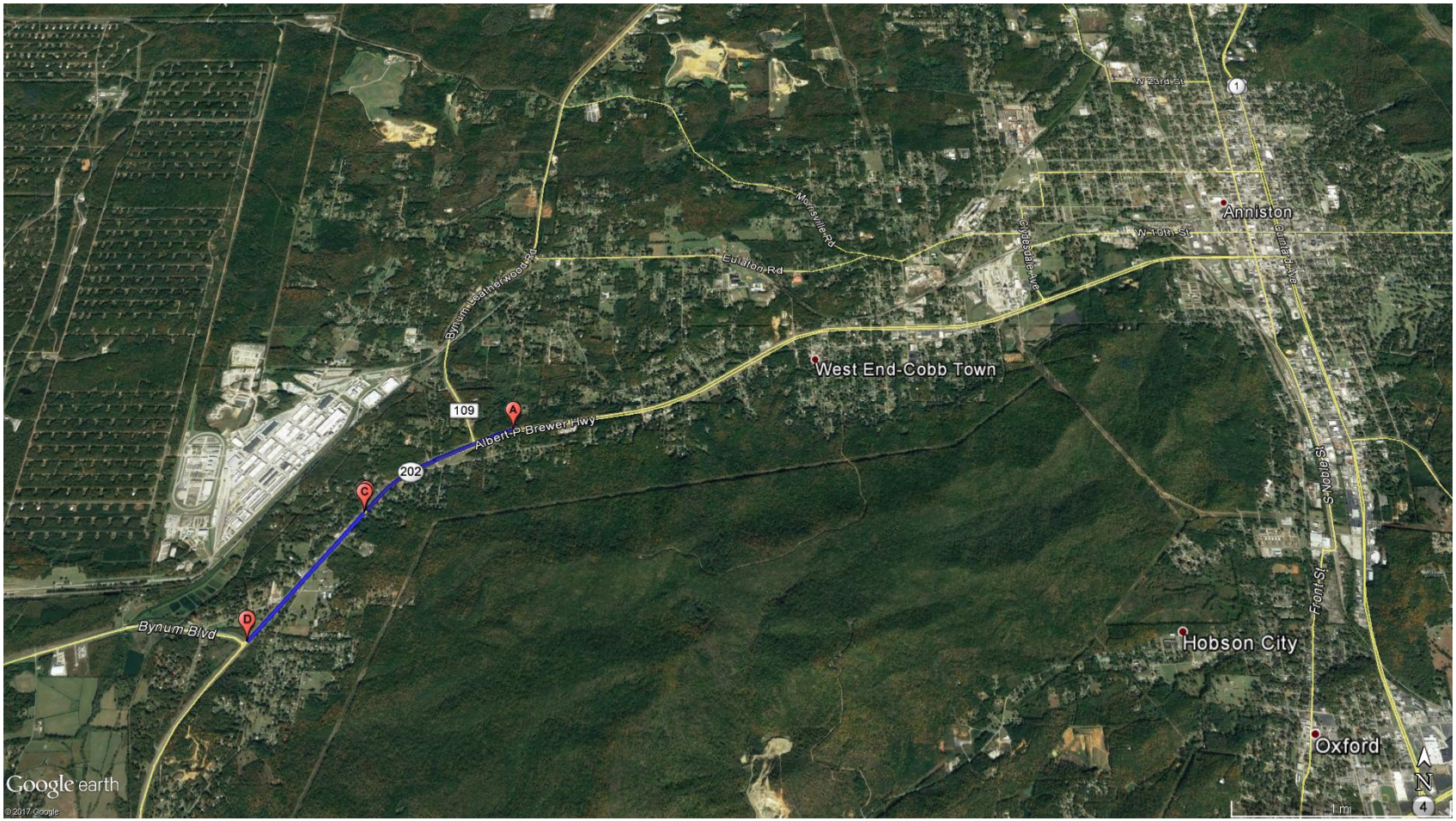
American Association of State Highway and Transportation Officials
AASHTO

Data Analyses & Findings

1. Project Overview
2. Data Collection
3. Data Processing
4. Data Summary

Data Analyses & Findings

Two Locations along AL 202



Data Analyses & Findings

Two Locations along AL 202

Data Analyses & Findings

Mixtures placed with Roadtec Rubber Tired Paver

Roadtec MTD used with hopper insert

Data Analyses & Findings

Mixture delivered to site with end dump discharge trucks.

Data Analyses & Findings

Roadway without tack coating applied

Roadway with tack coating applied

Data Analyses & Findings

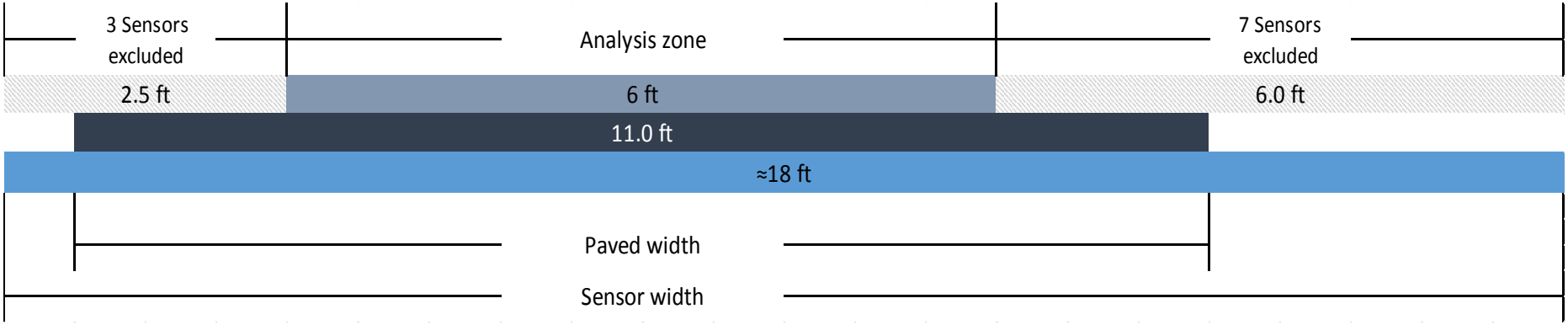
Compaction Train; all steel wheel rollers

Data Analyses & Findings

1. Project Overview
2. Data Collection
3. Data Processing
4. Data Summary

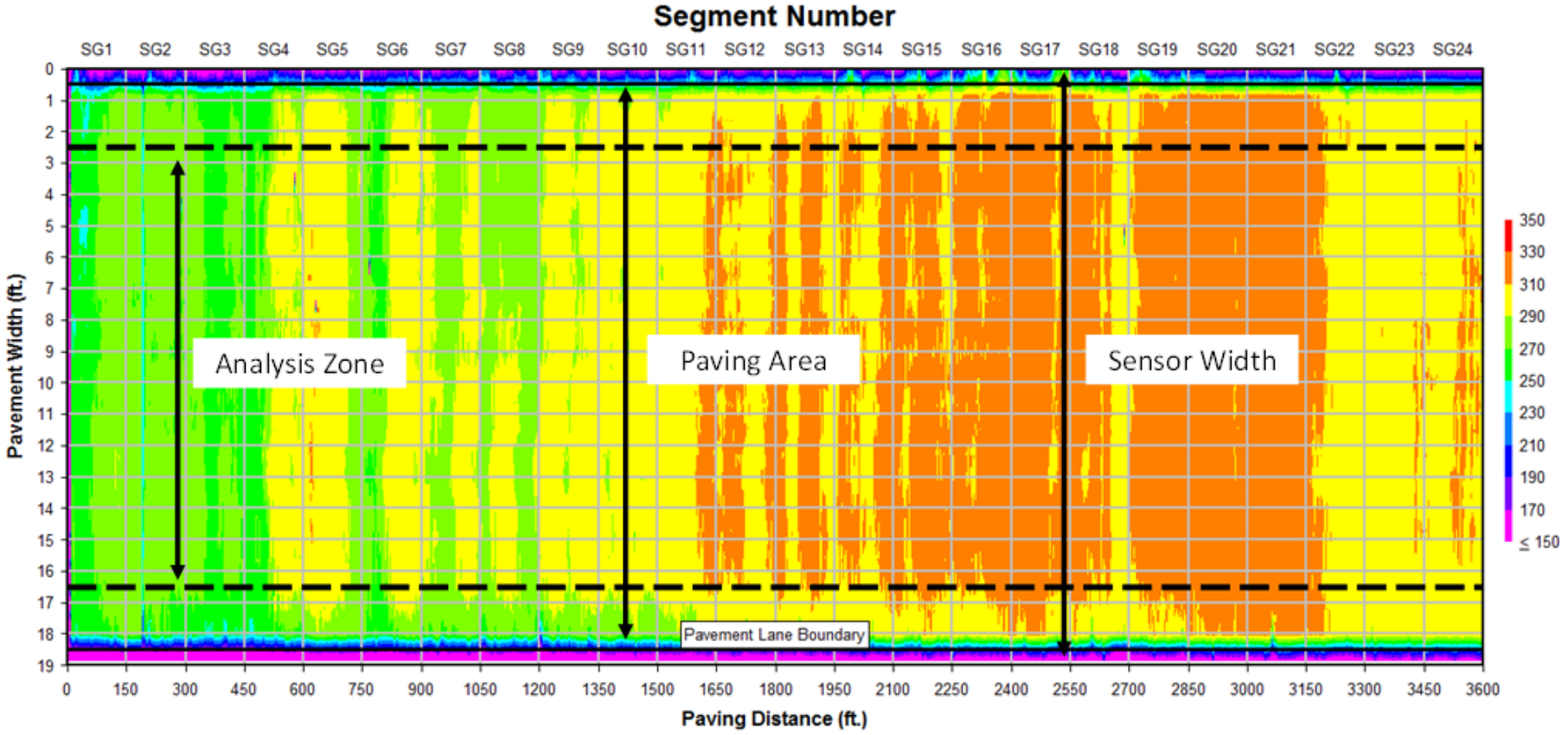
Data Analyses & Findings

Paving Width and Analysis Zones

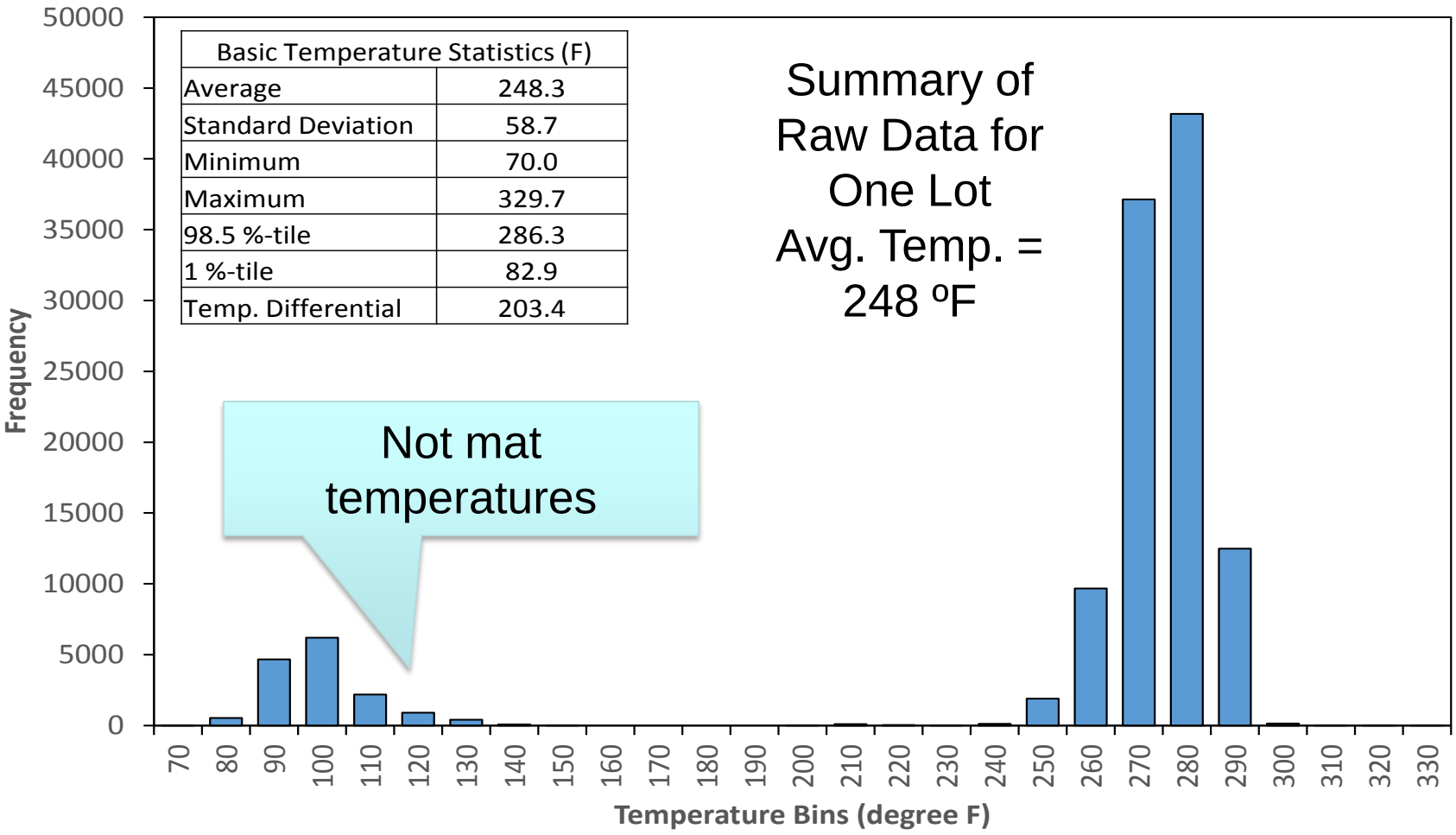


Data Analyses & Findings

Paving Width and Analysis Zones
Raw Temperature Profile Example



Data Analyses & Findings

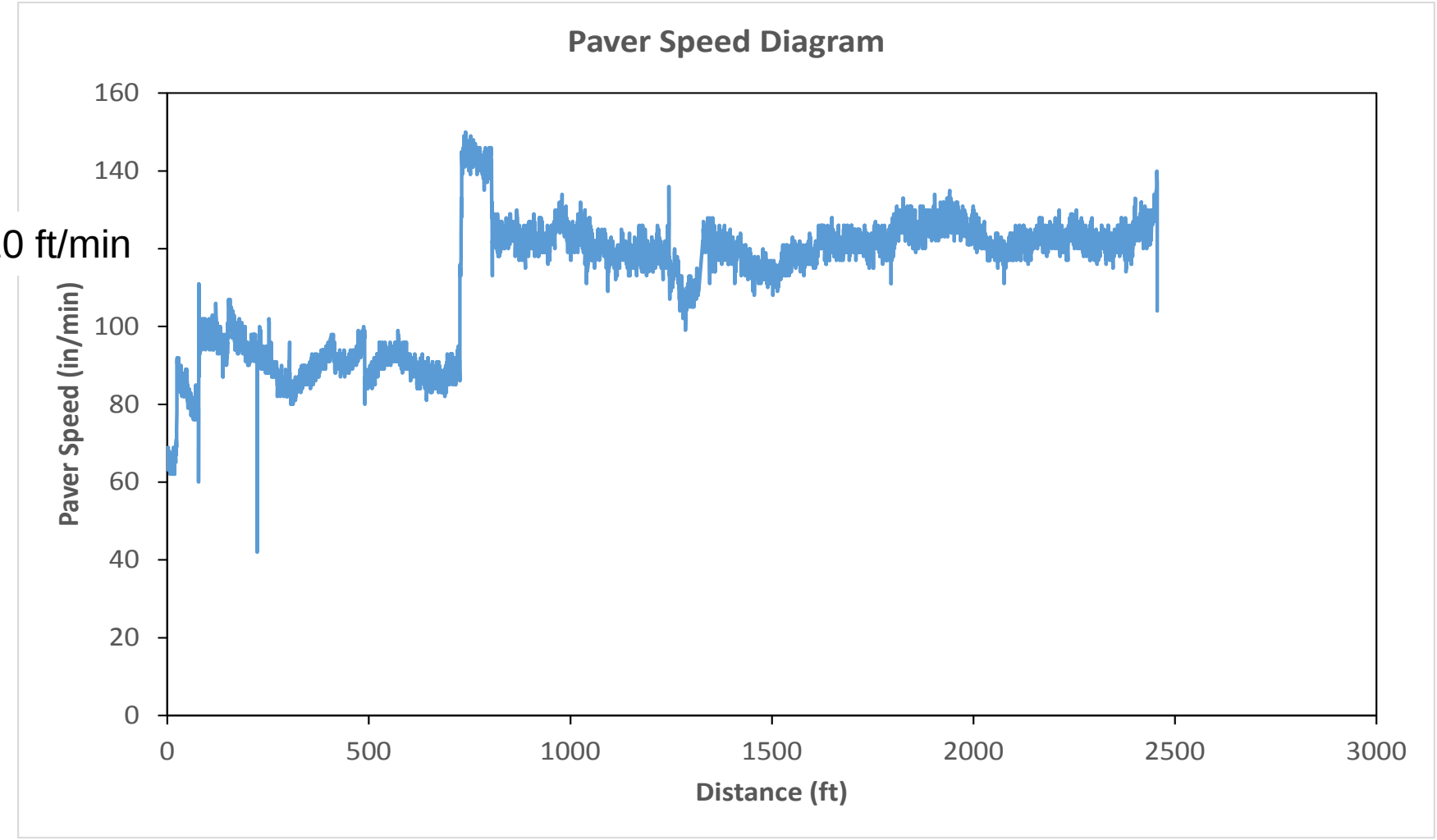


Data Analyses & Findings

Data diagrams reviewed during production:

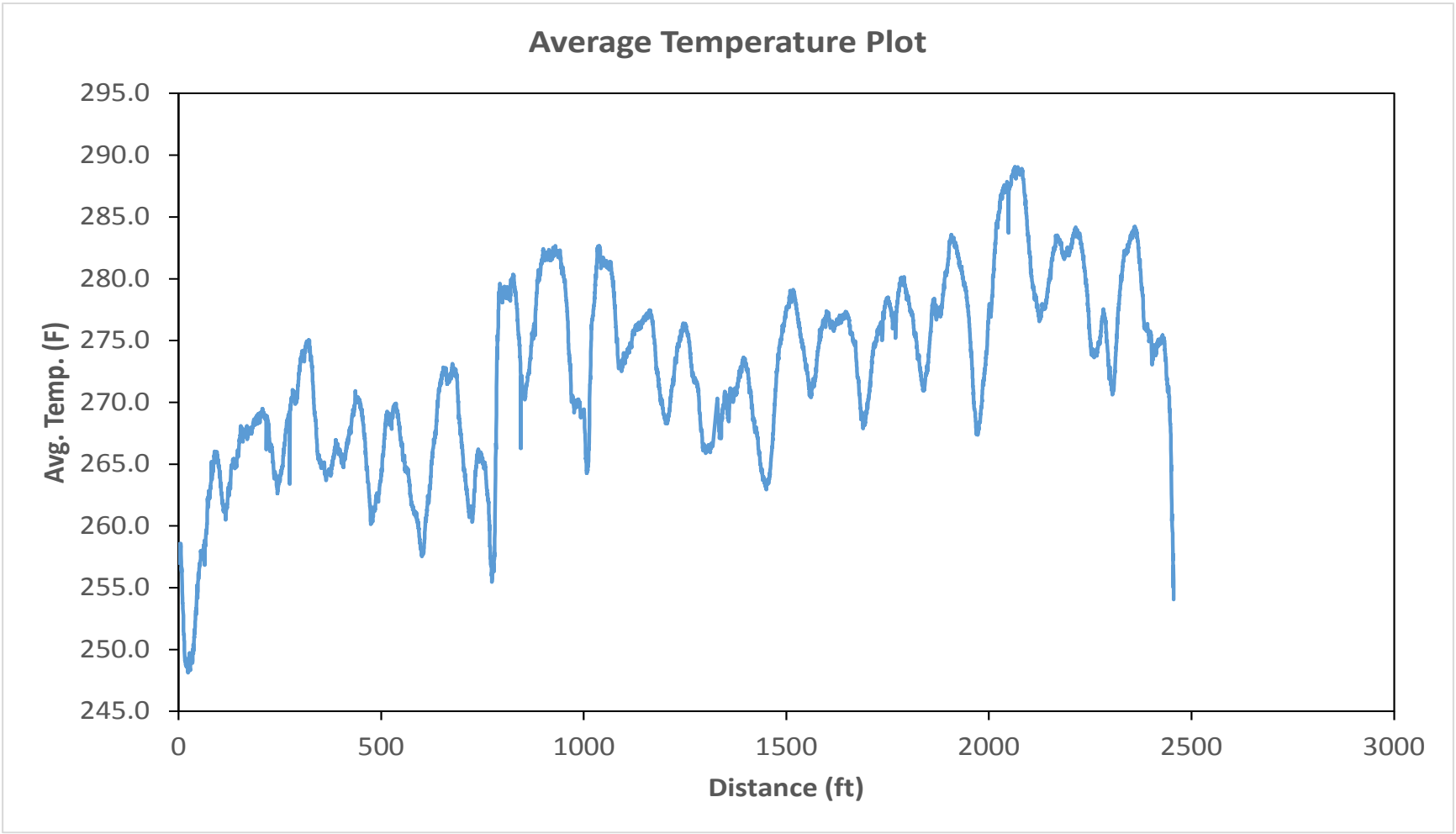
1. Paver speed diagram
2. Time plot
3. Average temperature plot

Data Analyses & Findings



10 ft/min

Data Analyses & Findings



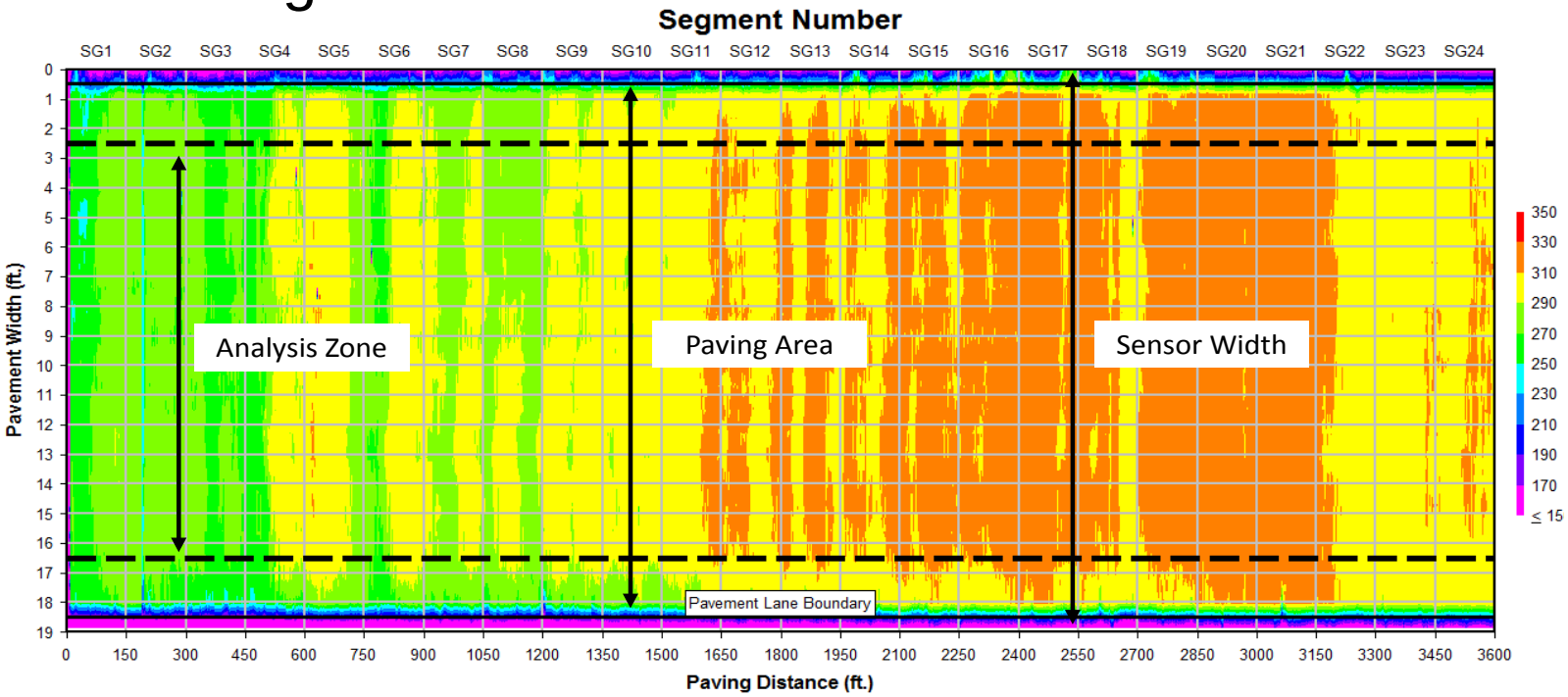
Data Analyses & Findings

1. Project Overview
2. Data Collection
3. Data Processing
4. Data Summary

Data Analyses & Findings

Data Processing—eliminate invalid temperature measurements:

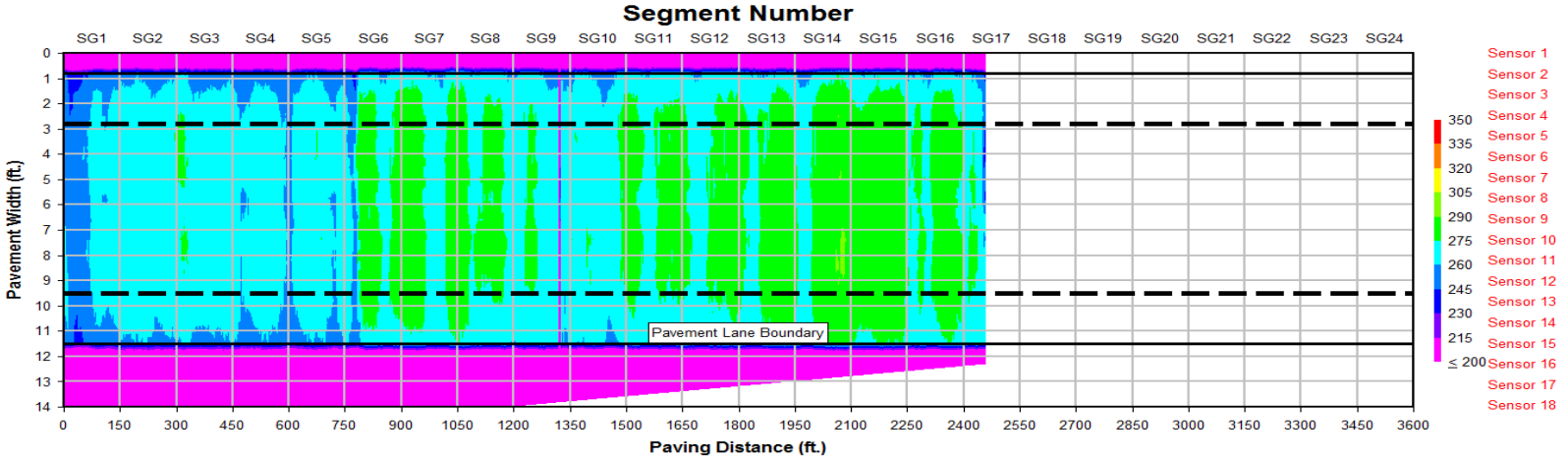
1. Eliminate measurement locations within 2 feet of the mat's edge.



Data Analyses & Findings

Data Processing—eliminate invalid temperature measurements:

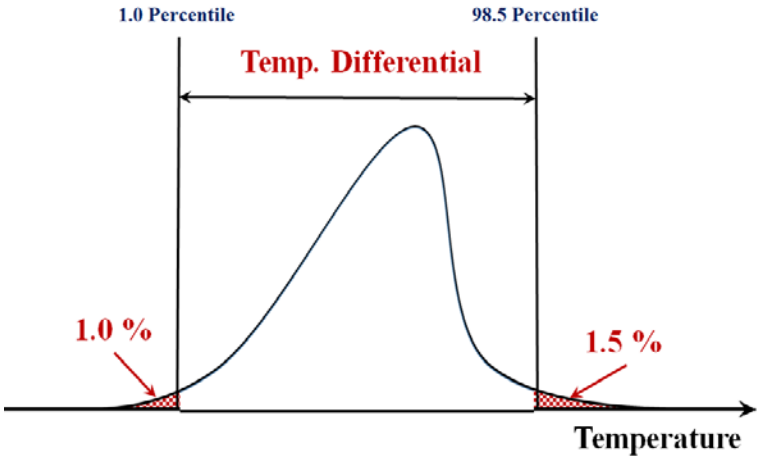
2. Eliminate data with paver stops greater than 60 seconds, between locations:
   - 2 feet behind measurement location of stop
   - 8 feet in front of measurement location of stop
3. Eliminate temperature readings < 170 ºF and > 400 ºF.



Data Analyses & Findings

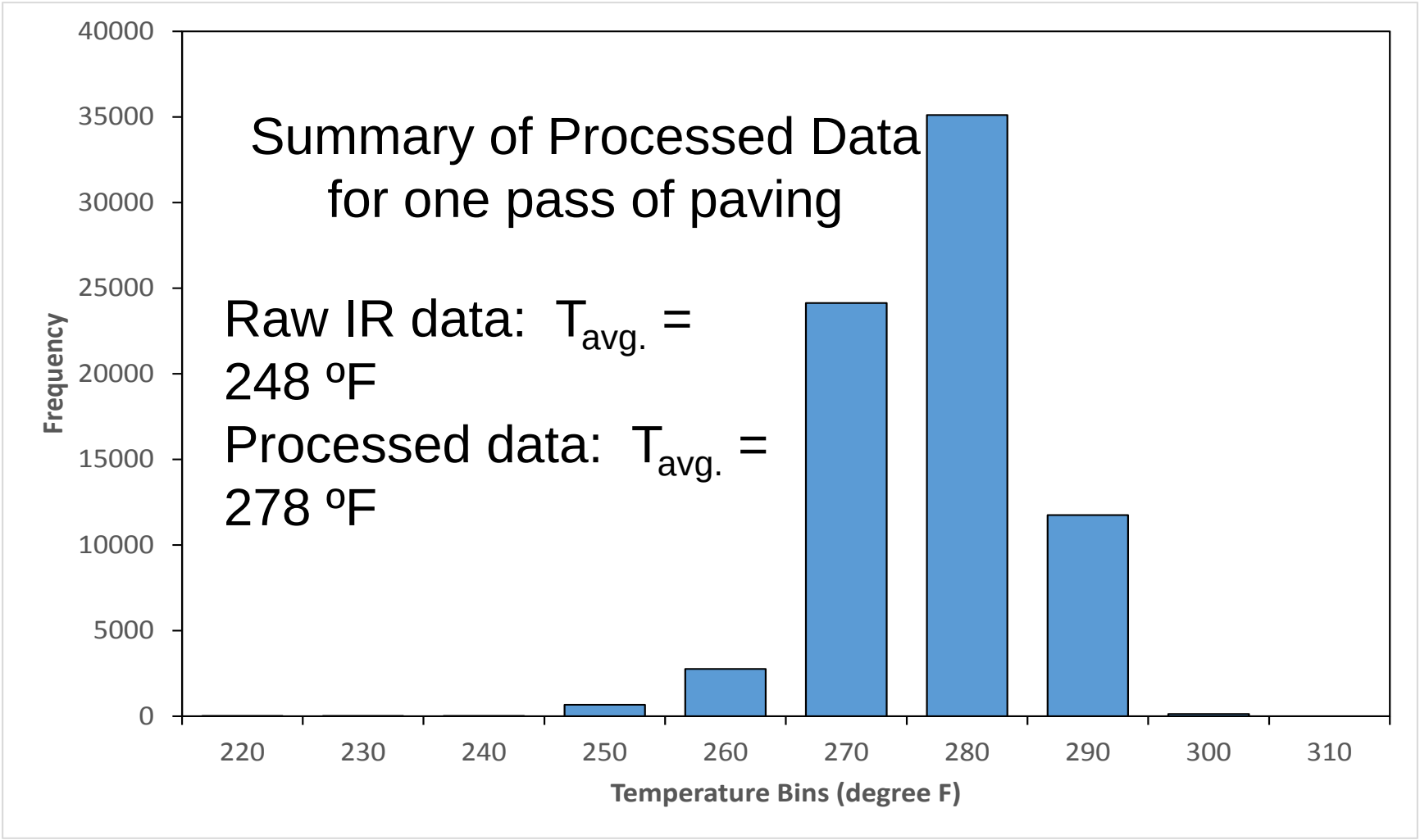
- Temperature Differential Criteria, each 150 foot segment:

$$T_{Diff} = T_{98.5} - T_{1.0}$$



- **$T_{diff} \leq 25$ ºF** — **No temperature difference**
- 25 ºF < $T_{diff} \leq 50$ ºF — Moderate temperature difference
- **$T_{diff} > 50$ ºF** — **Severe temperature difference**

Data Analyses & Findings



Data Analyses & Findings

1. Project Overview
2. Data Collection
3. Data Processing
4. Data Summary

R06C-IR Demonstration Projects

Paver Stops	Total Number of Increments	Number of Increments within Temp. Regimes			Thermal Streaking
		Minor	Moderate	Severe	
Alabama DOT Project					
Excluded	48	34	14	0	None
Included	47	34	11	2	None

To include or exclude paver stops?
If paver stop cause severe temperature differences:
they should be included

Data Analyses & Findings

Processed Data for IDOT

Paver Stops	Total Number of Increments	Number of Increments within Temp. Regimes			Thermal Streaking
		Minor	Moderate	Severe	
Alabama DOT Project					
Excluded	48	34	14	0	None
Included	47	34	11	2	None

Minnesota DOT's specification:

- Minor Temperature Difference: +$20 per Increment
- Moderate Temperature Difference: $0 per Increment
- Severe Temperature Difference: -$20 per Increment

Total Disincentive to Contractor:
+$640 for the projects [Including paver stops].

R06C-IR Demonstration Projects

Percentage of Segments with Severe Temperature Differentials

Project	Delivery Truck Type	MTV Included	Percent Severe Temp. Differentials	Thermal Streaking
Alaska	Bottom-Dump	Windrows	17	None
EFL	***End Dump***	***No***	***83***	***None***
Illinois	***End Dump***	***No***	***40***	***None***
Maine	End Dump	Yes	5	None
Missouri	End Dump & Flow Boys	Yes	25	None
NJ	End Dump	Yes	21	None
Virginia	End Dump	Yes	5	None
NC	End Dump	Yes	18	None
WV	***End Dump***	***No***	***41***	***None***
AL	End Dump	Yes	<1	None

Above include paver stops.

R06C-IR Demonstration Projects

Minnesota Acceptance Specification: Summary

Project	Delivery Truck Type	MTV Included	Incentive/Disincentive	
			Stops Included	Stops Excluded
Alaska	Bottom-Dump	Windrows	+$17,778	+$30,000
EFL	***End Dump***	***No***	***-$32,593***	***-$29,630***
Illinois	***End Dump***	***No***	***-$10,706***	***-$8,500***
Maine	End Dump	Yes	+$32,124	+$37,168
Missouri	End Dump & Flow Boys	Yes	+$11,471	+$30,147
NJ	End Dump	Yes	+$16,336	+$24,885
Virginia	End Dump	Yes	+$31,905	+$33,333
NC	End Dump	Yes	+$17,778	+$27,937
WV	***End Dump***	***No***	***-$16,566***	***-$10,101***
AL	End Dump	Yes	+$38,297	+$40,000

Based on 2,000 IR segments for each project.

Data Analyses & Findings

Good temperature distribution does not guarantee success

Questions?

NEXT:

- Break
- Part 4: Perspective of IR Scanner as a QA/QC Tool

SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Infrared Technology Showcase

Part 4: Perspective of IR Scanner as a QA and/or QC Tool

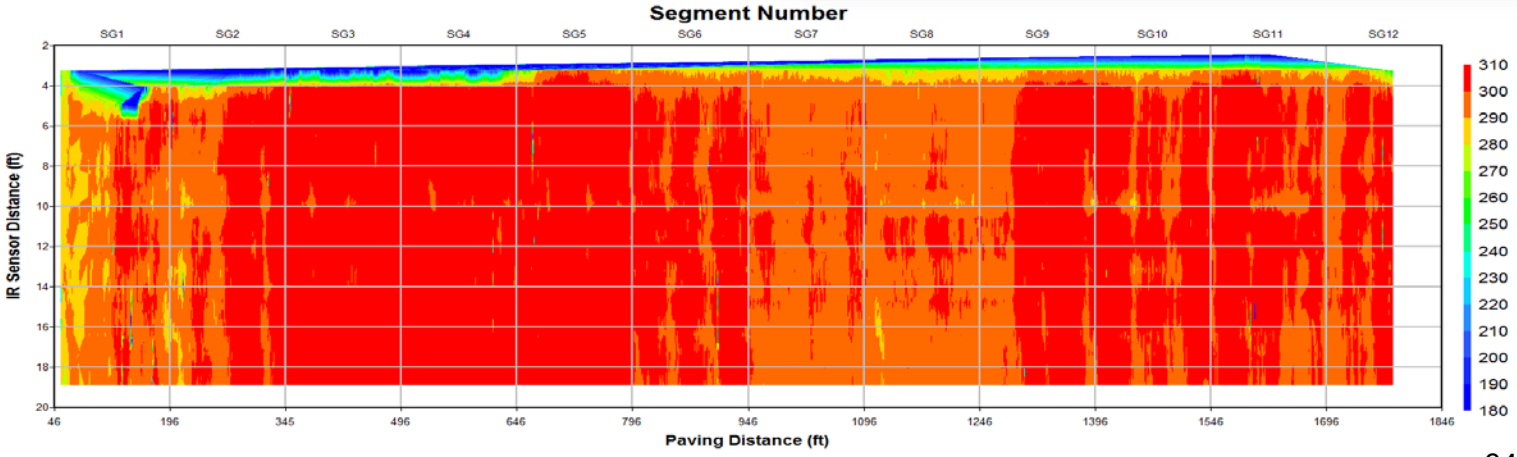
U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

Perspective as QA Tool

Application & Use:

- Continuous readings to evaluate mat uniformity through temperature uniformity.
- Non-uniform temperatures imply non-uniform densities, which usually mean higher maintenance.



Perspective as QA Tool

Role of IR in Quality Assurance Programs:

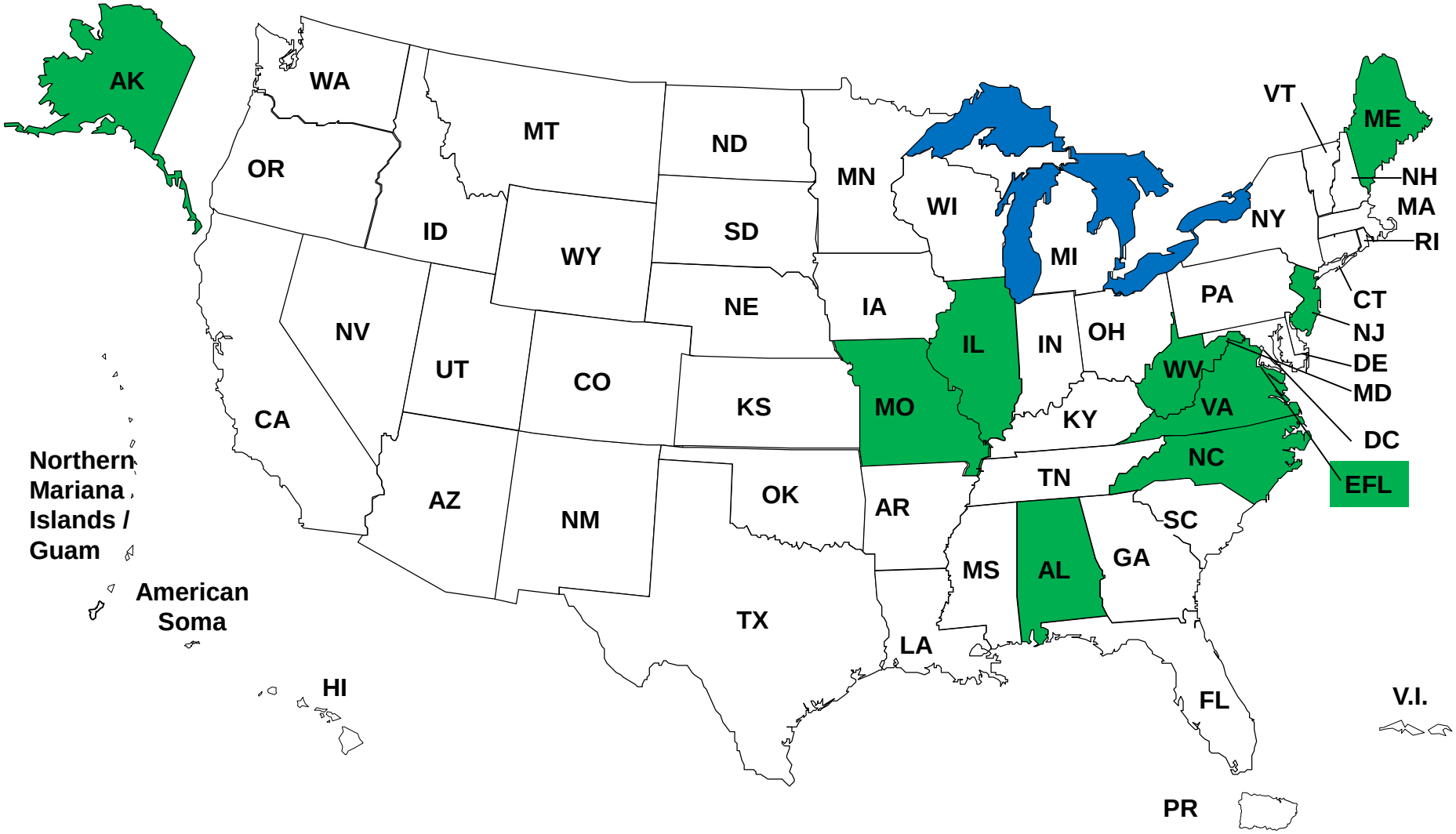
1. Contractor QC plan
   - Monitor production/placement operations to minimize temperature differentials of mat.
   - Minimize risk of being penalized.
   - Forensic tool to trouble shoot low or non-uniform mat densities.
2. Agency acceptance plan
   - Reduce future distress and maintenance costs.
   - Dispute resolution.

Perspective as QA Tool

IR role in QC plan, answering specific questions:

- What changes need to be made, if any?
  - Paver delays and speed.
  - Paver maintenance; augers, kick-back flights, slat conveyor, etc.
  - Number & loading of trucks
  - Tarps
  - Etc.
- When to make those changes?

Field Demonstration Projects



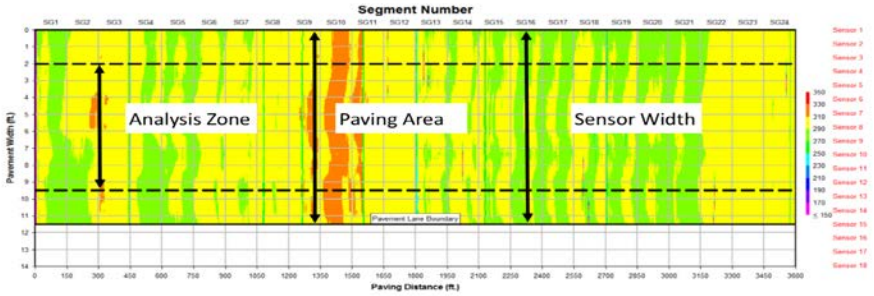
Field Demonstration Projects

Maine demonstration project; ***effect of reinforcement of good paving practice***:

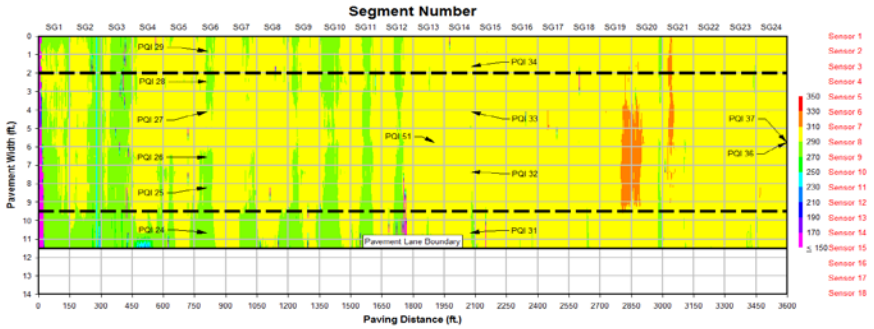
- Continuous improvement, more uniform mat temperatures, as paving progresses.

EFFECT: Reduced contractor's risk of being penalized.

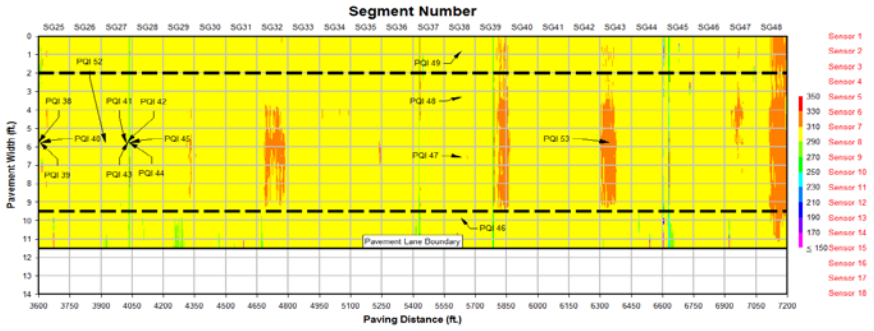
Near start of lot.



Near center of lot.



Near end of lot.

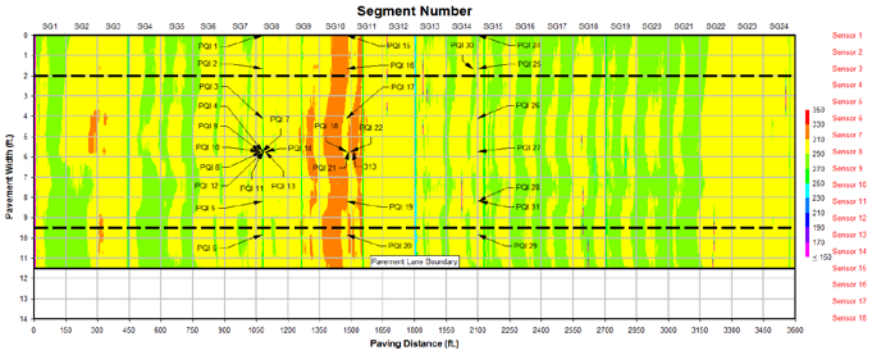


Field Demonstration Projects

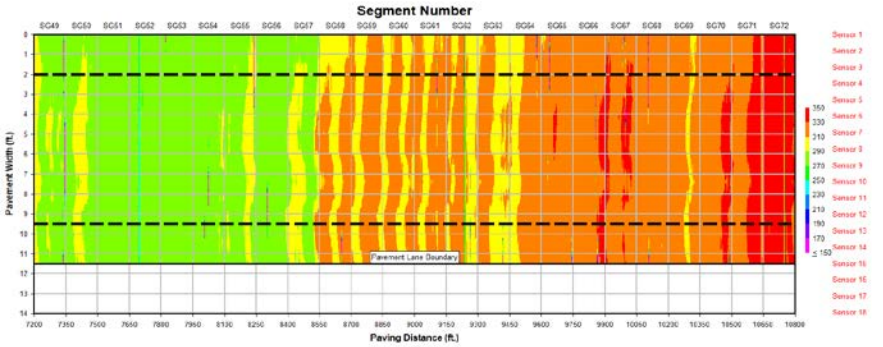
Missouri demonstration project; ***effect of communication***.

- Continuous improvement, more uniform mat temperatures, as paving progresses.

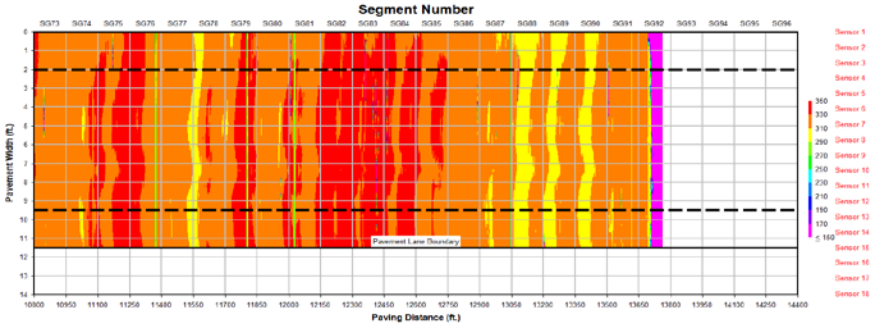
Near the beginning of day's production.



Later that morning.



Near end of day's production.



Field Demonstration Projects

Eastern Federal Lands demonstration project; ***effect of trucking***:

- High traffic, limited access; inconsistent delivery of material

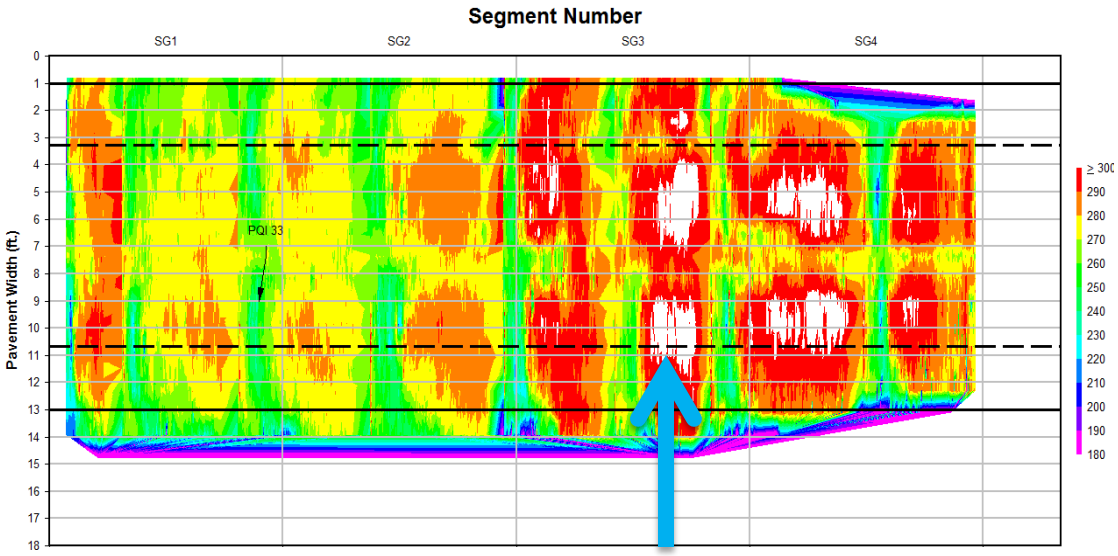
Few trucks with high local traffic = more paver stops.

more trucks = fewer paver stops & more uniform temp.

Field Demonstration Projects

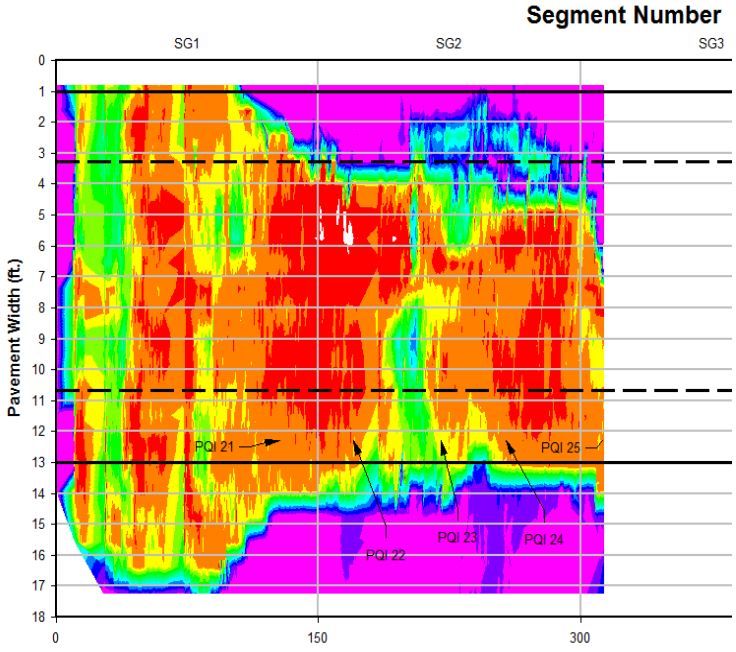
EFL demonstration project; ***effect of trucking***:

- Significant paver delay between trucks.



Extensive delay with screed heater on.

- Reduced paver delay between successive trucks.



EFFECT: Less variability in mat density, and reduced contractor's risk of being penalized.

Field Demonstration Projects

Multiple demonstration projects; ***effect of loading trucks***:

- One dump of mix in truck bed – severe temp. differential
- Two dump, no stockpile – reduced temp. differential.

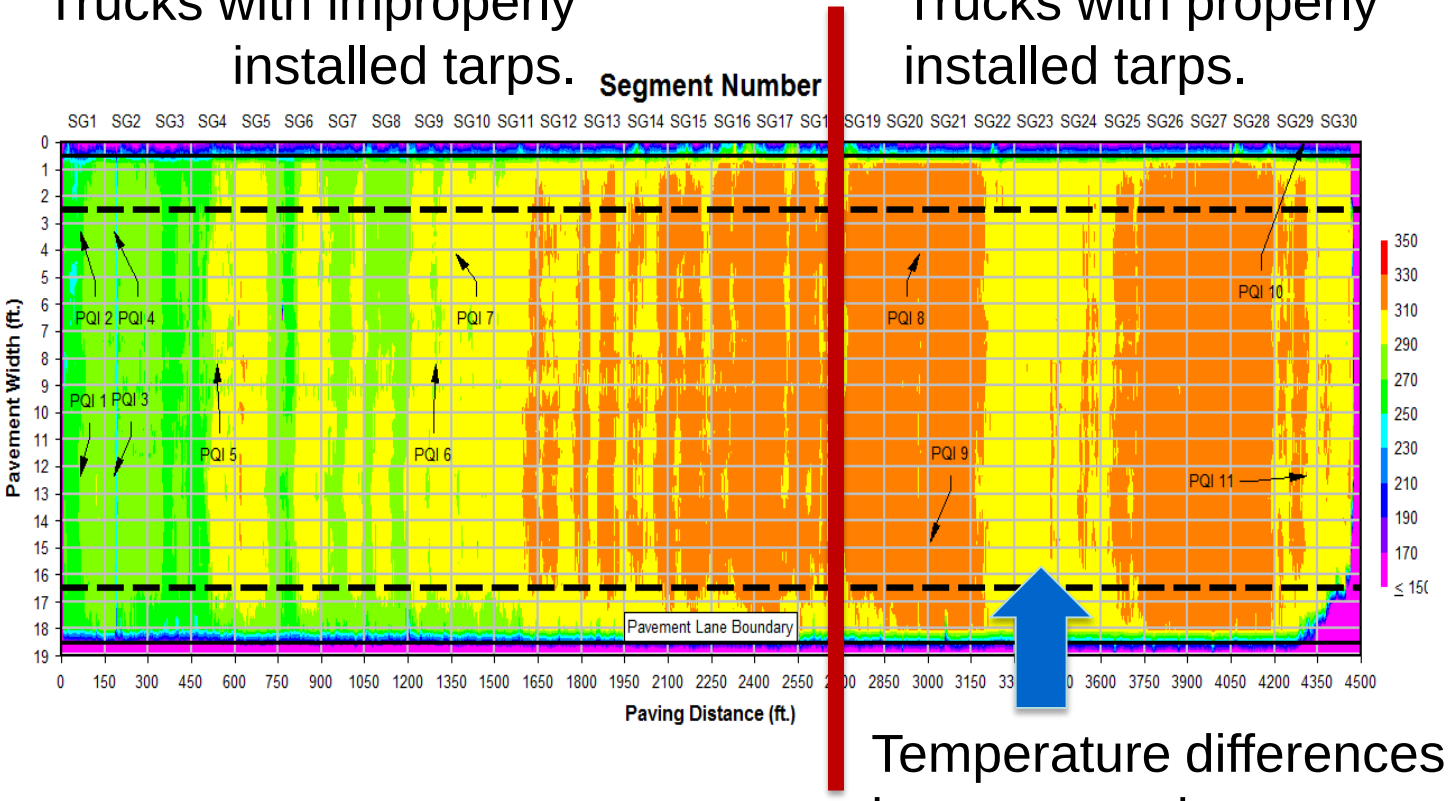
Properly loading trucks significantly reduced the number of severe temperature differentials.

Field Demonstration Projects

Multiple demonstration projects; ***effect of loading trucks***:

Trucks with improperly installed tarps.

Trucks with properly installed tarps.



Temperature differences between trucks.

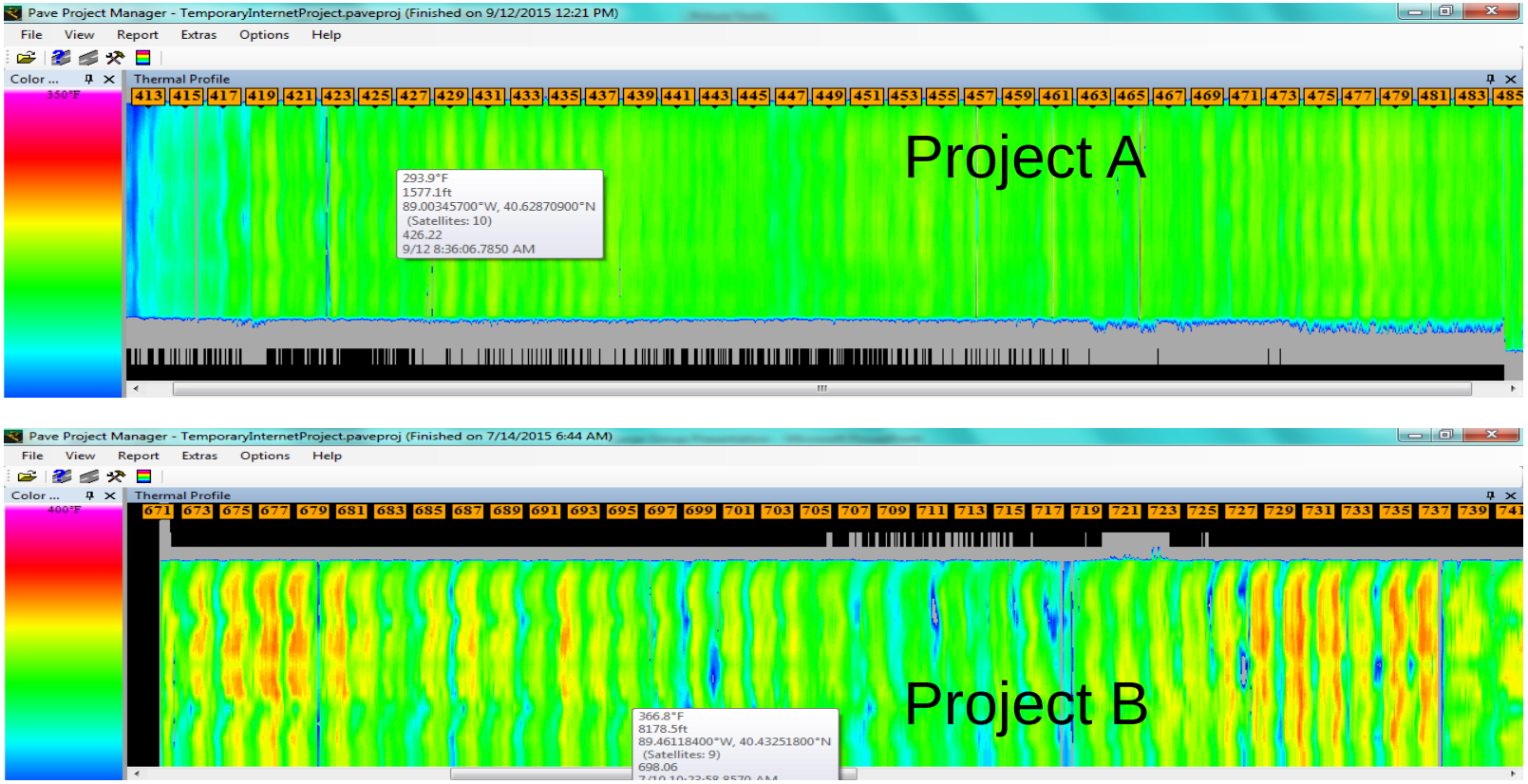
Field Demonstration Projects

Multiple demonstration projects; ***effect of tarps***:

Properly installed and maintained tarps significantly reduced the temperature differentials by about 40 percent.

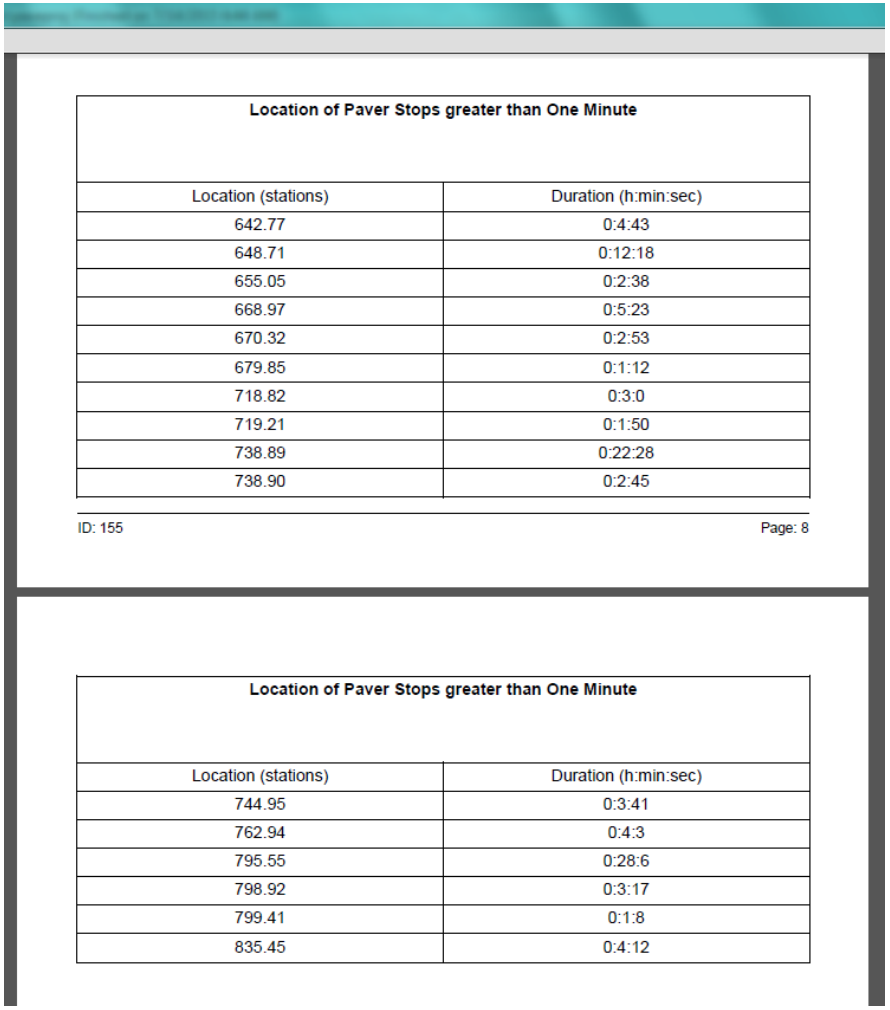
Field Demonstration Projects

Two Illinois demonstration projects: both used a MTV, so why the difference in temperature differentials?



Field Demonstration Projects

Illinois demonstration projects; ***effect of speed***:



Location of Paver Stops greater than One Minute

Location (stations)	Duration (h:min:sec)
642.77	0:4:43
648.71	0:12:18
655.05	0:2:38
668.97	0:5:23
670.32	0:2:53
679.85	0:1:12
718.82	0:3:0
719.21	0:1:50
738.89	0:22:28
738.90	0:2:45

ID: 155 Page: 8

Location of Paver Stops greater than One Minute

Location (stations)	Duration (h:min:sec)
744.95	0:3:41
762.94	0:4:3
795.55	0:28:6
798.92	0:3:17
799.41	0:1:8
835.45	0:4:12

- Paving time=640 min.
- Total Stop time=106 min.
- Effective paving time=534 min.
- Distance=23,900 ft.
- Average speed = 44.8 ft./min.
- Average speed (effective) =**37.3 ft./min.**

Field Demonstration Projects

All field demonstration projects; ***effect of MTVs***:

Project	Delivery Truck Type	MTV Included	Percent Severe Temp. Differentials	Thermal Streaking
Alaska	Bottom-Dump	Windrows	17	None
EFL	***End Dump***	***No***	***83***	***None***
Illinois	***End Dump***	***No***	***40***	***None***
Maine	End Dump	Yes	5	None
Missouri	End Dump & Flow Boys	Yes	25	None
NJ	End Dump	Yes	21	None
Virginia	End Dump	Yes	5	None
NC	End Dump	Yes	18	None
WV	***End Dump***	***No***	***41***	***None***
WV	End Dump	Yes	5	None

Above includes paver stops.

Field Demonstration Projects

Minnesota Acceptance Specification: Summary

Project	Delivery Truck Type	MTV Included	Incentive/Disincentive	
			Stops Included	Stops Excluded
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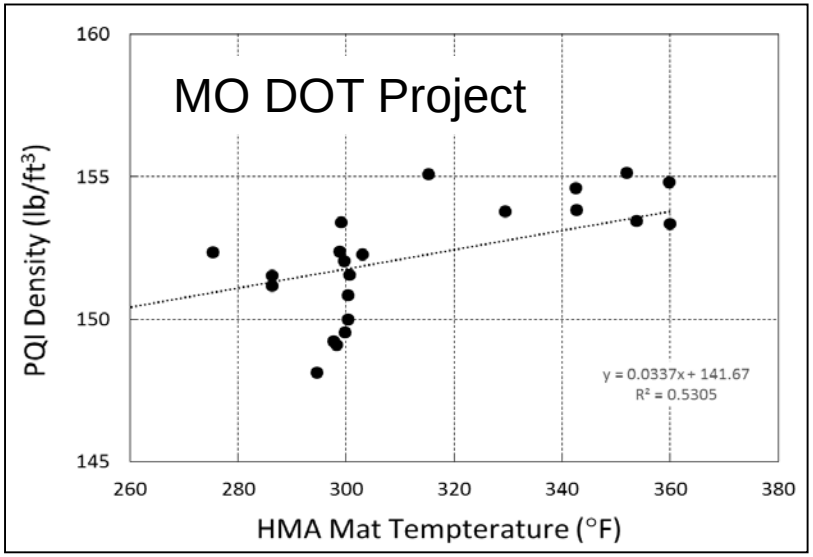
Virginia	End Dump	Yes	+$31,905	+$33,333
NC	End Dump	Yes	+$17,778	+$27,937
WV	***End Dump***	***No***	***-$16,566***	***-$10,101***
WV	End Dump	Yes	+$24,151	+$31,698

Based on 2,000 IR segments for each project.

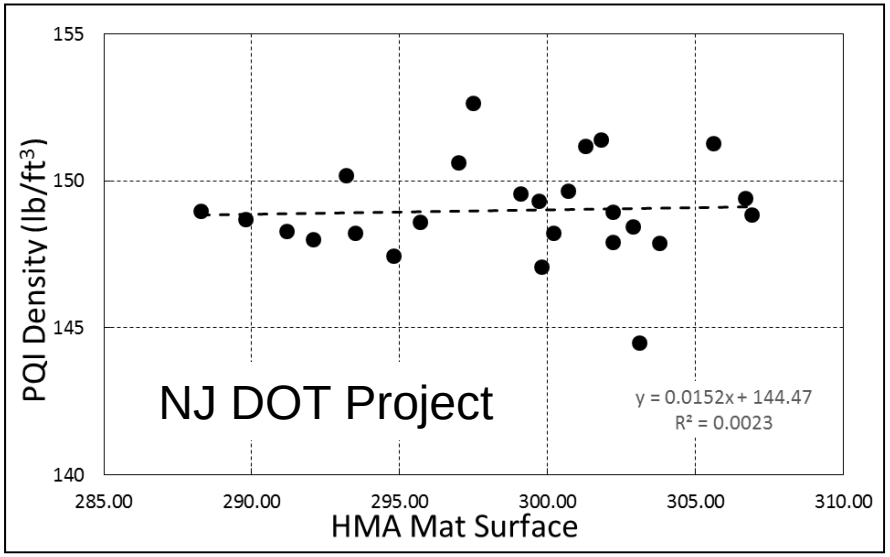
Field Demonstration Projects

Impact on Contractor's compaction operation:

Standard QC Plan; density measured after rolling.



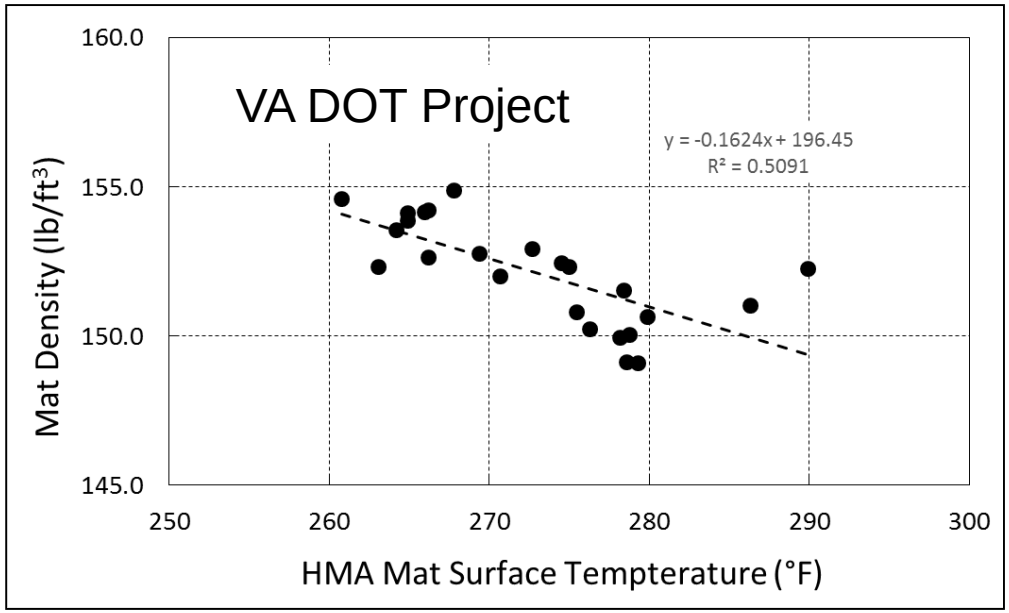
Aggressive QC Plan



Field Demonstration Projects

Impact on Contractor's compaction operation:

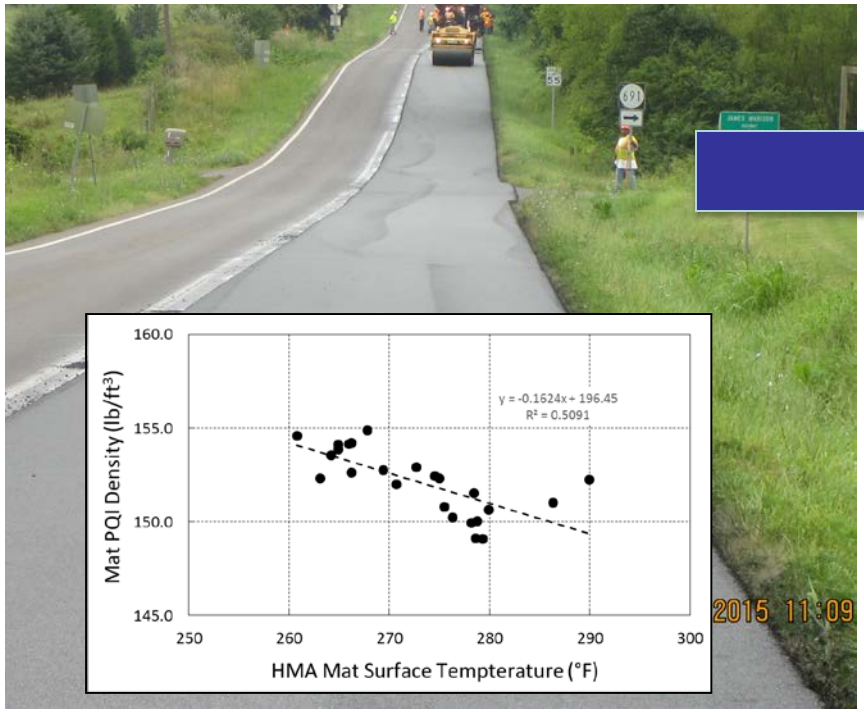
Monitoring Densities during Rolling

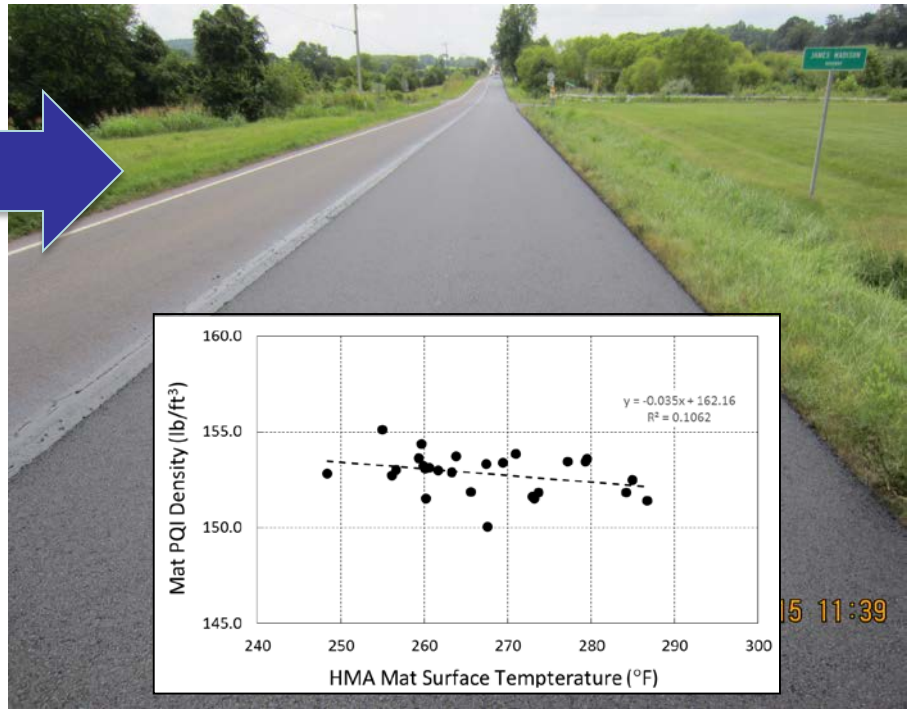


Rolling the mat within the temperature sensitive zone.

Field Demonstration Projects

Impact on Contractor's compaction operation:



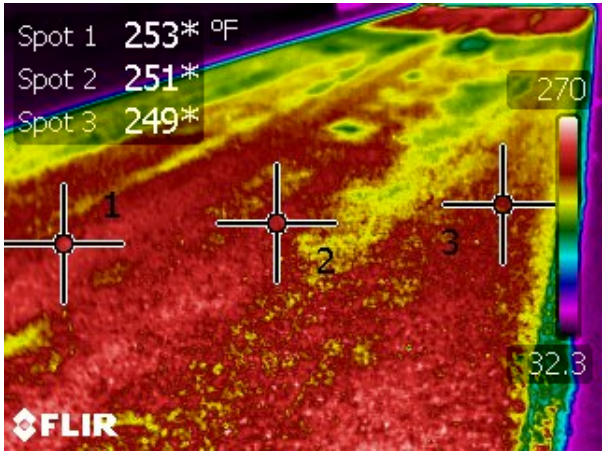


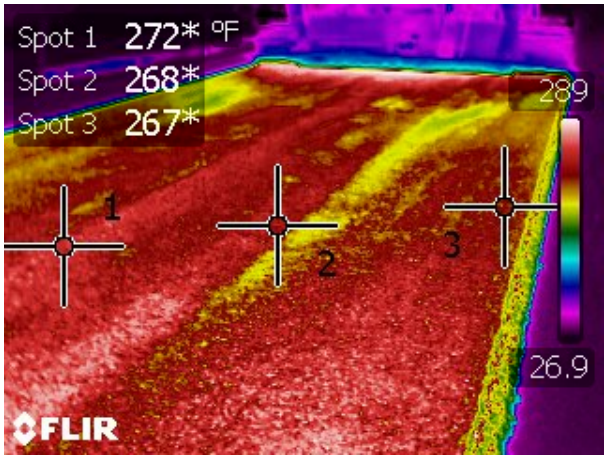
After recognizing the effect of temperature sensitive zone; VA DOT demonstration project.

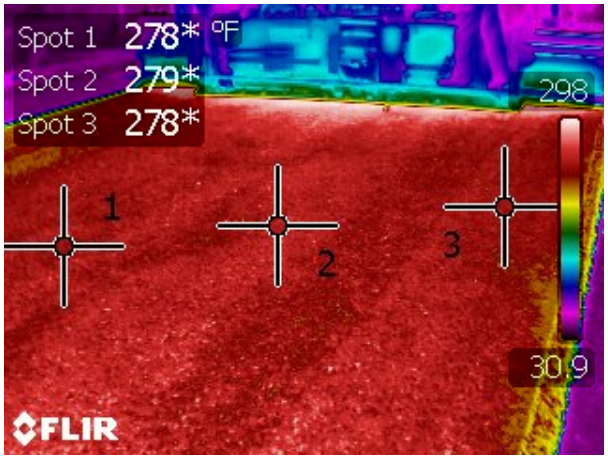
Perspective as QA Tool

IR Role in Acceptance Plan; examples:

1. Identify cold spots
   - Colorado, Michigan, Minnesota, Quebec, Texas, Washington
2. Identify thermal streaks
   - Quebec



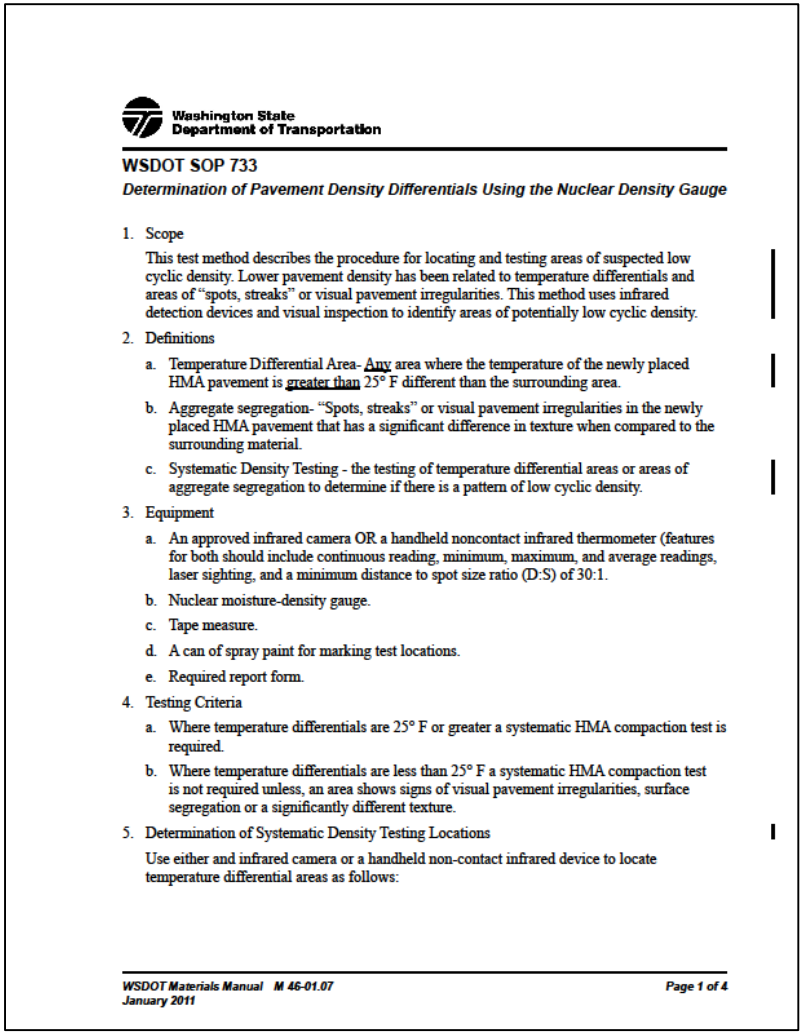




Perspective as QA Tool

IR Role in Acceptance Plan

- Determine biased areas for sampling and testing
  - Washington DOT
- Determine pay factors
  - Minnesota DOT
  - Quebec
- Minnesota pay factors for each 150 foot segment:
  - $20 bonus; <25ºF
  - $20 penalty; >50ºF



Washington State Department of Transportation

WSDOT SOP 733

Determination of Pavement Density Differentials Using the Nuclear Density Gauge

1. Scope

   This test method describes the procedure for locating and testing areas of suspected low cyclic density. Lower pavement density has been related to temperature differentials and areas of "spots, streaks" or visual pavement irregularities. This method uses infrared detection devices and visual inspection to identify areas of potentially low cyclic density.

2. Definitions

   a. Temperature Differential Area- Any area where the temperature of the newly placed HMA pavement is greater than 25° F different than the surrounding area.

   b. Aggregate segregation- "Spots, streaks" or visual pavement irregularities in the newly placed HMA pavement that has a significant difference in texture when compared to the surrounding material.

   c. Systematic Density Testing - the testing of temperature differential areas or areas of aggregate segregation to determine if there is a pattern of low cyclic density.

3. Equipment

   a. An approved infrared camera OR a handheld noncontact infrared thermometer (features for both should include continuous reading, minimum, maximum, and average readings, laser sighting, and a minimum distance to spot size ratio (D:S) of 30:1.

   b. Nuclear moisture-density gauge.

   c. Tape measure.

   d. A can of spray paint for marking test locations.

   e. Required report form.

4. Testing Criteria

   a. Where temperature differentials are 25° F or greater a systematic HMA compaction test is required.

   b. Where temperature differentials are less than 25° F a systematic HMA compaction test is not required unless, an area shows signs of visual pavement irregularities, surface segregation or a significantly different texture.

5. Determination of Systematic Density Testing Locations

   Use either and infrared camera or a handheld non-contact infrared device to locate temperature differential areas as follows:

Perspective as QA Tool

IR Role in Acceptance Plan:

- Paver stops excluded in most specifications from determining temperature differentials.
- Paver stops defined as more than 1 minute.
- Question answered from field demonstration projects;
  - Should paver stops be excluded or included in defining temperature differentials?

Perspective as QA Tool

Comments from Contractors and Agencies that have used the IR Scanner:

1. If the IR scanner technology saves one grind of a project, the equipment paid for itself; Maine DOT.
2. The IR scanner equipment is a self-policing tool.
3. Pike Industries purchased their first IR unit about 2 years ago and used it on a project in Vermont. Pike Industries found it to be a good tool to make real time adjustments.
4. It is a good forensic tool, compared to cores, especially to explain why an area has low density. A drop of 15 ºF can result in a significant drop in mat density.
5. The scanner helps in adding trucks for increased uniformity, adjusting practices, and shows the benefits of short hauling.

Perspective as QA Tool

Comments from Contractors and Agencies that have used the IR Scanner:

6. If the agencies provided the scanner equipment for free, then contractors would most likely take and use the equipment
7. Contractors see it as a great training tool for new operators or additional training for experienced crews.
8. The scanner data is a vivid tool for showing how rideability is influenced by the uniformity of temperatures.
9. Even though the EFL project had extensive thermal differences throughout the project, the contractor still achieved desired density – so PaveIR is not the whole story.

Questions?

NEXT:

- Part 5: Implementation Strategies of IR Technology

SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Infrared Technology Showcase

Part 5: Implementation Strategies of IR Technology

U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

Implementation Strategies

1. Some Common Steps for Deployment
2. Lead Agencies Strategies and Status

Steps for Deployment

Deployment Strategy, Common Steps/Tasks:

1. Define temperature differences that cause significant distress, increasing maintenance cost & reducing service life (Minnesota, Ontario, Texas, Washington).
   a) Many published reports that document the importance of temperature
2. Identify mat property changes between areas with severe temperature differentials (Ontario, Texas).
   a) Many research reports that identify how density affects the mat's properties related to performance
3. Draft IR specification (Minnesota, Ontario, Texas, Washington)
4. Obtain comments from industry for revising specification; getting input from other partners (Ontario, Minnesota, Texas)
5. Host/sponsor training sessions with equipment/software

Steps for Deployment

Deployment Strategy, Common Steps/Tasks:

6. Execute pilot projects over 1 to 2 years (Minnesota, Ontario)
7. Educate industry/agency personnel on results (Ontario)
8. Update/revise specification (Minnesota, Ontario, Texas, Washington)
9. Establish actions based on temperature profile differences (all)
    a) Increased density testing (Texas)
    b) Biased testing (Washington)
    c) Incentives/disincentives based temperature differentials (Minnesota, Ontario)
10. Confirm appropriateness of acceptance plan (Ontario)
11. Full deployment

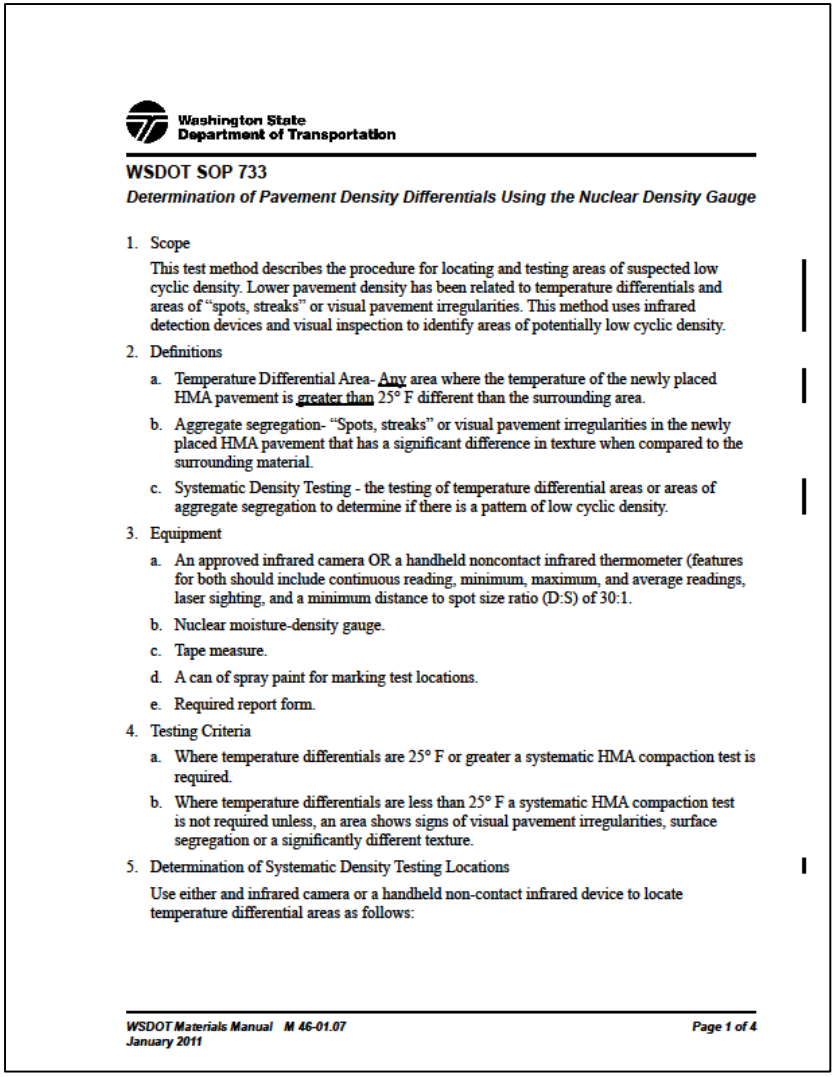
Implementation Strategies

1. Some Common Steps for Deployment
2. Lead Agency Strategies and Status
   - Washington, Texas, Minnesota DOT and Quebec Province—full deployment
   - Alaska, Maine, Missouri DOT—in deployment
3. Summary Comments from Agency and Contractor Personnel

Agency Strategies—Washington

Determine biased areas for sampling and testing:

- Based on use of IR camera; IR scanner is an option, and still allows an IR handheld device.
- Core density locations defined by cold spots.



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5. Determination of Systematic Density Testing Locations

   Use either and infrared camera or a handheld non-contact infrared device to locate temperature differential areas as follows:

Agency Strategies—Texas

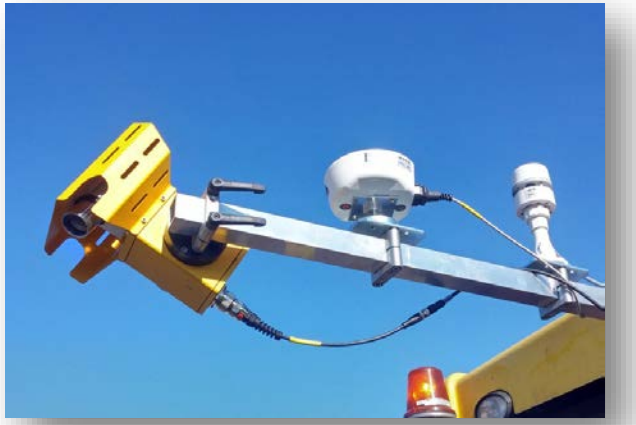
Goal: Improve pavement performance by encouraging Contractors to optimize paving operations.

- Optional for all paving projects.
- Specification incentives:
  - No density profiles or thermal profiles.
  - Can pave at lower temperatures.
  - Bonuses not waived for non compliance.
  - Automated documentation.
  - Contractor's ticket taker not required to measure mix temperature and record station # on haul tickets.

Agency Strategies—Texas

Current Specifications:

- “Pave-IR” replaced with “Thermal Imaging” system to include the scanner.
- Removes the option of using the thermal gun to perform thermal profiles.
- Updated thermal camera testing procedure.

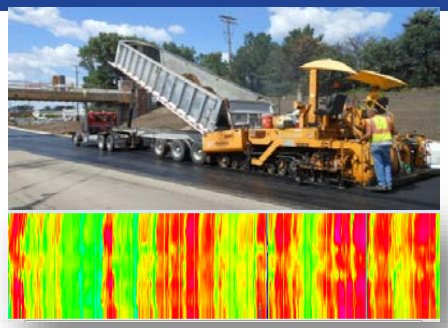


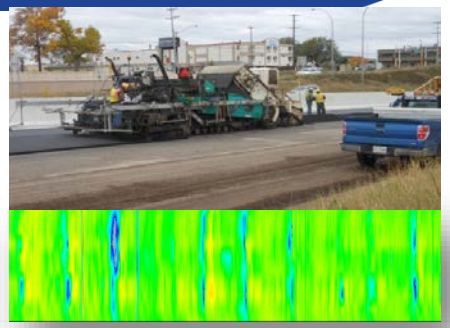
Agency Strategies—Texas

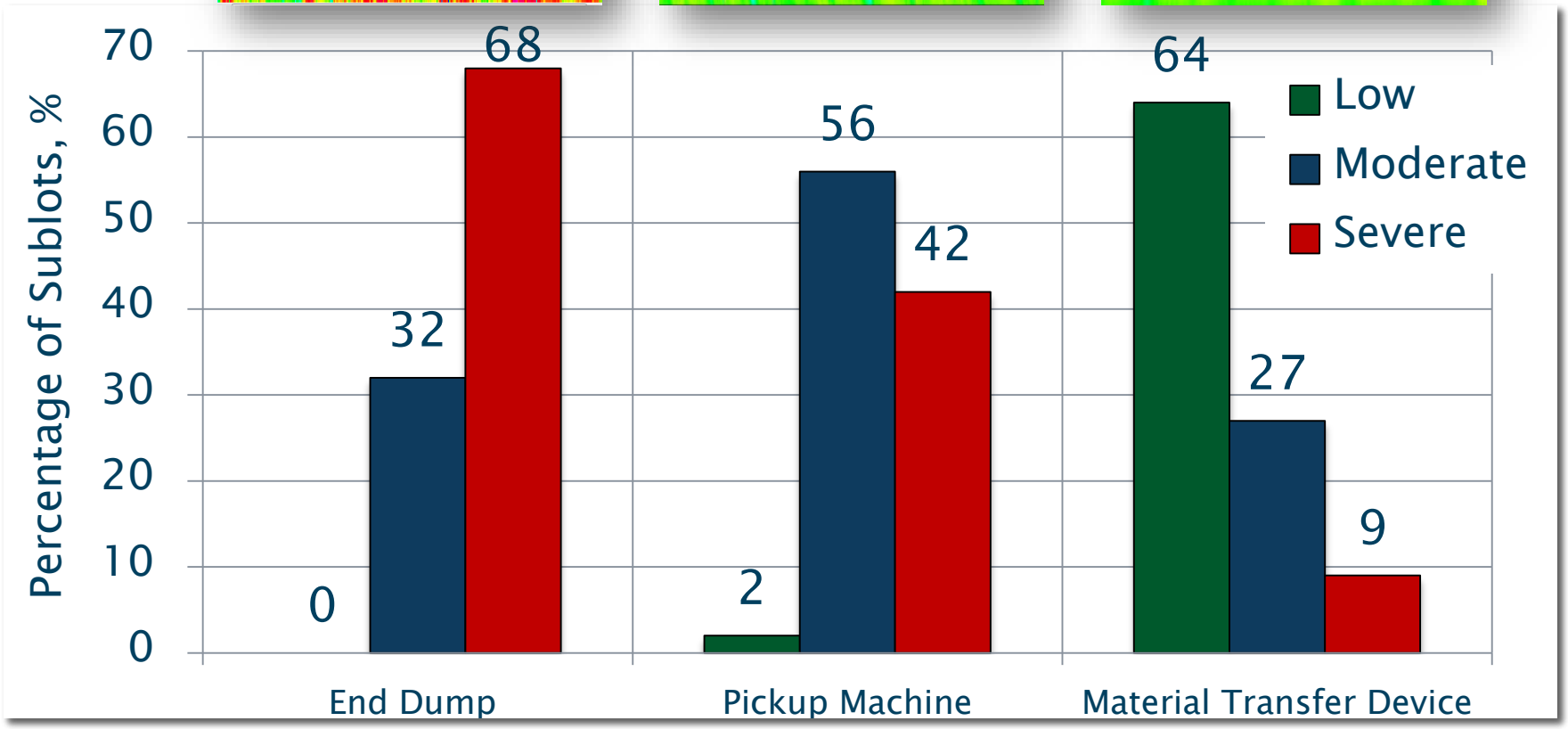
Texas Experience to Date:

- Eliminates the QC technician from having to perform segregation density profiles, and thermal profiles;
- Improves placement and ride bonus opportunities and minimizes penalties, resulting in a prompt return on investment cost;
- Data can be viewed locally at the paver and remotely in real time;
- Improves QC/QA confidence level when paving and compacting mix in cooler temperatures;
- Knowledge gained provides instantaneous feedback from the paver back to the plant.

Agency Strategies—Minnesota







Agency Strategies—Minnesota

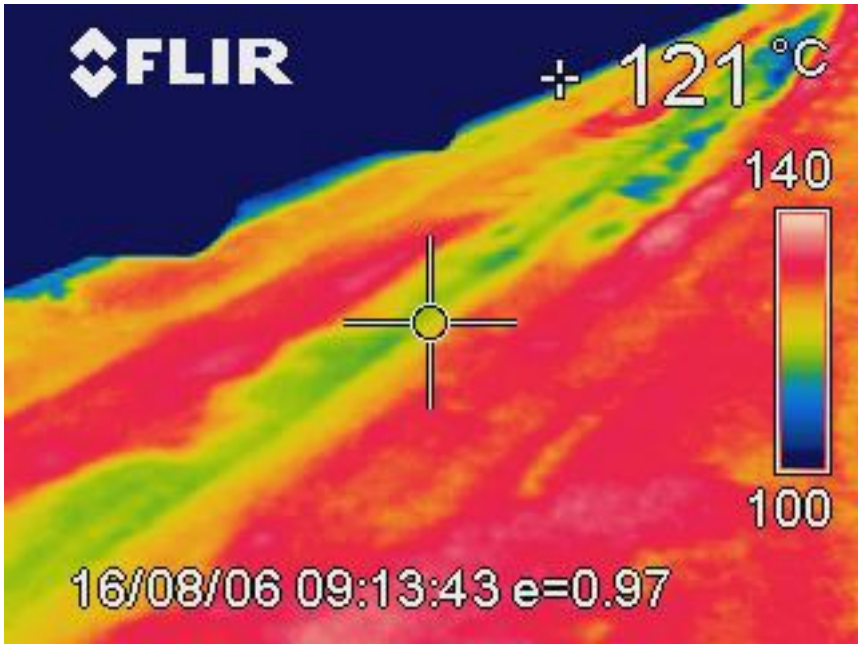
Minnesota pay factors for each 150 foot segment; based on identified cold spots and hot spots:

- $20 bonus; <25ºF
- $20 penalty; >50ºF

Agency Strategies—Quebec

Identifying thermal streaks using the IR camera:

- Locations or IR photos determined at random.
- Specific procedure identified for taking photos with IR camera and calculating streaks.
- Thermal streaks defined as ΔT greater than 5ºC along a longitudinal line.
- Penalty determined based on sealing longitudinal cracks.



Questions?

NEXT:

- Part 6: Products from Field Demonstration Projects

SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Infrared Technology Showcase

Part 6: Products from Field Demonstration Projects

U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

Products

1. Showcase
2. Trouble Shooting and Best Practices Guide
3. Specification Guide
4. IR Guide/Primer
5. Case Study/Demonstration Project

Products

1. Showcase:

COMPLETED IN JUNE 2016

- Showcase for IR Technology
  - Missouri DOT was the host agency
- Purpose
  - Highlight IR technology, provide training & operation.
  - Attendance includes agencies, contractors, industry, consultants and academia.
- Outcome
  - Report documenting showcase

Products

2. Trouble Shooting and Best Practices Guide

- Purpose of Guide
  - Provide guidance on:
    - Setting up the equipment and getting started.
    - Interpreting the raw data for making decisions.
  - Identify data collection and maintenance issues with the equipment and software.
- Outcome
  - Based on all 10 field demonstration projects.
  - Experience of agencies & consultants.

Draft Available.

Products

Topics included in the Lessons Learned Document: Trouble Shooting and Best Practices Guide

1. General Suggestions
2. Installation of the Paver-IR System
3. Getting Started and Setting up Project Files
4. Data Collection
5. Data Analysis
6. Recommended Additions to Streamline Data Processing

Products

USER MANUAL

PAVE-IR™ Scan

MOBA part no.: 05-60-12200

MOBA
MOBILE AUTOMATION

Other products available include the MOBA Installation Manual.

The Trouble Shooting, Best Practices, and Lessons Learned Guide are intended to supplement the MOBA User and Installation Manuals.

Products

3. Specification Guide

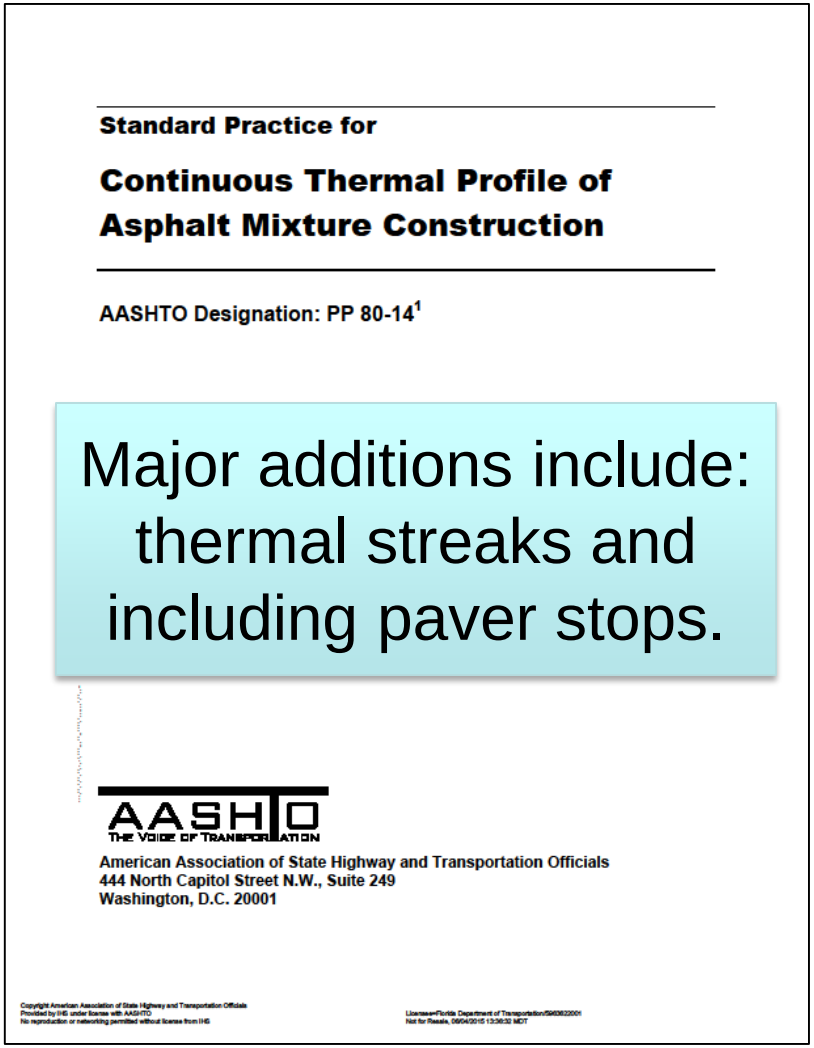
Red-lined version submitted to AASHTO.

- Purpose
  - Advance standardization of IR equipment and testing protocols through AASHTO.
  - Agencies can customize it to their needs.
- Outcome
  - Revised/Enhanced AASHTO PP 80-14.
- Based on:
  - Field demonstration projects
  - Agency Experience: Minnesota DOT, Texas DOT, etc.

Products

Specification Guide; AASHTO PP 80-14

1. Scope
2. Referenced Document
3. Terminology
4. General Thermal Profile Requirements
5. Hardware
6. Data File Format
7. Calibration
8. Profiler Accuracy
9. References
10. Appendices (Non-mandatory)
    1. Example Acceptance Criteria
    2. Terminology
    3. Criteria
    4. Monetary Adjustment



Products

4. IR Guide/Primer

Draft available

- Purpose
  - Introduce the Pave-IR method to transportation agencies and contractors.
  - Increase awareness of how IR can improve paving operations and increase uniformity of mat.
  - Demonstrate use of Pave-IR as a QC Tool.
- Outcome
  - Based on all 10 demonstration projects.

Products

5. Case Study/Demonstration Projects:

- Purpose
  - Enhance the deployment and use of the IR technology.
  - Identify/summarize lessons learned from field trials.
  - Confirm Pave-IR can identify the different types of temperature differentials that affect mat density and pavement performance.

Products

5. Case Study/Demonstration Projects:

- Outcome
  - Case Study Report
  - Workshop
    - Demonstrate and discuss value added using IR technology to agency and contractor.

Case Study document to be submitted in Sept 2017.

SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Infrared Technology Showcase

Questions/Answers and Closing Comments

U.S. Department of Transportation
Federal Highway Administration

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AASHTO

Some Questions

1. Is the type of project a consideration for IR use?
2. How easy is it to set up the project in Pave-IR Scan™?
3. Any problems experienced with the equipment or software?
4. Has the Pave-IR system changed daily practice?
5. Has use of the Pave-IR system changed interaction between the owner & contractor?
6. How easy is the IR data to extract and process?
7. Do you review the Pave-IR reports at the end of the day?
8. Are you getting a higher quality mat at the end of the day?
9. How have agencies/contractors used the IR products?
10. What is value of IR to the Contractor and Agency?
11. How many agencies are using Pave-IR Scan™?

Contact Information

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- Joe Reiter: jreiter@ara.com
- Harold Von Quintus: hvonquintus@ara.com

IR Workshop Wrap-Up

- Complete workshop forms
- R06C: additional information on Infrared Tech.
  - AASHTO Site: http://shrp2.transportation.org
  - FHWA Site: www.fhwa.got.gov/goshrp2