



# Ground Penetrating Radar Replacing Cores in Determining In-Place Density

2021 NEAUPG Annual Meeting – Albany, NY  
October 27, 2021

Image Your World.



**PaveScan® RDM 2.0**

# Agenda

- History/What is it?
- Features
- Calibration using Cores
- Calibration using Pucks
- System QA Procedures
- Export Range
- Lane Extents
- PWL Report
- Linear and Area Defects
- Output – Google Earth

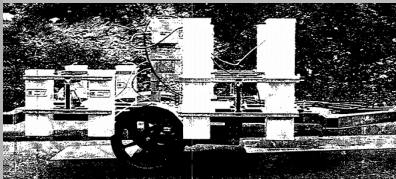


# History

How it started with the DOT/FHWA?



1992: SHRP1  
Initiative with  
TTI and GSSI



30 yrs: Pavement  
and Highway R&D

TTI, MnDOT, others  
with GSSI



2009:SHRP2 RO6C  
Initiative with

TTI/MnDOT and GSSI



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# PaveScan RDM 2.0 – What is it?

PaveScan RDM 2.0

It is a complete **Continuous Full Coverage (CFC)** GPR system that will:

- Provide on-site dielectric values of newly laid and compacted asphalt
- Provide continuous full coverage density information
- Provide compaction information in real-time, on-site using a 2D map
- Provide coring locations
- Allow input of core information for calibration and back calculation of %compaction, %void content, and density



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# PaveScan RDM 2.0 – What is it?

PaveScan RDM 2.0

Can be used as a:

- **Q/C Tool**
  - Roller Pattern Issues
  - Paver Issue
  - Number of Trucks Issue
  - Asphalt Issue
- **Q/A Tool**
  - PWL Reports
  - Google Earth Reports
- **Forensic Tool**



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# Features

PaveScan RDM 2.0

## Rugged Deployment Cart

- Modular assembly for easy deployment and transport
- Foldable deployment arms with high-visibility for work site safety
- Foot-activated brake on rear wheel
- Easy to attach and remove sensors



## Integrated Concentrator Box

- Accommodates up to 3 sensors
- Housing for cable management
- Hot-swappable, dual batteries

## Sensor Design

- Built specifically for the extremes of the asphalt paving environment
- Green laser to aid in location accuracy and collection guide

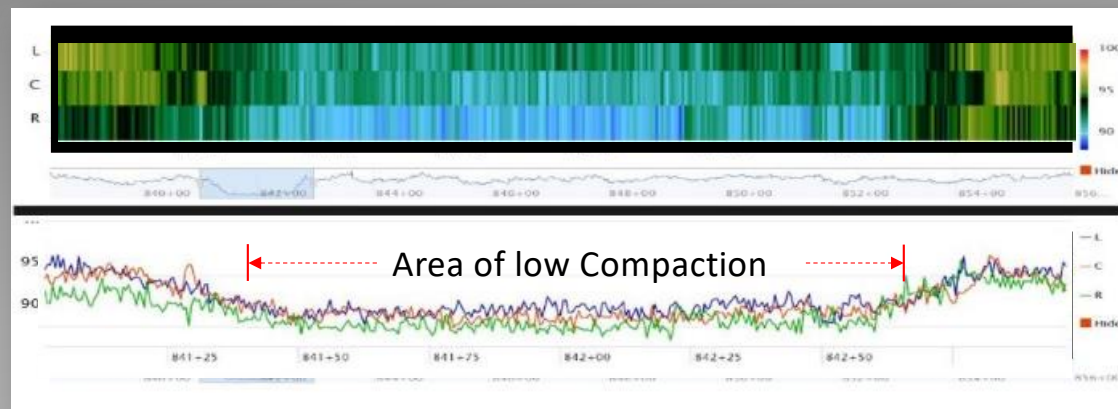


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# Features

PaveScan RDM 2.0



PaveScan RDM

Asphalt



Sub-Layer

☐ Air Voids



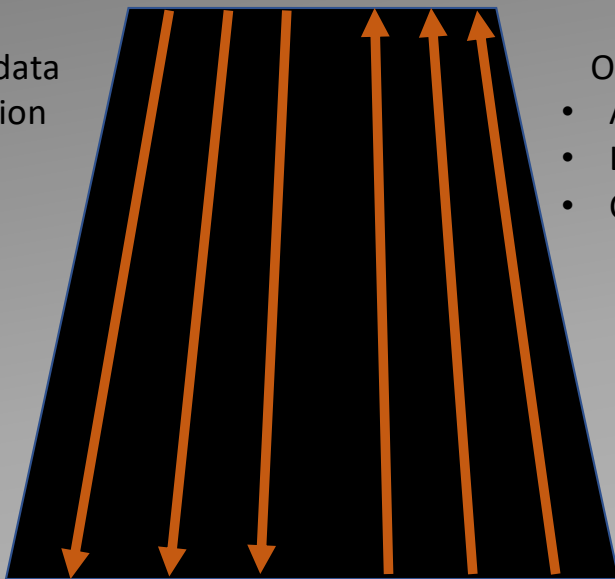
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# Features

PaveScan RDM 2.0

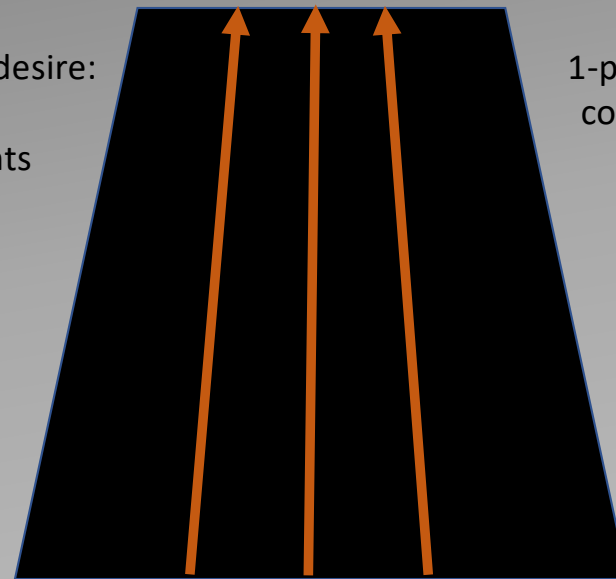
2-pass data collection



Or whatever you desire:

- Across the lane
- Longitudinal Joints
- Combination

1-pass data collection



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# Calibration using Cores

PaveScan RDM 2.0

- Field Cores are used for the correlation of dielectric to density (% void or % compaction)
- Field cores can come from a test strip or after one day of on-site data collection
- Core locations are determined by the system or DOT
- Dielectric is taken at the core location PRIOR to coring
- Cores are taken to the lab for density measurement (% void or % compaction)



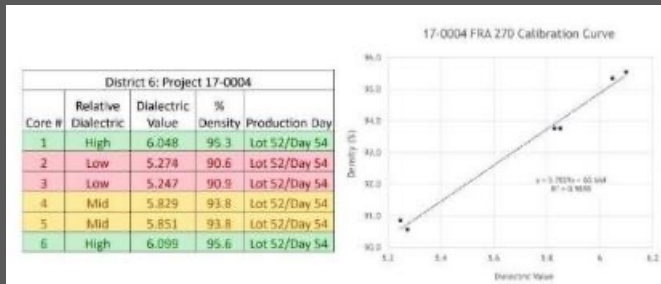
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# Calibration using Cores

PaveScan RDM 2.0

Values are entered into the system



Courtesy Ohio DOT

Core Calibration

PaveScan RDM

Core Calibration Filename: Select Calibration File

Core Measurement Type: Specify Measurement Type

A Value: A Value

B Value: B Value

GMM: GMM

Mix Info: Mix Info

R-Squared Fit: R-Squared Fit

Core Calibration Equation: Select Calibration Equation Type

Back New Calibration Calc from Cores Save

Core Data Entry and View Values

PaveScan RDM

Enter Core Information

Search

| Core # | Relative Dielectric | Yield (%)   |
|--------|---------------------|-------------|
| 1      | 5.48                | 7.2         |
| 2      | 5.20                | 7.7         |
| 3      | 5.20                | 8.9         |
| 4      | 5.48                | 8.5         |
| 5      | 5.52                | 8           |
| 6      | 5                   | 9.6         |
| 7      | Enter Value         | Enter Value |
| 8      | Enter Value         | Enter Value |
| 9      | Enter Value         | Enter Value |
| 10     | Enter Value         | Enter Value |

Showing 1 to 10 of 10 entries

Clear Recall List Calc A & B Back

GSSI

- Multiple mixes can be entered, named, and saved onto the system.
- Every project can have a specific mix calibration attached to it, even for day-to-day changes of mixes.



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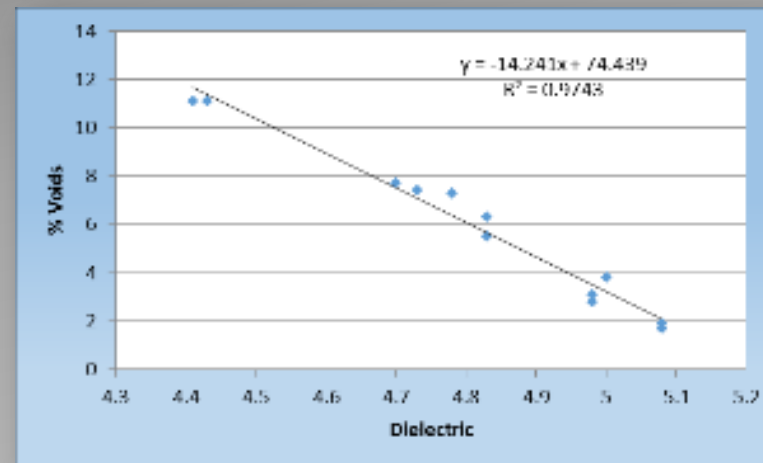


# Calibration using Cores

PaveScan RDM 2.0

Excel Example

| Dielectric | % Voids |
|------------|---------|
| 4.78       | 7.3     |
| 4.98       | 2.8     |
| 4.73       | 7.4     |
| 4.98       | 3.1     |
| 4.83       | 5.5     |
| 5.08       | 1.7     |
| 4.83       | 6.3     |
| 4.7        | 7.7     |
| 4.41       | 11.1    |
| 5.08       | 1.9     |
| 5          | 3.8     |
| 4.43       | 11.1    |



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# Calibration using Pucks

PaveScan RDM 2.0

- In an effort to reduce (or even eliminate) coring, pucks\* can be used from the plants to calibrate the PaveScan RDM 2.0 system.
- Minimum of 3 pucks is recommended
- Each mix (calibration) is named and stored in the system and can be attached to a specific project.
- Future projects, if a mix was used in a prior job, can simply be attached to an existing calibration.

The screenshot shows the 'Input Information' screen of the PaveScan RDM 2.0 system. The screen is titled 'PaveScan RDM 2.0' and 'Warmup Complete'. It features a list of input fields on the left and a corresponding data entry area on the right. The fields include: Name, Date Paved, Field ID (Test Summary Sheet #), Cumulative Daily Max Density, Bulk Specific Gravity (GMM), Temperature @ Gyration (Deg F), Agency Lab ID (Bituminous Mix #), Target Air Voids %, Sample ID, Tested Side (T - Top, B - Bottom), Air Void Content (%), Sample Thickness (mm), and Comments. Each field has a corresponding input box on the right. At the bottom, there are two large orange buttons: 'Back' and 'Collect'.

\* Other Terms – Pills, Biscuits, Bulks



Input Information

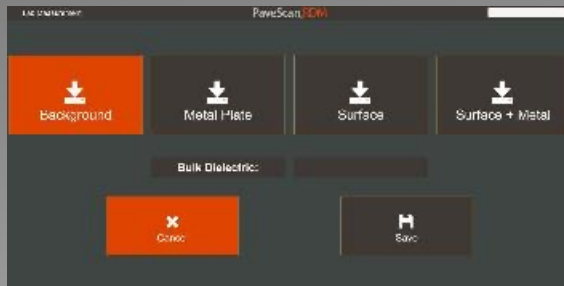
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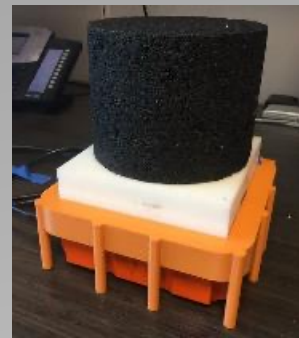


# Calibration using Pucks

PaveScan RDM 2.0



4-Step Process



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# Calibration using Pucks

PaveScan RDM 2.0

| Measurements     |                 |            |                   |             |                    |                 |
|------------------|-----------------|------------|-------------------|-------------|--------------------|-----------------|
| PaveScan RDM     |                 |            |                   |             |                    |                 |
| Loading complete |                 |            |                   |             |                    |                 |
| File Name        | Bulk Dielectric | Air Void % | Target Air Void % | Tested Side | Lab Thickness (mm) |                 |
| File             | 4.401           | 11.54      | 12                | B           | 115.5              | File Properties |
| File__001        | 4.401           | 11.54      | 12                | B           | 115.5              | File Properties |
| File__002        | 4.52            | 9.18       | 10                | B           | 115.5              | File Properties |
| File__003        | 4.583           | 9.18       | 10                | B           | 115.3              | File Properties |
| File__004        | 4.583           | 9.18       | 10                | B           | 115.3              | File Properties |
| File__005        | 4.69            | 7.9        | 8                 | B           | 116.4              | File Properties |
| File__006        | 4.714           | 7.9        | 8                 | B           | 116.4              | File Properties |
| File__007        | 4.892           | 5.01       | 6                 | B           | 114.8              | File Properties |
| File__008        | 4.892           | 5.01       | 6                 | B           | 114.8              | File Properties |
| File__009        | 4.934           | 3.63       | 4                 | B           | 114.9              | File Properties |
| File__010        | 4.908           | 3.63       | 4                 | B           | 114.9              | File Properties |
| File__011        | 4.992           | 2.84       | 2                 | B           | 115.1              | File Properties |
| File__012        | 4.992           | 2.84       | 2                 | B           | 115.1              | File Properties |

←  
Back

⚙️  
Generate Mix Calibration

Results



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# System QA Procedures

PaveScan RDM 2.0

Procedures were developed to assure the accuracy of the sensors.

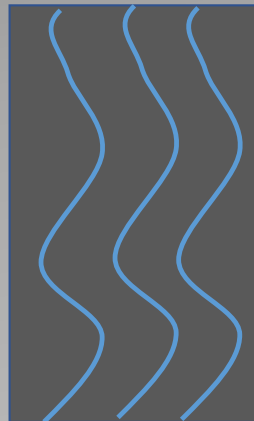
- HDPE Block
- Swerve Method
- Repeat Line Method

HDPE Block



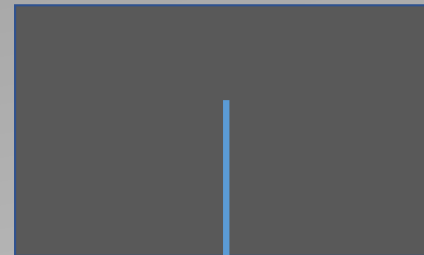
Each Sensor, Dielectric =  $\sim 2.35$ ,  $\pm .05$

Swerve Method



1. Suggested On-Site, walk about 250 feet using a swerve pattern
2. Outside sensors no closer than 1 foot from the longitudinal joint
3. Turn around and walk back 250 feet using the swerve pattern
4. Dielectric of sensors should be about .05 of each other

Repeat Line Method



1. Suggested On-Site, draw a single line about 6-10 feet across the lane
2. Walk each sensor, one at a time, *perfectly* along the line
3. Dielectric of sensors should be about .05 of each other



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# Export Range

PaveScan RDM 2.0

Throughout the day or project, multiple data files are collected and saved. This feature allows the user to combine chosen files to create a single file.



Playback Range screens allow the user to select which files to combine for displaying and exporting.



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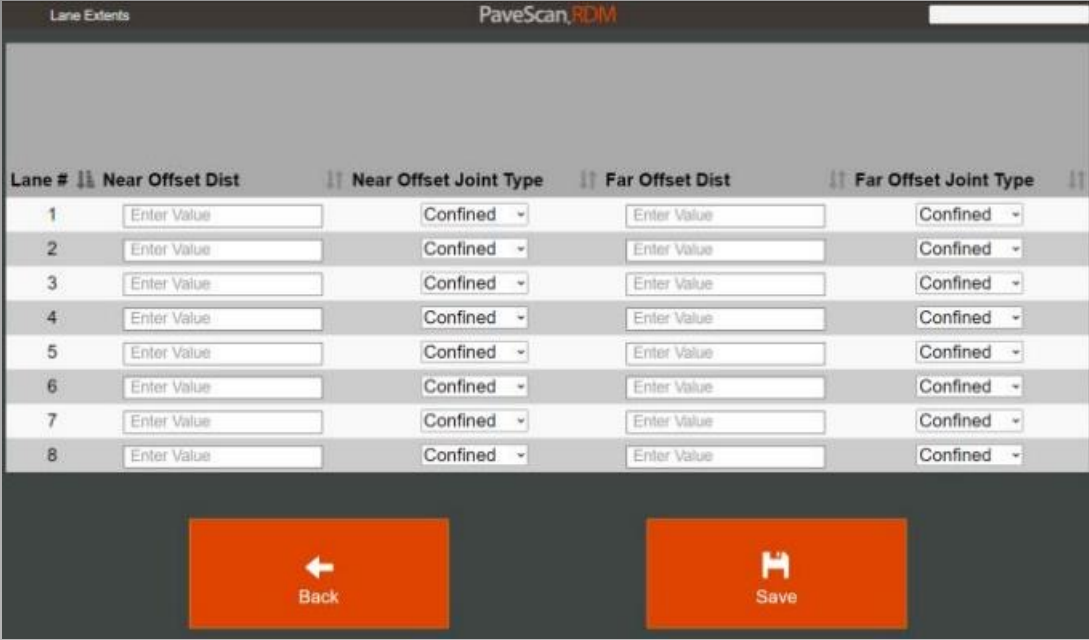
# Lane Extents

PaveScan RDM 2.0

The user has an option to define lane extents for each lane.

- Near and Far Offset Distance
- Near and Far Joint Type

This information is used if using the PWL option.



| Lane # | Near Offset Dist | Near Offset Joint Type | Far Offset Dist | Far Offset Joint Type |
|--------|------------------|------------------------|-----------------|-----------------------|
| 1      | Enter Value      | Confined               | Enter Value     | Confined              |
| 2      | Enter Value      | Confined               | Enter Value     | Confined              |
| 3      | Enter Value      | Confined               | Enter Value     | Confined              |
| 4      | Enter Value      | Confined               | Enter Value     | Confined              |
| 5      | Enter Value      | Confined               | Enter Value     | Confined              |
| 6      | Enter Value      | Confined               | Enter Value     | Confined              |
| 7      | Enter Value      | Confined               | Enter Value     | Confined              |
| 8      | Enter Value      | Confined               | Enter Value     | Confined              |

Back Save



# PWL Reports

PaveScan RDM 2.0

The user has an option to produce PWL reports by entering user specified limits that will be used to produce the reports.

Report Options

PaveScan RDM

Mat PWL Upper Limit (Dist.)

Mat PWL Lower Limit (Dist.)

Joint PWL Upper Limit (Dist.)

Joint PWL Lower Limit (Dist.)

Joint Line Max. Dist. from Closest Lane Extent (ft)

Mat Line Min. Dist. from Closest Lane Extent (ft)

Histogram Bin Interval (Dist.)

Histogram Maximum Value (Dist.)

Histogram Minimum Value (Dist.)

Back

Save

User-selected upper and lower limits

Summary Statistics

PaveScan RDM

Statistics Loaded

| Distance Range | Start Station | End Station | Min. Lat Offset | Max. Lat Offset | Mat PWL | Joint PWL | Mat Index | Joint Index | Mat S. Dev | Joint S. Dev |
|----------------|---------------|-------------|-----------------|-----------------|---------|-----------|-----------|-------------|------------|--------------|
| Segment        | 728+00        | 729+00      | 128             | 248             | 0       | 36.86     | 0         | 4.08        | 0          | 0.13         |
| Segment        | 728+00        | 740+00      | 128             | 248             | 0       | 27.47     | 0         | 4.01        | 0          | 0.10         |
| Segment        | 740+00        | 741+00      | 128             | 248             | 0       | 61.84     | 0         | 4.33        | 0          | 0.14         |
| Segment        | 741+00        | 742+00      | 128             | 248             | 0       | 61.54     | 0         | 4.33        | 0          | 0.14         |
| Segment        | 731+87        | 732+00      | 248             | 308             | 12.8    | 0         | 4.7       | 0           | 0.15       | 0            |
| Segment        | 732+00        | 733+00      | 248             | 308             | 0.89    | 0         | 4.74      | 0           | 0.17       | 0            |
| Segment        | 733+00        | 734+00      | 248             | 308             | 20.36   | 0         | 4.8       | 0           | 0.18       | 0            |
| Segment        | 734+00        | 735+00      | 248             | 308             | 14.90   | 0         | 4.75      | 0           | 0.14       | 0            |
| Segment        | 735+00        | 736+00      | 248             | 308             | 0.9     | 0         | 4.71      | 0           | 0.17       | 0            |
| Segment        | 736+00        | 737+00      | 248             | 308             | 26.07   | 0         | 4.81      | 0           | 0.2        | 0            |
| Total          | 731+87        | 971+00      | 128             | 308             | 60.7    | 50.80     | 4.87      | 4.91        | 0.19       | 0.16         |

Back

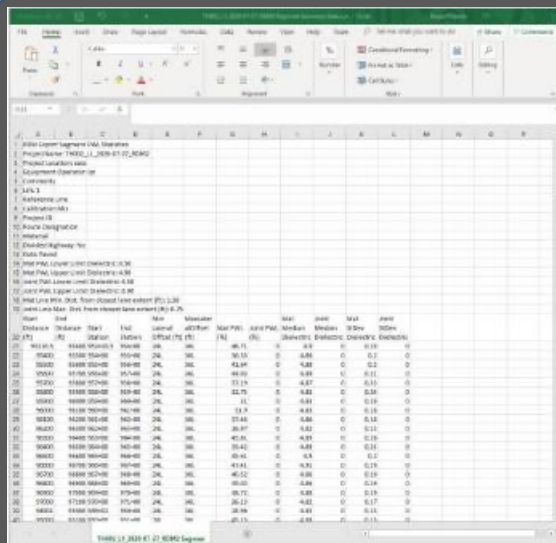
Displayed Report



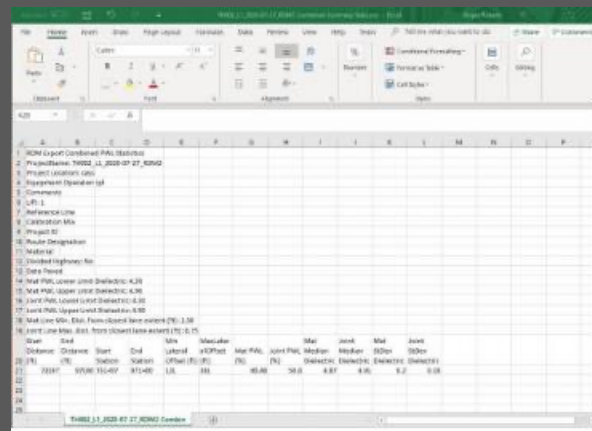
# PWL Reports

# PaveScan RDM 2.0

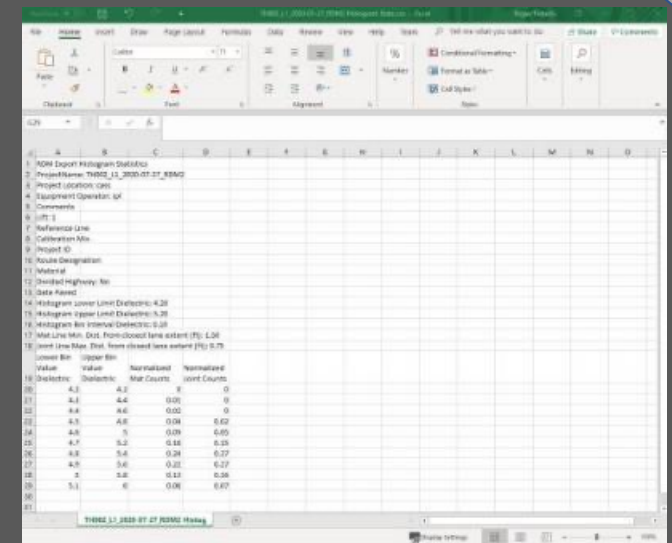
## Exported PWL Reports (.csv format)



Mat & Joint PWL, Median Values, and Standard Deviation for each segment



## Summary Statistics for mat and joint measurements for the entire project



### Histogram distribution of values



# Linear and Area Defects

PaveScan RDM 2.0

If checked, all defects are exported to .csv and .kml files



| Value Type                            | Value |
|---------------------------------------|-------|
| Dielectric less than                  | 4.5   |
| Percent Voids greater than            | 8     |
| Percent Compaction less than          | 92    |
| Density less than                     | 4     |
| Linear dist. greater than or equal to | 4     |
| Area greater than or equal to         | 8     |

Back Save

User-selected criteria



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# Linear and Area Defects

PaveScan RDM 2.0

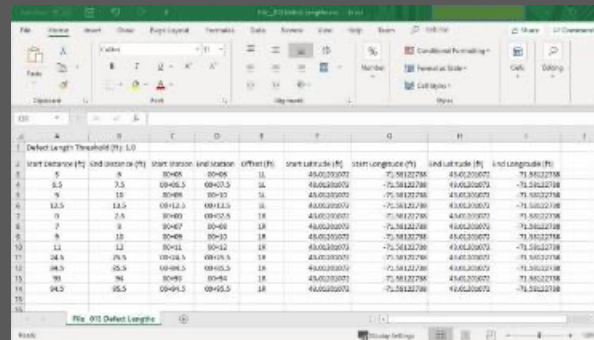
Exported Reports (.csv format)



This screenshot shows an Excel spreadsheet titled 'File Segment Defect Summary'. The spreadsheet contains a table with the following columns: Defect Threshold (% Compaction), Start Station (ft), Segment Length (ft), # Profiles, # Measurements, # Defects, % Defective, and Straddle Adjacent Segment. The data rows show a defect threshold of 95.00000, a start station of 12800, a segment length of 200, 3 profiles, 1201 measurements, 8 defects, 7.32% defective, and a 'FALSE' straddle adjacent segment.

| Defect Threshold (% Compaction) | Start Station (ft) | Segment Length (ft) | # Profiles | # Measurements | # Defects | % Defective | Straddle Adjacent Segment |
|---------------------------------|--------------------|---------------------|------------|----------------|-----------|-------------|---------------------------|
| 95.00000                        | 12800              | 200                 | 3          | 1201           | 8         | 7.32        | FALSE                     |

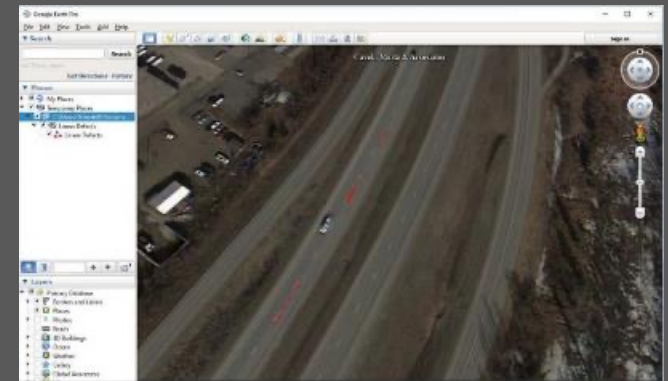
Segment Summary



This screenshot shows an Excel spreadsheet titled 'File LTI Defect Lengths'. The spreadsheet contains a table with the following columns: Defect Length Threshold (ft), Start Station and Location, Offset (ft), Start Latitude (ft), Start Longitude (ft), End Latitude (ft), and End Longitude (ft). The data rows show defect lengths ranging from 5 to 15 feet, with start and end coordinates in feet.

| Defect Length Threshold (ft) | Start Station and Location | Offset (ft) | Start Latitude (ft) | Start Longitude (ft) | End Latitude (ft) | End Longitude (ft) |
|------------------------------|----------------------------|-------------|---------------------|----------------------|-------------------|--------------------|
| 5                            | 00+00.5 00+00.5            | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 5.5                          | 00+05.5 00+05.5            | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 6                            | 00+10 00+10                | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 6.5                          | 00+15.5 00+15.5            | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 7                            | 00+20 00+20                | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 7.5                          | 00+25.5 00+25.5            | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 8                            | 00+30 00+30                | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 8.5                          | 00+35.5 00+35.5            | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 9                            | 00+40 00+40                | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 9.5                          | 00+45.5 00+45.5            | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 10                           | 00+50 00+50                | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 10.5                         | 00+55.5 00+55.5            | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 11                           | 00+60 00+60                | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 11.5                         | 00+65.5 00+65.5            | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 12                           | 00+70 00+70                | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 12.5                         | 00+75.5 00+75.5            | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 13                           | 00+80 00+80                | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 13.5                         | 00+85.5 00+85.5            | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 14                           | 00+90 00+90                | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 14.5                         | 00+95.5 00+95.5            | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |
| 15                           | 00+100 00+100              | 18          | 45.0730907          | 75.5832278           | 45.0730907        | 75.5832278         |

Linear Defect File



KML File (display using Google Earth)



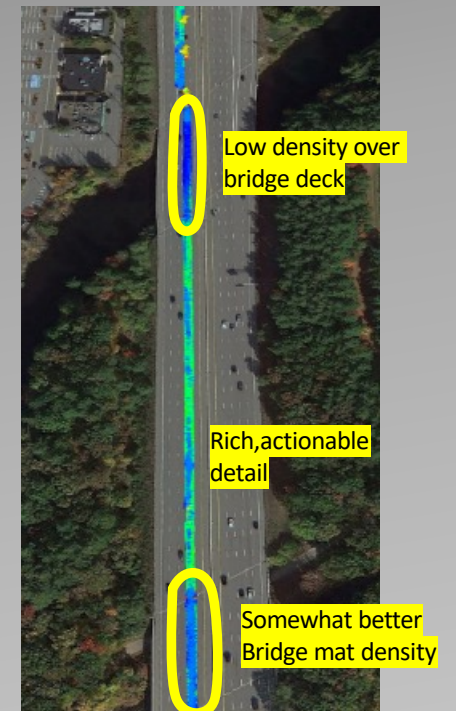
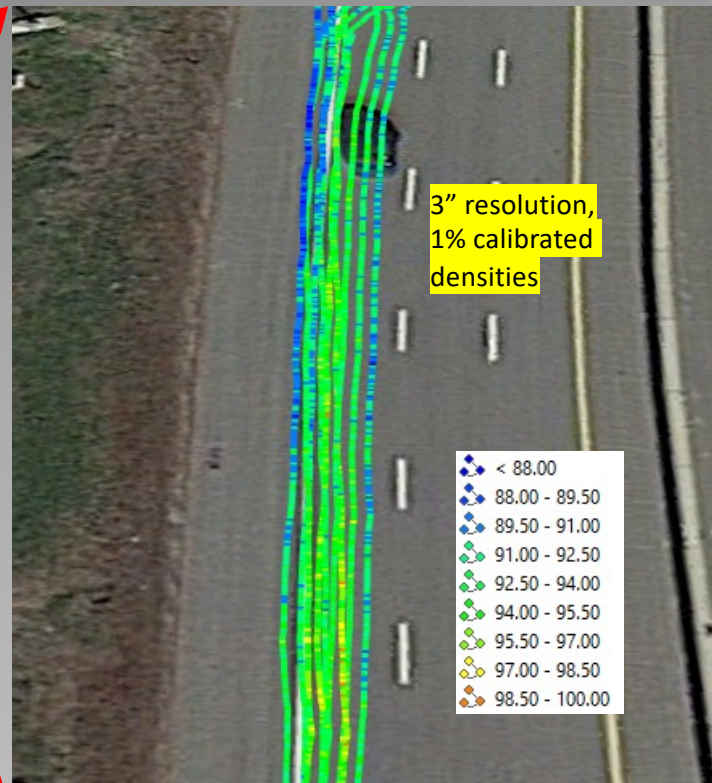
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# KML file (Google Earth)

PaveScan RDM 2.0

Examples



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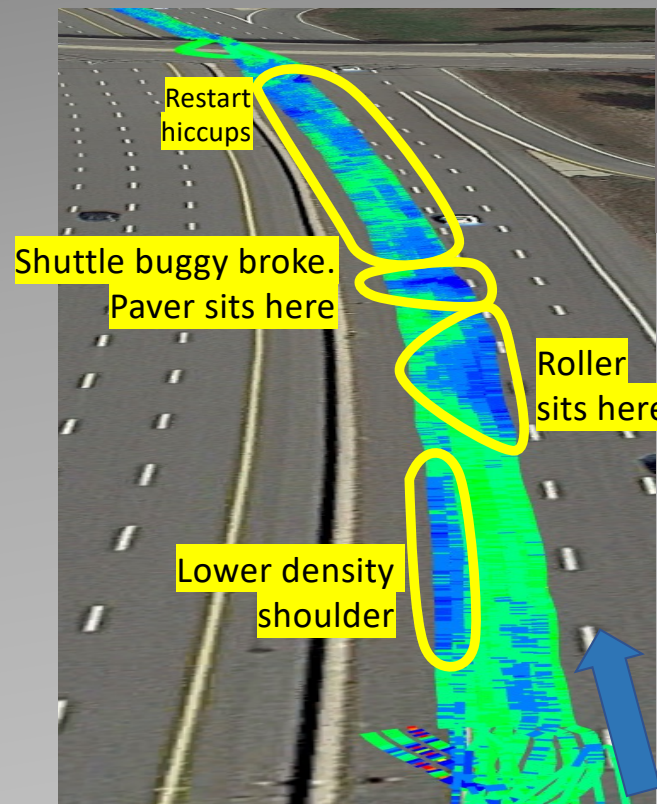


# KML file (Google Earth)

PaveScan RDM 2.0

## Examples

Densities correlate to known issues which can be mapped and perhaps rolled out.



1000ft section  
12 lines = 2mi.  
of GPR data  
~50k points



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# KML file (Google Earth)

PaveScan RDM 2.0

## Examples

Correlation:  
Lower density vs IR Map



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# Questions

PaveScan RDM 2.0

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Thank You!!



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