



PaveScan[®] RDM 2.0 Manual

MN36-716 Rev G

Geophysical Survey Systems, Inc.

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Chapter 1: Introduction

This manual describes the setup and data collection methodology for the PaveScan RDM asphalt density assessment system. It is intended as both a reference and a teaching tool and it is recommended the entire manual is read, regardless of the level of GPR experience.

If operation problems are experienced with your system, GSSI Technical Support can be reached Monday-Friday, 8:30 am - 5 pm EST, at 1-800-524-3011, or at (603) 893-1109 (International).

1.1: Unpacking Your System

Thank you for purchasing a GSSI PaveScan RDM (hereafter referred to as RDM). A packing list is included with the shipment that identifies all the items included in the order. Please check the shipment against the packing list upon receipt of the shipment. If an item is found missing or was damaged during the shipment, please call or fax your sales representative to immediately report the problem.

The PaveScan RDM system contains the following items:

- 1 – Panasonic G2 ToughPad with preloaded OS and cable
- 1, 2, or 3 – Orange Sensor(s) with cable(s)
- 1 – 4 Wheel Cart
- 1 – PaveScan Concentrator Box
- 2 – Batteries
- 1 – Battery Charger
- 1 – Operation Manual
- 1 – Metal Plate
- 1 – Sensor Verification HDPE Block
- 1 – GPS (optional)

Note: Protect metal plate from scratching when unpacking and using. Keep it in its protective case when not in use.

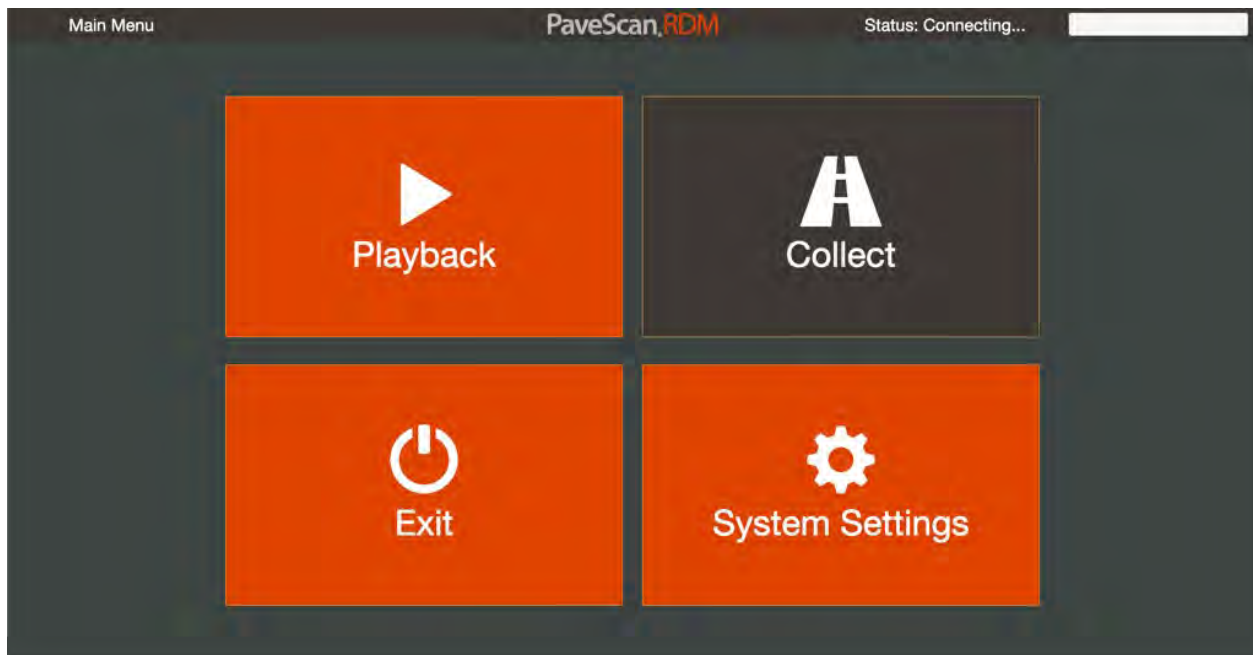
Note: Please see the PaveScan RDM 2.0 Quick Start Assembly Guide for instructions to assemble your system.

Chapter 2: Getting Started and Data Collection

In Chapter 2, instructions for starting the RDM Software and setting up for data collection. The calibration procedure for sensor(s) is also explained in detail.

2.1: Start-up

- 1** Press the button on the top panel of the concentrator box. The power light illuminates, and the sensors are powered-up.
- 2** Power-up the ToughPad computer by pressing and holding down the power button until the green light just to the left of the power button lights up. The computer takes 20-30 seconds to start. After it is fully started, the Main Menu of the PaveScan RDM application appears.



Main Menu

- 3** If there are no sensor(s) detected by the system, the **Collect** button remains unavailable. Once the sensor(s) are detected, the **Collect** button turns **green** and the Collect option is now available.

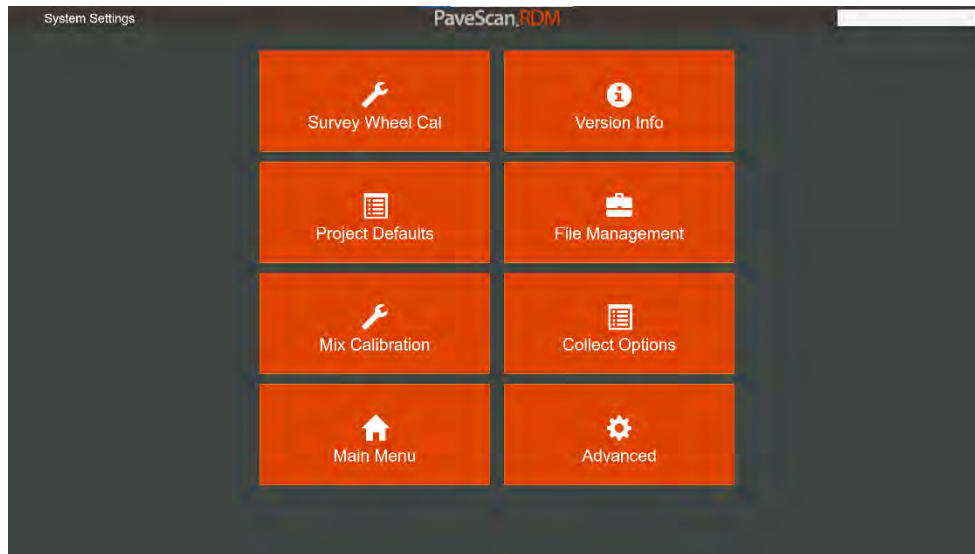
Application Shortcut
(double-click to start)



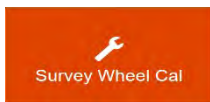
The application can also be started via a desktop shortcut that appears on the desktop after the application is shutdown.

2.2: System Settings

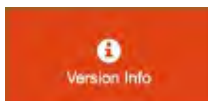
There are several user-adjustable settings that are accessible from the Main Menu. Pressing System Settings in the Main Menu displays the System Settings screen.



System Settings Screen



Survey wheel calibration is accessible by pressing this button (see page 6).



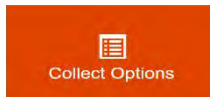
Shows the current version of the PaveScan RDM application.



Opens a screen enabling the editing of data files, modification of data file information, and the removal of data files (see page 7).



Options for removing Files, Projects, and Project Groups. Project Groups are added using this option as well (see page 10).



Options to modify the number of measurements per unit distance (see page 11).



Press this button to enter new or modify existing mix calibrations which are required to generate % voids, % compaction, or densities from dielectrics.



The button returns the user back to the starting menu which provides access to collection and playback options.



Directs the user to options related to sensor settings and updating the application software. Most of these options are password protected (see Page 11).

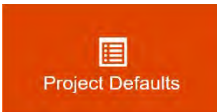
Survey Wheel Calibration

The screenshot shows the "Survey Wheel Calibration" screen in the PaveScan RDM application. The screen has a dark grey background. At the top left, it says "Survey Wheel Calibration" and at the top right, "PaveScan RDM". Below the title bar, there are three input fields: "Calibration Distance (ft)" with the value "100", "Survey Wheel Calibration Number" with the value "-3876", and "Survey Wheel Tick Count" which is currently empty. At the bottom of the screen, there are four large buttons: "Cancel" (red with a white 'X' icon), "Start" (red with a white play button icon), "Stop" (dark grey with a white square icon), and "Save" (dark grey with a white floppy disk icon).

Survey Wheel Calibration Screen

- 1** To perform as survey wheel calibration, enter in the calibration distance. Recommended distance is 100ft/30m or more because the longer the calibration distance the more accurate the calibration.
- 2** Next, line-up the cart at the starting point, and press **Start**.
- 3** Move the cart along the length of the measured distance, then press **Stop**.
 - Press **Save** to accept the new calibration number or **Cancel** to keep the old one.

Note: If you know the survey wheel calibration number ahead of time, you can enter its value and press **Save**.



Project Defaults

Project defaults are all the settings that can be preset and are inherited in newly created projects. These settings include units, GPS Settings, and preferences. Pressing the **Project Defaults** button opens the Project Properties screen containing these options.

The screenshot shows the 'Project Defaults' screen with the following settings:

Setting	Value
Distance Units	Feet
Depth Units	Inches
Density Units	g/cm ³
Temperature Units	Fahrenheit
Number of Cores to Calculate	9
Mounting Setup	Cart
Use Stationing Format	<input checked="" type="checkbox"/>
Auto Start Distance	<input type="checkbox"/>
Apply Valid Data Range	<input type="checkbox"/>
Apply QA Dielectric Correction	<input type="checkbox"/>

Bottom navigation bar buttons: Back, QA Options, Range Settings, GPS Settings, Export Options, Save.

Project Defaults Screen

Distance Units: Feet or meters can be selected for distance units. Note, once a project is created and saved, the distance units cannot be modified.

Depth Units: Various Imperial and metric units can be selected for depth units. Note, once a project is created and saved, the depth units cannot be modified.

Density Units: When Density is selected as the Calibration Type or for displaying measurements, the user can adjust the density units. Options include: oz/in³, lb/ft³, g/cm³, and kg/m³.

Temperature Units: The two temperature unit options are Fahrenheit and Celsius.

Number of Cores to Calculate: This is the default number of core locations that are found when the user presses the **Core Locations** button found on the bottom of the Playback File screen. Once a project is created, the number of core locations for the project is adjustable from the Core Locations screen (see Section 3.1).

Mounting Setup: There are two options, Cart and Vehicle. Selecting the Vehicle mount setup disables the height alert (which is triggered when the antenna is mounted outside the range of 8.5-9.5"). It also allows the user to specify custom antenna offsets in the Sensor Configuration Screen.

Use Stationing Format: Check this to show distances in station format (for example, 5250 ft in station format is 52+50).

Auto Start Distance: When this option is selected, the ending distance of the previous file is automatically specified as the starting distance for the next file. The starting distance value is always editable prior to starting data collection.

Apply Valid Data Range: When this option is selected, only measurement values within a specified range are included in the file statistics. All values outside this range appear as zeros in the display. Valid data range settings are accessed by pressing the **Range Settings** button. See Appendix D for more details.

Apply QA Dielectric Correction: When this option is selected, a dielectric correction is applied to the data using the selected Dielectric Correction methodology in the QA Options screen which is accessed by pressing the **QA Options** button (see Section 3.4)

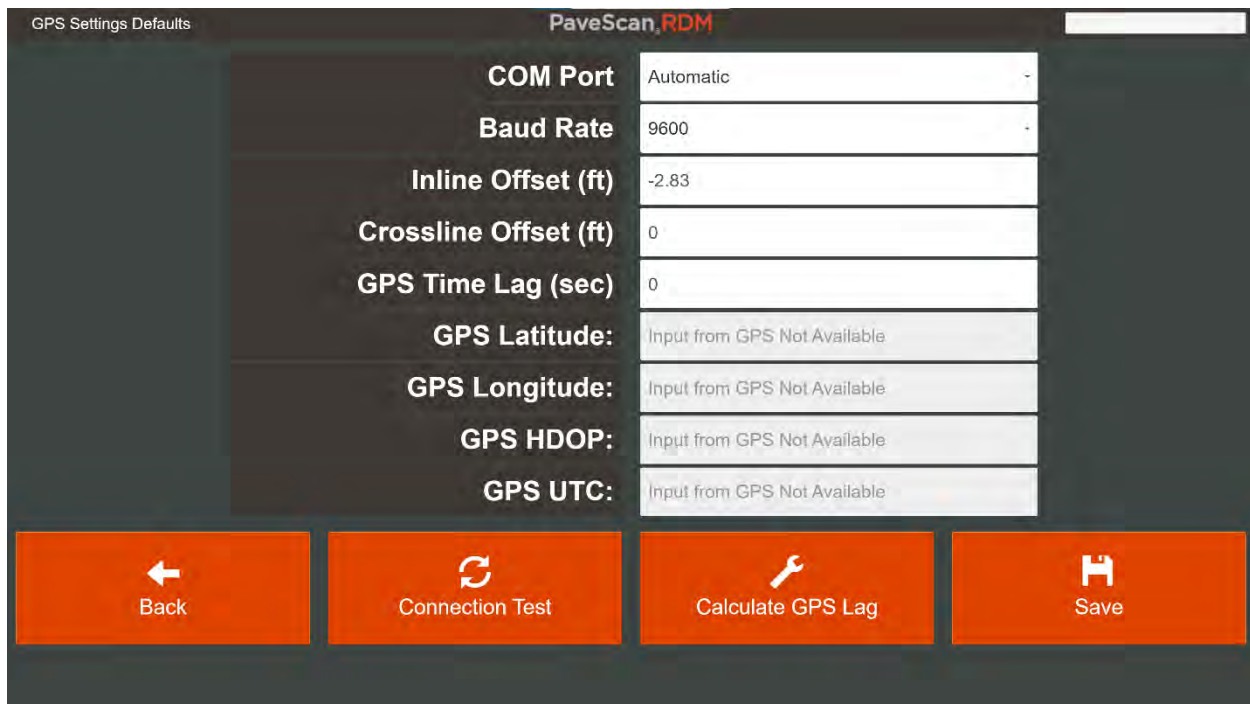


Pressing the **Back** button returns the user to the previous screen. If the **Save** button hasn't been pressed, changes won't be saved prior to navigating to the previous screen.



Pressing the **QA Options** button takes you to a screen where dielectric correction options associated with QA files are accessed. QA corrections are a means of removing minor shifts in dielectric associated with specific sensors that appear during data collection. The dielectric shifts are typically 0.1 or less. See Section 3.4 for details.

The GPS Settings screen is shown below. The current GPS status is indicated on the top right. NMEA GGA sentences are updated at the GPS update rate when the GPS is properly connected.



GPS Settings Screen

Baud Rate: The Baud Rate of the GPS. The Baud Rate of the Garmin GPS that is available as an accessory to the RDM system is 9600.

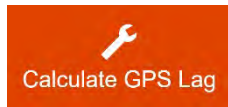
Inline Offset (ft): The inline offset of the GPS relative to the center sensor. If the GPS is in front of the center when looking in the direction of travel, the value is positive. If the GPS is in back of the sensor (e.g., between the sensor and the Toughpad) the value is negative.

Crossline Offset (ft): The crossline offset of the GPS relative to the center of the cart. Typically, this will be 0.0, but if the GPS is to the left of the center sensor looking in the direction of travel, the value is positive. Correspondingly, if the GPS is to the right of the center sensor facing the direction of travel, the value is negative.

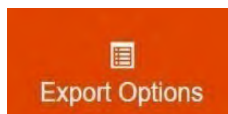
GPS Time Lag (seconds): For high-accuracy GPS systems, the lag, or time difference between the arrival of the PaveScan dielectric measurement and the GPS position information can be calculated and entered here. This value is then used to correct the time synchronization between the two measurements. The time lag for a GPS device can be calculated using a procedure that is accessed by pressing the **Calculate GPS Lag** button. See Appendix I for details on the GPS lag calculation.



Pressing this button when the GPS isn't being detected starts a procedure that automatically cycles through all the available COM ports to detect the GPS.



Utilizes a procedure to calculate the GPS lag for a GPS. See Appendix I for details.



There are numerous export options that provide extensive customization to exported files and project statistics. These are described below.

The screenshot shows the 'Default Export Settings' screen in the PavScan RDM software. The interface is dark-themed with white text and input fields. The settings are as follows:

- Measurement Type:** Dielectric (dropdown menu)
- Distance File Moving Average (ft):** 0.5
- Distance File Measurement Interval (ft):** 0.5
- Time File Measurement Moving Average (sec):** 1
- Time File Measurement Interval (sec):** 1
- Export Defects:**
- Provide Segment Statistics:**
- Output Segment Interval (ft):** 100
- Output Descriptive Header Lines:**
- One Measurement Per Row:**
- Export to Veta TDS File:**

At the bottom of the screen, there are four large orange buttons with white icons and text: 'Back' (left arrow), 'Save' (floppy disk), 'Export Defect Settings' (download icon), and 'Report Options' (gear icon).

Export Options Screen

Measurement Type: The measurement value to export. Dielectric is the default. This value is always exported. Additional options are: Percent Voids, Percent Compaction and Density. For measurement types other than dielectric, the core calibration information must be entered for the project (see Core Calibration). If no core calibration information is available, zeros are exported in the measurement value column.

Distance File Moving Average: When this value is non-zero, a central moving average of the size specified is applied to each data point prior to export. For example, if a 0.5ft (20cm) moving average is specified, each exported data point is an average of all the data points at the measurement location $\pm 0.25\text{ft}$ ($\pm 10\text{cm}$).

Distance File Measurement Interval: The output interval between exported measurements. For general purposes where data may be obtained over a distance of hundreds of feet, an export interval of 0.5ft (20cm) is useful.

Time File Moving Average: When this value is non-zero, a central moving average of the time specified is applied to each data point prior to export. The units are in seconds.

Time File Measurement Interval: The output time interval between exported measurements. The units are in seconds.

Export Defects: Linear and 2-dimensional defect locations are exported to separate files when this box is checked. See Appendix E for details.

Provide Segment Statistics: Check this selection box to provide statistics over specified distance intervals. For example, exported statistics can be calculated for each station interval. The exported statistics appear in the individual file segment statistics and the Selected Range statistics files.

Output Distance Segment Interval: When Provide Segment Statistics is checked, this is the segment interval over which the statistics are calculated.

Output Descriptive Header Lines: Check this selection box so show all the available information on the file when the file is exported. The extended header appears as a series of lines at the top of the exported file.

One Measurement Per Output Row: Check this selection box to export multi-sensor data in a format with individual sensor measurement values in their own rows. For example, if project data were obtained with 3 sensors, when this box is checked, the exported data from each sensor would be in separate rows. When this box is unchecked, multi-sensor data from one measurement location are written to one row.

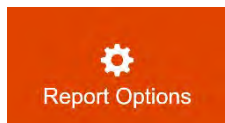
Export to Veta TDS File: Check this selection box to export the file data to a TDS file, which can be imported onto Veta versions that have the capability to display and analyze dielectric data.



Press the **Save** button to save all changes made in the Project Properties screen sub-screens (i.e., GPS, Lane Names, and Export Options).



Press the **Export Defect Settings** button to access options related to characterizing defects. See Appendix D for details.

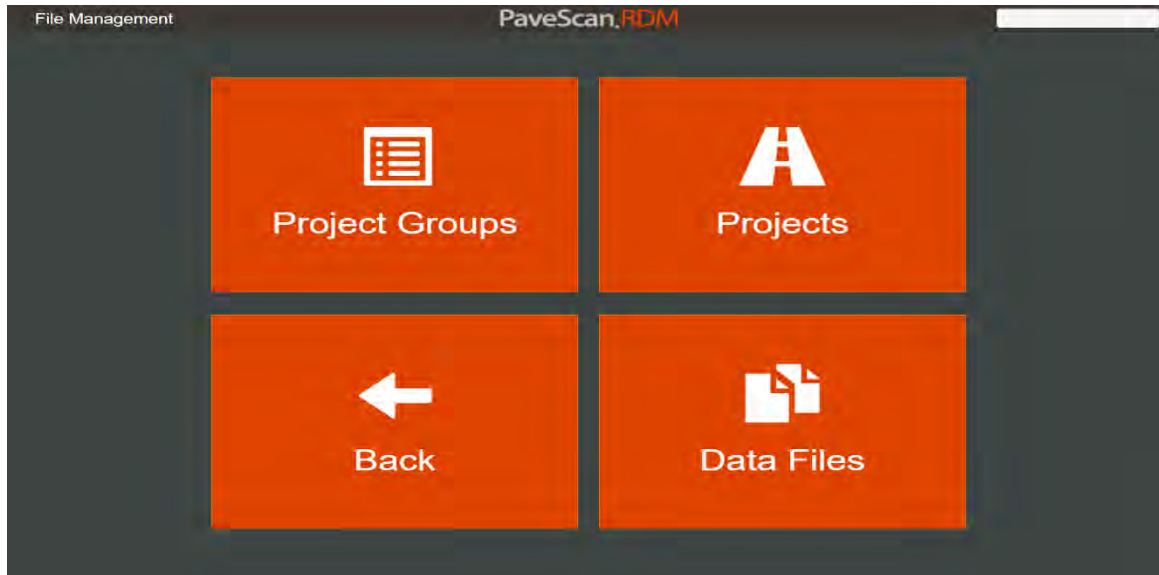


Press **Report Options** to access parameters used to assess Percent Within Limits (PWL) calculations. See Appendix F for details.

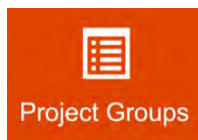
File Management



Options for removing Files, Projects, and Project Groups. Additionally, file properties, such as starting distance, and Y-coordinate, can be modified. Currently files and projects are not deleted. They become invisible to the user, similar to the recycle bin in Windows.



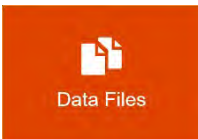
File Management Screen



Opens a screen enabling editing of project group names and the creation of new project Groups.

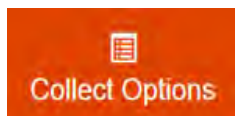


Opens a screen enabling the editing of project names, modification of project properties, and the removal of projects.



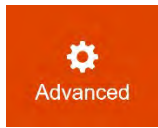
Opens a screen enabling editing of data file name and other information.

Collect Options

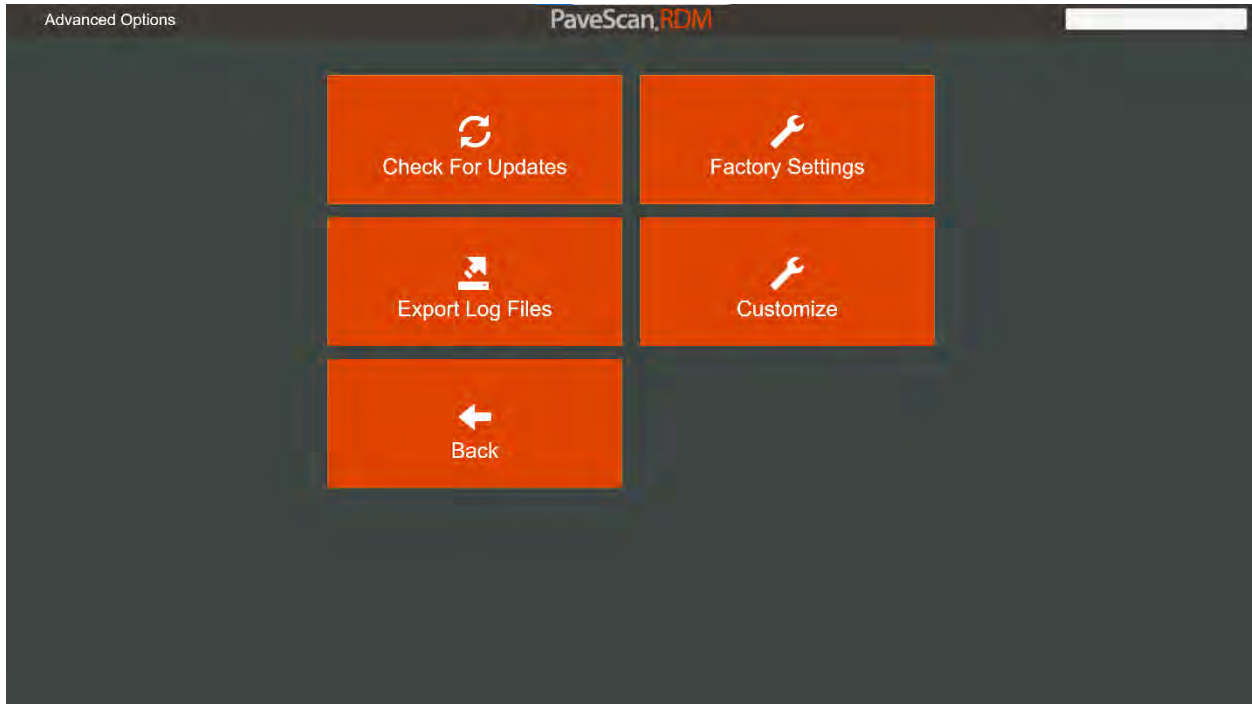


The user may modify the number of measurements per unit distance. The options are “Walk,” “Fast Walk,” and “Vehicle.” The measurement densities corresponding to these options are 10 scans/ft (40/m), 5 scans/ft (20 scans/m), and 2 scans/ft (8 scans/m). It is best to set the option to match the pace of the user and “Walk” is typically used. There is an over-speed indicator on the data collection screen so the user can adjust walking speed to ensure no measurements are skipped.

Advanced Options



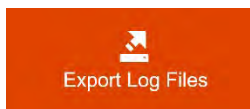
Select the **Advanced** button to check for updates, modify sensor settings or customize new project information fields and exported file information. Sensor settings are not typically modified after they are entered the first time a sensor is attached to the PaveScan system.



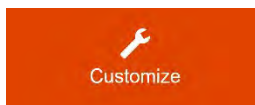
Advanced Options Screen



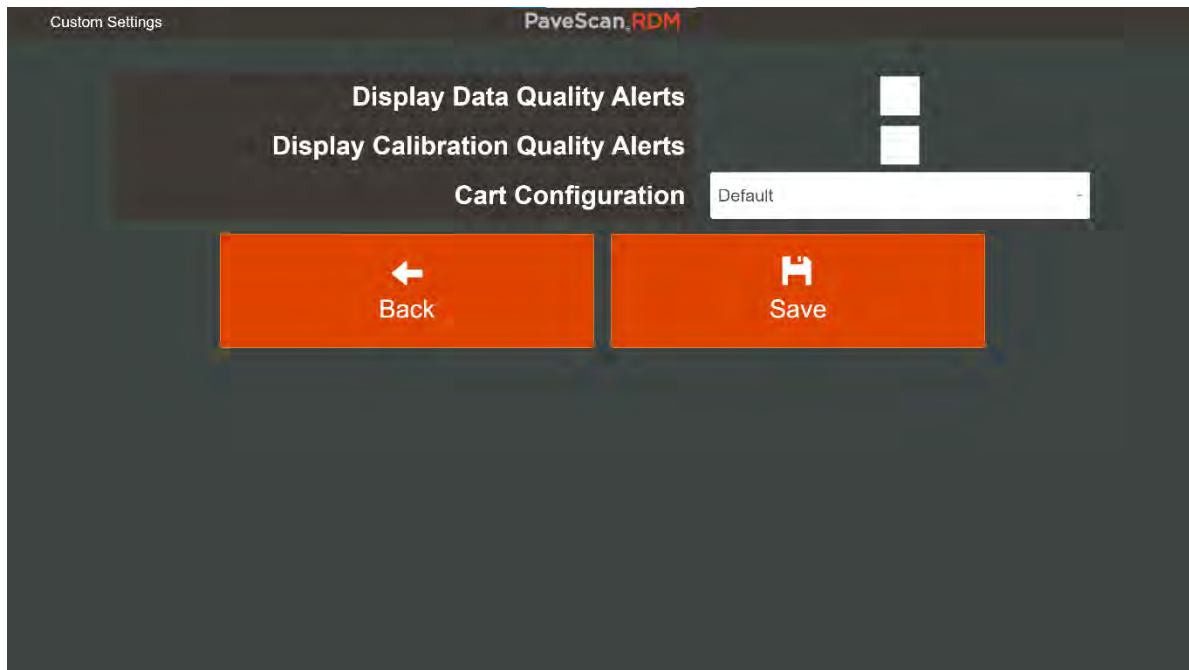
This is how software or sensor firmware updates are accessed and applied.



Press this button to export log files to a USB flash drive. The log files help diagnose sensor or system trouble. If you are having sensor or system trouble, the GSSI technical support person you contact may request that you export the log files and send them to GSSI for analysis.



Press this button to access system-wide settings that are rarely changed.



Display Quality Alerts: When this box is checked, quality alert pop-up windows appear during data collection. A display quality alert appears if, while collecting a data file, any one of the following circumstances occurs: (1) Dielectric is outside a range of 2.0 – 8.0; (2) Antenna height is outside a range of 4-39 inches (10-100 cm); and (3) internal temperature of sensor is greater than 60C. Only one data quality alert is shown per data file. The appearance of a data quality alert does not impact data collection. Unchecking the Display Quality Alert checkbox disables the display of data quality alerts.

Display Calibration Quality Alerts: When this box is checked, pop-up windows appear prior to exiting the calibration screen if a potential calibration problem has been detected. Calibrations are not prevented, when this happens, but you are prompted to either make an adjustment and recalibrate or warned that one or more sensors may be malfunctioning. The circumstances that a pop-up warning window appears include:

1. **The sensor time position is out of range.** When this occurs, the antenna may be malfunctioning.
2. **The sensor temperature exceeds the calibrated limits.** Data can still be acquired, but its accuracy may be below acceptable limits.
3. **Sensor height is out of range.** For cart-mounted sensors, the acceptable height range is 8.5-9.5 inches (21.6-24.1 cm).
4. **Interference from a nearby object.** An abnormal reflection from the metal plate is obtained, which may be associated with an object (e.g. someone's foot) within 12 inches (30 cm) of the sensor.
5. **Lower than normal power output.** When this occurs, the antenna may be malfunctioning.
6. **High noise level.** When this occurs, the sensor is impacted by a nearby source of interference such as a cell phone tower.

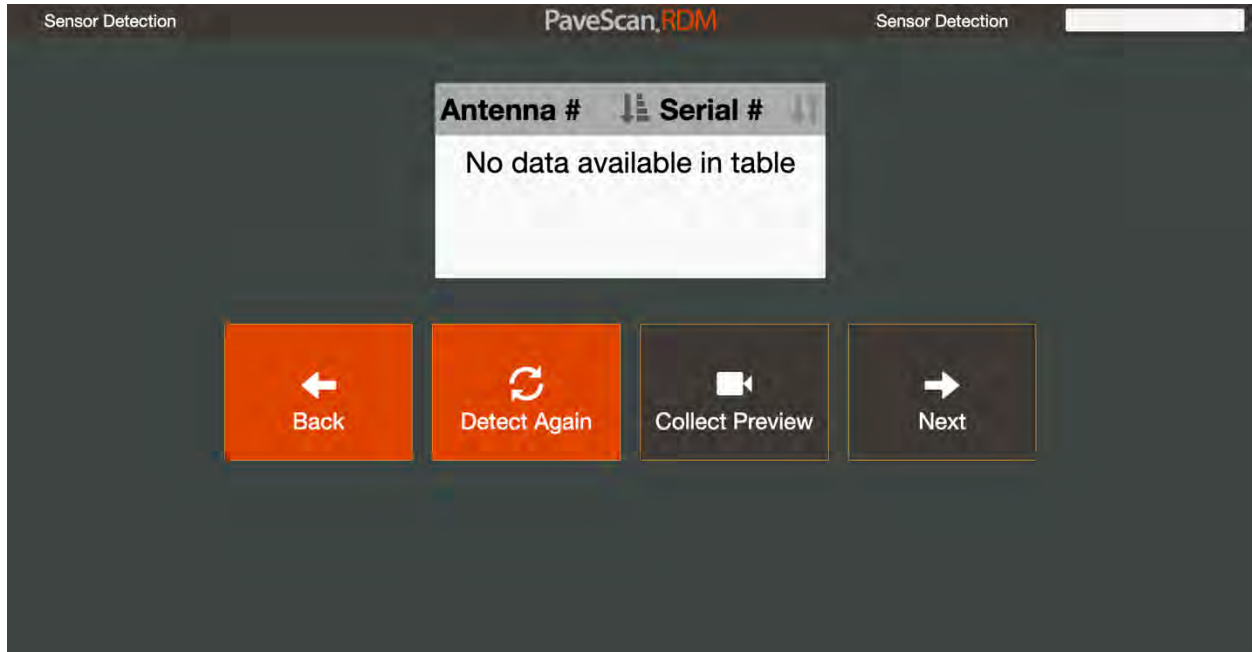
7. **Low amplitude metal plate reflection.** This message will appear if you have mistakenly not placed the metal plate beneath the antenna during the metal plate calibration.

Unchecking the **Display Calibration Quality Alerts** button prevents the pop-up warning from appearing on the screen.

Cart Configuration: The default cart configuration limits the user to lateral sensor offsets that correspond to the hole locations on the orange bar that is mounted on the front of the cart. For situations where there is a discrepancy between the actual lateral sensor position and the hole intervals, you can select “custom” to enter in that actual sensor lateral offset in the Sensor Configuration Screen. (One scenario where this may occur is if the project is using metric units and the orange bar has Imperial unit hole spacing).

2.3: Data Collection Setup

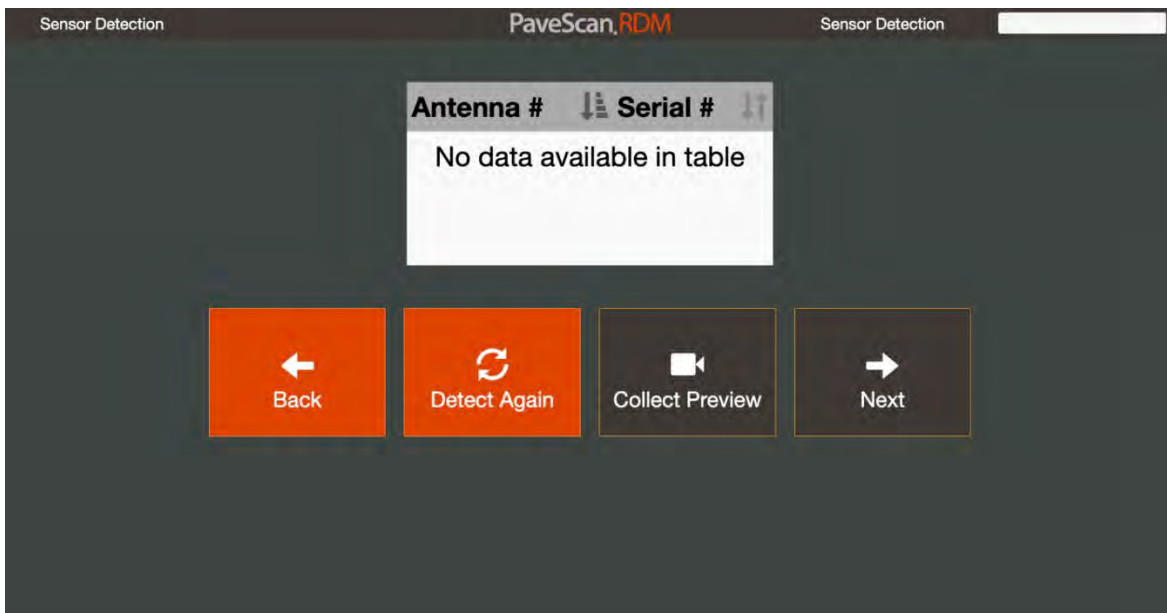
- 1 Clicking on the **Collect** button from the Main Menu screen displays the Sensor Detection screen.



Sensor Detection Screen

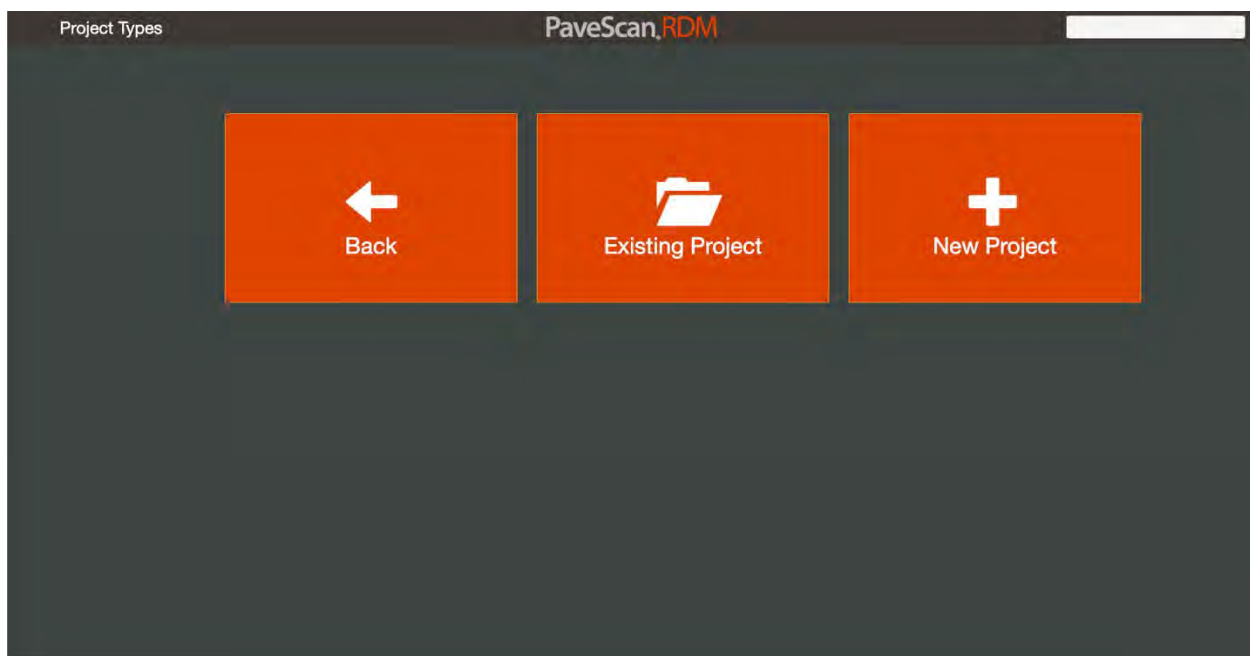
- 2 The detected sensors appear in this table and the **Collect Preview** button is enabled. The user can press Collect preview to preview collection using the last calibration.

NOTE: The sensors serial numbers are displayed once the sensors are detected. They may NOT be in order. That option comes later.



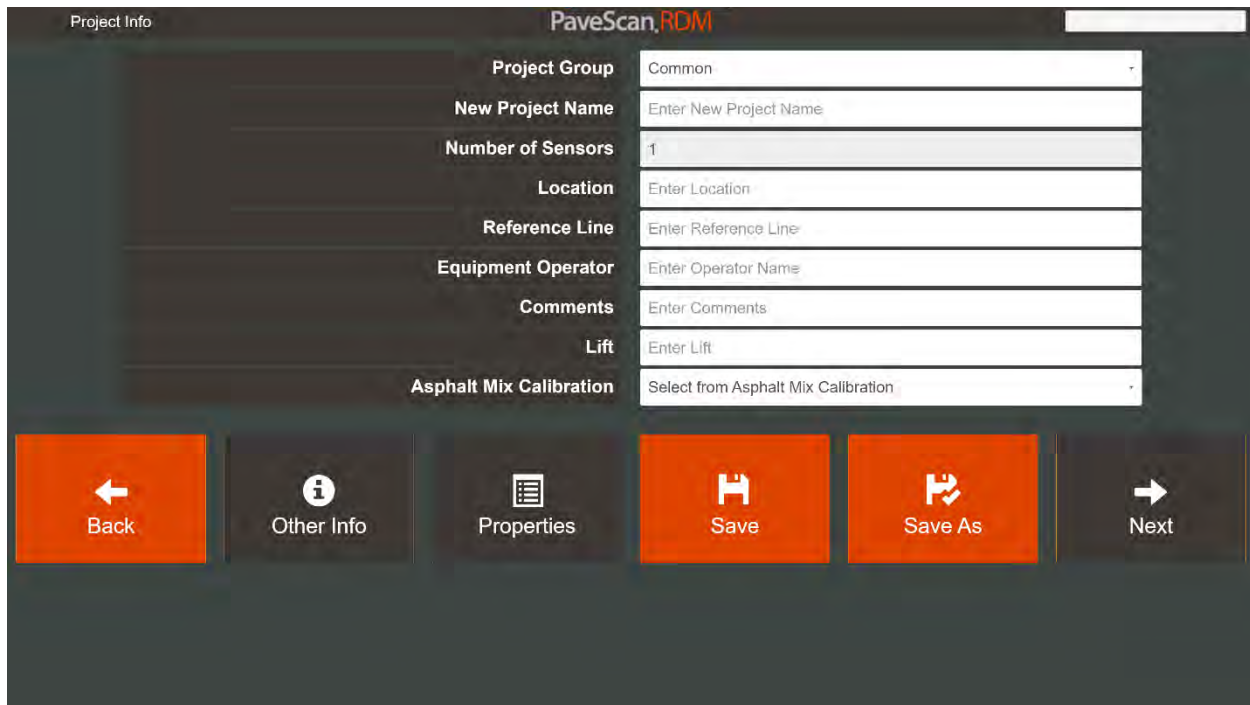
- 3** If a connected sensor does not appear, press **Detect Again** to retry.
- 4** Once all sensors are detected press the **Next** button.
- 5** The following screen appears. The user selects an existing project or a new project. Only existing projects containing the detected sensors are recalled.

Note: If the Status changes to “Sensor Not Found” (which may happen infrequently), turn off the sensors by pressing the button on the top panel of the concentrator box, shutdown the application as described in Chapter 4, then follow the Start-up procedure described in Section 2.1.



Project Types Screen

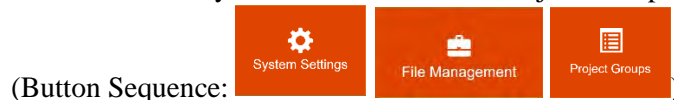
- 6** After pressing the **Existing Project** or **New Project** buttons, the Project Settings screen appears. This screen contains numerous items that the user can use to fill in project-specific information.
 - For New Projects, enter the new project name, then press **Save**.
 - For Existing Projects, the **Save As** button is enabled.
 - When **Save As** is pressed, enter a new project name and then press **Save**.
 - The “Save As” option is useful to create a new project from an existing project’s settings.



Project Info Screen

The options shown allows filling in details related to the project. Adjustable options here are:

Project Group: Specify the group the file belongs to. Suggestions for Group Names range from highway or road names to years and months. New Project Groups can be created and edited in the System Settings



Project Name: The name associated with the project. Project names must be unique. Click the **New Project** button to create a new project. When this is done, a screen appears asking to inherit the settings for the current project. Select yes to use the same settings as the current project or cancel to inherit the default project settings.

Number of Sensors: The number of sensors attached to the concentrator box. 1, 2, or 3 sensors. This is a read-only field and is present for informative purposes only.

Location: Optional entry for specifying information related to where the data are being obtained. This information is exported with the data.

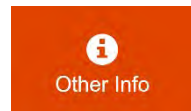
Reference Line: Optional entry for specifying the reference used for the lateral coordinates assigned to a file. Examples include: curb, outside lane stripe, or pavement edge. This is included in the exported data. See Appendix C for more details on specifying the Lateral Offset Reference.

Equipment Operator: Optional entry for specifying who is operating the equipment. This is included in the exported data.

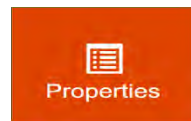
Comments: Project-specific comments that is included in the exported data.

Lift: Optional entry for specifying the asphalt lift being measured.

Asphalt Mix Calibration: Once a Mix Calibration has been generated, it can be applied to any project. A dropdown list is provided for you to select the desired mix calibration. Mix Calibrations are created and accessed from **System Settings** – see Section 2.2.

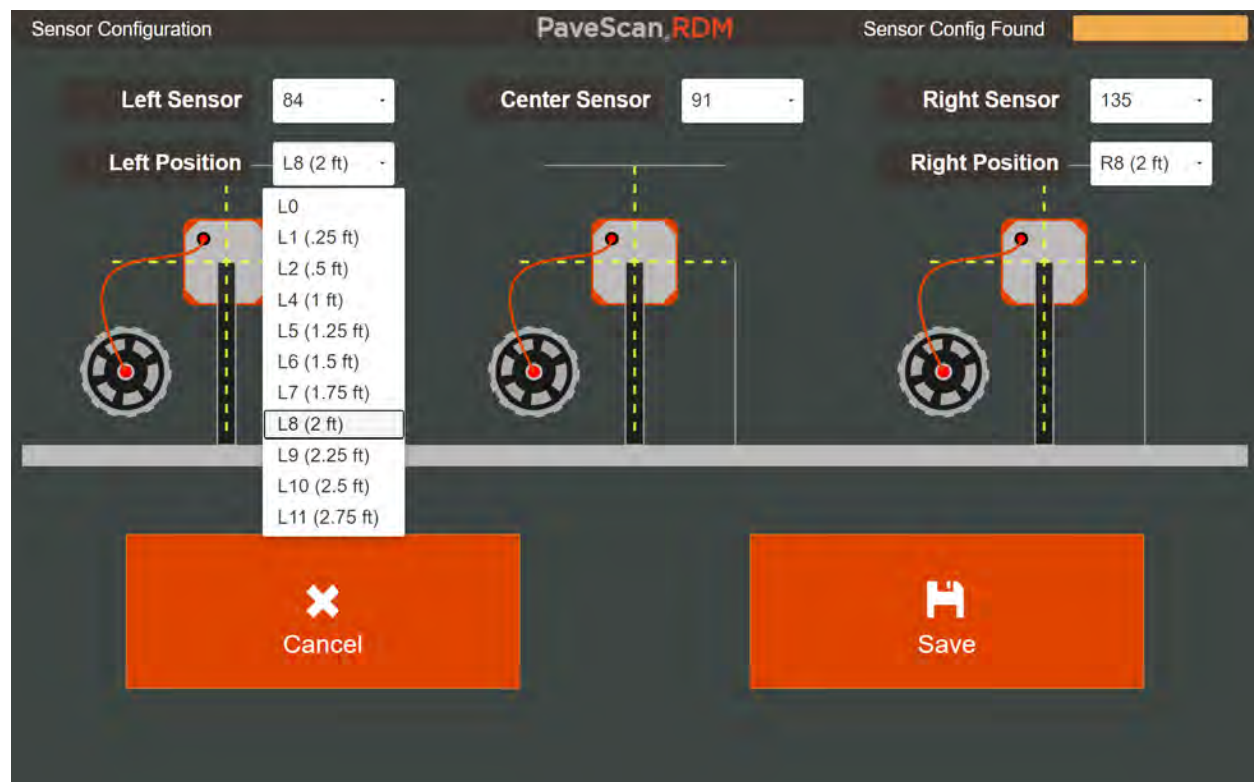


The **Other Info** button allows you to enter other project-related information and access the results of core measurements made as part of the project data collection. Other project info is detailed in Appendix G.



Enabled after a project is saved, this option allows the modification of the project settings. These are the same settings that are shown when the **Project Defaults** button is pressed in the System Settings screen. These settings include such things as GPS settings and export options.

7 By pressing the **Save** button navigates, the Sensor Configuration screen is displayed. The next screen shows the sensors detected and allows for changing the position of the sensors.



Sensor Configuration Screen

8 First, use the dropdown list to associate the sensor serial # with the sensor that most closely matches its position on the cart. The sensor # is the serial number that can be seen on the side of the sensor when it is mounted on the cart. For example, if Sensor serial # 8 is located on the left side of the cart, it should be positioned on the left side of the screen, as shown in the image above. If mounted on a vehicle, the orientation of the sensors is what is seen as facing the direction of travel (i.e., the left sensor would be on driver’s side of the vehicle if the vehicle has the driver’s side on the left side).

- 9 Set the crossline positions of the left and right sensors. The dropdown options correspond to the hole locations on the orange mounting bar. The cross-line position reference is distance from the center of the cart. Distances are positive numbers. It is a good strategy to always place the same sensor in the same relative location: left, center, or right.
- 10 Press **Save** when the sensors are properly located. Note, once the sensor positions are setup, they will be remembered with the project so that the next time the system is started, the relative positions are recalled.
- 11 After pressing **Save** the File Information screen opens. There are several user entries tied to each file.

The screenshot shows the 'File Information' screen in the PaveScan RDM application. The interface is dark-themed with white text and orange buttons. At the top, it says 'PaveScan RDM' and 'Disconnected'. The main area contains several input fields and dropdown menus. Below these is a section for optional fields, and at the bottom, a row of six orange buttons with icons and labels: Back, Playback Last, Display Options, View Layout, Calibrate, and Collect.

File Information Screen

Measurement Type: Select the measurement type.

- **Field Measurement:** Collects dielectric measurements in a continuous file using all the attached antennas.
- **Quality Assurance:** Collects measurements that are used to verify the sensors are working properly and optionally add dielectric corrections to sensors that exhibit dielectric drift
- **Core:** Collects measurements specific to core locations.

Collect Mode: Select the collection mode.

- **Distance Mode:** Collects measurements at specified distance intervals as the sensors are moved. The distance intervals are determined by the collect option selected in System Settings (see Section 2.3).
- **Time Mode:** Collects a continuous file at a rate of 60 measurements per second. This mode is often used when making a static (non-moving) measurement at a specific location.
- **Log Mode:** Collects measurements continuously at 60 measurements per second in time mode. The current dielectric and the running average are displayed. The entire file can be played back as a normal file. The log measurements are saved in 10-minute chunks, so that at most 10 minutes of measurements are lost if data collection is interrupted by an unexpected event, such as a loss of power.

Starting Station Number: This is that starting station number of the file. If stationing is disabled (accessed by **Project Info** button), this entry will not appear. When the Auto Start Distance Project option is selected (accessed by **Project Info** button), this value is automatically specified based on the ending distance of the previously collected file.

Starting Station Distance (ft/m): This is shown when stationing is being used. It's a value ranging from 0-99.9. When the Auto Start Distance Project option is selected (accessed by **Project Info** button), this value is automatically specified based on the ending distance of the previously collected file.

Starting Distance (ft/m): This value, shown when stationing is not being used, is the distance used as the starting distance in the output file containing dielectrics and % voids. When the Auto Start Distance Project option is selected (accessed by **Project Info** button), this value is automatically specified based on the ending distance of the previously collected file.

Decreasing Distance: When this box is checked, the distance values decrease as the data are being collected. This occurs when collecting data down station.

Lateral Offset from Reference Line to Cart Center(ft/m): This field is the distance of the center of the cart from the Reference Line entered in the Project information page. It is recorded in the output file. See Appendix C for more information on specifying the Lateral Offset.

Cart Position Relative to Reference Line: This is direction of the line relative to the reference line, left or right. This is always obtained while facing the increasing station direction.

File Name: The first part of the output filename. All files after the first file with the same name have numbers appended to them that increment from file to file. For example, if the first file name is MP101, the second file MP101_001, etc.

Optional Fields

Comments: Miscellaneous information that will be tied to the file.

Lane: The lane the data are obtained in.

Lot: This is one of the filter options in the Playback Range menu.

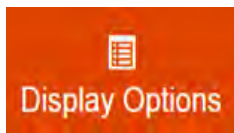
Sublot: This is one of the filter options in the Playback Range menu.



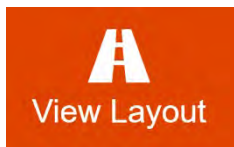
Navigates back to the Project Information screen where project information and properties can be viewed and modified.



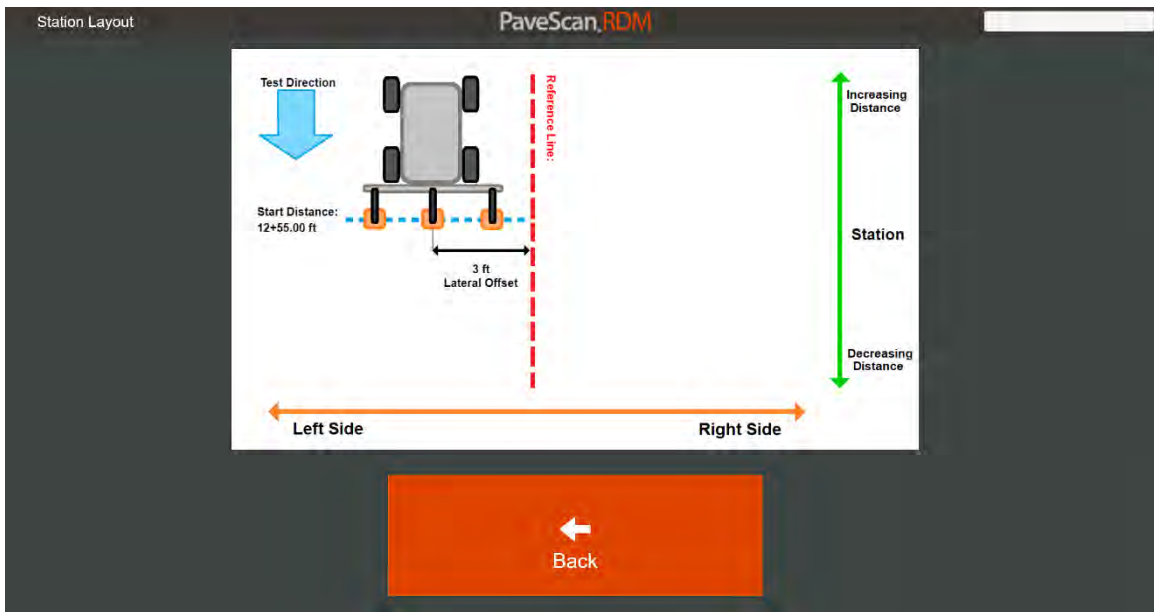
Plays back the most recently collected file in the current project.



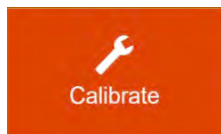
Access the display options for data collection and playback. These options include display ranges and display of dielectrics, percent voids, percent compaction or density. The options are discussed in more detail in a later section.



Shows the layout based on the starting distance, data collection direction, and lateral offset. In the image below, the starting station is 12+55, data are being collected in the decrementing distance direction, and the offset from the reference line is 3 ft to the left.



View Layout Screen

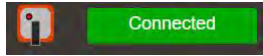


If necessary or required, the user is directed to perform air and metal plate calibrations.

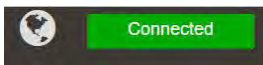


Directs the user to the data collection screen to start a file. This button becomes enabled once the sensors are warmed up sufficiently. The warm-up status is shown by the progress bar at the top right.

The top status bar in the File Information screen contains icons that indicate the status of the sensors, GPS, and battery on the Toughpad computer.



There is one icon per sensor indicating communication status. When the adjacent square is green, the sensors are connected and active. The square may turn red for several seconds when the file information screen is opened due to communication between the sensor(s) and the Toughpad. Once the communication is completed, the rectangle should turn green.



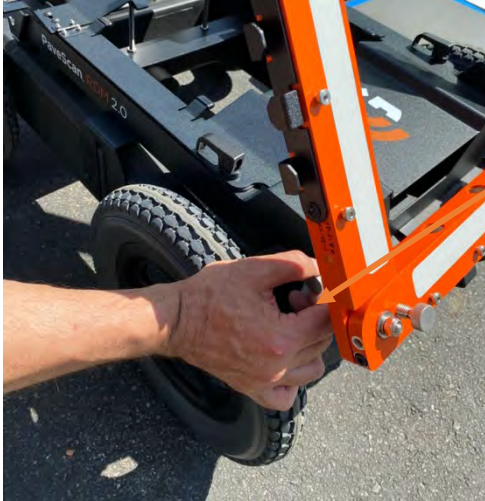
The right-center icon on the status bar contains information on the GPS stream. When the square is green, NMEA GPS sentences are being received by the Toughpad. The color of the icon indicates the GPS quality. Green means acceptable quality. Orange and red indicate low quality.



The rectangle adjacent to the right-most icon indicates the level of the Toughpad battery in percent.

2.4: Calibration

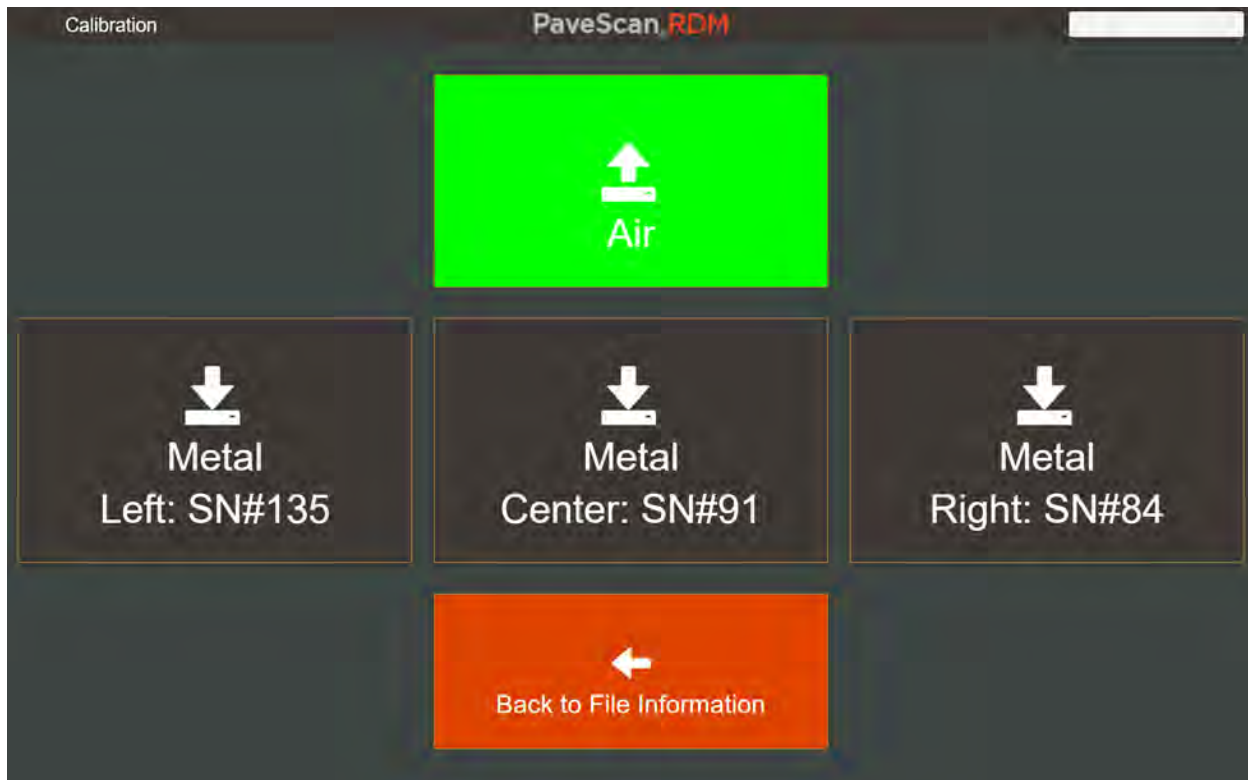
If calibration is desired or necessary, press the **Calibration** button and the calibration screen is displayed. Air and metal plate calibrations are required daily. While the sensors are warming up, the buttons are all gray. The warm-up progress is shown in the progress bar at the top right. When the sensor are ready for calibration, the **Air** button turns green. The air measurement requires that all the sensors be lifted at least 45 degrees off the ground.



Loosen this thumbscrew, lift sensor arm, and then retighten prior to airwave measurement



Sensors in position for airwave measurement



The image above indicates that the calibration procedure is ready to begin with the airwave measurement.

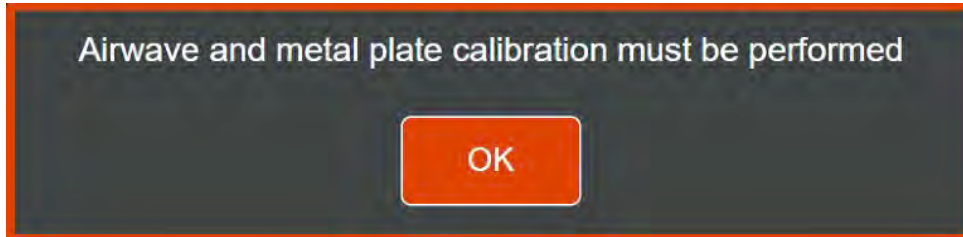
- 1** Press the **Air** button. When pressed, it turns orange while the calibration measurement is being performed. The air calibration takes about 10 seconds per sensor.
 - For a 3-sensor set-up, the total measurement time is about 30-45 seconds.
 - **All sensors must be in the air-measurement position during the calibration.**
- 2** Once the air calibration is completed, the Metal Plate Calibration step can be initiated. One of the buttons turns green. Make certain that the position indicated on the button matches the position of the sensor on the cart. In the example shown above, sensor #153 should be on the left side of the cart. If it is not, then the system should be shutdown and restarted with changes made to the Sensor Configuration (2.2).



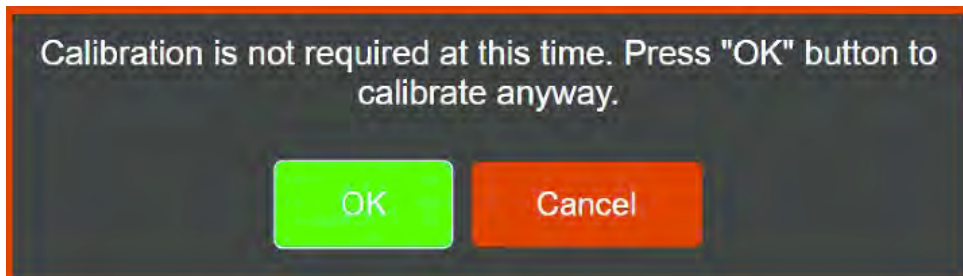
- 3** Place the metal plate underneath one of the sensors. Be sure to line up the metal plate so that the sensor laser is directed into the small hole in the center of the metal plate. **The metal plate and cart also need to be on a level surface or surface with a non-changing slope. If the metal plate is not flush with the surface, move to another location where it is flush.**

- 4 Once the metal plate is in place, lower the antenna, and press the green button that corresponds to the sensor. It turns orange during calibration. The metal plate calibration takes from 5-10 seconds. Once it is complete, move the metal plate to another sensor and repeat the process until a metal plate measurement has been performed for each sensor.

The following is displayed if calibration is required.



The following is displayed if no calibration is required.



If a pop-up alert appears during calibration, it signifies one of a number of possible issues associated the calibration. It is recommended to follow the instructions in the pop-up alert and make any necessary adjustments then re-perform the calibration.

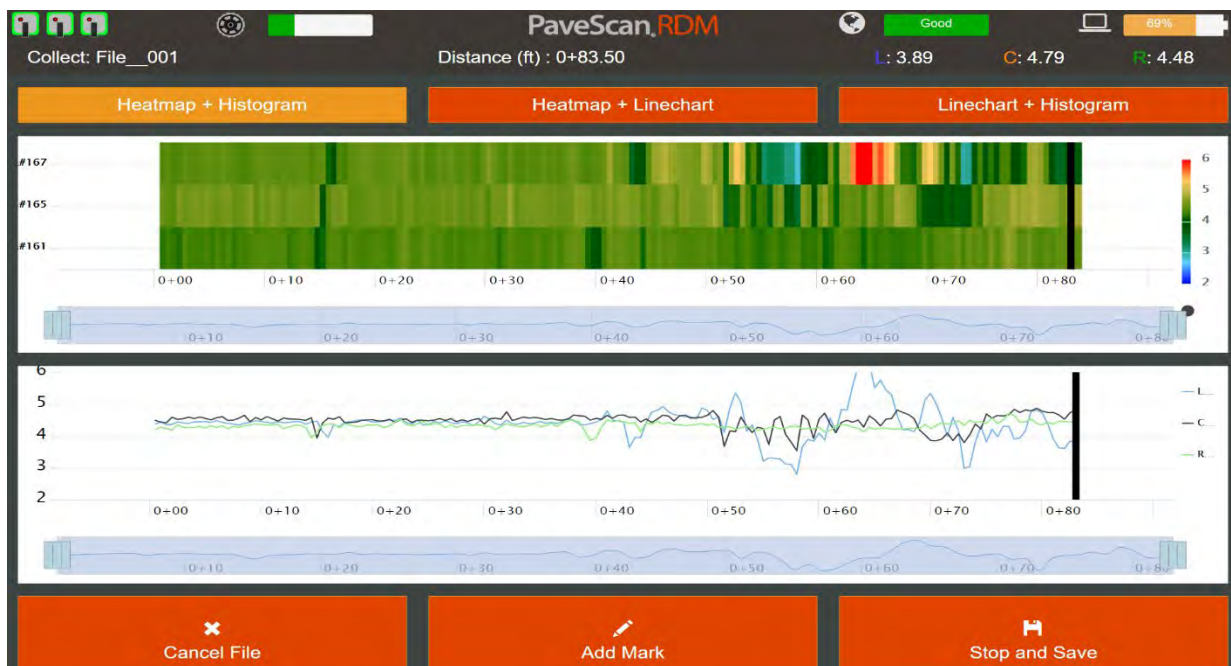
2.5: Data Collection

There are three different measurement types:

- (1) Field Measurements
- (2) Quality Assurance
- (3) Core measurements.

Field Measurements

Pressing the **Collect** button, when Field Measurements is selected as the measurement type and after calibration is completed, redirects the user to the Collect screen and starts data collection. The data collection screen is shown in the image below.

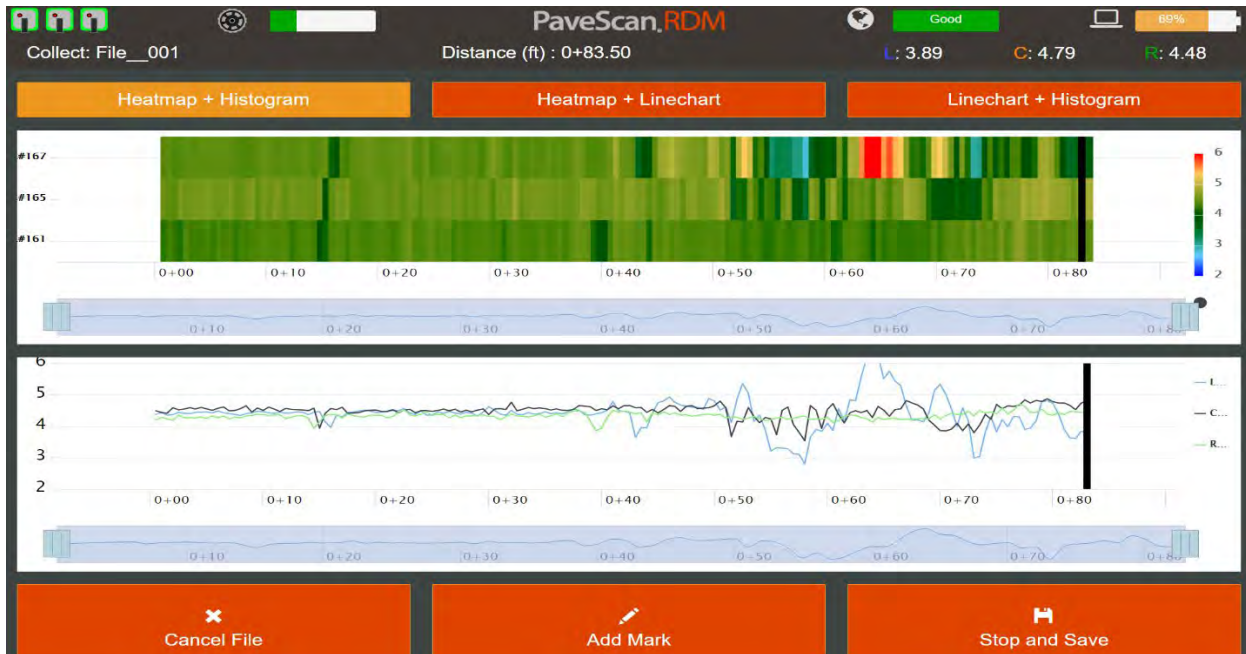


The current speed data can be collected in walk mode is about 5ft per second (1.5m/s). If this rate is exceeded by a small fraction, the missing data points is filled in with duplicates from neighboring values. Exceeding the limit by a large amount may lead to system instability. Keep an eye on the overspeed indicator in the status bar, which turns red when the allowable rate of speed is exceeded.

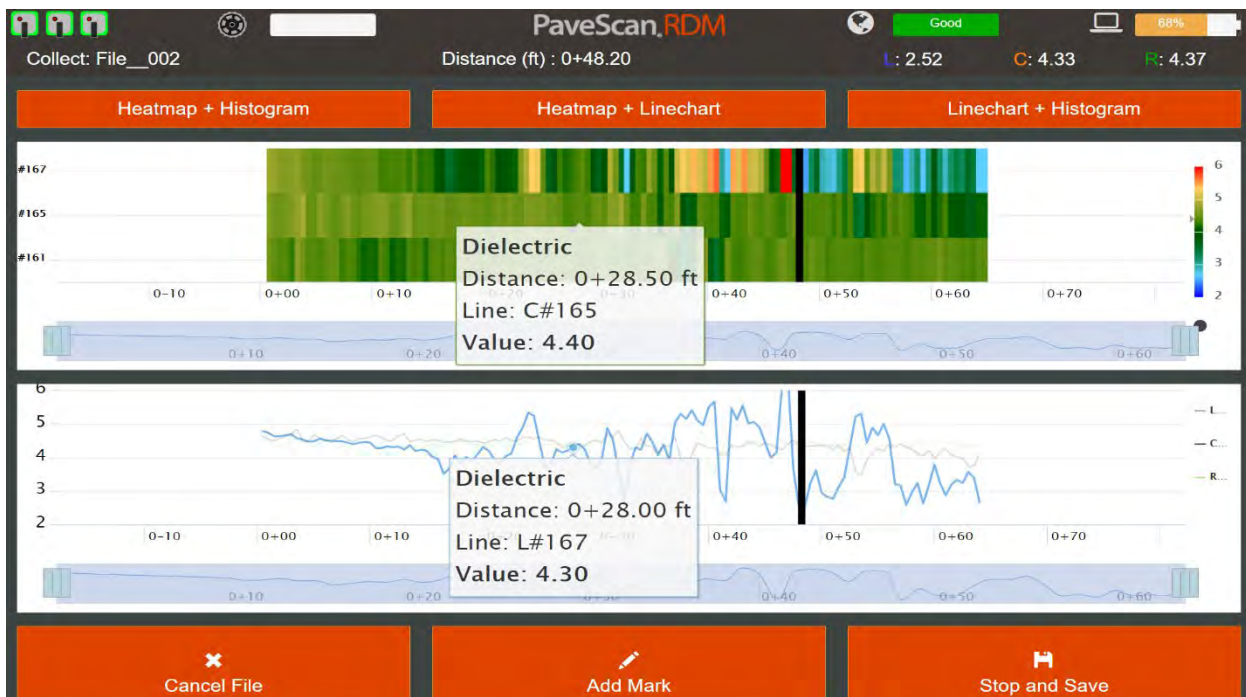
During Data Collection

As the sensor is moved, the dielectrics of each sensor are plotted together and the sensors are denoted by their relative positions: L = Left, C = Center, and R = Right.

In addition, the scales of the charts have a “#” followed by the serial number of the sensor. At any time, the dielectrics at a certain distance can be displayed by placing the pointer (or touching) at the desired location on the chart.



When backing up, the current distance and dielectrics associated with the sensor positions are indicated at the top of the screen and the back-up location in the data is indicated by a large black bar.



Clicking on the different buttons on the top of the screen shows different combinations of screens.

Heatmap + Linechart

Shows a heatmap of the displayed values (dielectrics or calibrated physical property value) on top and a linechart of the values on the bottom.

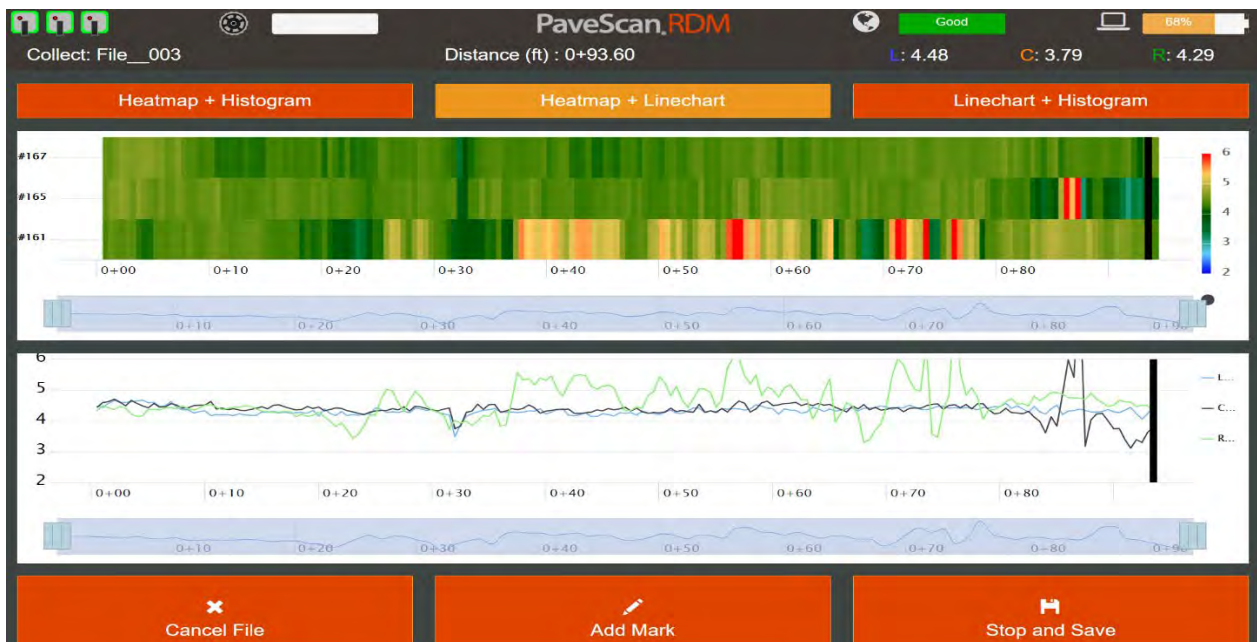
Heatmap + Histogram

Shows a heatmap of the displayed values (dielectrics or calibrated physical property value) on top and a histogram showing the distribution of the displayed values on the bottom.

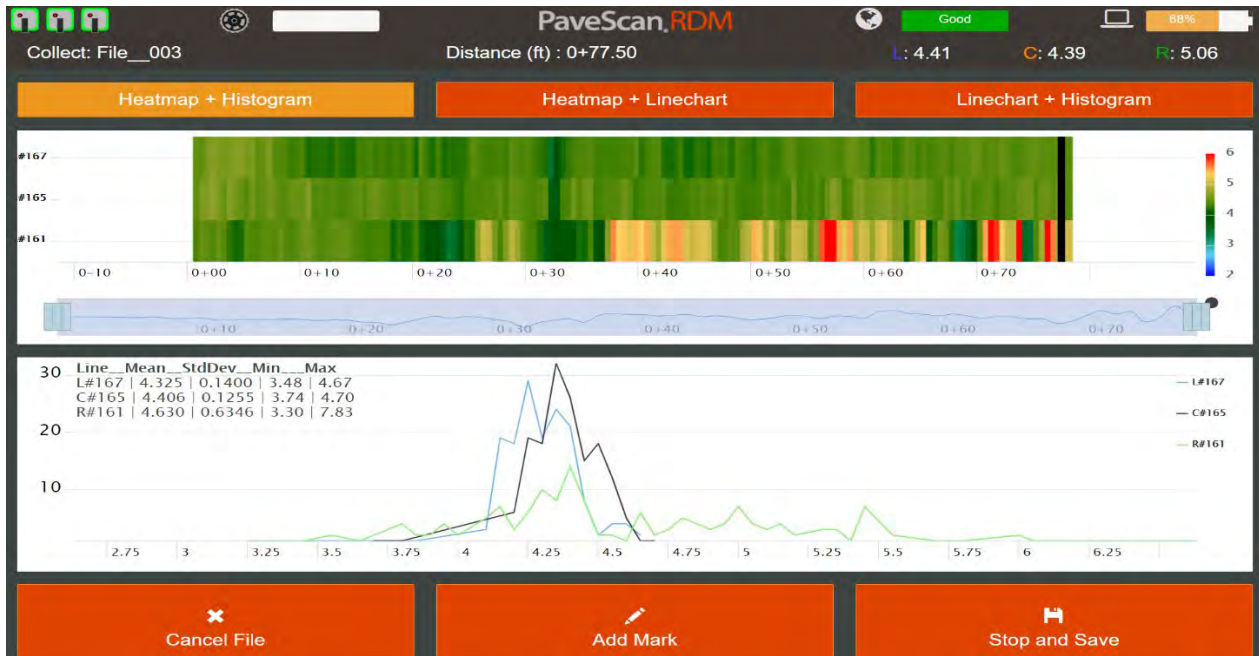
Linechart + Histogram

Shows a linechart of the displayed values (dielectrics or calibrated physical property value) on top and a histogram showing the distribution of the displayed values on the bottom.

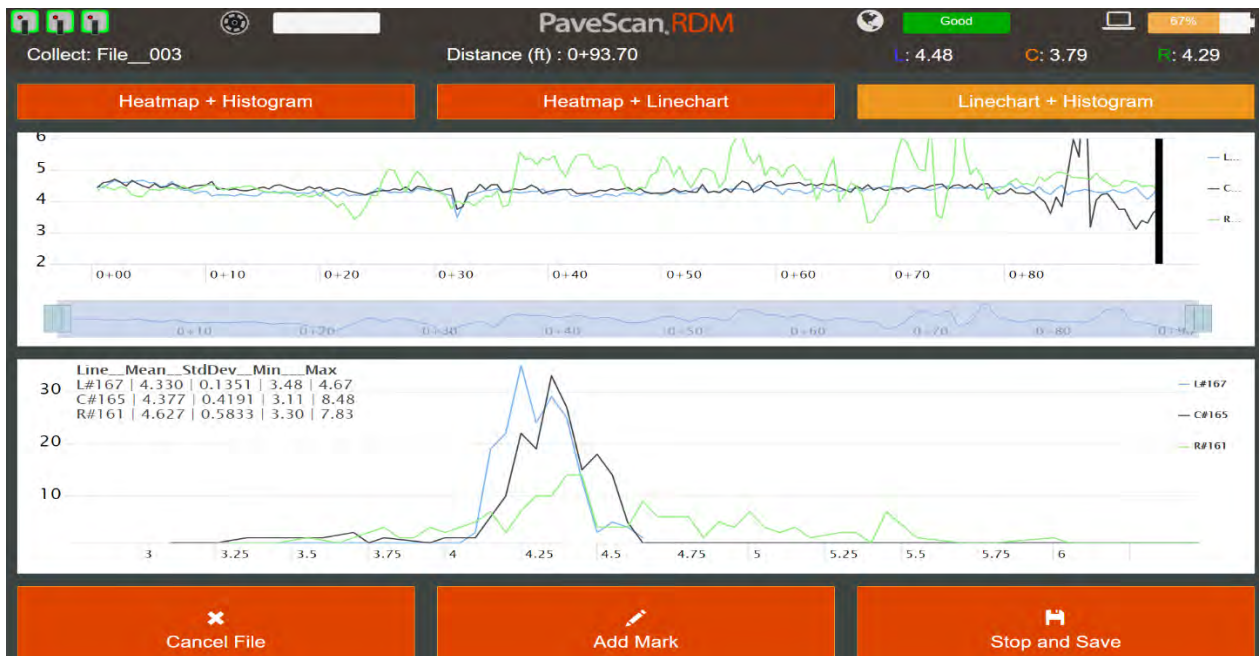
By default, the Heatmap + Linechart combination is shown.



The Heatmap + Histogram combination is shown below.



The Linechart + Histogram combination is shown below.



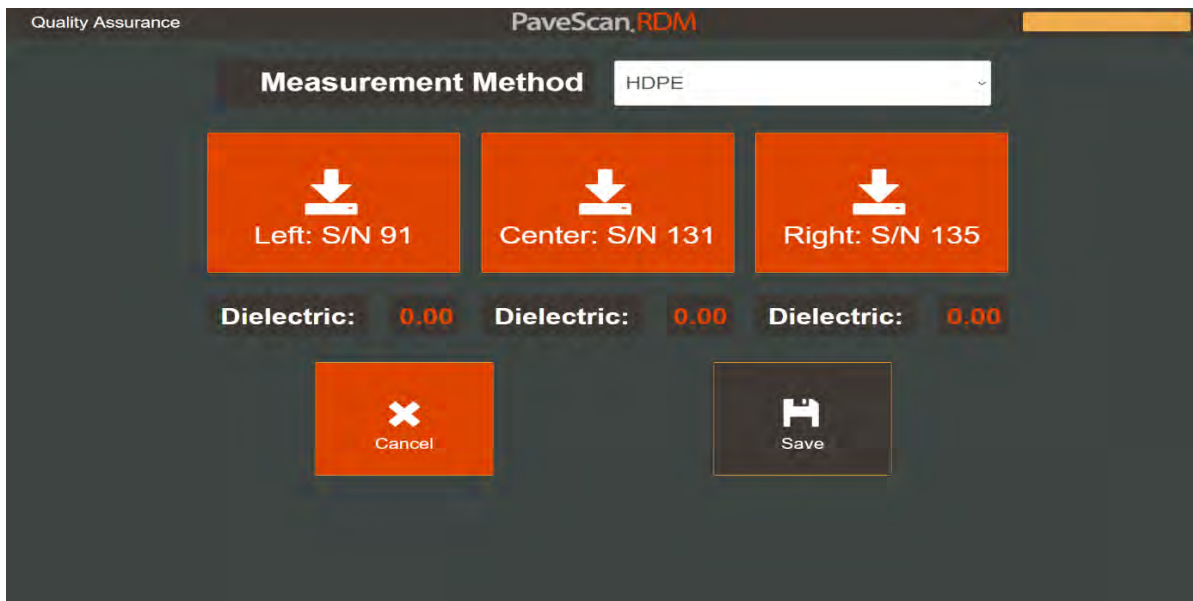
Grabbing the handle on the thin bar allows shrinking or enlarging an area. The area being viewed can then be shifted by placing the pointer (or touching) and dragging the shaded area left or right. Once the sensors are moved, the area changes back to the default data collection area.



When finished collecting a data file, press **Stop and Save**. This redirects the user back to the File Information web page where custom changes can be made to the file information before collecting the next file.

Quality Assurance

Pressing the green **Collect Data** button when Quality Assurance is selected as the measurement type and after calibration is completed redirects the user to the Quality Assurance Collect screen.



Measurement Method: Select the measurement method

- **HDPE:** Collects dielectric measurements with the sensor centered over a HDPE verification block. The user places a HDPE verification block underneath the desired antenna, then presses the red button corresponding to the sensor serial number. A measurement is collected, which takes about 10 seconds. Then the HDPE block is placed under a different sensor and the process is repeated until all sensors have been selected. HDPE dielectrics should typically range from 2.30 to 2.42. HDPE dielectrics differing significantly from this range (for example a dielectric of 2.0 or 2.5 or higher) indicate that there is a problem with either the air and metal plate calibration or the sensor.
- **Repeat Line:** Collects dielectric measurements along a line that is the same for each sensor. The user enters the distance to be measured, places one sensor at the beginning of the line, presses the red button corresponding to the sensor serial number, then proceeds to collect data along the line. The file is automatically closed when the specified collection distance is reached. Then the user places the next sensor at the beginning of the line, presses the red button corresponding to the sensor serial number, and moves it along the same line. The file will be closed when the specified distance is reached. This process is repeated for all sensors. Repeat line measurements can be used to correct for minor shifts in dielectrics that may occur during data collection. See Section 3.4 for details.
- **Swerve:** Simultaneously collects data from all three sensors. The user enters the distance to be measured, places the sensors at the beginning of the line to be measured, then presses any red button with a serial number. The measurements are recorded as the user performs the swerve until the specified distance has been reached, at which point the file is closed and the median dielectrics for each sensor are displayed. Swerve measurements can be used to correct for minor shifts in dielectrics that may occur during data collection. See Section 3.4 for details.
- **Custom Material:** Collects dielectric measurements with the sensor centered over a block of material with a known dielectric. When custom material is selected a line appears that permits the user to enter the known dielectric of the material. The user places the custom material block underneath the desired antenna, then presses the red button corresponding to the sensor serial number. A measurement is collected, which takes about 10 seconds. Then the custom material block is placed under a different sensor and the process is repeated until all sensors have been selected. The dielectrics from the custom material, assuming its dielectric is greater than 4.0, should vary between sensors by 0.1 or less. Custom material dielectrics differing significantly from this range indicate that there is a problem with either the air and metal plate calibration or the sensor.

Measured Distance: Distance over which the measurement will be made. This option appears when the Repeat Line or Swerve Measurement options are selected.

Core Measurement

Pressing the green **Collect Data** button when Core is selected as the measurement type and after calibration is completed redirects the user to the Core Collect screen. A core measurement is initiated by pressing the red button corresponding to the serial number of the sensor that is placed at the location of the core. After the measurement is completed, the dielectric appears below the red button that was pressed. Optionally, if there is a companion core (i.e. another nearby core for validation purposes), the user can then move the same sensor to the companion core location and press the same red button to obtain the dielectric at the companion core location. When the **Save** button is pressed, the dielectrics of the core and companion core (if obtained) are saved.

The screenshot shows the 'Core Collect' interface for PaveScan RDM 2.0. At the top, the 'Measurement Method' is set to 'Time'. Below this is a checkbox for 'Use Imported Core Locations'. The interface displays three core locations in a table-like format:

Core ID	Station	Lat. Offset
Core ID	10+50.00	2L
Left: S/N 91	Center: S/N 131	Right: S/N 135
Dielectric: 0.00	Dielectric: 0.00	Dielectric: 0.00
Companion Diel: 0.00	Companion Diel: 0.00	Companion Diel: 0.00

At the bottom of the screen, there are two buttons: 'Cancel' (with a red 'X' icon) and 'Save' (with a floppy disk icon).

Measurement Method: Select the measurement method

- **Time:** Collects dielectric measurements with the desired sensor centered over a core location. The measurement takes about 10 seconds. At the end of the measurement the dielectric appears below the red button that was pressed.
- **Distance:** Collects dielectric measurements over a distance of 6" (0.15 m). The user positions the desired antenna on one edge of the core location, presses the red button with the serial number corresponding to the antenna at the core location, then slowly pushes the antenna across the core surface area. The measurement automatically completes after 6" (0.15 m) is traversed and the core location dielectric appears below the red button that was pressed.

Use Imported Core Locations: Check this button to load a list of core locations imported for this project. See Appendix E for import details.

Core ID: the ID information associated with the core measurement. If the user checked the **Use Imported Core Locations** button, this will be a dropdown list of core ids. Otherwise, it is empty and needs to be filled in by the user.

Station: The station # corresponding to the core location.

Lat. Offset: The lateral offset of the core location relative to the reference line.

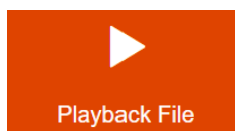
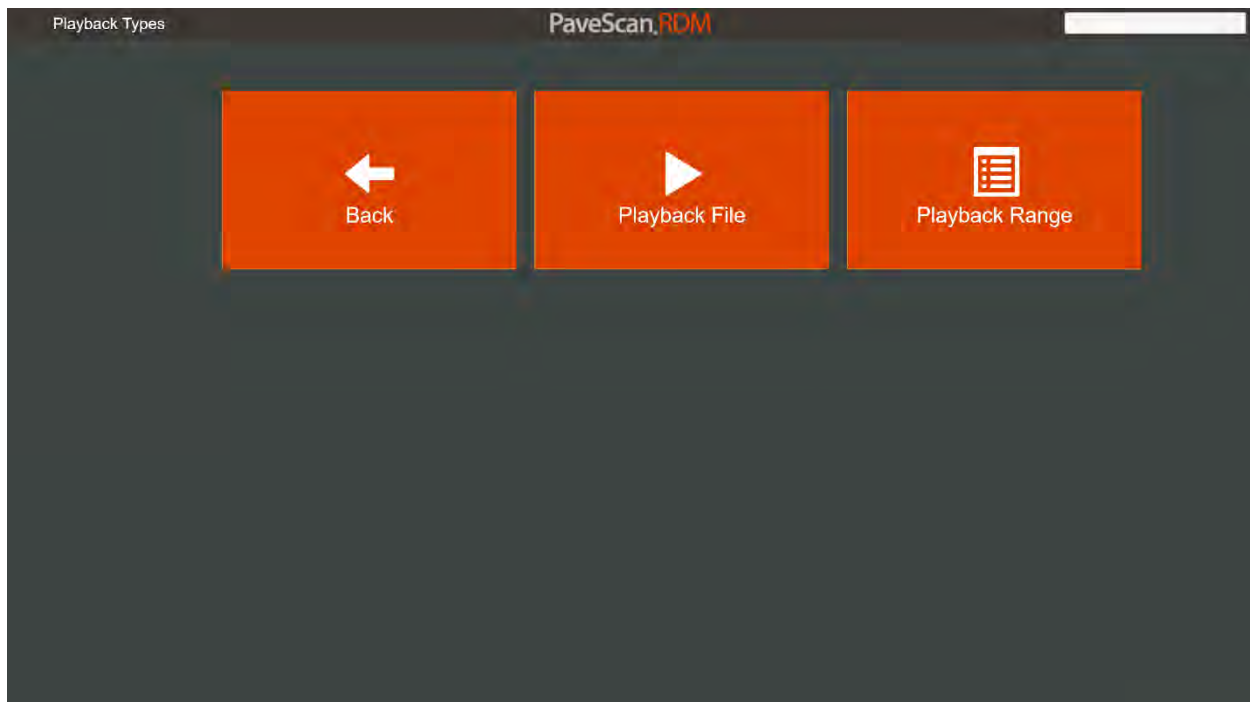
Chapter 3: Data Playback and Export

3.1: Playback and Review Collected Files

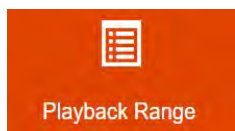
Playback and review previously collected data. To do this:

- 1** The most recent file in the current project can be played back from the File Information screen using **Playback Last**.
- 2** Any file can be played back by clicking on the **Playback** button from the Main Menu.

When accessing playback from the **Playback** button, a screen appears specifying to playback one file or a range. These options are described below.

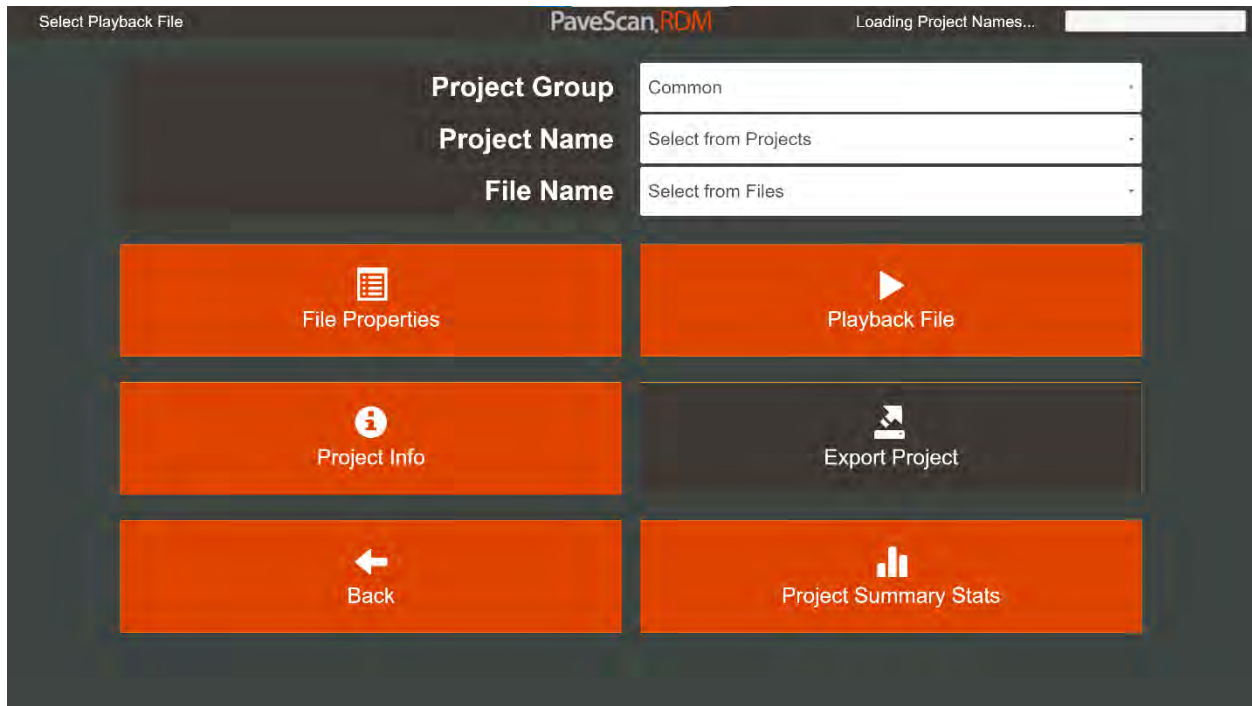


This plays back one user-selected file.



Displays a screen that allows a selection of different individual lines of data and specific distance ranges from one or more files that can then be displayed together and exported to a single file. See page 39.

The single file playback option screen, which accessed by pressing **Playback File** is shown below.



Select Playback Screen

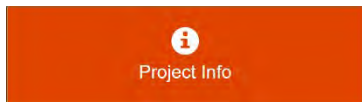
Select the desired Project and File from the dropdown lists, then press the **Playback File** button. Additional options in the Playback screen include:



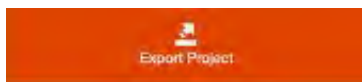
Allows user to edit file information such as starting distance, ending distance, and filename.



This plays back the selected file.



Shows the selected project information and allows the user to edit project information.



Allows user to export all files in the selected project folder.

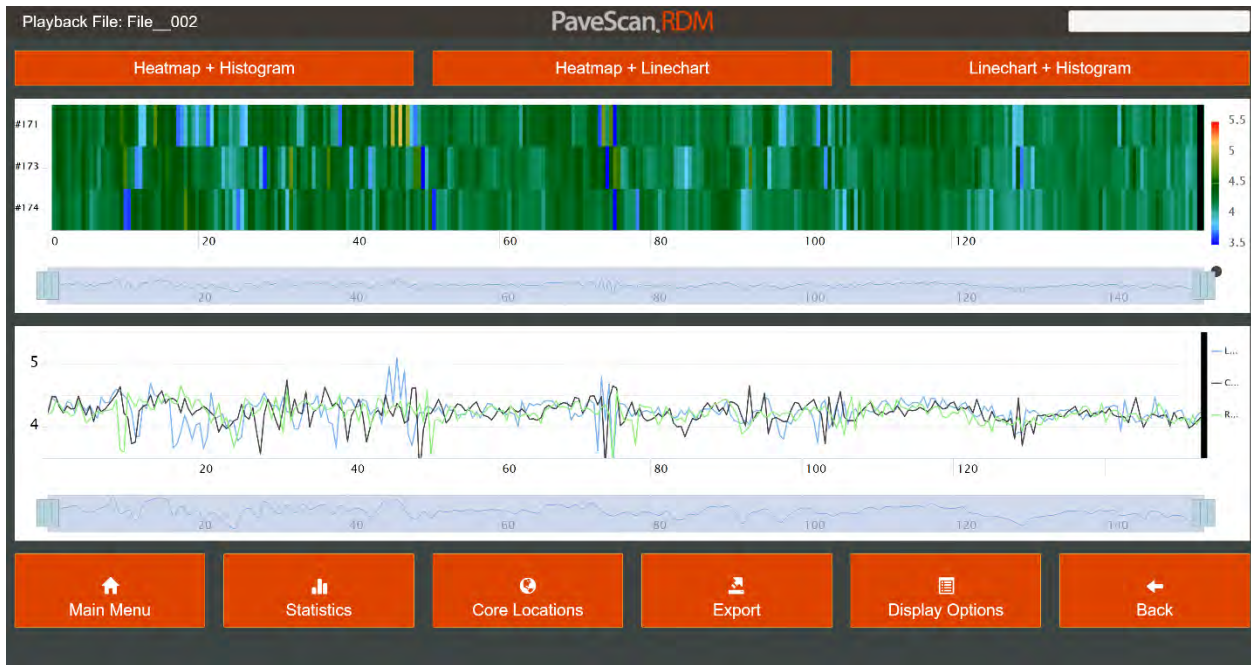


Displays PWL summary statistics from mat and joint measurements from entire project. See Appendix F for details.



Brings user back to the start-up screen which allows access to data collection and system settings.

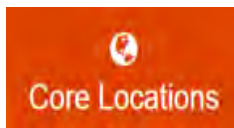
A played-back file is shown below.



Display start-up screen (Main Menu) which allows access to data collection, playback data and system settings.



Opens a screen which displays statistics related to the currently open file.



Locates High Dielectric, Mid Dielectric, and Low Dielectric areas in the current file that are suitable for obtaining cores used to generate a dielectric or compaction curve. The columns shown contain the following information:

The Core Locations screen is shown below. The first column, Relative Dielectric, has entries High, Medium, and Low. These entries correspond to how dielectric at the specific location relates to the average dielectric along the data file. For example, the dielectric at station 00+13.5 (distance 13.5) has a high dielectric relative to the average values in the file. Each picked location shown on the screen is obtained using a 6" (15cm) central moving average. The picked locations are also chosen where the lateral variation in dielectric is small to help minimize positioning errors when extracting a core. It is

highly recommended to collect core measurement at the exact location of the extracted core so that the measured dielectric is confidently tied to the core location. (see Section 2.5) This may require preselecting core locations using the screen below, then recollecting a core measurement at the exact location.

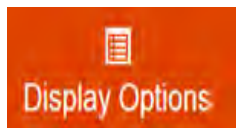
Relative Dielectric	Lateral Offset	Sensor Position	Serial #	Station	Distance	Latitude	Longitude	Di
High	2R	Right	165	00+13.5	13.5	43.01197776	-71.58123216	
High	2R	Right	165	00+88.7	88.7	43.01187986	-71.58148029	
High	2R	Right	165	00+43.1	43.1	43.0119393	-71.58133037	
Low	2R	Right	165	00+00.7	0.7	43.01199335	-71.58119016	
Low	2L	Left	167	00+24.6	24.6	43.01195365	-71.58126182	
Low	2L	Left	167	00+40.7	40.7	43.01193281	-71.58131554	
Medium	0	Center	160	00+32.8	32.8	43.01194774	-71.58129256	
Medium	0	Center	160	00+63.6	63.6	43.01190748	-71.5813941	

Number of Cores: 9

Back to File



Exports the data from the currently displayed file using the current display options.



This button accesses all the Display Options that can be adjusted during collection and playback.

Display Options Screen

Measurement Type: Selecting this option to display the desired measurement type. Different measurement units include: dielectric, percent voids, percent compaction, and density. In the screen above, dielectric is currently selected.

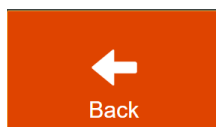
Note: The mix calibration must be specified in the project information to be able to display measurement values other than dielectric. Mix calibration numbers are accessible from **Mix Calibration** button in the Project Settings screen (see Section 2.3).

Maximum Value: The maximum measurement value shown in both the heatmap and line chart.

Minimum Value: The minimum measurement value shown in both the heatmap and line chart.

Display Moving Average: When this value is non-zero, a central moving average of the size specified is applied to each data point prior to display. For example, if a 0.5ft (20 cm) moving average is specified, each displayed data point is an average of all the data points at the measurement location $\pm 0.25\text{ft}$ ($\pm 10\text{ cm}$). For time-based files, the units of the moving average are seconds.

Display Distance Interval: The output interval between displayed measurements. For general purposes where data may be obtained over a distance of hundreds of feet, a display interval of 0.5ft (20 cm) is useful. For time-based files, the units of the display interval are seconds.



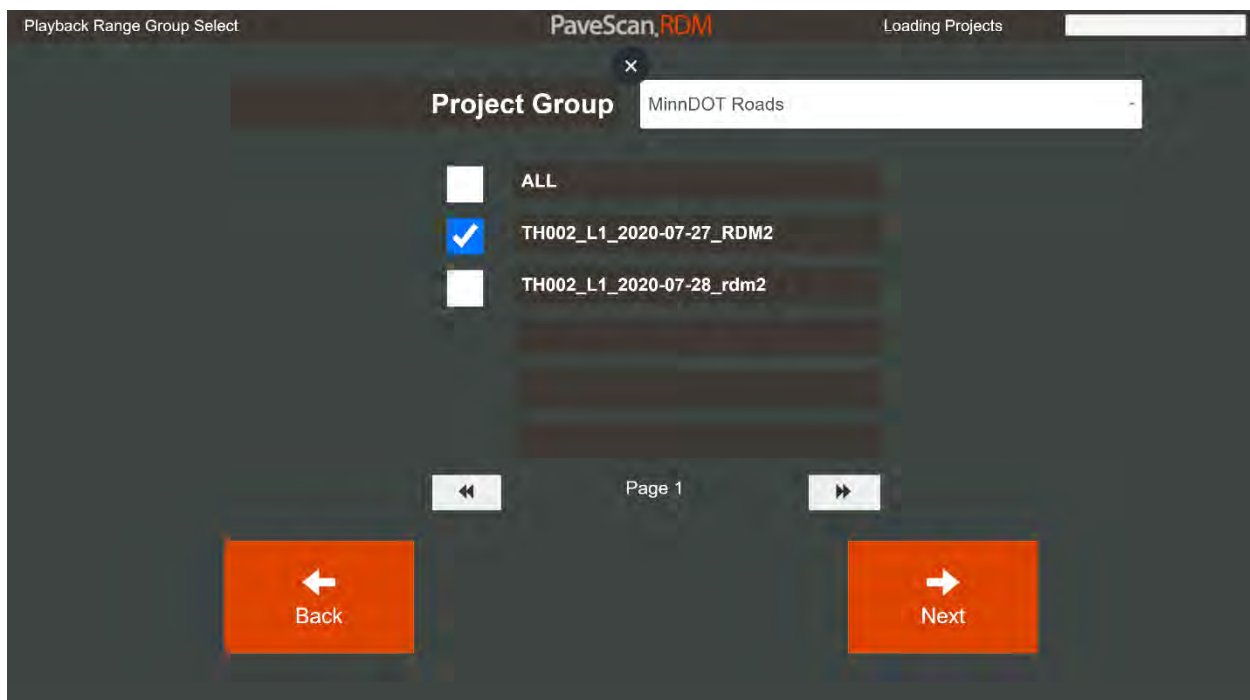
Return to the previous screen - either the File Information screen or the Playback screen to select a different playback file.



Playback Range

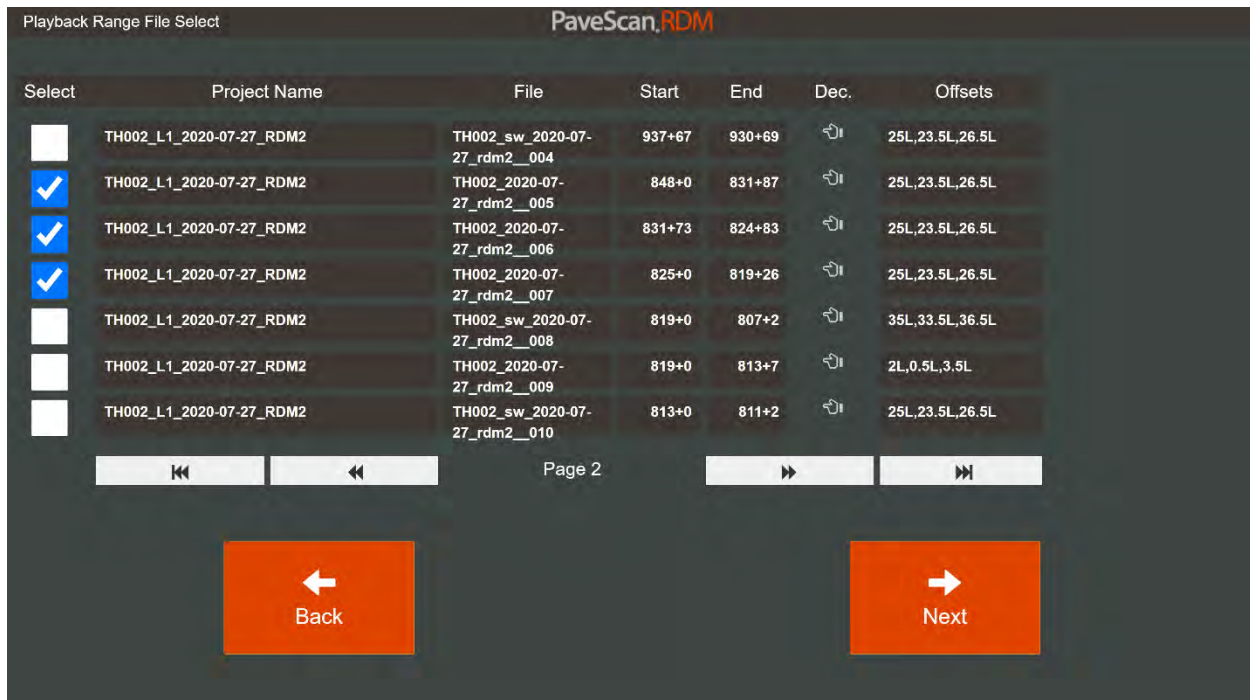
The Playback Range option, accessed by pressing **Playback Range** in the Playback Types screen, permits playing back and exporting selected portions of one or more files from one or more projects belonging to the same project group. For example, all the measurements from a selected Station (or distance) range associated with a specific lane could be quickly assembled, viewed, and exported. Other filters can also be applied, such as assembling measurements by lot, subplot, position in the lane (joint or mat), and by lift.

- 1 The first screen appearing after pressing the **Playback Range** button prompts you to select the Project Group and once the Project Group is selected, the projects that will be included in the range to be played back and/or exported. Below, the Project Group “MinnDOT Roads” has been selected and from that group, the project “Th002_L1_2020-7-28_rdm2.”



Playback Range Screen

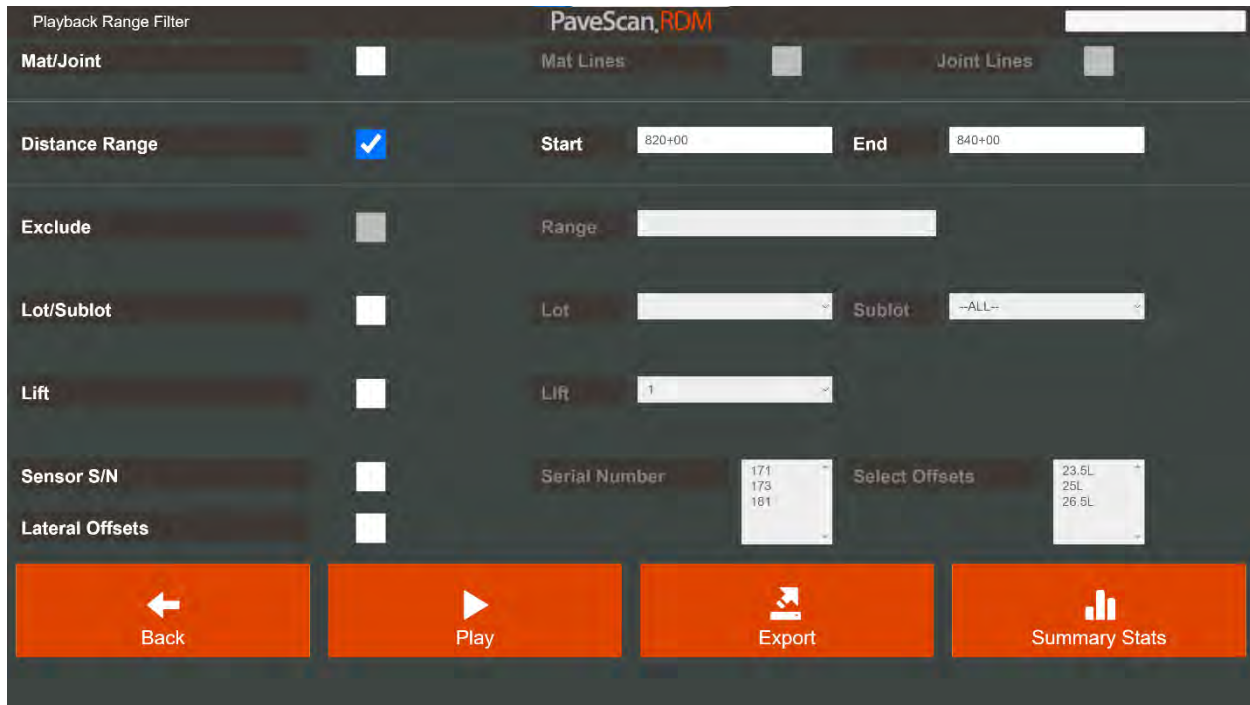
- 2 Once the project(s) have been selected, press the **Next** button. All the files associated with the selected project(s) appear along with their starting and ending distances and lateral offsets. You can choose to select all the files or only selected files. Once the file selection choice has been made, press the **Next** button to view and select filtering options.



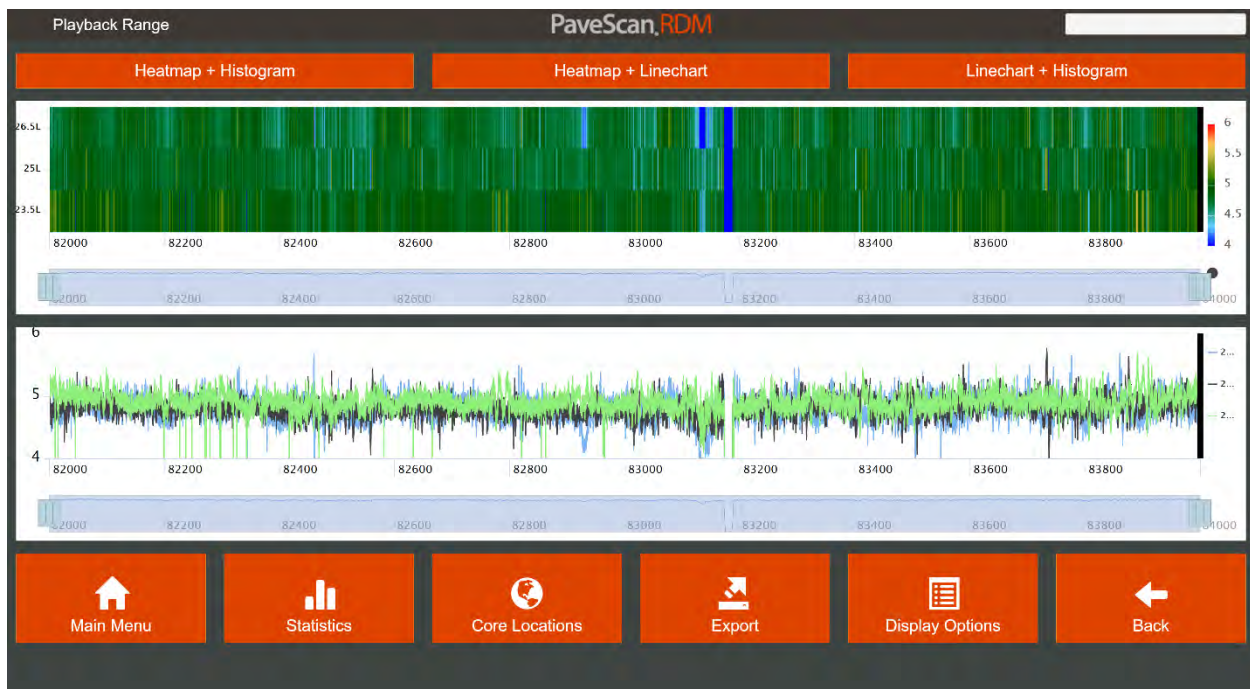
Filters: The filters are activated by checking the box next to each category. Below, for example, the Distance Range Filter has been checked and the station range 840+00 to 820+00 has been selected. Other filters can also be applied. For example, by checking the box next to “Lateral Offsets” you can select only the desired lateral offsets to view and within the selected distance range.

Mat and Joint Lines: Mat lines are classified as all measurements made beyond a minimum distance from joints. Conversely, joint lines are specified as measurements made within a specified distance from joints. The specified distances for mat and joint measurements are set in the Report Options screen. See Appendix F for details.

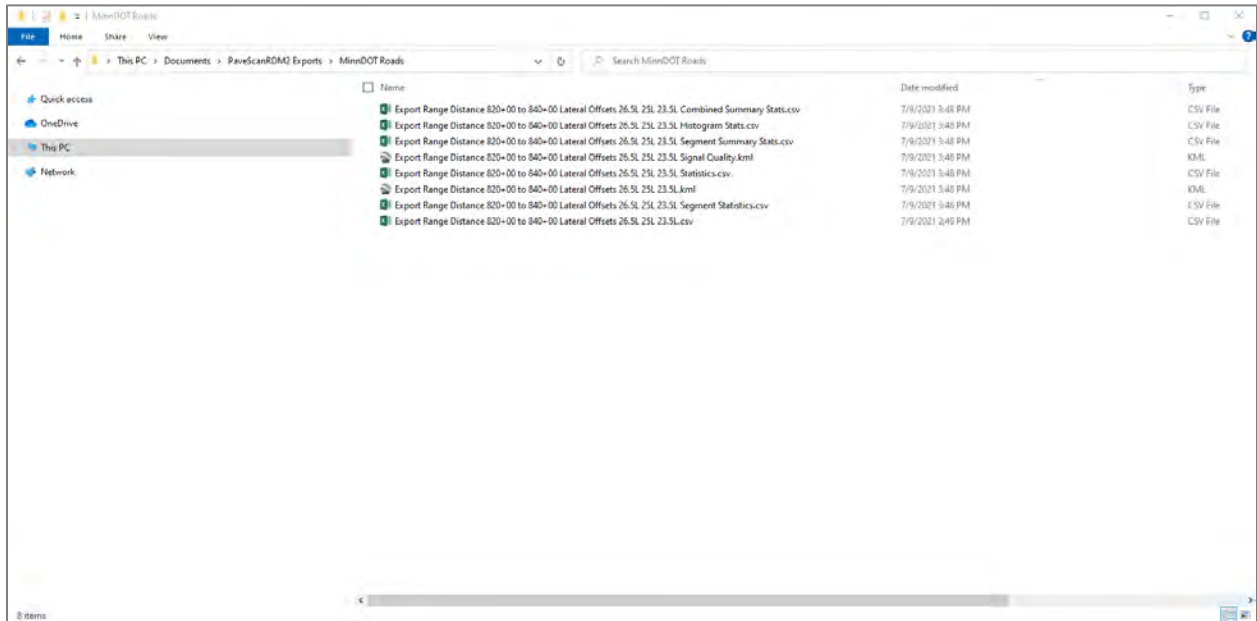
Exclude Filter: The Exclude filter option allows one or more specified subsets of distance ranges within the selected distance range to be excluded from the export. One example where this might be used is for cases where the road being paved extends over a bridge and the bridge compaction results are desired to be excluded from the statistics calculated from the exported range. The format used to exclude a distance range is a bit tricky and is currently only available for stationing formatted distances. Let’s say that there are two bridges within the stretch from 820+00 to 840+00 and the locations of these bridges are 829+50 to 831+00 and 834+25 to 836+10. To enter in these coordinates to be excluded, use the format start:stop, start:stop, etc.. where start is the starting station and stop is the ending station. The text to be entered on the Range line is: 829+50:831+00,834+25:836+10. This option is currently disabled, but will be available in a future PaveScan version.



- After completing the filter selections, press **Play** to playback the data or **Export** to export the data to CSV and KML files. Or, press **Summary Stats** to view the PWL statistics for the mat and joint measurements. The played back data appears in the same format as played back data files with all the associated options.



The export settings of the first project selected are used during the export process. Exported files are saved in a folder with the Project Group name. The files are named so that the exported distance range and lateral offsets are included for easy reference and identification. The folder and exported files from distance range selected in the above example is shown in Windows Explorer below. The Histogram Stats, Segment Summary Stats, and Combined Summary Stats files are calculated based on report option selections, which are described in Appendix F.



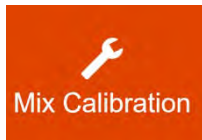
An example of the displayed Summary statistics is shown below. The statistics are calculated for the joint and mat data from each segment of each lane. At the bottom of the table is the mat and joint summary from all the mat and joint measurements in the selected playback range.

Summary Statistics PaveScan[®] RDM Statistics Loaded

Distance Range	Start Station	End Station	Min Lat Offset	Max Lat Offset	Mat PWL	Joint PWL	Mat Median	Joint Median	Mat St Dev	Joint St Dev
Segment	830+00	831+00	24L	36L	24.88	0	4.78	0	0.21	0
Segment	831+00	832+00	24L	36L	22.89	0	4.6	0	0.58	0
Segment	832+00	833+00	24L	36L	25.87	0	4.8	0	0.16	0
Segment	833+00	834+00	24L	36L	24.88	0	4.8	0	0.15	0
Segment	834+00	835+00	24L	36L	13.93	0	4.75	0	0.16	0
Segment	835+00	836+00	24L	36L	19.4	0	4.78	0	0.18	0
Segment	836+00	837+00	24L	36L	47.26	0	4.89	0	0.13	0
Segment	837+00	838+00	24L	36L	21.39	0	4.8	0	0.17	0
Segment	838+00	839+00	24L	36L	19.9	0	4.76	0	0.2	0
Segment	839+00	840+00	24L	36L	42.79	0	4.87	0	0.16	0
Total	820+00	840+00	12L	36L	21.92	49.25	4.79	4.9	0.19	0.15

←
Back

3.2: Setting Up the Void Percentage Relationship



The **Mix Calibration** button is located in System Settings.

- 1 Pressing the **Mix Calibration** button opens up a screen that shows the calibration options. There are multiple options for the Mix Calibration Equation. Analysis of a large database of mix calibrations has led to the preference for using a GSSI Calibration curve. The default equation is GSSI Curve 2. The details of the different mix calibration equations are presented in Appendix A.

The GSSI curves are very useful because they only require a single dielectric value, the Gmm Dielectric, to calculate the % Voids from a measured dielectric.

Mix Calibration	
Mix Calibration Filename	Select Calibration File
Mix Measurement Type	Percent Voids
Gmm Dielectric	Gmm Dielectric
Standard Dev.	Gmm Dielectric StDev
Gmm	Gmm
Mix Info	Mix Info
Mix Calibration Equation	GSSI Curves
GSSI Curve	Curve 2

Buttons at the bottom: Back, New Calibration, Calc from Meas., Export, Save.

- 2 Enter a previously-calculated Gmm Dielectric or press the **Calc from Meas.** button to calculate the Gmm dielectric from dielectrics and void percentage (or percent compaction or density) obtained from cores or gyratory-compacted samples using PaveScan MDM.

Mix Measurement Type: The core physical property that is to be correlated to dielectrics. Different options include: Percent Compaction, Percent Voids, and Density.

Gmm Dielectric: This value is the dielectric corresponding to the mix at 0% voids. Appears when the selected mix calibration equation is GSSI Curves.

Standard Dev.: The standard deviation of the Gmm Dielectric values calculated from each core or gyratory-compacted sample measurement. Appears when the selected mix calibration equation is GSSI Curves.

Gmm: “Gravity, mix maximum” which is the maximum specific gravity of the mix. The maximum specific gravity is measured without any air voids in the mix. This value is necessary when converting from % Voids or %Compaction to density and visa-versa.

Mix Info: An optional field for entering in mix information, such as an ID or mix name.

Mix Calibration Equation: There are three types of core calibration equations: GSSI Curves, Straight Line, and Exponential. One of the GSSI Curves is preferred for numerous reasons. See Appendix A for details.

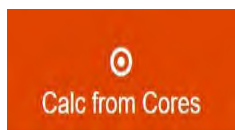
GSSI Curve: The GSSI equation used to calculate the Gmm Dielectric. There are two options “Curve 1” and “Curve 2.” The curves are very similar. Curve 2 is the default option.

Other Options that Appear when the User Chooses a Mix Calibration Equation other than GSSI Curves.

A Value: This is the first value used in the equation relating dielectric to another physical property. Appears when the selected mix calibration equation is *not* GSSI Curves. (see Appendix A for details)

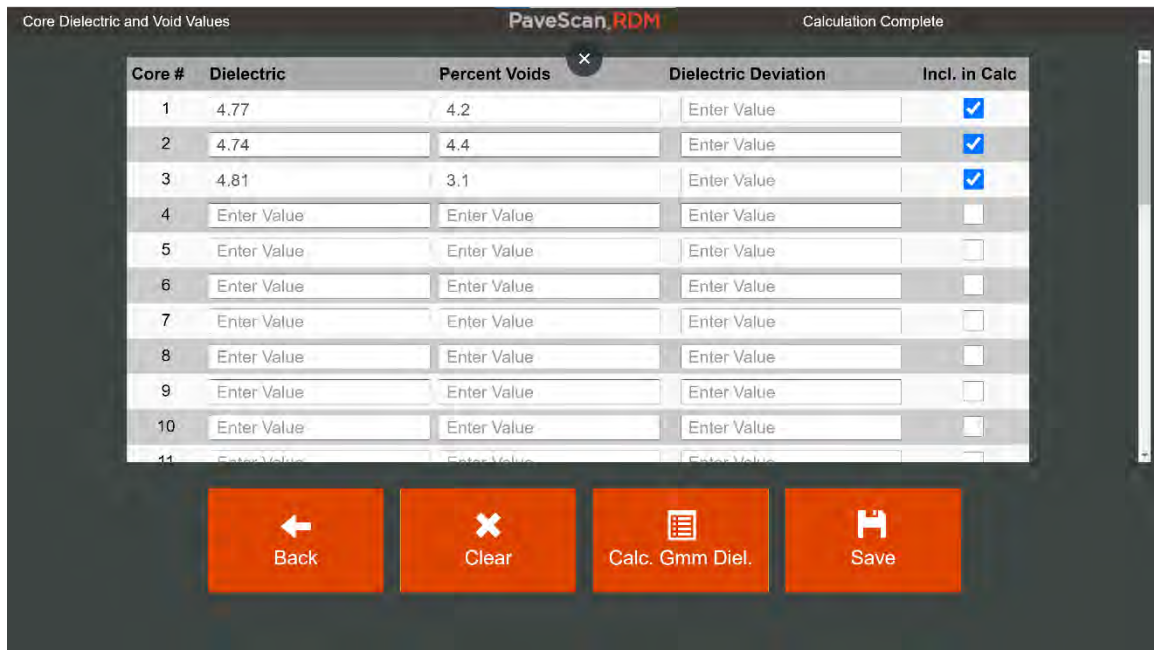
B Value: This is the second value used in the equation relating dielectric to another physical property. Appears when the selected mix calibration equation is *not* GSSI Curves. (see appendix A for details)

R-Squared Fit: This is for information purposes-only and is auto-generated when **Calc from Cores** is selected. It provides a good indication of confidence level that the calculated equation is useful. Values less than 0.6 – 0.7 lead to low confidence levels. Appears when the selected mix calibration equation is *not* GSSI Curves.



Press this button to automatically generate the calibration equation relating the desired physical property to dielectrics. A screen is displayed to enter in the core-measured values and corresponding dielectric values.

- 1** In the screen that appears enter in the dielectrics and corresponding core-measured physical property (i.e. % Voids, %Compaction, Density) from up to 30 cores. Make sure you check the checkbox on the right side to include the values in the calculation, then press the **Calc. GMM Diel** button.



- 2 The calculated values are returned in a pop-up screen. Press the **Save** button to transfer the values back to the Mix Calibration screen when the **Back** button is pressed.
- 3 Note, pay close attention to the calculated Dielectric Deviation in each row. If one or more pair of Dielectric, Percent Voids has a dielectric deviation much greater than the other values, then it is likely an outlier and some consideration should be given to unchecking the “Incl in Calc” box(es) and recalculating the Gmm Dielectric.

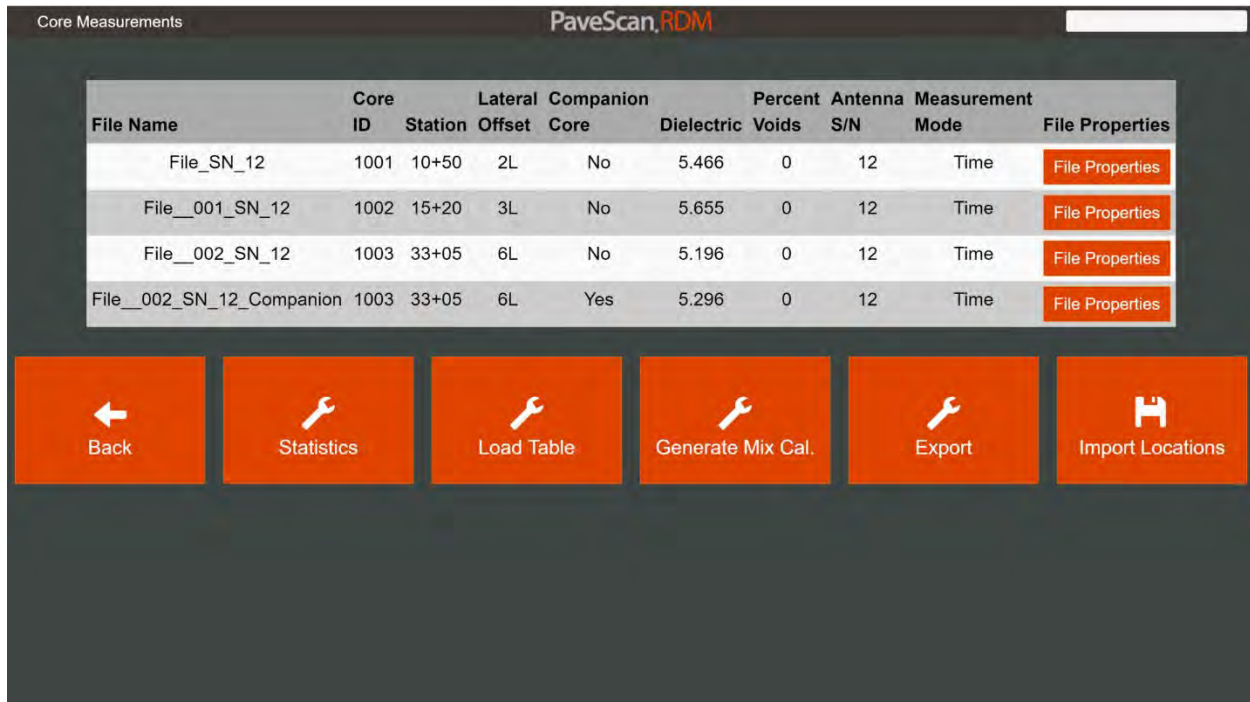
- 4 After returning to the Mix Calibration screen, to save the Gmm Dielectric and Standard Deviation values with the project, press the **Save** button. These values are used to calculate the physical property (i.e. %voids, compaction or density) from the dielectric values when the option is selected in the Display Options screen. Exported data can also contain the physical property value once core calibration is completed.



Press the **Export** button to export the mix calibration to a CSV file. The exported filename is the name entered for the mix. The exported mix files are located in the PaveScanRDM2 Exports subfolder “Core Calibrations.”

3.3: Accessing Core Measurements

Once a project is created, the **Core Meas.** button appears in the Project Info screen when it is accessed from the Playback screen.



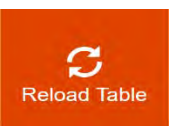
The screen shows all the collected core along with their companion core measurements. Each measurement’s file properties are accessible and editable by pressing the **File Properties** button in the same row as the measurement. One important file property that can be entered after the measurement is made is the “Percent Voids.” This information can then be used to generate a mix calibration (see section 3.1). Below, the function of each one of the buttons is described.



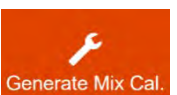
Navigates back to the Project Info Screen



File statistics associated with each measurement. These are the same statistics as for field measurements (see Section 3.1).



Press this button to reload the core measurement values from the files that were used to collect them. Normally it is not necessary to press this button, but it is necessary for cases where the user deletes a core file.



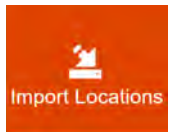
This takes all the core dielectrics and associated percent voids and sends them to the Core Calibration screen for the purpose of generating a calibration file (See Section 3.2).



Exports all the core measurements to a CSV file. An example exported file is shown below.

FileName	Core ID	Distance (ft)	Station	Lateral Offset (ft)	Measurement Mode	Company	Antenna Serial Number	Dielectric	Voids	Percent	CalcPerce	Ave. Height (in)	Median	Ave. Sig. Quality	Ave. Noise Level	Median DCNormA	Ave. Latitude	Ave. Longitude	Temp Cal Num	Total Time (Sec.)	Flapped Time Since Metal Plate Cal (Hours)	File Start Date: Comment
coreone_sn_327	1	0	00+00	0	Distance	FALSE	327	5.095	0	7.95	9.416	24.5	97	0.014	1.001	42.33391995	-72.68005466	69.48	4.9	0.37	2021-11-04	core 1
coreone_sn_327_Companio	1	0	00+00	0	Distance	TRUE	327	5.084	0	7.89	9.42	24.5	97	0.016	1.001	42.33392022	-72.68005457	69.48	1.3	0.37	2021-11-04	core 1
coreone_001_sn_161	1	0	00+00	0	Distance	FALSE	161	5.114	0	2.55	9.644	22.5	97	0.018	1.005	42.33392125	-72.68004897	113.18	3.6	0.41	2021-11-04	core 1 center
coreone_001_sn_161_Com	1	0	00+00	0	Distance	TRUE	161	5.143	0	2.24	9.652	22.5	97	0.018	1.004	42.33392115	-72.68004908	113.18	3.3	0.42	2021-11-04	core 1 center
coreone_002_sn_285	1	0	00+00	0	Distance	FALSE	285	4.979	0	8.88	9.14	26.25	97	0.02	1.013	42.333892	-72.68004187	80	2.2	0.44	2021-11-04	core 1 right
coreone_002_sn_285_Com	1	0	00+00	0	Distance	TRUE	285	5.001	0	8.75	9.143	26.25	97	0.018	1.013	42.33392036	-72.68004222	80	2.1	0.44	2021-11-04	core 1 right
coreone_003_sn_327	1	0	00+00	0	Time	FALSE	327	5.089	0	8.08	9.332	24.25	96	0.022	1.004	42.3339187	-72.6800858	69.48	13.6	0.44	2021-11-04	core 1 left
coreone_003_sn_327_Com	1	0	00+00	0	Time	TRUE	327	5.056	0	8.19	9.37	24.25	97	0.018	1.004	42.33391858	-72.68008529	69.48	11	0.44	2021-11-04	core 1 left
coreone_004_sn_161	1	0	00+00	0	Time	FALSE	161	5.133	0	7.34	9.637	22.5	96	0.025	1.005	42.33391931	-72.68005313	113.18	23.6	0.46	2021-11-04	core 1 center
coreone_004_sn_161_Com	1	0	00+00	0	Time	TRUE	161	5.135	0	7.33	9.637	22.5	96	0.021	1.005	42.33391927	-72.68005099	113.18	10.4	0.47	2021-11-04	core 1 center
coreone_005_sn_285	1	0	00+00	0	Time	FALSE	285	5.023	0	8.62	9.139	26.25	97	0.017	1.013	42.33391971	-72.68004321	80	5.3	0.49	2021-11-04	core 1 right
coreone_005_sn_285_Com	1	0	00+00	0	Time	TRUE	285	5.024	0	8.6	9.135	26.25	97	0.018	1.013	42.33391977	-72.68004313	80	5.3	0.49	2021-11-04	core 1 right
coreone_006_sn_327	2	0	00+00	0	Distance	FALSE	327	5.341	0	5.09	9.275	23.75	93	0.028	1.003	42.33393151	-72.68043771	69.48	20.8	0.5	2021-11-04	core 2 left
coreone_006_sn_327_Com	2	0	00+00	0	Distance	TRUE	327	5.35	0	4.91	9.381	23.75	94	0.036	1.005	42.33393206	-72.68043756	69.48	9.3	0.51	2021-11-04	core 2 left
coreone_007_sn_161	2	0	00+00	0	Distance	FALSE	161	5.44	0	1.6	9.266	22	89	0.046	1.006	42.33393431	-72.68042984	113.18	2.7	0.53	2021-11-04	core 2 center
coreone_007_sn_161_Com	2	0	00+00	0	Distance	TRUE	161	5.476	0	3.64	9.572	21.75	94	0.033	1.006	42.33393501	-72.68042998	113.18	2.6	0.54	2021-11-04	core 2 center
coreone_008_sn_285	2	0	00+00	0	Distance	FALSE	285	5.259	0	6.02	9.02	25.5	94	0.034	1.015	42.33393584	-72.68042301	80	2.7	0.56	2021-11-04	core 2 right
coreone_008_sn_285_Com	2	0	00+00	0	Distance	TRUE	285	5.256	0	5.67	9.014	25.5	93	0.028	1.016	42.33393562	-72.68042295	80	2.3	0.56	2021-11-04	core 2 right
coreone_009_sn_327	2	0	00+00	0	Time	FALSE	327	5.357	0	4.81	9.289	24.5	94	0.033	1.004	42.33393929	-72.68043817	69.48	15.1	0.55	2021-11-04	core 2 left
coreone_009_sn_327_Com	2	0	00+00	0	Time	TRUE	327	5.358	0	4.81	9.296	24.5	95	0.028	1.004	42.33393934	-72.68043837	69.48	10.5	0.55	2021-11-04	core 2 left
coreone_010_sn_161	2	0	00+00	0	Time	FALSE	161	5.486	0	3.35	9.561	22	94	0.033	1.006	42.33393267	-72.68043047	113.18	18.1	0.57	2021-11-04	core 2 center
coreone_011_sn_285	2	0	00+00	0	Time	FALSE	285	5.294	0	5.5	9.044	25.5	95	0.029	1.016	42.33393241	-72.68042291	80	5.3	0.6	2021-11-04	core 2 right
coreone_011_sn_285_Com	2	0	00+00	0	Time	TRUE	285	5.298	0	5.44	9.05	25.5	96	0.025	1.015	42.33393231	-72.68042299	80	5.3	0.6	2021-11-04	core 2 right

The file is exported to the exported project folder name and is named with the project name followed by “Core Measurements.” So, for example, if the project name was “NH93,” then the exported file name would be “NH93 Core Measurements.csv”



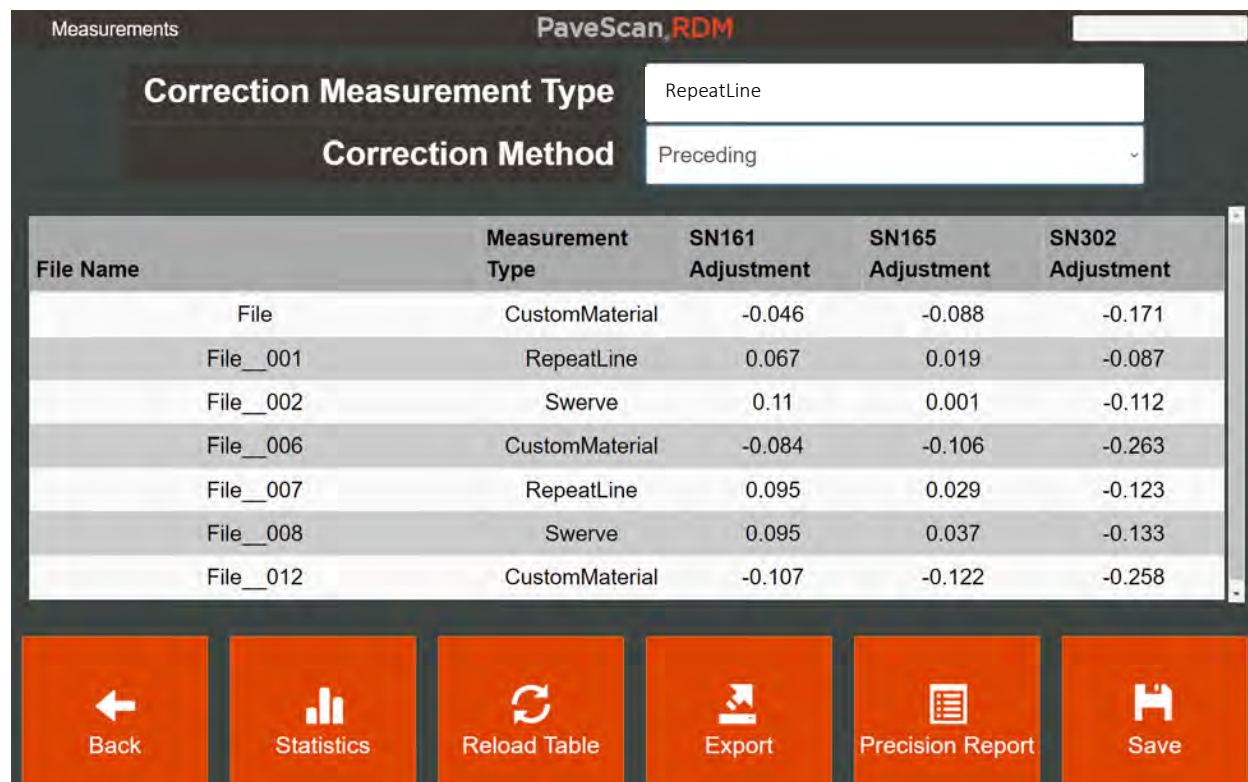
Pressing this button loads the file “Core Locations.csv” from a thumb-drive inserted into the USB drive of the ToughPad. The file is loaded into the current project. The “CoreLocations.csv” file contains a list of pre-selected core locations that can automatically be loaded into the Core Collect Screen (See Section 2.5.2). The format of the “CoreLocations.csv” file is described in Appendix E.

3.4: Accessing Quality Assurance Measurements

Once a project is created, go to Playback, select a project, then press **Project Info**.

Once in the Project Info screen, press **Properties**.

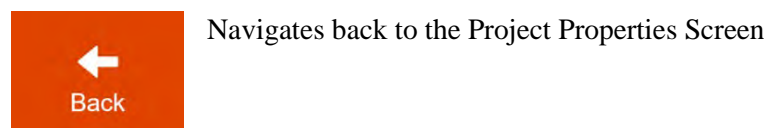
On the Project Properties screen that appears, press **QA Options**. This will bring you to the QA Measurements screen.



The measurements screen shows all Quality Assurance measurements in the project, allows you to change the dielectric correction approach and provides a few other options accessible from buttons on the bottom of the screen. A description of all the options follows.

Correction Measurement Type: If a dielectric correction is to be applied to the data (which is a checkbox option in the Project Properties screen), the specified measurement type will be used to perform the correction. The options are RepeatLine, Swerve, and Custom Material.

Correction Method: For cases where more than one QA measurement is made in a project, there are options for how these measurements will be applied. The options include: (1) First QA Measurement, (2) Preceding, (3) Average of 2 preceding, (4) Average of 3 preceding, and (5) Last QA Measurement.





File statistics associated with each measurement. These are the same statistics as for field measurements (see Section 3.1).



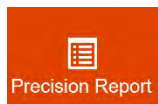
Press this button to reload the quality assurance measurement values from the files that were used to collect them. Normally it is not necessary to press this button, but it is necessary for cases where the user deletes a quality assurance file.



Exports all the quality assurance measurements to a CSV file. An example exported file is shown below.

FileName	Measurement Method	Antenna Serial Number	Dielectric Correction
File_006	HDPE	160	0.009
File_006	HDPE	165	0
File_006	HDPE	167	-0.009
File_009	HDPE	160	0.008
File_009	HDPE	165	-0.002
File_009	HDPE	167	-0.006
File_014	RepeatLine	160	0.038
File_014	RepeatLine	165	-0.023
File_014	RepeatLine	167	-0.014
File_015	RepeatLine	160	0.067
File_015	RepeatLine	165	-0.051
File_015	RepeatLine	167	-0.017
File_017	Swerve	160	0.052
File_017	Swerve	165	-0.031
File_017	Swerve	167	-0.022
File_018	Swerve	160	0.041
File_018	Swerve	165	-0.033
File_018	Swerve	167	-0.009

The file is exported to the exported project folder name and is named with the project name followed by “QA Measurements.” So, for example, if the project name was “NH93,” then the exported file name would be “NH93 QA Measurements.csv.”



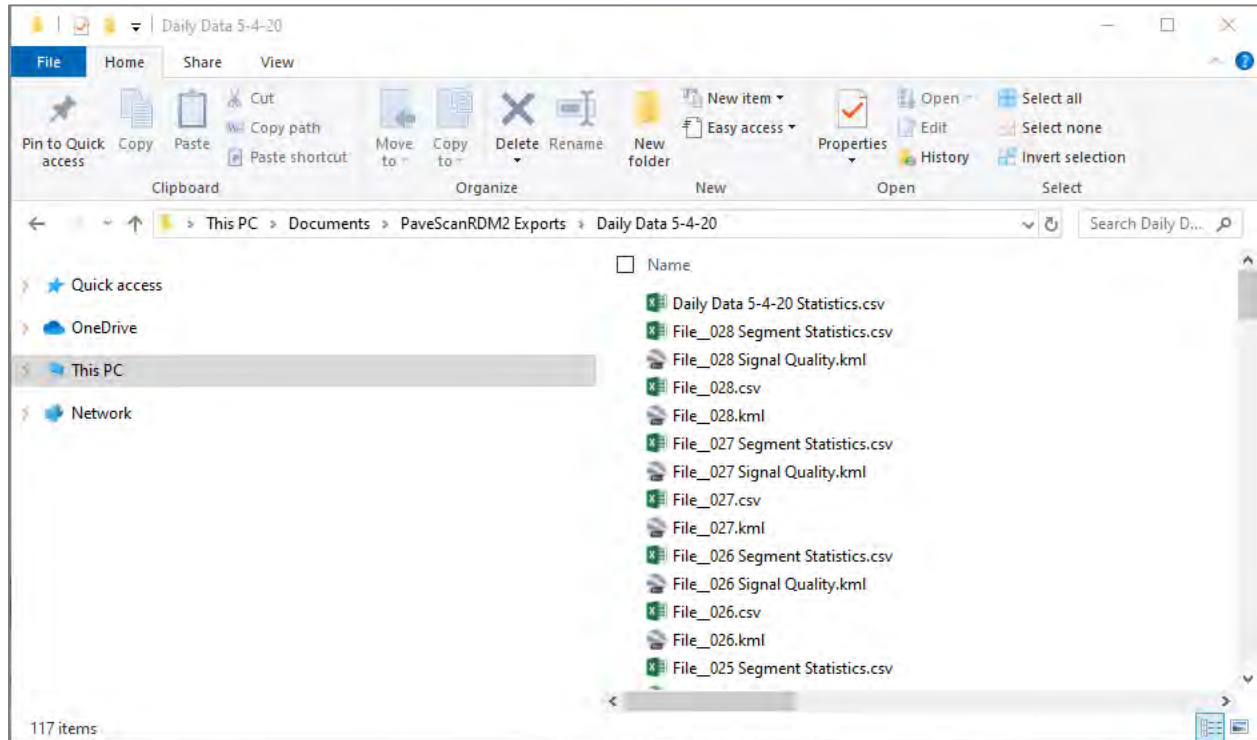
Calculates precision statistics from QA files. See Appendix H for details.



Saves the selected Corrected Measurement Type and Correction Method.

3.5: Exporting Collected Files

When files are exported, a folder with the same name as the project is created in the **PaveScanRDM2 Exports** folder. The exported data is saved in this subfolder. The name of the file is the same as the filename with **Exported Data** appended to the end. Below, the file **“File__028”** belonging to the project **Daily Data 5-4-20** has been exported.



The exported file is an ASCII file containing a number of header lines, containing project and file information, followed by the exported data. The exported data consists of comma separated values. Skipping exporting the header lines can be done by deselecting the Use Extended Header option in the Export Settings screen (which is accessed from the Project Properties screen). A portion of a typical exported file is shown below.

23	Distance (Time (Sec.))	Station (ft)	Latitude	Longitude	Elevation (LateralOff	Dielectric	Dielectric	NoiseLeve	Height (in)	SerialNum	NormDCAI	SensorTen	TimeStam	MPCalTim	UserMark	
24	0	1.52	0	43.01200091	-71.58120728	106	0	5.193	5.193	0.007	25.8	160	1.004	28.75	420422.5	421319.8	0
25	0	1.52	0	43.01200091	-71.58121476	106	2R	5.24	5.24	0.006	24.2	165	0.999	29.5	420422.5	421301.3	0
26	0	1.51	0	43.01200091	-71.58119981	106	2L	5.341	5.341	0.007	24.9	167	1.001	27.5	420422.5	421343.2	0
27	0.1	1.64	0	43.01199921	-71.58120728	105.98	0	5.491	5.491	0.007	25.8	160	1.002	28.75	420422.6	421319.8	0
28	0.1	1.65	0	43.01199921	-71.58121476	105.98	2R	4.327	4.327	0.006	24.1	165	0.998	29.5	420422.6	421301.3	0
29	0.1	1.64	0	43.01199921	-71.58119981	105.98	2L	5.25	5.25	0.008	24.8	167	1.002	27.5	420422.6	421343.2	0
30	0.2	1.74	0	43.01199498	-71.58120728	105.92	0	4.686	4.686	0.006	25.8	160	1.002	28.75	420422.7	421319.8	0
31	0.2	1.76	0	43.01199498	-71.58121476	105.92	2R	4.202	4.202	0.006	23.8	165	1	29.5	420422.7	421301.3	0
32	0.2	1.74	0	43.01199498	-71.58119981	105.92	2L	4.282	4.282	0.006	24.6	167	0.999	27.5	420422.7	421343.2	0
33	0.3	1.84	0	43.01199328	-71.58120728	105.9	0	4.235	4.235	0.006	25.6	160	1.001	28.75	420422.8	421319.8	0
34	0.3	1.86	0	43.01199328	-71.58121476	105.9	2R	4.414	4.414	0.007	24	165	0.998	29.5	420422.8	421301.3	0
35	0.3	1.84	0	43.01199328	-71.58119981	105.9	2L	4.214	4.214	0.007	24.4	167	1	27.5	420422.8	421343.2	0

The default columns order of the exported file depends on if stationing is used for position and how many sensors are used during data collection. See Appendix D for details on how to customize the exported columns. The column details are below

Time: Time in seconds since the start of the file. This field only appears when files are collected in time mode.

Distance: Distance corresponding to measurement from the starting distance of the file.

Station: Station# corresponding to measurement. Only appears when Station option is checked in project properties.

The following columns appear for each sensor used during data collection:

Longitude: Longitude of measurement from GPS in decimal degrees.

Latitude: Latitude of measurement from GPS in decimal degrees.

Elevation: Elevation of measurement in meters.

Lateral Offset: Lateral offset of sensor from the Lateral Reference (e.g. curb, centerline ...).

Measurement Name: Depends on the display option, either dielectric, % Voids, % Compaction, Density.

Dielectric: Dielectric value of exported measurement.

Noise Level: A measure the signal-to-noise in the data. Higher noise levels indicate more potential interference from outside sources.

Height: Height of the bottom of the sensor above the asphalt surface.

Normalized Amplitude: Used to assess the change in signal amplitude over time. This is used for data quality assessment.

Sensor Temp: Temperature of electronics inside sensor. This is used for data quality assessment.

Signal Quality: The quality of the portion of the signal used to calculate the dielectric. The portion of the signal used is from the asphalt surface reflection. Maximum value is 100. Values greater than 95 are typical. Values less than 90 indicate poor signal quality that is most often associated with external interference from other RF and/or Microwave transmitters.

Time Stamp: Time Stamp, in seconds, associated with measurement

MPCal Time Stamp: Time Stamp of Metal Plate calibration measurement used to calculate the dielectric.

All the files in a project are exported and a project statistics file is created when the **Export Project** button is pressed from the Select Playback File screen.

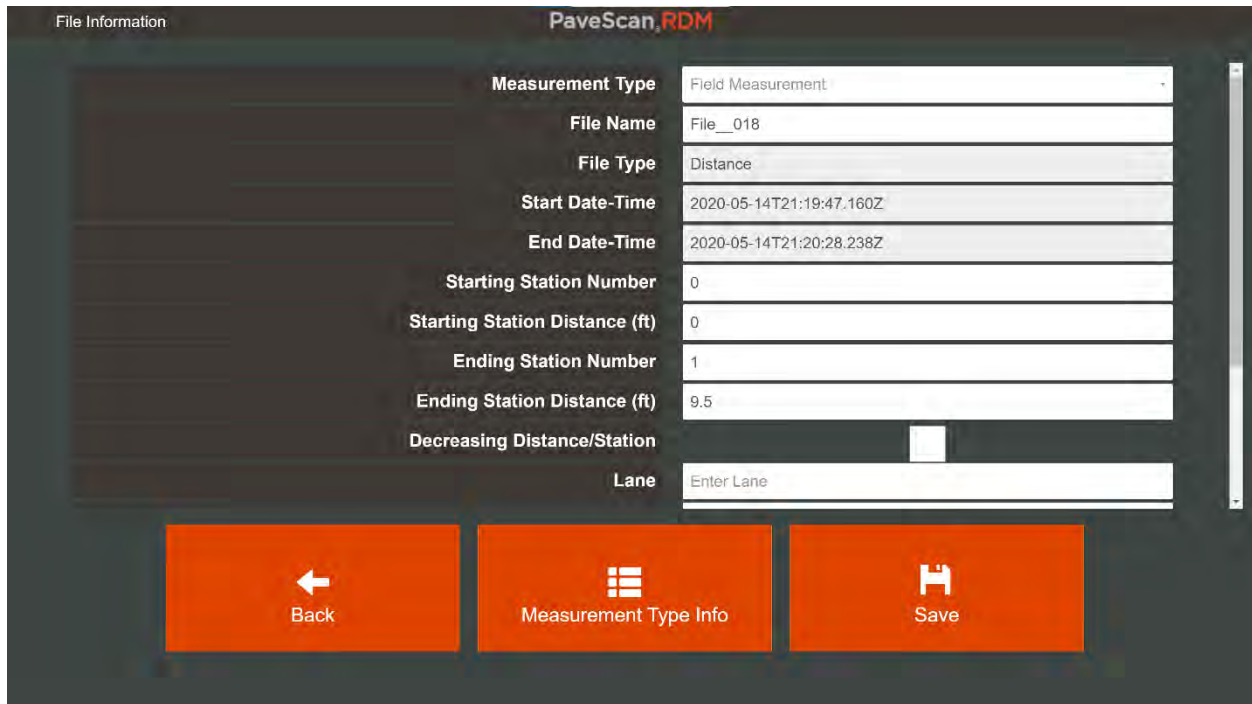
1	Filename	Lateral Offset (f)	Sensor Ser	Total Time	Start Dista	End Distan	Ave. Diele	Median Di	Min. Diele	Max. Diele	St.Dev. Di	Histogram	Ave. Noise	Max. Nois	File Comments	Start Date-Time	Elapsed Tim
2	File_010	0	160	0	0	100.1	4.6	4.6	4.19	5.2	0.1	4.44	0.007	0.018	Line - SN165	2020-05-04T20:17:12.	0
3	File_010	2R	165	0	0	100.1	4.64	4.64	3.95	5.38	0.16	4.4	0.007	0.032	Line - SN165	2020-05-04T20:17:12.	0
4	File_010	2L	167	0	0	100.1	4.7	4.7	4.22	5.45	0.12	4.51	0.007	0.01	Line - SN165	2020-05-04T20:17:12.	0
5	File_011	0	160	0	0	100.1	4.6	4.6	4	5.38	0.11	4.43	0.007	0.027	Line - SN165	2020-05-04T20:23:44.	0
6	File_011	2R	165	0	0	100.1	4.65	4.64	3.32	5.55	0.17	4.41	0.007	0.069	Line - SN165	2020-05-04T20:23:44.	0
7	File_011	2L	167	0	0	100.1	4.7	4.7	4.23	5.49	0.12	4.52	0.007	0.012	Line - SN165	2020-05-04T20:23:44.	0
8	File_012	0	160	0	0	100.2	4.57	4.56	3.9	5.58	0.16	4.34	0.007	0.035	Line - SN160	2020-05-04T20:25:48.	0
9	File_012	2R	165	0	0	100.2	4.68	4.68	4.2	5.07	0.11	4.5	0.007	0.034	Line - SN160	2020-05-04T20:25:48.	0
10	File_012	2L	167	0	0	100.2	4.68	4.68	4.19	5.39	0.11	4.5	0.007	0.026	Line - SN160	2020-05-04T20:25:48.	0
11	File_013	0	160	0	0	100.2	4.58	4.57	3.85	5.47	0.16	4.35	0.007	0.011	Line - SN160	2020-05-04T20:27:49.	0
12	File_013	2R	165	0	0	100.2	4.69	4.69	4.16	4.98	0.11	4.51	0.007	0.011	Line - SN160	2020-05-04T20:27:49.	0
13	File_013	2L	167	0	0	100.2	4.68	4.68	4.22	5.5	0.11	4.5	0.007	0.01	Line - SN160	2020-05-04T20:27:49.	0
14	File_014	0	160	0	0	100.2	4.59	4.59	4.24	4.96	0.11	4.41	0.007	0.024	Line - SN167	2020-05-04T20:38:22.	0
15	File_014	2R	165	0	0	100.2	4.69	4.68	4	5.38	0.11	4.53	0.007	0.011	Line - SN167	2020-05-04T20:38:22.	0
16	File_014	2L	167	0	0	100.2	4.64	4.63	4.14	5.52	0.16	4.38	0.007	0.025	Line - SN167	2020-05-04T20:38:22.	0
17	File_015	0	160	0	0	100.2	4.57	4.57	4.22	5.38	0.11	4.4	0.007	0.01	Line - SN167	2020-05-04T20:41:00.	0
18	File_015	2R	165	0	0	100.2	4.68	4.68	4.05	5.45	0.11	4.52	0.007	0.011	Line - SN167	2020-05-04T20:41:00.	0
19	File_015	2L	167	0	0	100.2	4.64	4.63	4.13	5.48	0.16	4.4	0.007	0.01	Line - SN167	2020-05-04T20:41:00.	0
20	File_016	0	160	0	100	-0.4	4.61	4.61	4.15	5.67	0.1	4.46	0.007	0.016	Line - Decrease	2020-05-04T20:44:37.	0
21	File_016	2R	165	0	100	-0.4	4.64	4.64	4.11	5.45	0.12	4.46	0.007	0.011	Line - Decrease	2020-05-04T20:44:37.	0
22	File_016	2L	167	0	100	-0.4	4.69	4.69	4.03	5.63	0.12	4.51	0.007	0.009	Line - Decrease	2020-05-04T20:44:37.	0
23	File_017	0	160	0	0	106.4	4.59	4.59	3.92	5.49	0.13	4.38	0.007	0.029	Swerve - West	2020-05-04T20:47:00.	0

In addition, there is a separate file containing statistics over specified distance ranges when the Provide Segment Statistics option in the Export Options screen is checked. A segment statistics file is shown below. The output segment interval selected for the file was 100 ft.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Lateral Offset (ft)	Start Distance (ft)	End Distance (ft)	Ave. Dielectric	Median Dielectric	Min. Dielectric	Max. Dielectric	St.Dev. Dielectric	Histogram 5% Dielectric	Ave. Noise Level	Max. Noise Level	
2	1L	0	99.96	4.18	4.22	1.36	5.73	0.29	3.7	0.01	0.036	
3	1L	99.96	199.92	4.13	4.14	3.27	5.02	0.16	3.91	0.009	0.039	
4	1L	199.92	246.9	4.2	4.2	3.14	4.63	0.15	3.99	0.012	0.037	
5	0	0	99.96	4.26	4.19	3	14.89	0.7	3.87	0.009	0.03	
6	0	99.96	199.92	4.2	4.09	3	17.51	1.11	3.84	0.009	0.02	
7	0	199.92	246.9	4.29	4.19	3.31	17.26	1.08	3.95	0.011	0.029	
8	1R	0	99.96	4.25	4.25	3.03	5.63	0.23	3.92	0.009	0.034	
9	1R	99.96	199.92	4.17	4.18	3.13	4.97	0.14	3.95	0.009	0.024	
10	1R	199.92	246.9	4.12	4.1	3.58	4.93	0.19	3.9	0.011	0.023	
11												

3.6: Accessing and Editing File Properties

Once a file has been collected, its properties can be viewed and edited by selecting the file in the “Select Playback File” screen, then pressing **File Properties**. An example file is shown below.



The screen shows file properties that are common to all measurement types. Specific Measurement Type info is accessible by pressing the **Measurement Type Info** button. For example, for a Core Measurement Type the following appears:

The screenshot shows the 'Measurement Type Info' form in the PaveScan RDM application. The form is set for a 'Core' measurement. The fields are as follows:

Measurement Type	Core
Core ID	Enter Core ID
Percent Voids	Enter Percent Voids
Companion Core Measurement	<input type="checkbox"/>
Antenna S/N	160
Include With Field Measurements	<input checked="" type="checkbox"/>

At the bottom of the form are two orange buttons: 'Cancel' (with a white 'X' icon) and 'Save' (with a white floppy disk icon).

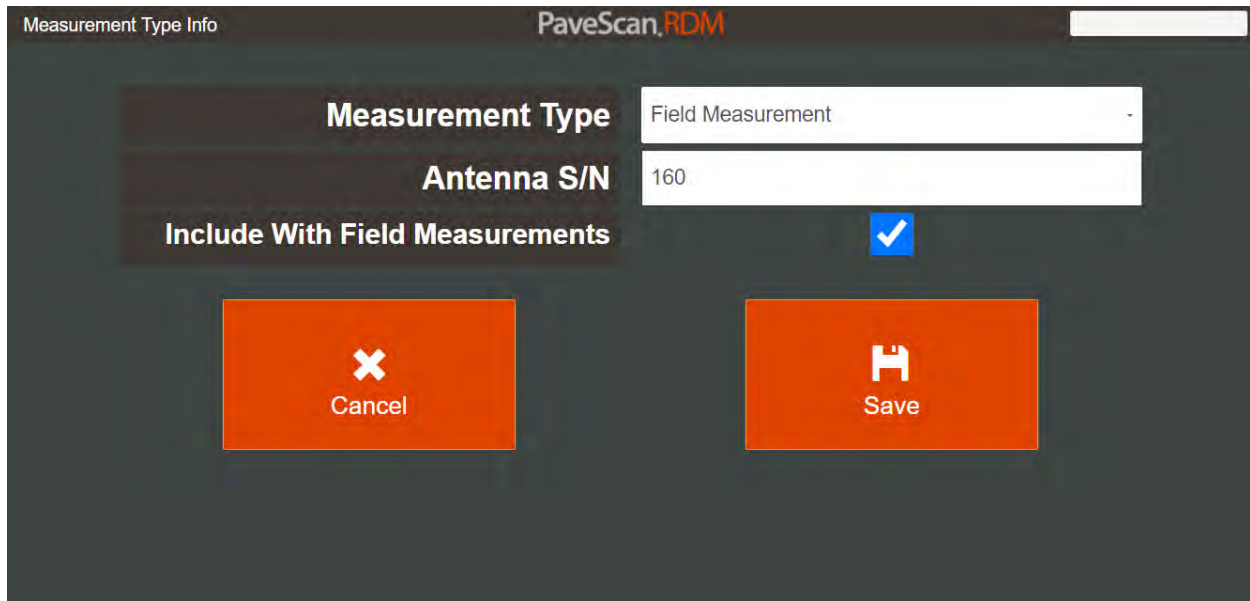
For Quality Assurance the following options are available:

The screenshot shows the 'Measurement Type Info' form in the PaveScan RDM application, configured for a 'Quality Assurance' measurement. The fields are as follows:

Measurement Type	Quality Assurance
Measurement Method	Swerve
Antenna S/N	160
Include With Field Measurements	<input checked="" type="checkbox"/>

At the bottom of the form are two orange buttons: 'Cancel' (with a white 'X' icon) and 'Save' (with a white floppy disk icon).

And, for Field Measurements:



The screenshot shows a dark-themed dialog box titled "Measurement Type Info" with the "PaveScan.RDM" logo in the top right. It contains three input fields: "Measurement Type" with the value "Field Measurement", "Antenna S/N" with the value "160", and a checked checkbox for "Include With Field Measurements". At the bottom, there are two orange buttons: "Cancel" with a white 'X' icon and "Save" with a white floppy disk icon.

The ability to change the measurement type of a file permits some forward compatibility for projects that were collected before these features became available. When changing the measurement type, and then accessing the Core Measurements or Quality Assurance screens, you will need to press the **Load Table** button to reload the measurements. This forces the changed file to be added to the existing measurement list or removed, depending on the Measurement Type selection.

Playback Range exported files are exported to the project folder and are also exported in a segment statistics file when the Segment Statistics option in the Export Options screen is checked.

If GPS position information is available, the automatically-created Google Earth KML file will show the exported values corresponding to the GPS coordinates in Google Earth. The KML file is located in the same folder as the exported data. The display range of the values and value type (i.e., dielectric or compaction) in the KML file is the same display range used for Playback. So, what you see in playback is what you get when you export the data to a KML file.

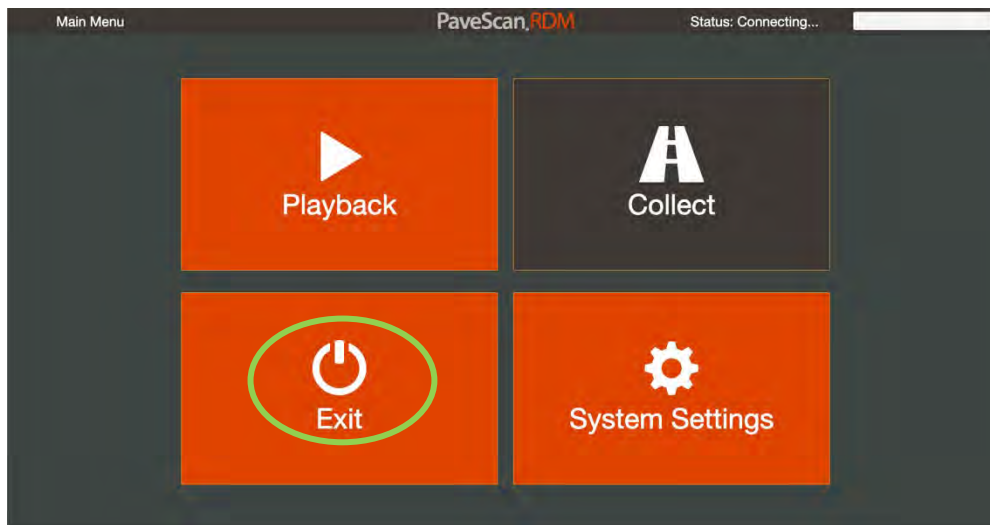
Once the data is exported onto the ToughPad, this data can be transferred to a USB drive using the port on the right side of the tablet.

Chapter 4: System Shutdown and Updates

In Chapter 4, steps for reviewing shutting down the system after data collection are listed. Steps for updating the PaveScan RDM with the latest software package are also listed.

4.1: System Shutdown

The application is shutdown from the **Exit** button that is accessed by in the Main Menu. The application screen closes, and the screen desktop appears.



The final step is to press the power button on the concentrator box to power-down the sensors.

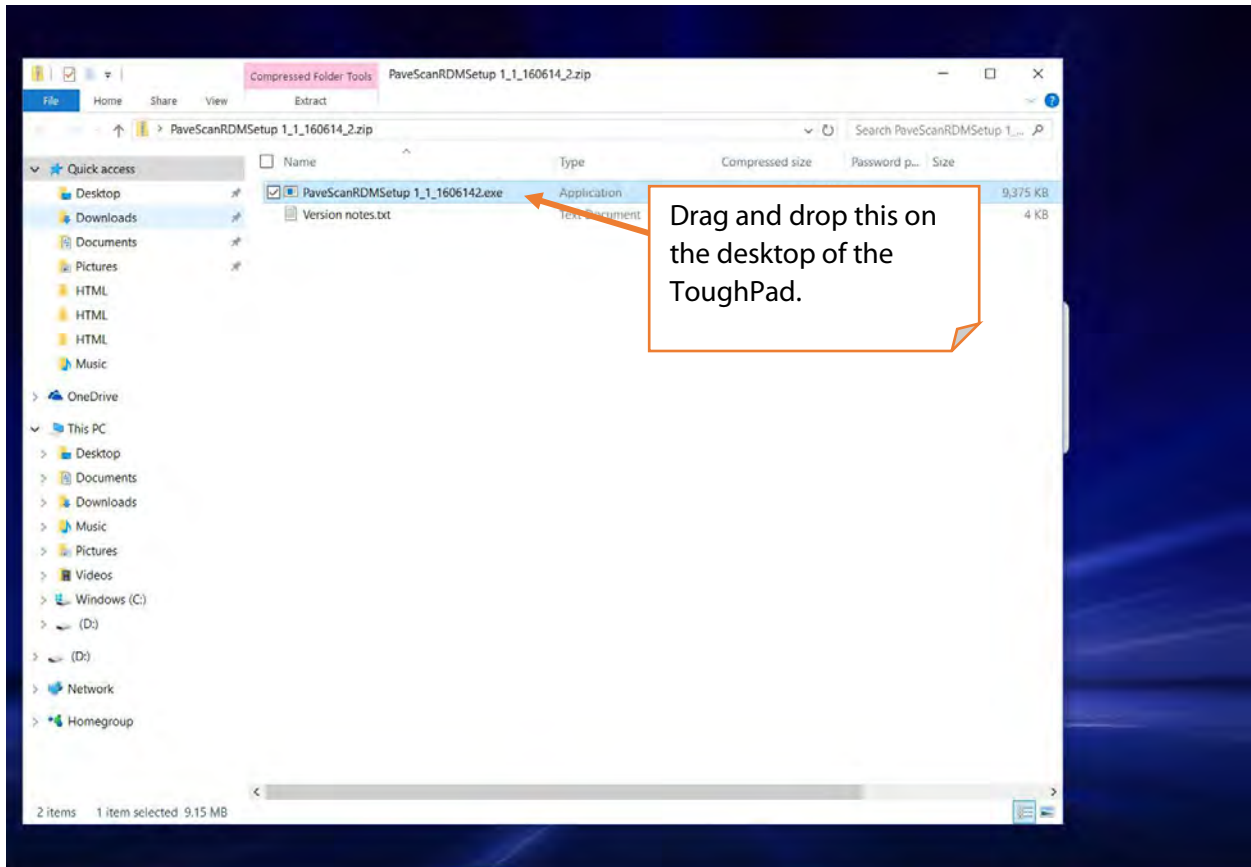


Press this button to turn off power to sensors.

4.2: Software Updates

The RDM application is updated from time to time to add features and fix issues. The new software can be downloaded from the Resources section at <https://www.geophysical.com> in the form of a .ZIP file.

- 1 Open Windows Explorer, locate the Zipped folder, click on it and a setup file (has a .EXE extension) is displayed on the right pane of the Windows Explorer screen.



- 2 Drag and drop this folder onto the Windows desktop.
- 3 After this is done, double-click on the Setup file icon on the desktop to start the installation of the new application version. It automatically removes the older version before installing the new version during the setup process.

Troubleshooting

1 Is it OK to connect and disconnect the sensors when the power is on?

Yes and No: No physical damage is done. However, if sensors are disconnected or connected when the application is running on the Touchpads, a restart of the entire system should be done (i.e., sensors, application, and webpages) because the application may become confused.

2 What should I do if not all the sensors are recognized when I start the system?

Restart the entire system. To do this, shutdown the application and power-off the sensors. Follow the start-up procedure described in Section 2.1. If one or more sensors are still not recognized, check all the connections and retry. ss attempts may be required.

3 Why don't I see any data when I collect files in distance mode?

Is the DMI cable attached to a sensor with the survey wheel connector on the side? If not, attach it.

Is the Apply Valid Data Range checkbox in the Project Properties screen checked? If so, are the proper Valid Range values set (see Appendix C)? If the values are outside the actual range of values, no data will appear on the screen.

Appendix A – Calculation of % Voids, % Compaction, or Density from Dielectric

There are three equation types that currently can be used in the PaveScan RDM to calculate another physical property, such as % Voids, % Density, or Compaction from Dielectric: (1) GSSI Curves; (2) linear equation, and (3) exponential equation. A significant amount of data now exists from a wide range of pavements to critically examine the merits of each equation type. These data include the dielectric values and % voids of cores and gyratory-compacted samples.

There three key advantages to using a GSSI curve compared to the linear and exponential equations. First, the GSSI curve equation incorporates a single dielectric value. This value is the theoretical dielectric of the asphalt at zero percent voids. This is effectively the “Gmm dielectric.” Using this approach, for each asphalt mix possessing a Gmm value, there is a corresponding Gmm dielectric. Changes in the Gmm of a mix are usually reflected in the Gmm dielectric. So, by tracking the Gmm dielectric, it is also possible to predict changes in the Gmm of the mix.

Second, a GSSI Curve equation can be obtained from a single core or gyratory-compacted sample. This means that the, often difficult, task of obtaining cores or gyratory-compacted samples over a wide range of dielectrics can be avoided. There is some variability in the mix and the measurements of dielectric and % voids from one core or gyratory-compacted sample to the next. So, it is recommended that at least 3 cores or gyratory samples be used to generate the Gmm dielectric. These 3 samples can be at any level of compaction, even the same level of compaction.

Third, it is easy to distinguish if there are cores or pucks that possess dielectrics or % voids that are outside acceptable bounds. This is because a Gmm dielectric is calculated for each core or gyratory-compacted sample, and each of these Gmm dielectric values should, in theory be identical. Cores or gyratory samples with Gmm dielectrics significantly different than the group average can be eliminated from the calculation and put aside for forensic analysis.

There are two GSSI Curve equations that provide very similar results. The linear and exponential equations take the form shown in Equations (3) and (4), respectively.

$$PV = A + B\epsilon_m \quad \text{Equation (3)}$$

$$PV = Ae^{B\epsilon_m} \quad \text{Equation (4)}$$

Where:

PV = Percent Voids;

A = value obtained from least-squares fit exponential or linear curve of PV versus dielectric calculated from a number of calibration cores or gyratory-compacted samples;

B = value obtained from least-squares fit exponential or linear curve of PV versus dielectric calculated from a number of calibration cores; and

ϵ_m = measured dielectric.

The linear and exponential equations are included to provide backward compatibility.

NOTE: It is possible to load existing calibration files and convert linear and exponential equations into a GSSI Curve equation.

Appendix B – Choosing the Correct Lateral Offset

The PaveScan RDM system is designed to view all data looking up-station, which is increasing distance. Paving direction and collection direction are irrelevant. This must be kept in mind when configuring the system regarding referring to the direction of the Lateral Offset side. This is done to remove all relative information and display all data as an actual one-way direction.

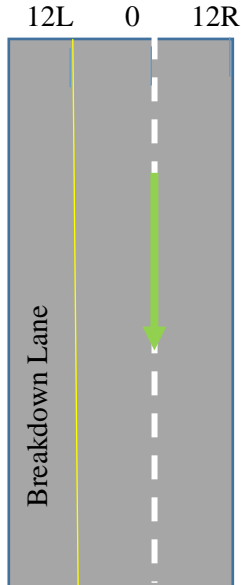
Choosing a Reference Line

Facing the direction of increasing distance, choose a reference line that all the measurements can be associated with. Enter this for the “Reference Line” in project info. This reference must be used for the entire project.

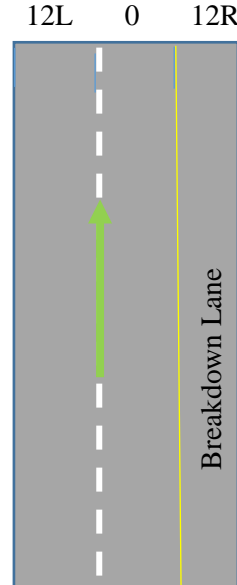
Choosing a Lateral Offset for a File

During collection of a file, the distance to choose for the lateral offset should be the distance from the lateral offset reference to the center of the cart.

The Lateral Offset direction is the position (left or right) of the cart relative to the reference line when facing the increasing distance direction.



Southbound (decreasing distance)
Breakdown lane is on “Left Side”



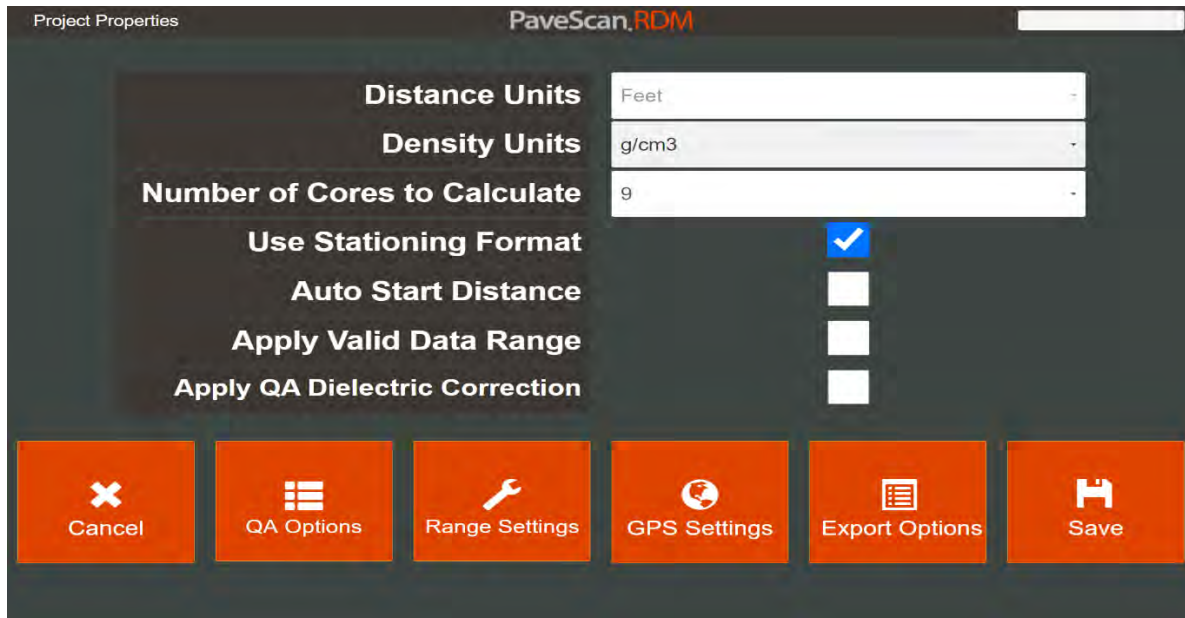
Northbound (increasing distance)
Breakdown lane is on “Right Side”

In the figures above, the Reference line is the center line (dotted white line) between the travel and passing lanes, denoted by “0.” The green arrow indicates the direction of vehicle travel. In the left figure the joint between the breakdown lane and the travel lane (yellow line) has a lateral offset of 12L for the southbound figure and 12R for the northbound figure.

Appendix C – Valid Data Range

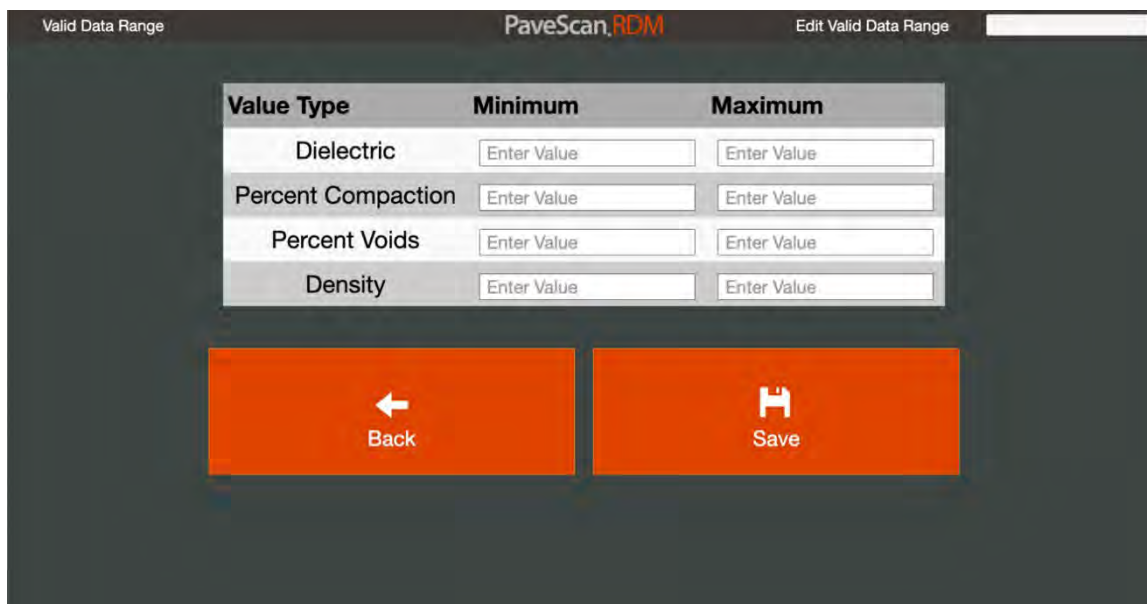
Valid Data Range

This option is found in the Project Properties as a new checkbox “Apply Valid Data Range.” When this option is checked, a pre-selected value range is used.

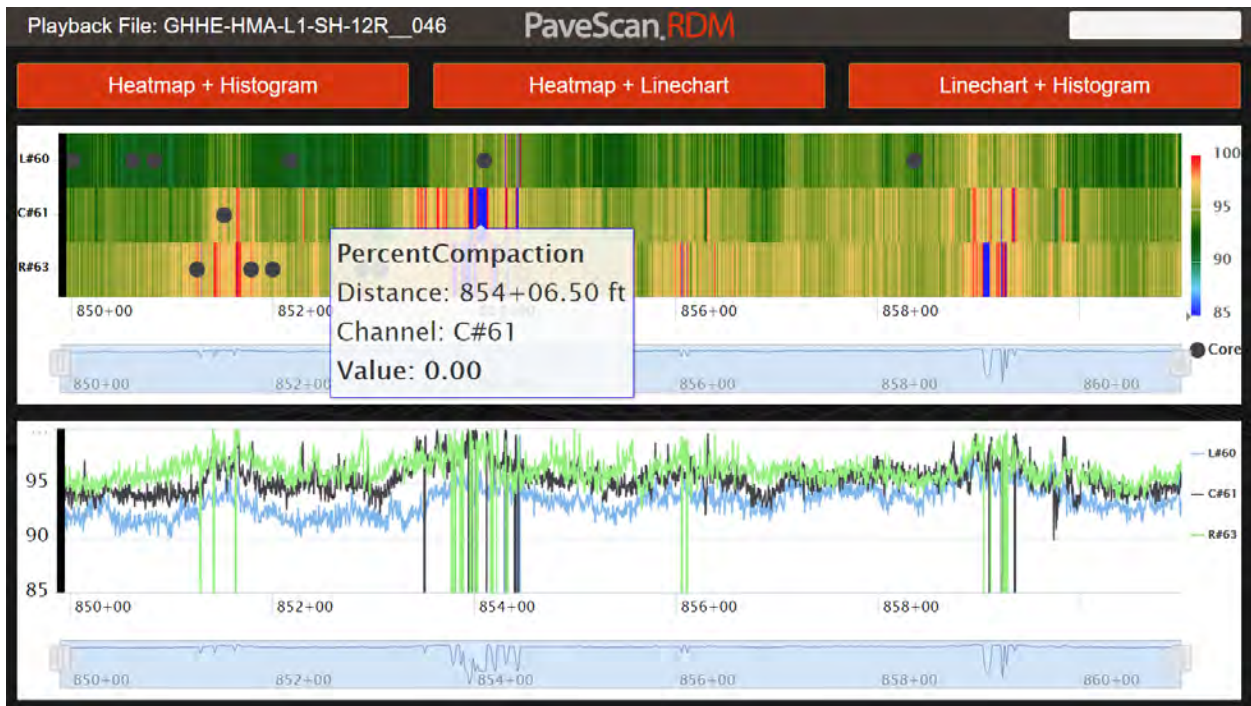
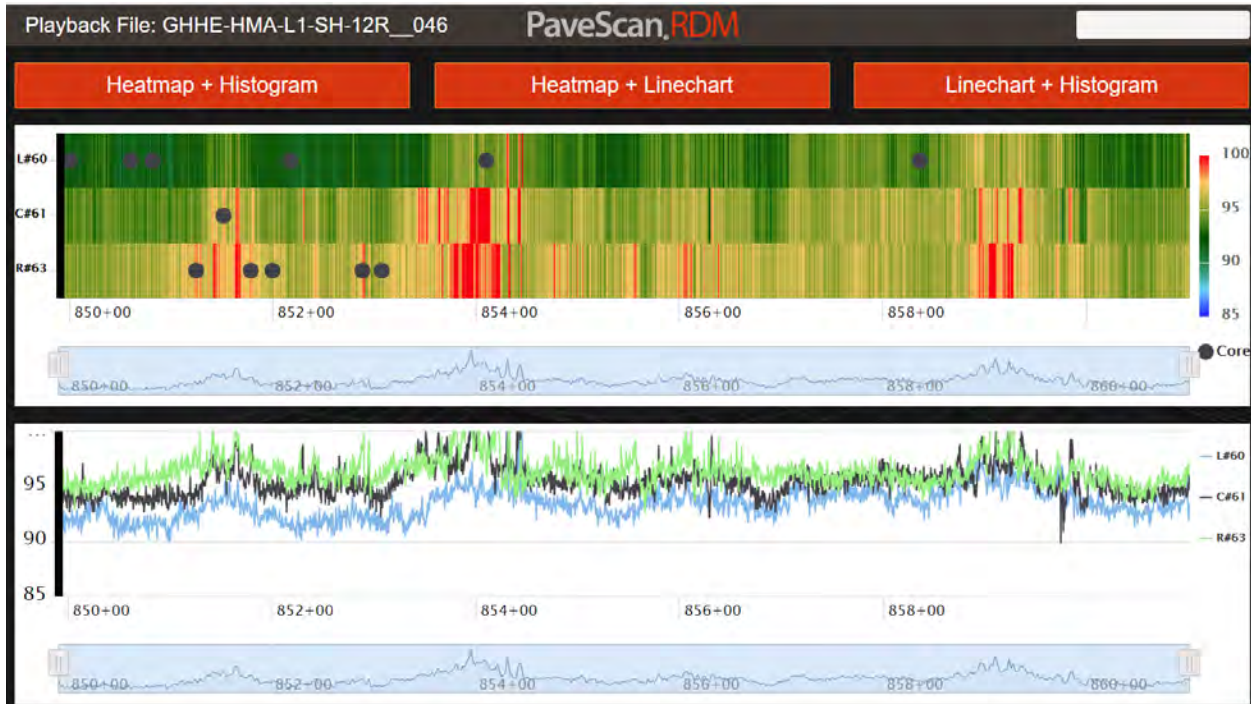


The value range is specified in the screen that appears when pressing the **Range Settings** button.

Note, there are valid range settings for Dielectric, Percent Voids, Compaction, and Density.



When the **Apply Valid Data Range** button is checked, all values outside the specified range are replaced by zeros in the display. The two images below show percent compaction data from a file before (top), and after (bottom) applying a Valid Range filter from 85 – 100%.



The statistics are only applied to the valid data.

The valid data range is written to the header of the exported file.

1	RDM Export File																			
2	Project Name: ghhe																			
3	Project Location: sb-It lane-sta 1143																			
4	Operator: Rich																			
5	Project Comments:																			
6	Lateral Offset Reference: It shoulder																			
7	Lateral Offset Reference Side: Right																			
8	Lateral Offset from Reference (ft): 3																			
9	Collection Direction: Decreasing Distance																			
10	Sensor Lateral Offsets (ft): Serial#60=1;Serial#61=3;Serial#63=5;																			
11	Sensor Positions on metal rail(ft): Serial#60=2;Serial#61=0;Serial#63=2R;																			
12	Lot:																			
13	Sublot:																			
14	File Name: GHHE-HMA-L1-SH-12R_046																			
15	File Type: Distance																			
16	Creation Date and Time: 2017-05-31.08:21:52																			
17	File Comments:																			
18	Moving Average Window Size (ft): 0.50																			
19	Output Interval (ft): 0.50																			
20	GPS Inline Position Offset (ft): 0.00																			
21	GPS Crossline Position Offset (ft): 0.00																			
22	GPS Time Lag (sec): 0.00																			
23	Calibration A & B Values 0.09																			
24	Calibration Equation Type = Exponential																			
25	Valid Data Range: 85.00 100																			
26	Distance (ft)	Station	Longitude	Latitude	Elevation	Lateral Of	PercentCc	Signal Qui	Longitude	Latitude	Elevation	Lateral Of	PercentCc	Signal Qui	Longitude	Latitude	Elevation	Lateral Of	PercentCc	Signal Quality
27	84990.5	849+90.50	61.36841	-149.532	84.1	1	92.2126	96.2945	61.36841	-149.532	84.1	3	97.4253	95.2115	61.36841	-149.532	84.1	5	96.3841	96.4032
28	84991	849+91.00	61.36841	-149.532	84.1	1	92.7759	96.21	61.36841	-149.532	84.1	3	95.9146	95.1576	61.36842	-149.532	84.1	5	96.7588	96.4727
29	84991.5	849+91.50	61.36841	-149.532	84.1	1	92.1623	96.1393	61.36841	-149.532	84.1	3	93.781	95.1394	61.36842	-149.532	84.1	5	94.7862	96.4007
30	84992	849+92.00	61.36841	-149.532	84.1	1	93.309	96.4055	61.36842	-149.532	84.1	3	94.6603	95.2336	61.36842	-149.532	84.1	5	94.3735	96.3776
31	84992.5	849+92.50	61.36841	-149.532	84.1	1	93.1271	96.5046	61.36842	-149.532	84.1	3	94.5668	95.2044	61.36842	-149.532	84.1	5	93.9352	96.3818
32	84993	849+93.00	61.36842	-149.532	84.2	1	91.2607	96.7288	61.36842	-149.532	84.2	3	94.1468	95.2941	61.36842	-149.532	84.2	5	94.8966	96.359

The values in the exported file outside the data value range are replaced by zeros.

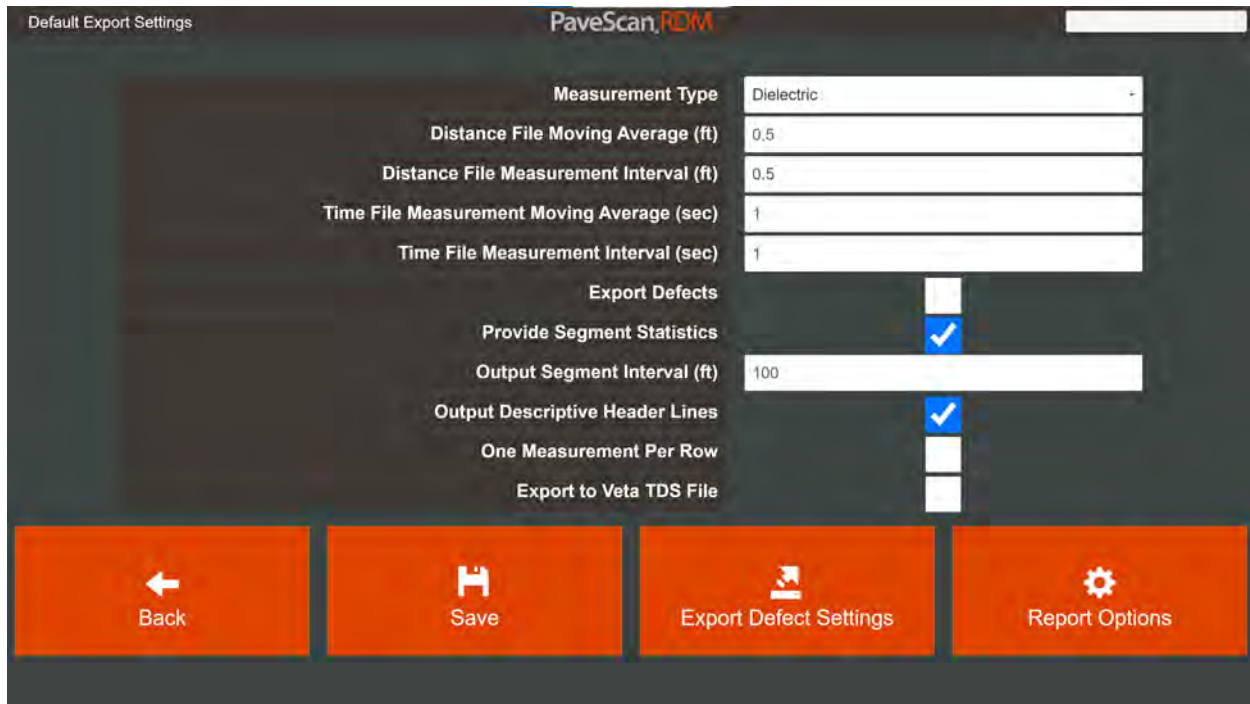
85440	854+40.00	61.36958	-149.531	80.6	1	94.1648	96.4073	61.36958	-149.531	80.6	3	0	95.5065	61.36958	-149.531	80.6	5	94.3439	96.0858
85440.5	854+40.50	61.36958	-149.531	80.6	1	95.2935	96.3543	61.36958	-149.531	80.6	3	98.4148	95.4006	61.36958	-149.531	80.6	5	95.5865	96.1201
85441	854+41.00	61.36958	-149.531	80.6	1	96.9247	96.3534	61.36958	-149.531	80.6	3	99.4207	95.5212	61.36958	-149.531	80.6	5	94.1221	96.0841
85441.5	854+41.50	61.36958	-149.531	80.6	1	99.1083	96.2447	61.36958	-149.531	80.6	3	0	95.4676	61.36958	-149.531	80.6	5	96.31	96.0627
85442	854+42.00	61.36958	-149.531	80.64	1	0	96.2835	61.36958	-149.531	80.64	3	0	95.4928	61.36959	-149.531	80.64	5	95.3327	96.0615
85442.5	854+42.50	61.36958	-149.531	80.69	1	97.9939	96.3952	61.36959	-149.531	80.69	3	0	95.5406	61.36959	-149.531	80.69	5	95.9787	96.2448
85443	854+43.00	61.36958	-149.531	80.7	1	94.5837	96.3976	61.36959	-149.531	80.7	3	0	95.5126	61.36959	-149.531	80.7	5	96.4907	96.2688
85443.5	854+43.50	61.36959	-149.531	80.7	1	94.7103	96.4029	61.36959	-149.531	80.7	3	96.3812	95.6184	61.36959	-149.531	80.7	5	99.1358	96.327
85444	854+44.00	61.36959	-149.531	80.7	1	93.5585	96.3557	61.36959	-149.531	80.7	3	95.8625	95.6251	61.36959	-149.531	80.7	5	98.8915	96.3751
85444.5	854+44.50	61.36959	-149.531	80.67	1	0	96.3746	61.36959	-149.531	80.67	3	97.6476	95.6118	61.36959	-149.531	80.67	5	96.7024	96.4148
85445	854+45.00	61.36959	-149.531	80.61	1	99.4002	96.3898	61.36959	-149.531	80.61	3	96.6313	95.5692	61.36959	-149.531	80.61	5	94.3146	96.3869
85445.5	854+45.50	61.36959	-149.531	80.6	1	96.3433	96.2947	61.36959	-149.531	80.6	3	96.9067	95.5597	61.36959	-149.531	80.6	5	96.4547	96.3194
85446	854+46.00	61.36959	-149.531	80.6	1	94.2948	96.3334	61.36959	-149.531	80.6	3	95.7936	95.6004	61.3696	-149.531	80.6	5	94.4797	96.2997
85446.5	854+46.50	61.36959	-149.531	80.6	1	93.8228	96.306	61.36959	-149.531	80.6	3	95.721	95.6688	61.3696	-149.531	80.6	5	96.1743	96.2978
85447	854+47.00	61.36959	-149.531	80.6	1	94.4254	96.3317	61.3696	-149.531	80.6	3	96.609	95.7012	61.3696	-149.531	80.6	5	94.628	96.3115
85447.5	854+47.50	61.3696	-149.531	80.6	1	94.2394	96.2585	61.3696	-149.531	80.6	3	96.0933	95.648	61.3696	-149.531	80.6	5	95.5808	96.3765
85448	854+48.00	61.3696	-149.531	80.6	1	95.1436	96.1283	61.3696	-149.531	80.6	3	97.261	95.749	61.3696	-149.531	80.6	5	95.2779	96.2331
85448.5	854+48.50	61.3696	-149.531	80.6	1	93.4248	96.1106	61.3696	-149.531	80.6	3	95.6198	95.8074	61.3696	-149.531	80.6	5	95.6985	96.2954

The values outside the valid data range are excluded from the segment statistics file.

1	Lateral Of	Start Dist	End Dist	Ave. Perc	Median. P	Min. Perc	Max. Perc	St.Dev. Pe	Histogram	Ave. Signal	Min. Signal Quality
2	1	84990.5	85090.5	91.96	91.93	90.18	93.97	0.8	90.71	97.63	96.14
3	1	85090.5	85190.5	92.81	92.84	89.98	95.57	1.05	91.15	96.66	95.83
4	1	85190.5	85290.5	91.9	91.91	90.13	94.16	0.69	90.89	96.42	95.82
5	1	85290.5	85390.5	93	92.65	90.49	96.67	1.4	91.06	97.29	96.13
6	1	85390.5	85490.5	94.32	94.12	91.95	99.5	1.21	92.84	96.85	95.69
7	1	85490.5	85590.5	93.04	92.99	91.2	95.54	0.77	91.89	96.42	95.41
8	1	85590.5	85690.5	93.56	93.51	91.68	97.37	0.84	92.22	96.37	95.69
9	1	85690.5	85790.5	94.14	94.21	91.56	95.77	0.81	92.66	97.28	96.17
10	1	85790.5	85890.5	94.33	94.33	91.98	97.59	0.99	92.91	96.41	96.02
11	1	85890.5	85990.5	95.22	95.27	92.02	97.87	1.07	93.72	96.85	95.89
12	1	85990.5	86090.5	93	92.95	91.33	95.02	0.62	92.08	96.97	95.68
13	1	86090.5	86100	93.77	93.69	91.91	96.72	1.05	92.62	96.14	95.91
14	3	84990.5	85090.5	94.04	94.02	92.65	97.43	0.66	93.05	95.74	95.11
15	3	85090.5	85190.5	95.4	95.29	92.82	99.04	1.46	93.33	96.08	95.36
16	3	85190.5	85290.5	94.93	94.79	92.62	98.76	0.9	93.75	96.29	95.83

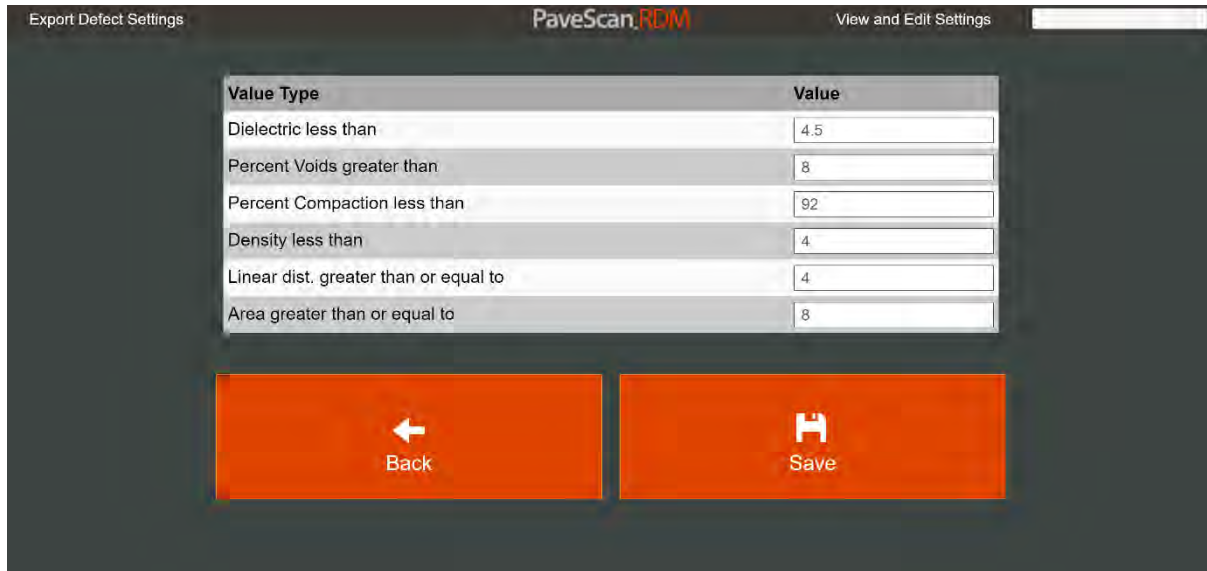
Appendix D – Export of Linear and Area Defects

Linear and area defect export is found in the Export Settings screen shown below. Click the accompanying checkbox next to **Export Defects** to enable defect export.

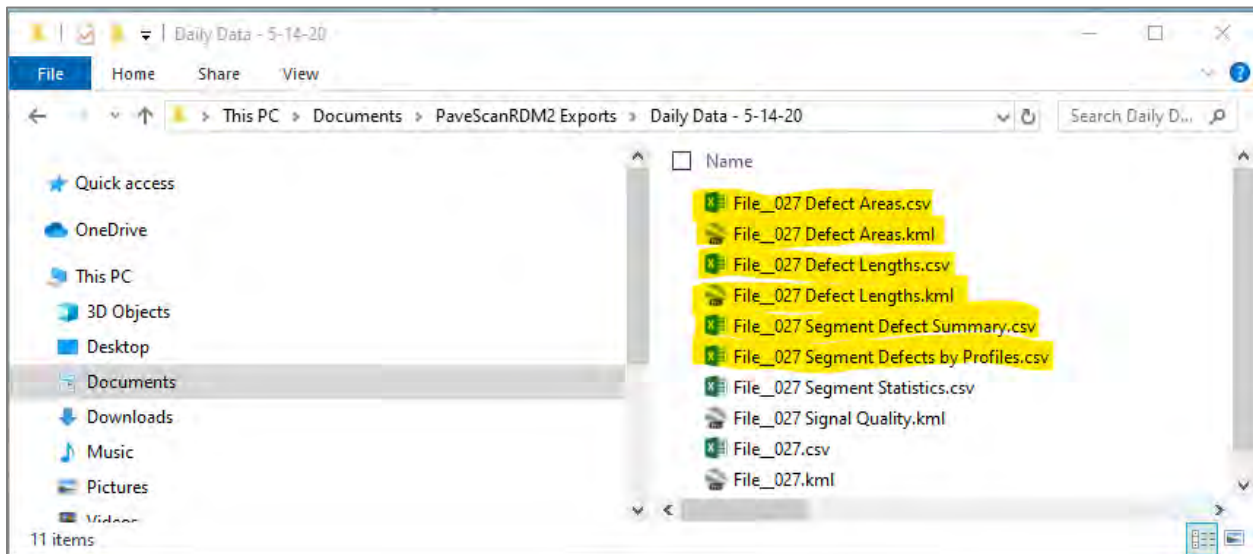


When the **Export Defects** option checked, all defects are exported to CSV and KML files. The criteria defining the defects are accessible by pressing the **Export Defect Settings** button and are shown below.

The first four rows consist of threshold values where data values below or above the threshold are classified as defects. Contiguous defects that meet the specified minimum length and/or area size are exported. The length of each data measurement is the spacing between exported values. The area of each data measurement is the spacing between exported values multiplied by 2.0 ft (0.6 m).



When the **Export Defects** button is checked, six additional files are created when the playback file or playback range is exported. Separate files are generated for defect lengths and defect areas.



Segment Defects by Profiles Format

The Segment Defects by Profiles file contains a list of the percent defects for each profile in the selected playback file or playback range on a segment-by-segment basis. The segment length used for the export is the segment interval specified in the Export Settings.

Start Distance (ft)	Start Station	Segment Length (ft)	Lateral Offset	# Measurements	% Defective
1200	12+00	100	0	201	3.24
1300	13+00	100	0	201	7.5
1200	12+00	100	2L	201	46.88
1300	13+00	100	2L	201	24.46
1200	12+00	100	2R	201	8.48
1300	13+00	100	2R	201	6.21

The table provides defect information at the selected segment length (which is defined in the Export Options as the “Output Segment Interval”). The information in each column is described below:

Start Distance: Starting distance of the interval.

Start Station: This column is present when “Use Stationing Format” is checked in the Project Properties.

Segment Length: The length within the segment that contains data. This may be less than the segment length at the beginning and/or end of the file or selected playback range.

Lateral Offset: The position of the profile that the data were obtained relative to the lateral offset reference. The ‘L’ and ‘R’ appended to the number indicate if the lateral offset is to the left or right of the reference line looking in the increasing distance direction.

Measurements: Number of valid measurements used in the % Defective calculation

Percent Defective: The percentage of the data within the segment that meets the defective criteria defined by the defect threshold value.

Segment Defect Summary Format

The segment defect summary contains a listing of the percent defects as well as the number of 2-dimensional defects and if any of the 2-dimensional defects straddle adjacent segments.

	A	B	C	D	E	F	G	H
1	Defect Threshold % Compaction: 92.000000							
2	Start Distance (ft)	Start Station	Segment Length (ft)	# Profiles	# Measure # 2D Defects	% Defective	Straddles Adjacent Segment	
3	1200	12+00	100	3	1203	0	19.53	FALSE
4	1300	13+00	100	3	1203	0	7.25	FALSE
5								
6								
7								

The table provides statistical information on segment-by-segment intervals. The information provided in each column is as follows:

Starting Distance: Starting distance of the interval.

Starting Station: This column is present when “Use Stationing Format” is checked in the Project Properties screen.

Segment Length: The length within the segment that contains data. This may be less than the segment length at the beginning and/or end of the file or selected playback range.

Profiles: Number of profiles (i.e. lines at different offsets used in the %Defective calculation.

Measurements: Number of valid measurements used in the % Defective calculation.

Percent Defective: The percentage of the data within the segment that meets the defective criteria defined by the defect threshold value.

of 2-D Defects: The total number of defects detected over the segment length.

Defect Straddles Segments: A “TRUE” indicates that a defect was located that extends into an adjacent segment.

Linear Defect File Format

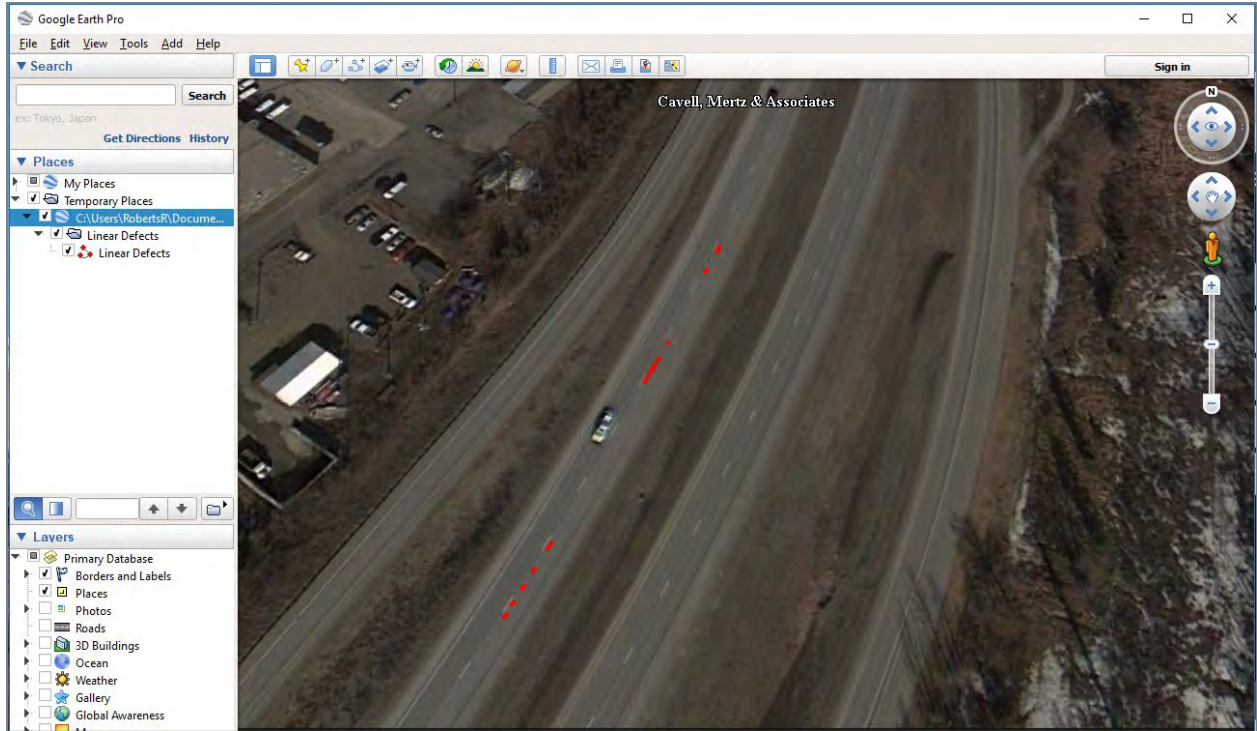
The linear defect CSV file consists of a header line indicating the defect detection criteria followed by a table. The image below is resized to show how the header and table are positioned.

1	Defect Length Threshold (ft): 1.0									
2	Start Distance (ft)	End Distance (ft)	Start Station	End Station	Offset (ft)	Start Latitude (ft)	Start Longitude (ft)	End Latitude (ft)	End Longitude (ft)	
3	5	6	00+05	00+06	1L	43.01201072	-71.58122738	43.01201072	-71.58122738	
4	6.5	7.5	00+06.5	00+07.5	1L	43.01201072	-71.58122738	43.01201072	-71.58122738	
5	9	10	00+09	00+10	1L	43.01201072	-71.58122738	43.01201072	-71.58122738	
6	12.5	13.5	00+12.5	00+13.5	1L	43.01201072	-71.58122738	43.01201072	-71.58122738	
7	0	2.5	00+00	00+02.5	1R	43.01201072	-71.58122738	43.01201072	-71.58122738	
8	7	8	00+07	00+08	1R	43.01201072	-71.58122738	43.01201072	-71.58122738	
9	9	10	00+09	00+10	1R	43.01201072	-71.58122738	43.01201072	-71.58122738	
10	11	12	00+11	00+12	1R	43.01201072	-71.58122738	43.01201072	-71.58122738	
11	24.5	25.5	00+24.5	00+25.5	1R	43.01201072	-71.58122738	43.01201072	-71.58122738	
12	84.5	85.5	00+84.5	00+85.5	1R	43.01201072	-71.58122738	43.01201072	-71.58122738	
13	93	94	00+93	00+94	1R	43.01201072	-71.58122738	43.01201072	-71.58122738	
14	94.5	95.5	00+94.5	00+95.5	1R	43.01201072	-71.58122738	43.01201072	-71.58122738	
15										
16										

The header line of the file indicates the minimum defect length.

The first 3-5 columns indicate the starting and ending location of the defect in terms of the distance along the file and the lateral offset. The Start Station and End Station Columns are only present if “Use Stationing Format” is checked in the Project Properties screen. The last four columns show the Latitude and Longitude of the starting and ending locations of the linear defects. Note, that for scenarios where the defect extends around a curve, the GPS coordinates may not adequately describe the location of the defect between the end points.

The KML file drops seamlessly into Google Earth. The linear defects appear as red lines extending along the length at which they were detected.



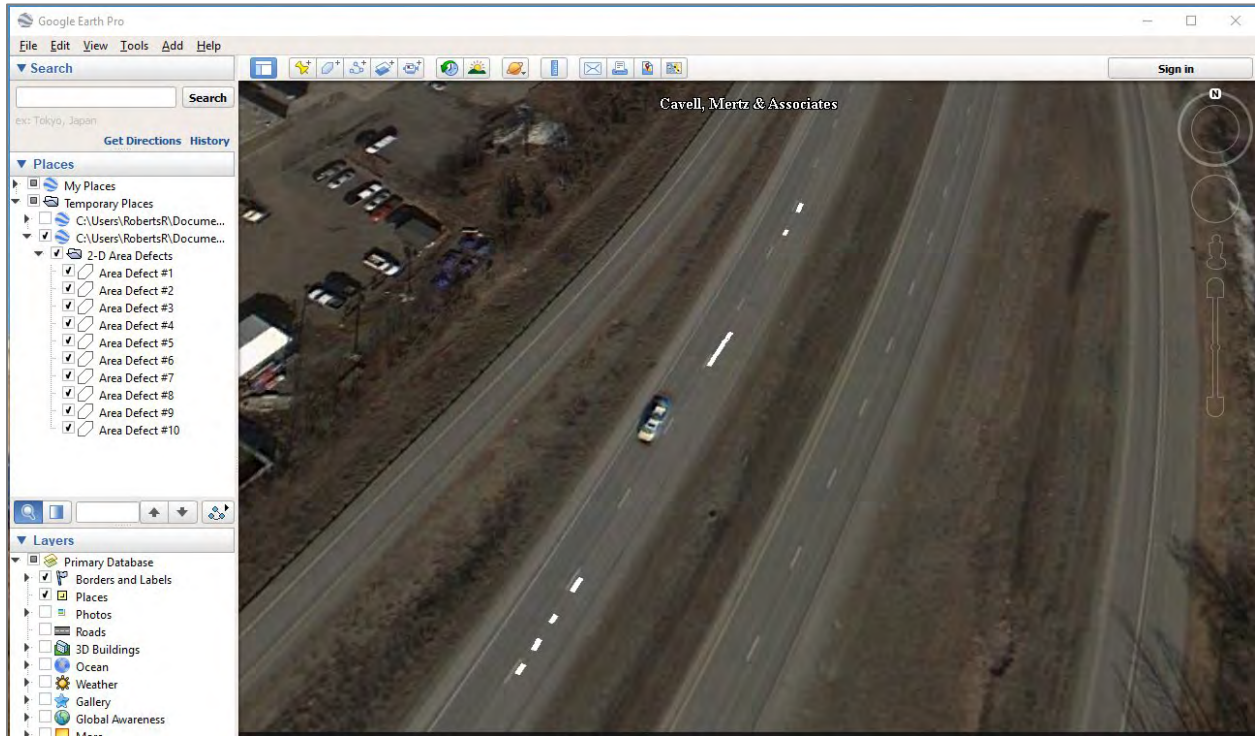
Area Defect File Format

The area defect file is similar to the linear defect file format in that there is a header line followed by a table. The header line displays the minimum defect size threshold. The image below is resized to show the overall format of the file.

1	Defect Area Threshold (ftxft): 8.0													
2	Start Distance (ft)	End Distance (ft)	Start Station	End Station	Start Offset (ft)	End Offset (ft)	Latitude 1 (ft)	Longitude 1 (ft)	Latitude 2 (ft)	Longitude 2 (ft)	Latitude 3 (ft)	Longitude 3 (ft)	Latitude 4 (ft)	Longitude 4 (ft)
3	0	4.5	00+00	00+04.5	1R	3R	43.01201072	-71.58122738	43.01201072	-71.58122738	43.01201072	-71.58122738	43.01201072	-71.58122738
4														
5														
6														
7														
8														

The first 4-6 columns indicate the outline of the defect in terms of file distance and lateral offset. The Start Station and End Station Columns are only present if “Use Stationing Format” is checked in the Project Properties The last 8 columns provide the GPS coordinates of the 4 corners of the defect. Note, that for scenarios where the defect extends around a curve, the GPS coordinates may not adequately describe the true area of the defect.

The Defect Area KML file drops into Google Earth. Each defect appears as a white filled polygon. White was chosen as the color so that both linear and area defects can be shown overlaid.



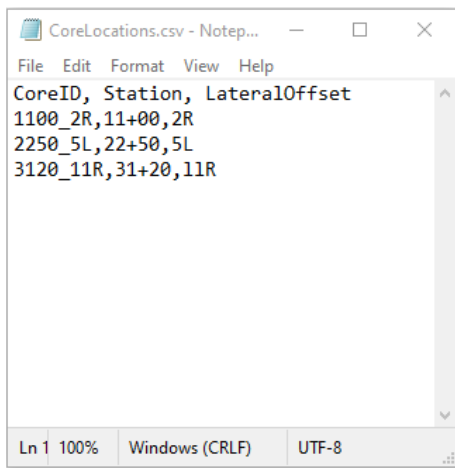
Appendix E – Format of Imported Files

Core Locations CSV File

The CoreLocations.csv file is an ASCII text file that contains a header row and successive rows following the header row with core location information. The header row describes the fields in the columns of the rows that follow.

An example file opened in notepad is shown below. **Note: you must match the spelling and capitalization of the header column names exactly.**

If Using Stationing:

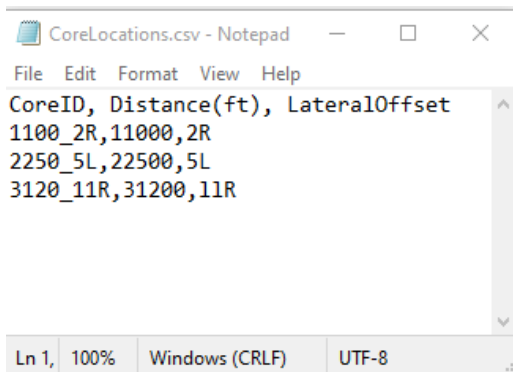


```
CoreLocations.csv - Notepad...
File Edit Format View Help
CoreID, Station, LateralOffset
1100_2R,11+00,2R
2250_5L,22+50,5L
3120_11R,31+20,11R
Ln 1 100% Windows (CRLF) UTF-8
```

Each row must contain, separated by commas:

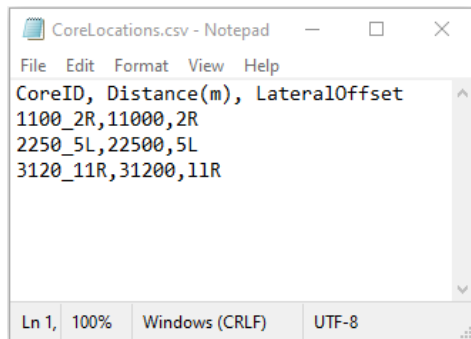
- (1) Core ID
- (2) Station
- (3) Lateral Offset

If Not Using Stationing and Horizontal Units of Feet:



```
CoreLocations.csv - Notepad
File Edit Format View Help
CoreID, Distance(ft), LateralOffset
1100_2R,11000,2R
2250_5L,22500,5L
3120_11R,31200,11R
Ln 1, 100% Windows (CRLF) UTF-8
```

If Not Using Stationing and Horizontal Units of Meters:



If using Distance so specify the horizontal coordinate of the core, each row must contain, separated by commas:

- (1) Core ID
- (2) Distance
- (3) Lateral Offset

Appendix F – Reports

Report Options

The Report Options screen allows you to select the PWL limits that will be used in the calculations in the report. The screen also contains Joint and Mat offset distances and histogram options. Reports are only generated if Lane Extents are specified for the project. See Appendix G for details.

One important thing to note regarding reports: statistics are generated at specified distance intervals corresponding to the export distance interval selected in the Export Settings screen.

Setting	Value
Mat PWL Upper Limit (Diel.)	0
Mat PWL Lower Limit (Diel.)	0
Joint PWL Upper Limit (Diel.)	0
Joint PWL Lower Limit (Diel.)	0
Joint Line Max. Dist. from Closest Lane Extent (ft)	0
Mat Line Min. Dist. from Closest Lane Extent (ft)	0
Histogram Bin Interval (Diel.)	0
Histogram Maximum Value (Diel.)	0
Histogram Minimum Value (Diel.)	0

Buttons: Back, Save

Mat PWL Upper Limit: The upper value of the limit to be used in percent-within-limits (PWL) calculations of values obtained from the portion of the asphalt defined as the mat.

Mat PWL Lower Limit: The lower value of the limit to be used in percent-within-limits (PWL) calculations of values obtained from the portion of the asphalt defined as the mat.

Joint PWL Upper Limit: The upper value of the limit to be used in percent-within-limits (PWL) calculations of values obtained from the portion of the asphalt defined as the joint.

Joint PWL Lower Limit: The lower value of the limit to be used in percent-within-limits (PWL) calculations of values obtained from the portion of the asphalt defined as the joint.

Joint Line Max. Dist. from Closest Lane Extent: This is the maximum lateral distance a measurement can be obtained relative to a lane extent to be classified as a joint measurement. Commonly this distance is about 1 ft (0.3 meters).

Mat Line Min. Dist. from Closest Lane Extent: This is the minimum lateral distance a measurement can be obtained relative to a lane extent to be classified as a mat measurement. Commonly this distance is about 3 ft (0.9 meters).

Note: The values used for the PWL calculations are the export measurement type specified in the Export Settings screen. This means PWL reports can be made for %Compaction, %Voids, and density as well as dielectric values.

Displayed Report

Pressing the **Project Summary Stats** button in the Playback Screen or the **Summary Stats** button in the Playback Range screen generates a table as shown below. Each row of the vertically scrollable table shows the PWL statistics for the Joint and Mat on a station by station basis for each lane of data obtained.

The median and standard deviation of the measurements is also shown within each station for the mat and joint measurements.

Distance Range	Start Station	End Station	Min Lat Offset	Max Lat Offset	Mat PWL	Joint PWL	Mat Median	Joint Median	Mat St Dev	Joint St Dev
Segment	953+10.5	954+00	24L	36L	46.71	0	4.9	0	0.19	0
Segment	954+00	955+00	24L	36L	36.35	0	4.86	0	0.2	0
Segment	955+00	956+00	24L	36L	41.64	0	4.88	0	0.2	0
Segment	956+00	957+00	24L	36L	44.03	0	4.89	0	0.21	0
Segment	957+00	958+00	24L	36L	42.19	0	4.88	0	0.22	0
Segment	958+00	959+00	24L	36L	32.75	0	4.85	0	0.24	0
Segment	959+00	960+00	24L	36L	31	0	4.83	0	0.19	0
Segment	960+00	961+00	24L	36L	31.9	0	4.83	0	0.18	0
Segment	961+00	962+00	24L	36L	37.44	0	4.86	0	0.18	0
Segment	962+00	963+00	24L	36L	16.97	0	4.82	0	0.13	0
Segment	963+00	964+00	24L	36L	45.81	0	4.89	0	0.16	0
Segment	964+00	965+00	24L	36L	40.02	0	4.89	0	0.24	0

The last row of the table shows the total PWL statistics from all the joint and mat measurements in the selected project or playback range (see below).

Summary Statistics PaveScan RDM Statistics Loaded

Distance Range	Start Station	End Station	Min Lat Offset	Max Lat Offset	Mat PWL	Joint PWL	Mat Median	Joint Median	Mat St Dev	Joint St Dev
Segment	737+00	738+00	12L	24L	0	20.07	0	4.32	0	0.13
Segment	738+00	739+00	12L	24L	0	36.86	0	4.86	0	0.13
Segment	739+00	740+00	12L	24L	0	27.47	0	4.81	0	0.19
Segment	740+00	741+00	12L	24L	0	61.94	0	4.93	0	0.14
Segment	741+00	742+00	12L	24L	0	61.54	0	4.93	0	0.14
Segment	731+97	732+00	24L	36L	12.9	0	4.7	0	0.15	0
Segment	732+00	733+00	24L	36L	5.69	0	4.74	0	0.17	0
Segment	733+00	734+00	24L	36L	20.38	0	4.8	0	0.16	0
Segment	734+00	735+00	24L	36L	14.59	0	4.78	0	0.14	0
Segment	735+00	736+00	24L	36L	0.9	0	4.71	0	0.17	0
Segment	736+00	737+00	24L	36L	28.97	0	4.81	0	0.2	0
Total	731+97	971+00	12L	36L	40.7	50.89	4.87	4.91	0.19	0.16

←
Back

Exported Report

Each time a project export or playback range export is performed, three report files are exported. Two of these files contain PWL statistics and one file contains the histogram distribution of values.

The exported PWL statistics are contained in two files. The file ending in “Segment Summary Stats.csv” contains the Mat and Joint PWL, median values, and standard deviation for each segment of data. The segment length is the length specified in the export options. An example of an exported file is shown below. In the example below, the segment length is 100 ft (30.4 m), which corresponds to station length.

1 RDM Export Segment PWL Statistics
 2 ProjectName: TH002_L1_2020-07-27_RDM2
 3 Project Location: cass
 4 Equipment Operator: ipt
 5 Comments
 6 Lift: 1
 7 Reference Line
 8 Calibration Mix
 9 Project ID
 10 Route Designation
 11 Material
 12 Divided Highway: No
 13 Date Paved
 14 Mat PWL Lower Limit Dielectric: 4.50
 15 Mat PWL Upper Limit Dielectric: 4.90
 16 Joint PWL Lower Limit Dielectric: 4.50
 17 Joint PWL Upper Limit Dielectric: 4.90
 18 Mat Line Min. Dist. from closest lane extent (ft): 1.50
 19 Joint Line Max. Dist. from closest lane extent (ft): 0.75

Distance (ft)	Station	Station	Min Lateral Offset (ft)	MaxLateral aOffset (ft)	Mat PWL (%)	Joint PWL (%)	Mat Dielectric	Joint Dielectric	Mat StDev	Joint StDev		
20	95310.5	95400	955+10.5	954+00	24L	36L	46.71	0	4.9	0	0.19	0
22	95400	95500	954+00	955+00	24L	36L	36.35	0	4.86	0	0.2	0
23	95500	95600	955+00	956+00	24L	36L	41.64	0	4.88	0	0.2	0
24	95600	95700	956+00	957+00	24L	36L	44.03	0	4.89	0	0.21	0
25	95700	95800	957+00	958+00	24L	36L	37.19	0	4.87	0	0.33	0
26	95800	95900	958+00	959+00	24L	36L	32.75	0	4.85	0	0.24	0
27	95900	96000	959+00	960+00	24L	36L	31	0	4.83	0	0.19	0
28	96000	96100	960+00	961+00	24L	36L	31.9	0	4.83	0	0.18	0
29	96100	96200	961+00	962+00	24L	36L	37.44	0	4.86	0	0.18	0
30	96200	96300	962+00	963+00	24L	36L	16.97	0	4.82	0	0.13	0
31	96300	96400	963+00	964+00	24L	36L	45.81	0	4.89	0	0.18	0
32	96400	96500	964+00	965+00	24L	36L	39.42	0	4.89	0	0.25	0
33	96500	96600	965+00	966+00	24L	36L	45.61	0	4.9	0	0.2	0
34	96600	96700	966+00	967+00	24L	36L	47.41	0	4.91	0	0.19	0
35	96700	96800	967+00	968+00	24L	36L	40.52	0	4.86	0	0.19	0
36	96800	96900	968+00	969+00	24L	36L	29.92	0	4.86	0	0.19	0
37	96900	97000	969+00	970+00	24L	36L	38.72	0	4.88	0	0.19	0
38	97000	97100	970+00	971+00	24L	36L	26.13	0	4.82	0	0.17	0
39	94901	95000	949+01	950+00	24L	36L	28.96	0	4.83	0	0.15	0
40	95000	95100	950+00	951+00	24L	36L	45.15	0	4.88	0	0.15	0

The second PWL file contains the summary statistics for mat and joint measurements in the entire project. This filename ends in “Combined Summary Stats.csv.” An example of this file is shown below.

1 RDM Export Combined PWL Statistics
 2 ProjectName: TH002_L1_2020-07-27_RDM2
 3 Project Location: cass
 4 Equipment Operator: ipt
 5 Comments
 6 Lift: 1
 7 Reference Line
 8 Calibration Mix
 9 Project ID
 10 Route Designation
 11 Material
 12 Divided Highway: No
 13 Date Paved
 14 Mat PWL Lower Limit Dielectric: 4.50
 15 Mat PWL Upper Limit Dielectric: 4.90
 16 Joint PWL Lower Limit Dielectric: 4.50
 17 Joint PWL Upper Limit Dielectric: 4.90
 18 Mat Line Min. Dist. from closest lane extent (ft): 1.50
 19 Joint Line Max. Dist. from closest lane extent (ft): 0.75

Distance (ft)	Station	Station	Min Lateral Offset (ft)	MaxLateral aOffset (ft)	Mat PWL (%)	Joint PWL (%)	Mat Dielectric	Joint Dielectric	Mat StDev	Joint StDev		
20	73197	97100	731+97	971+00	12L	36L	40.48	50.8	4.87	4.91	0.2	0.16
21												
22												
23												
24												
25												

The third and final report file contains a histogram distribution of values. The file ends in “Histogram Stats.csv.” An example of this file is shown below. The bin counts are normalized by the total number of counts.

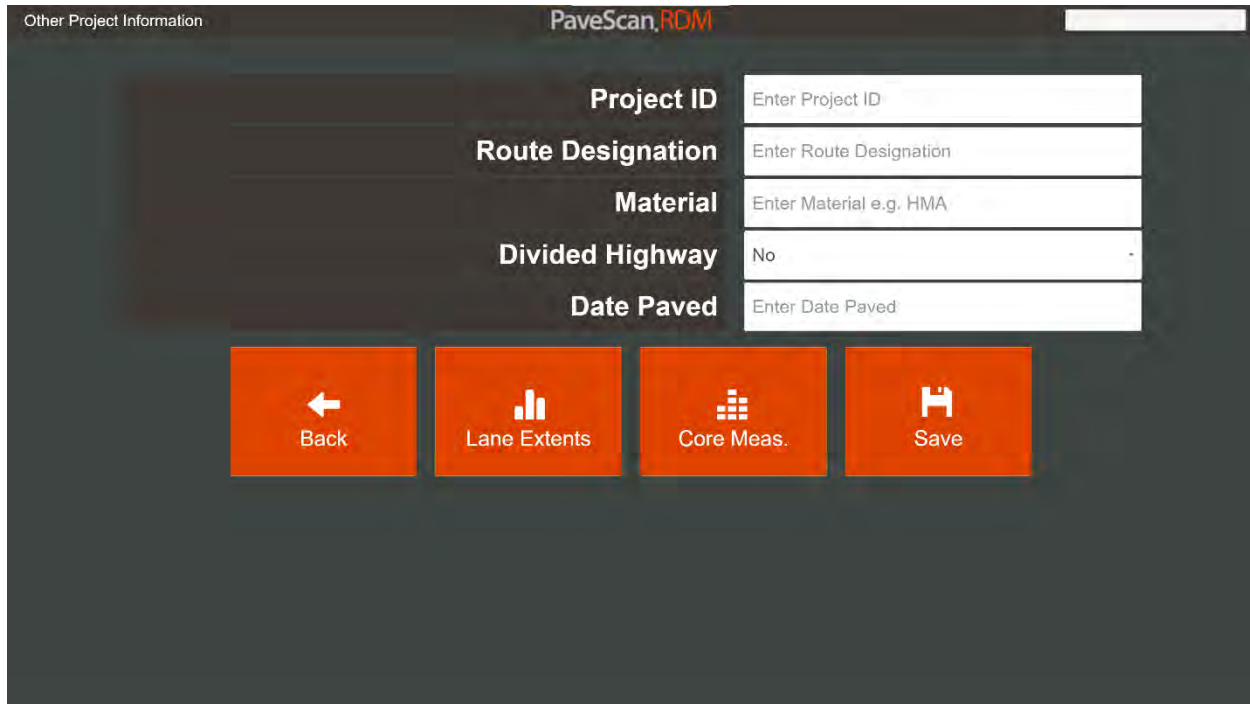
The screenshot shows an Excel spreadsheet with the following data:

Lower Bin Value	Upper Bin Value	Normalized Mat Counts	Normalized Joint Counts
4.2	4.2	0	0
4.3	4.4	0.01	0
4.4	4.6	0.02	0
4.5	4.8	0.04	0.02
4.6	5	0.09	0.05
4.7	5.2	0.18	0.15
4.8	5.4	0.24	0.27
4.9	5.6	0.22	0.27
5	5.8	0.13	0.16
5.1	6	0.06	0.07

Appendix G – Other Project Info

Other Project Information

The Other Project Information screen contains other project information that can be exported with the project data. It also provides access to user-entered lane extents that are needed for PWL calculations and access to collected core measurements.



Project ID: Optional entry. Series of numbers and or letters used to identify the project.

Route Designation: Optional entry. Series of numbers and or letters used to identify the route.

Material: Optional entry. Typically used to identify the type of asphalt (e.g., HMA, WMA).

Divided Highway: Optional entry. If project is located on a road that is classified as a divided highway, select “Yes.” Otherwise select “No.”

Date Paved: Optional entry. The date that paving occurred.



Press this button to access a table that allows you to enter in the lane extents and joint types of the lane(s) that will be paved as part of the project.

Lane Extents

Use the lane extents screen to enter in the distances of the lane joints from the reference line and also enter in the joint types.

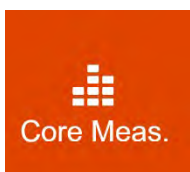
Lane #	Near Offset Dist	Near Offset Joint Type	Far Offset Dist	Far Offset Joint Type
1	Enter Value	Confined	Enter Value	Confined
2	Enter Value	Confined	Enter Value	Confined
3	Enter Value	Confined	Enter Value	Confined
4	Enter Value	Confined	Enter Value	Confined
5	Enter Value	Confined	Enter Value	Confined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

Near Offset Dist: Distance of the lane’s joint that is closest to the reference line followed by a capital “L” or “R” to signify if it is located to the left or right of the reference line from the viewpoint obtained by looking in the increasing distance direction. For example, suppose the lane is located 12-24 ft from the reference line and it is to the right of the reference line when looking in the increasing distance direction. Then the Near Offset Dist entry would be 12R.

Near Offset Joint Type: Optional entry. The type of joint associated with the Near Offset Dist. Options are confined, unconfined, or other.

Far Offset Dist: Distance of the lane’s joint that is furthest from the reference line followed by a capital “L” or “R” to signify if it is located to the left or right of the reference line from the viewpoint obtained by looking in the increasing distance direction. For example, suppose the lane is located 12-24 ft from the reference line and it is to the right of the reference line when looking in the increasing distance direction. Then the Far Offset Dist entry would be 24R.

Far Offset Joint Type: Optional entry. The type of joint associated with the Far Offset Dist. Options are confined, unconfined, or other.



Press this button to access a table showing the core measurements obtained as part of the project.

Appendix H – Precision Calculations

Summary

PaveScan QA Measurements can be used in the calculation of Precision and Reproducibility statistics. The approach follows the methods employed in ASTM Spec E691¹. When following the wording of the ASTM spec, replace “cell” by “measurement” and “Lab” by “sensor” for application to PaveScan RDM data. The Reproducibility statistics are calculated by comparing the results from different sensors with measurements over the same dielectric material.

Precision reports are generated from static QA measurements with HDPE and a custom material. This custom material is intended to be G10, but can be any material with a flat surface, lateral dimensions at least 17.5x 17.5” (44.5x44.5 cm). The minimum thickness of the material depends on its dielectric. For G10, the minimum thickness is (1.25”) 3.2 cm. For HDPE, the minimum thickness is 2” (5.1 cm).

Data Collection

Collection of data to be used for precision measurements is limited to QA files collected in time mode. These two measurement types are HDPE and Custom. Typically, for precision calculations, a number of measurements are obtained over a short period of time. Texas Transportation Institute (TTI) performed precision tests and used 10 measurements². Though, any number of QA files greater than one in any project can be used for a precision report.

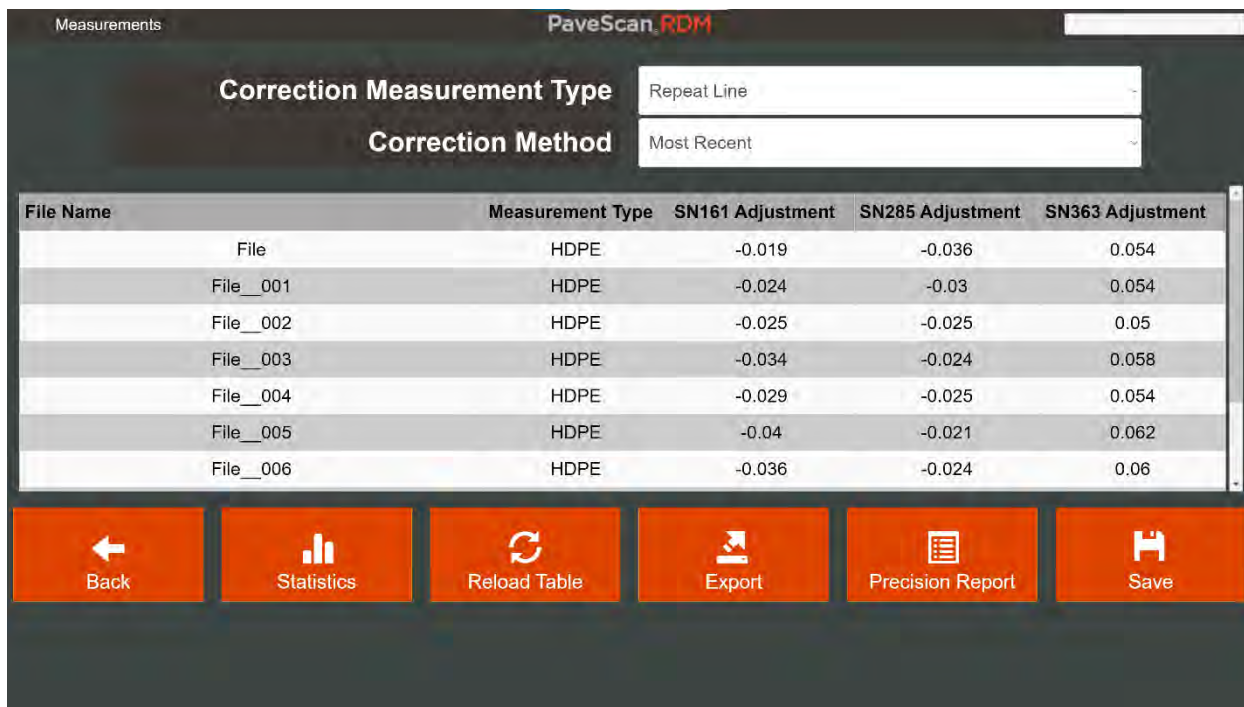
If it is desirable to start with a new project, here are the steps for data collection assuming you’ll be collecting 10 measurements for precision calculations:

- 1** Create a new project.
- 2** Calibrate the antennas.
- 3** Collect either a HDPE or Custom QA measurement.
- 4** Collect 9 more HDPE or Custom QA measurements making sure that Custom and HDPE measurement types are not interchanged. Once you collect the first measurement, all the following measurements must be the same type.

Precision Report Creation

Go to Playback, select the project with the QA measurements, then press the following buttons to get to the QA options screen: Project Info -> Properties -> QA Options.

Notice the QA measurements screen has a button labeled **Precision Report**. Press this button to generate the precision report from the QA measurements.



While the report is being generated, the status bar on the top right corner of the screen will show the following text “Exporting...” Once export is complete, the status bar will show the text “Export Successful.”

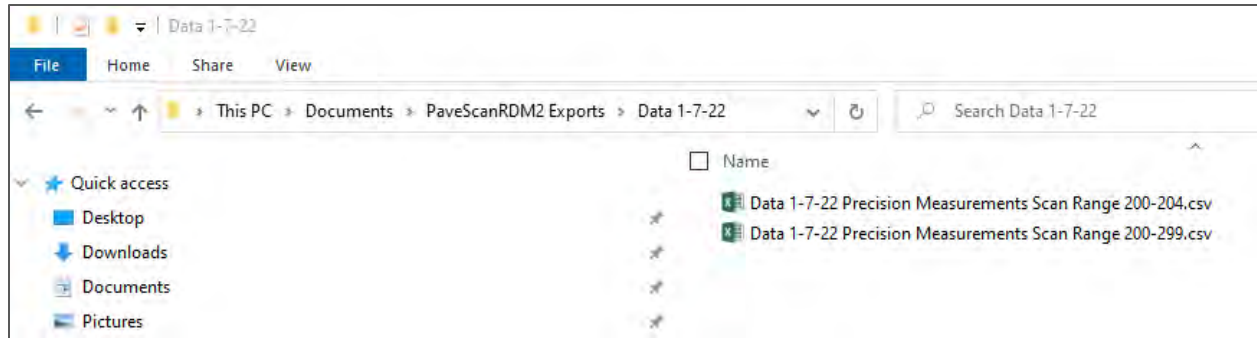
Precision Report Location and Naming Convention

All QA files contain multiple individual measurements that are then combined when viewed in the QA measurement screen. The individual measurements are used for precision calculations.

Two precision reports are created. One precision report is generated from the average of individual dielectric measurement indexes 200-204. The second precision report is generated from the average of individual measurements 200-299.

The precision reports are located in a folder with the name corresponding to the project name. This subfolder is located in the PaveScanRDM2 Exports folder. The names of the precision report files indicate the scan range over which the dielectric measurements were used for the precision statistics.

In the accompanying figure, the two precision reports: “Data 1-7-22 Precision Measurements Scan Range 200-204.csv” and “Data 1-7-22 Precision Measurements Scan Range 200-299.csv” are from a project with the name “Data 1-7-22.”



The precision reports are written in ASCII. The measurements are separated by commas. These files are readily opened up in Microsoft Excel. Below is an example of a precision report as it is viewed in Excel. The columns have been expanded so that the column names are fully visible.

	A	B	C	D	E	F
1	RDM Precision and Reproducibility Statistics					
2	Scan Range Used for Statistics:: 200-204					
3	Average Dielectric of All Sensors: 4.68					
4	Standard Deviation of Sensor Averages : 0.05					
5	Repeatability Standard Deviation: 0.02					
6	Between Sensor Standard Deviation: 0.05					
7	Reproducibility Standard Deviation: 0.05					
8	Repeatability Limit: 0.05					
9	Reproducibility Limit: 0.15					
10						
11	Serial#	Average	Standard Deviation	Deviation	Between Sensor Consistency	Sensor Consistency
12	161	4.72	0.01	0.03	0.63	0.85
13	285	4.71	0.02	0.03	0.52	1.01
14	363	4.62	0.02	-0.06	-1.15	1.12
15						
16	Measurement Number	Time (Minutes)	Dielectric SN 161	Dielectric SN 285	Dielectric SN 363	
17	1	0	4.711	4.73	4.623	
18	2	1.198	4.724	4.741	4.608	
19	3	2.96	4.708	4.711	4.644	
20	4	4.175	4.75	4.726	4.616	
21	5	5.391	4.729	4.712	4.588	
22	6	8.311	4.711	4.71	4.626	
23	7	9.53	4.706	4.709	4.634	
24	8	10.775	4.705	4.687	4.608	
25	9	11.972	4.715	4.696	4.642	
26	10	13.175	4.722	4.697	4.642	
27						
28						
29						
30						
31						

The units of all the statistics are dielectric. The full definitions and details regarding their significance are contained in ASTM SPEC E691. Short definitions are provided below.

Sensor Average: Average of all measurements from a sensor (cells B12-B14 in the accompanying figure are the averages for sensors 161,285, and 363).

Sensor Standard Deviation(S): The standard deviation of all measurements from a sensor (cells C12-C14 in the accompanying figure are the standard deviations of sensors 161, 285, and 363).

Average Dielectric of All Sensors(A): Average of Sensor Averages (the value in cell A3 is the average of cells B12-B14 in the accompanying figure).

Deviation(d): Deviation of Sensor Average from Average Dielectric of All Sensors (for example, cell D12 in accompanying figure is obtained by the following cell math: B12 – A3)

Standard Deviation of Sensor Averages (S_x): The standard deviation of the Sensor Averages (the value in cell A4 in accompanying figure is the standard deviation of Columns B12-B14 in the accompanying figure).

Repeatability Standard Deviation (S_r): $S_r = \sqrt{(\text{sum } S^2)/(\#\text{Sensors})}$ (value is in cell A5 in accompanying figure)

Between Sensor Consistency(h): d/S_x (values in cells E12-E14 in accompanying figure)

Sensor Consistency(k): S/S_r (values in cells F12-14 in accompanying figure)

Between Sensor Standard Deviation (S_L): $S_L = \sqrt{(S_x^2 - S_r^2)/(\#\text{Sensors})}$ (value in cell A6 in accompanying figure)

Reproducibility Standard Deviation (S_R): $S_r = \sqrt{(S_L^2 + S_r^2)}$ (value in cell A7 in accompanying figure)

Repeatability Limit(r): $2.8 * S_r$ (value in cell A8 in accompanying figure)

Reproducibility Limit(R): $2.8 * S_R$ (value in cell A9 in accompanying figure)

The “Time” column in the accompanying figure is the time difference between measurements and serves no purpose in the calculations. It’s just there as a reference. The values in the “Dielectric” columns are the averaged dielectric measurements used to calculate the precision statistics. So, the value “4.711” in cell C17 is the calculated average of dielectrics from scans 200-204 from the first measurement file obtained with Sensor SN 161.

References

Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method, Designation: E691-19, ASTM, 2019, 26p.

Wilson, Bryan, Sebesta, Stephen, and Scullion, Tom, 2019, Evaluation of the Rolling Density Meter for Rapid Continuous Measurement of Asphalt Mixture Density, Report # FHWA/TX-17/0-6889-R1, Texas A&M Transportation Institute, 94p.

Appendix I – GPS Time Lag Calculation

Summary

PaveScan utilizes a method that allows the user to calculate the GPS time lag for the purposes of improving the position accuracy of measurements obtained with GPS. The feature is designed to permit the calculation of time lag without the necessity of prior knowledge of the GPS coordinates at any location(s) used during the data collection.

Data Collection

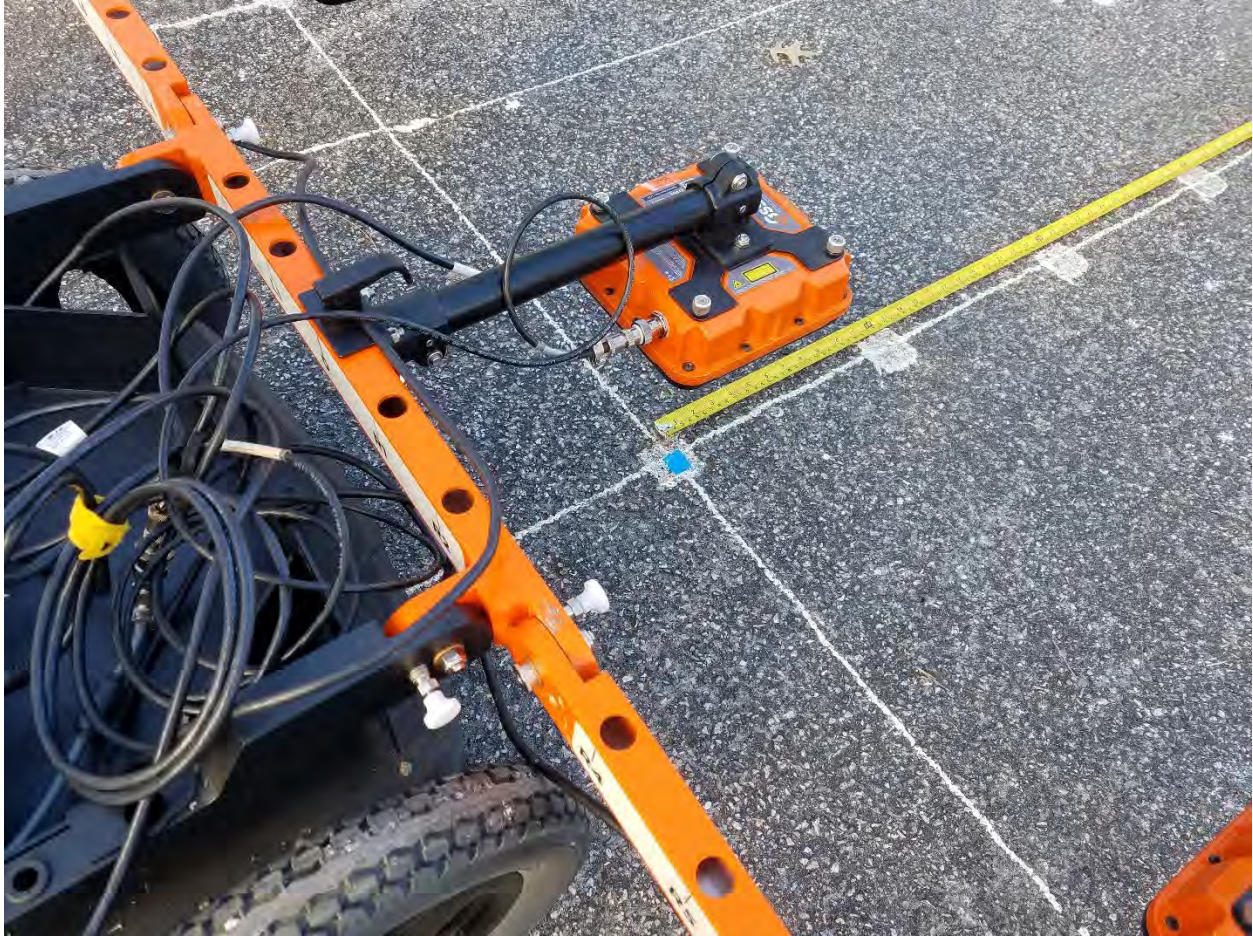
Two data files need to be obtained in order to calculate the time lag. The data collection sequence is presented below:

- 1** The first step is to perform a distance calibration. See the Section 2.2 for distance calibration details. It's easiest to do using a tape measure. Leave the tape measure on the surface once the distance calibration is done.
- 2** Following distance calibration, Create a new project.
- 3** Move the cart along the tape. Keep the center antenna aligned with the tape measure and stop at a location at least 10 ft from the start of the tape measure. Record the distance corresponding to the location where laser from the center antenna strikes the tape measure.
- 4** Without moving the cart, collect a 30 second time file. To keep the files organized, it's helpful to name the file with some information, such as, "Time File at 15 ft."



Cart positioned at 15' along the line at the location of the time-mode file.

- 5** Move the cart backward until the laser from the center antenna is positioned over the beginning of the tape measure (i.e., zero distance). Change the data collection mode to “Distance.” Collect a distance file that extends at least 10 ft beyond the location where you made the time file measurement. This concludes the data collection portion of the procedure.



Cart positioned at the beginning of the line prior to starting to collect the Distance Mode file.

Lag Calculation Procedure

- 1** From the Main Menu, Press **System Settings** button.
- 2** Press the **Project Defaults** button.
- 3** In the Project Defaults Screen press the **GPS Settings** button.
- 4** In the GPS Settings Defaults screen press the **Calc GPS Lag** button.
- 5** Select the Project Group and Project that was used to collect the two files described above.
- 6** From the dropdown list, select the Distance Filename, enter the distance corresponding to the Time File location, then enter in the time filename collected at the GPS location.
- 7** Press the **Calculate** button. The GPS time lag is calculated and displayed on the “Calculated Time Lag” line.
- 8** Press the **Save** button to save the calculated GPS lag. This completes the GPS lag procedure.

The screenshot shows the 'Calculate GPS Lag' interface. At the top, it says 'Calculate GPS Lag' on the left, 'PaveScan RDM' in the center, and 'File Lists Loaded' on the right. The main area contains a form with the following fields:

- Project Group:** A dropdown menu with 'Common' selected.
- Project Name:** A dropdown menu with 'Select from Projects' selected.
- Distance File Name:** A dropdown menu with 'Select from Files' selected.
- Distance to GPS Location (ft):** A dropdown menu with 'Select Distance' selected.
- GPS Location File Name:** A dropdown menu with 'Select from Files' selected.

Below these fields is the label 'Calculated Time Lag:'. At the bottom of the screen, there are three buttons: a red 'Back' button with a left arrow icon, a red 'Calculate' button with a calculator icon, and a dark grey 'Save' button with a trash can icon.

Screen used to calculate the GPS lag.

Discussion

It is possible to collect multiple static GPS files and distance files, then calculate the average GPS Time lag from each value appearing on the line. Then, press the **Back** button and enter in the average lag value in the “GPS Time Lag” line found in the “GPS Settings Defaults” screen.

Once the GPS time lag is calculated, the accuracy of the correction can be easily tested by collecting a static time file at a particular location, then collecting a distance file that crosses over that location and entering a user-mark when the center antenna is at the location of the time file measurement. Then, when post-processing, export the time and distance files and open the time and distance file KML files in Google Earth. The Placemarks of the two files should be offset by the separation distance between the GPS and the antenna. When using the cart for data collection, the placemark corresponding to the static measurement should be approximately 2.47 ft (0.75 meters) behind the placemark from the distance file.



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