PaveScan® RDM Manual

MN36-540 Rev E

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FCC Class B Compliance

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) the device may not cause harmful interference, and (2) this device must accept any interference received including interference that may cause undesired operation.

This Class B digital apparatus complies with Canadian ICES-003

Contains FCC ID: VRA-SG9011089E

Warning: Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment or residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the introduction manual, may cause harmful interference to radio communications. However, there is not guarantee that interference will not occur in a particular installation.

Shielded cables must be used with this unit to ensure compliance with the Class B FCC limits.

Canadian Emissions Requirements

This Class B digital apparatus complies with Canadian ICES-003.

Cet appareil numerique de la classe B est conforme a la norme NMB-003 du Canada.

Notice

Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Table of Contents

Chapter 1: Introduction

This manual will describe 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 that you read the entire manual, regardless of your level of GPR experience.

If you experience operation problems 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 your shipment that identifies all the items included in your order. You should check your shipment against the packing list upon receipt of your shipment. If you find an item is missing or was damaged during the shipment, please call or fax your sales representative to immediately report the problem.

Your PaveScan RDM system contains the following items:

1 – Panasonic G1 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

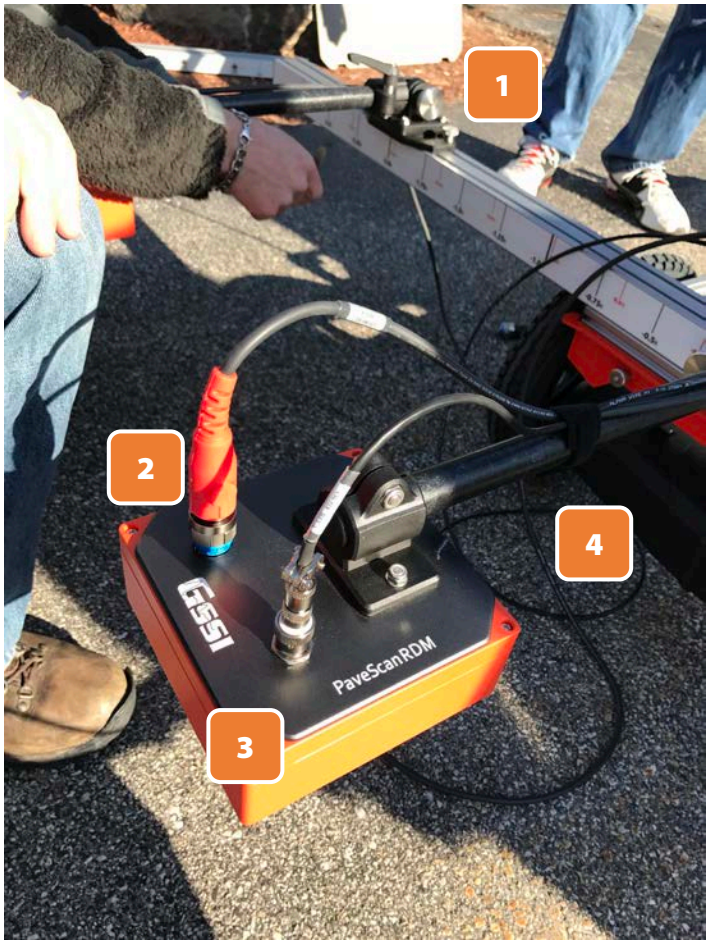
1 – Metal Plate

1 – Garmin GPS

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

1.2: Setup

1. Insert the tube end of the sensor(s) into the connectors on the front of the cart and tighten by turning the knob clockwise.
2. Connect the long black cables to the sensor(s).
3. Connect the short black cable to the middle sensor.
4. Tighten down the two straps on the cables along the tubes; one near the sensor(s), and one near the cart. Do this for all sensors. **It is very important that these are secure so that there is no free movement of the cables. Also, leave a little room at the cable end attached to the sensor so the cable connector isn't stressed.**
5. Connect the distance encoder cable from the cart to the black cable attached to a predetermined sensor.



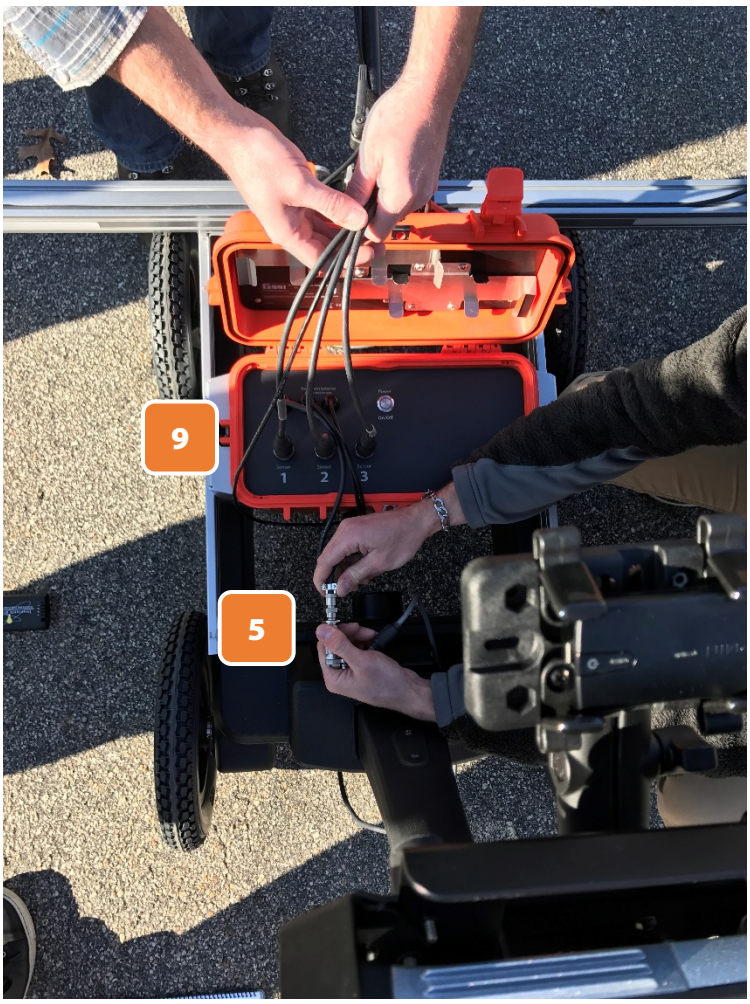
6 Connect the other black cable from the concentrator box to the connector on the back of the ToughPad.

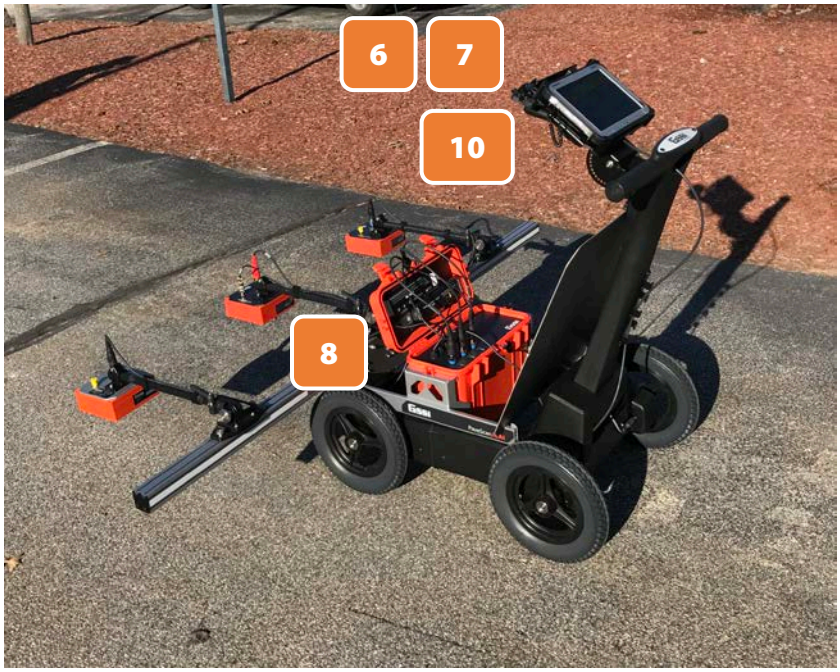
7 Mount the ToughPad on the bracket on the handle of the cart. This is done by lining up the holes on the back of the ToughPad bracket to the rubber stubs on the mounting plate on the handle. Then, flip the handles on the underside of the mounting plate down to lock the ToughPad to the mounting plate. There will be some resistance.

8 Slide the battery connectors on the ends of the batteries and insert them in the metal brackets embedded in the top of the orange box.

9 Connect the three cables from the sensors to the connectors on the front panel of the orange box. The order in which they are connected does **not** matter.

10 Mount the GPS inside the “fingers” of the RAM mount.



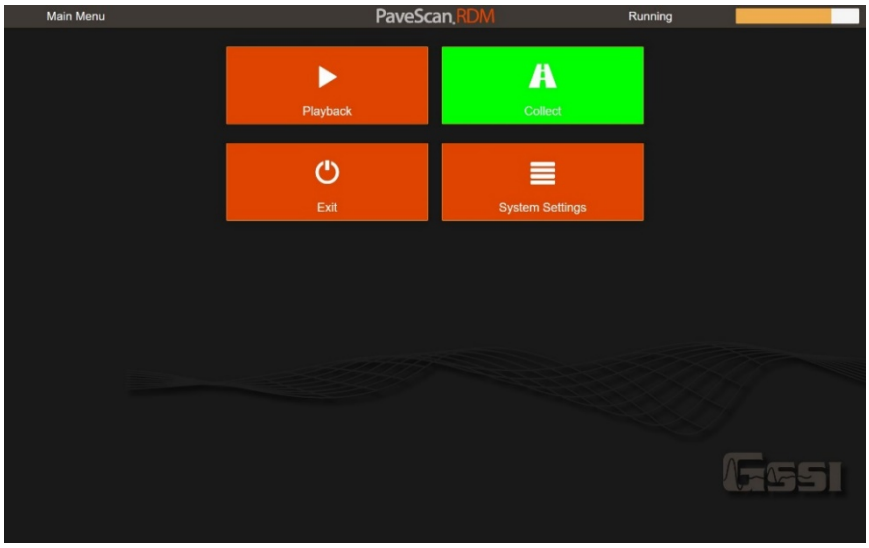


Chapter 2: Getting Started and Data Collection

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

2.1: Start-up

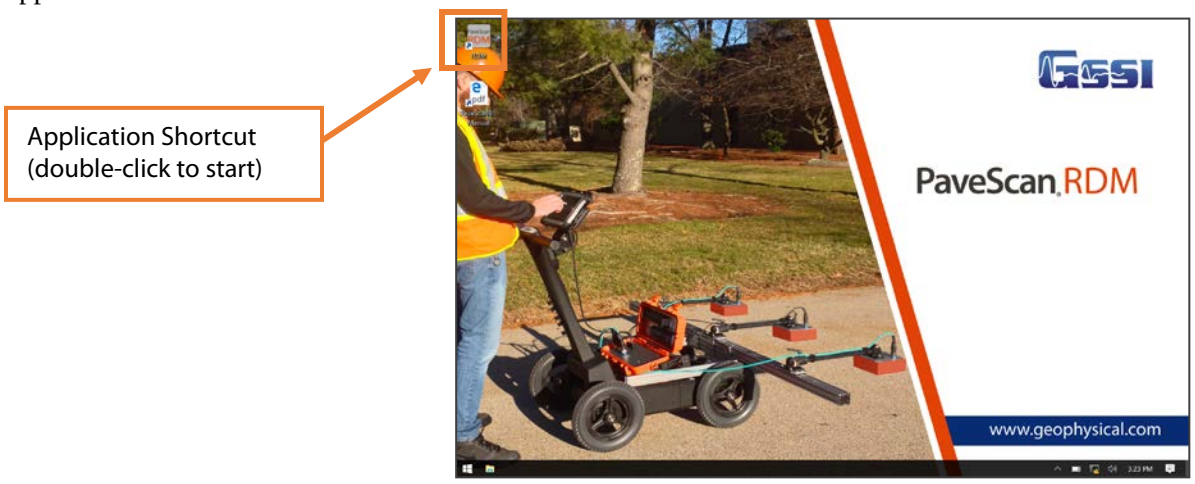
1. Press the button on the front panel of the orange box. It should light-up. This powers up the sensor(s).
2. Power-up the ToughPad computer by pressing and holding down the power button until the green light just to the left of the power button lights up. The computer will take 20-30 seconds to start. After it is fully started the Main menu of the PaveScan RDM application will appear.



3. Once the status changes to Running and the color of the Collect button turns **green**, then the system is ready and the user can proceed. At this time the user will also have access to the Playback and System Settings buttons.

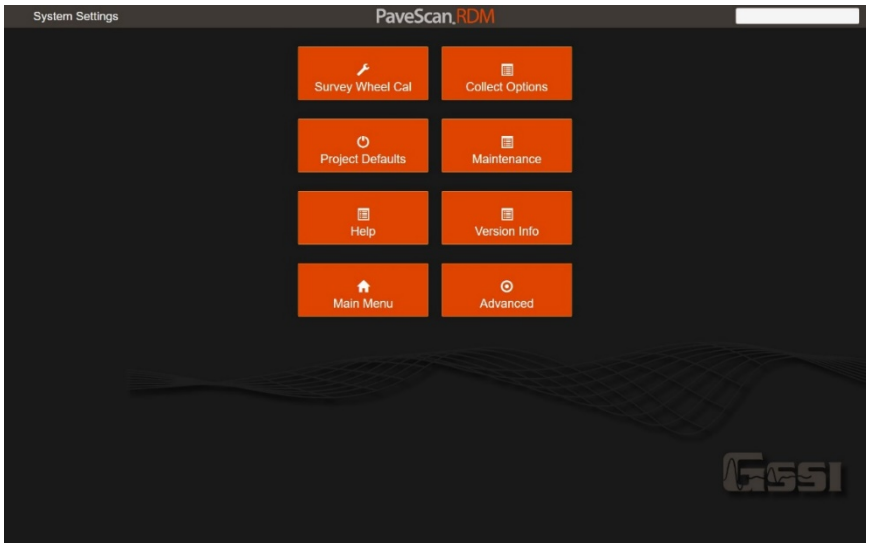
The application can also be started via a desktop shortcut 

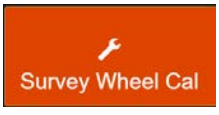
that appears on the desktop after the application is shutdown.



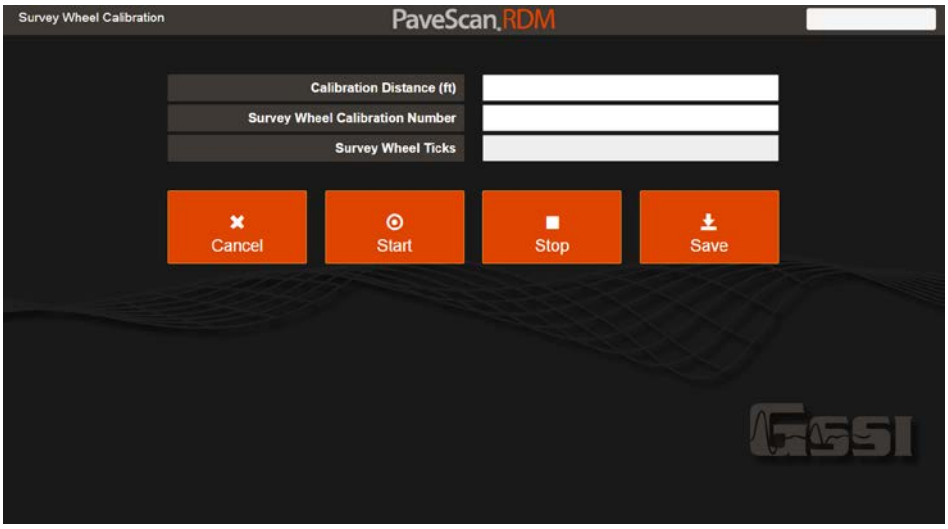
2.2: System Settings

There are several user-adjustable settings that are accessible from the Main Menu. Pressing System Settings in the Main Menu will open the System Settings webpage.

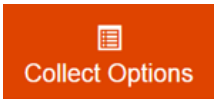




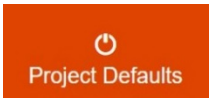
Survey wheel calibration is accessible by pressing this button. The survey wheel calibration window is shown below.



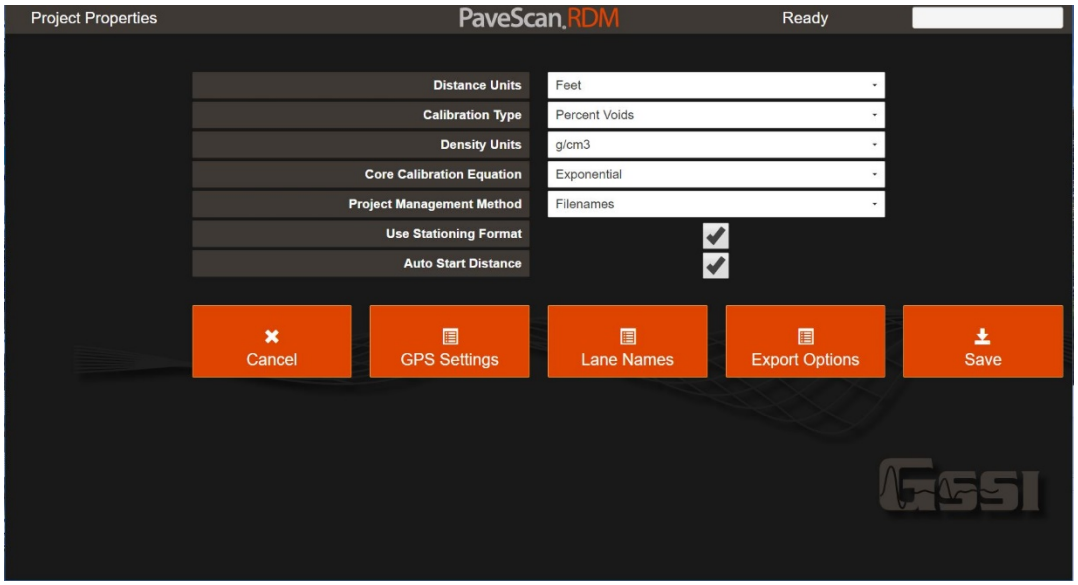
1. To perform a survey wheel calibration, enter in the calibration distance, which is recommended to be as long as feasible (recommended to be 50ft/15m or more because the longer the calibration distance the more accurate the calibration).
2. Next, line-up the cart at the starting point, and press Start.
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. When saving a new calibration number, the system will automatically restart. This will take a few seconds.



The user has the ability to modify the number of measurements per unit distance. The options are “Walk”, “Fast Walk”, “Vehicle”. The measurement densities corresponding to these options are 10 scans/ft (32.81/m), 5 scans/ft (16.4 scans/m), and 3 scans/ft (9.84 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.



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 up the Project Properties window containing these options.



Distance Units: Feet or meters can be selected for distance units.

Calibration Type: PavescanRDM measurements are dielectric values. Dielectrics can be converted to physical properties by generating a least-squares fit relationship derived from dielectric values and known physical properties of cores obtained over a range of dielectric values. The calibration "type" options are: (1) Percent voids, (2) Density, and (3) Percent compaction.

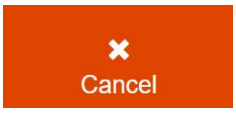
Density Units: When Density is selected as the Calibration Type, the user can adjust the density units. Options include: oz/in^3, lb/ft^3, g/cm^3, and kg/m^3.

Core Calibration Equation: When the user collects a series of cores at known dielectrics, and measures a physical property of each core, (e.g. density, percent voids, etc…) , then plots the physical property vs. dielectric, a least-squares-fit line can be calculated that can then be used to calculate the physical property from subsequent dielectric values. There are two equation options: (1) exponential, which is of the form $y=ae^{bx}$; and (2) linear: $y = a+ bx$;

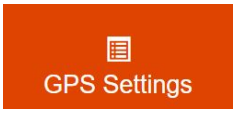
Project Management Method: When "Filenames" is selected, a filenames line appears that the user can specify for each file collected. This is hidden when "Lane Locations" is selected. The idea behind using the "Lane Locations" option is that each "file" is really a distance segment tied to a specified lane and can be reviewed individually or together with other segments in the "Playback Range" menu. (Note: this can also be done using "Filenames" as the project management method.)

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

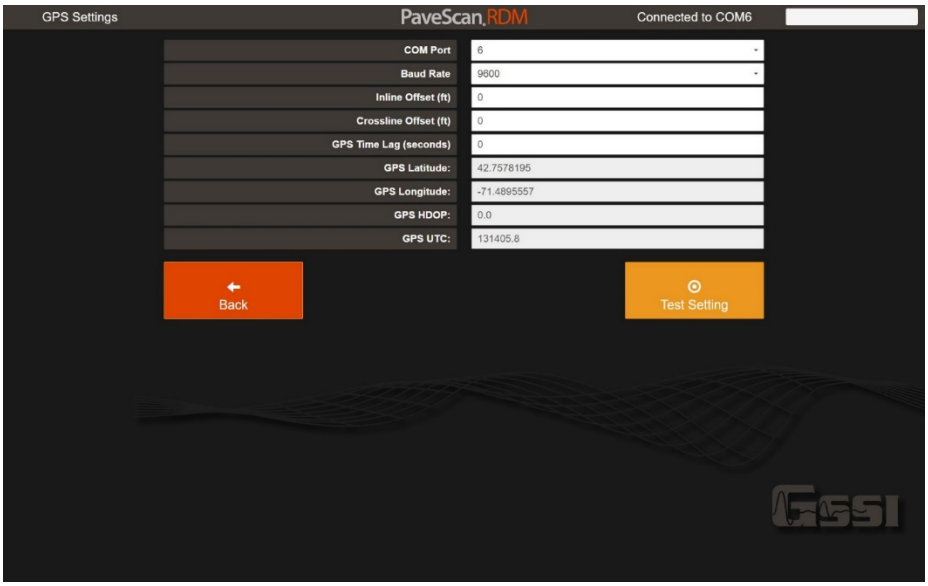
Auto Start Distance: When this option is selected, the ending distance of the previous file is automatically specified as the starting distance for the next file. The starting distance value is always editable prior to starting data collection.



Canceling will return the user to the previous screen without saving any changes made in the Project Properties window or other windows accessed through it. So, if the user modifies



The GPS Settings window 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. Different GPS configurations (COM Port and Baud Rate) can be adjusted using the dropdown lists. After making a setting change, press Test Setting and wait up to 5 seconds for the setting to be applied. If the setting application is successful, GPS data will appear.



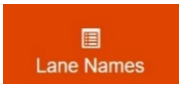
COM Port: The COM port the GPS is attached to. You may have to scroll through the different available COM ports to detect the COM port the GPS is attached to. Do this by selecting a COM Port, then pressing the **Test Setting** button and waiting 5 seconds.

Baud Rate: The Baud Rate of the GPS. The Baud Rate of the Garmin GPS that comes with the RDM system is 9600.

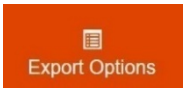
Inline Offset (ft): The inline offset of the GPS relative to the sensors.

Crossline Offset (ft): The crossline offset of the GPS relative to the center of the cart.

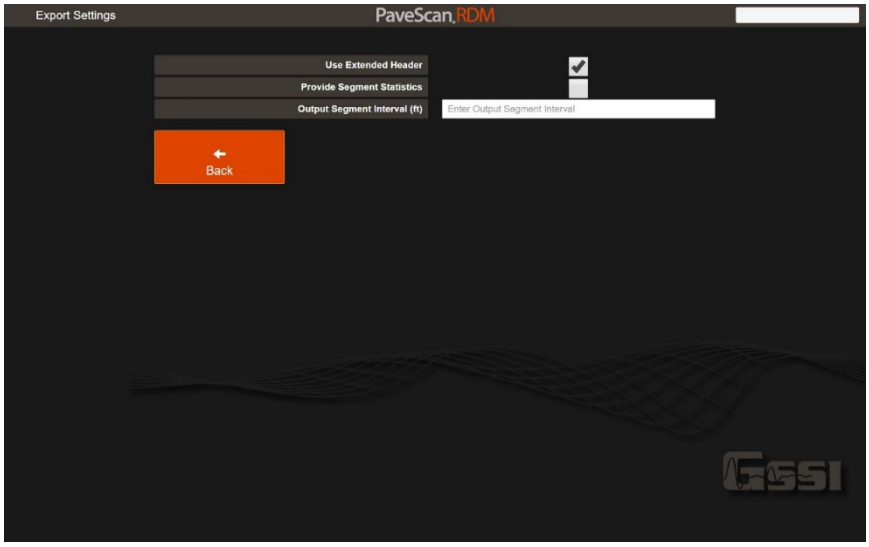
GPS Time Lag (seconds): For high-accuracy GPS systems, the lag, or time difference between the arrival of the PaveScan dielectric measurement and the GPS position information can be calculated and entered here. This value is then used to correct the time synchronization between the two measurements. Typically, to calculate the GPS time lag, a number of measurements are made traversing over a location where the dielectric contrasts with the surrounding asphalt (which can be achieved by placing a metal strip on the asphalt). The GPS coordinates at this dielectric contrast are also known. Then, the data are exported to Google Earth using different GPS Time Lags and the lag used that most closely corrects the GPS locations of the exported data is subsequently used as the entry for this field. The accuracy of the Garmin GPS that comes with the PaveScan RDM isn't high enough to warrant using the GPS Time Lag correction. By default, this value is 0.0.



Allows you to specify the names of the lanes used in the project. The list of lane names is provided as a changeable option in the File Information window



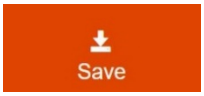
There are several export options that provide limited customization to exported files and project statistics.



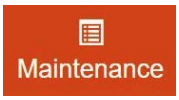
Use Extended Header: Check this selection box so show all the available information on the file when the file is exported. The extended header appears as a series of lines at the top of the exported file.

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.

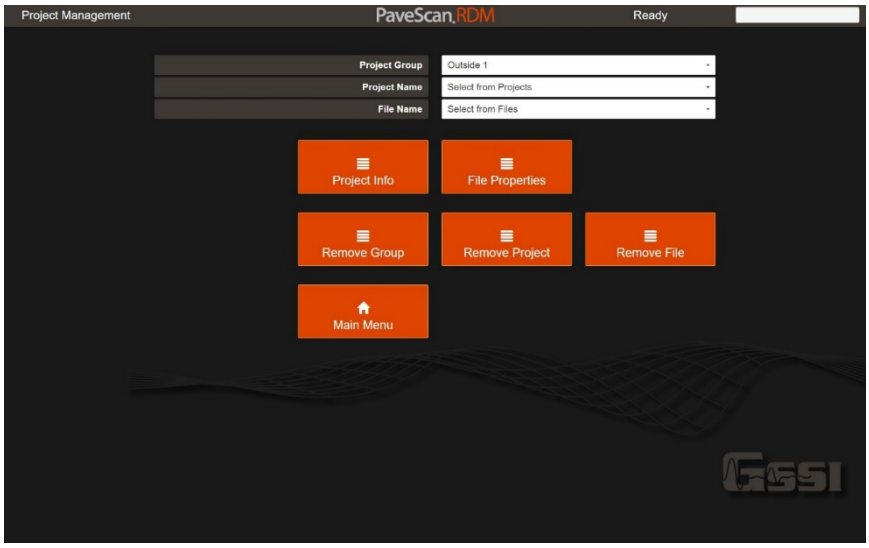
Output Segment Interval: When Provide Segment Statistics is checked, this is the segment interval over which the statistics are calculated.

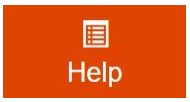


Press the Save button to save all changes made in the Project Properties window sub-windows (i.e. GPS, Lane Names, and Export Options)



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.

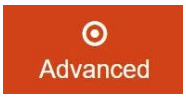




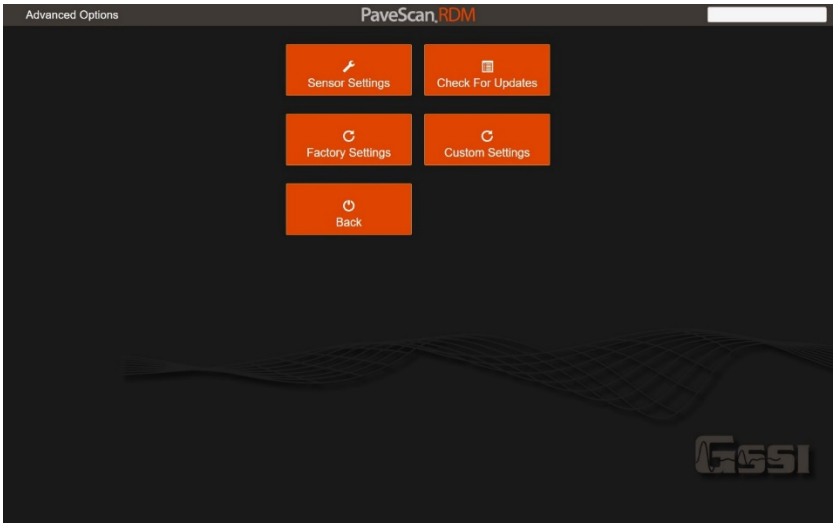
Pressing this button will open this manual as a PDF file.

Shows the current version of the PaveScan RDM application.

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



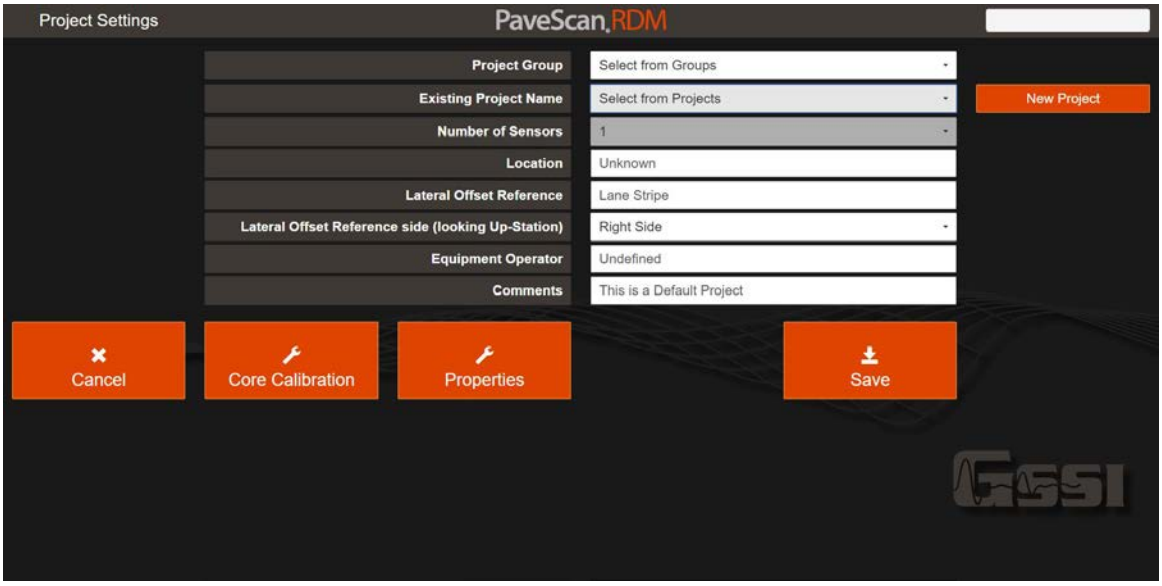
Directs you to options related to sensor settings and updating the application software. Most of these options are password protected.



Select the Advanced button to check for updates or modify sensor settings. Sensor settings are not typically modified after they are entered the first time a sensor is attached to the PaveScan system.

2.3: Data Collection Setup

Clicking on the Collect button from the Main Menu window will allow you to create a new project or recall an existing project and directs you to the Project Settings page.



This page contains several options. Some of the options allow you to fill in details related to the project. The three items that must be specified are the Project Group, Project Name, and Number of Sensors. 1, 2, or 3 sensors can be used. 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 added when New Projects are created.

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 window appears asking if you want to inherent the settings for the current project. Select yes if you want 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 orange concentrator box. 1, 2, or 3 sensors can be used.

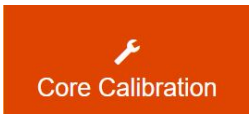
Location: Optional entry for specifying information related to where the data are being obtained. This information is exported with the data.

Lateral Offset Reference: 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 will be included in the exported data. See Appendix C for more details on specifying the Lateral Offset Reference.

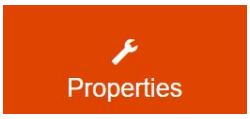
Lateral Offset Reference Side (looking Up-Station): When operating the PaveScan RDM, this will be the side of the cart that the Lateral offset reference is located (e.g. where the curb is) when the cart is facing the direction where distance values increase (e.g. the Up-Station direction). This is necessary to correctly assign coordinates to the sensor data. This will be included in the exported data. See Appendix C for more details on specifying the Lateral Offset Reference Side.

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

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

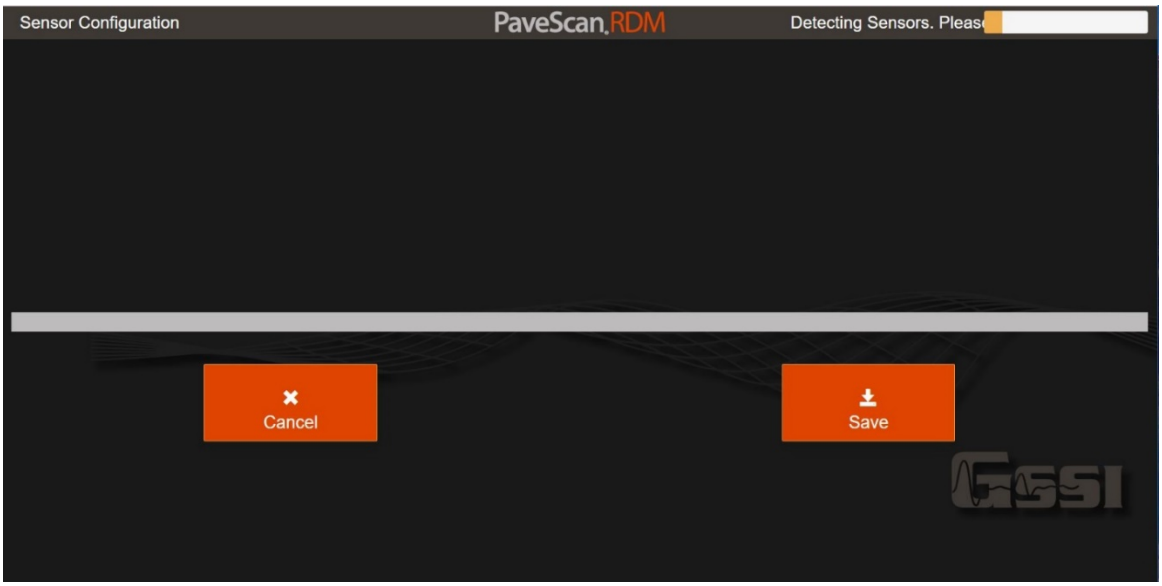


This option is the core calibration button, which allows you to specify the A and B core calibration numbers that are required to generate % voids, %compaction, or densities from dielectrics.

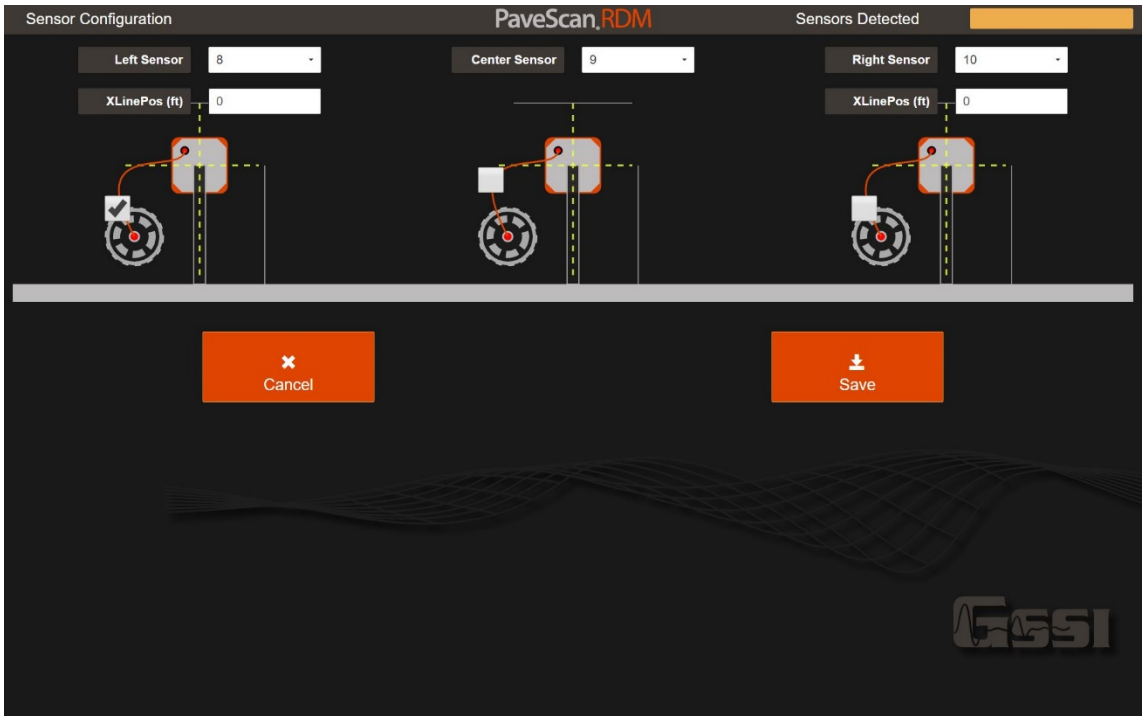


This option allow you to modify the project settings. These are the same settings that are shown when you press the Project Defaults button in the System Settings window. These settings include such things as GPS settings, measurement units, export options, and lane names.

Pressing the Save button navigates you to the Sensor Configuration window. The next window shows the sensors detected and allows for you to change the position of the sensors. During the detecting state, which may take 15-30 seconds, the yellow progress indicator in the top right will continue moving.



Once the sensors are detected, they will appear as shown in the image below. You must specify their relative location on the cart.



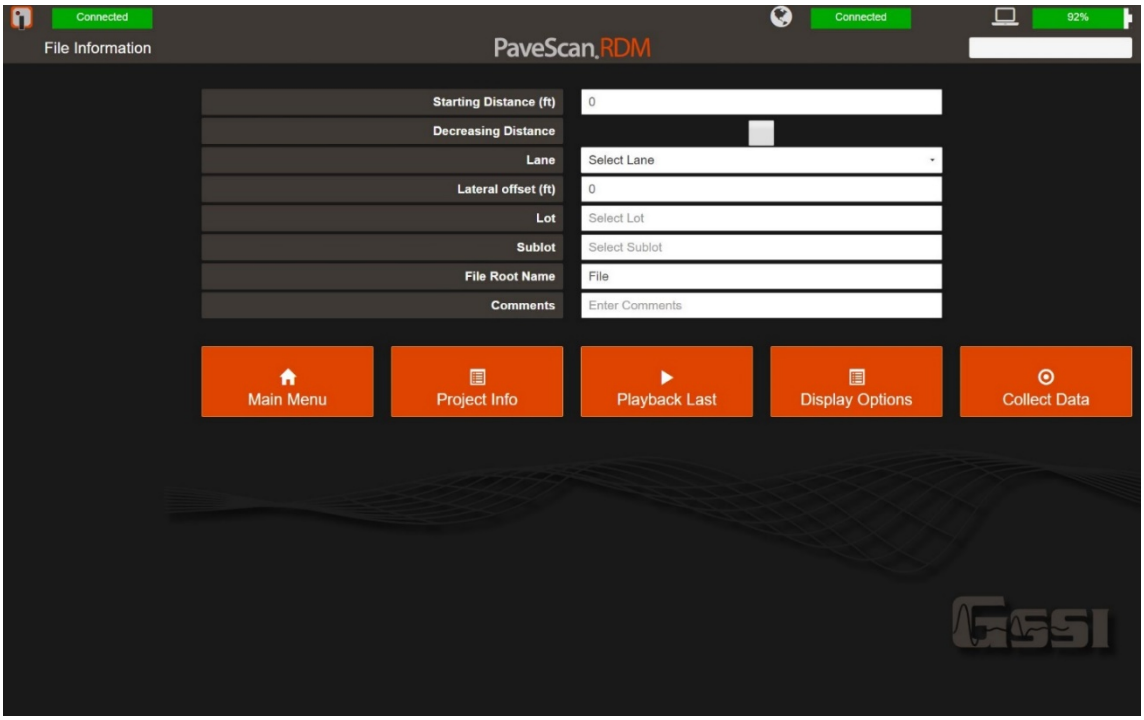
1 First, use the dropdown list to associate the sensor serial # with the sensor that most closely matches its position on the cart. The sensor # is the serial number that can be seen on the side of the sensor when it is mounted on the cart. For example, if Sensor serial # 8 is located on the left side of the cart, it should be positioned on the left side of the window, as shown in the image above.

2 Set the crossline positions of the left and right sensors. The cross-line position reference is distance from the center of the cart. Distances are positive numbers. (Note, in a previous version the user was directed to enter a negative number for the sensor on the right side of the cart. This is no longer the case. Previously collected data can still be played back.) It is a good strategy to always place the same sensor in the same relative location: left, center, or right.

3 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 will be recalled.

> **Note:** If the Status changes to "Sensor Not Found" (which may happen infrequently), turn off the sensors by pressing the button on the front panel of the orange concentrator box, shutdown the application as described in Section 2.7, then follow the Start-up procedure described in Section 2.1.

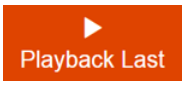
4 After pressing Save the file information window opens. There are several user entries tied to each file.



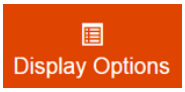
- **Starting Station:** This is that starting station of the file. If stationing is disabled (accessed by Project Info button), this entry will not appear. When the Auto Start Distance Project option is selected (accessed by Project Info button), this value is automatically specified based on the ending distance of the previously-collected file.
- **Starting Distance (ft/m):** This value is the distance used as the starting distance in the output file containing dielectrics and % voids. If stationing is being used, this value is 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.
- **Decreasing Distance:** When this box is checked, the distance values decrease as the data are being collected.
- **Lane:** The lane the data are obtained in. Select the lane from a dropdown list of available names.
- **Lateral Offset (ft/m):** This field is the distance of the center of the cart from the Lateral Offset Reference entered in the Project information page. It is recorded in the output file. See Appendix C for more information on specifying the Lateral Offset.
- **Lot:** Optional entry. This is one of the filter options in the Playback Range menu.
- **Sublot:** Optional entry. This is one of the filter options in the Playback Range menu.
- **File Root Name:** The first part of the output filename. All files have numbers appended to them that increment from file to file. For example, of the root name is MP101_1, the first file will be MP101_1000, the second file MP101_1001, etc… This option is hidden when the Project Management Mode is Lane Locations (accessed by Project Info button).

Redirects you back to the start-up window.

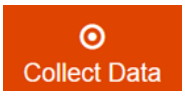
Redirects you back to the project information window where project information and properties can be viewed and modified.



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

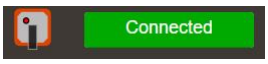


Access the display options for data collection and playback. These options include display ranges, and display of dielectrics versus percent voids. The options are discussed in more detail in a later section.

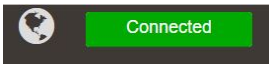


Directs you to the data collection window. If the sensors haven't been calibrated yet, it directs you to the sensor calibration window. Each time the system starts up a new calibration must be performed. The calibration window is shown in 2.4. You must wait until the buttons turn green before you can perform calibration. The first button to turn green is the Air button. This button will turn green once the sensors are warmed up sufficiently. The warm-up status is shown by the progress bar at the top right. It takes 10 minutes for the sensors to warm up unless a file has been collected or previous calibration performed in the preceding 20 minutes. For these cases, the warm-up time will be less than 10 minutes.

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



The left-most icon is the sensor 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 window 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. Note, no indication of the quality of the GPS data is provided.

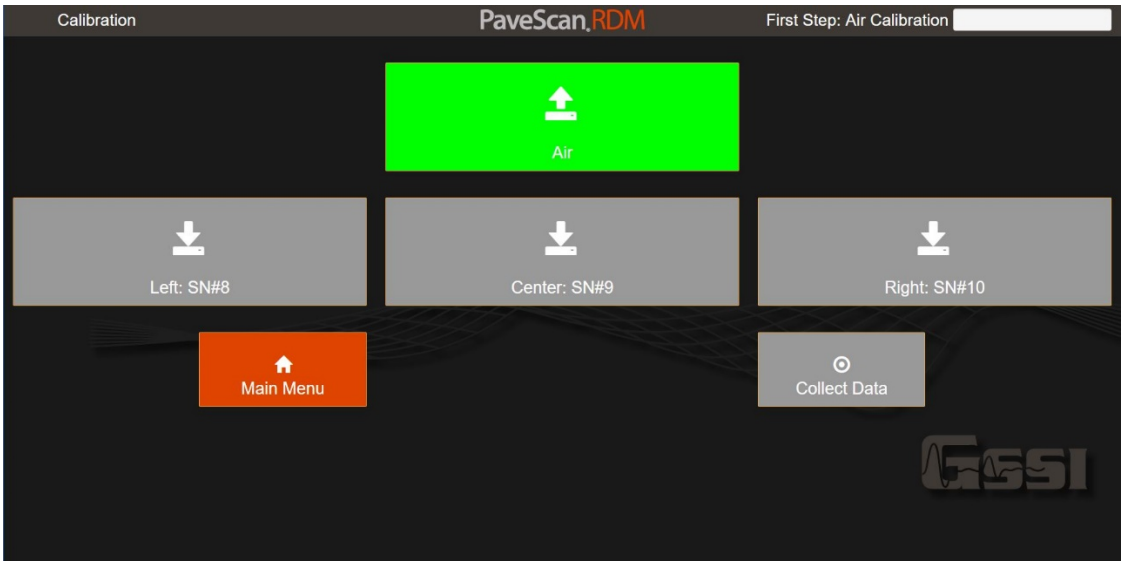
The rectangle adjacent to the right-most icon indicates the level of the Toughpad battery in percent.

2.4: Calibration

Pressing the Collect Data button prior to calibrating the sensors directs you to the Calibration window. 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 will turn green. The air measurement requires that all the sensors be lifted at least 2ft (60cm) off the ground. To accomplish this, untighten the large metal thumb screw and lift the sensor arm up to about a 45 degree angle, then retighten.

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

Sensors in position for airwave measurement



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

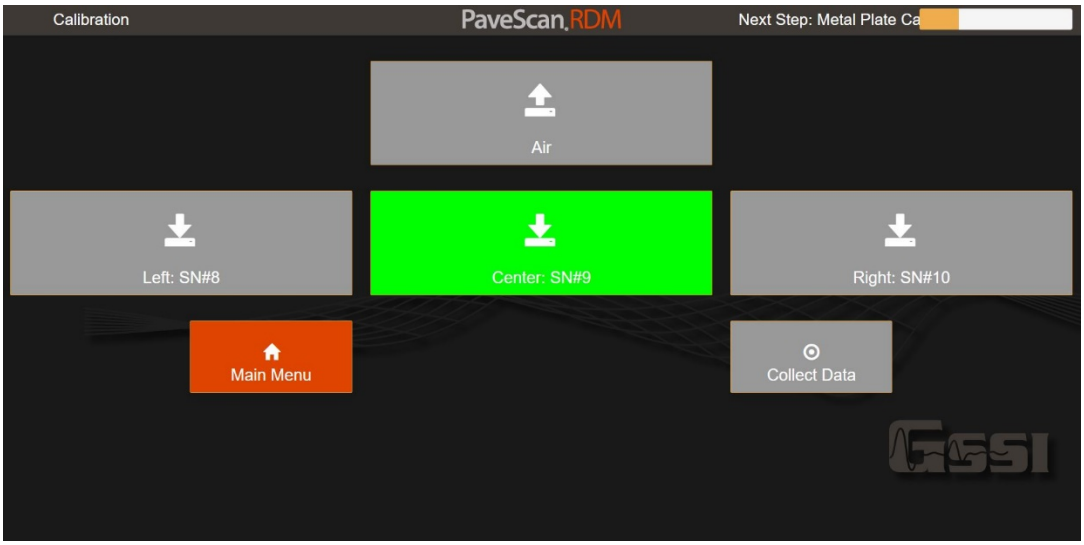
5 Press the **Air** button. When pressed, it turns orange while the calibration measurement is being performed. The air calibration will take 5-10 seconds per sensor.

- For a 3-sensor set-up, the total measurement time will then be about 15-30 seconds.
- **All sensors must be in the air-measurement position during the calibration.**

6 Once the air calibration is completed, the Metal Plate Calibration step can be initiated. One of the buttons will turn green. Make sure that the position indicated on the button matches the position of the sensor on the cart. In the example below, sensor #12 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).

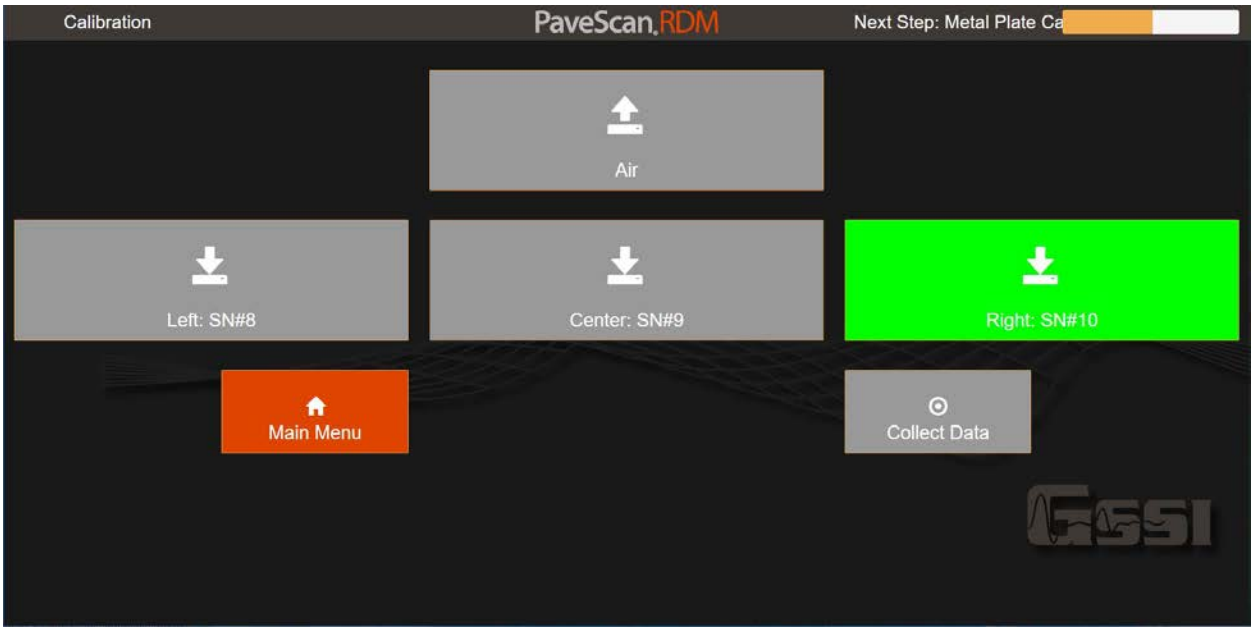
7 Place the metal plate underneath the sensor indicated. **The metal plate needs to be centered under the sensor to within ± 1" (2.5cm).** To assist with this, view the position of the metal plate from the sides to see if the notches on the metal plate line up with the center of the sensor. **The metal 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.**

The order in which the buttons turn green may vary.

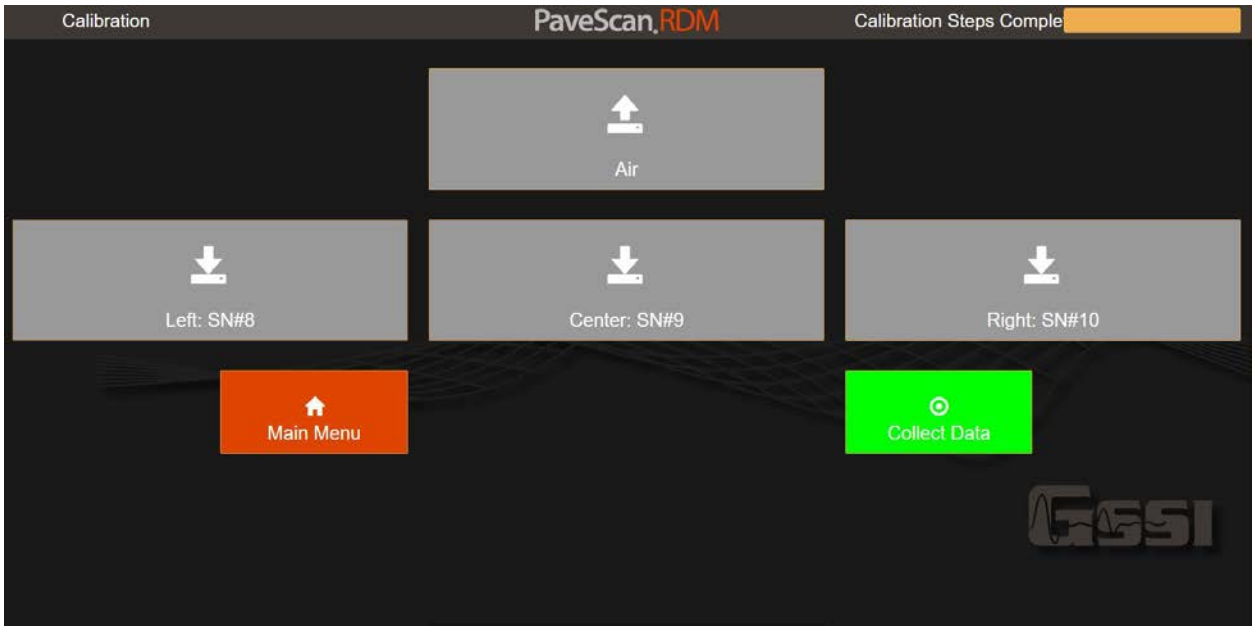


8 Once the metal plate is in place, lower the antenna, and press the green button. It will turn orange during calibration. The metal plate calibration takes from 5-10 seconds. Once it is complete, a different button will turn green.

In the window below, the right sensor, #10, is ready for the metal plate calibration. In this scenario, the the metal plate would be placed under this sensor, then the green button would be pressed.

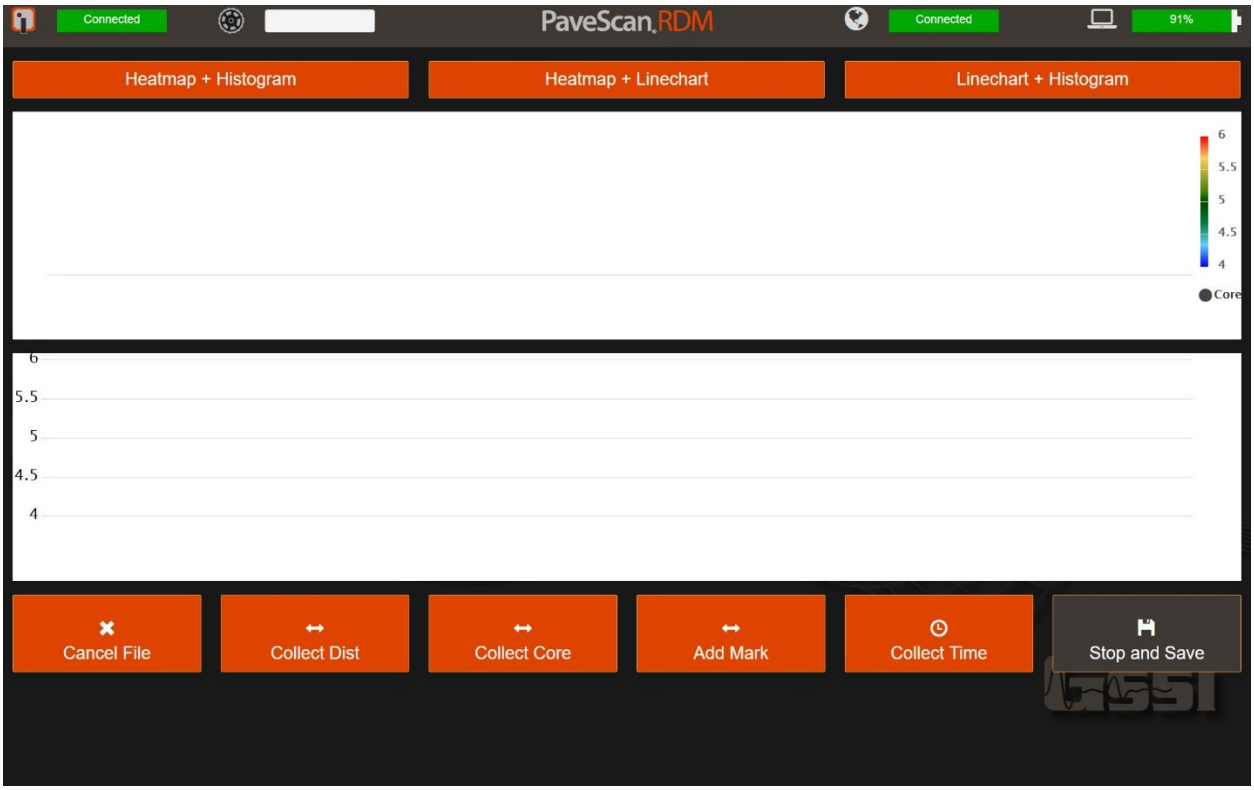


9 Repeat the process until all sensors are calibrated and the Collect Data button turns green.



2.5: Data Collection

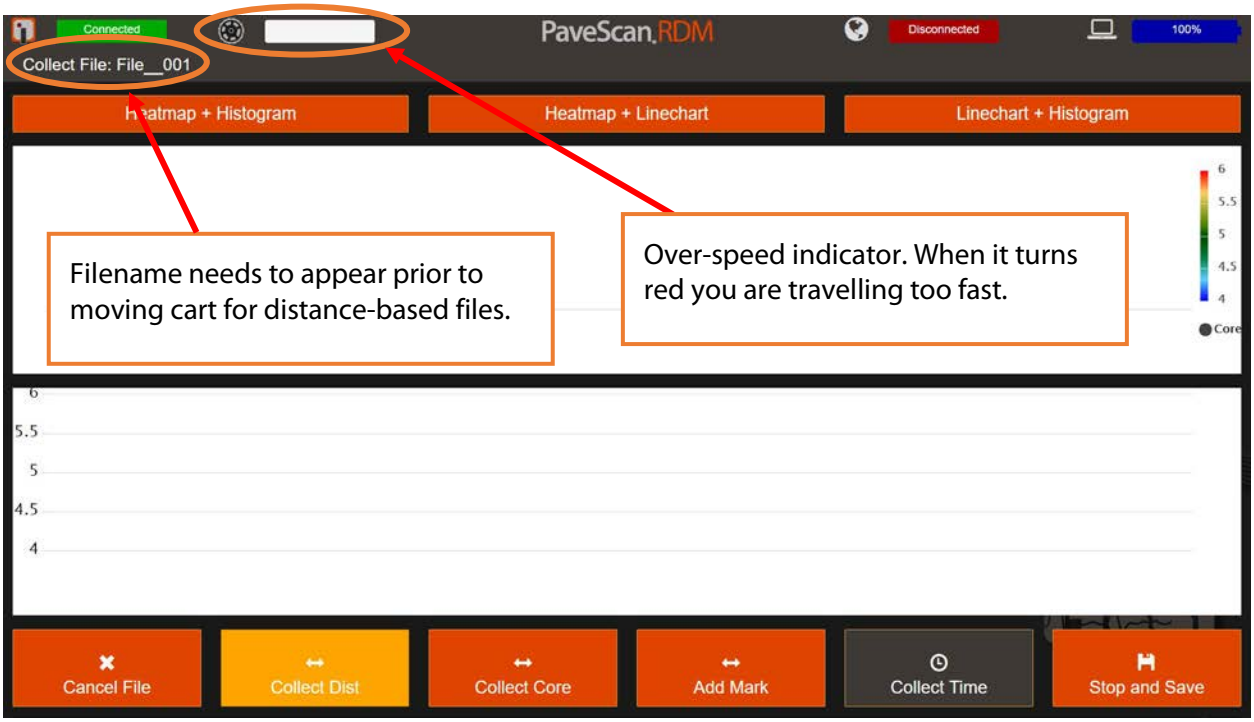
Pressing the green Collect Data button after calibration is completed redirects you to the Collect window.



No data collection starts until either the Collect Dist, Collect Core or Collect Time buttons are pressed.

Collect Dist

Pressing the Collect Dist button will start data collection of a file using a survey wheel. Once the correct filename appears on the top left of the window, the system is ready and the sensors can be moved. **Do not move the sensors until the filename appears.** If the filename does not appear after 5 seconds, press the Cancel File button and then press Collect Data from the File Information page.



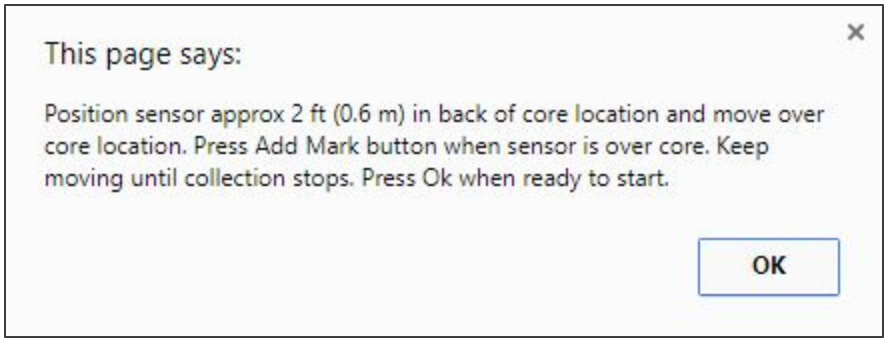
The current speed at which you can collect data in walk mode is about 5ft per second (1.5m/s). If you exceed this rate by a small fraction, the missing data points will be filled in with duplicates from neighboring values. Exceeding the limit by a large amount may lead to system instability. Keep an eye on the overspeed indicator in the status bar, which will turn red when you are walking too fast.

Collect Time

Pressing Collect Time initiates collection of a continuous file at a rate of about 60 measurements per second. This mode is often used when making a static (non-moving) measurement at a specific location.

Collect Core

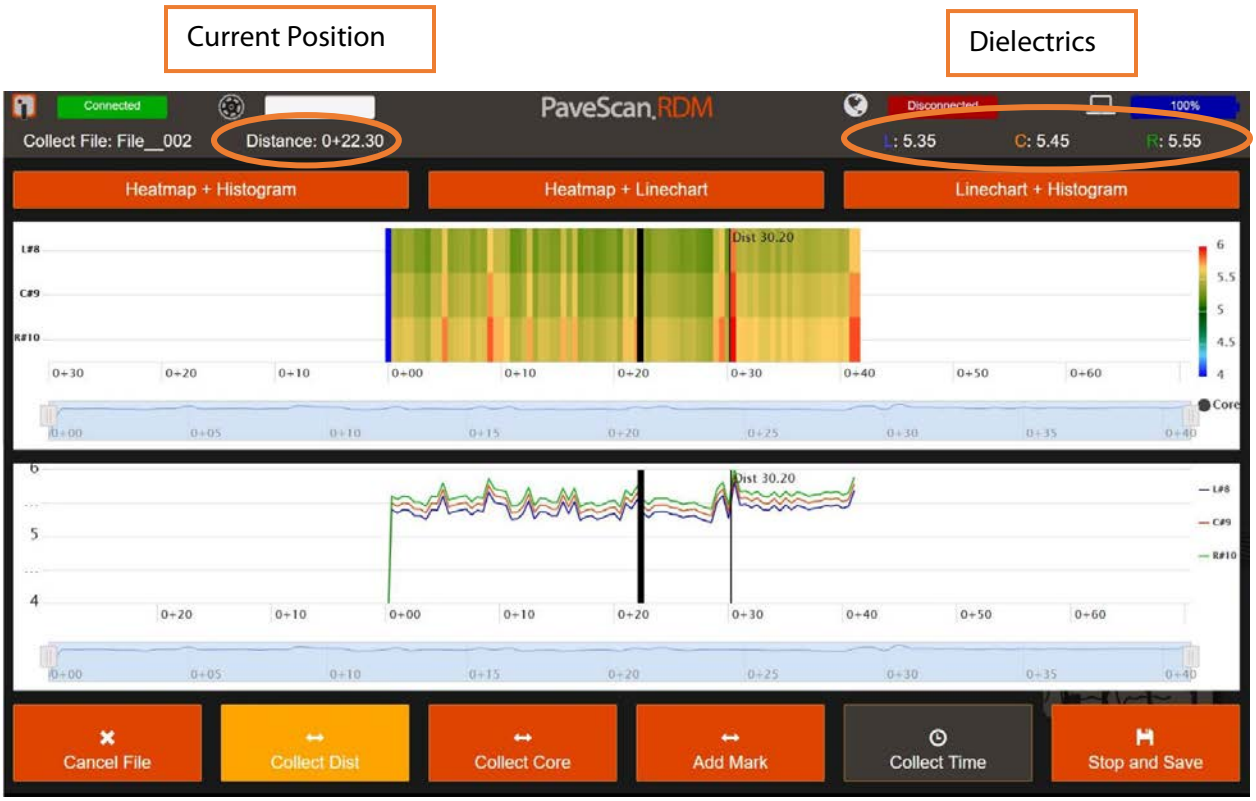
Pressing the Collect Core button will start data collection of a 4 ft (1.2 m) file using a survey wheel. A message box appears with instructions when this button is pressed. **After pressing OK do not move the sensors until the filename appears.** If the filename does not appear after 5 seconds, press the Cancel File button and then press Collect Data from the File Information page.



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 your finger) 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 window and the back-up location in the data is indicated by a large black bar.



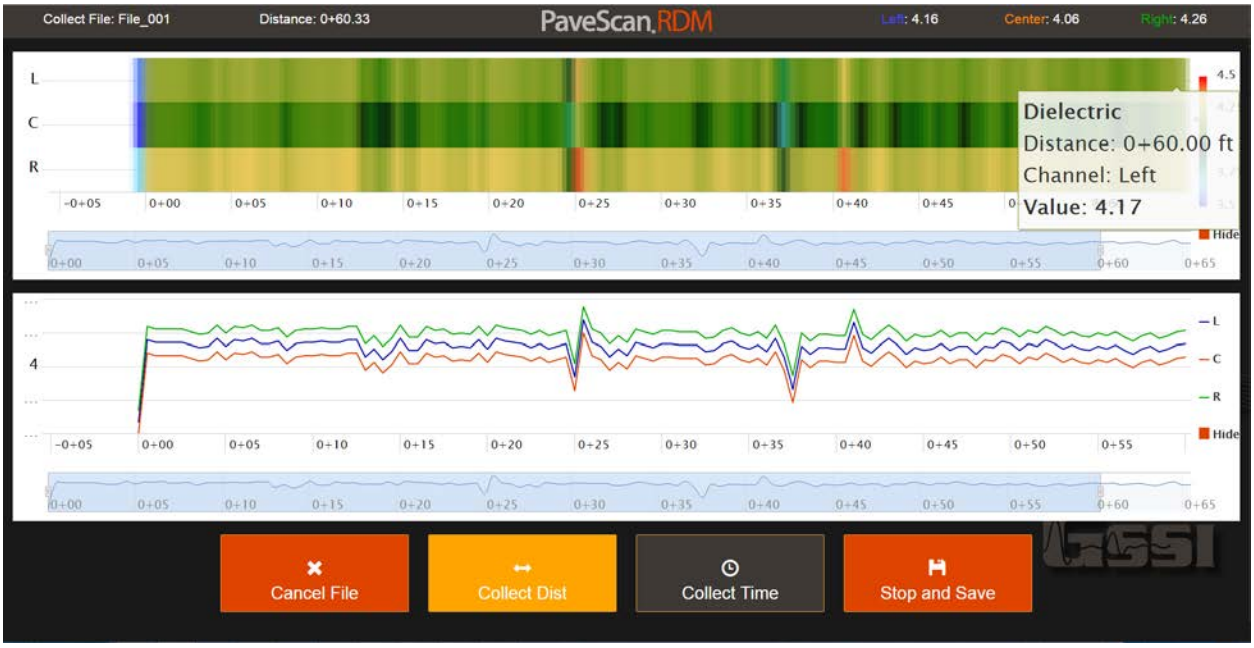
Clicking on the different buttons on the top of the window shows different combinations of windows.

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.

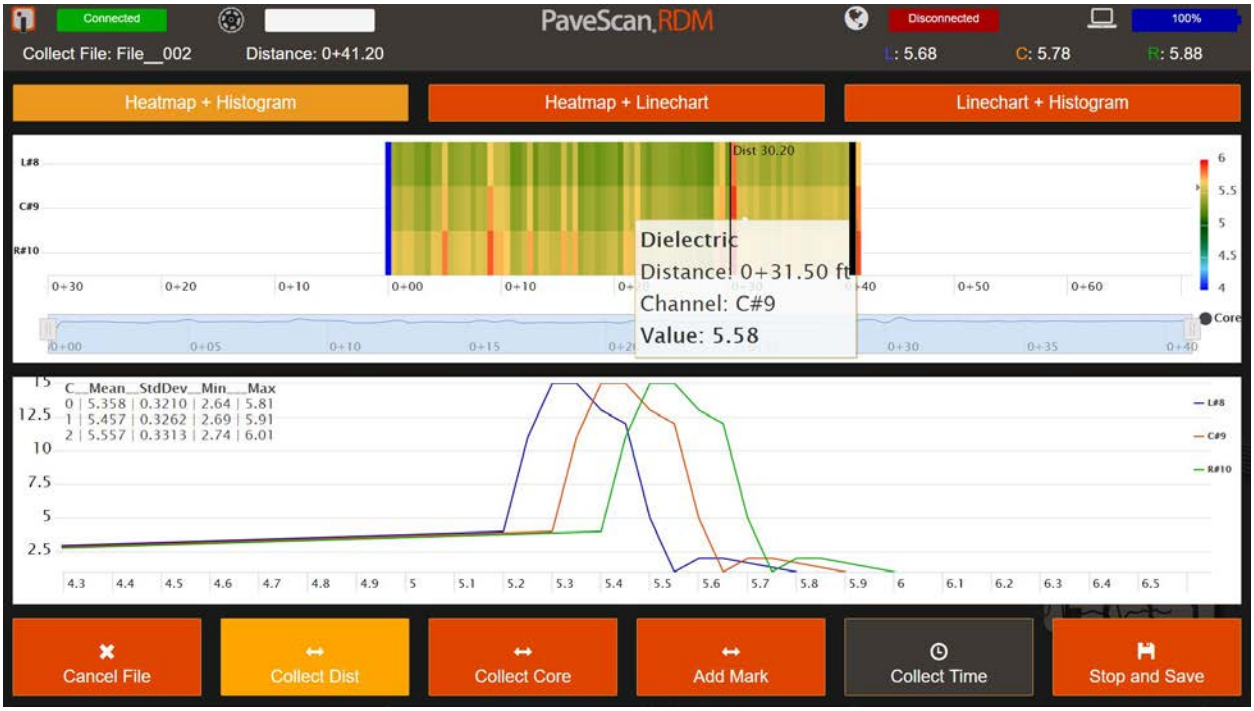
Heatmap + Histogram Shows a heatmap of the displayed values (dielectrics or calibrated physical property value) on top and a histogram showing the distribution of the displayed values on the bottom.

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.

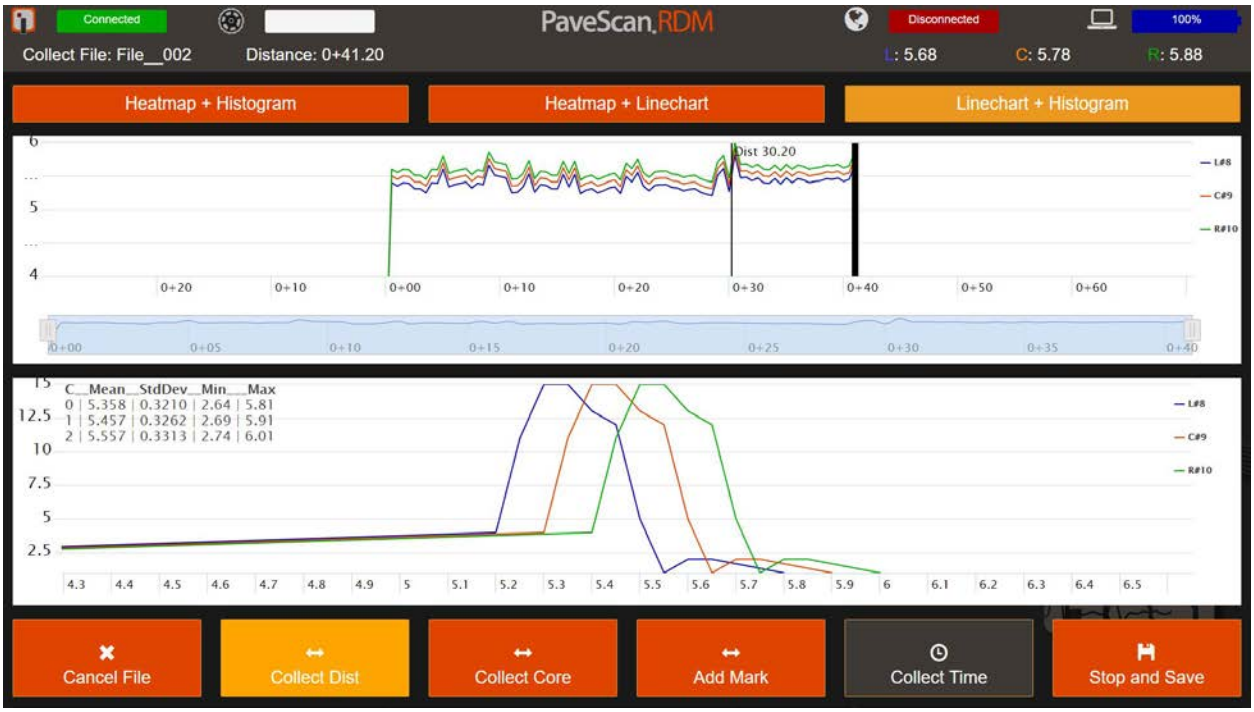
By default, the Heatmap + Linechart combination is shown.



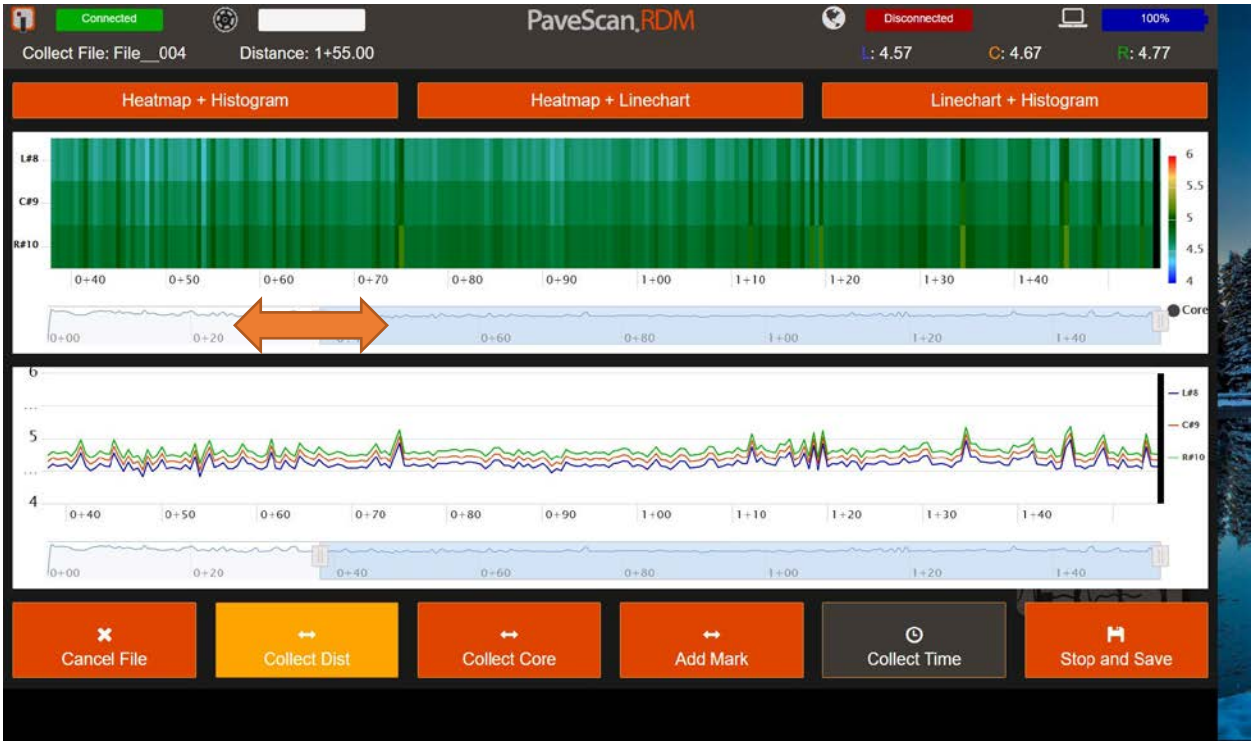
The heatmap+histogram combination is shown below.



The linechart+histogram combination is shown below.



Grabbing the handle on the thin bar allows you to shrink or enlarge an area. The area being viewed can then be shifted by placing the pointer (or your finger) 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 will redirect you back to the File Information web page where custom changes can be made to the file information before collecting the next file.

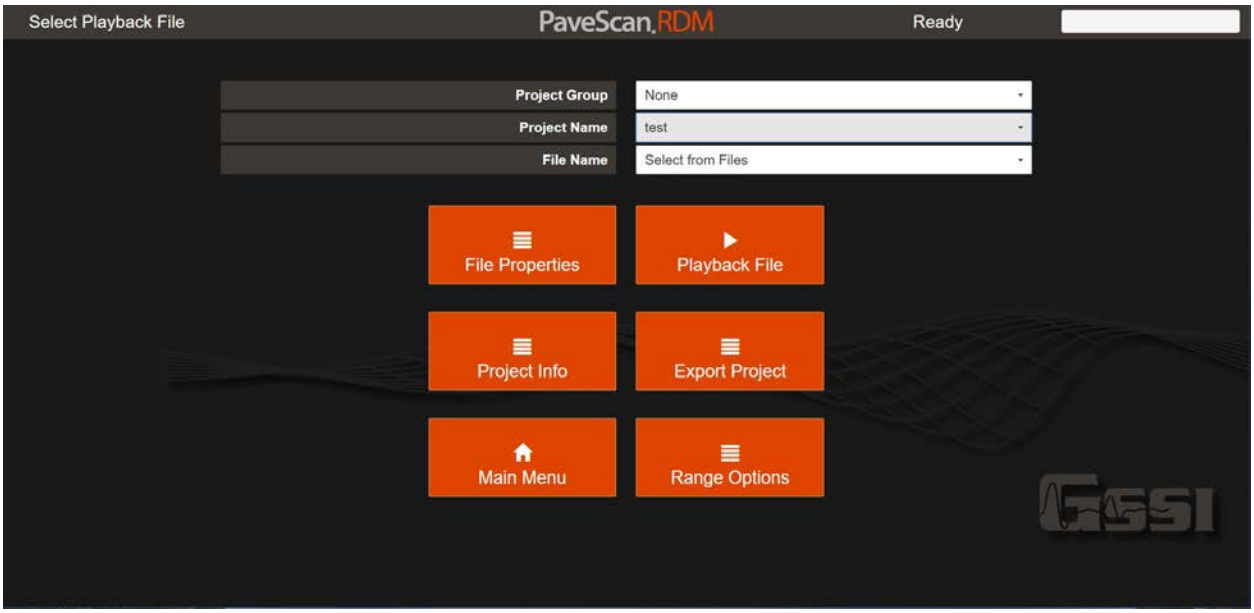
Chapter 3: Data Playback and Export

3.1: Playback and Review Collected Files

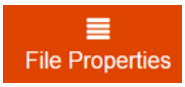
You can playback and review data collected in distance or time mode. To do this:

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

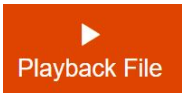
When accessing playback from the Playback button, a window appears allowing you to specify the Project and File to play back.



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

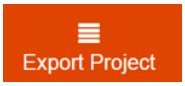


Allows user to edit file information such as starting distance, ending distance, and filename.



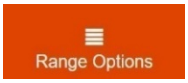
This plays back the selected file.

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

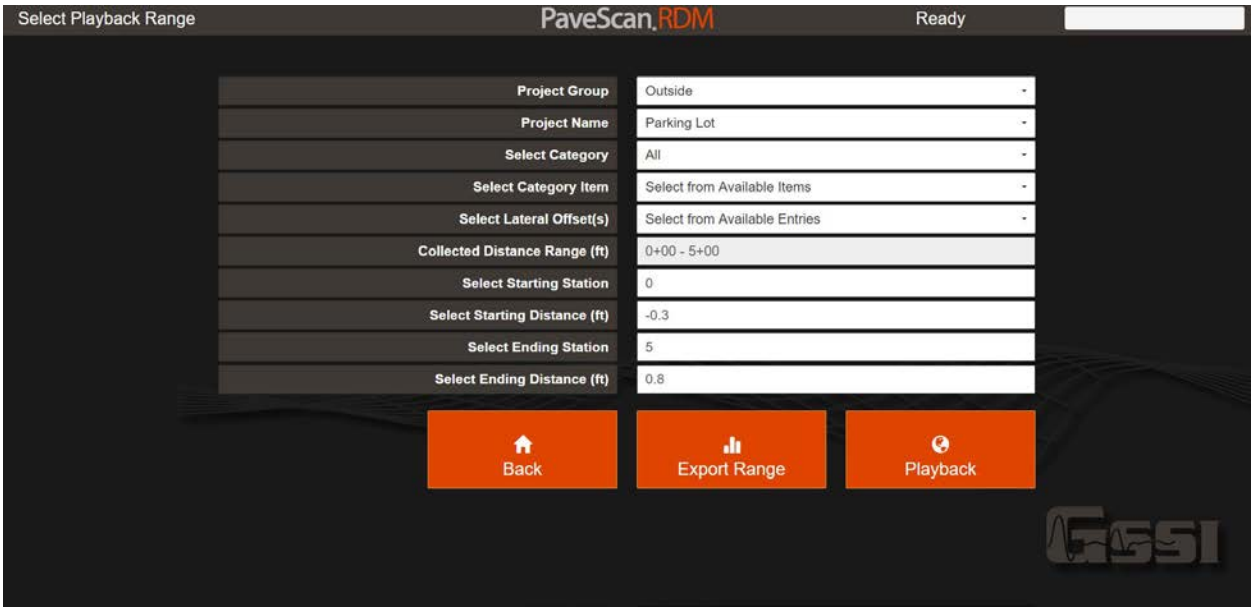


Allows user to export all files in the selected project folder.

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

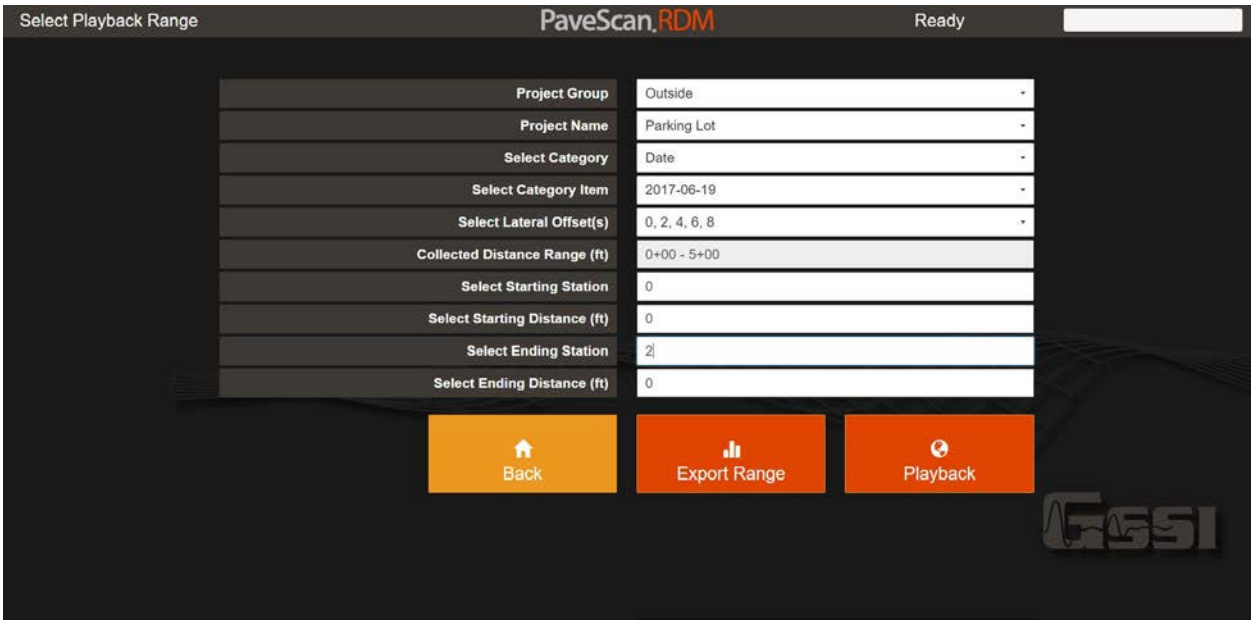


Brings the user to a window that allows a selection of different individual lines of data and specific distance ranges from one or more files that can then be displayed together and exported to a single file.



Each item in the Playback range window serves as a filter to progressively narrow the choice of measurements. Currently, only data from a single project can be combined in a playback range. Within one project you can select to filter the data by different specified categories that include Lane Name, Lot Sublot, and Date. Measurements fitting the selected category can then be further filtered by the Lateral Offsets. The Distance range of measurements corresponding to the selected lateral offsets are shown on the next line (i.e. the Collected Distance Range line) Multiple lateral offsets can be chosen. Finally, the measurements can be filtered by the selected starting and ending distances.

In the figure below, the user has selected Date as the category, specified the date 2017-06-19, selected measurements along lateral offsets 0,2,4,6, and 8 ft. These profiles extend over a station range 0+00 to 5+00. The user selected to playback or export measurements over the station range from 0+00 to 2+00.

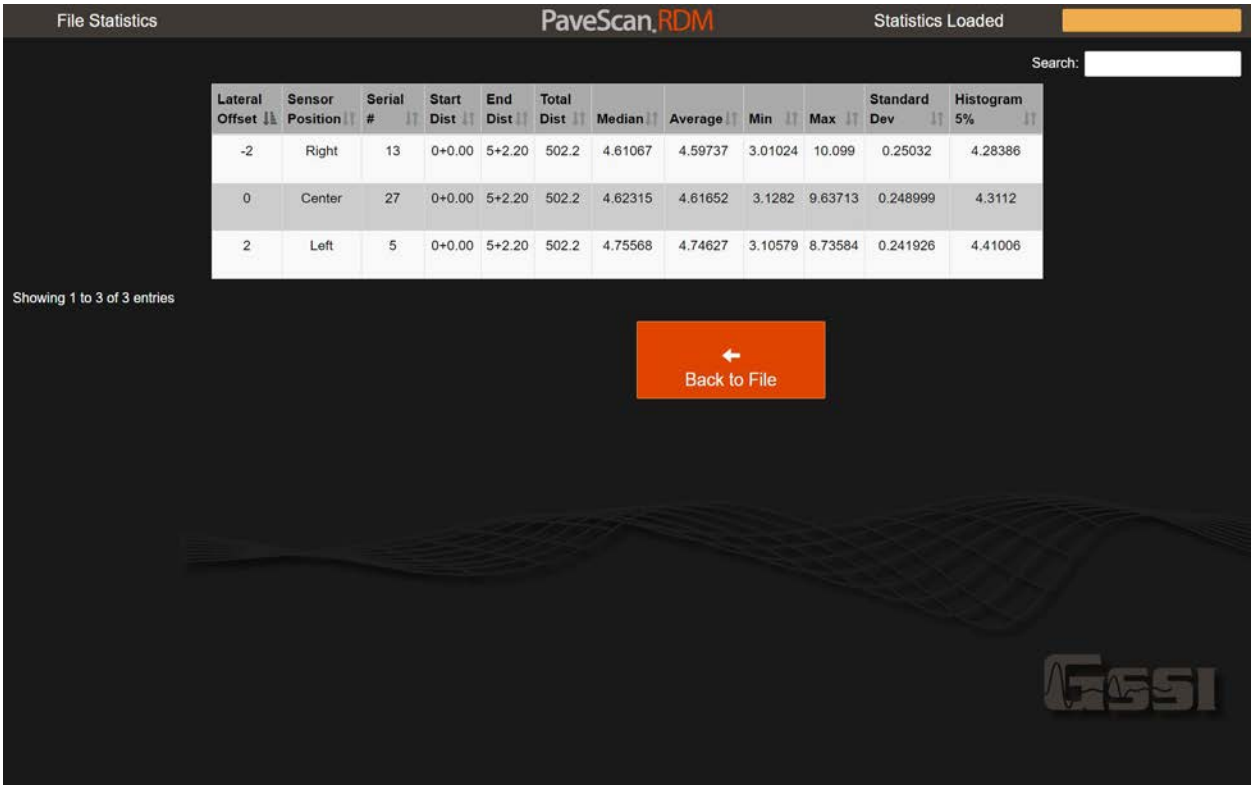


The file and selected range playback window is very similar to the Collect window. The major difference is the different group of buttons at the bottom. The functions of these buttons are described below.

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

Statistics

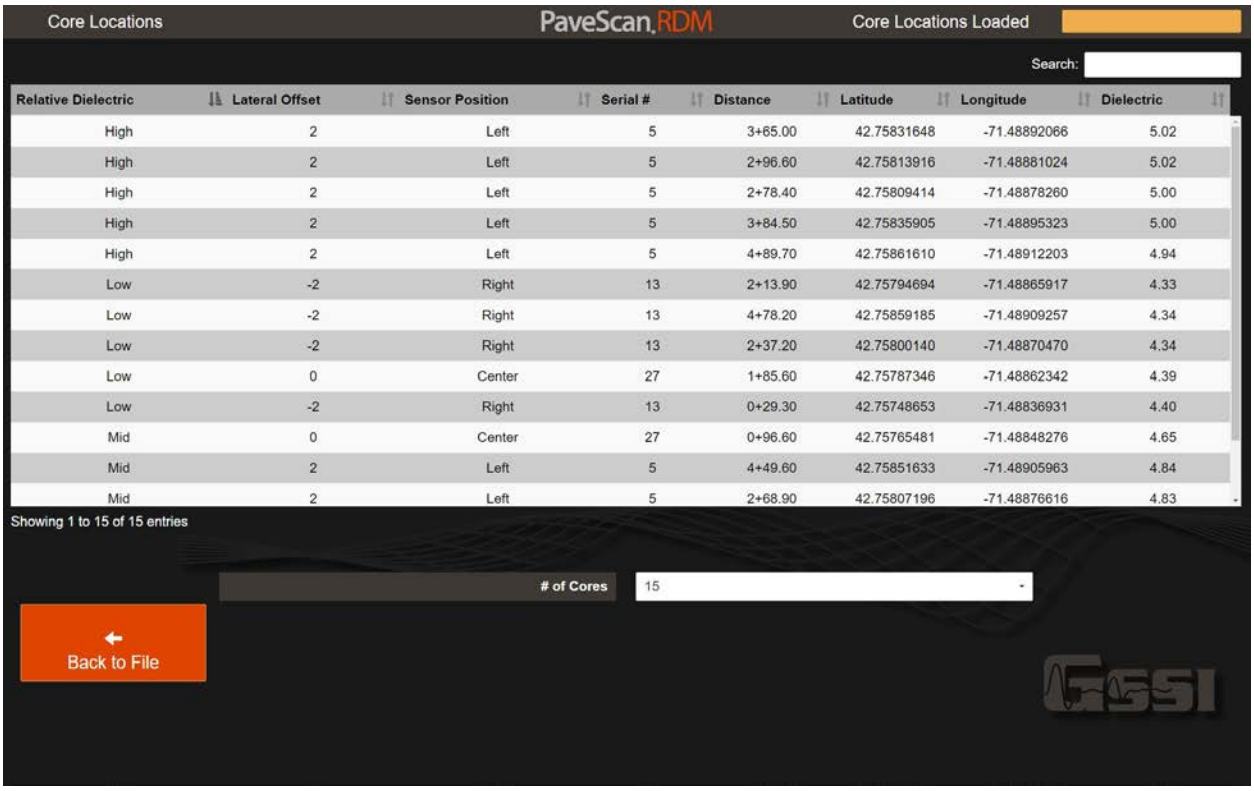
Opens a window which displays statistics related to the currently open file.



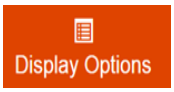
Core Locations

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 % void curve. The columns shown contain the following information:

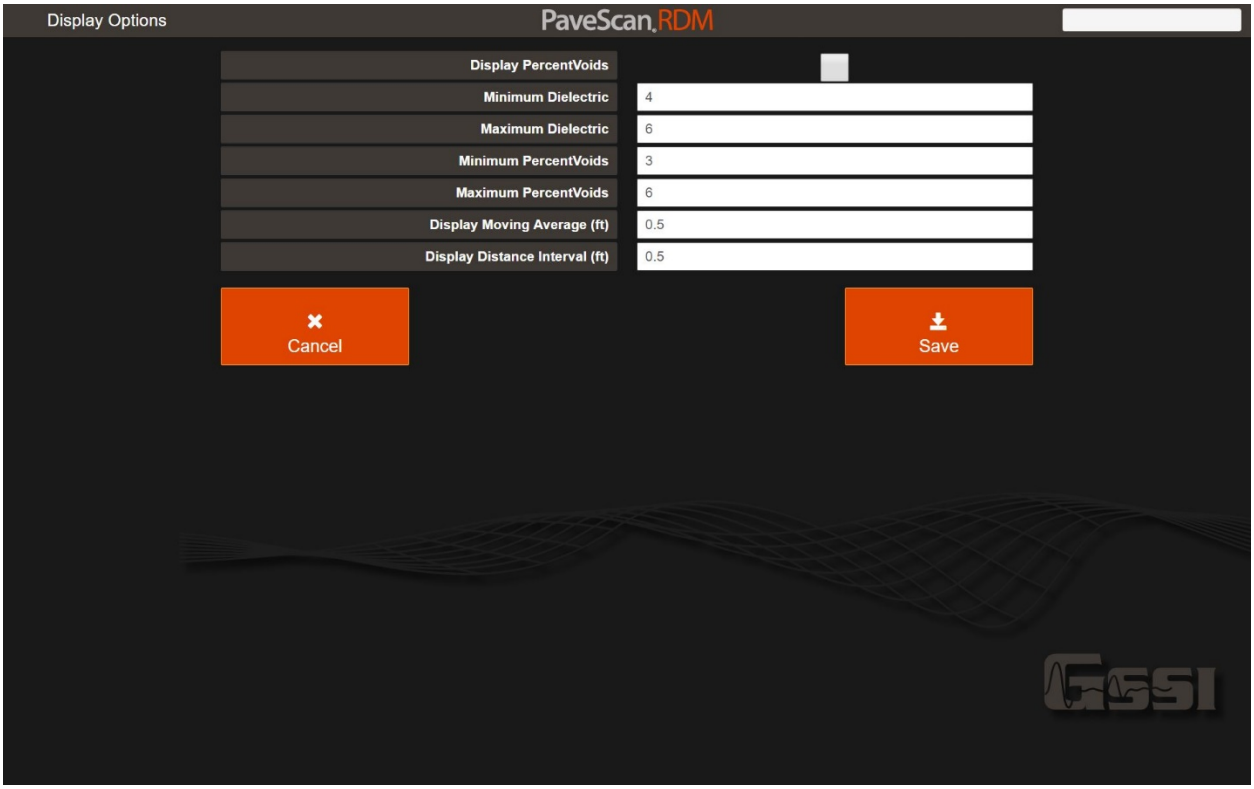
- **Relative Dielectric:** Either a High, Mid, or Low dielectric
- **Lateral Offset:** Distance of sensor from lateral offset reference location
- **Sensor Position:** Position of sensor on the cart – Left side, Center, or Right side
- **Serial#:** Serial # of the sensor
- **Distance:** Distance at which the dielectric value is located
- **Latitude, Longitude:** global position of core if GPS was used during data collection
- **Dielectric:** Average dielectric at the location using a 6” (15cm) central moving average window



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 Percent Voids/Density/Percent Compaction: Selecting this option will change the data display to the currently selected Calibration Type in the Project Properties. In the window above, % voids is the currently selected calibration type. Note, you must enter in core calibration numbers for this option to be useful. Core calibration numbers are accessible from the Core Calibration button in the Project Settings window.

Minimum Dielectric: When dielectric values are shown, this value is the minimum dielectric shown in both the heatmap and line chart.

Maximum Dielectric: When dielectric values are shown, this value is the maximum dielectric shown in both the heatmap and line chart.

Minimum Percent Voids/Density/Percent Compaction: When calibrated physical property values are shown, this value is the minimum shown in both the heatmap and line chart.

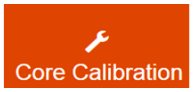
Maximum Percent Voids/Density/Percent Compaction: When calibrated physical property values are shown, this value is the maximum shown in both the heatmap and line chart.

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 (15cm) moving average is specified, each displayed data point is an average of all the data points at the measurement location ± 0.25ft (± 7.5cm). For time-based files, the units of the moving average are seconds.

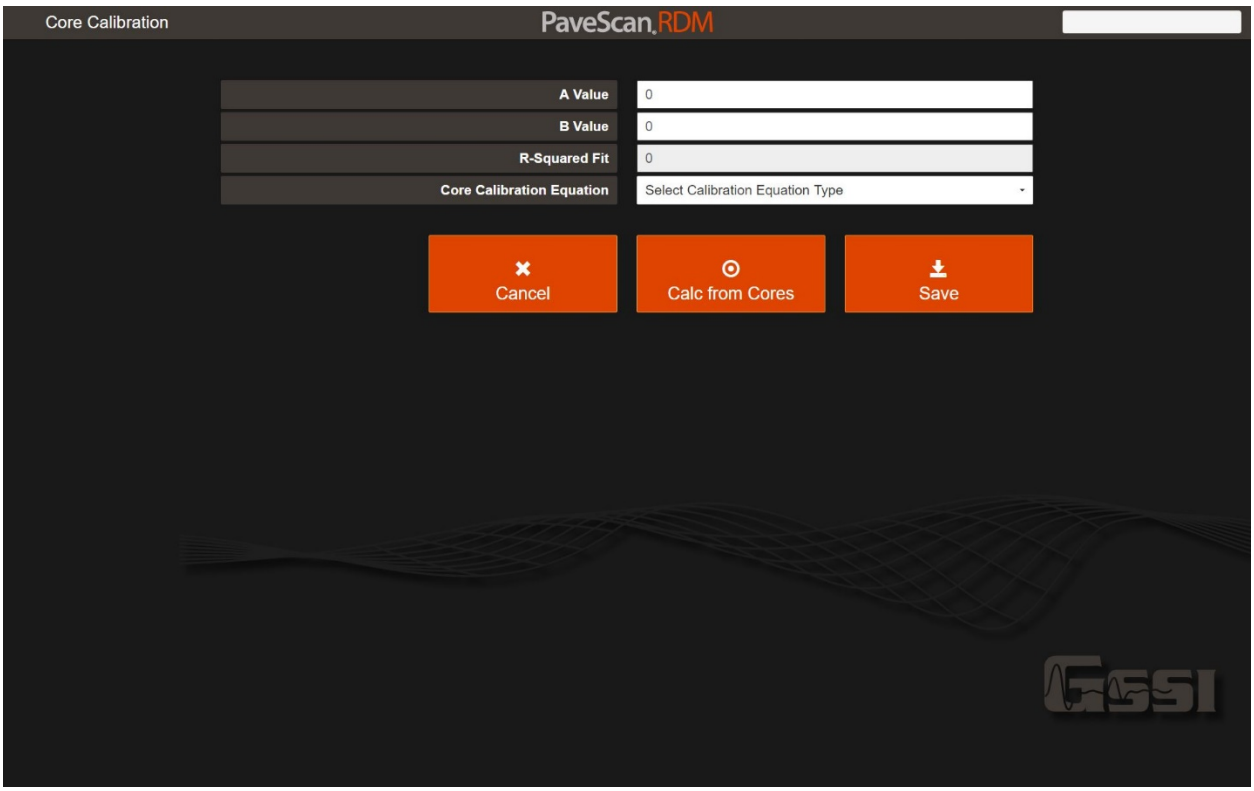
Display Distance Interval: The output interval between displayed measurements. For general purposes where data may be obtained over a distance of hundreds of feet, a display interval of 0.5ft (15cm) is useful. For time-based files the units of the display interval are seconds.

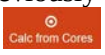
Brings you back to the previous window - either the File Information window or the Playback window to select a different playback file.

3.2: Setting Up the Void Percentage Relationship



Once a project is created, the Core Calibration button appears when the project settings window is accessed. Pressing the Core Calibration button opens up a window that shows the two calibration values “A” and “B” that are used in the equation to calculate void percentage from dielectric. The details of the equation are in Appendix B.

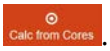


You can enter in previously calculated “A” and “B” values and the equation type used to calculate these values, or press the 

button to calculate the “A” and “B” values from dielectrics and void percentage obtained from cores.

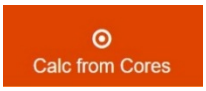
A Value: This is the first value used in the equation relating dielectric to another physical property (see Appendix B for details)

B Value: This is the second value used in the equation relating dielectric to another physical property (see appendix B for details)

R-Squared Fit: This is for information purposes-only and is auto-generated when you select 

. It provides a good indication of how confident you can be that the calculated equation is useful. Values less than 0.6 – 0.7 lead to low confidence levels.

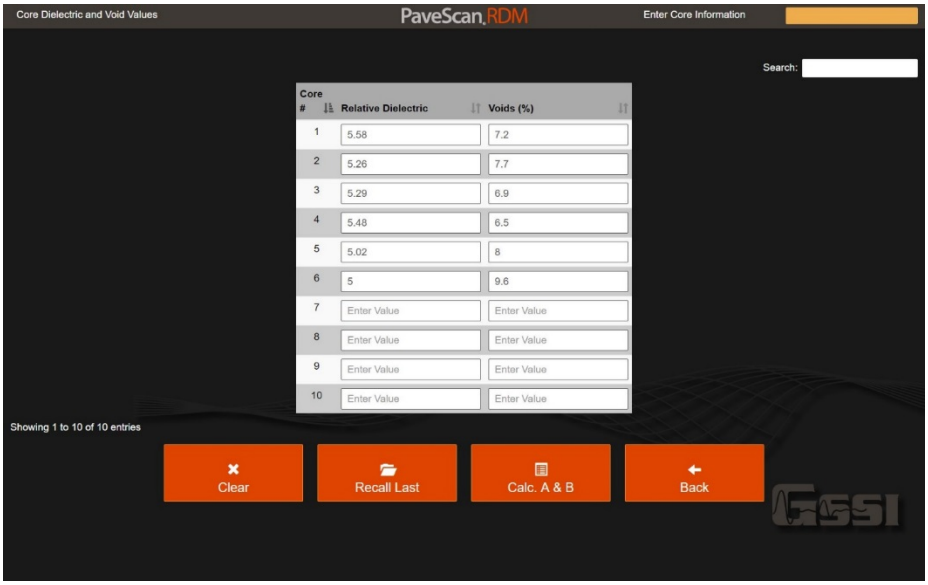
Core Calibration Equation: There are two types of core calibration equations: Exponential and Linear. The type entered must match the type used to calculate the A and B values.



Press this button to automatically generate the calibration equation relating the desired physical property to dielectrics. You will be directed to a window to enter in the core-measured values and corresponding dielectric values.

In the window that appears enter in the dielectrics and corresponding core-measured physical property (i.e. % Voids, %Compaction, Density) from up to 10 cores and then press the 

button. Note, the physical property entered needs to be the same as the Calibration Type specified in the Project Properties window. The equation type used to calculate the A & B values will also be the equation type specified in the Project Properties window.



The calculated values are returned in a pop-up window that prompts you to either save the values by pressing OK, or not to save the values by pressing Cancel.

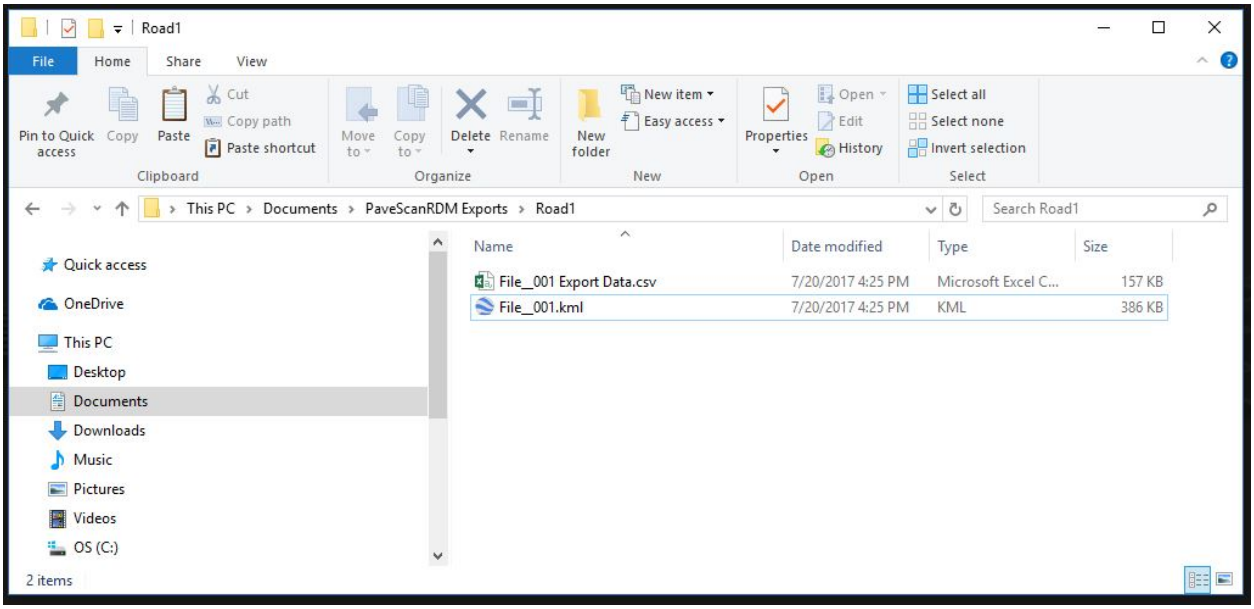
If you select OK, the values are input into the “A” and “B” entries in the Core Calibration window when you press the 

button. Then, to save these values with the project, press the 

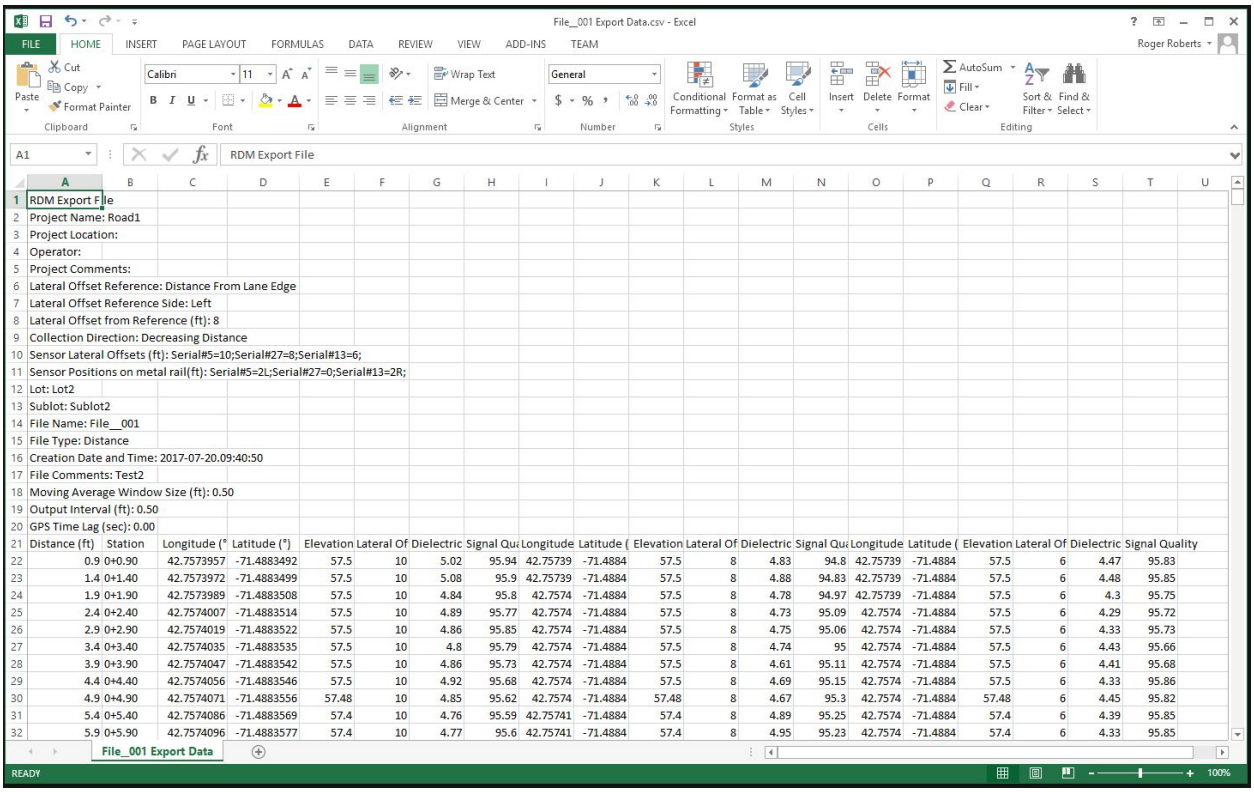
button. These values will then be used to calculate the physical property (i.e. %voids, compaction or density) from the dielectric values when the option is checked in the Display Options window. Exported data will also contain the physical property value when the option is checked.

3.3: Exporting Collected Files

When files are exported, a folder with the same name as the project is created in the **PaveScanRDM 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__001"** belonging to the project **Road1** 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, which consists of comma separated values. You can choose to skip exporting the header lines by deselecting the Use Extended Header option in the Export Settings window (which is accessed from the Project Properties window). A portion of a typical exported file is shown below.



RDM Export File
Project Name: Road1
Project Location:
Operator:
Project Comments:
Lateral Offset Reference: Distance From Lane Edge
Lateral Offset Reference Side: Left
Lateral Offset from Reference (ft): 8
Collection Direction: Decreasing Distance
Sensor Lateral Offsets (ft): Serial#5=10;Serial#27=8;Serial#13=6;
Sensor Positions on metal rail(ft): Serial#5=2L;Serial#27=0;Serial#13=2R;
Lot: Lot2
Sublot: Sublot2
File Name: File__001
File Type: Distance
Creation Date and Time: 2017-07-20.09:40:50
File Comments: Test2
Moving Average Window Size (ft): 0.50
Output Interval (ft): 0.50
GPS Time Lag (sec): 0.00

Distance (ft)	Station	Longitude (°	Latitude (°)	Elevation	Lateral Of	Dielectric	Signal Qu	Longitude	Latitude (	Elevation	Lateral Of	Dielectric	Signal Qu	Longitude	Latitude (	Elevation	Lateral Of	Dielectric	Signal Quality
0.9	0+0.90	42.7573957	-71.4883492	57.5	10	5.02	95.94	42.75739	-71.4884	57.5	8	4.83	94.8	42.75739	-71.4884	57.5	6	4.47	95.83
1.4	0+1.40	42.7573972	-71.4883499	57.5	10	5.08	95.9	42.75739	-71.4884	57.5	8	4.88	94.83	42.75739	-71.4884	57.5	6	4.48	95.85
1.9	0+1.90	42.7573989	-71.4883508	57.5	10	4.84	95.8	42.7574	-71.4884	57.5	8	4.78	94.97	42.75739	-71.4884	57.5	6	4.3	95.75
2.4	0+2.40	42.7574007	-71.4883514	57.5	10	4.89	95.77	42.7574	-71.4884	57.5	8	4.73	95.09	42.7574	-71.4884	57.5	6	4.29	95.72
2.9	0+2.90	42.7574019	-71.4883522	57.5	10	4.86	95.85	42.7574	-71.4884	57.5	8	4.75	95.06	42.7574	-71.4884	57.5	6	4.33	95.73
3.4	0+3.40	42.7574035	-71.4883535	57.5	10	4.8	95.79	42.7574	-71.4884	57.5	8	4.74	95	42.7574	-71.4884	57.5	6	4.43	95.66
3.9	0+3.90	42.7574047	-71.4883542	57.5	10	4.86	95.73	42.7574	-71.4884	57.5	8	4.61	95.11	42.7574	-71.4884	57.5	6	4.41	95.68
4.4	0+4.40	42.7574056	-71.4883546	57.5	10	4.92	95.68	42.7574	-71.4884	57.5	8	4.69	95.15	42.7574	-71.4884	57.5	6	4.33	95.86
4.9	0+4.90	42.7574071	-71.4883556	57.48	10	4.85	95.62	42.7574	-71.4884	57.48	8	4.67	95.3	42.7574	-71.4884	57.48	6	4.45	95.82
5.4	0+5.40	42.7574086	-71.4883569	57.4	10	4.76	95.59	42.75741	-71.4884	57.4	8	4.89	95.25	42.7574	-71.4884	57.4	6	4.39	95.85
5.9	0+5.90	42.7574096	-71.4883577	57.4	10	4.77	95.6	42.75741	-71.4884	57.4	8	4.95	95.23	42.7574	-71.4884	57.4	6	4.33	95.85

The columns order of the exported file depends on if stationing is used for position and how many sensors are used during data collection. 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

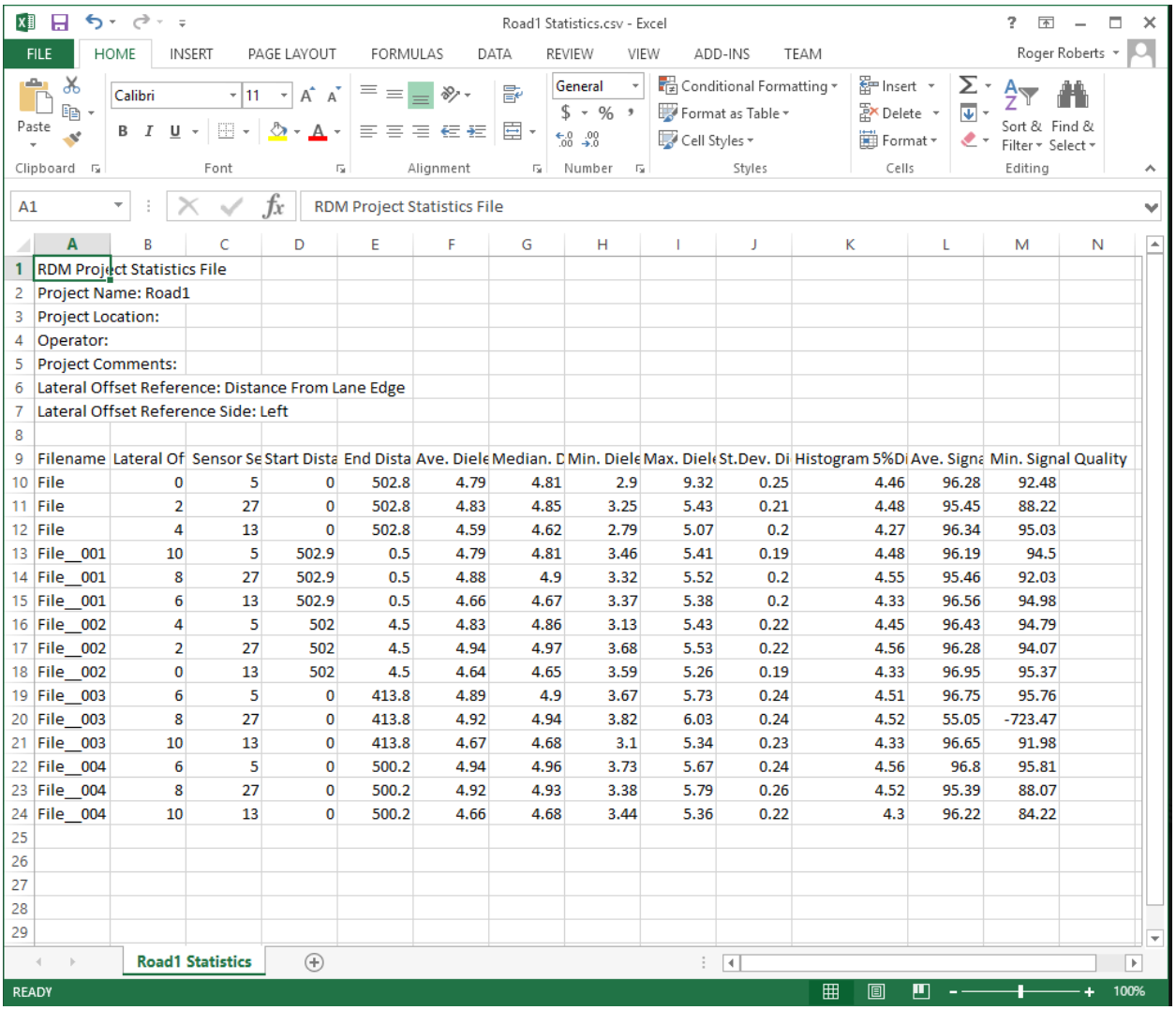
Elevation: Elevation of measurement in meters

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

Signal Quality: A measure the signal-to-noise in the data. Values greater than 90 constitute good quality data. Values less than 90 indicate significant levels of external interface and measurement values should not typically be used.

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 window.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	RDM Project Statistics File													
2	Project Name: Road1													
3	Project Location:													
4	Operator:													
5	Project Comments:													
6	Lateral Offset Reference: Distance From Lane Edge													
7	Lateral Offset Reference Side: Left													
8														
9	Filename	Lateral Of	Sensor Se	Start Dista	End Dista	Ave. Diele	Median. D	Min. Diele	Max. Diele	St.Dev. Di	Histogram 5%Di	Ave. Signa	Min. Signal Quality	
10	File	0	5	0	502.8	4.79	4.81	2.9	9.32	0.25	4.46	96.28	92.48	
11	File	2	27	0	502.8	4.83	4.85	3.25	5.43	0.21	4.48	95.45	88.22	
12	File	4	13	0	502.8	4.59	4.62	2.79	5.07	0.2	4.27	96.34	95.03	
13	File__001	10	5	502.9	0.5	4.79	4.81	3.46	5.41	0.19	4.48	96.19	94.5	
14	File__001	8	27	502.9	0.5	4.88	4.9	3.32	5.52	0.2	4.55	95.46	92.03	
15	File__001	6	13	502.9	0.5	4.66	4.67	3.37	5.38	0.2	4.33	96.56	94.98	
16	File__002	4	5	502	4.5	4.83	4.86	3.13	5.43	0.22	4.45	96.43	94.79	
17	File__002	2	27	502	4.5	4.94	4.97	3.68	5.53	0.22	4.56	96.28	94.07	
18	File__002	0	13	502	4.5	4.64	4.65	3.59	5.26	0.19	4.33	96.95	95.37	
19	File__003	6	5	0	413.8	4.89	4.9	3.67	5.73	0.24	4.51	96.75	95.76	
20	File__003	8	27	0	413.8	4.92	4.94	3.82	6.03	0.24	4.52	55.05	-723.47	
21	File__003	10	13	0	413.8	4.67	4.68	3.1	5.34	0.23	4.33	96.65	91.98	
22	File__004	6	5	0	500.2	4.94	4.96	3.73	5.67	0.24	4.56	96.8	95.81	
23	File__004	8	27	0	500.2	4.92	4.93	3.38	5.79	0.26	4.52	95.39	88.07	
24	File__004	10	13	0	500.2	4.66	4.68	3.44	5.36	0.22	4.3	96.22	84.22	
25														
26														
27														
28														
29														

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

	Lateral Offset (ft)	Start Distance (ft)	End Distance (ft)	Ave. Dielectric	Median. Dielectric	Min. Dielectric	Max. Dielectric	St.Dev. Dielectric	Histogram 5%Dielectric	Ave. Signal Quality	Min. Signal Quality
2	10	0.9	100.9	4.79	4.79	4.24	5.18	0.14	4.57	96.34	94.75
3	10	100.9	200.9	4.8	4.81	4.28	5.41	0.15	4.57	96.05	94.73
4	10	200.9	300.9	4.69	4.7	3.46	5.1	0.21	4.43	95.97	94.88
5	10	300.9	400.9	4.9	4.91	4.35	5.37	0.17	4.65	96.73	94.89
6	10	400.9	500.9	4.78	4.82	4	5.15	0.18	4.45	95.86	94.5
7	10	500.9	502.9	4.53	4.52	4.43	4.6	0.06	4.43	95.65	95.59
8	8	0.9	100.9	4.88	4.88	4.44	5.52	0.14	4.67	96.1	92.03
9	8	100.9	200.9	4.9	4.9	4.3	5.25	0.15	4.63	94.14	92.28
10	8	200.9	300.9	4.8	4.84	3.32	5.29	0.23	4.43	94.82	94.27
11	8	300.9	400.9	4.99	5	3.91	5.5	0.2	4.72	95.57	94.57
12	8	400.9	500.9	4.82	4.88	3.64	5.17	0.21	4.53	96.64	94.64
13	8	500.9	502.9	4.92	4.94	4.79	4.99	0.08	4.79	94.72	94.65
14	6	0.9	100.9	4.6	4.61	4.28	4.95	0.14	4.33	96.58	94.98
15	6	100.9	200.9	4.67	4.68	4.15	5.06	0.15	4.45	96.48	95.29
16	6	200.9	300.9	4.6	4.61	3.37	5.27	0.22	4.33	96.76	95.08
17	6	300.9	400.9	4.79	4.78	3.51	5.38	0.22	4.48	96.67	95.38
18	6	400.9	500.9	4.65	4.69	3.82	5.07	0.19	4.26	96.35	95.47
19	6	500.9	502.9	4.74	4.73	4.64	4.95	0.12	4.64	96.59	96.56

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 window is checked.

If GPS position information is available, a Google Earth KML file is automatically created when files and selected ranges are exported. 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.

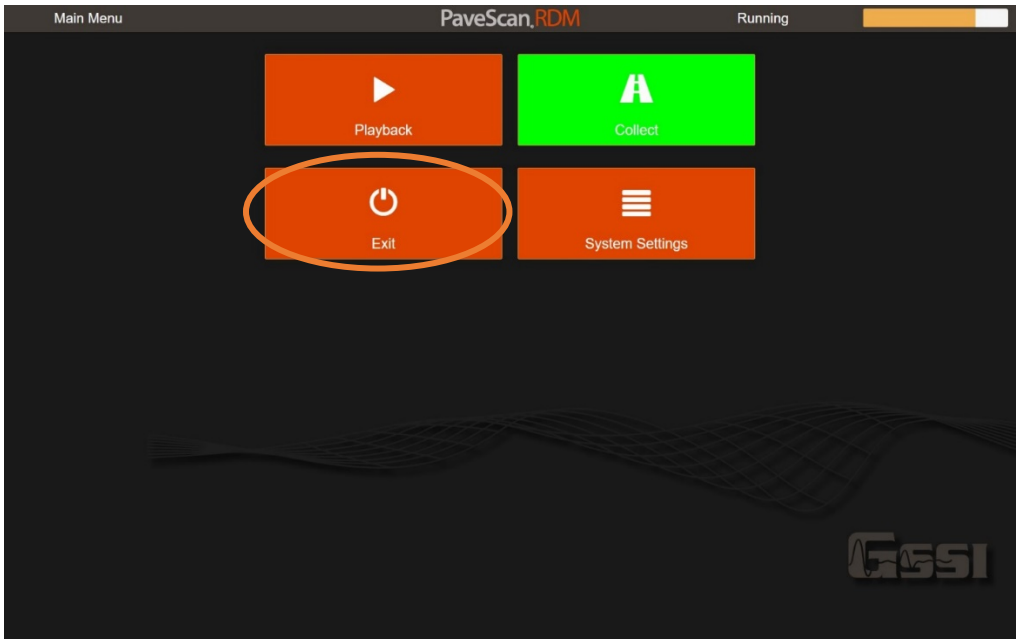
Once the data is exported onto the ToughPad, you can transfer the files to a USB drive using the port on the right side of the tablet.

Chapter 4: System Shutdown and Updates

In Chapter 4, we will review steps for shutting down the system after data collection. You will also find steps for updating your RDM with the latest software package.

4.1: System Shutdown

The application is shutdown from the Exit button that is accessed by in the Main Menu. The application window will then close and the window desktop will appear.



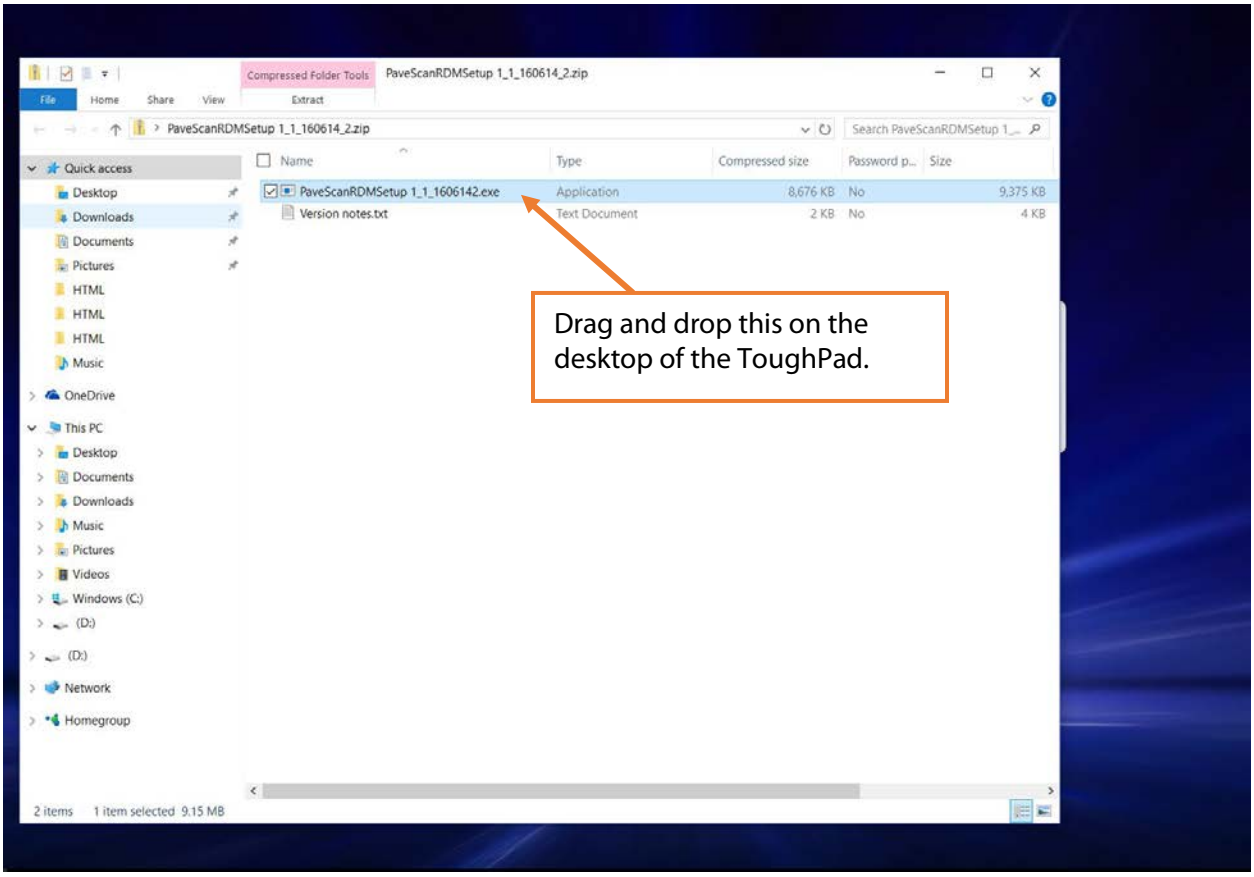
The final step is to press the power button on the orange concentrator box to power-down the sensors.

Press this button to turn off power to sensors.

4.2: Software Updates

The RDM application will be updated from time to time to add features and fix issues. The new software will be downloadable from the web 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) will show up on the right pane of the Windows Explorer window.



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 will automatically remove 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 will be done. However, if you do disconnect or connect a sensor when the application is running on the ToughPad you will need to restart the entire system (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. Then 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. You may need to retry several times. Note, all the sensors connected must be detected for the detection process to be successful (otherwise a "No Sensors found" status appears). So, in a worst-case scenario, connect only one sensor and create a 1-sensor project and try again. If successful, try a 2-sensor project, then 3-sensor project. If only 2 sensors are detected, then likely the 3rd sensor is not working.

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

Is the DMI cable (small black cable) attached to designated sensor with the survey wheel connector on top? If not, attach it.

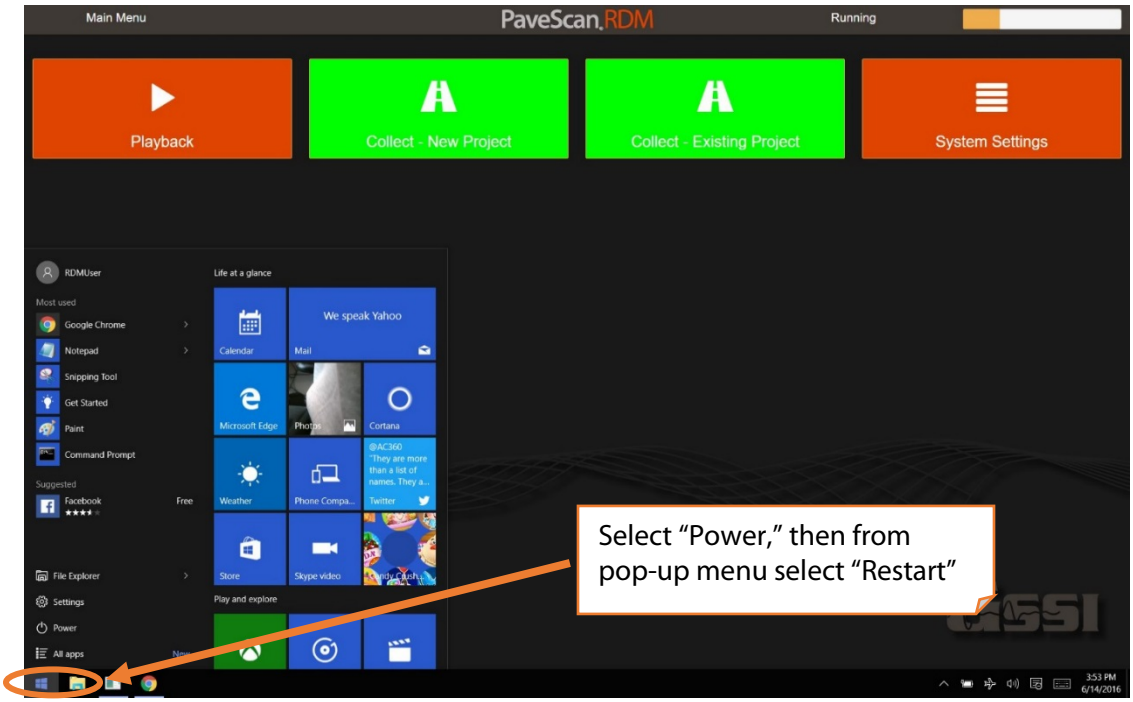
4 How can I exit the application if the Shutdown button doesn't work?

a) Try pressing the shutdown button again.

b) See (5) below.

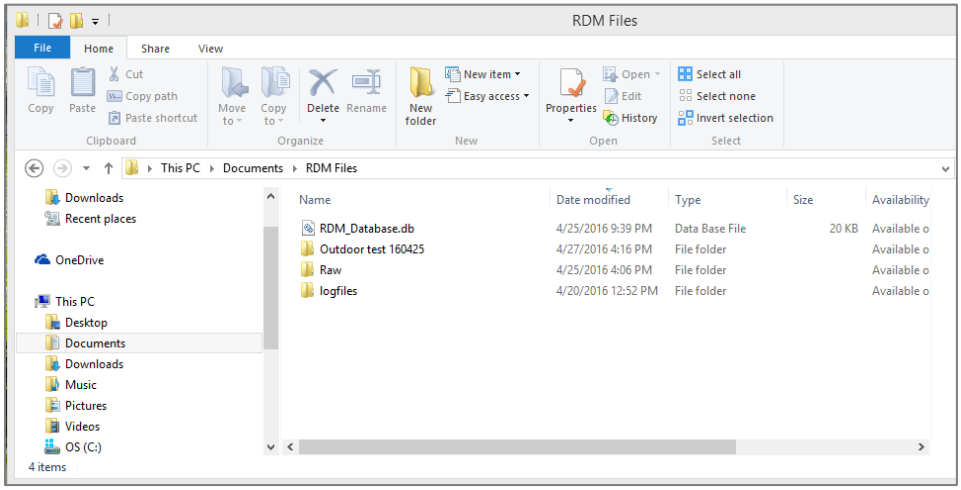
5 How can I exit the application if the buttons stop working?

Press the round windows button on the ToughPad (third button to the right of the A2 button) to open the Windows 10 Menu, then select Power->Restart.



Appendix A – Raw File Information

There is a RDM Files subfolder in the Documents folder that contains all unprocessed RDM data.



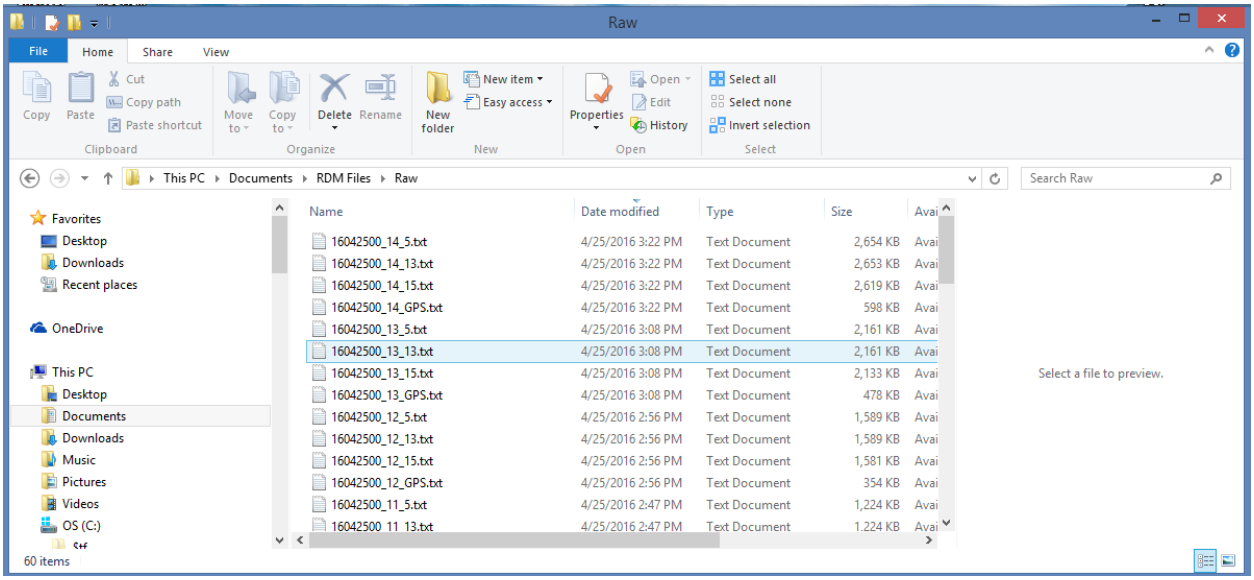
The software utilizes a SQLite database file to store the project and file information. The name of the file is “RDM_Database.db.” The dielectric file data are stored in ASCII files in the “Raw” subfolder. The naming convention of the dielectric files is YYMMDDNN_FN_SN.txt

YYMMDD = Date the project was created in years, months and days.

NN = Project Number created during the same day. For example, the first project created for the day will have a value “00”. If a second project is created, the number for this project is “01”, etc.

FN = Sequential file number collected with the project open.

SN = Serial Number of Sensor



The raw data are saved as comma separated values. An example is shown below. The column description is as follows:

Column 1: Scan #

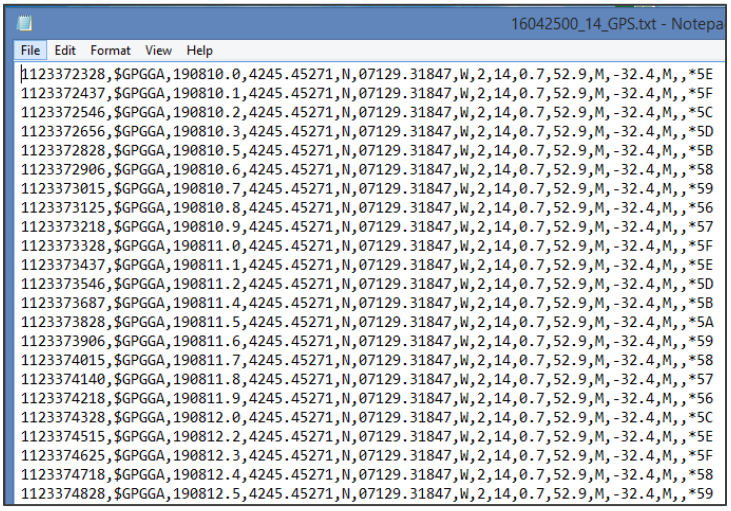
Column 2: Calculated dielectric

Column 3: System time (milliseconds)

Column 4: Normalized amplitude of scan direct-coupling relative to the airwave. This is used in compensating for temperature-related effects.

```
0,4.76494,1123382437,0.995657,
1,4.76494,1123382437,0.995657,
2,4.68428,1123384046,0.996564,
3,4.85172,1123385437,0.996262,
4,4.71907,1123385437,0.995083,
5,4.72127,1123385640,0.998857,
6,4.86563,1123385640,0.997564,
7,4.83446,1123385640,1.0003,
8,4.71681,1123385640,0.996125,
9,4.71809,1123385843,0.997605,
10,4.74884,1123385843,0.996807,
11,4.59055,1123385843,0.997681,
12,4.519,1123385843,0.997203,
13,4.51505,1123385843,0.999385,
14,4.43243,1123385843,0.997052,
15,4.38463,1123385843,0.996366,
16,4.40613,1123385843,0.997723,
17,4.46605,1123386046,0.997613,
18,4.12363,1123386046,0.99969,
19,4.304,1123386046,0.998065,
20,4.2439,1123386046,0.998434,
21,4.15193,1123386046,0.995683,
```

If GPS data are also obtained, the GGA sentences are stored as ASCII files with the following naming convention: YYMMDDNN_FN_GPS.txt. An example of a GPS file is shown below.



Incoming GPS sentences are timestamped in the same manner as incoming dielectric values. The timestamp associated with each GPS sentence is the first column in the file. The unmodified GGA sentence is written to the right of the timestamp.

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

There are two equation types that can be used in the PaveScanRDM to calculate another physical property, such as % Voids, % Density, or Compaction from Dielectric.

The exponential equation takes the form:

$$P = Ae^{Bd}$$

The linear equation uses the form:

$$P = A + Bd$$

where:

P = the measured physical property from the core, which can be density, % voids, or % compaction;

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

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

e = natural logarithm; and

d = dielectric value;

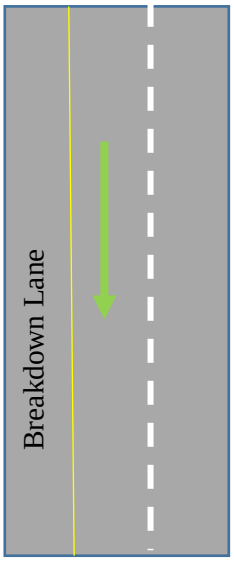
Appendix C – Choosing the Correct Lateral Offset

Choosing the correct lateral offset side and distance can be confusing. This is because you can be collecting data with increasing distance, decreasing distance, using a lateral offset reference on the left side, or using a lateral offset reference on the right side.

Choosing a Lateral Offset Reference

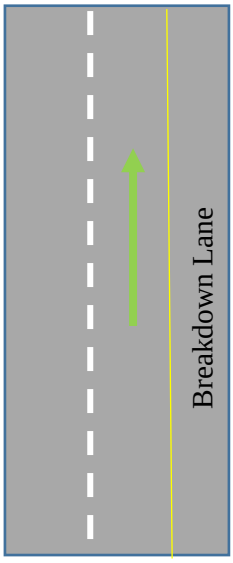
As you face the direction of increasing distance, choose a lateral reference that all the measurements can be associated with. Enter this in the "Lateral Reference" line in project info. This reference must be used for the entire project. If your lateral reference, which could be a center line, curb, lane edge, etc… is on the left side of the cart, choose "Left Side" as the Lateral Offset Reference Side. And choose "Right Side" if the reference is on the right side of the cart. Once the lateral offset reference side is chosen, it also must be used for the entire project.

If your direction of travel is in the decreasing distance direction (e.g. "down-station"), then you should turn to face in the increasing distance direction and choose the reference side based on if the lateral reference is on the left or right side. The figures below show two scenarios.



Southbound (decreasing distance)

Breakdown lane is on "Left Side"



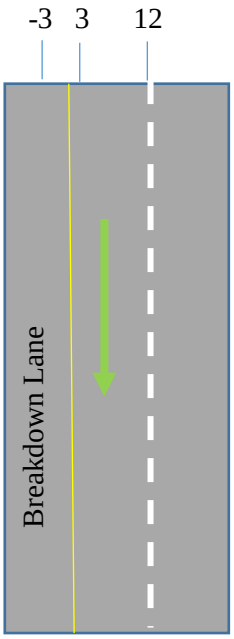
Northbound (increasing distance)

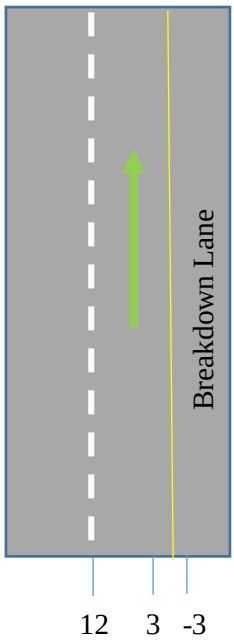
Breakdown lane is on "Right Side"

If the user chooses to use the yellow stripe associated with the breakdown lane as the lateral offset reference, then it will be on the “Left Side” for the South-bound lanes and the “Right Side” for the Northbound lanes.

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. When this is done and the cart is positioned at the start of the line and looking in the increasing distance direction.





Southbound (decreasing distance)

Breakdown lane is on “Left Side”

Decreasing Distance

Northbound (increasing distance)

Breakdown lane is on “Right Side”

Increasing Distance

In the figures above, for the South-bound data, the offsets are positive to the right of the yellow line when facing up-station. These represent positive lateral offset values. The image above shows lateral offsets of -3 for a data line collected left of the yellow line, and 3 and 12 for the positions right of the yellow line.

Correspondingly, for the North-bound data, the lateral offsets are positive to the left of the yellow line and negative to the right of the yellow line.

The decreasing distance scenario is not immediately intuitive. It is highly recommended that you check the project statistics file to make sure you understand the lateral offset values associated with each antenna and make sure they make sense to you.