Sensors & Software

Pavement Density Profiler (PDP)

User's Guide

2020-00005-00

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Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
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1999-00236-04

Important Safety Information

The battery charger/AC adapter must only be connected to a power outlet which provides a protective earth (ground).

Connect the AC power cord only to designated power sources as marked on the battery charger/AC adapter.

The battery charger/AC adapter is rated for indoors use only.

Do not replace detachable MAINS supply cords for the battery charger/AC adapter by inadequately RATED cords.

The exterior of this product should be cleaned using a damp cloth.

Safety Symbols


Consult this documentation in all cases where this safety symbol appears. This symbol is used to inform you of any potential HAZARD or actions that require your attention.

Table of Contents

1. Overview

Congratulations on your purchase of a Pavement Density Profile (PDP) system. PDP provides a way to measure density of newly laid asphalt over a large area rapidly, in a non-invasive manner. Areas of high and low density can then be targeted for further investigation or corrective action.

The PDP system works by transmitting a radio wave signal towards the ground surface and detects the reflected wave, measuring the dielectric permittivity of the near surface. This information is then converted into density, for real-time results.

Data can be acquired continuously along a line profile, or at discrete locations. Data can be downloaded for processing and creating summary reports.

Features of the PDP include:

- Rugged, sunlight readable display tablet
- Wireless connection from tablet to PDP sensor
- Internal and optional external GPS receiver for georeferencing data
- Simple user interface providing results in real-time
- Different types of measurements can be displayed:
    - Relative Permittivity
    - Density
    - Density – Site Specific bulk density
    - Relative Density
    - Air Void Content
- Data export via Wi-Fi

This manual references embedded software version V1.3.

For those users looking to post-process the data, please refer to the manual for the PDP Toolkit PC Software.

A glossary of terms relating to PDP and asphalt density can be found in Appendix H:.

2. Getting Started

A fully assembled PDP system is shown in Figure 2-1. Follow the steps below to assembly the PDP after you receive it.

Figure 2-1: Fully assembled PDP

2.1 Assembly

PDP is shipped nearly assembled, and only requires a few connections to be made.

Place the main cart handle onto the frame of the fiberglass cart (Figure 2-2), then insert the handle pin through the holes on both sides and close them (Figure 2-3).

Figure 2-2: Attaching the main handle to the cart frame.

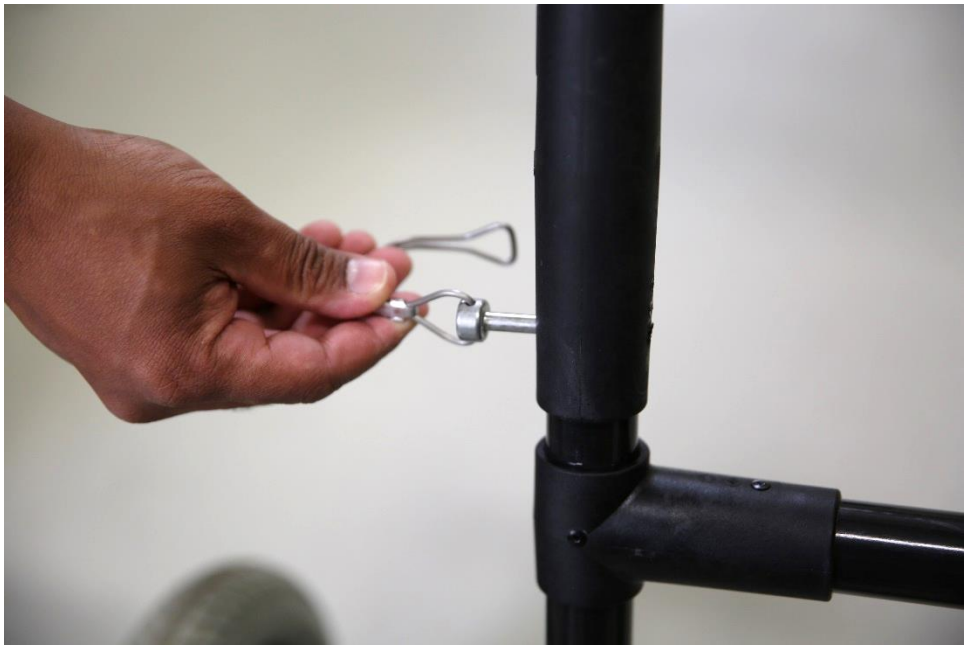


Figure 2-3: Inserting pin to secure handle to cart

Place the PDP sensor onto the cart (Figure 2-4) and secure tightly using the two straps on either end of the sensor (Figure 2-5). Make sure the ports on the PDP sensor are facing the handle side.

Figure 2-4: Place PDP sensor onto the cart frame

Figure 2-5: Secure PDP sensor with straps on either end

Place the tablet into the docking station and secure by pressing down on the clamp above until firmly secured (Figure 2-6).

Figure 2-6: Securing tablet to docking station

To remove the tablet, release the locking mechanism on the back side (Figure 2-7), then remove the tablet.

Figure 2-7: Release locking mechanism to remove tablet

2.2 External GPS (optional)

Insert the GPS mount into the PDP handle, as shown in Figure 2-8, and insert pin through the hole to secure (Figure 2-9).

Figure 2-8: Inserting GPS mount

Figure 2-9: Securing GPS mount with pin

Screw the Topcon GPS receiver onto the threaded GPS mount (Figure 2-10).

Figure 2-10: Screw the Topcon GPS receiver onto the GPS mount

2.3 Charging the Battery

Plug the battery charger into port #4 in Figure 2-11. Before using the PDP system for the first time, the battery should be charged for at least 4 hours, so it is fully charged. The charge indicator (#5 in Figure 2-11) will light up when charging and turn off when it's done.

2.4 Connections and Cable Management

There are a few connections that need to be made.

Figure 2-11: Labelled items on the PDP sensor. 1) GPS port 2) Odometer port 3) Power button 4) Battery charger port 5) Battery charge indicator

1. Connect the serial port end of the GPS cable into port #1 in Figure 2-11
2. Connect the odometer cable into port #2 in Figure 2-11

To minimize interference and ensure consistency of measurements, it is important that cables are secured to the cart frame, and not left dangling. Dangling wires will interfere with the quality of data collected by the PDP.

For the GPS cable, connect it to the PDP sensor and make sure the cable is tight and fastened to the fibreglass frame as you route it upwards towards the GPS receiver (Figure 2-12). If there is any excess cable, secure it near the GPS using the Velcro straps provided. Finally, connect the GPS cable into the GPS receiver (Figure 2-13).

Figure 2-12: Make sure the GPS cable is routed as shown and secured to the cart, as it moves from the PDP sensor up to the GPS receiver along the cart frame.

Figure 2-13: Plug the GPS cable into the GPS receiver

The completely assembled PDP system should look as shown in Figure 2-14.

Figure 2-14: Assembled PDP System

2.5 Powering up the PDP

When ready, press the Power button (label #3 in Figure 2-11) to power up the PDP sensor. The light on the button will turn on and remain on while the PDP sensor is powered up. Turn on the tablet and, from the main screen, double-click the PDP icon 

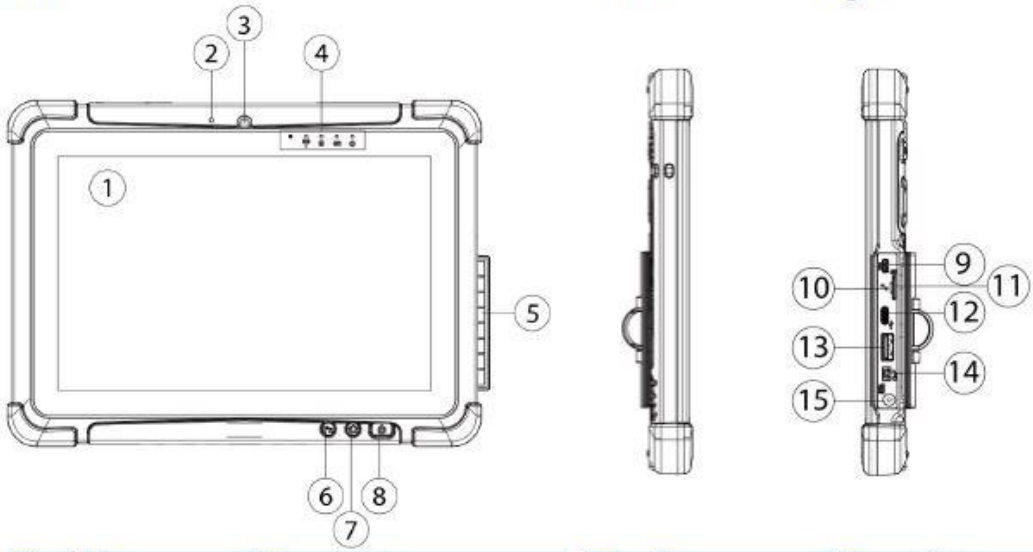
to launch the PDP Application Software (Section 4).

When shutting down the PDP system, it is best to shut down from the PDP software (Figure 4-2). If necessary, the PDP sensor can also shut down by pressing and holding the Power button for a few seconds.

3. Navigating the Tablet

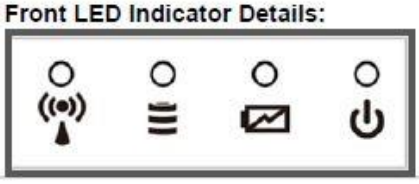
The tablet that is included with PDP is a Winmate M101P-ME tablet, running the Windows operating system. Some basic functions are described below; for full operational details, please consult the online User's Guide

Front: **Left:** **Right:**



No	Item	Description
1	10.1" Touch Screen	Display and act as one of the inputs for the Tablet Computer
2	Digital Mic with noise cancellation	Use during video recordings and communications.
3	Front Camera	2 Megapixel Webcam
4	Light Sensor and LED Indicators	Show the current status of the Tablet Computer. RF communications, storage, battery status, power status.
5	I/O Cover	Protect I/O ports
6	Fn1 Button	Programmable function key configured by Hottab Utility
7	Menu Button	Hottab Quick Access
8	Power Button	Power on/off tablet

Front LED Indicator Details:



No	Item	Description
9	Micro HDMI	HDMI output to external display
10	Clear CMOS	Hardware reset button.
11	MicroSD Card Reader	Memory card reader port for MicroSD Card
12	USB 3.0 Type C	High speed USB port connects to USB devices, such as USB flash drive, mouse, keyboard, printer, etc. ※No ALT Support, Power Output 5V/0.9A
13	USB 3.0 Type A	USB 3.0 port connects to USB devices, such as USB flash drive, mouse, keyboard, printer, etc.
14	Mic In/Line Out	Headset or headphone can be connected (Mic is only supported with 3.5mm 4-pin headset)
15	Power Jack	DC power input jack.

Figure 3-1: Functions of the Winmate tablet

Press and hold the #8 Power button in Figure 3-1 for a few seconds to turn on the tablet. The blue power LED will illuminate. Once the tablet has booted up, you will see the main screen in Figure 3-2. Tap the PDP icon twice to launch the program.

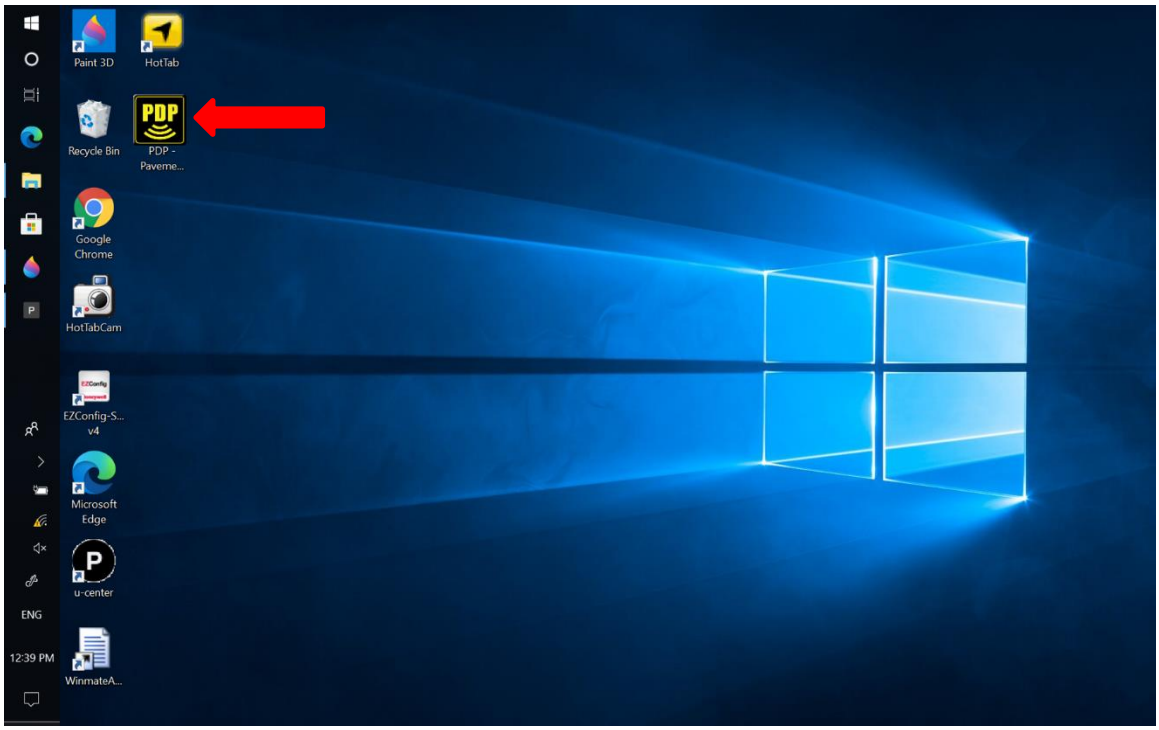


Figure 3-2: Main screen when turning on tablet

To shut down the tablet, press the Windows icon in the top left, then press the power icon as shown in Figure 3-3. From here you have the option of putting the tablet to sleep, shutting it down or doing a restart.

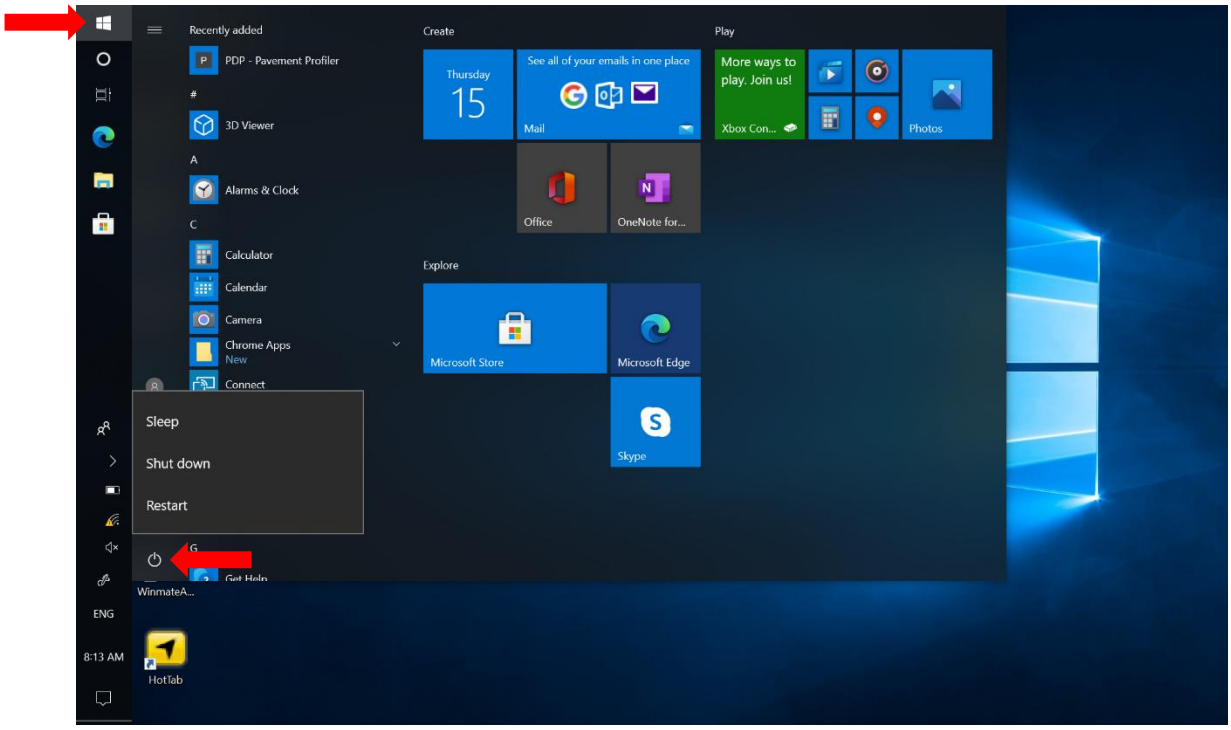


Figure 3-3: Power off button

3.1 Wi-Fi Connectivity

Once the tablet and PDP have both been turned on, they will automatically connect to each other. This can be confirmed by pressing the Wi-Fi icon in Figure 3-4 and seeing which network is connected to the tablet. The PDP network will have the format of PDPxxxxxxxx, where the xxxxxxxx represents the last 8 digits of the PDP serial number, which can be found on a sticker on the PDP.

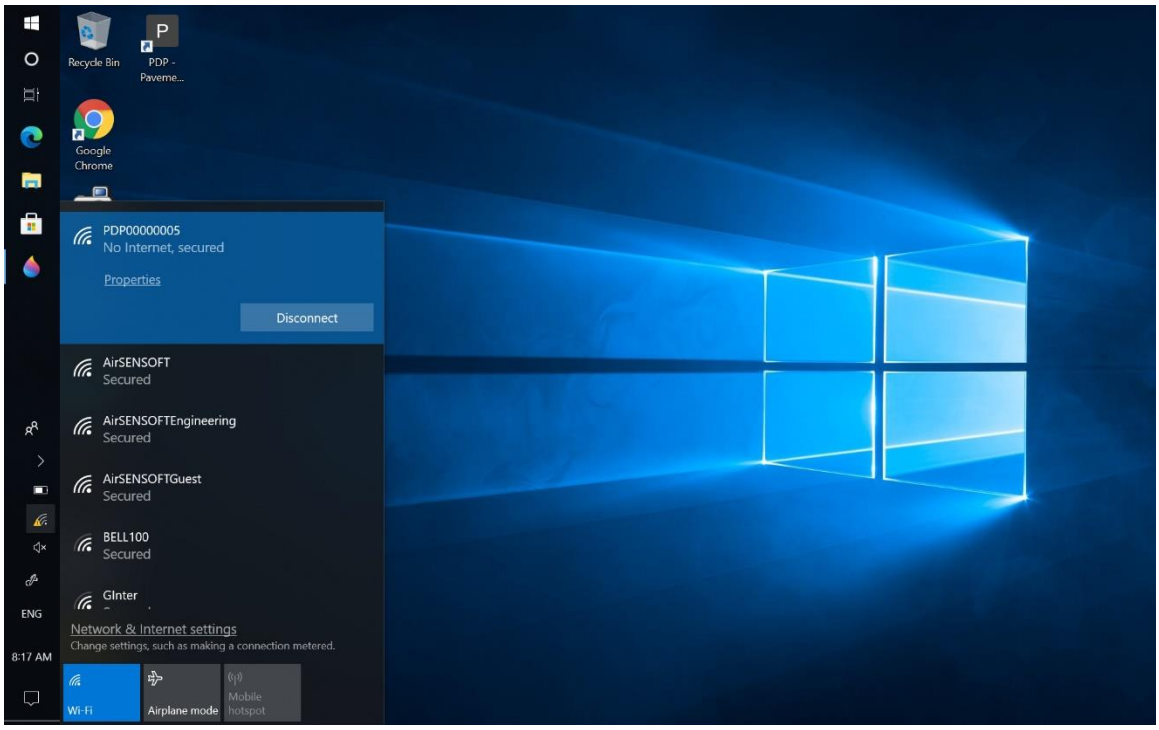


Figure 3-4: Connecting to a Wi-Fi network

If the tablet has lost Wi-Fi connection with the PDP for whatever reason, first ensure that the PDP is powered up. Press the Wi-Fi icon as shown in Figure 3-4 and swipe down (if required) to see available Wi-Fi networks. Select the network name that starts with PDP. If there are multiple PDP sensors within range, the PDP network can be identified by the last 8 digits of the PDP serial number.

> **NOTE:** If prompted, the password for the PDP is the same as the network name. For example, if the network is called PDP00000005, then that is also the password.

3.2 Brightness

Since the PDP will usually be used outdoors, ensure the brightness is set for comfortable viewing. The back side of the tablet has a +/- button to increase and decrease the brightness level respectively.

3.3 Battery Level

The battery level of the tablet is indicated by the icon on the left side. For a more detailed view, press the battery icon as shown in Figure 3-5.

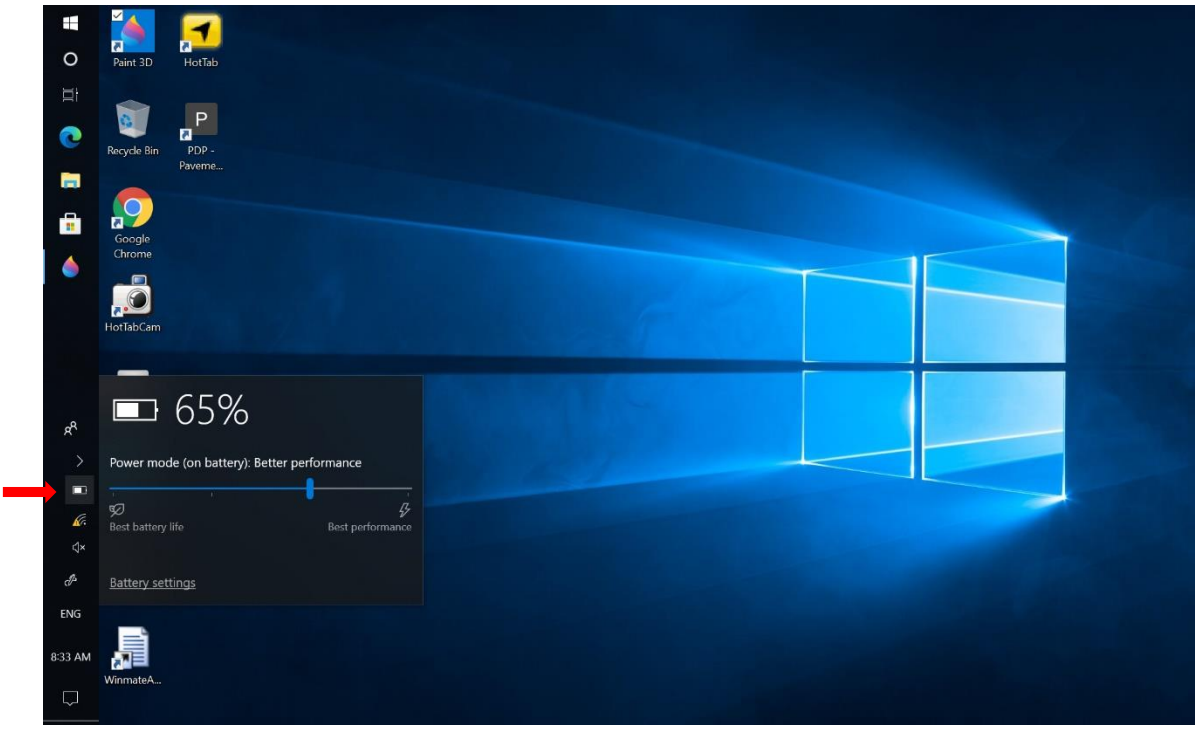


Figure 3-5: Highlighting the battery icon

4. PDP Collection Software

Once the tablet has booted up, double click the PDP icon shown in Figure 3-2. This will launch the PDP software shown in Figure 4-1.

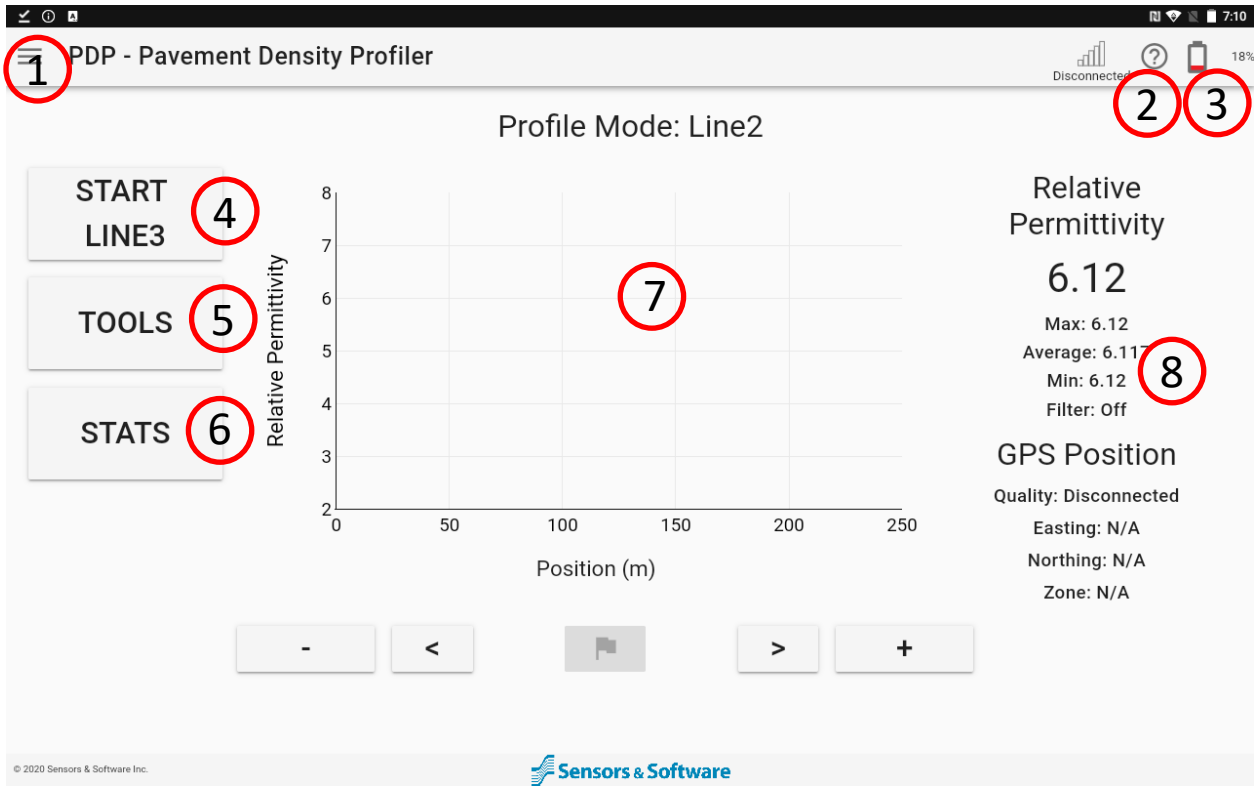


Figure 4-1: Main screen of the PDP software

The circled, numbered items in Figure 4-1 are briefly explained to provide an overview of operations. These are all described in futher detail in this section.

#1 – side menu to switch between Collection mode and Admin settings. There is also the option to shutdown PDP from here and to change the display theme.

#2 – GPS indicator, battery indicator and the ability to launch this manual

#3 – PDP sensor battery level, icon and percentage display

#4 – pressing this button will start collecting data

#5 – configure settings prior to collecting data

#6 – creates a PDF report using the currently-loaded data and selected display parameter, for example, relative permittivity or density (set under **Plot Options**: Section 4.1.3)

#7 - main screen where data are plotted. The plot title at the top indicates the collection mode: Stationary or Profile

#8 – displays the value of the measurement, depending on the currently-selected display parameter (set under **Plot Options**: Section 4.1.3)

The circled #1 in Figure 4-1 points to three horizontal bars (often called a Hamburger button). Pressing this button displays a menu as shown in Figure 4-2.

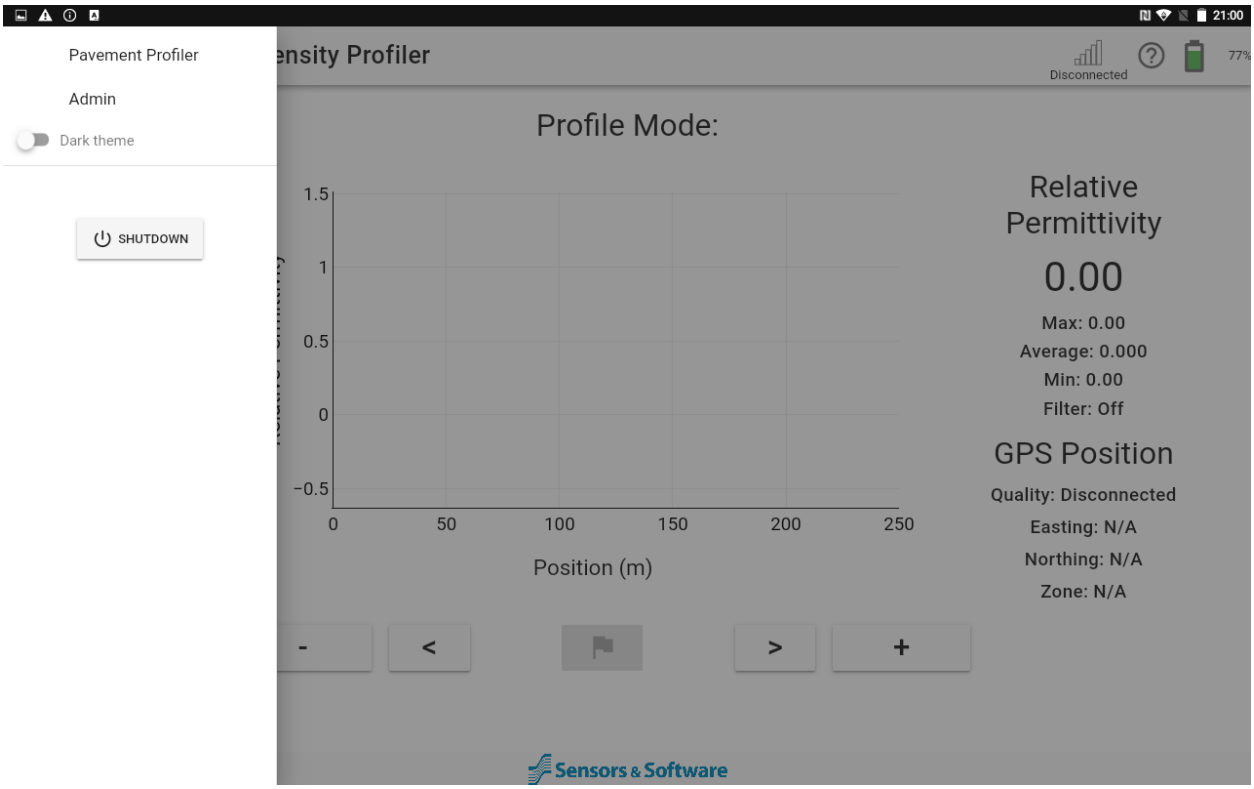


Figure 4-2: Dropdown menu on left

Pressing **Admin** switches to the Admin screen described in Section 4.4.

Pressing **Pavement Profiler** returns to the main data collection screen.

Use the slider to change the **Theme**. The background can be toggled between Light (default) and Dark themes. This is a personal preference, however most users find the Dark Theme to be better suited for operation in direct sunlight.

Press the **Shutdown** button to power down the PDP.

4.1 Tools

Pressing the Tools button launches a window with four tabs (Figure 4-3). Each tab is explained in detail below. It is important to confirm your settings before collecting PDP data.

4.1.1 System Config

The System Config tab allows you to set collection parameters, as well as configuring and enabling the GPS.

Collection Mode – this is the first, and most important, setting to consider as it determines how you will collect data. This setting also controls the display of some of the other options on the screen.

- Profile (shown in Figure 4-3) – this mode involves pushing the PDP over a survey line or area and collecting a continuous profile of data. Typically, this is done to investigate density changes over an area. In most cases, this is done immediately after the asphalt has been laid, compacted and allowed to cool. Multiple profiles can be collected and used to build a plan map, showing density changes or other types of measurements over the survey area. Profiles can be run in any direction, with the external GPS used for positioning. Plan maps are created in the PDP Toolkit PC software.

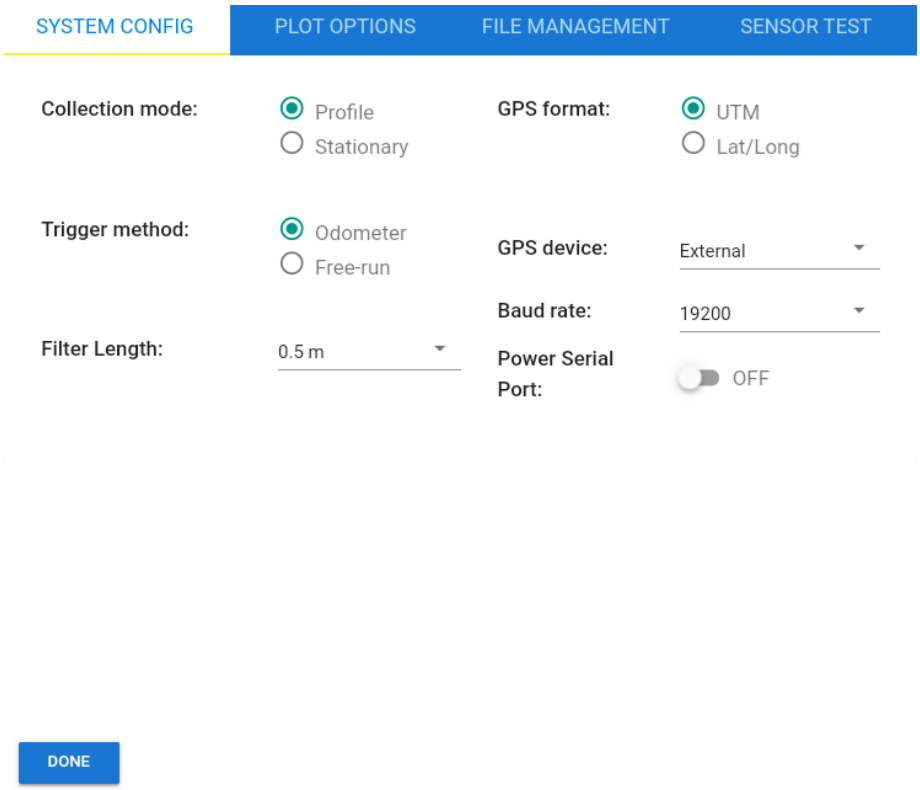


Figure 4-3: The System Configuration screen showing Profile collection mode

- Stationary (show in Figure 4-4) – the PDP is kept stationary, and measurements are collected (and averaged) over a set time interval. Stationary mode is often used as a follow-up to profile mode to investigate areas of high/low density at a specific location. Additionally, stationary mode is used to collect data at core locations.

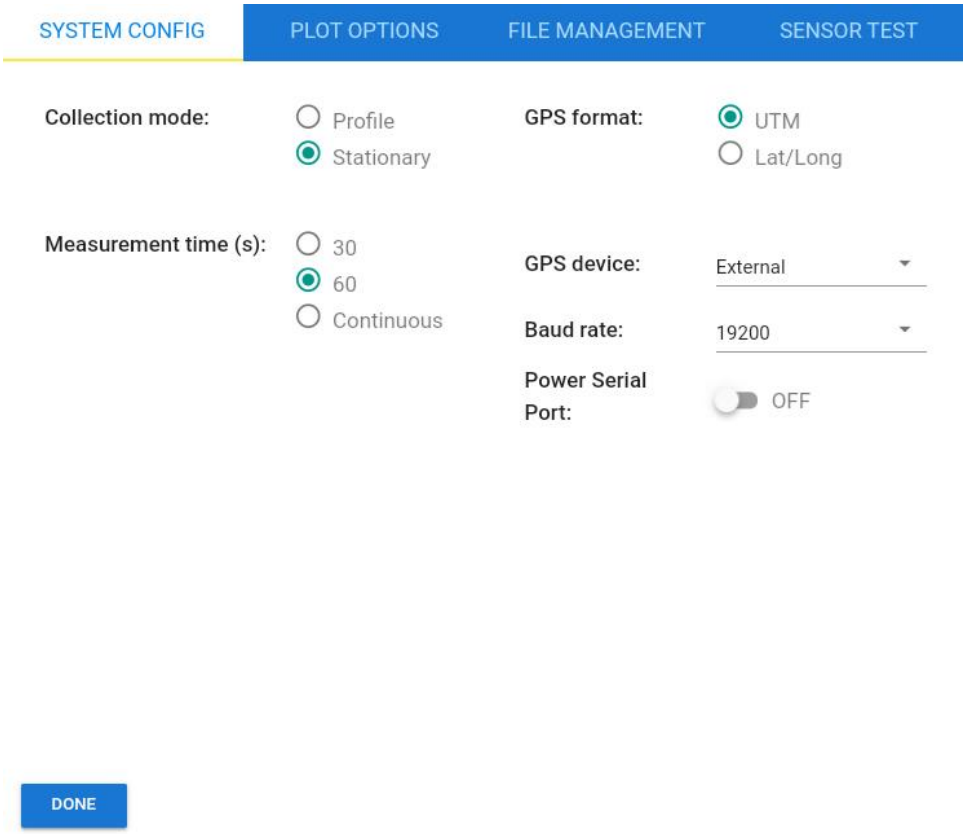


Figure 4-4: The System Configuration screen showing Stationary collection mode

Trigger Method (*only available when Collection mode = Profile*). User has the following options (Figure 4-3):

- Odometer – data collection is controlled by the integrated odometer connected to the left rear wheel of the cart. A data sample (or trace) is collected every 10 cm of distance travelled.
- Free-Run –data is acquired based on a time interval. A data sample (or trace) is collected every x seconds, where x can range in pre-set intervals from 0.1s to 5s.

Filter Length (*only available if Collection mode = Profile*) – the filter applies a horizontal smoothing filter to the data to reduce variations in the observed data. The filter length options are an indication of how aggressive the filter is; the larger the number of traces, the more smoothed the data will be as erratic "jumps" will be filtered out (Figure 4-3).

If running using the odometer, available filter lengths are 0.5 m, 1.0 m, 5.0m or OFF.

If running in free-run mode, available filter lengths are 6, 11 or 51 traces or OFF.

While applying a filter does change the saved data, the original data can be restored in the PDP Toolkit PC software by removing the applied filter.

Measurement Interval (*only available if Collection mode = Profile and Trigger method = Free run*) - the measurement interval controls how often a data sample is collected, for example, one sample every 0.2 seconds. Available options are: 0.1, 0.2, 0.25, 0.5, 1, 2 (in seconds). See Figure 4-5.

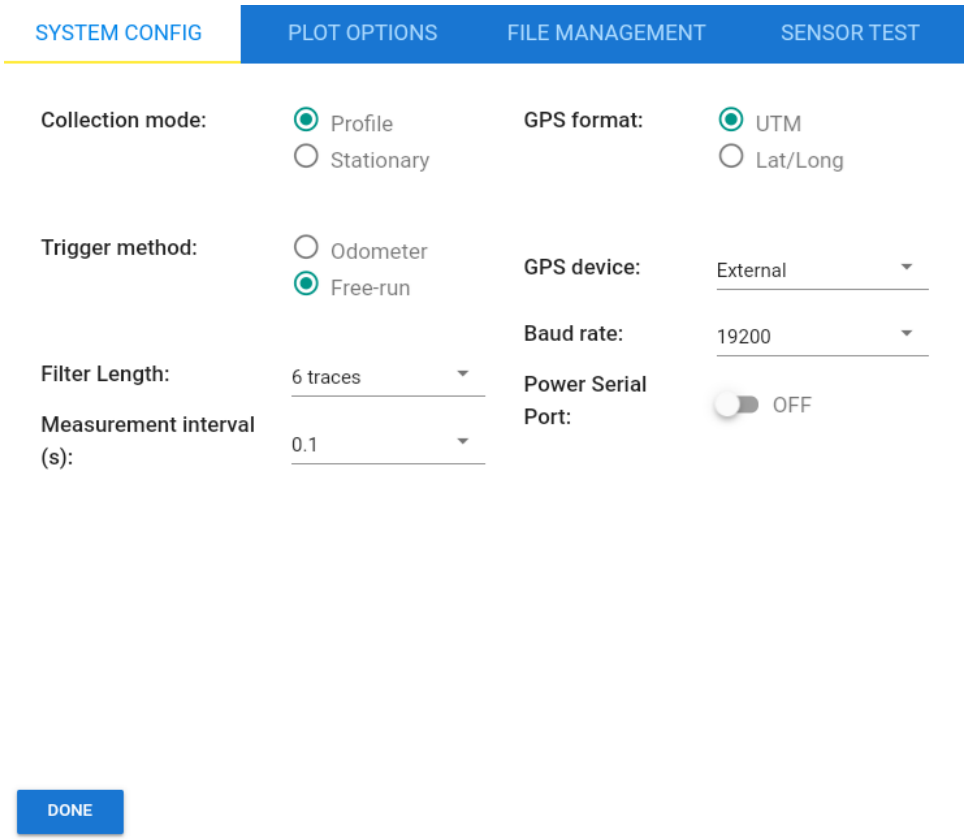


Figure 4-5: In Profile, Free-Run mode, the user can select the Filter Length and Measurement Interval

Measurement time (*only available if Collection mode = Stationary*) - the data parameter to be displayed (e.g. density) is averaged over the set time, after which data collection is stopped and the file is created. Available options are: 30 s, 60 s and continuous. If continuous is selected, data is collected until the user presses Stop. See Figure 4-4.

4.1.2 GPS

The PDP contains an internal GPS and has the option of using an external GPS for greater positional accuracy when collecting georeferenced data (Figure 4-6).

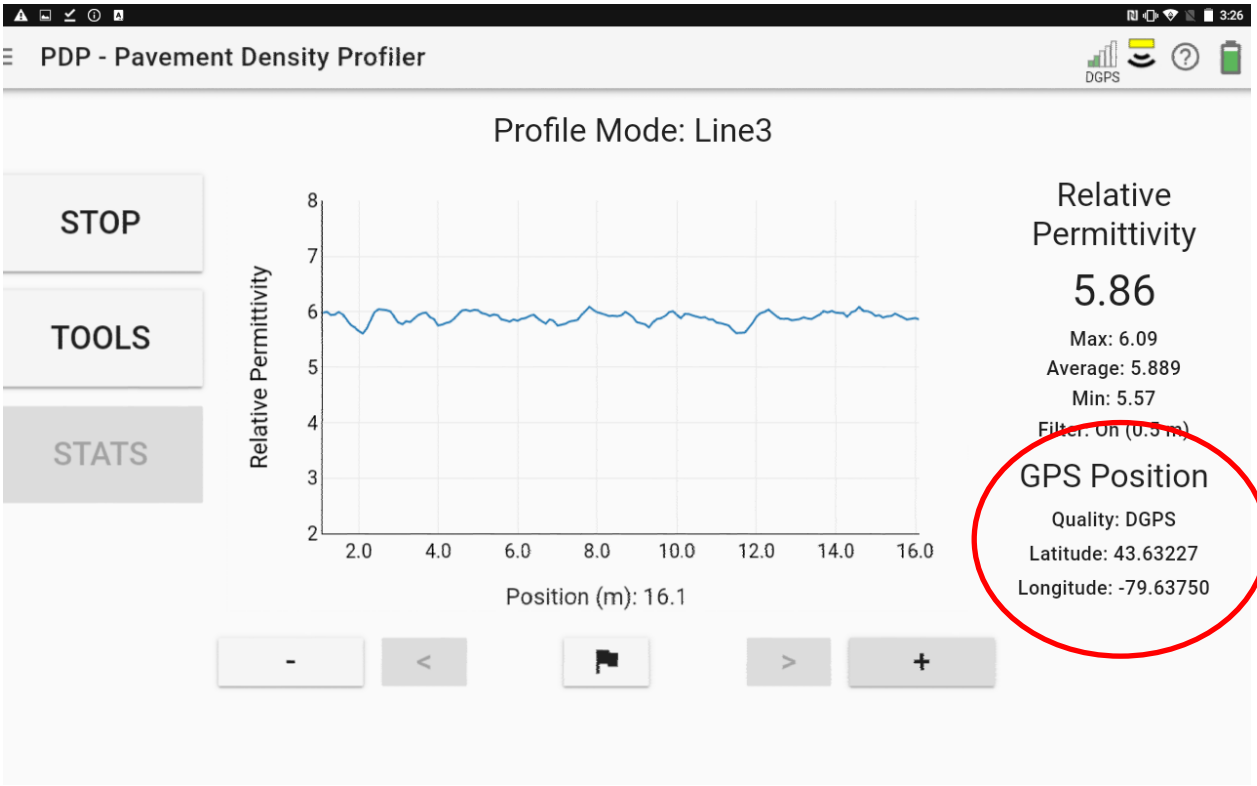


Figure 4-6: Profile collection showing GPS data

An optional external Topcon GPS can be supplied, which is pre-configured to seamlessly connect with the PDP. The built in Internal GPS has a stated accuracy of +/- 10m, while the external Topcon has a stated accuracy of +/- 1m.

If you choose to connect and utilize a 3rd party GPS, it must meet the following criteria:

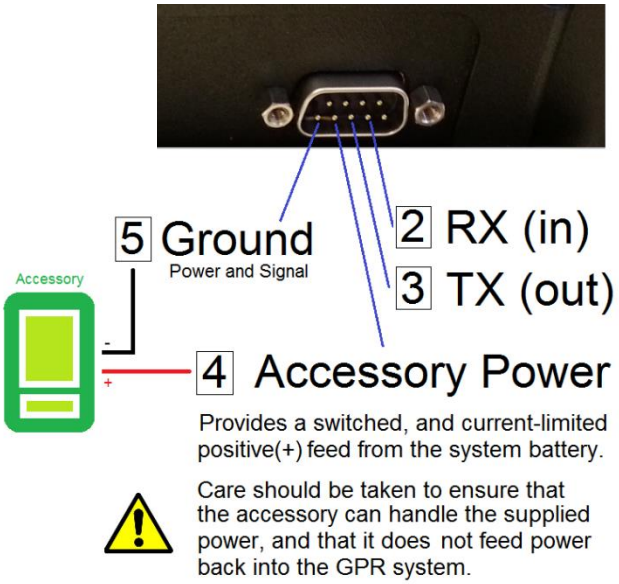
- Able to communicate over RS232 with a standard 9-pin serial output cable.
- Output a NMEA GGA string in ASCII format, at a rate no faster than 20 Hz.
- Support a baud rate of between 4800 and 115200.

- If it cannot safely accept power via the serial port (as shown below), it must have its own battery or power supply.
- GPS must not expect any handshaking from the PDP.

The following options apply to GPS.

- **GPS Format**: Select **UTM** or **Latitude/Longitude** (decimal degrees)
- **GPS Device**: PDP comes with a built-in **Internal** GPS device. There is also an option for an **External** GPS. Select which one you want to use or turn **OFF** GPS altogether.
- **Baud rate** (*only available if GPS Device = External*) - Select the desired Baud rate to communicate with the GPS. If using the Topcon GPS supplied with PDP, this is set to 19200.
- **Power Serial Port** (*only available if GPS Device = External*) - the serial port where the GPS cable is connected can also output power, thereby enabling a single GPS cable to be used for power and data.

  NOTE: If using a 3rd party GPS, it is the responsibility of the user to confirm with the GPS manufacturer that the serial cable does not provide power to the GPS or that the GPS will accept 12V power from the serial cable on the pins shown below. ***Sensors & Software is not responsible for damage caused to a GPS from using the serial port.*** The pin diagram for the serial port is shown below:



  As well, if using a 3rd party GPS, remember to strap the cable to the PDP cart frame and keep excess cable close to the GPS receiver and away from the PDP sensor.

4.1.3 Plot Options

This tab controls how the data is displayed in the main window (Figure 4-7).

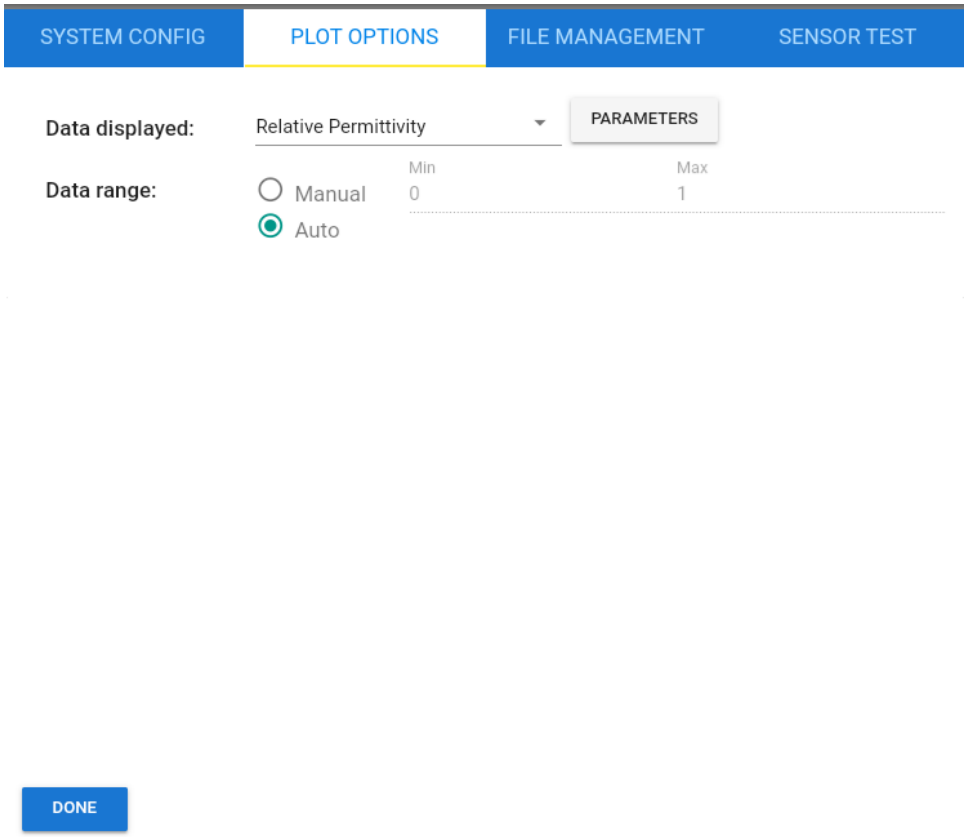


Figure 4-7: The display for Plot Options

Data displayed: during data collection, one of five different measurements can be displayed (Figure 4-8). Note that all measurements are calculated from the reflection amplitude of the GPR wave. The measurements are described below. Details on how these measurements are derived can be found in Appendix G:.

- **Relative Permittivity** (K) – also known as the relative dielectric permittivity, this is the initial value calculated by PDP. Relative permittivity is expressed as a unitless quantity relative to the permittivity of free space. All other parameters below are derived from the relative permittivity.
- **Density** – displays absolute density of the asphalt, expressed in units of g/cm^3. This is a simple calculation that derives density from the observed relative permittivity. If you have a core sample with a known density, you can apply a density offset, such that the measured PDP parameter at the core location equals the known density of the core. This offset is then applied to all the PDP data. Note that in some cases a nuclear density gauge reference value may be used to determine a suitable offset.

- **Density – Site Specific** – measurements of the asphalt properties at the survey site are used to create a unique, site-specific means of translating relative permittivity to density. When the information is available, other parameters such as relative density can be displayed in addition to the absolute density of the asphalt, expressed in units of g/cm^3. This is a far more complex calculation that relies on inputting the A, B & C coefficients of the parametric relationship as well as the Maximum Density. A, B, C and Maximum Density values can be obtained from a core sample using the PDP Toolkit PC Software. While more complex, this is a more accurate representation of the true density.

  > **NOTE:** Selecting this option requires A, B & C coefficients and Maximum Density values filled in under the Parameters tab, otherwise an error will result

- **Relative Density** – sometimes called normalized density or percentage compaction, this parameter expresses the density measured as a percentage of the site-specific maximum density. To calculate the relative density, the max density must be set under Plot Options. This is usually obtained from a core sample via a testing lab. Note: relative density = (1 – Air Void Content).

  > **NOTE:** Selecting this option requires site specific A, B & C coefficients and maximum density values filled in under the Parameters tab, otherwise an error will result

- **Air Void Content** – expressed as a percentage of how much of the volume of the asphalt is air. This requires the Max Density value to be set under Plot Options. Note: Air Void Content = (1 – Relative Density).

  > **NOTE:** Selecting this option requires site specific A, B & C coefficients and Maximum Density values filled in under the Parameters tab, otherwise an error will result

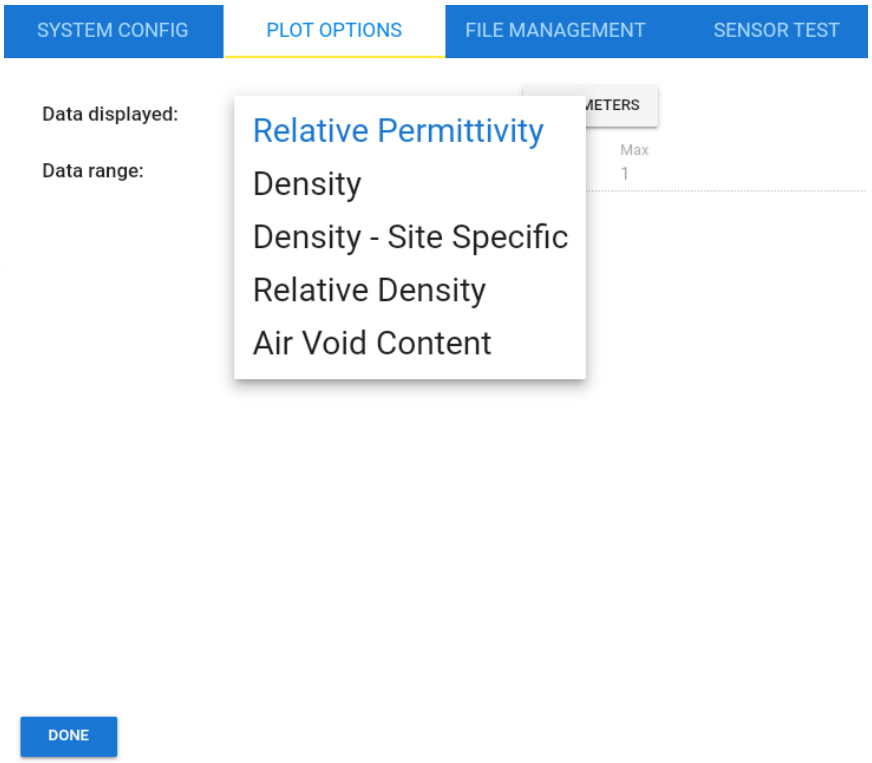


Figure 4-8: Plot Options showing the data to be displayed

Pressing the **Parameters** button will display a window (Figure 4-9) with the following options:

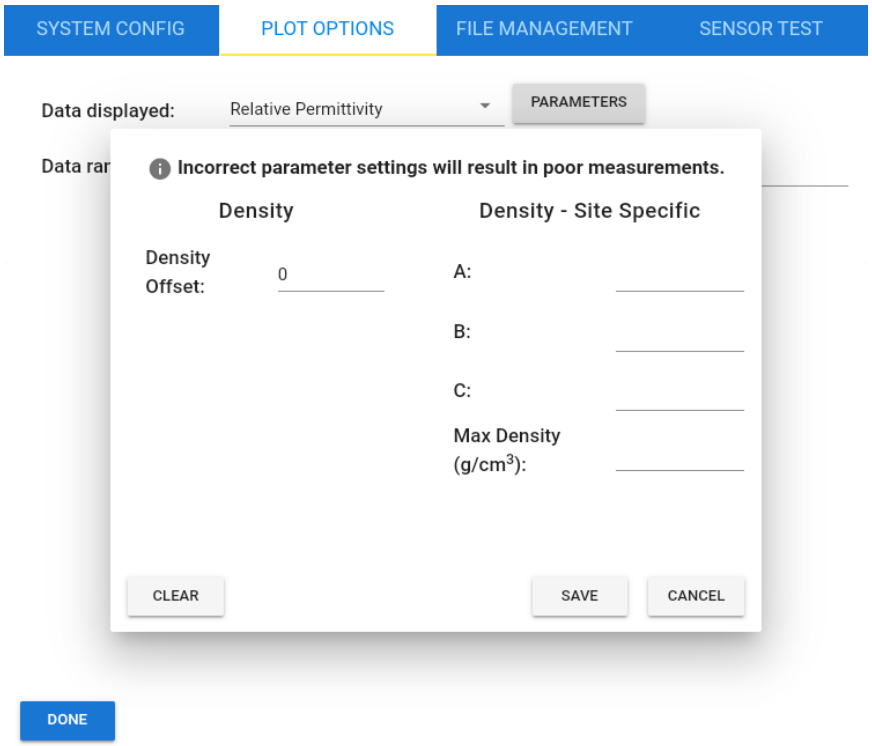


Figure 4-9: Window for entering Parameters

- **Density Offset** – used when calculating Density. This applies a shift in the data. A user would input a density offset value to bring the PDP surveyed measurements in line with that from a core sample or possibly calibrated nuclear gauge measurement.
- **Density - Site Specific** - **A**, **B** & **C** coefficients, as well as **Maximum Density** are used in a polynomial equation that accurately transform permittivity to density (this is explained in Appendix G:). Once cores are obtained, these coefficients can be calculated from the PDP Toolkit software. The coefficients can be input here so subsequent PDP measurements will be accurate. The more accurate the information obtained, the more accurate the future PDP measurements for that section of road.

  The above 4 values are required before data can be plotted showing Density-Site Specific, Relative Density and Air Void Content.

  The details on measuring maximum density are part of AASHTO Designation PP 98-xx, where xx is the revision number.

Data Range: Controls the display of data on the vertical axis on the main display. If set to **Auto**, the labels on the vertical axis will display the full range of data. If set to **Manual**, the user can set the min and max values accordingly.

4.1.4 File Management

This tab allows the user to download, delete and view previously collected PDP data (Figure 4-10).

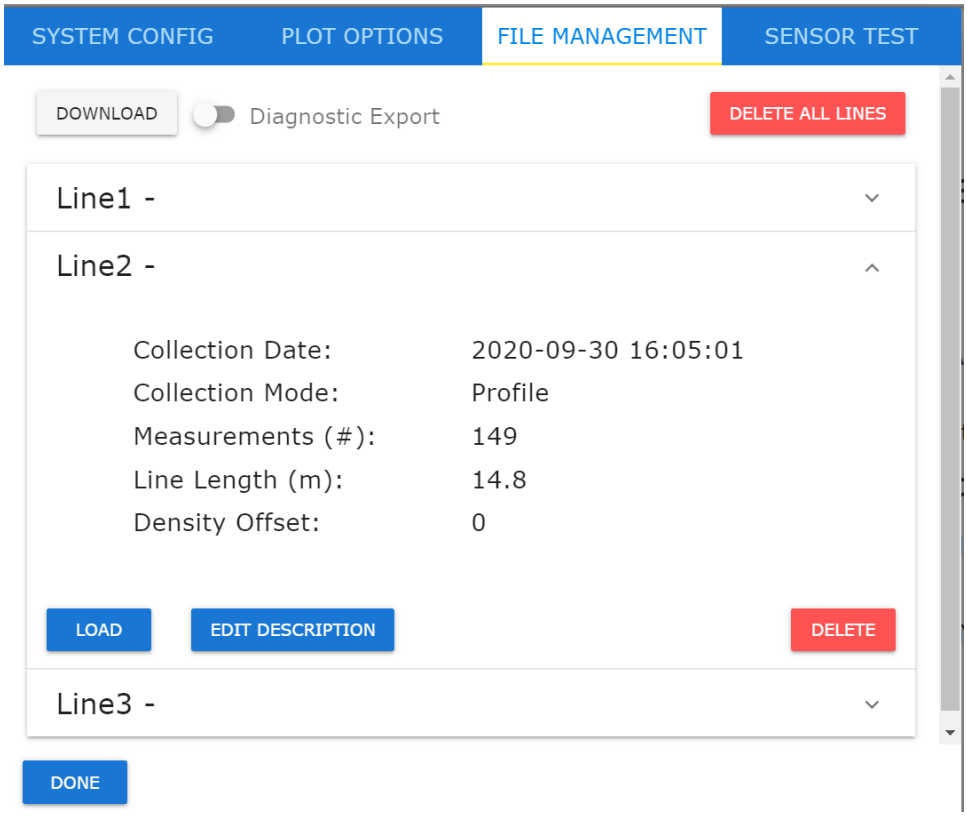


Figure 4-10; Viewing a line details and adding a description

The options are explained below:

- **Download** – collected data files reside on the PDP sensor itself. Touching the Download button copies the files to the Winmate tablet, where they can be exported to a USB drive. Details of downloading data and the files obtained, are discussed in Section 6.
- **Diagnostic Export** - toggle the Diagnostic Export button off and on to download additional data used for system diagnosis, only if advised to by the manufacturer.
- **Delete All Lines** – touching this button will delete all collected lines on the PDP. There is a confirmation window that pops up, as this action cannot be undone.

All the collected PDP lines are listed on this page. Touching the small down arrow on the right side of each line will expand the details for that line (Figure 4-10). From here, the user has the following options:

- **Load** – loads this line into the main screen for viewing. A pop-up message will advise that "*the data will be displayed with the settings used during collection and may differ from the current settings*". This means that whatever settings were used during the original data collection will be applied to the data that is loaded, rather than the current settings in the Tools menu.
- **Edit Description** – displays a window where the user can edit, or add, a description for that line. The description gets appended to the line number making it easier to reference the line at a quick glance.
- **Delete** – deletes this line only

4.1.5 Sensor Test

The PDP Sensor is calibrated at the factory. If the unit has not been operated in some time, or you feel that it is not working properly, you can do a validation test. The validation test ensures that the system is operating properly by measuring an object with a known response. You will need the validation target supplied with the system. The test will take approximately 5 minutes to complete. The sensor needs to be set upside down on the asphalt. Ensure there are no objects within 1 meter of the PDP Sensor and that nobody walks by the sensor during the test.

From the PDP main screen, press **Tools**, then press the **Sensor Test** tab. You will see the screen in Figure 4-11.

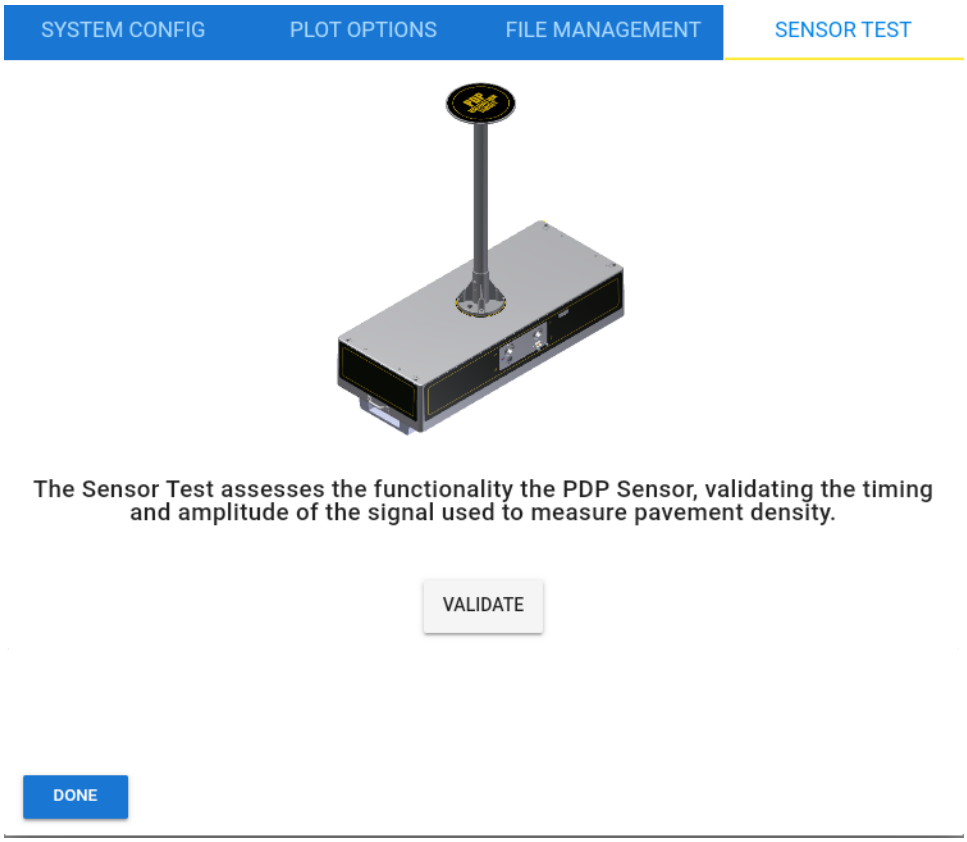


Figure 4-11: Sensor validation test

Follow the directions on the screen for orientating the PDP sensor and the validation target. These are illustrated in Figure 4-12, Figure 4-13 and Figure 4-14.

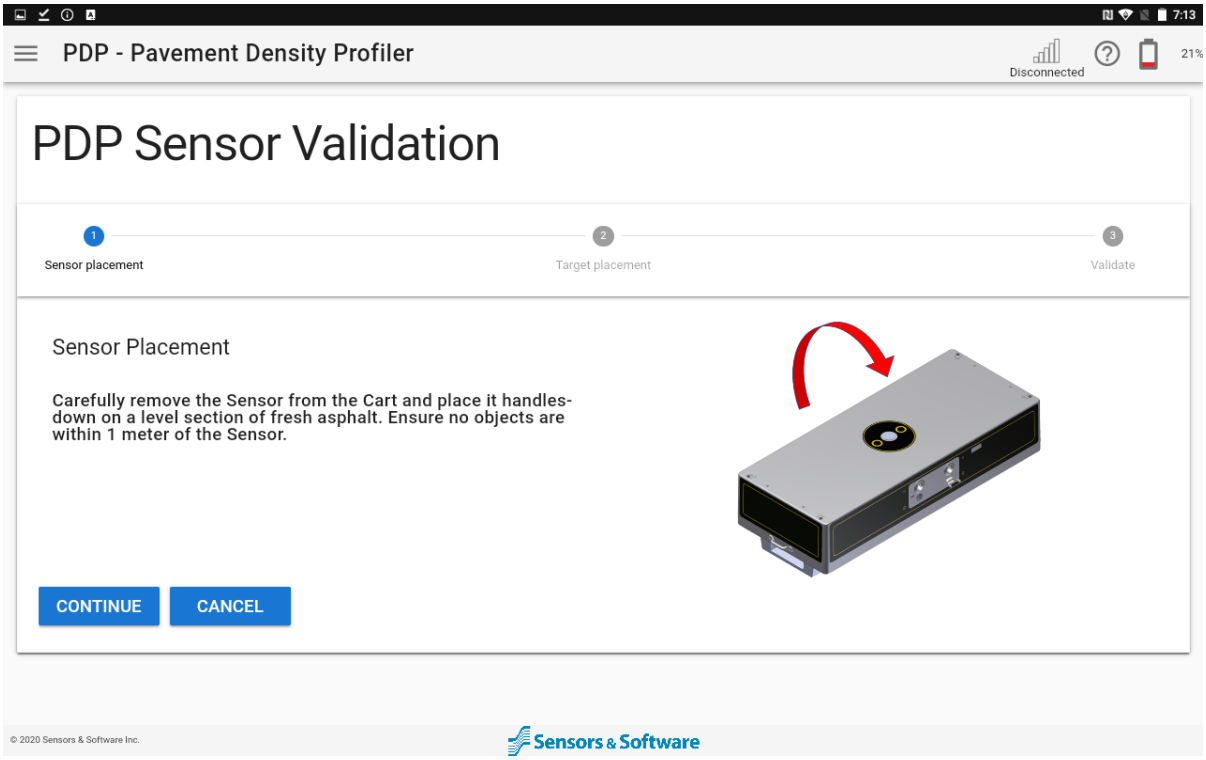


Figure 4-12: Turn Sensor upside down on a flat surface

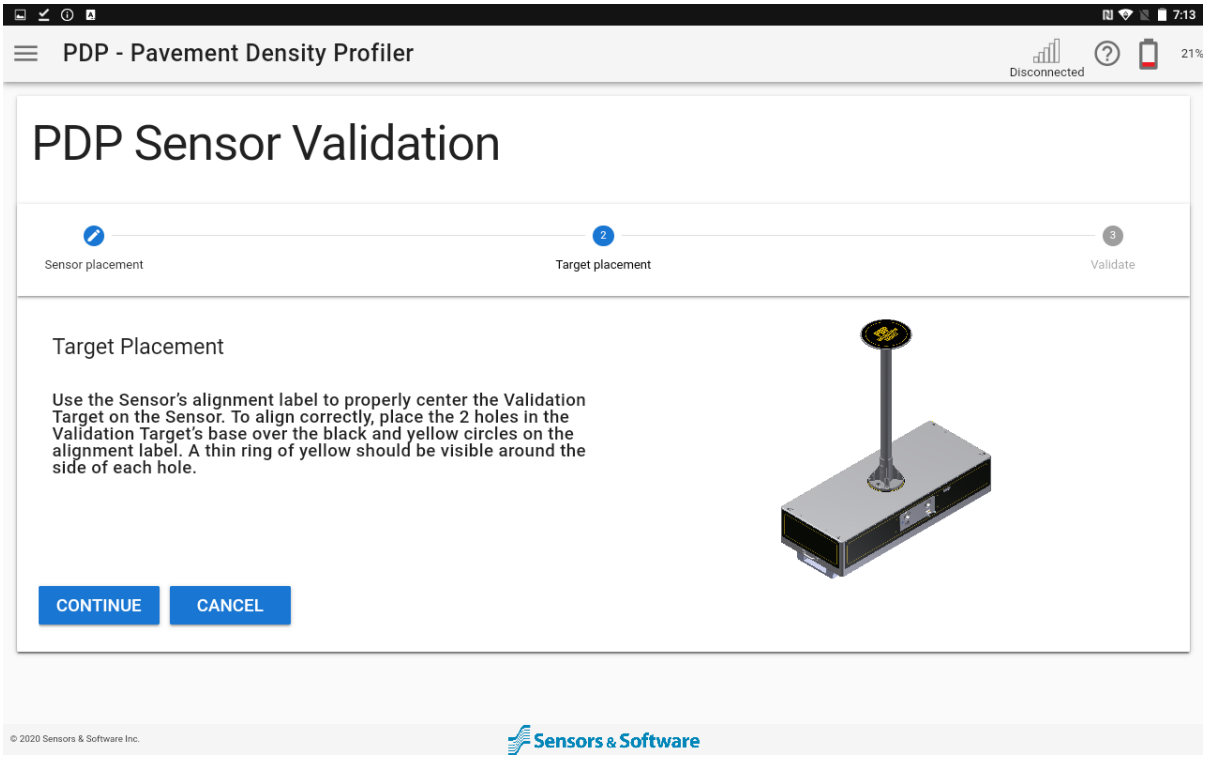


Figure 4-13: Place validation target as described on-screen

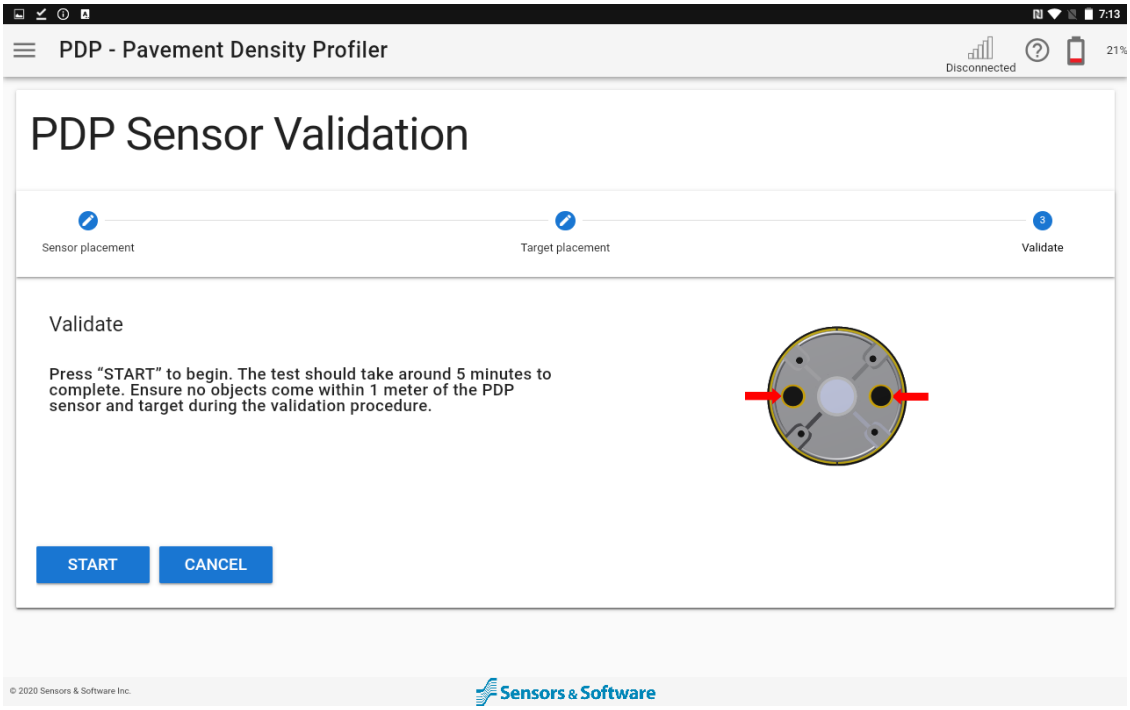


Figure 4-14: Beginning the validation test

You will see a message indicating whether it passed or failed (Figure 4-15). If it failed, you will be able to re-try the test. Failure of the test does not mean the system is not working; data can still be collected. It is still a good idea to contact Sensors & Software if the validation test fails repeatedly.

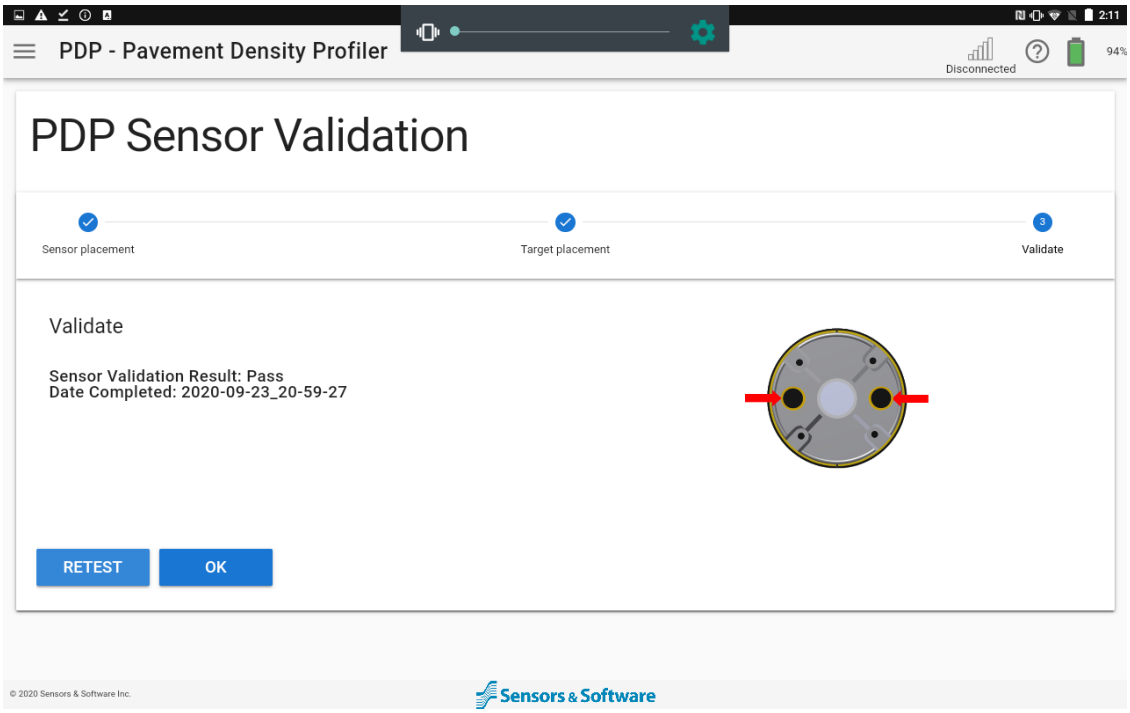


Figure 4-15: Validation test passed

4.2 Collecting Data

Once the settings are configured, you can begin collecting data.

> **NOTE:** Since PDP measures surface reflection which can be affected by the presence of standing water, do not use the PDP during rain or on wet pavement as this will produce incorrect values. PDP is intended for use on fresh asphalt, when it has cooled sufficiently to safely walk on.

Touch the **Start** button to begin. The number of the next available line is displayed under Start.

If desired, enter a description of the line (Figure 4-16). Otherwise, leave the description blank and just touch **Apply**.

If a description was used for an earlier line, the **Last Used Text** button will be enabled (otherwise it will be greyed out). Pressing this button will insert the most recently used description.

The system will then start collecting data. Collection modes are described below.

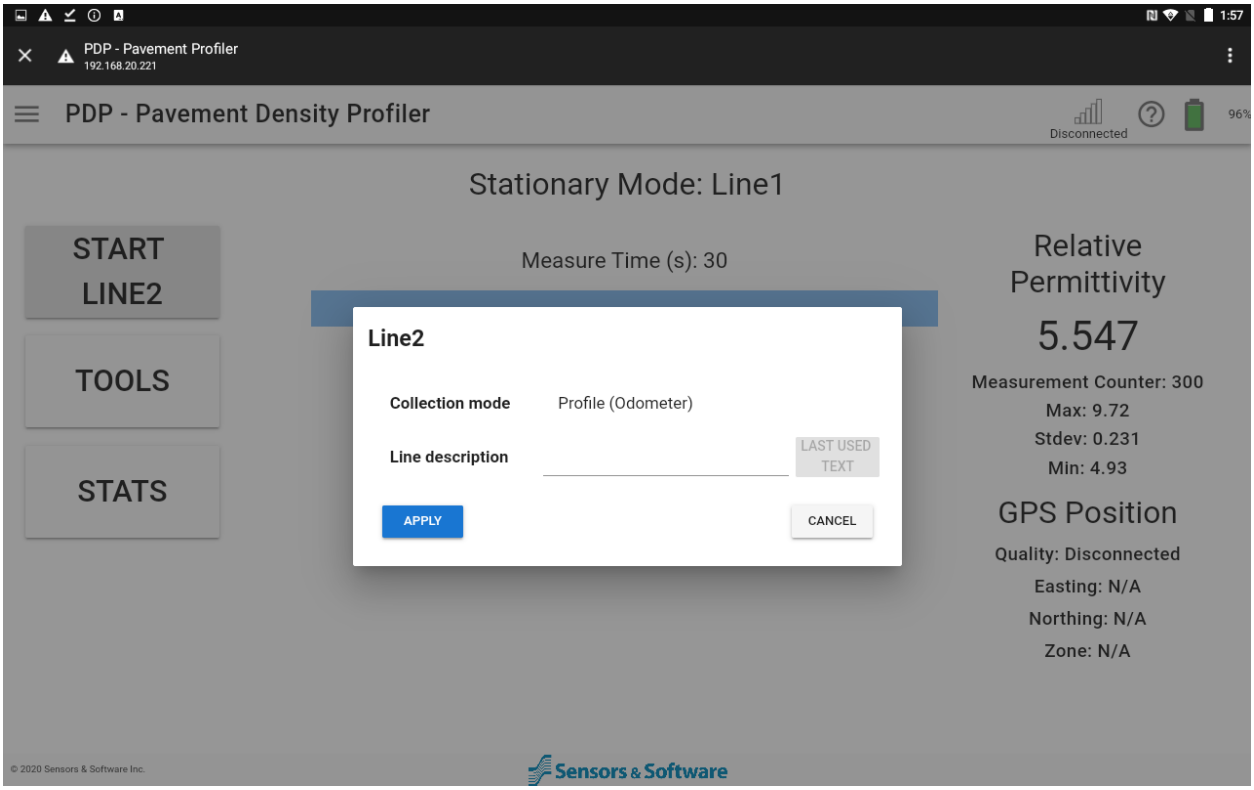


Figure 4-16: Entering a description for the line

4.2.1 Profile Mode

In Profile mode, PDP data is collected while the cart is moved. Typically, this is done to investigate density changes over an area. In most cases, this is done

immediately after the asphalt has been laid, compacted and allowed to cool, to check for the for the consistency of the asphalt density.

As the cart is pushed along, distance is plotted along the horizontal axis, and whatever data parameter is selected from Plot Options (Section 4.1.3) is plotted on the vertical axis (Figure 4-17).

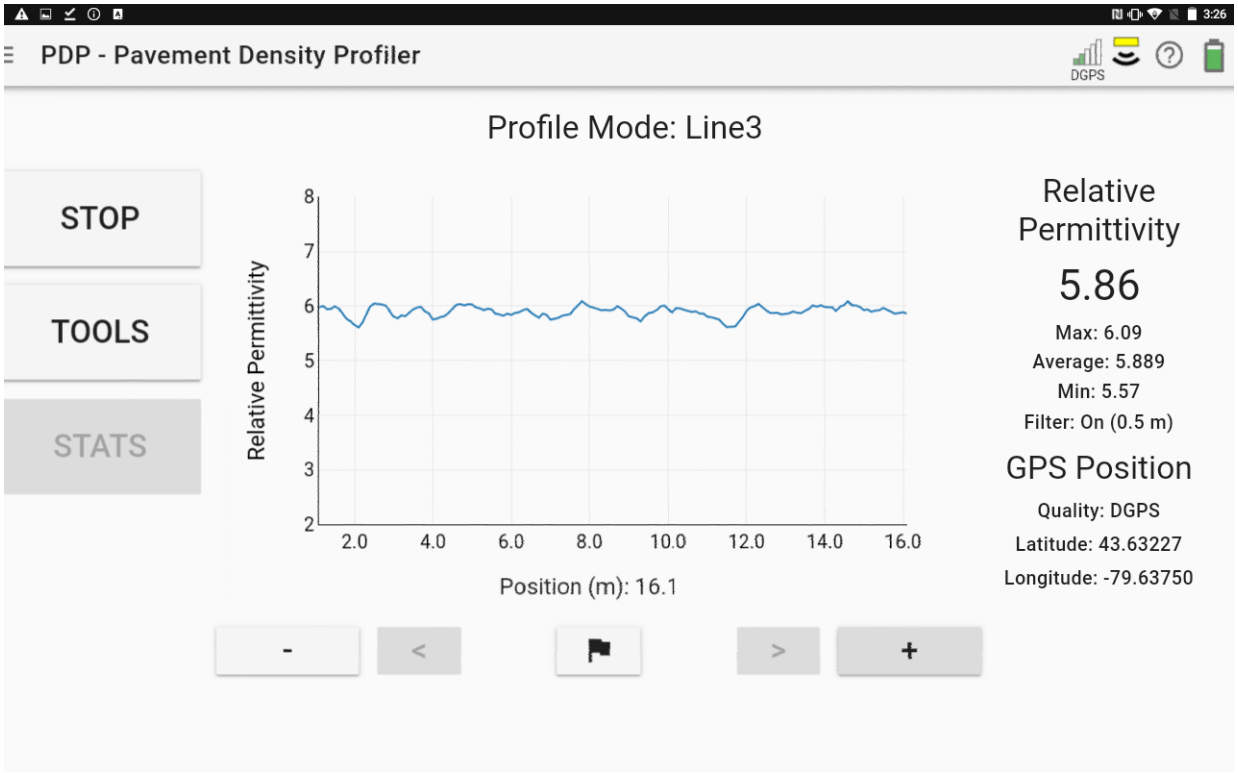


Figure 4-17: Collecting data in Profile mode

The measurement stats are displayed on the right side, showing the current value as well as the min, max and average values obtain for this line.

If a GPS is enabled, the GPS positions are also displayed.

In the top right of the screen there are few icons. These are explained from left to right:

- GPS quality indicator – refers to the external GPS. Highlighted bars indicate quality of signal. If it says "Disconnected", then the GPS is unplugged. If it says, "No Signal", the view of the sky is obstructed.
- GPR active indicator – it will animate as the system is collecting data
- Question mark – pressing this will launch this user's guide
- Battery power – icon and percentage power are shown

Profile mode incorporates a back-up feature (only in odometer mode) to enable you to accurately locate anomalous areas. After acquiring some data, pull the cart backwards. A red vertical line appears over the data. As you pull the cart backwards, the vertical line moves to mark the current location of the PDP sensor (Figure 4-18). This can be lined up with any readings on the screen to see where they occurred, provided you moved forwards and backwards in a straight line.

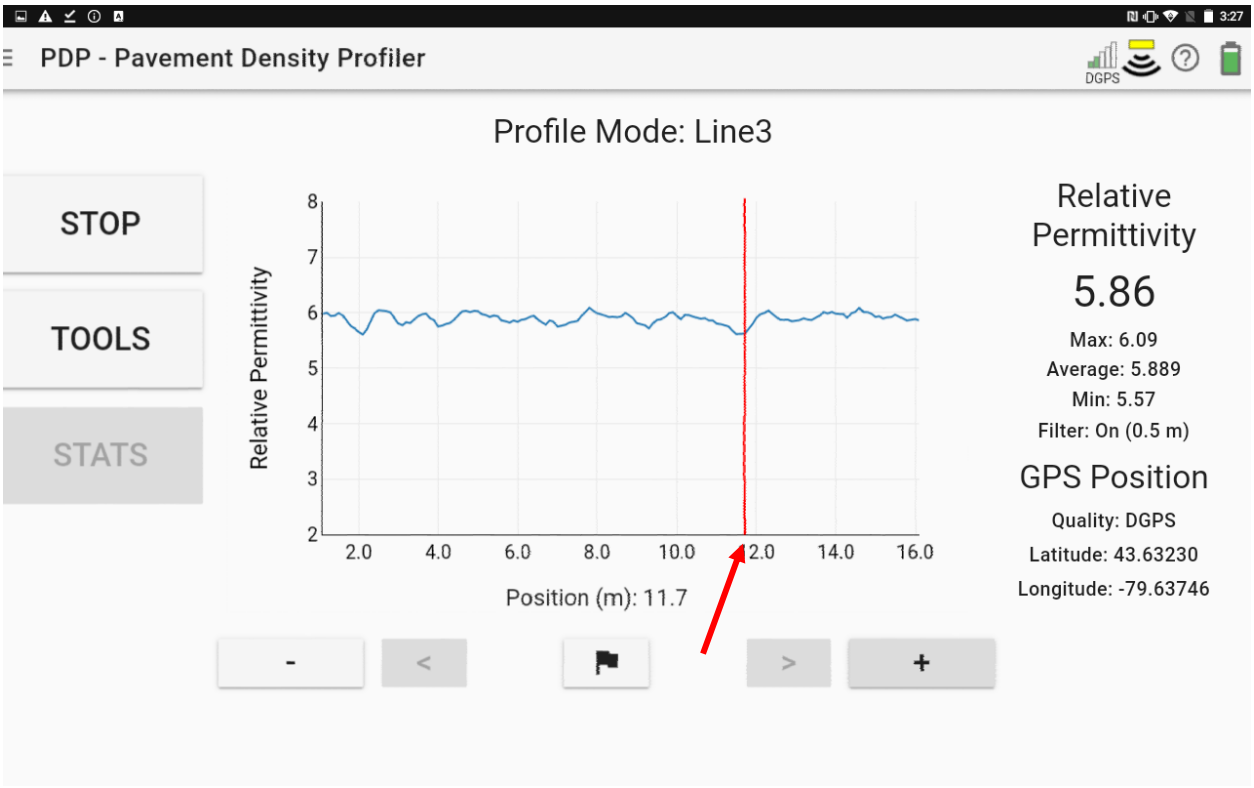


Figure 4-18: Showing the back-up arrow

To put a flag on the screen to mark this area, touch the flag button at the bottom of the screen. A number flag is inserted at that point (Figure 4-19). Flags are sequentially numbered, so multiple flags can be added on a line. It is recommended to use flags to mark locations of cores, or other surface features, such as pavement joints for example. The flag numbers reset on each new line.

To resume data collection, move the system forward along the same path. Once you reach the point where you initially started backing-up, the system will continue acquiring new data.

The **<** and **>** buttons allow you to scroll left and right to view data that is not currently on the screen.

The **+** and **-** buttons allow you to zoom in and out on the horizontal scale.

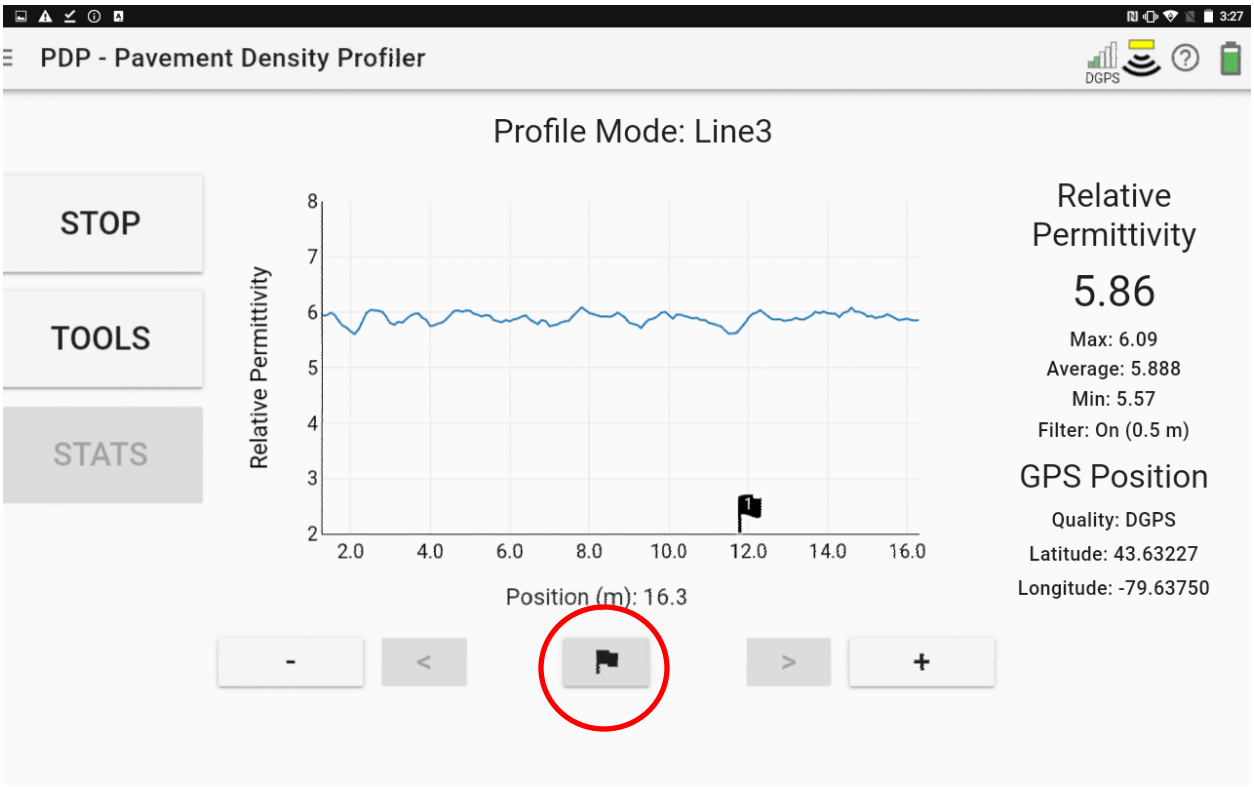


Figure 4-19: Inserting a flag

4.2.2 Stationary Mode

Stationary mode is used to collect data over a single area without moving the PDP (Figure 4-20). Under Plot options (Section 4.1.3), the user can specify the duration of the data collection. Data collection will be stopped after the specified time has passed, and the file written. A progress bar displays the time completed as a percentage of the total time selected. Pressing **Stop** before the time has passed will stop collection and write the file.

If the user selects Continuous data collection, it will keep collecting data until the user presses Stop. No progress bar is displayed.

A common use of this mode is to determine density more precisely at a specific area to correlate with coring.

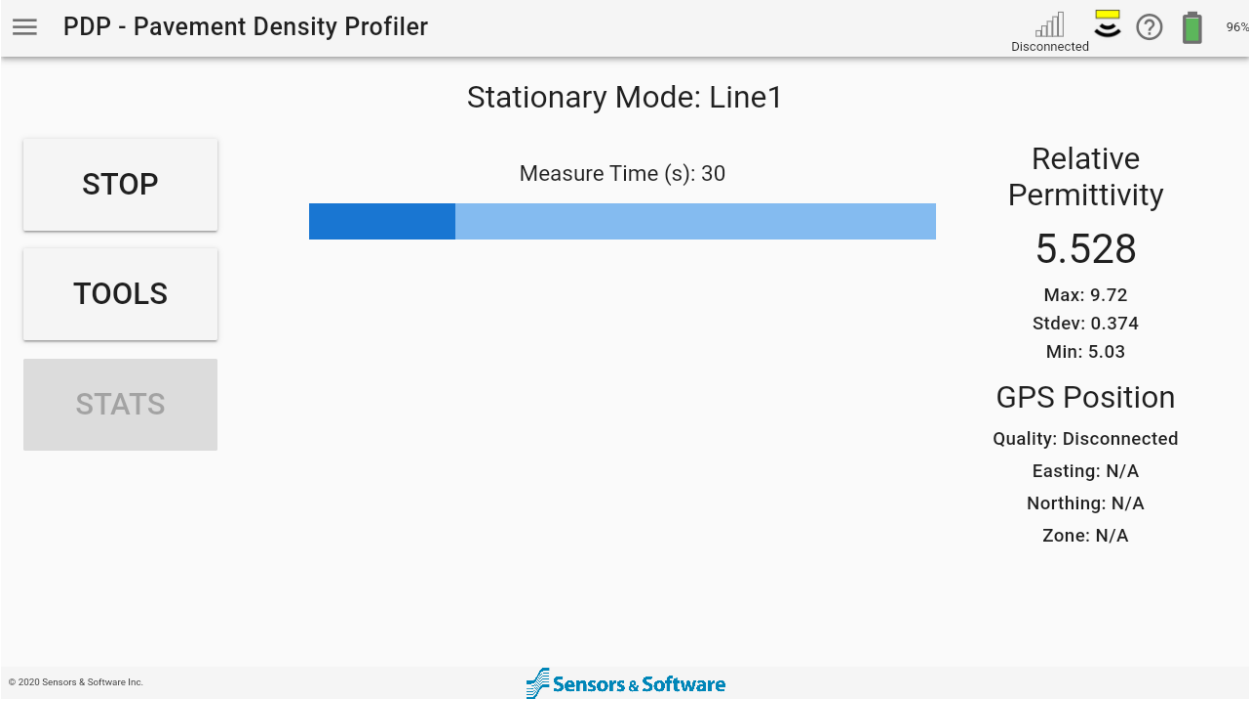


Figure 4-20: Collecting data in Stationary mode

4.2.3 Warning Messages

During collection, the PDP might display warning messages if any of the following occur:

1. Going too fast – if the PDP is pushed too fast (faster than regular walking speed), an error message will momentarily pop up at the bottom of the screen saying, "skipped traces detected, please slow down". Data collection will still continue.
2. If the PDP is unable to determine the desired measurement, it will display an error saying, "an error has occurred while processing data". This is rarely encountered, and data collection will still continue. However, check to make sure that no loose items/cables have fallen under the PDP and the sensor is still seated properly in the PDP cart.

4.3 Stats

Pressing the Stats button will generate a PDP Summary Report, as a PDF file.

Whatever data is currently displayed is used to generate the Summary Report. So, if profile collection mode is used displaying Density, then this is plotted in the Summary Report. Note that density and permittivity are calculated automatically can be easily plotted from each other. But if the user wants to plot any of the others (Density – Site Specific, Relative Density or Air Void Content), they would need to enter the A, B, C and Max Density Values under the Parameters button before these can be plotted.

After pressing the Stats button, a window will pop-up advising that the user can view the file (press View) or just move on with out viewing (press Done).

Pressing View will download the PDF file immediately to the Tablet (Downloads directory), where it can be opened.

Pressing Done will do nothing, but the PDF file is generated and will be downloaded along with the actual PDP data when the user selects Download (see Section 4.1.4 on File Management).

The report is discussed and shown in Section 6.3.

4.4 Admin Settings

The Admin settings tab describes how to update the software, set date & time, and displays system information. Admin settings can also be accessed from the hamburger button shown in Figure 4-2. Each tab is described in detail below.

4.4.1 System Admin

The system admin tab displays an overview of version numbers for the hardware and software (Figure 4-21). There are several buttons available on this page, described below:

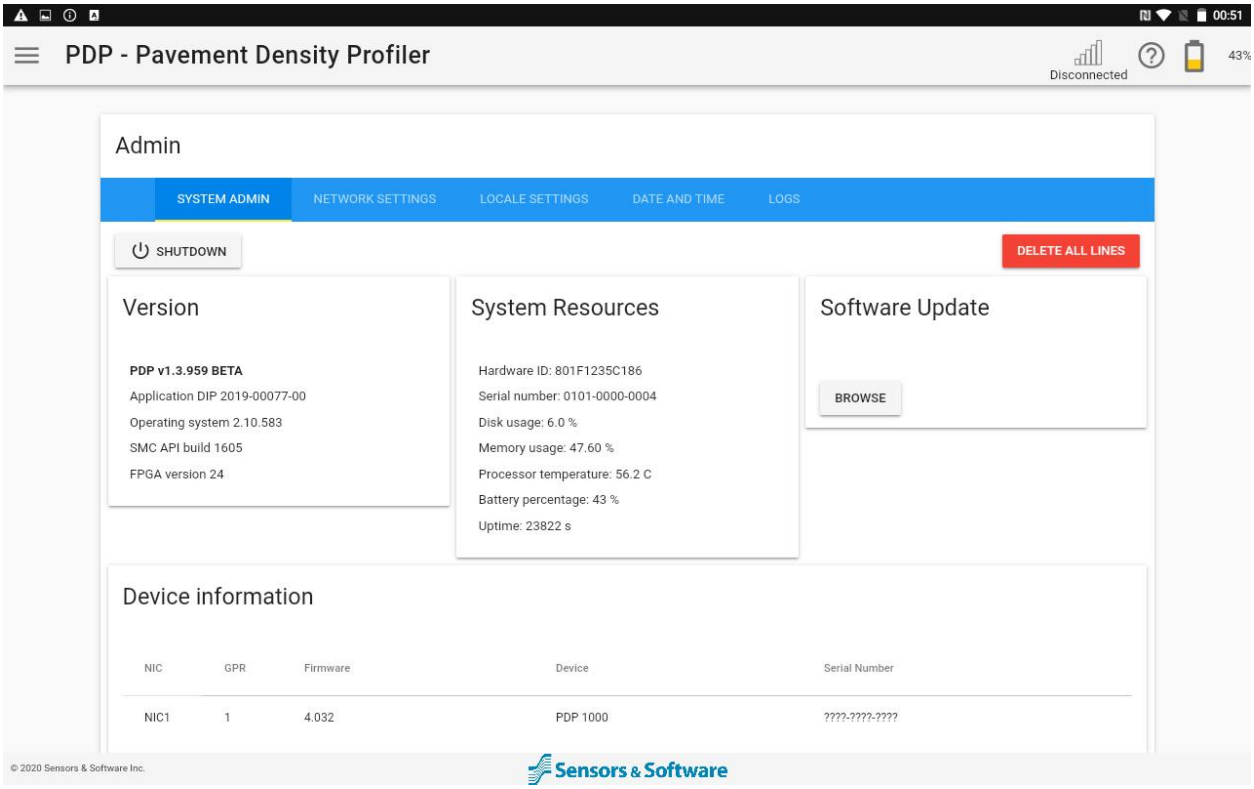


Figure 4-21: Admin page

- Shutdown – press this button to shutdown the PDP sensor
- Delete All Lines – press this button to delete all lines saved on the PDP.
- Browse – pressing this button in the Software Update window allows the user to update the firmware on the PDP itself. Details are in the following section.

4.4.2 Software Update

Upon pressing the Browse button, it will first pop up a window warning that all collected data on the PDP will be deleted. Once you proceed, you will see the screen in Figure 4-22.

> **NOTE:** Updating the software will delete all collected data on the PDP. Make sure you download any important data to the tablet before performing this operation.

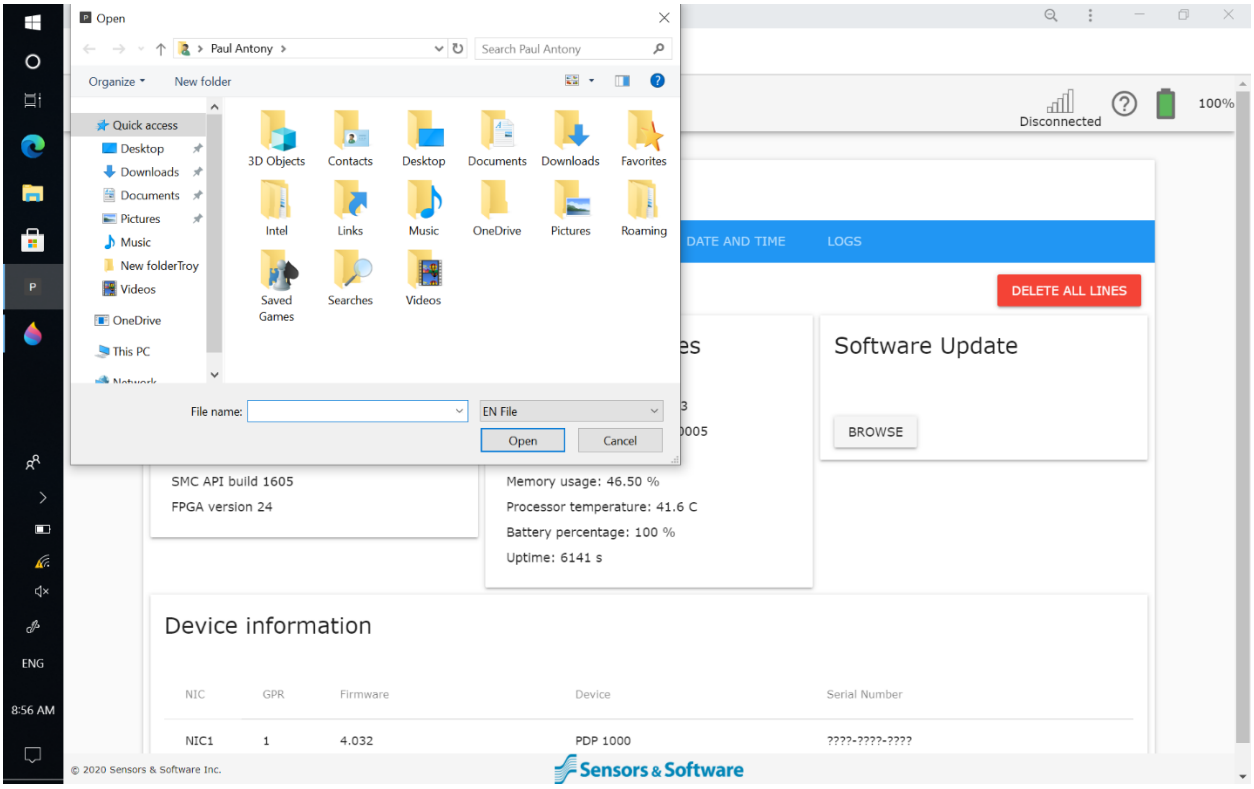


Figure 4-22: Select the file to begin the upgrade process

Make sure the file is on a USB Drive, and the USB Drive is connected to the tablet. Navigate to the USB drive and to the directory containing the .en file.

If the file is already on the tablet, navigate to the directory containing the .en file. Pressing this file will start copying the file to the PDP.

You will see the progress indicator as its uploading (Figure 4-23).

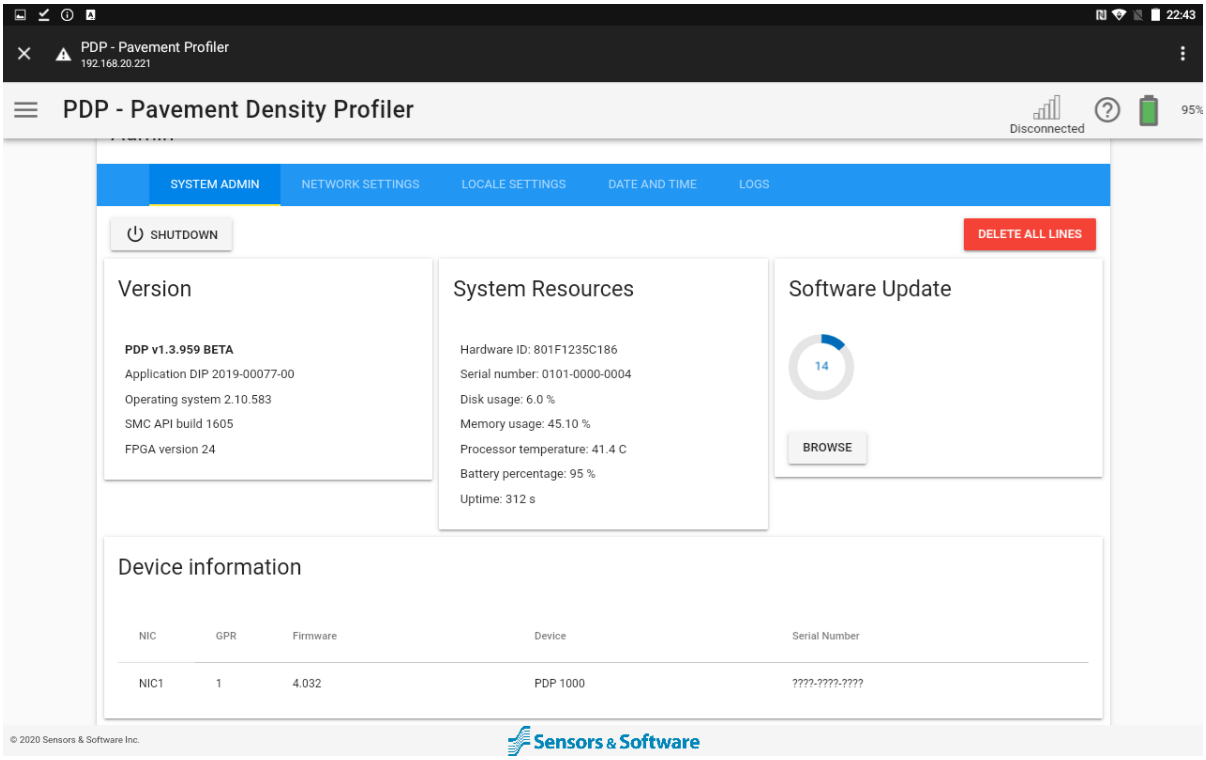


Figure 4-23: Uploading the file

Press **Reboot** to complete the PDP application installation (Figure 4-24). After installation completes you will have to manually start the PDP by pressing the On button on the PDP Sensor. If you decide to abort his process and not update the new firmware, press **Clear**.

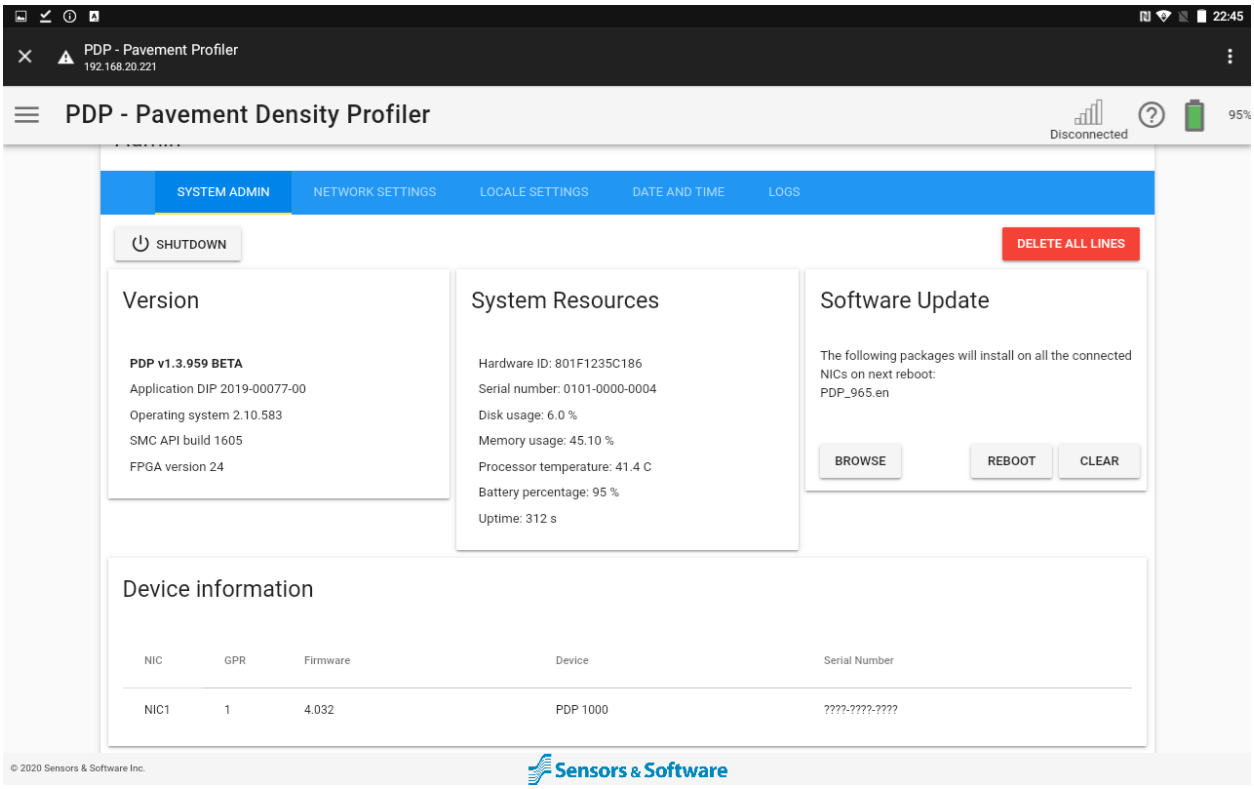


Figure 4-24: Software update ready to proceed

4.4.3 Network Settings

Displays settings related to the PDP Wi-Fi connection (Figure 4-25). None of these fields can be edited by the user.

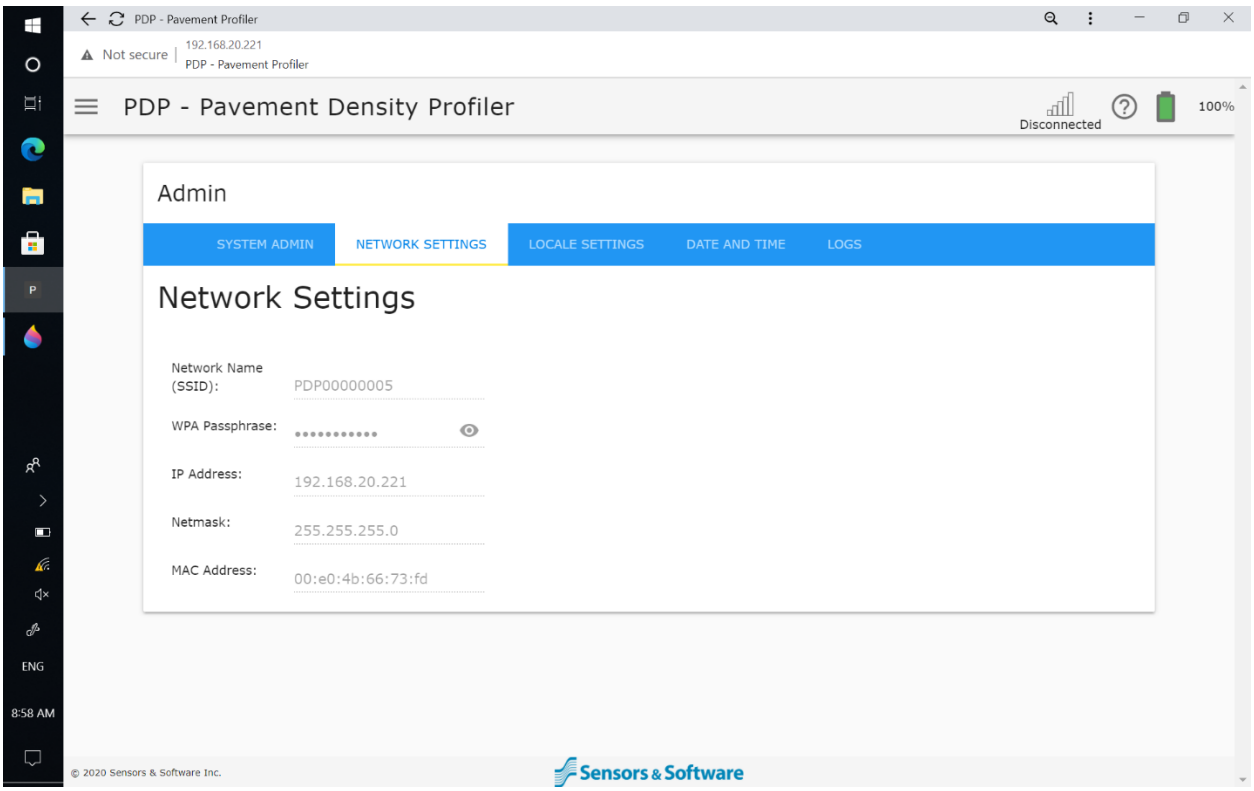


Figure 4-25: Network Settings window

4.4.4 Locale Settings

Touch the **Country/Region** drop down menu to select the country where PDP will be operated (Figure 4-26). This sets the Wi-Fi power appropriately to meet local standards and regulations. Touch **Submit** make the change, and then reboot the system for the change to take affect.

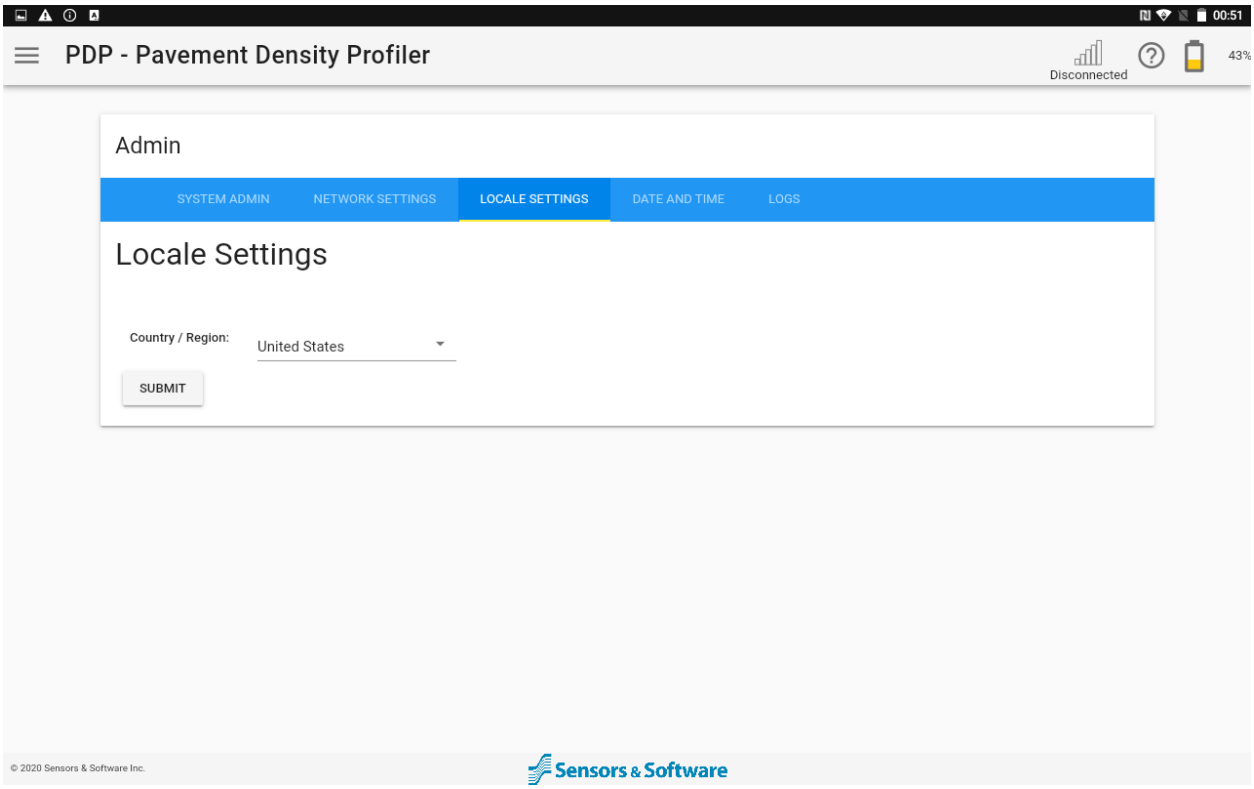


Figure 4-26: Locale Settings

4.4.5 Date and Time

The Date and Time tab displays the current time and date on the PDP (Figure 4-27). Pressing **Synchronize** will set the time on the PDP as the same time on the tablet. Pressing **Submit** will upload the changes to the PDP.

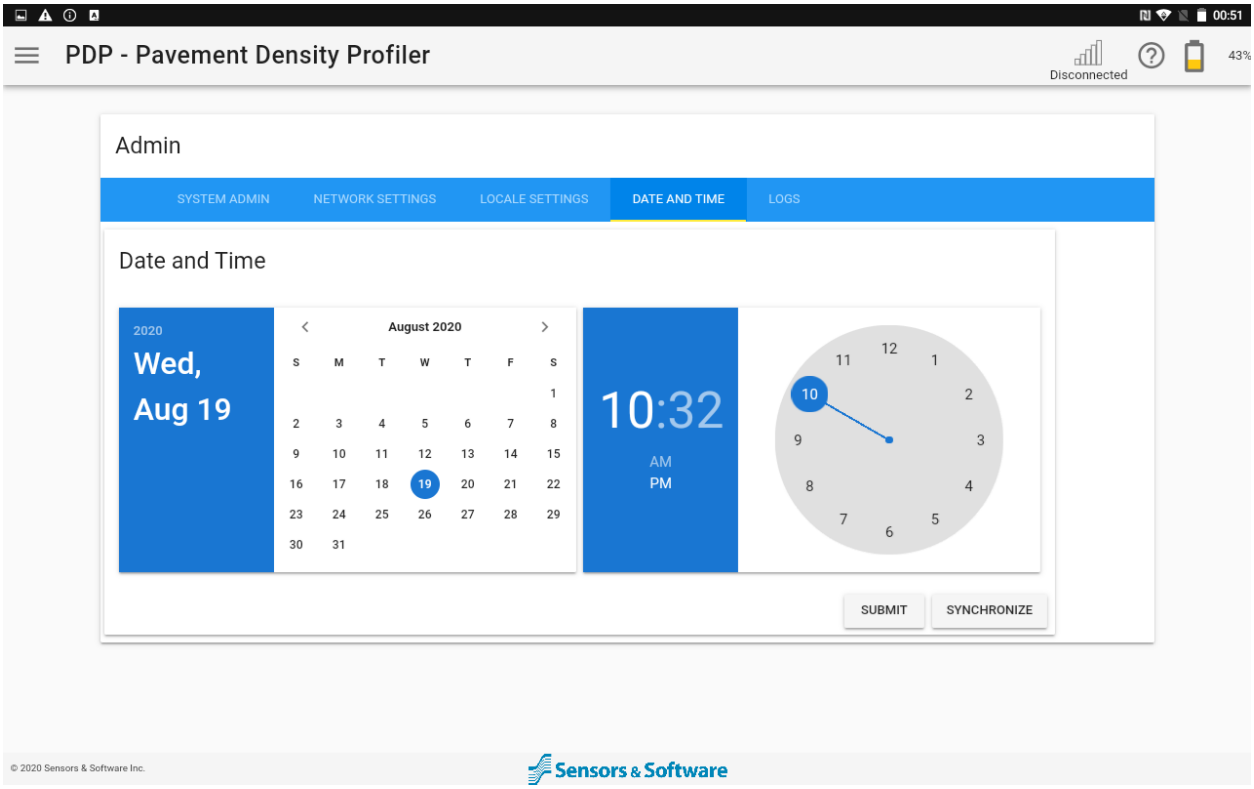


Figure 4-27: Setting date & time

4.4.6 Logs

This tab displays a run-time log of the PDP (Figure 4-28). Pressing the **Download Logs** button will download the logs to tablet. The logs can be useful when troubleshooting the system.

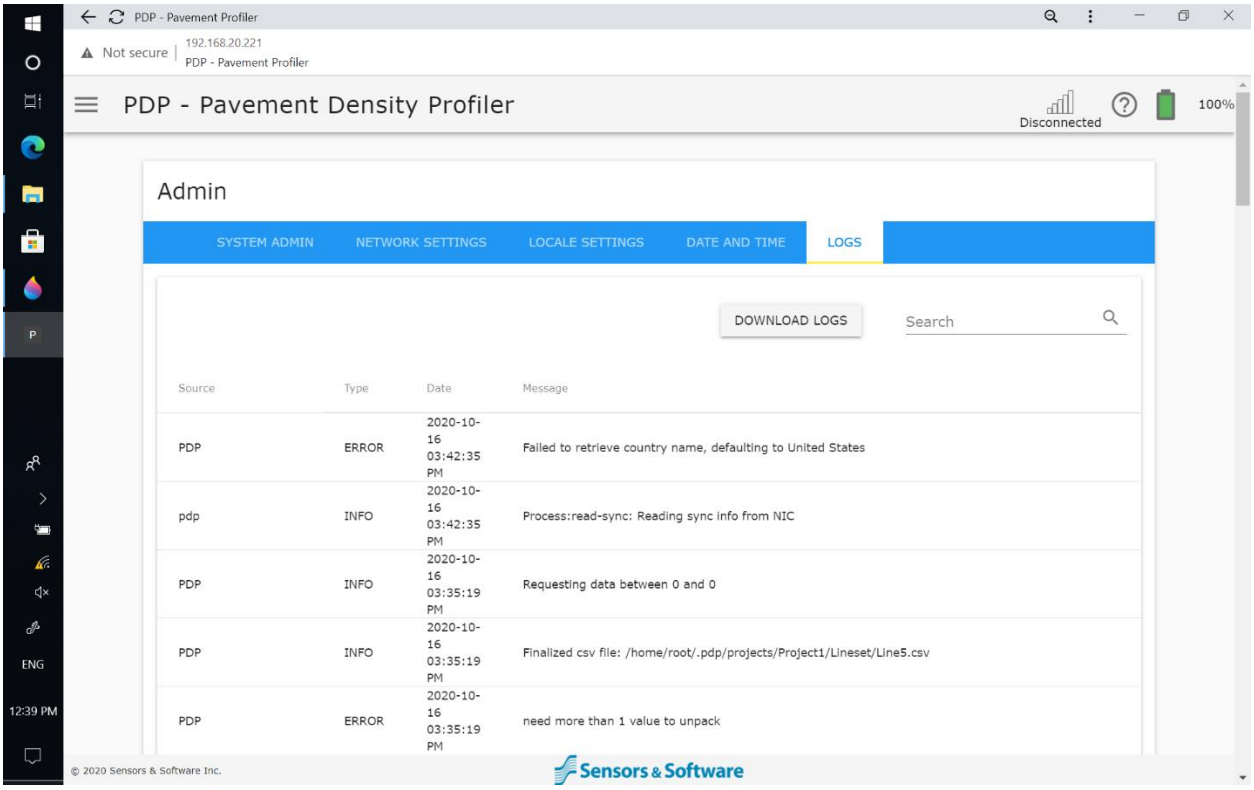


Figure 4-28: Displaying the Log report

5. Methodology

This chapter explains the basic theory, use scenarios and methodology for using PDP.

> **NOTE:** Since PDP measures surface reflection, do not use this during rain or on wet pavement as this will produce incorrect values. PDP is intended for use on fresh asphalt.

5.1 Importance of density measurements

The life of asphalt pavement has been demonstrated to be dependent on the consistency and uniformity of paving. Measuring the density of the final compacted asphalt is an accepted way of assessing the quality and consistency.

After paving, density is often obtained by taking cores. Cores are destructive and the holes must subsequently be repaired. In addition, cores provide only point measurements, and most of the time do not provide adequate sampling coverage over an area. Non-destructive methods (such as nuclear density and dielectric gauges) do not damage the asphalt, but only offer point measurements, which is not representative of an entire asphalt pour.

5.2 How PDP works

PDP is based on Ground Penetrating Radar (GPR) technology. It works by measuring the bulk electrical properties of the asphalt based on the reflected radio wave from the surface of the material.

A radio wave is transmitted from the PDP sensor downward towards the asphalt. When the wave hits the asphalt surface, some of the energy is reflected back to the PDP sensor, while the remainder travels down through the asphalt. The magnitude of the reflected wave is measured and is a direct indicator of the dielectric permittivity (K) of the asphalt. This value must be translated into the desired measurement, that being density.

5.3 Usage scenarios

Most users will want to use PDP right after asphalt compaction to check for uniformity or any anomalous areas.

PDP can be used to collect a profile of data over an area, providing a plot of K vs position. Or it can take measurements while stationary showing the distribution of K values at a specific location.

In terms of user scenarios, there are three main approaches:

1. Determine simple pavement variability using permittivity (K) data.
2. Determine pavement density variability using permittivity (K) transformed to density.
3. Determine site specific pavement density where permittivity (K) is transformed to 'true' density using field cores to obtain a conversion relationship.

Each method is explained below:

5.3.1 Dielectric Permittivity (K) for uniformity

Knowing that K is directly related to density, determining the variability of K over an area provides the same information as the variability of density over that area.

Since K values can be determined at cm intervals, the detail on variability can be mapped at a far higher spatial resolution than could ever be attained for coring density determinations.

Statistics on the variation of K will be very similar to the statistics of density. The location of extreme high and low K values will indicate the location of areas of high and low density. Such areas can then be targeted for coring. If the extremes are acceptable then all areas between can be assumed to be acceptable.

Start by traversing a line or run multiples lines to cover an area. Display K vs. position on the plot (Figure 5-1).

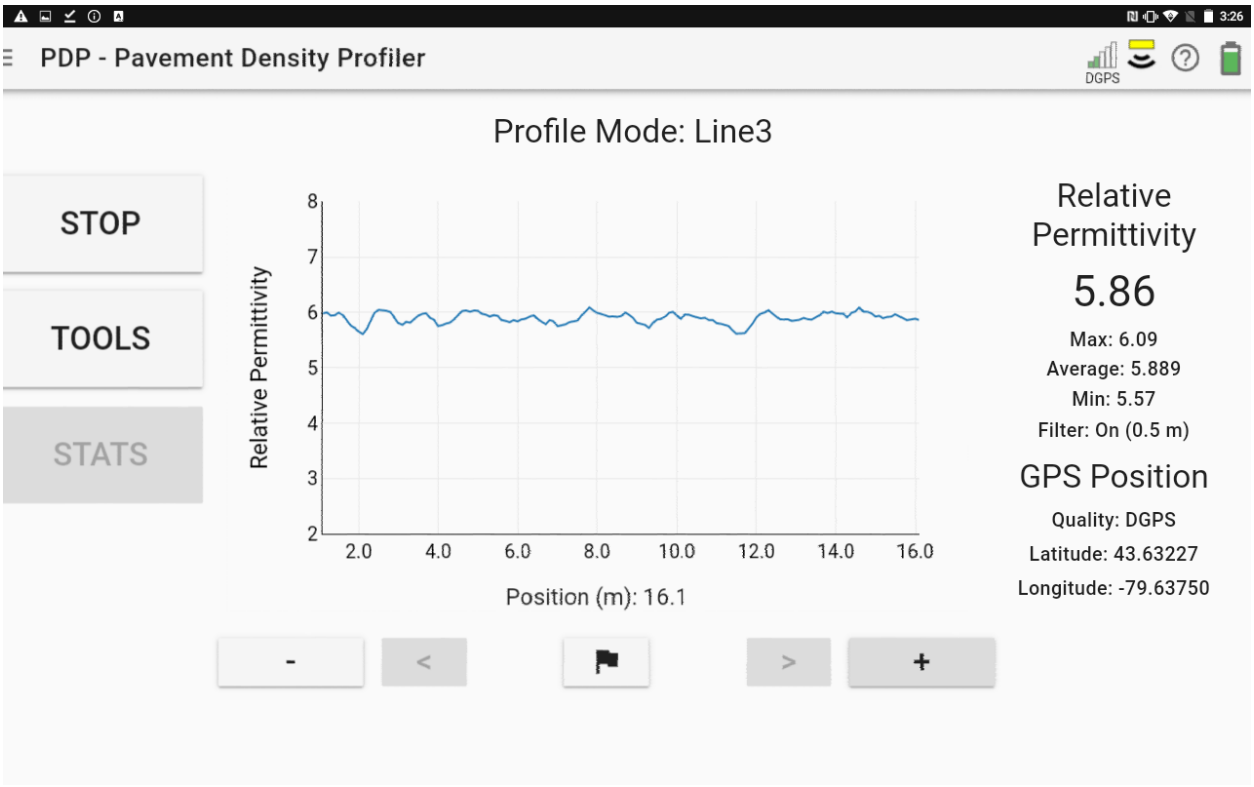


Figure 5-1: Sample plot showing K vs. position

This will already provide an indication of anomalous regions. For further investigation in areas where K is noticeably high or low, move the PDP to those areas and obtain stationary measurements of K.

5.3.2 Transforming Dielectric Permittivity (K) to density

For some users, seeing the data from the PDP in actual density units is helpful as density is the standard asphalt variability measurement. All of the steps described in using permittivity above are followed in this methodology.

The user has only to select display density instead of permittivity K. PDP will now output density in grams per cubic centimeter (g/cm^3).

The variation in density will be the same as the variation of asphalt density, but the absolute value of density may differ slightly because a simplified conversion formula is used.

Start by traversing a line or run multiples lines to cover an area. Display density vs. position on the plot.

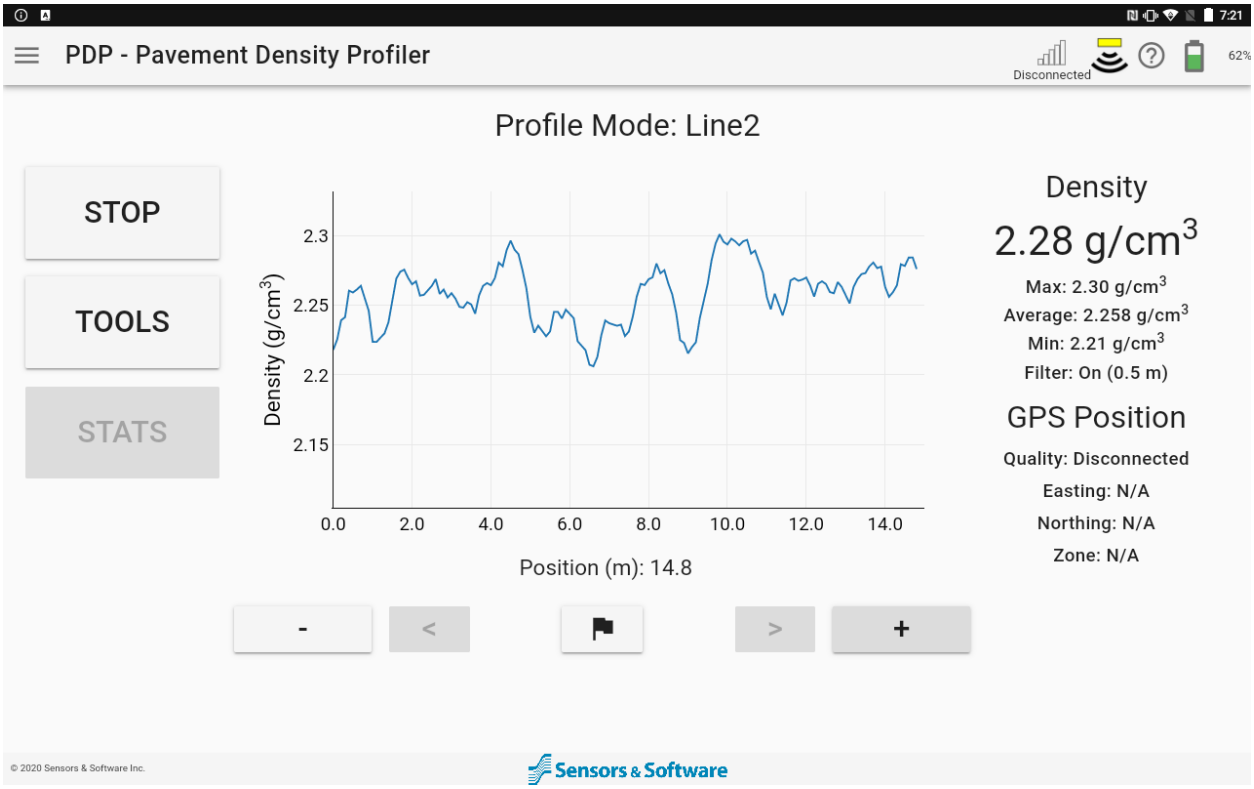


Figure 5-2: Sample plot of density vs. position

The user can immediately see areas of high and low density. For further investigation, move the PDP to those areas and obtain stationary measurements. The system generates a histogram report showing the variation in density.

If any cores are obtained where PDP data is collected, the data can be "corrected" by applying a density offset (under the Parameters button). This is essentially ground truthing by verifying the observed PDP measurements with the actual value obtained from the cores. This correction factor can be applied to the whole data set.

5.3.3 Transforming Dielectric Permittivity (K) to Site Specific Density

To obtain a site specific density, the PDP requires a more detailed conversion of permittivity to density. The approach normally used is to take PDP measurements over an area or along a transect of new asphalt pavement. A series of points where there are zones of high, low and intermediate range values are identified as reference points. The density at these locations (called reference density values) are determined from core samples (or possible nuclear density or Q-meter measures).

The measured PDP values of K and the reference density values (from coring or non-destructive methods) are then used to create the 2nd order polynomial curve

for the site specific relationship between K and density (details in Appendix G:). The PDP Toolkit PC Software is provided with the PDP system to carry out this computation which results in site specific coefficients A, B and C as well as the user defined maximum density. The values of A, B and C and maximum density are entered into the PDP and the PDP will display site specific density.

The basic steps are as follows:

- Traverse a line or run multiple passes to cover an area using the K or standard density data display.
- Identify anomalous areas (where high and low values are observed) and target these locations for cores to obtain reference density values (via coring or other non-destructive technique such as Nuclear Density Gauge)
- Run PDP in stationary mode to collect data at these locations
- Use the PDP Toolkit PC Software to enter this information in a chart form, along with the site specific maximum density.
- Use the PDP Toolkit PC Software to compute and determine the A, B and C coefficients
- Apply the calculated A, B and C coefficients and the Maximum Density in the PDP Toolkit software (using the modify parameters utility)
- Now any collected lines will display the true density
- If necessary, the A, B and C coefficients, along with Maximum Density can be entered into the PDP collection software in the field for future lines collected at that site.

5.4 Outputs

Data collected with the PDP can be output into a summary report (PDF file) using the Stats button (described in Section 5).

Plan maps can also be generated by collecting a series of profiles over a given area. Once the data is downloaded from the PDP, it needs to be imported into the PDP Toolkit PC Software to create plan maps. Details are explained in the PDP Toolkit PC manual.

6. Exporting Data

When data is collected, whether in Profile or Stationary mode, the files created reside on the PDP sensor itself. To transfer the data to a computer, the data must first be downloaded from the PDP to the tablet, then exported on a USB drive, which can then be inserted into a computer.

6.1 Downloading Data

In Tools, under the File Management tab, all the files that are on the PDP are listed (Figure 6-1). Touch **Download** to wirelessly copy the files to the tablet. Toggle the Diagnostic Export button to include additional data used for system diagnosis, only if advised to by the Sensors & Software.

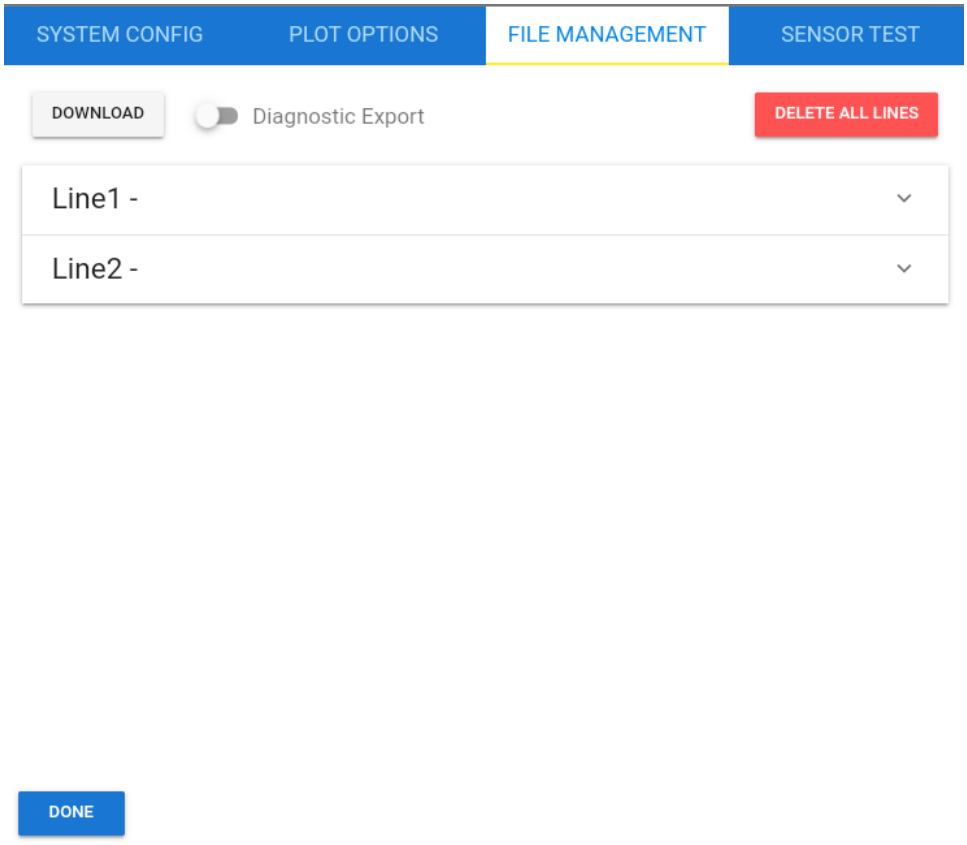


Figure 6-1: Downloading data under the File Management tab

The PDP files will be downloaded as a ZIP file (date and time embedded in the name) into the Windows Downloads directory. Open Windows Explorer and navigate to the Downloads directory to see the downloaded files (Figure 6-2).

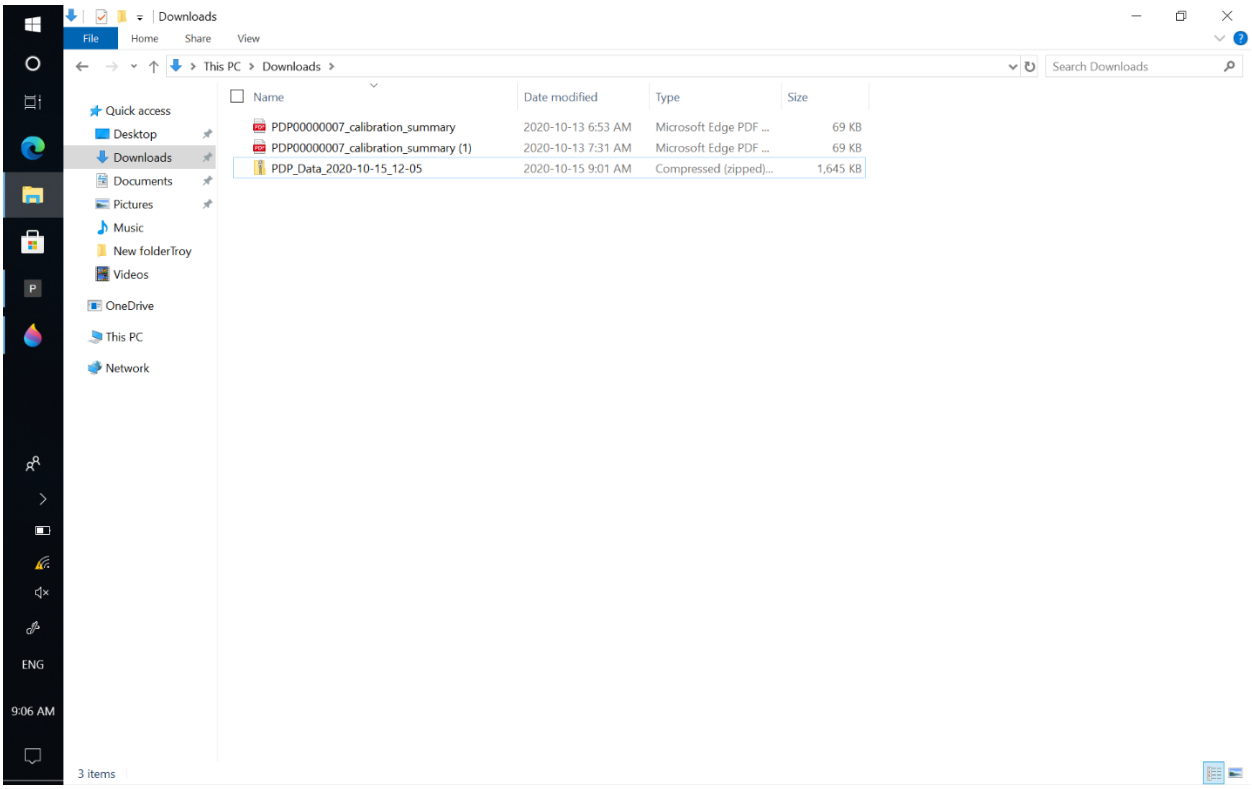


Figure 6-2: Viewing the downloaded files in Windows Explorer

Insert a USB drive into the port on the tablet. Copy the file from the Downloads directory to USB drive. The USB can now be inserted into a computer.

6.2 Downloaded files

Insert the USB into a computer. You will first need to extract the files from the .zip file that is downloaded. Double click on that file, or right-click and select Extract All.

Once you extract, the directory structure will be as follows:

- Lineset
  - Line1.csv
  - Line1.pdp
  - Line1.pdf (only generated if user presses Stats)
- System Info
  - app.log
  - cp.log

For every PDP Line that was collected, you will have the following files in the Lineset directory, where X is the line number:

- Line<X>.csv – contains details about the collection, such as date, time, collection and trigger modes, descriptive file name.

  If the data was collected in Profile mode, for every trace position, it will list the values of the five data types.

  If the data was collected in Stationary mode, it will list the average value, along with the minimum, maximum and standard deviation for each of the five data types.

- Line<X>.pdp – contains the binary data and can be opened in the PDP Toolkit PC software.
- Line<X>.pdf – this file is only generated if the **Stats** button is pressed on the main collection screen when a collected line is displayed. The file is a summary report and is described in Section 6.3.

The app.log and cp.log files contains system diagnostic information and is used to troubleshoot issues.

If the Diagnostic Export button was enabled, a file ending in GPZ is also exported. This maybe requested by the Sensors & Software for technical support.

6.3 PDP Summary report

All Summary Reports contain a histogram plot. This plot shows the distribution of the selected display parameter (e.g. relative density) for the given number of measurements. The distribution are the values obtained for say, relative density, plotted again the number of times that measurement was recorded measurements.

Other stats are also shown, such as the min, max, average and standard deviation. If collection mode was set to profile, the displayed parameter vs. position is also generated.

Stationary Plot

The plot for a Stationary line is shown in Figure 6-3. The measurement time was 30s with a measurement interval of 0.1s, giving a total number of measurements collected as 300.

Since Density was chosen as the parameter to display, the histogram plot shows the distribution of density for the 300 measurements.

Sensors & Software

PAVEMENT DENSITY PROFILER

Stationary Summary Report: Line1

General Information

Date of Collection: 2020-09-30 16:04:02
PDP (S/N): 0101-0000-0005

Survey Information

Data Collection Mode: Stationary
Measurement Interval: 0.1
Measurements (#): 300
Line Description:
GPS Type: External
GPS Position (Average): N/A

Statistics

Measurement Parameter: Density (g/cm^3)
Minimum: 2.13
Maximum: 2.30
Average: 2.219
Standard Deviation: 0.024

Processing Parameters

Density Offset: 0

Histogram

Bin Size (0.02)	Density	
	#	%
2.10 - 2.12	0	0.00
2.12 - 2.14	1	0.33
2.14 - 2.16	3	1.00
2.16 - 2.18	8	2.67
2.18 - 2.20	51	17.00
2.20 - 2.22	94	31.33
2.22 - 2.24	91	30.33
2.24 - 2.26	40	13.33
2.26 - 2.28	10	3.33
2.28 - 2.30	1	0.33
2.30 - 2.32	1	0.33
Totals	300	100

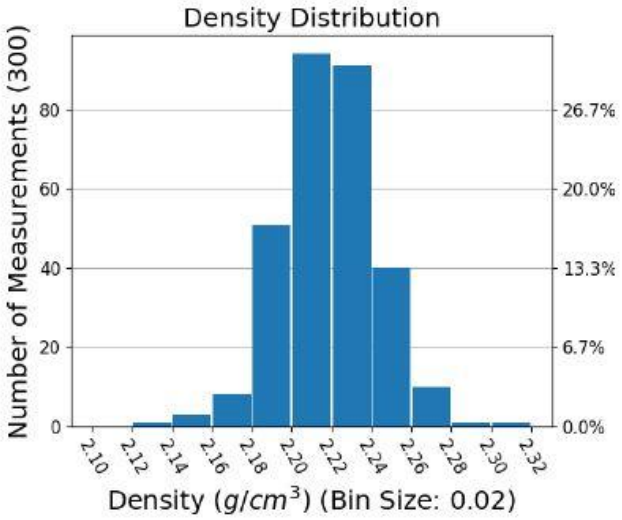


Figure 6-3: Summary report for a Stationary line

Profile Plot

The plot for a Profile line is shown in Figure 6-4. The total line length was 14.8m, and since a data sample is taken every 0.1m, a total of 149 measurements were taken.

Since Density was chosen as the parameter to display, the histogram plot shows the distribution of density for the 149 measurements.

A complete Profile view of density vs. position is shown, starting on page 2 (Figure 6-5). If the line is longer than 10m, then the position range auto scales and generates subplots beneath, allowing the user to see more detail.

Sensors & Software

PAVEMENT DENSITY PROFILER

Profile Summary Report: Line2

General Information

Date of Collection: 2020-09-30 16:05:01
PDP (S/N): 0101-0000-0005

Survey Information

Data Collection Mode: Profile
Trigger Setting: Odometer
Line Length (m): 14.8
Line Description:

GPS Type: External
GPS Start: 0.0E, 0.0N, 0.0
GPS Stop: 0.0E, 0.0N, 0.0

Statistics

Measurement Parameter: Density (g/cm^3)
Minimum: 2.21
Maximum: 2.30
Average: 2.258
Standard Deviation: 0.022

Processing Parameters

Data Filter: ON (0.5 m)
Density Offset: 0

Histogram

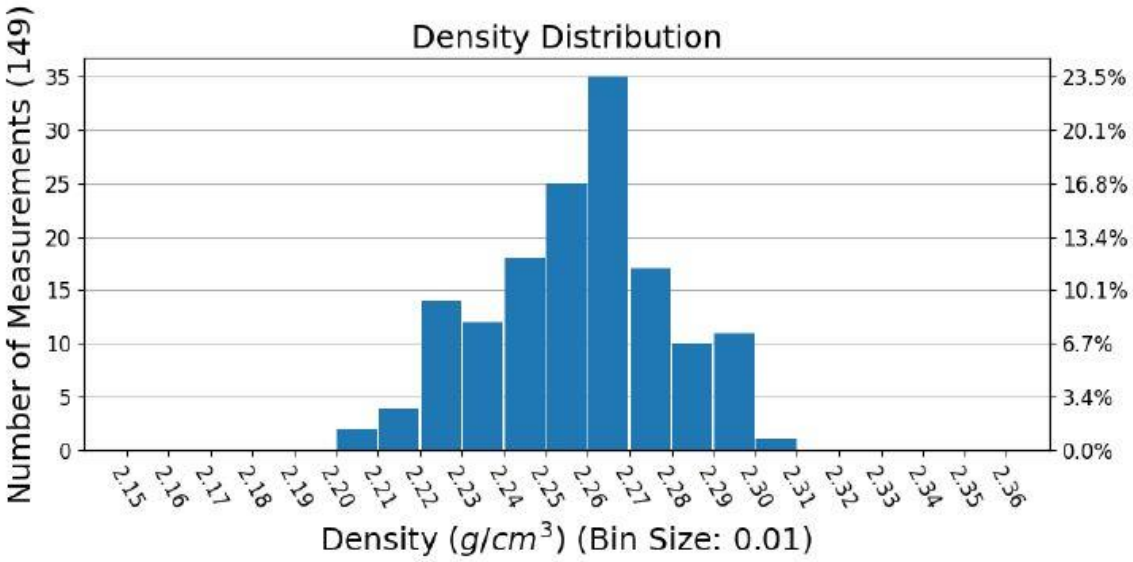


Figure 6-4: Summary report for a Profile Line – page 1

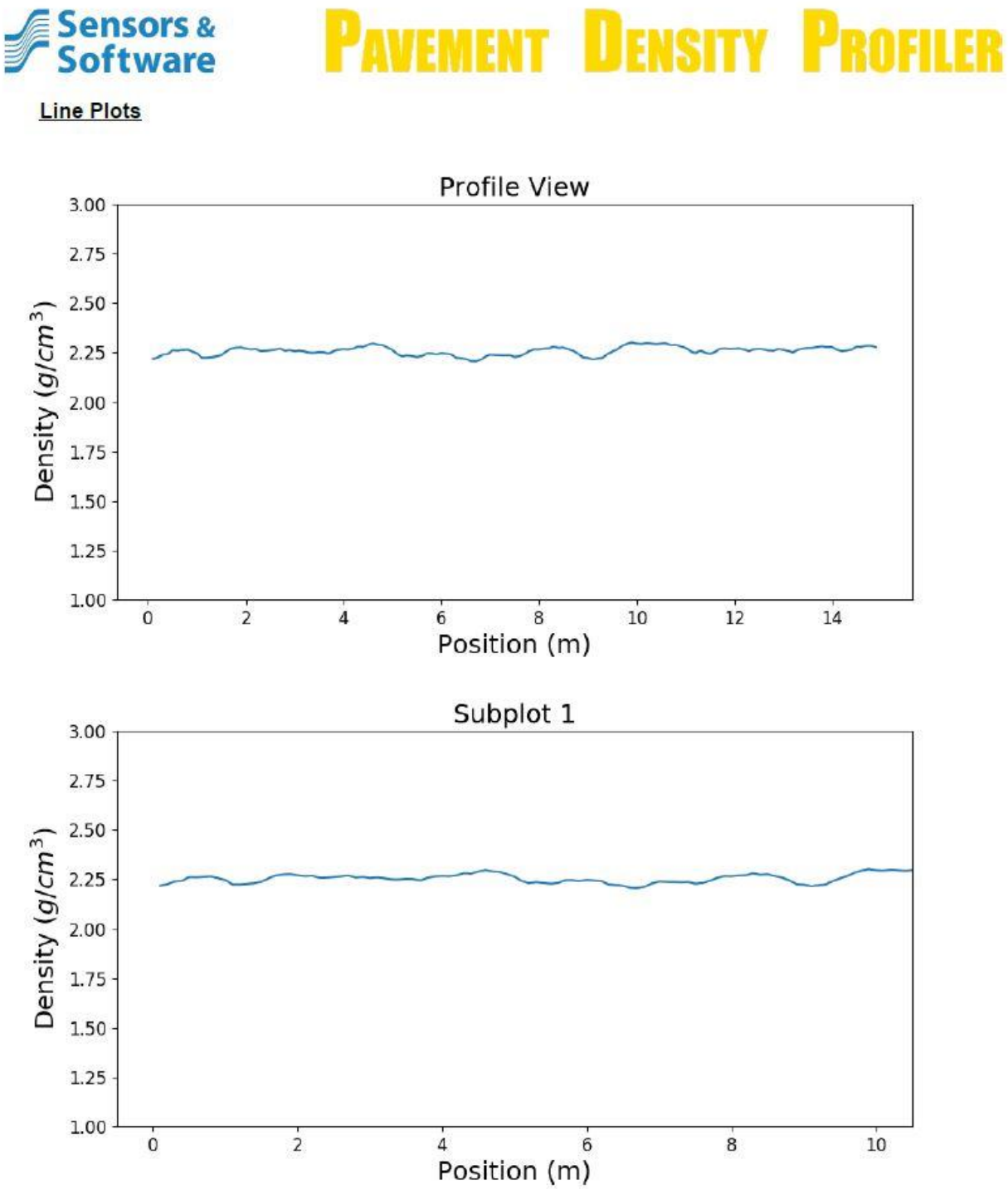


Figure 6-5: Summary report for a Profile line – page 2

6.4 Formatting USB Sticks

There may be times when a USB stick is not recognized by the tablet. In this case, you may need to format the USB stick. Ensure that it's formatted as FAT/FAT32. Also ensure that there are no hidden or write-protected partitions on the USB drive.

If the problem persists after formatting, try another USB stick.

7. Troubleshooting & Product Care

The PDP system is designed to minimize user problems; however, all electronic devices are subject to possible failure. The following are also troubleshooting hints which can be referred to if your system fails to operate.

7.1 Battery

The most common problem that can occur while trying to run the system is insufficient power, usually from a dead battery. When connected to the PDP sensor, you can check the amount of battery power remaining from the top right corner of the PDP collection software (Figure 7-1).

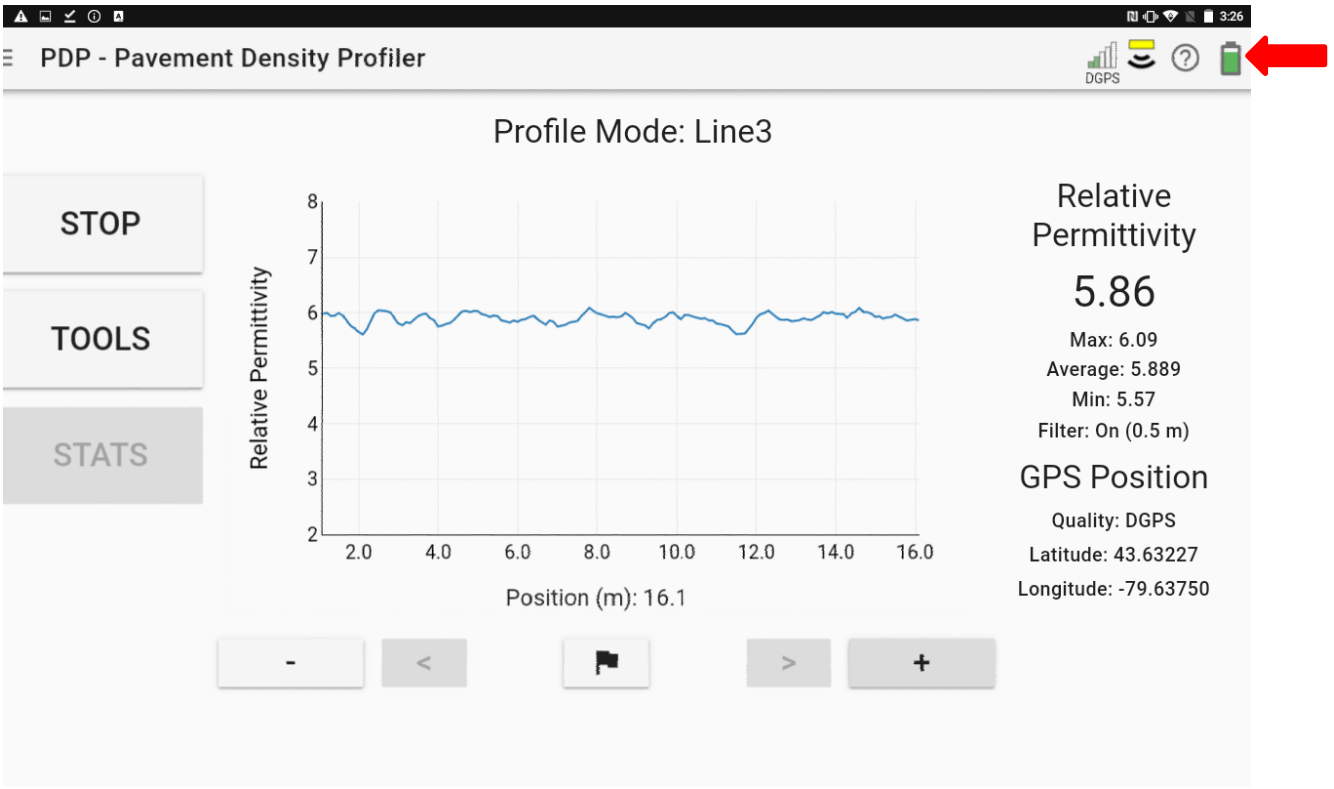


Figure 7-1: Checking remaining battery power

The PDP contains a 9 Amp-hour Li-Ion battery, which will run the PDP continuously for 4-6 hours, before recharging is necessary.

7.2 Cable Care

With the use of this product in rough, dusty and outdoor environments, users can minimize potential downtime if they care for cables and treat connectors with respect.

1) The cable connectors need to stay clean and free of dust and moisture. Use a brush or air spray to clean dust, lint and other foreign particles from these connectors.

2) After working in rainy conditions, disconnect the cables and check for water in the receptacles. Remove the water or allow to air dry, if necessary. Never allow the system to sit in rainy conditions for long periods of time.

Cables are not covered by the warranty. Improper use and/or neglect will result in downtime until they are repaired or replaced.

7.3 Connectivity Issues

The tablet is configured to wirelessly connect to the PDP sensor at the factory. Occasionally, it is possible that it might lose this connection. If it fails to connect, see Section 3.1 for re-establishing Wi-Fi connectivity.

You can also press the refresh button located in the top left of the window, as shown in Figure 7-2.

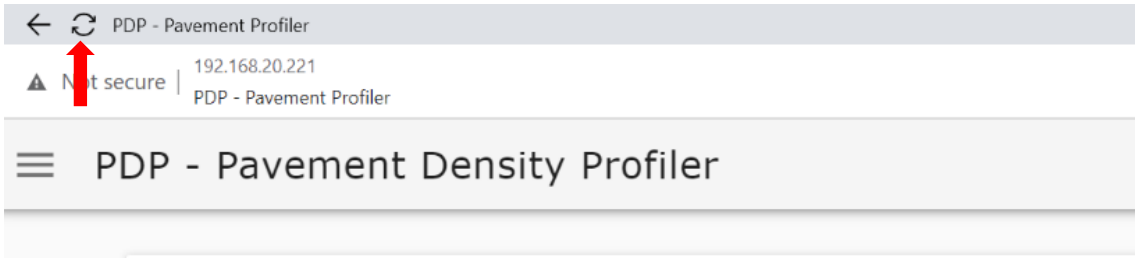


Figure 7-2: Refresh button shown

8. Parts & Components

The following is a list of components and their associated part number from the image above:

Number in image above	Part Number	Description
1	100-53-0119	PDP Cart Assembly
2	100-53-0120	PDP Tablet Tray Assembly
3	100-53-0121	PDP Validation Target
4	100-52-0138	Topcon GPS Cable for PDP Cart System
5	100-53-0100	LMX200 Cart GPS Mount Assembly
6	125-30-0006	Topcon GPS Antenna
7	100-22-0100	Pavement Density Profile (PDP) Electronics (also referred to as the PDP Sensor)
8	126-90-0090	PDP Hold Down Strap
9	100-22-0101	Winmate 10” Tablet PC
10	122-10-0093	Safety Locking Pin
	100-55-0024	PDP AC Power Adapter (not shown above)

9. Technical Specifications

Hardware

Weight and dimensions	Dimension (L x W x H): 145 x 84 x 118 cm (57 x 33 x 46 in)
	Weight (including Tablet, Sensor and Cart): 14.2 kg (31.3 lbs)
Display (Rugged Tablet PC)	Screen size: 10.1-inch display with LED Backlight
	Dimension (L x W x H): 27.2 x 19.7 x 1.9 cm (10.7 x 7.76 x 0.7 in)
	Weight: 1.2 kg (2.64 lbs)
Footprint size (Fresnel Zone)	30 cm (11.8 in)
Environmental & Temperature	Ruggedized environmentally sealed unit and connections
	IP65
	Operating Temperature: -10 – 50°C (-14 – 122°F)
Sensor Power Supply	Li-Ion 8850 mAh Battery Pack offering 4 to 6 hours of operation on a single charge

Software

Derived Measurements	User Selectable – Permittivity, Density, Density – Site Specific, Relative Density & Air Void Content.
Modes of Operation	Stationary & Profile
Data Export	Summary Report (.PDF) PDP Value Spreadsheet (.CSV) PDP Data (.PDP)
Data Collection Interval	Standard 10 cm in Profile Mode User selected interval (0.1s to 5s) in free-run mode

Measurement Specifications

Reference HDPE relative permittivity accuracy (K = 2.30)	±0.04
Single location relative permittivity repeatability	±1.5%

PDP is factory calibrated and can be quickly validated in the field with the provided validation procedures.
Ground Penetrating Radar is part of AASHTO Designation PP 98-xx, where xx is the revision number

Appendix A: **Health & Safety Certification**

Radio frequency electromagnetic fields may pose a health hazard when the fields are intense. Normal fields have been studied extensively over the past 30 years with no conclusive epidemiology relating electromagnetic fields to health problems. Detailed discussions on the subject are contained in the references at the end of this Appendix.

The USA Federal Communication Commission (FCC) and Occupational Safety and Health Administration (OSHA) both specify acceptable levels for electromagnetic fields. Similar power levels are mandated by corresponding agencies in other countries. Maximum permissible exposures and time duration specified by the FCC and OSHA vary with excitation frequency. The lowest threshold plane wave equivalent power cited is 0.2 mW/cm^2 for the general population over the 30 to 300 MHz frequency band. All other applications and frequencies have higher tolerances as shown in graphically in Figure B-1.

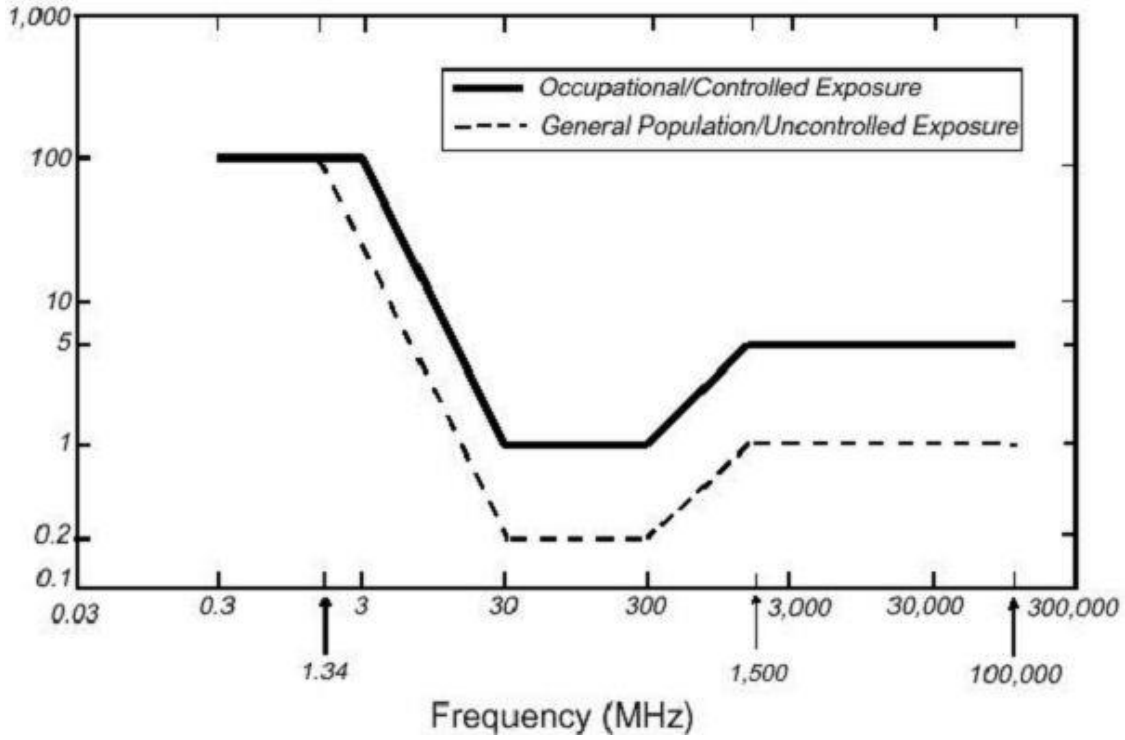


Figure B-9-1: FCC limits for maximum permissible exposure (MPE) plane-wave equivalent power density mW/cm^2.

All Sensors & Software Inc. GPR products are normally operated at least 1 m from the user and as such are classified as "mobile" devices according to the FCC. Typical power density levels at a distance of 1 m or greater from any Sensors & Software Inc. products are less than 10^{-3} mW/cm^2 which is 200 to 10,000 times lower than mandated limits. As such, Sensors & Software Inc. products pose no health and safety risk when operated in the normal manner of intended use.

References

1. Questions and answers about biological effects and potential hazards of radio-frequency electromagnetic field.

   USA Federal Communications Commission, Office of Engineering &

   Technology OET Bulletin 56
   (Contains many references and web sites)

2. Evaluation Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields.

   USA Federal Communications Commission, Office of Engineering &

   Technology OET Bulletin 56
   (Contains many references and web sites)

3. USA Occupational Safety and Health Administration regulations paragraph 1910.67 and 1910.263

Appendix B: **GPR Emissions, Interference and Regulations**

All governments have regulations on the level of electromagnetic emissions that an electronic apparatus can emit. The objective is to assure that one apparatus or device does not interfere with any other apparatus or device in such a way as to make the other apparatus non-functional.
The manufacturer tests their GPR products using independent professional testing houses and comply with latest regulations of the USA, Canada, European Community, and other major jurisdictions on the matter of emissions.
Electronic devices have not always been designed for proper immunity. If a GPR instrument is placed in close proximity to an electronic device, interference may occur. While there have been no substantiated reports of interference to date, if any unusual behavior is observed on nearby devices, test if the disturbance starts and stops when the GPR instrument is turned on and off. If interference is confirmed, stop using the GPR.
Where specific jurisdictions have specific GPR guidelines, these are described below.

B-1 FCC Regulations

This device complies with Part 15 of the USA Federal Communications Commission (FCC) Rules. Operation in the USA is subject to the following two conditions:
this device may not cause harmful interference and

this device must accept any interference received, including interference that may cause undesired operation.

Part 15 – User Information

This equipment has been tested and found to comply with the limits for a Class A digital device, where applicable, and for an ultra-wide bandwidth (UWB) device where applicable, 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. This equipment uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his/her own expense.

WARNING

Changes or Modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.
Certification of this equipment has been carried out using approved cables and peripheral devices. The use of non-approved or modified cables and peripheral devices constitutes a Change or Modification outlined in the warning above.

Operating Restrictions

Operation of this device is limited to purposes associated with law enforcement, firefighting, emergency rescue, scientific research, commercial mining, or

construction. Parties operating this equipment must be eligible for licensing under the provisions of Part 90 of this chapter.

FCC Interpretation of Operation Restrictions issued July 12, 2002
(FCC Order DA02-1658, paragraph 9)

The regulations contain restrictions on the parties that are eligible to operate imaging systems (See 47 C.F.R. 5.509(b), 15.511(b), and 15.513(b)). Under the new regulations, GPRs and wall imaging systems may be used only by law enforcement, fire and emergency rescue organizations, by scientific research institutes, by commercial mining companies, and by construction companies. Since the adoption of the *Order*, we have received several inquiries from the operators of GPRs and wall imaging systems noting that these devices often are not operated by the users listed in the regulations but are operated under contract by personnel specifically trained in the operation of these devices. We do not believe that the recent adoption of the UWB rules should disrupt the critical safety services that can be performed effectively only through the use of GPRs and wall imaging systems. We viewed these operating restrictions in the broadest of terms. For example, we believe that the limitation on the use of GPRs and wall imaging systems by construction companies encompasses the inspection of buildings, roadways, bridges and runways even if the inspection finds no damage to the structure and construction does not actually result from the inspection; the intended purpose of the operation of the UWB device is to determine if construction is required. We also believe that the GPRs and wall imaging systems may be operated for one of the purposes described in the regulations but need not be operated directly by one of the described parties. For example, a GPR may be operated by a private company investigating forensic evidence for a local police department.

FCC Permitted Mode of Usage

The GPR antenna must be kept on the surface to be in compliance with FCC regulations. Use of the antenna is not permitted if it is lifted off the surface. Use as a through-the-wall imaging device is prohibited.

GPR Use Coordination

FCC regulation 15.525(c) (updated in February 2007) requires users of GPR equipment to coordinate the use of their GPR equipment as described below:

TITLE 47--TELECOMMUNICATION
CHAPTER I--FEDERAL COMMUNICATIONS COMMISSION
PART 15_RADIO FREQUENCY DEVICES
Subpart F_Ultra-Wideband Operation Sec.
15.525 Coordination requirements.

(a) UWB imaging systems require coordination through the FCC before the equipment may be used. The operator shall comply with any constraints on equipment usage resulting from this coordination.

(b) The users of UWB imaging devices shall supply operational areas to the FCC Office of Engineering and Technology, which shall coordinate this information with the Federal Government through the National Telecommunications and Information Administration. The information provided by the UWB operator shall include the name, address and other pertinent contact information of the user, the desired geographical area(s) of operation, and the FCC ID number and other nomenclature

of the UWB device. If the imaging device is intended to be used for mobile applications, the geographical area(s) of operation may be the state(s) or county(ies) in which the equipment will be operated. The operator of an imaging system used for fixed operation shall supply a specific geographical location or the address at which the equipment will be operated. This material shall be submitted to:
Frequency Coordination Branch, OET
Federal Communications Commission
445 12th Street, SW, Washington, D.C.
20554
Attn: UWB Coordination
(**Sensors & Software Inc. Note**: The form given on the following page is a suggested format for performing the coordination.)

(c) The manufacturers, or their authorized sales agents, must inform purchasers and users of their systems of the requirement to undertake detailed coordination of operational areas with the FCC prior to the equipment being operated.

(d) Users of authorized, coordinated UWB systems may transfer them to other qualified users and to different locations upon coordination of change of ownership or location to the FCC and coordination with existing authorized operations.

(e) The FCC/NTIA coordination report shall identify those geographical areas within which the operation of an imaging system requires additional coordination or within which the operation of an imaging system is prohibited. If additional coordination is required for operation within specific geographical areas, a local coordination contact will be provided. Except for operation within these designated areas, once the information requested on the UWB imaging system is submitted to the FCC no additional coordination with the FCC is required provided the reported areas of operation do not change. If the area of operation changes, updated information shall be submitted to the FCC following the procedure in paragraph (b) of this section.

(f) The coordination of routine UWB operations shall not take longer than 15 business days from the receipt of the coordination request by NTIA. Special temporary operations may be handled with an expedited turn-around time when circumstances warrant. The operation of UWB systems in emergency situations involving the safety of life or property may occur without coordination provided a notification procedure, similar to that contained in Sec. 2.405(a) through (e) of this chapter, is followed by the UWB equipment user.[67 FR 34856, May 16, 2002, as amended at 68 FR 19751, Apr. 22, 2003]

Effective Date Note: At 68 FR 19751, Apr. 22, 2003, Sec. 15.525 was amended by revising [[Page 925]] paragraphs (b) and (e). This amendment contains information collection and recordkeeping requirements and will not become effective until approval has been given by the Office of Management and Budget.

The information to be submitted for coordination takes the form listed below. This is a general example; the correct FCC ID to be submitted for coordination on the regulatory label on your device. Please use the FCC ID from the product when submitting a coordination request.

FCC GROUND PENETRATING RADAR COORDINATION NOTICE
NAME:
ADDRESS:
CONTACT INFORMATION [CONTACT NAME AND PHONE NUMBER]:
AREA OF OPERATION [COUNTIES, STATES OR LARGER AREAS]:
FCC ID:
EQUIPMENT NOMENCLATURE:

Send the information to:
Frequency Coordination Branch., OET
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554
ATTN: UWB Coordination
Fax: 202-418-1944

INFORMATION PROVIDED IS DEEMED CONFIDENTIAL

B-2 ETSI Regulations for the EC (European Community)

In the European Community (EC), GPR instruments must conform to ETSI (European Technical Standards Institute) standard EN 302 066-1 v1.2.1. Details on individual country requirements for licensing are coordinated with this standard. For more information, contact Sensors & Software's technical staff.
All Sensors & Software ground penetrating radar (GPR) products offered for sale in European Community countries or countries adhering to ETSI standards are tested to comply with EN 302 066 v1.2.1.
For those who wish to get more detailed information, they should acquire copies of the following documents available from ETSI.
ETSI EN 302 066-1 V1.2.1 (February 2008) Electromagnetic compatibility and Radio spectrum Matters (ERM); Ground and Wall- Probing Radar applications (GPR/WPR) imaging systems; Part 1: Technical characteristics and test methods
ETSI EN 302 066-2 V1.2.1 (February 2008) Electromagnetic compatibility and Radio spectrum Matters (ERM); Ground and Wall- Probing Radar applications (GPR/WPR) imaging systems; Part 2: Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive
ETSI TR 101 994-2 V1.1.2 (March 2008) Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 2: Ground- and Wall- Probing Radar applications; System Reference Document

B-3a Industry Canada Regulations - English

Industry Canada published it regulations for ground penetrating radar (GPR) on Mar 29, 2009 as part of the RSS-220 titled 'Devices Using Ultra-Wideband (UWB) Technology'.
Industry Canada has made a unique exception for GPR by not requiring user licensing. The user does have to comply with the following directives:
This Ground Penetrating Radar Device shall be operated only when in contact with or within 1 m of the ground.
This Ground Penetrating Radar Device shall be operated only by law enforcement agencies, scientific research institutes, commercial mining companies, construction companies, and emergency rescue or firefighting organizations.
Should the ground penetrating radar be used in a wall-penetrating mode then the following restriction should be noted by the user:
This In-wall Radar Imaging Device shall be operated where the device is directed at the wall and in contact with or within 20 cm of the wall surface.
This In-wall Radar Imaging Device shall be operated only by law enforcement agencies, scientific research institutes, commercial mining companies, construction companies, and emergency rescue or firefighting organizations.
Since operation of GPR is on a license-exempt basis, the user must accept the following:
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.

B-3b Règlement d'Industrie Canada - Français

Industrie Canada a publié des règlements pour les appareils géoradar (GPR) le 29 mars 2009, dans le cadre du RSS-220 intitulé "Dispositifs utilisant la bande ultra-large (UWB)".
Industrie Canada a faite une exception unique pour GPR en n'exigeant pas de licence par utilisateur. L'utilisateur doit se conformer aux directives suivantes:
Ce géoradar périphérique doit être utilisé que lorsqu'il est en contact avec ou moins de 1 m du sol.
Ce géoradar périphérique doit être utilisé que par les organisations d'application de la loi, les instituts de recherche scientifique, des sociétés minières commerciales, entreprises de construction et de secours d'urgence ou des organisations de lutte contre les incendies.
Si le géoradar est utilisé dans un mode de pénétration au mur, la restriction suivante est à noter par l'utilisateur:
Ce dispositif d'imagerie radar doit être utilisé lorsque l'appareil est orienté vers le mur et en contact avec ou dans les 20 cm de la surface du mur.
Ce dispositif d'imagerie radar doit être utilisé que par les organisations d'application de la loi, les instituts de recherche scientifique, des sociétés minières commerciales, entreprises de construction et de secours d'urgence ou des organisations de lutte contre les incendies.
Parce que l'exploitation de GPR est sur une base exempte de licence, l'utilisateur doit accepter le texte suivant:
La fonctionnement est soumis aux deux conditions suivantes: (1) cet appareil ne peut pas provoquer d'interférences et (2) cet appareil doit accepter toute interférence, y compris les interférences qui peuvent causer un mauvais fonctionnement du dispositive

Appendix C: **Instrument Interference**

Immunity regulations place the onus on instrument/apparatus/device manufacturers to assure that extraneous interference will not unduly cause an instrument/apparatus/device to stop functioning or to function in a faulty manner. Based on independent testing house measurements, Sensors & Software Inc. systems comply with such regulations in Canada, USA, European Community and most other jurisdictions. GPR devices can sense electromagnetic fields. External sources of electromagnetic fields such as TV stations, radio stations and cell phones, can cause signals detectable by a GPR which may degrade the quality of the data that a GPR device records and displays.

Such interference is unavoidable but sensible survey practice and operation by an experienced GPR practitioner can minimize such problems. In some geographic areas emissions from external sources may be so large as to preclude useful measurements. Such conditions are readily recognized and accepted by the professional geophysical community as a fundamental limitation of geophysical survey practice. Such interference being present in the GPR recordings is not considered as an equipment fault or as a failure to comply with immunity regulations.

Appendix D: **Safety around Explosive Devices**

Concerns are expressed from time to time on the hazard of GPR products being used near blasting caps and unexploded ordnance (UXO). Experience with blasting caps indicates that the power of Sensors & Software Inc.'s GPR products is not sufficient to trigger blasting caps. Based on a conservative independent testing house analysis, we recommend keeping the GPR transmitters at least 5 feet (2m) from blasting cap leads as a precaution. Some customers do experimental trials with their particular blasting devices to confirm with safety. We strongly recommend that GPR users routinely working with explosive devices develop a systematic safety methodology in their work areas.

The UXO issue is more complex and standards on fuses do not exist for obvious reasons. To date, no problems have been reported with any geophysical instrument used for UXO. Since proximity and vibration are also critical for UXO, the best advice is to be cautious and understand the risks.

Appendix E: **Wi-Fi Module**

FCC Notice:
NOTE: This equipment has been tested and
found to comply with the limits for a Class A 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. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to
radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to
correct the interference at his/her own expense.

Industry Canada Notice:
This device complies with Industry Canada's license-exempt RSSs. 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.

Appendix F: **Calibration**

This Ground Penetrating Radar (GPR) system has been manufactured according to Sensors & Software's strict quality standards. All components used in the manufacture of this product are obtained from qualified vendors.

This product has been through a stringent set of tests to ensure all quality requirements are met which includes final system calibration and configuration.

This system is equipped with built-in diagnostic tests. By running the tests and getting a passing result, you can be confident that the system is operating within specification. No further user calibration is required.

Appendix G: **Converting Permittivity to Density**

The relationship between permittivity and density is a function of many variables, namely, the properties of the binder and the properties of the aggregate. As a result, the permittivity to density conversion must address these factors.

Site specific conversion of permittivity, K, to density ρ can expressed in many ways. The various forms are density, site-specific density, normalized density, and air-void content, the latter being expressed as a fractional volume (or ratio) of the total volume.

We have determined that the simplest way to express the relationship is a quadratic equation. Any of the above listed density forms, X, can be expressed in the basic form:

$$X = A + B * K + C * K^2$$

At many sites, the most common parameter *X* is density, ρ; as a result we have chosen always to use the **A**,**B** and **C** values that represent density (other form coefficients can be readily determined from these values).

The common practice is to use the PDP to measure the permittivity K at a number of locations and obtain the density from cores or indirectly from nuclear density gauge measurements. The end result is a set of tabulated data such as below.

Permittivity K	Density, ρ
K1	$\rho 1$
K2	$\rho 2$
K3	$\rho 3$
K4	$\rho 4$
K5	$\rho 6$
K6	$\rho 6$

The observed data are used to do a regression analysis to obtain A, B, and C. A, B, C have the same units (g/cm^3, Mg/m^3, lb/ft^3) as the density measurement; K is a dimensionless parameter.

The PDP Toolkit PC software provides a ready means to compute A, B, and C. The site- specific values of A, B, and C can be used to recompute density for data already collected and can also be entered into the PDP system to convert observations into site-specific density while collecting data in real-time.

Note that an additional important parameter that needs to be obtained for site-specific density analysis is the **maximum density** for the asphalt mix. The maximum density must be known to convert density into normalized density,

compaction and air-void ratio. To measure the maximum density, the material has to be formed or compressed to a state with no air. This is normally done at a materials testing lab.

Appendix H: **Glossary**

Below is an explanation of terminology used in PDP. For a full glossary of GPR-specific terms, please visit: https://www.sensoft.ca/glossary-of-gpr-terms/

Air Void Content – expressed as a percentage of how much of the volume in the asphalt is air.

AASHTO – short for American Association of State Highway and Transportation Officials. This group sets technical standards for design and construction of roads, bridges and associated materials.

Compaction – refers to the process of running a steamroller over newly poured asphalt to remove air and ensure uniformity and smoothness of the asphalt road. Compaction is also a measured quantity and is often used in place of normalized density. Both mean the same thing.

Density – refers to the absolute density of the asphalt, expressed in units of g/cm^3.

Density Offset – this value is used when calculating Density by applying a shift in the data. A user would input a density offset value to bring the PDP surveyed measurements in line with that from a core sample or possibly calibrated nuclear gauge measurement.

Density – Site Specific –measurements of the asphalt properties at a site are used to create a unique site-specific means of calculating density. While more complex than just density, this can be a more accurate representation of the true density of the asphalt.

Filter Length – the filter applies a horizontal smoothing filter to the data to reduce noise "jumps" in dielectric permittivity that are observed. The filter trace length options are an indication of how aggressive the filter is; the larger the number of traces, the more smoothed the data will be as erratic "jumps" will be filtered out.

Free Run - data is acquired based on a time interval. A data sample (or trace) is collected every x seconds, which can be specified.

GPR – short for Ground Penetrating Radar, this is a geophysical method of using low-power radio waves to explore the subsurface. PDP is based on GPR technology.

Histogram – a graphical display showing the shape and spread of values for continuously measured data

Normalized density – sometimes called relative density or compaction, expresses the density measured as a percentage of the site-specific maximum density

Maximum Density – the maximum given density possible for a given sample of asphalt, assuming there are no air voids (in other words 100% compacted)

Non-Destructive Testing (NDT) – using non-invasive technologies to examine a specimen. The specimen is not altered or affected in any way by the testing

Profile collection mode – a mode of operation where PDP is moved along the surface and data is collected. Data is displayed as some parameter (density, permittivity) vs. permittivity

Relative Density – sometimes called normalized density or compaction, this parameter expresses the density measured as a percentage of the site-specific maximum density.

Relative Permittivity (K) – also known as the relative dielectric permittivity, this is the initial value calculated by PDP. Relative permittivity is expressed as a unit-less quantity relative to the permittivity of free space.

Stationary collection mode – a mode of operation whereby the PDP is kept stationary, and data is collected and averaged over a time interval

Validation Test – on onboard test that ensures the PDP is operating properly

Validation Target – a cylindrical object that is used as part of the validation test

B-4 Emissions Reduction in Operation

All regulations make reference to a requirement that the GPR device automatically cease emitting signals within 10s of a operator terminating measurments. Sensors & Software products are all operated under computer control. If no data are requested by the operator, UWB emmisions do not occur and sources are not active. All systems are designed to eliminate un-needed UWB emissions. Control lies solely with the operator.

GPR measurments require the measurement devise to move over the ground surface. Sensors & Software GPR units are deployed with a motion sensor, such as an odometer wheel, to trigger data acquisition. When the system is not in motion, the system ceases operation and there is no UWB emmissions when stationary.

All controls are established to address the'deadman' switch concepts using modern digital controlled operation.

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