



LMX200

User's Guide

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Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Comp:	Serial #	Comp:	Serial #
Vendor Name:	Date Received:		

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Important Safety Information

Use the Display Unit only as specified in these operating instructions or the protection provided by the unit may be impaired.

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.

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1. Overview

The manual references embedded software version V1R1. To see which software version is installed on your system, see the Swipe Down menu in Section 3.4.

The LMX200 is a complete Ground Penetrating Radar system, offering two modes for acquiring data: Line Scan and Grid Scan. Once the unit is assembled and powered-up, you can start conducting a GPR survey in less than a minute.

Features of the LMX200 include:

- High visibility, touch screen display
- Display depth slices from collected grids, right in the field
- UWB Antenna producing highest data quality
- Dynamic Target Enhancement (DynaT), allows user to selectively view small, medium or large subsurface targets
- Lightweight fibreglass cart frame
- Built-in WiFi capability
- Integrated GPS receiver with optional external GPS for increased positional accuracy for geo-referencing data
- Ability to mark surface flags and subsurface interpretations
- Display your travelled path and targets in Map View
- Seamless export of data to EKKO_Project software for further data analysis



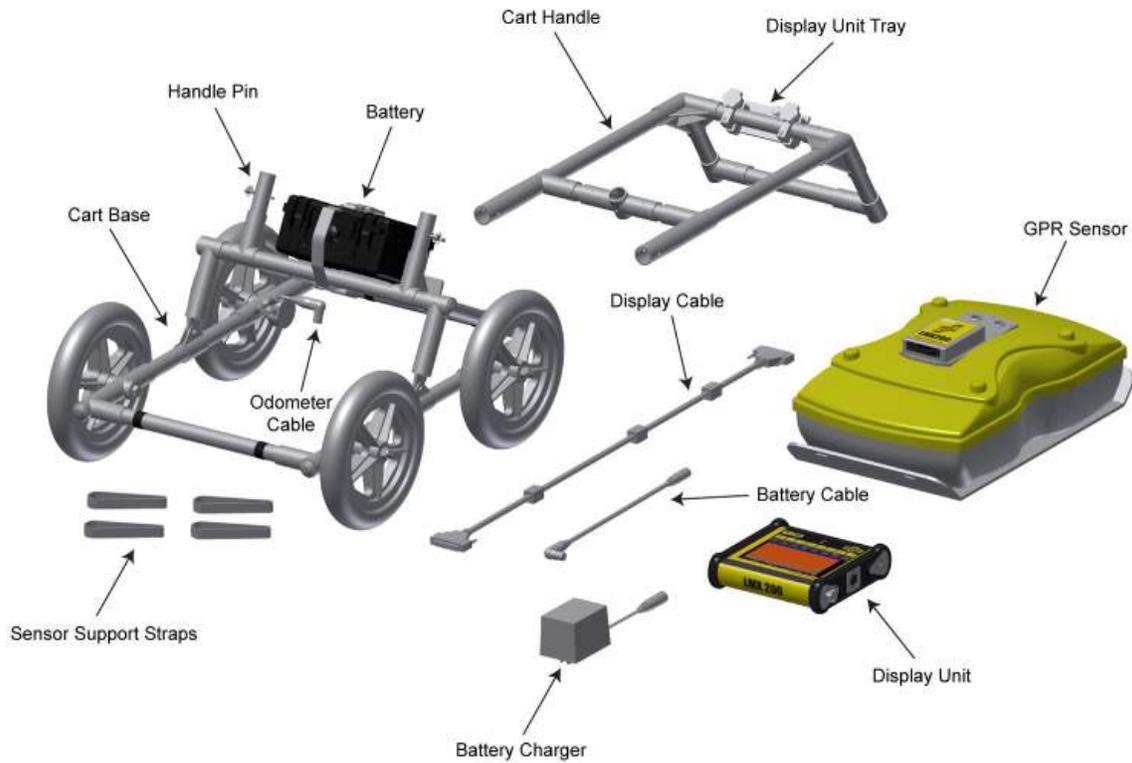
The LMX200 is also available in an Enhanced configuration. The chart below summarizes the differences between the two configurations:

Criteria	<u>LMX200</u>	<u>LMX200 Enhanced</u>
How is data saved?	Screenshots (.JPG)	Screenshots (.JPG) and .GPZ files
How much data can be saved?	<ul style="list-style-type: none"> • 10 grids • 99 lines • 999 screenshots 	9 Projects each with: <ul style="list-style-type: none"> • 10 grids • 99 lines • 999 screenshots
File organization	Lines and Grids	Projects containing Lines, Grids & Screenshots
Map View	Displays a single line or grid	Shows all lines/grids in a Project
PC-based data display	Any .JPG viewing software	Data can be opened in EKKO_Project

2. Assembly

2.1. Out of the box

You will find the following components in your LMX200 box. Some of these may already be assembled.



Attach the Cart Handle to Cart Base using the Handle Pins. Ensure the Display Unit Tray is facing the operator.



Attach the GPR Sensor to the Cart using the Sensor Support Straps. Ensure the Sensor is oriented the correct way with the connections toward the back of the Cart. Using the Sensor Support Straps, adjust the height of the Sensor so it is 1-2 cm ($\frac{1}{2}$ – $\frac{3}{4}$ inch) above the ground. The best way to get a uniform Sensor height is to place a couple of sheets of thick cardboard, particle board or Styrofoam under the sensor before securing the Sensor Support Straps.



Attach the Display Unit onto the Display Unit Tray on the Cart. The Display unit slides down into the tray, catching on both sides of the mount and is held in place with the pull pin. When a click is heard, the Display Unit is firmly in place. Adjust the angle of the Display Unit by loosening the hand-screws underneath the Display Unit Tray, rotating the Display Unit to the desired angle and tightening the hand-screws. To remove the Display Unit, disconnect all cables, pull out the pull pin and lift the Display Unit up.



Attach the Display Cable to the back of the Display Unit with the jackscrews. Connect the other end of the cable to the Sensor. Ensure the cable is routed as shown below.



Attach the Odometer and Battery Cables. The Odometer Cable connects to the closest receptacle on the Sensor. Attach the Battery Cable to the Sensor and the Battery. The system is now setup and ready to use.



2.2. External GPS (optional)

The instructions for connecting the GPS, mount and cable are below:

GPS Mount – The GPS mount attaches to the crossbar frame above the battery, using a quick release pin. There is a pipe plug that needs to be removed first.

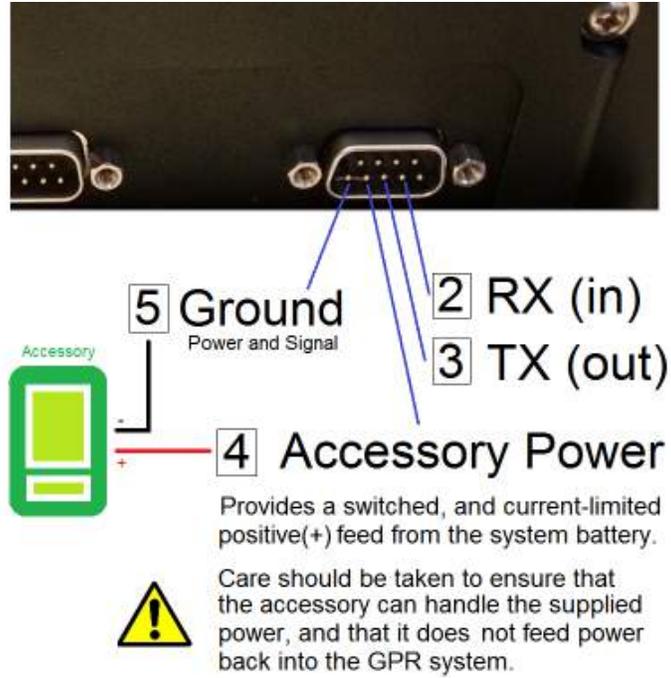


Once that is done, ensure the pole is pointed up, then insert the GPS mount into the opening where the plug was removed and secure with the quick release pin. This allows the GPS to sit directly over the middle of the GPR sensor. It comes with 5/8-11 UNC-1A threads at the top of the pole, which is standard for many GPS receivers.



GPS – If you have purchased the Topcon GPS from Sensors & Software, this can be screwed onto the threads at the top of the GPS mount. Connect one end of the GPS cable to the GPS receiver, and the other end to the serial port on the back of the display unit. This single cable powers the GPS and receives data from it. Ensure that the Display Unit is powered down when connecting or disconnecting the GPS cable.

NOTE: Since the serial port of the Display Unit outputs power (current=1A, voltage=12V), be very careful if connecting other GPS units to the serial port. Verify the pins on the drawing below.



2.3. Fully Assembled

The fully assembled LMX200 will look like the following. Simply reverse directions to disassemble for transport.



3. Getting Started

3.1. Powering up

When the battery is first plugged in, the LED goes green for 5 seconds then disappears.

To start the system, press the red power button on the display unit. The LED on the front panel will light up red.



Figure 3-1: Front of Display Unit

Once boot up is complete, the colour of the LED will indicate the amount of battery power remaining:

- 100% to 20% = green
- 20% to 10% = orange
- 10% to 0% = red

Once the system boots up, you will see the main screen (Figure 3-2). If you have purchased (or upgraded to) the LMX200 Enhanced system, you will see a slightly different main screen (Figure 3-3).



Figure 3-2: Main Screen for LMX200



Figure 3-3: Main Screen for LMX200 Enhanced

The differences between the two configurations are described in Section 1. Everything remains the same in the on-board software, except for the Enhanced system, the main screen will allow you to organize data into projects. Within each project, you can have a number of lines and/or grids.

From the main menu of the Enhanced system, select the project number to work in. Projects that contain data are in red color, whereas those with no data are in green. As you change projects, the main screen will also display the number of lines and grids collected in each project. These will appear under the Line Scan and Grid Scan buttons respectively.

3.2. Shutting down

To power down, press the red power button on the display unit once. A confirmation message will appear, after which you can press **Yes** to proceed. If necessary, a hard reboot can be done by pressing and holding the red power button until the unit shuts down.

3.3. Interacting with the Display Unit

Data collection is controlled by the Display Unit. The Display Unit has embedded software to set survey parameters and collect, display and store data.

The Display Unit offers touch screen operation, as well as a water-resistant membrane keypad with a number of buttons that can be pressed to perform various tasks. Most operations can be done using either the touch screen or the keypad.

Use the following table as a guide to working with the keypad on the Display Unit:

Item	Description
Menu Buttons 	The yellow buttons labelled 1 to 8 correspond to menu choices that appear on the screen.
4-way directional keypad 	Controls Up/Down/Left/Right operations in certain menus.
Camera 	Saves a screenshot of line data, grid data or the Map View display.
Asterisk / Special Function 	Used for adding Flags during data acquisition, and to quickly enter the No Save mode for Line Scan data collection.

3.4. Swipe Down menu



Figure 3-4: Swipe-Down menu

When the Display Unit is powered on (except during data acquisition), you can “swipe” your finger from the top of the screen towards the bottom, to bring up a drop-down menu (Figure 3-4) with the following items:

Date and Time: The current date and time (12 hour clock). The time needs to be changed in areas that observe daylight-savings-time.

Battery: The battery icon displays the amount of power remaining in the battery. If the battery power is getting low, the icon will change color to orange and red to match the LED color on the keypad.

GPS: Shows which GPS is being used (Internal or External) and the signal strength.

WiFi Network: Indicates if the system is connected to a wireless network and, if so, the name of the network. See 4.2.2 for details on connecting the system to a wireless network.

Volume: The Volume + and - buttons are used to increase and decrease speaker volume.

Brightness: The Brightness + and - buttons are used to increase and decrease the screen brightness. For example, increasing the Brightness setting may improve the visibility of the screen in bright sunlight. Note, however, that increasing the screen brightness also increases power consumption, thus reducing battery life.

To close the Swipe-Down menu, touch anywhere on the screen below the swipe-down menu.

4. Tools & Setup

From the main screen shown in Figure 3-2 or Figure 3-3, press **Tools** to enter this sub-menu. Here you can set preferences, adjust system settings, perform system tests and manage files. You will see the screen shown in Figure 4-1:



Figure 4-1: Tools menu

4.1. Preferences

Selecting the preferences option will take you to the sub-menu shown in Figure 4-2.

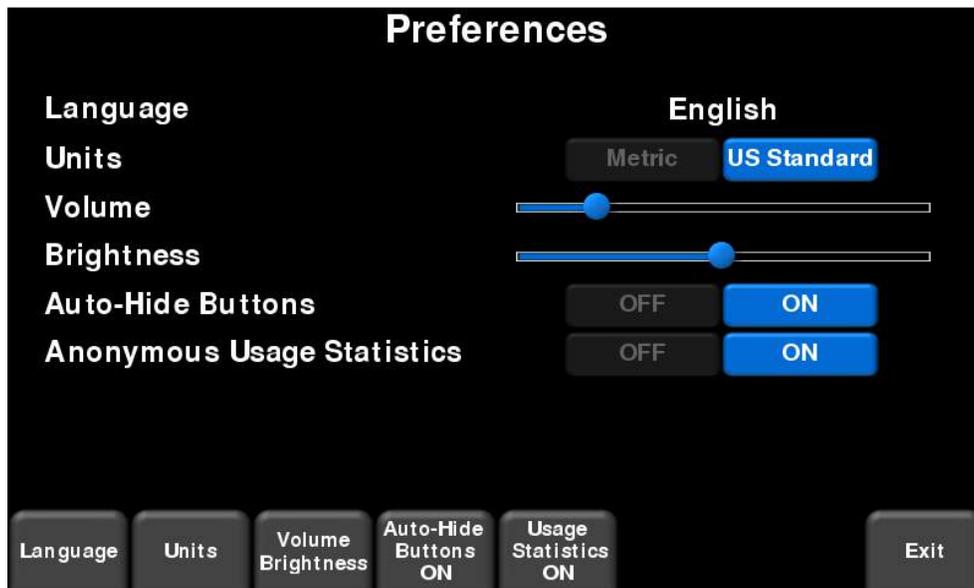


Figure 4-2: Setting Preferences

From here you can select the following:

4.1.1. Language

Pressing **Language** will cycle between available languages.

4.1.2. Units

Pressing **Units** will cycle between US Standard and Metric Units.

4.1.3. Volume

Scroll bar for adjusting the volume of clicks and beeps heard during operation. This can also be changed by using the Swipe Down menu (Section 3.4) anytime the system is not collecting data.

4.1.4. Brightness

Scroll bar for adjusting the brightness of the screen. Note that increasing the brightness consumes more battery power. This can also be changed by using the Swipe Down menu (Section 3.4) anytime the system is not collecting data.

4.1.5. Auto-Hide Buttons

If this is set to ON, then in Line Scan mode, the buttons at the bottom of the screen disappear shortly after data collection begins, effectively enlarging the area for data display. The buttons will re-appear after a couple of seconds whenever the sensor stops moving forward, is in back-up mode or any button is pressed on the keypad.

4.1.6. Anonymous Usage Statistics

This is set to OFF by default. When this is set to ON and the user is connected to a wireless network, any system malfunctions will trigger an automatic notification to Sensors & Software. This is to help with gathering information about any system irregularities. As the name suggests, the notification is completely anonymous and no personal information is sent.

4.2. Systems Settings

Press **System Settings** to enter the menu shown in Figure 4-3.

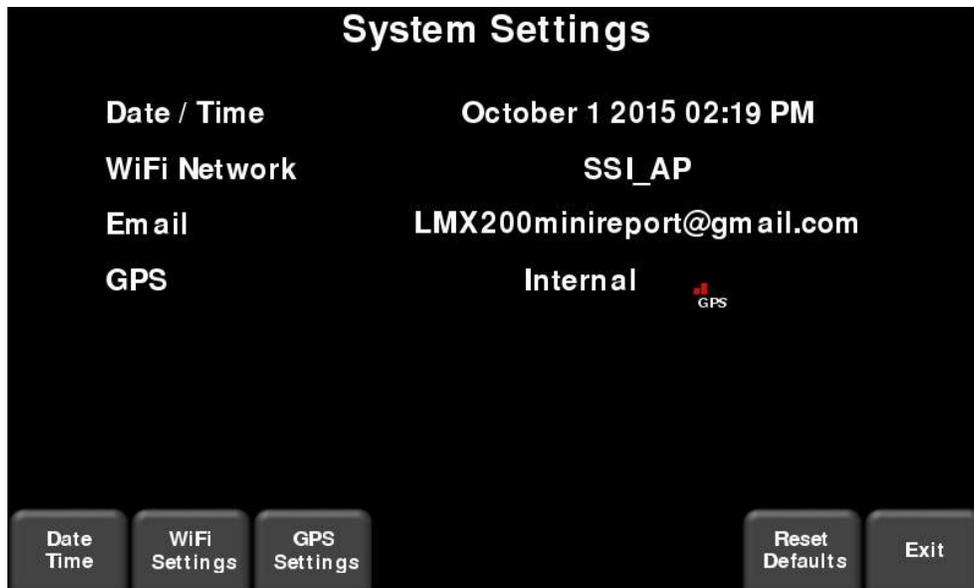


Figure 4-3: System Settings

From here, the following settings can be changed:

4.2.1. Date/Time

Set the date & time by pressing this button.

4.2.2. WiFi Settings

Connecting to a wireless network allows you to send a mini-report to someone by e-mail. In order to send reports to an e-mail address there are 2 main steps required.

First, the user must establish a Gmail account online. This account is used as the account that sends the message to the desired recipient. All mini-reports received by the recipient will look like they are coming from this account. This account will contain all the seny messages in its sent box.

The second step is to connect to a wireless network. This connection gives you access to the internet to connect to your Gmail account. This connection can be through a standard wireless network or through a hotspot on your cell phone for connecting while in the field.

If you are already connected to a WiFi network, the name of the network is listed beside the WiFi Network field. Pressing the **WiFi Settings** button at the bottom of the screen takes you to a sub-menu (Figure 4-4) for connecting and configuring WiFi settings, as well as setting up an e-mail address.

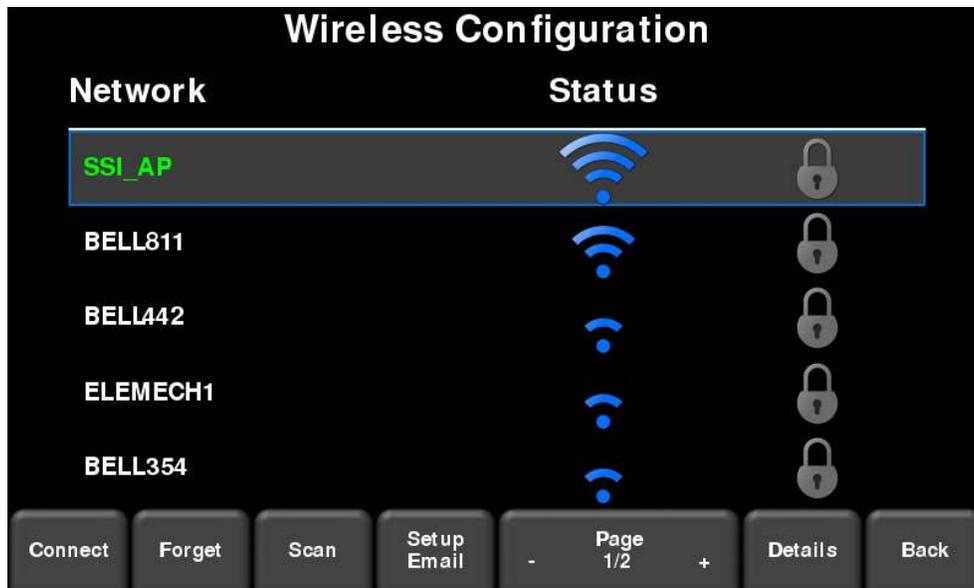


Figure 4-4: Configuring Wireless settings and E-mail address

The color of the Network Name indicates the status:

- Green = Connected
- Yellow = not currently connected, but remembered from before when you previously connected and entered a password.
- White = Not connected

Note that LMX200 CANNOT connect to Public Hotspots (typically restaurants, hotels and airports) that require a web-based login and acceptance of their Terms & Conditions. It also CANNOT connect to unsecured networks (networks that do not require a password).

- **Connect** – Select the desired network and press Connect. If the connection is successful (this can take a minute or so) a screen appears asking for the password for that network. If the network name is yellow (from a previous connection to this network), it will not ask for a password because it is a remembered network. Once it connects the Network Name will turn green.
- **Forget** – Use the Forget button to remove the password for connected or remembered networks (text in green or yellow). Use the 4-way directional arrows or touch screen to select the network. Once the 'forget' button is pressed on a selected network it will remove the password and the Network Name will turn white.
- **Scan** – Scans for any available networks in the area and displays them in order of strength of signal.
- **Details** – pressing this button displays the security settings related to the selected network.

- **Setup E-mail** – This option allows the user to save their Gmail account (email and password) to the LMX200, thereby enabling them to e-mail mini reports from the job site. Before selecting this option:
 1. You must be connected to WiFi – a wireless network listed must be green.
 2. The Gmail account needs to be set up prior to adding it into the system (go to <https://accounts.google.com/SignUp>).

After entering the email address, a message appears stating either that the email address has been saved, or that the setup has failed.

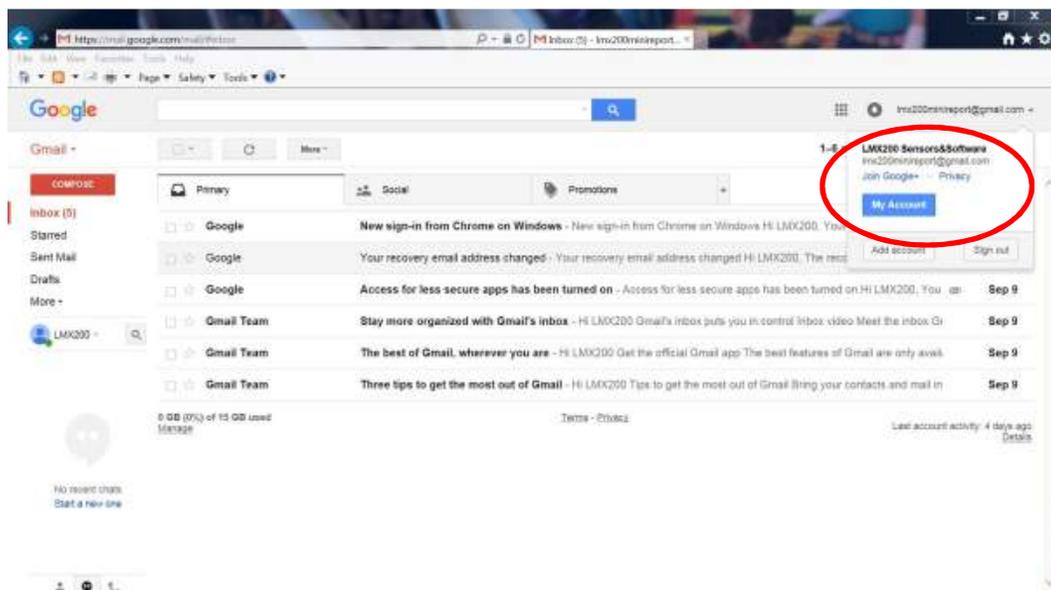
If the address has been saved, you are ready to send mini reports.

If setup failed, there are 3 possible reasons:

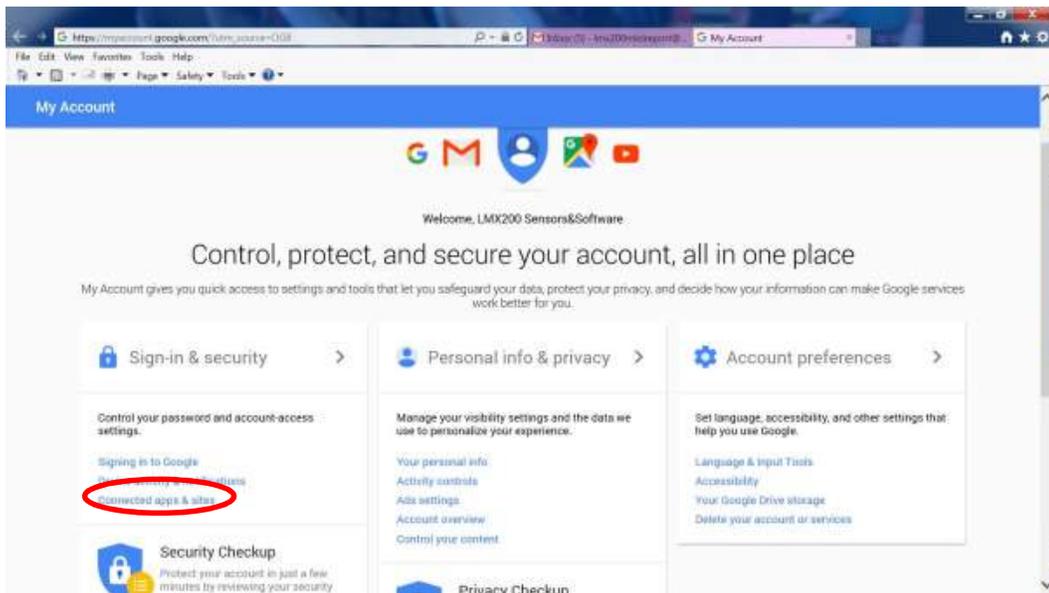
1. Email address or password was entered incorrectly – try re-entering these fields.
2. The Display Unit is not connected to the internet – try reconnecting to a known network. Note that any networks requiring a web-based login will not work on the Display Unit.
3. Your email security settings **may need** to be adjusted, as shown below.

Note: the following screen images from Gmail are current as of writing this manual. However, these may change over time as Gmail updates their menu layout.

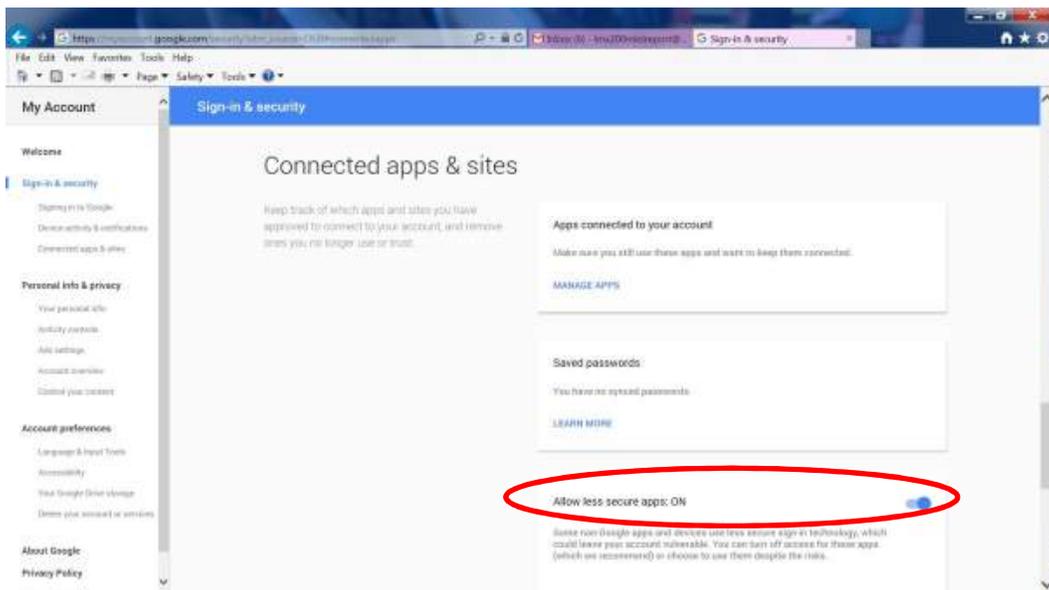
To edit the security settings, open your Gmail account in a web browser and click on your email address in the top right corner. In the drop down Window that follows, click on My Account.



You will then see the screen below. Click on **Connected apps & sites**



On the page that follows, ensure the setting “Allow less secure apps” is set to ON



4.2.3. GPS

Pressing **GPS** from the System Settings menu takes you to the GPS sub-menu (Figure 4-5). The options displayed in the sub-menu are listed below:



Figure 4-5: GPS Sub-menu

- **GPS Mode** –you can select whether to use the internal GPS, external GPS or no GPS at all (Off)
- **Units** – GPS units can be either UTM (Universal Transverse Mercator) or Latitude/Longitude coordinates
- **GPS Test** – see Section 4.4.6

4.2.4. Reset to Defaults

This will reset all settings & preferences back to the initial settings when the system was shipped. Pressing this will ask you to confirm the Reset to Defaults. If **Yes** is selected, the next screen will ask if you would like to remove all saved wireless networks and e-mails addresses.

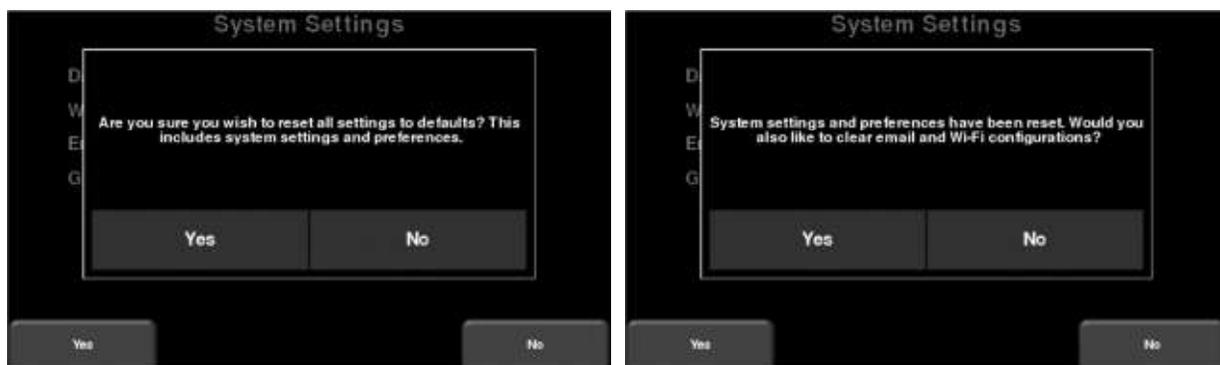


Figure 4-5: Reset to Defaults, a) Image on left is the first confirmation screen. b) If you press Yes, you will see the second confirmation screen on the right asking about deleting e-mails and WiFi settings.

4.3. File Management

Press **File Management** to enter this sub-menu. From here, the user can view screenshots, export data and delete all data. If you have the regular LMX200, you will see the image in Figure 4-6a. If you have the LMX200 Enhanced system, you will see the image in Figure 4-6b.



Figure 4-6: a) LMX200 system on left, displays the total number of lines, grids and screenshots saved on the system.
b) The LMX200 Enhanced system on the right displays the lines, grids and screenshots for a given project in the middle column. The right column displays the total for each that are saved on the system.

A description of each of the buttons is given below:

4.3.1. Screenshot Gallery

This allows the user to view all screenshots that were saved by pressing the Camera button (Section 10.1). The display will show a Tile View of four screenshots per page (Figure 4-7). If there are more than four screenshots, swipe the screen from right to left to view the rest. Alternatively, you can also use the **Left** and **Right** arrow keys on the 4-way directional keypad

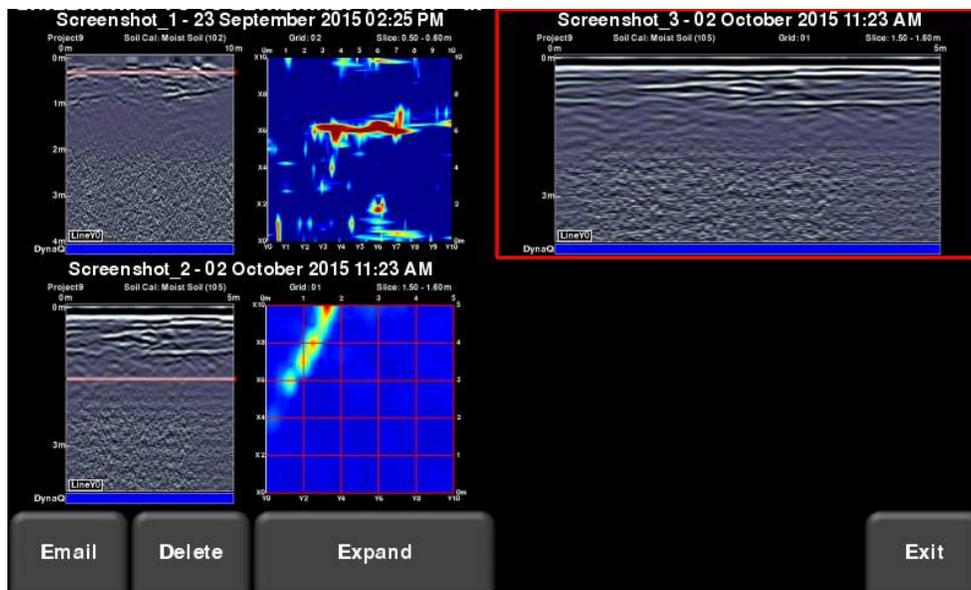


Figure 4-7: Tile View in Screenshot Gallery

From the Tile View, the user has the following options:

- **E-mail** – pressing this button will e-mail the selected screenshot (provided you are connected to a wireless network and have setup a Gmail account to send from, Section 4.2.2). You will be prompted to enter an e-mail address, or you may use the most recent one which will be listed by default.
- **Delete** – pressing this button will delete the displayed screenshot.
- **Expand** – press this button to show the selected screenshot as a full screen image. On the subsequent screen, press Tile View to return to the screen displaying four screenshots per page.

4.3.2. Delete All Saved Data

Pressing this will delete all data saved on the system. There is a confirmation window asking if you are sure; press Yes to continue deleting, press No to cancel.

4.3.3. Delete Project (Enhanced system)

Pressing this will delete the current project number. There is a confirmation window asking if you are sure; press Yes to continue deleting, press No to cancel.

4.3.4. Map View (Enhanced system)

Pressing this will display a map view for all the data (lines & grids) in a given Project (Figure 4-8). Map View is only enabled if a GPS was on during data collection. Map View shows the survey path travelled, as well as any flags or interpretations added to the data. Map View is fully explained in Section 9. While Map View is available in both configurations, the Map View button in File Management is only available in the Enhanced version.

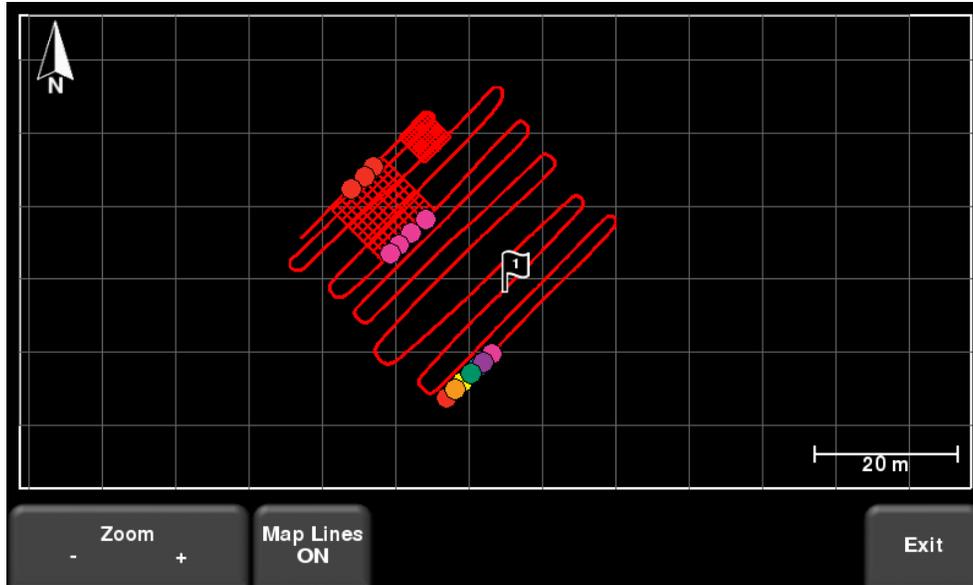


Figure 4-8: Map View showing two grids and a long line with interpretations. Map View is enabled because the data was collected with GPS.

4.3.5. Export Data

Screenshots and data are always saved to the internal memory of the Display Unit. If a USB-drive (memory stick) is inserted into the USB port on the Display Unit, pressing the **Export Data** button will copy all the data files to the USB-drive. If no USB-drive is inserted, this option will not be accessible.

4.4. System Test

The system test sub-menu (Figure 4-9) allows the user to perform certain tests to ensure proper operation of the system. Select the component to test then press **Start**. After completing a test there is an indication of whether the system passed or failed the test. Each test is described below in more detail.

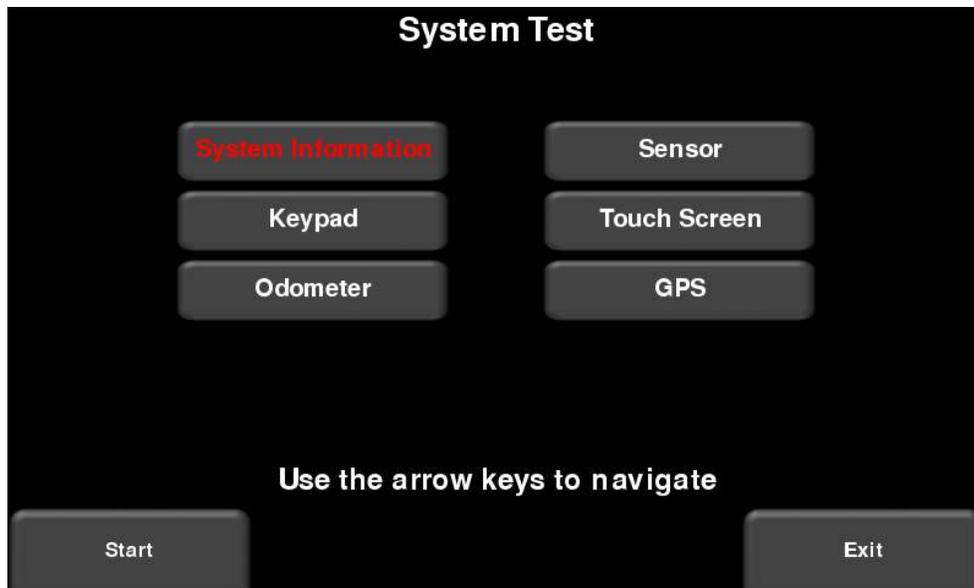


Figure 4-9: System Test menu

4.4.1. System Information

System Information is the only option in System Test which is not actually a test. Here information such as the version, serial numbers, temperature and battery power are displayed. (Figure 4-10).

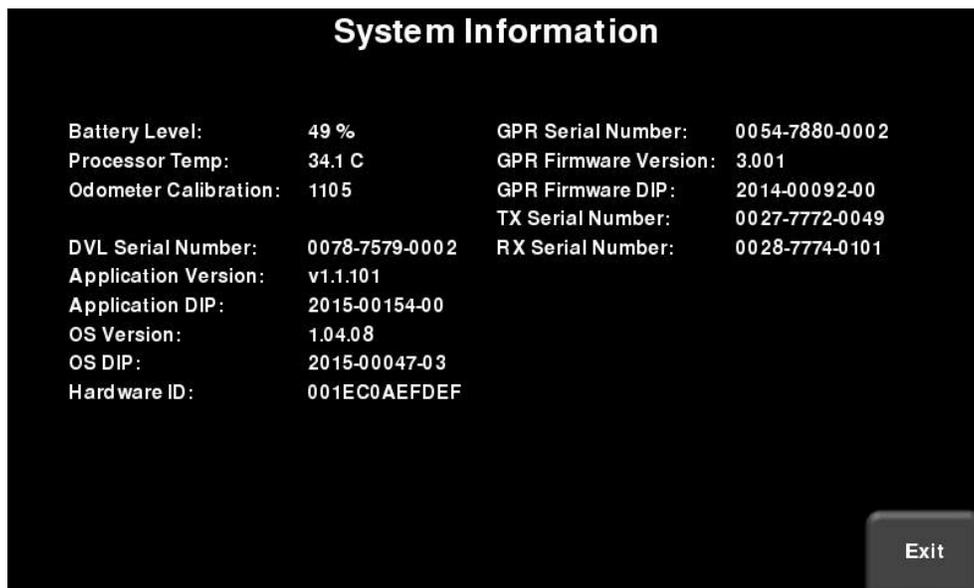


Figure 4-10: System Information

4.4.2. Keypad Test

The keypad test ensures that all buttons on the membrane keypad are working. Press **Start** to begin the test which requires the user to press each button once, within a 20 second timeframe (Figure 4-11).

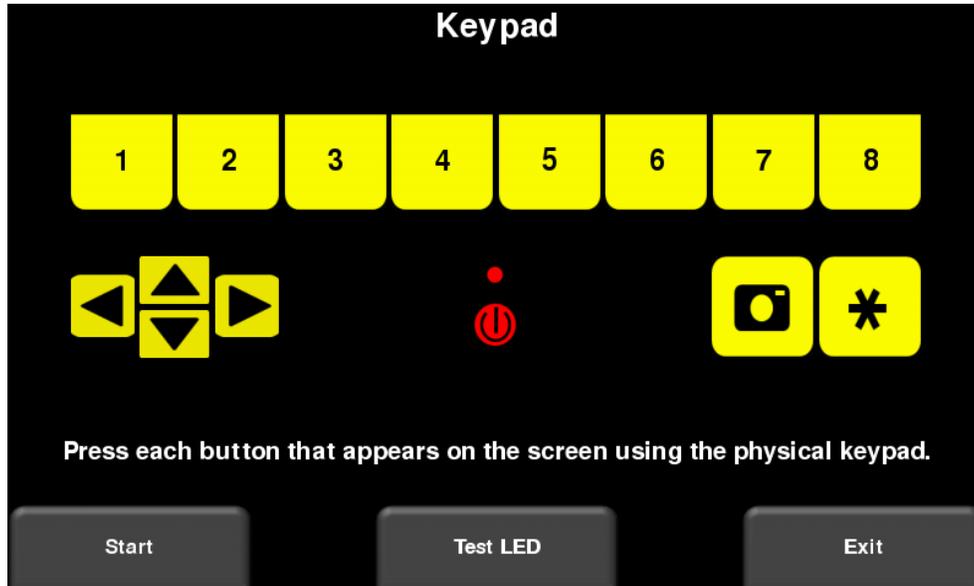


Figure 4-11: Keypad Test

The **Test LED** button will test just the LED, and ensure that the color of the light on the screen matches the color of the LED itself.

4.4.3. Odometer Calibration

This test ensures that the odometer is calibrated properly for distance. Even though the odometer is calibrated in the factory, you must calibrate it periodically to ensure accuracy.

Choose a set distance from the screen, press **Start** and then move the system that exact distance, using a measuring tape or other known distance indicator. Press **Finish** when you have travelled that distance (Figure 4-12).

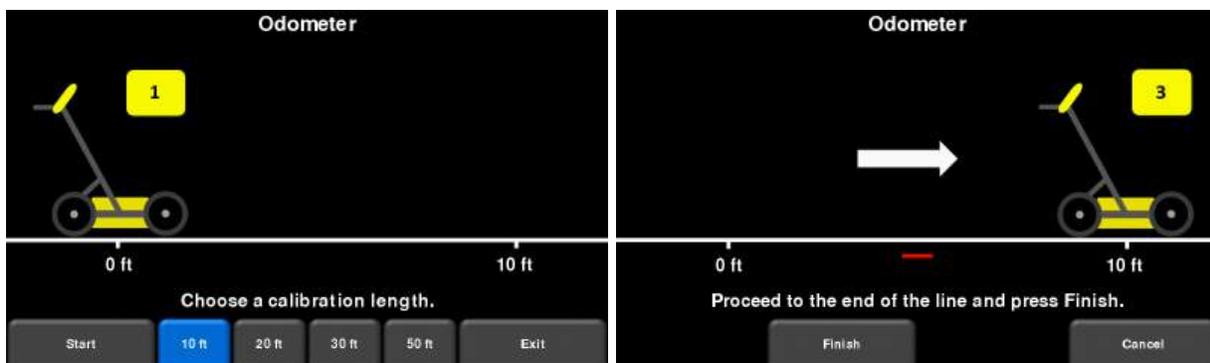


Figure 4-12: Odometer Test. Image on the left shows the screen where the user must select a distance. The image on the right instructs you to move that distance then press Finish.

Upon completion, it displays the screen in Figure 4-13. The new calibration value is shown to the right of the arrow in number 1. You can either accept the new value (by pressing '1' on the keypad) or revert back to the previous value (by pressing '8' on the keypad). If the new value is significantly out of range, the test will fail.

The odometer calibration value is stored in the Display Unit. If the Display Unit is changed, or swapped out, you will need to run the Odometer Calibration test again.

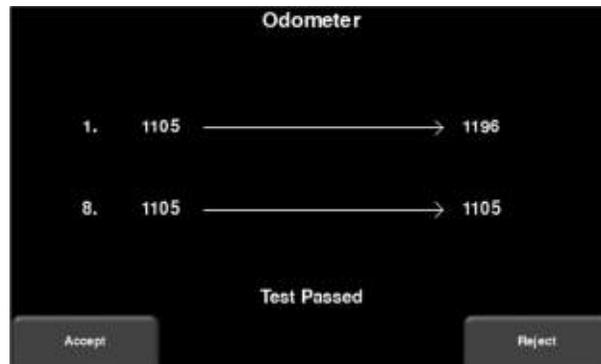


Figure 4-13: Results of Odometer Test

4.4.4. Sensor Test

This test checks proper operation of the GPR sensor, including the amplitude of the pulse. Once the cart is tipped backwards and start is pressed, it will conduct the test (Figure 4-14). If there are any irregularities, the test will indicate failure.

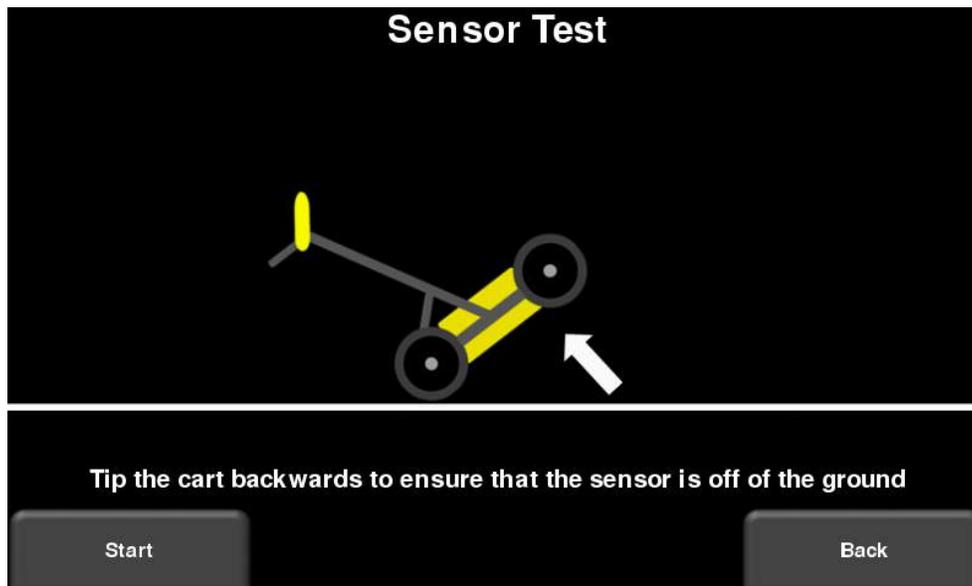


Figure 4-14: Sensor Test

4.4.5. Touch Screen

The test checks proper operation of the touch screen (Figure 4-15). It allows you to test the screen (by pressing **Test**) or perform a quick calibration followed by a test (by pressing **Calibrate**). Both involve touching targets on the screen in the allotted time.

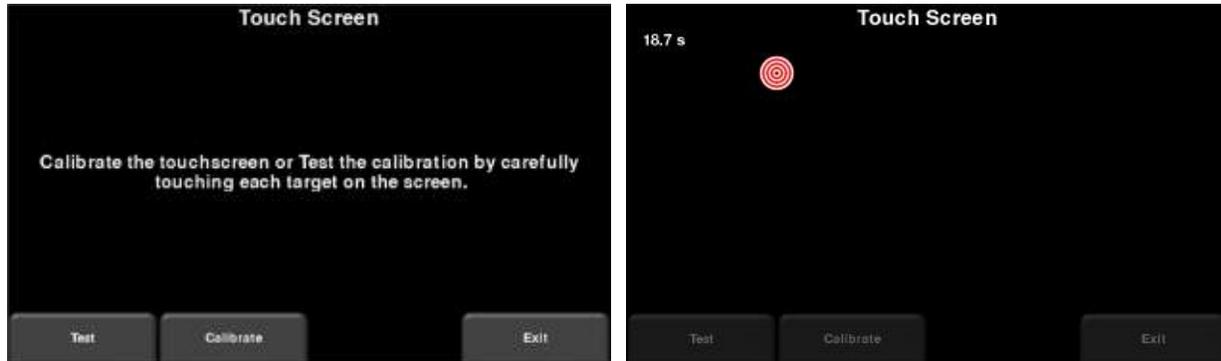


Figure 4-15: Touch Screen test on the left, Touch Screen calibration test on the right

4.4.6. GPS

The GPS test will ensure that the system is communicating properly with the GPS and receiving data. Whichever GPS mode is selected in the System Settings (4.2.3) will be the one used for the test. Pressing **GPS** will show the screen in Figure 4-16.



Figure 4-16: GPS Test

The basic position and time information is displayed on the screen. On the screen, the Fix Type notes if there are any corrections being applied, such as DGPS.

Pressing **Strings** will display the raw data strings that are outputted by the GPS (Figure 4-17) as they scroll down the screen. The user may select this option to verify the GPS is outputting the proper NMEA string format.



Figure 4-17: GPS Strings

Pressing **Clear** will clear the strings. Pressing **Info** will return to the main GPS test menu.

If you choose to connect a 3rd party GPS receiver, you must ensure the following parameters are set for the GPS to communicate with the Display Unit:

- Baud rate = 19,200
- Output string = NMEA
- NEMA string must include \$##GGA
- Parity = None
- Stop Bits = 1
- Data Bits = 8

5. GPR Concepts

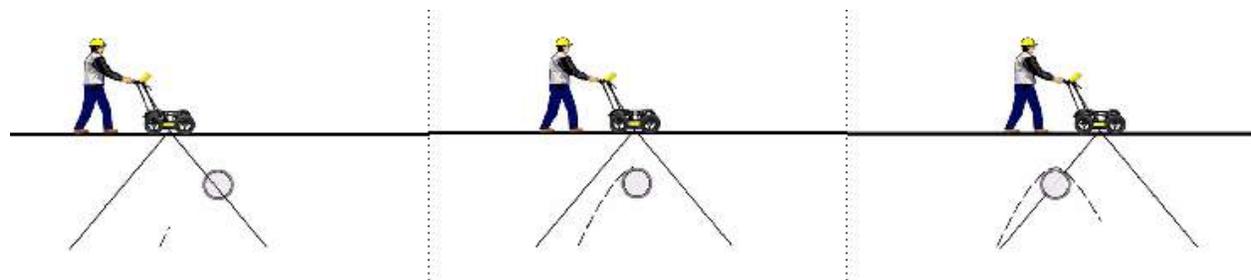
5.1. Theory

Ground penetrating radar (GPR) technology uses radio waves to image objects in the subsurface. The subsurface may consist of soil, rock, asphalt and other materials. GPR systems emit high frequency radio wave pulses and detect the echoes that return from objects within the subsurface. Echoes are produced when the target material is different from the host material (eg. PVC pipe in gravel)

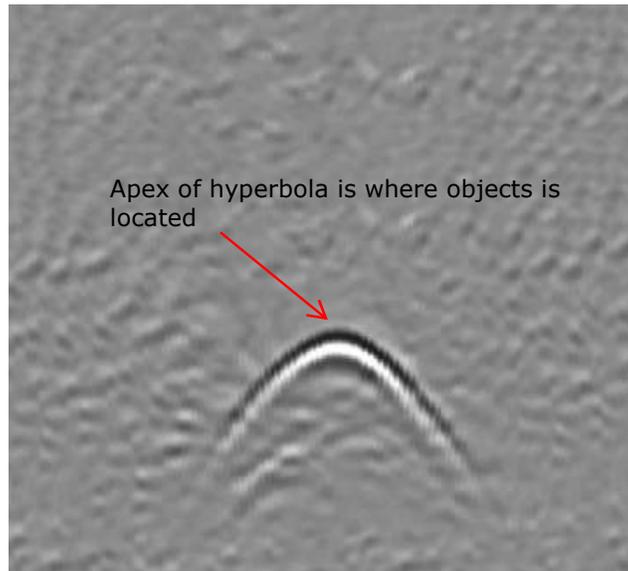


5.2. Hyperbolas

The GPR display shows signal amplitude versus depth (time) and sensor position along a line. This is called a “Line Scan”. Since radar energy radiates in a 3D cone shape rather than a thin beam, a **hyperbola** (or inverted U) is the GPR response from a small point target like a pipe, rock, or a tree root. The radar wave hits the object before and after going over it and forms a hyperbolic reflection that can appear on the record even though the object is not directly below the radar:



Hyperbolas are best viewed when subsurface targets are crossed perpendicularly or at a 90 degree angle. The actual position of the object is located at the apex of the hyperbola.



5.3. Calculating Depth

Ground penetrating radar records the time it takes a radio wave to travel to a target and back; it does not measure the depth to that target directly. Depth to target is calculated based on the velocity with which the wave travels to the target and back.

To calculate depth:

$$D = V \times T/2$$

Where D is Depth

V is Velocity

T is the Two – way travel time

For the LMX200, velocity is indicated by the Soil Calibration Value, known as Soil Cal. Once the Soil Cal values are set, the measured depths will be determined accurately (Section 6.6.6)

5.4. Soil Calibration values

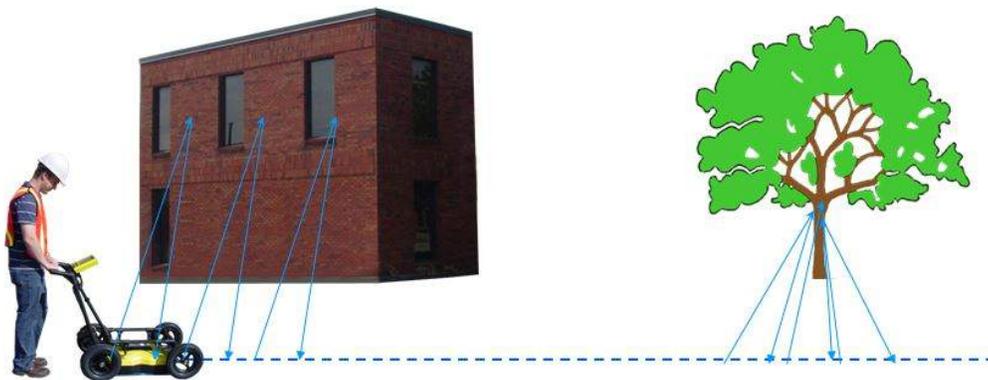
Below is a table of common subsurface materials and their corresponding Soil Cal. This is only a guideline and there is some variation based on the fact that there can be a mixture of different materials in the subsurface. By far, the soil water content has the biggest influence on Soil Cal values.

Material	Soil Cal
Air	300
Ice	160
Dry Soil	140
Dry Rock	120
Soil	100
Wet Rock	100
Concrete	100
Pavement	100
Wet Soil	65
Water	33

5.5. Air Waves

Some hyperbolas are caused by air wave reflections from objects above ground, such as posts, fences, overhead wires, and trees.

The following image displays how air wave reflections affect data:



An important part of understanding the data image is learning to recognize these unwanted "air" targets and distinguish them from the targets in the ground. Good field notes are indispensable for helping identify unwanted events on the data.

The best way to identify air reflections is the target hyperbola method. Hyperbolas from above ground objects are wider than objects in the ground and will have a Soil Cal at, or close to, 300.

To learn more, see Soil Cal (6.6.6).

6. Line Scan

Line Scan mode allows the operator to acquire data along a straight line and examine it as a cross-section image. The operator can locate a feature and easily back-up and mark the location of that object on the ground. Line Scan mode can be used to identify the alignment of subsurface features, check for linearity and acquire accurate depth measurements.

If you have the LMX200 Enhanced, ensure you are in the appropriate project before entering this mode.

From the main screen, press the **Line Scan** button; you will see the screen shown in Figure 6-1.



Figure 6-1: Line Scan mode

The GPS Status indicates the quality of the GPS signal, which is based on the number of satellites that it sees. The chart below explains what the colours and bars mean:

Indicator Color	# of bars	# of Satellites
Red	1	4, 5
Red	2	6, 7
Orange	3	8, 9
Green	4	10, 11
Green	5	12+

6.1. Selecting a line

To select the desired line, press the **+** and **-** buttons under **Line Number** on the bottom of the screen. Alternatively, you can also use the **+** and **-** buttons beside the word **Line** on the upper part of the screen.

New line numbers are shown in white, whereas lines that already contain data are shown in red.

If a line is shown in white (Figure 6-1), the following options are available:

6.1.1. Collecting a line - saving data

Press **Start** to enter data acquisition. All data collected will be saved under this line number.

6.1.2. Collecting a line – No Save Mode

Press **No Save Mode** to enter data acquisition or press the **Asterisk** key on the Display Unit. Any data collected will NOT be saved.

If a line is shown in red (Figure 6-2), the following options are available:

6.1.3. Delete line

Press **Delete** to delete this line.

6.1.4. View line

Press **View** to view the line. See Section 6.6 on Line Scan menu options.

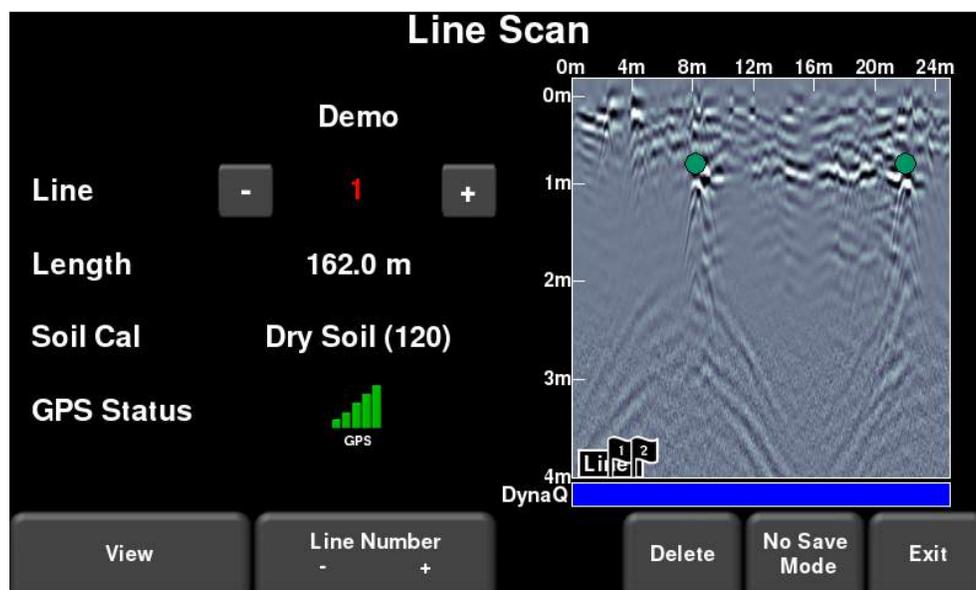


Figure 6-2: Line Scan mode, showing a line that was previously collected

6.2. Acquiring Data

Press the **Start** button to begin collecting data. The screen will change to the data acquisition screen. As the system is pushed along a straight line, the collected GPR data scrolls onto the screen from the right and moves to the left (Figure 6-3).

The depth scale along the side of the GPR Line image and the position scale along the top of the image are set to Metric or US Standard units based on the setting in the Preferences menu (4.1.2)

If Auto-Hide Buttons is set to ON (Section 4.1.5), the menu at the bottom of the screen disappears as soon as you start collecting new data, thereby maximizing the data display area. When the user stops, backs up or presses a button on the keypad the menu reappears.

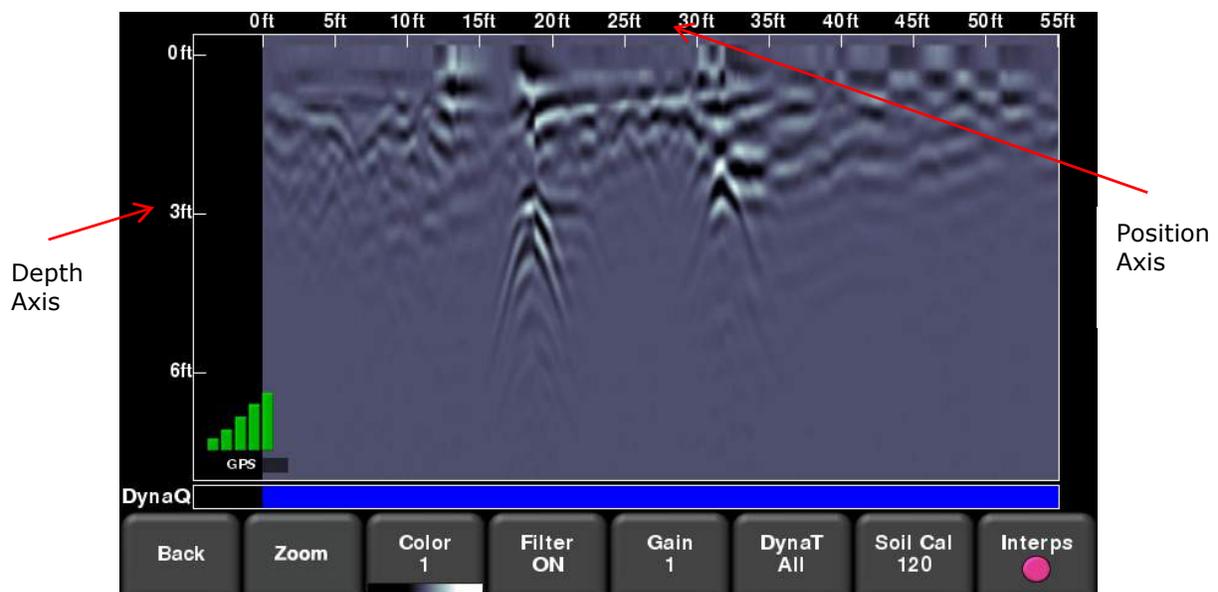


Figure 6-3: Line Scan acquisition mode, showing collected data and axis labels

6.3. DynaQ

The LMX200 uses DynaQ, an advanced patented technology that adjusts data quality as the system movement speed varies. In most situations, moving the system at a comfortable walking speed generates data of good quality. In situations where target resolution or maximum penetration depth is critical, moving slower increases data quality.

As the Line Scan data scrolls on the screen, the DynaQ Index Bar is displayed along the bottom of the screen (Figure 6-3). The color of the bar indicates the quality of the data at that point along the line:

White	= No Data (too fast!)
Yellow	= Moderate quality

Light blue = Better quality
 Dark Blue = Highest quality

In general, avoid collecting data at extremely high speeds.

6.4. Back-up Indicator

Line Scan mode incorporates a back-up feature to enable you to accurately locate targets and mark them on the ground. After acquiring some data on the screen, move the system backwards (Figure 6.4a). During back-up mode, there will be two indicators:

- **Position Indicator:** The red vertical line corresponds to the location at the center of the GPR sensor. As you pull the cart backwards, the Position Indicator moves to mark the current location of the cart in the image and a box appears with the current position, relative to the start of the line, listed as the top number.

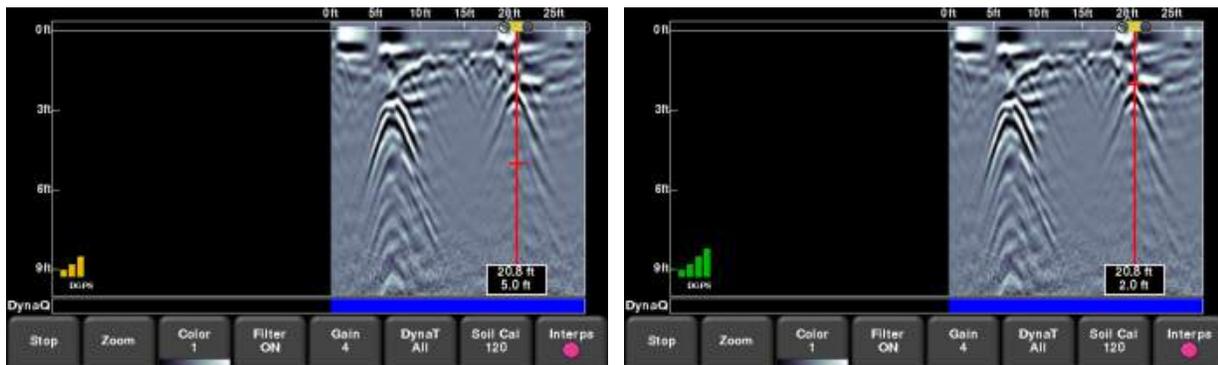


Figure 6-4: a) Back-up Indicator, b) Moving the Depth Indicator to the top of the hyperbola

- **Depth Indicator:** A short red horizontal line corresponds to the current depth value, as shown in the bottom number in the box. To determine the depth of an object, move the indicator up or down by dragging the horizontal line to the desired location (Figure 6-4b). Alternatively, you can also use the **Up** and **Down** arrows on the 4-way directional keypad. Note: make sure you have done a Soil Cal to ensure depth accuracy (Section 6.6.6).

To locate a feature, simply roll the system back along the same path until the red vertical line is exactly over the response (usually a hyperbola). You can mark the location of the object on the surface and continue data collection. Once you reach the point where you initially started backing-up, the system will continue acquiring new data.

You can also obtain depth and position information anywhere on the Line Scan by touching the screen and holding for a second. A cross-hair appears where you touched the screen, with a box displaying the position and depth (Figure 6-5). To get the position and depth information

about a different point on the screen, simply touch and drag the box or cross-hair to the desired position.

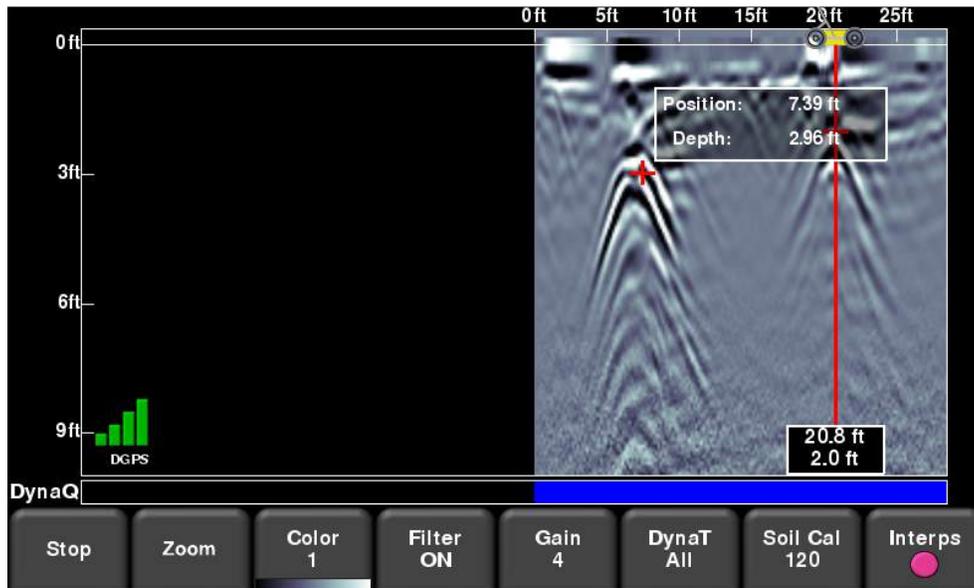


Figure 6-5: Touch screen to get depth and horizontal position at any point

Pressing Stop ends the line. This line is saved internally on the system and cannot be added to.

6.5. Flags

Flags are often inserted to mark noteworthy surface features, such as poles, sidewalks, changes in terrain etc. These markers may help you correlate subsurface targets with above ground features.

Pressing the **asterisk** button on the keypad will insert a flag at your current position, either during forward data acquisition or when backed-up. Flags are sequentially numbered (Figure 6-6).

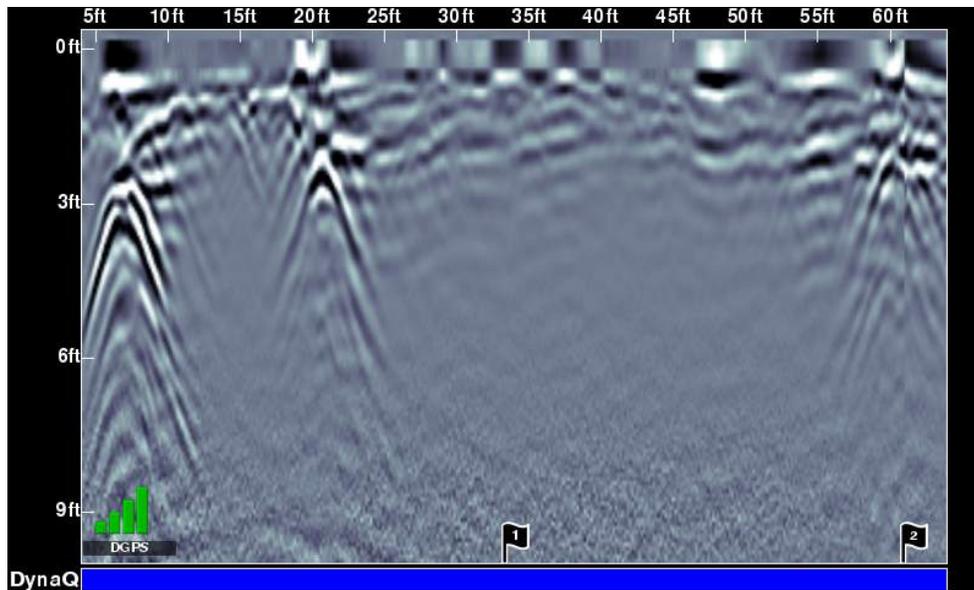


Figure 6-6: Inserting Flags

6.6. Line Scan menu options

All the settings described below change the way the data is viewed on the screen. They do not alter the saved data in any way. These settings can be altered while you are still collecting data, or after you have pressed Stop.

6.6.1. Zoom

This button controls the aspect ratio of the displayed GPR data. Pressing the **Zoom** button changes the buttons on the bottom menu, which are explained below:

- **Depth** – Pressing **+** and **-** under the **Depth** button allows you to change the display depth of the data. This is commonly referred to as the depth window. The pre-set values range from 1m to 8m (3' to 25'), see Figure 6-7.

If the data was collected with a shallower depth, the depth setting can still be increased after the fact, when reviewing the data. In general, it's a good idea to set your displayed depth to 1.5 - 2 times the depth you expect the deepest target to be.

- **Position** – Pressing **+** and **-** under the **Position** button allows you to change the length of data display on a single screen. This is also known as horizontal scaling. The pre-set values range from 10m to 30m (25' to 100'), see Figure 6.8. One reason for setting this to 30m would be to fit more data on the screen and look for consistency among hyperbolas that were crossed.

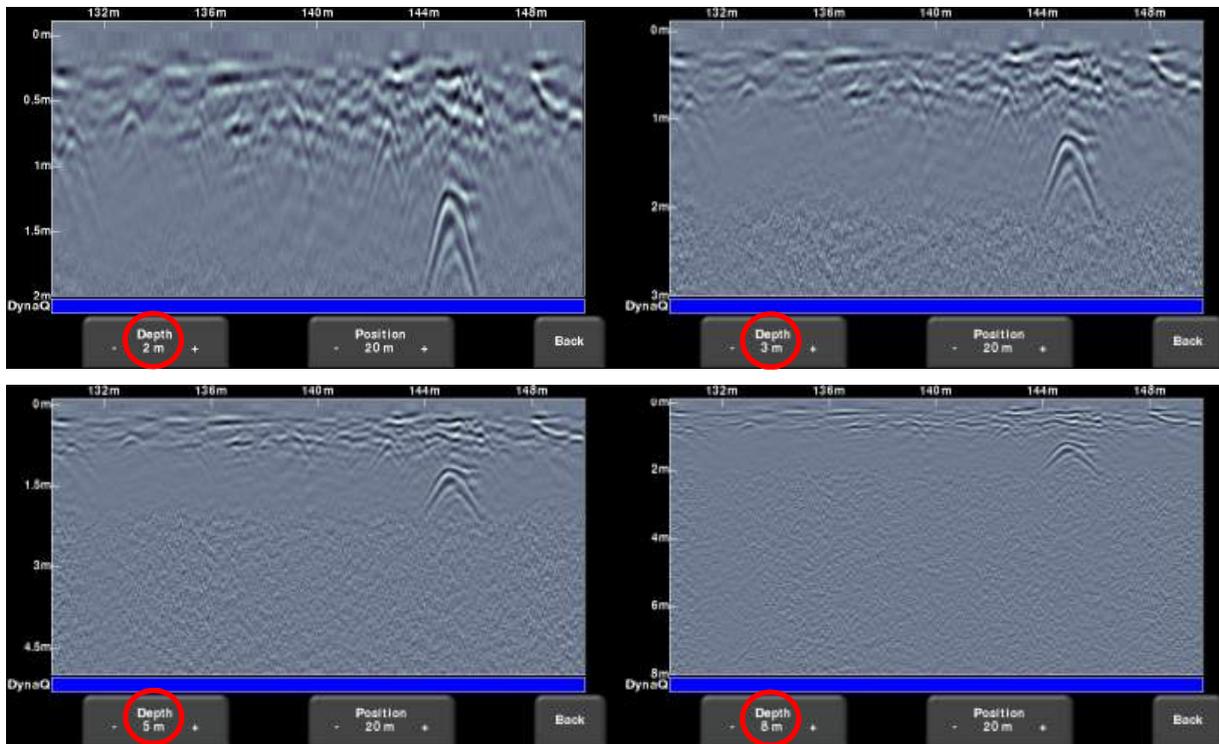


Figure 6-7: Varying displayed depth

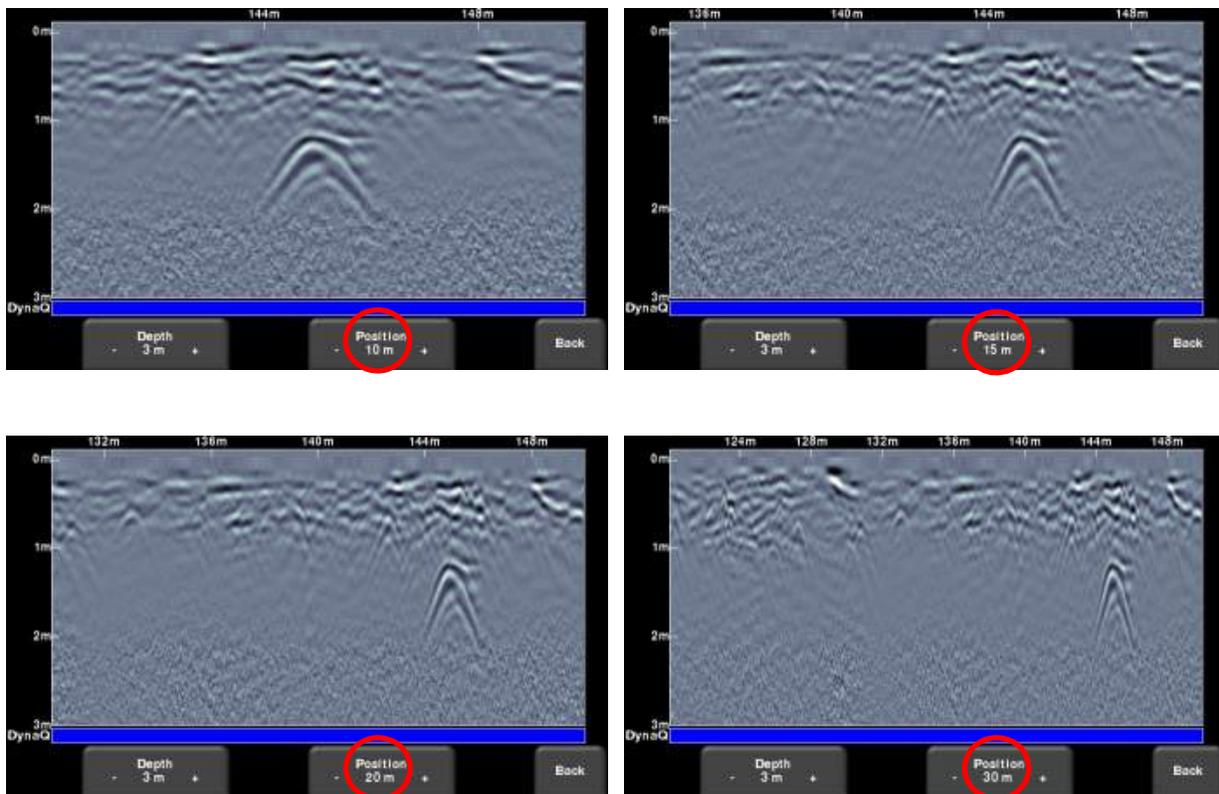


Figure 6-8: Varying position, or horizontal scaling

6.6.2. Color

Pressing this changes the color palette for the GPR Lines. There are 8 different color palette options. The image is automatically re-displayed as the color palette changes. A few sample color palettes are shown in Figure 6-9.

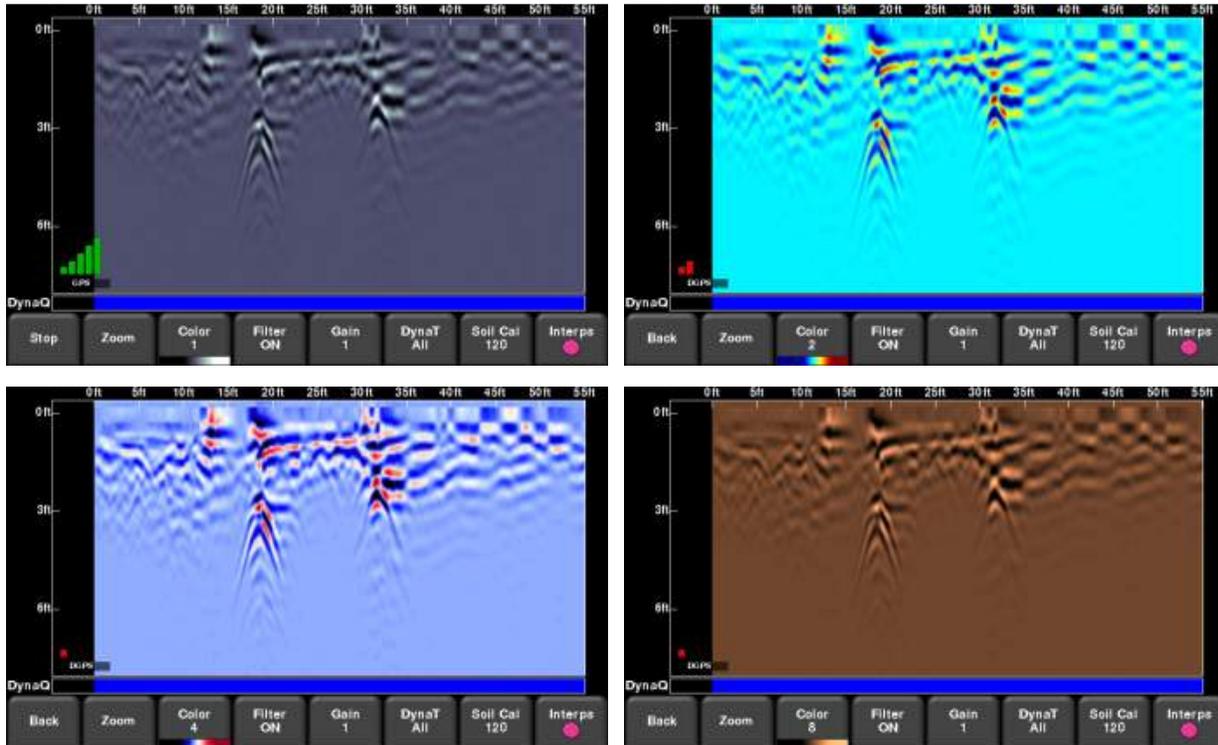


Figure 6-9: Changing Color palettes

6.6.3. Filter

When the filter is ON, flat-lying responses in the data are filtered out so that hyperbolic responses from objects are enhanced (Figure 6-10). Filtering also helps identify shallow targets that might be masked by the strong signals at the top of the image. However, it will also filter out other flat-lying responses, such as soil boundaries, so be careful when using this option if your target is flat. The filter is set to ON by default

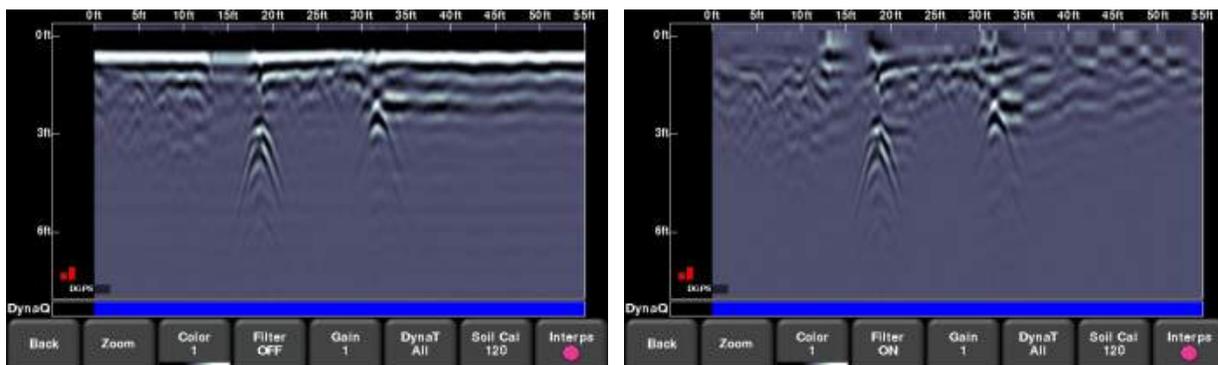


Figure 6-10: Left image shows Filter On, while the right shows the same data with the Filter Off.

6.6.4. Gain

Since the material being scanned absorbs the GPR signal, deeper targets return weaker signals. Gain acts like an audio volume control, amplifying signals and making deeper targets appear stronger in the image. Gain values vary from 1 to 9 where 1 means a minimal amplification has been applied and 9 means that maximum amplification has been applied. Pressing this button increments the gain; once you reach 9 it cycles back to 1. Avoid over-gaining the data as it can make interpretation difficult. In general, soils that are more electrically conductive (eg. clays) will require a higher gain compared to soils that are less electrically conductive (eg. sand).

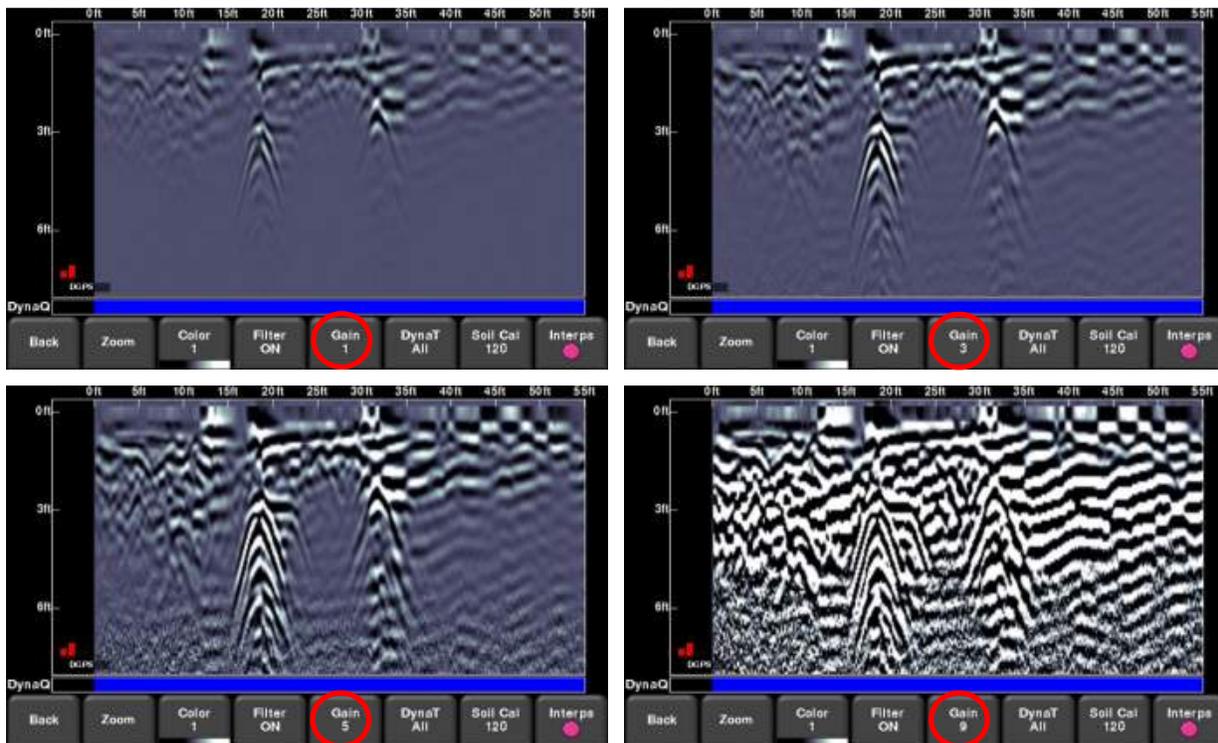


Figure 6-11: Varying the Gain

6.6.5. DynaT

DynaT is a feature that can selectively enhance small, medium or large size targets for easier viewing and detection. Pressing **DynaT** cycles between options: **All**, **Small**, **Medium** and **Large**. Each option allows the user to enhance part of the ultra-wide band (UWB) spectrum to focus on those desired features.

Selecting **Small** will show more of the smaller hyperbolas and more detail, whereas **Large** will focus more on the larger targets with better depth penetration. Selecting **All** will show a combination of small, medium and large targets.

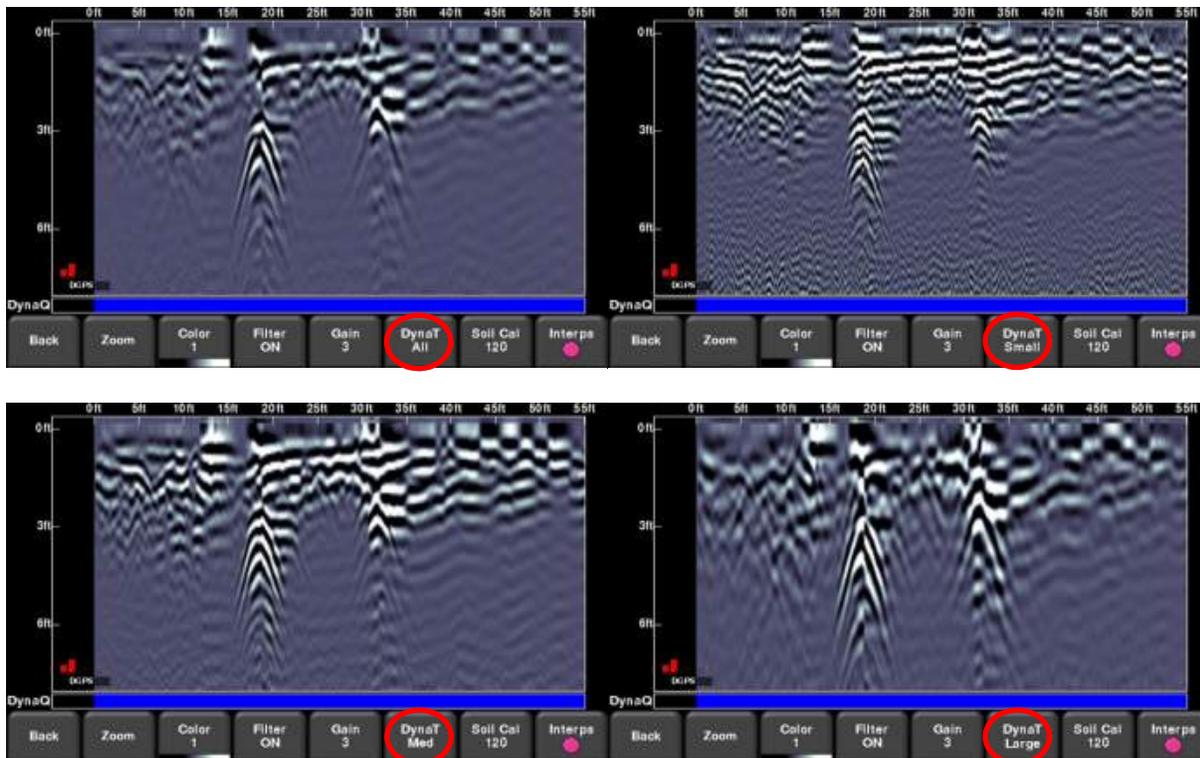


Figure 6-12: DynaT settings: a) Top left shows All b) Top right set to Small targets c) Bottom left set to Medium targets d) Bottom right set to Large targets

6.6.6. Soil Cal

The soil calibration (also known as velocity) is a parameter used to ensure that measured depths are accurate. The best way to ensure this is by using the hyperbola-fitting method, since it is based on data collected in the area.

Crossing linear targets like pipes or cables at a 90 degree angle produces a hyperbola suitable for soil type calibration. The Soil Cal value obtained will be used to compute a depth estimate of a target. These depths will be *incorrect* if the soil type is calibrated on a target hyperbola produced at an oblique angle, rather than 90 degrees.

Once you have a hyperbola on the screen from a subsurface target, press **Soil Cal**. The menu at the bottom of the screen will change, giving you the option of specifying a Soil Type or adjusting the Soil Cal using the hyperbola-fitting method (Figure 6-13a).

- **Soil Types** – If there are no targets to calibrate to, and you know the type of soil, press this button to vary between the following mediums, with the pre-set Soil Cal value shown in brackets:
 - very wet (60)
 - wet (80)
 - moist (100)

- dry (120)
- very dry soil (150)
- air (300)
- **Soil Cal** – allows you to use hyperbola-fitting to determine a more accurate Soil Cal. Touch the screen to move the red hyperbola such that it lies over a real hyperbola from the ground (Figure 6-13b). Use the 4-way directional keypad to fine tune the movements. Then use the + and – buttons on the Soil Cal button to widen or tighten the shape. Once the shape is matched (as shown), you now have the correct Soil Cal and the measured depths will be most accurate. Press **Apply** to use this value. If you get a Soil Cal near 300, this could be an Air Wave (Section 5.5), and you should calibrate to a different hyperbolic response.

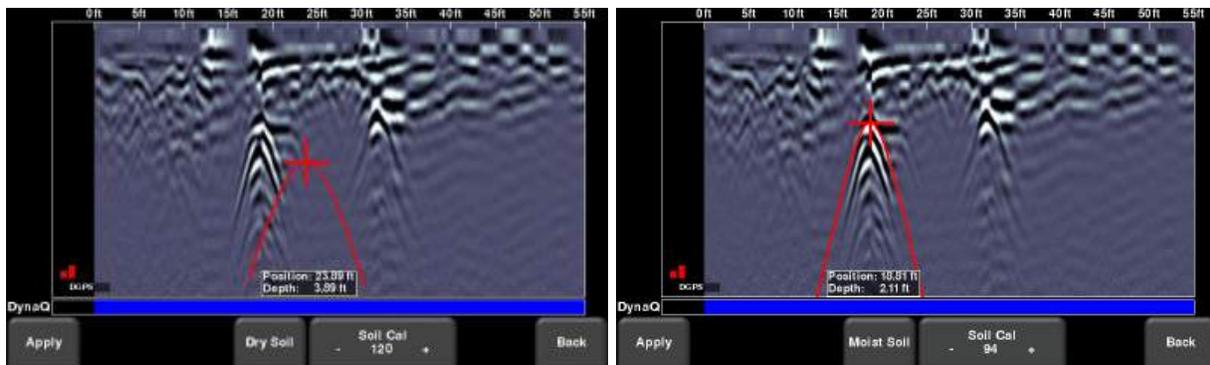


Figure 6-13: Adjusting Soil Cal, a) initial screen b) moving the red hyperbola over a hyperbolic response from a subsurface target

6.6.7. Interp

Short for field interpretation, Interps are used to mark subsurface features. Seven colours are available, which allow you to designate different types of subsurface objects.

Either during collection, back-up or review, you can simply touch anywhere on the screen to add an Interpretation (Figure 6-14). This appears as a dot of whatever colour is selected. To change the color, press the **Interp** button to see a selection of colours and to select a new one (Figure 6-15).

To remove an Interp, ensure the same color is currently active and simply touch the Interp to make it disappear.

These field interpretations remain with the data and can be used to check if a feature is linear (in Map View or in Google Earth™), but only if the more accurate external GPS is used.

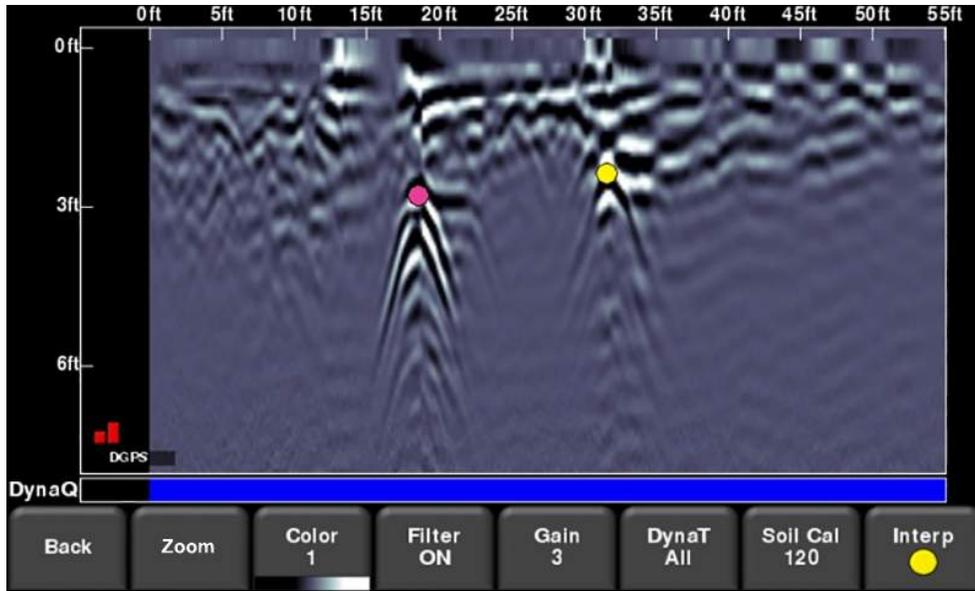


Figure 6-14: Touching the screen to put Interps

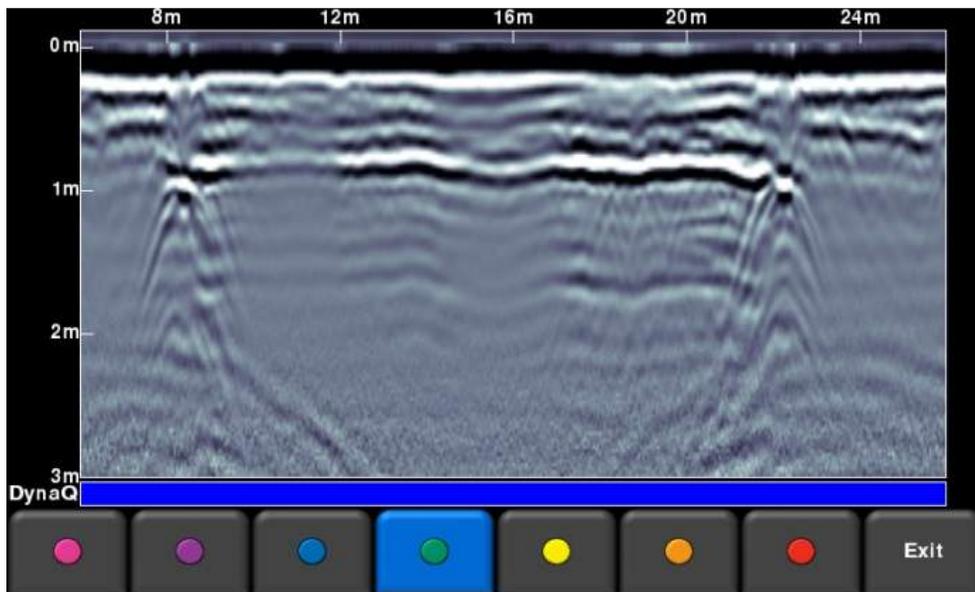


Figure 6-15: Available colors for Interps

7. Grid Scan

Grid scans are conducted to generate depth slices over a given area. This is useful for locating all known and unknown objects, as well as their orientation, in a graphical manner that is easy to interpret.

From the main menu (either in Figure 3.2 or 3.3), press the **Grid Scan** button to enter the Grid setup menu.

7.1. Grid Parameters

The screen in Figure 7-1 will allow you to set parameters of the grid, before data acquisition begins.

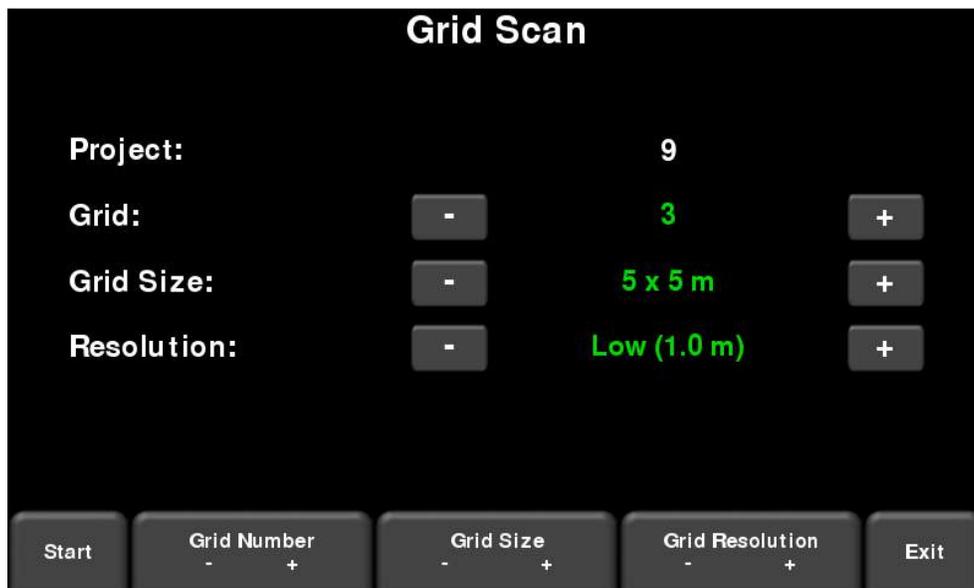


Figure 7-1: Grid Scan setup, from the Enhanced system. On the standard LMX200, it will be the same, except there will not be a project number

7.1.1. Grid Number

To select a grid number, press the + and - buttons under **Grid Number** at the bottom of the screen. Alternatively, you can press the + and - buttons on the screen beside **Grid** on the upper part of the screen. Grids that contain no data will have the text shown in green.

If a grid already contains some data, it will be shown in red and you will not be able to change the size or resolution. You will just have the option to select:

- **Slice View** – view the depth slices
- **Delete Grid** – delete all the data in this grid

You can press Start to enter a previously collected grid, either to view data or recollect a line.

7.1.2. Grid Size

Press the + and - buttons under **Grid Size** at the bottom of the screen to change the dimensions of the grid. Alternatively, you can press the + and - buttons on the screen beside **Grid Size** on the upper part of the screen.

In metric units, the available grid sizes are 5m x 5m, 10m x 10m and 15m x 15m.

In US standard units, the available grid sizes are 10ft x 10ft, 20ft x 20ft and 50ft x 50ft

7.1.3. Grid Resolution

Grid resolution determines the spacing between grid lines. This can be varied by pressing the + and - buttons under **Grid Resolution** at the bottom of the screen. Alternatively, you can press the + and - buttons on the screen beside **Grid Resolution** on the upper part of the screen.

Available options are 0.25m, 0.5m and 1.0m in metric units and 1, 2 & 5 ft in US standard units. The best images will result when the smallest resolution value is used.

Calculating Resolution

The size of target will determine line spacing. The system must pass over a target to detect it; line spacing needs to be on the order of the size of the target or smaller when practical. This can be adjusted to a larger spacing for larger targets or targets that are linear. As well, these rules may have to be bent for practical purposes such as survey production rates. Tighter line spacing takes longer to collect and may not be economically possible in all circumstances.

Note that the system will not allow you to select a 10'x10' grid with a low resolution of 5', as this resulting image will be very poor due to inadequate data collected.

7.1.4. Starting data collection

Press **Start** when all the parameters are setup and data collection is ready to begin

7.2. Laying out the grid

Positional accuracy of each line is vital to locating targets of interest once data has been processed.

For linear targets such as pipes and utilities, the best GPR responses occur when the GPR survey line crosses the target at right angles. Keep this in mind when laying out the grid and the orientation. Sometimes, laying out a grid with straight lines and corners at 90 degree angles can be difficult. Sensors & Software's "EasyGrid" makes this task easy. To learn more, contact Sensors & Software.

An example grid layout is shown in Figure 7-2.



Figure 7-2: Example of a grid survey. The red lines are superimposed just to illustrate the concepts.

7.3. Data Collection

7.3.1. Physical Data collection

It is critical that the starting position is consistent on every line. Line up the middle of the unit with the starting line, and then push the system straight towards the end of the line. It is helpful to have a marker at the end so you have something to aim for.

Not all lines have to be finished. If there is an obstruction preventing you from finishing the line, you can simply press Stop and end the line early.

In addition, not all lines have to be collected. If your area of interest is only 4m x 4m, set the Grid Size to 5m x 5m, but just don't collect the outer lines.

7.3.2. Data collection on the Display Unit

The data collection screen is shown in Figure 7-3. The right half of the screen is a graphic representation of the grid, illustrating the size of the grid and the lines that need to be collected. The left half of the screen will display the last grid line collected.

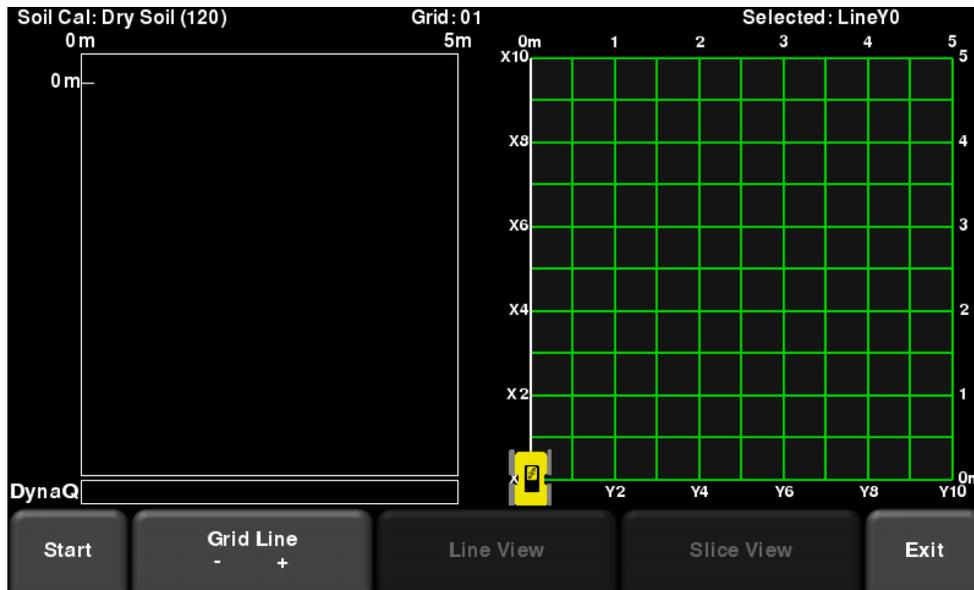


Figure 7-3: Grid data collection screen

Press **Start** when you are positioned at the start of the line. Push the system in a straight line towards the end of the line. The system knows the length of each line, and will automatically stop acquisition once that distance has been covered. If the data acquisition ends prior to reaching the end of the line, or continues noticeably past it, you likely need to do an Odometer Calibration (Section 4.4.3).

Once data is collected, the Grid Line will turn red. The current line will now advance to the next one and is shown in white. The remaining lines to be collected are shown in green.

Move back to the start of the next line and repeat the process. Once all the lines are done in one direction, it will automatically prompt you to collect lines in the other direction.

7.3.3. Recollecting & skipping lines

You may want to recollect a line if you make a mistake. To move to a different line:

- Press the **+** and **-** buttons under **Grid Line** OR
- Touch any **line** on the grid image on the right OR
- Use the **4-way directional keypad**

Then simply hit **Start**. You will be prompted with a message asking if you want to overwrite that line (Figure 7-4). Press **Yes** to proceed.

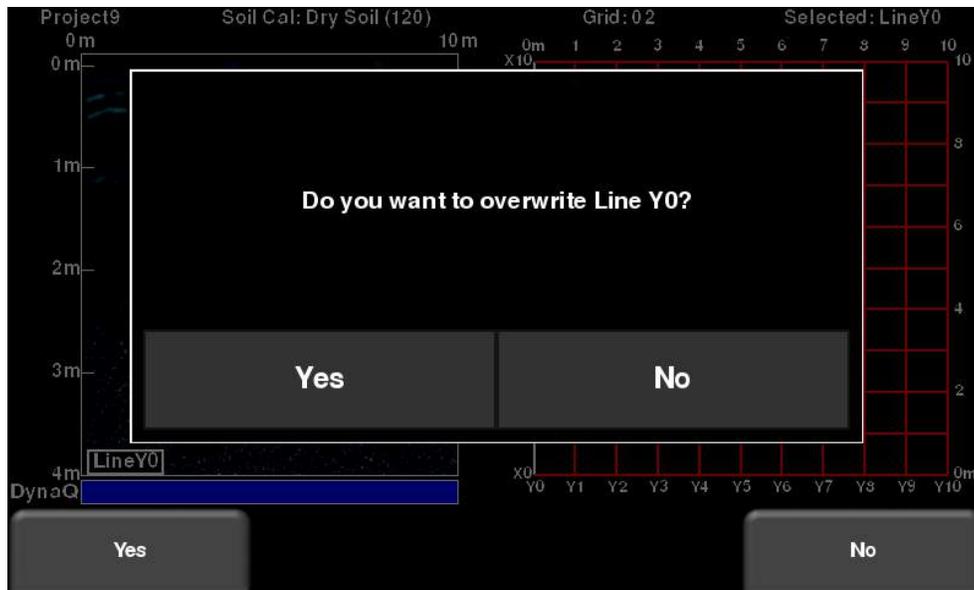


Figure 7-4: Overwriting a line

7.3.4. Processing data

Once you have finished collecting all the data, press **Slice View** at the bottom of the screen. The data will be processed and depth slices will be generated. See the next section on using Slice View.

8. Slice View

Slice View displays data collected in a grid as a series of depth slices moving deeper into the subsurface. Objects and features appear in plan view, which can be an easier way of visualizing the data. In addition, data in this view can be exported into other software, such as Google Earth™.

Upon entering Slice View, the screen will be displayed as shown in Figure 8.1.

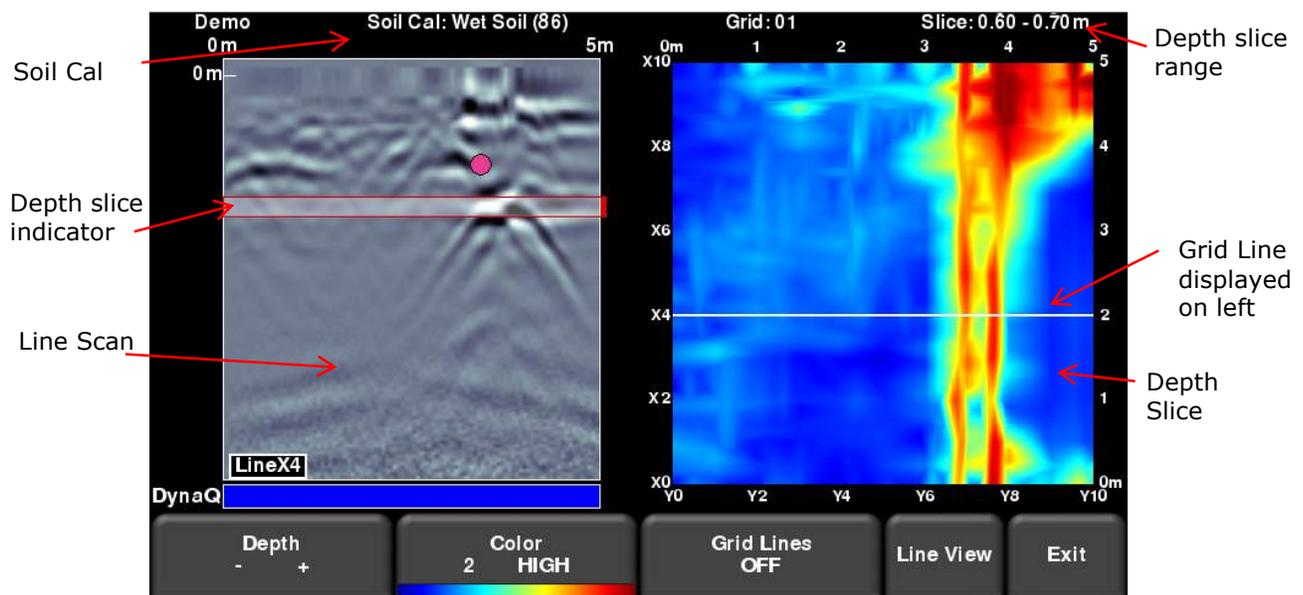


Figure 8-1: Slice View screen

The right half of the screen shows one of the depth slices. These slices are 10cm or 4" thick. The top and right sides of this image show the dimensions of the grid while the left and bottom sides show the line numbers.

The left half of the screen displays one of the grid lines, and any flags or interpretations that were made. The shaded area in between the horizontal red lines corresponds to the depth slice shown on the right. To move to another grid line, use the 4-way directional keypad on the Display Unit.

At the top of the screen, the grid number is listed, along with the slice thickness range. The Soil Cal number was automatically determined when the grid data was processed and is indicated here.

The button functionality is explained below:

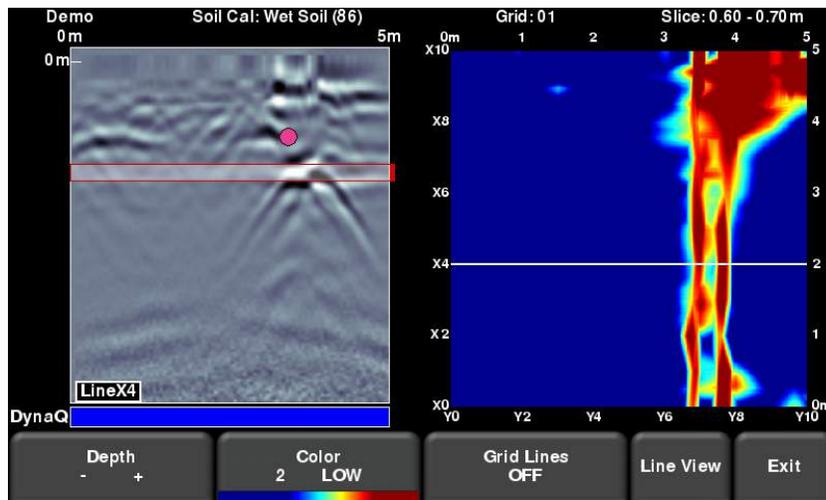
8.1. Depth

Pressing the + and - buttons on the **Depth** button will increase or decrease the depth of the depth slice currently displayed. This allows the user to “slice through” the ground, and locate features that appear at different depths.

8.2. Color

This heading has two button functions beneath it:

- Color Palette** - The number corresponds to the color palette used for the depth slice image. Pressing this button cycles between the 9 available color palettes available on the system.
- Color Sensitivity** - cycles between **LOW**, **MEDIUM** and **HIGH**. This is a function of how much signal data is displayed. A setting of HIGH is useful for revealing weaker targets which can sometimes be difficult to see. Setting to LOW will help “clean up” the data and only show the strong targets, but will hide some of the weak signals so be CAREFUL when setting to LOW. Figure 8-2 shows the variations in color sensitivity



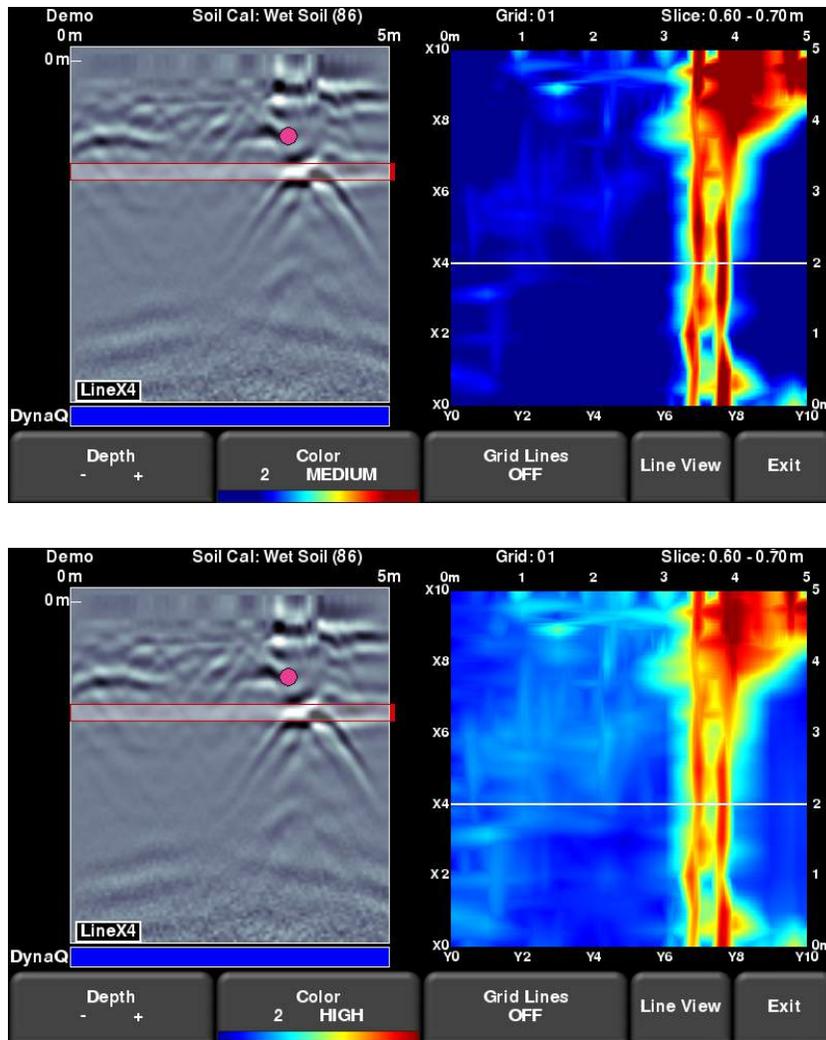


Figure 8-2: Varying the sensitivity, from top to bottom: Low, Medium and High settings. High shows more subtle targets but may sometimes appear cluttered while the Low setting only displays the strongest targets so be cautious when using it.

8.3. Grid Lines

Press this button to overlay the grid lines on the depth slice image. It is useful to see grid lines so you know the position of the GPR Line in the grid (displayed in white). Pressing this button cycles between **ON**, **PARTIAL** or **OFF**. When set to ON, all the collected lines are displayed. When set to PARTIAL, only some of the grid lines are displayed. This may be necessary for some larger grids as having all the grid lines ON tends to obscure the image beneath (Figure 8-3).

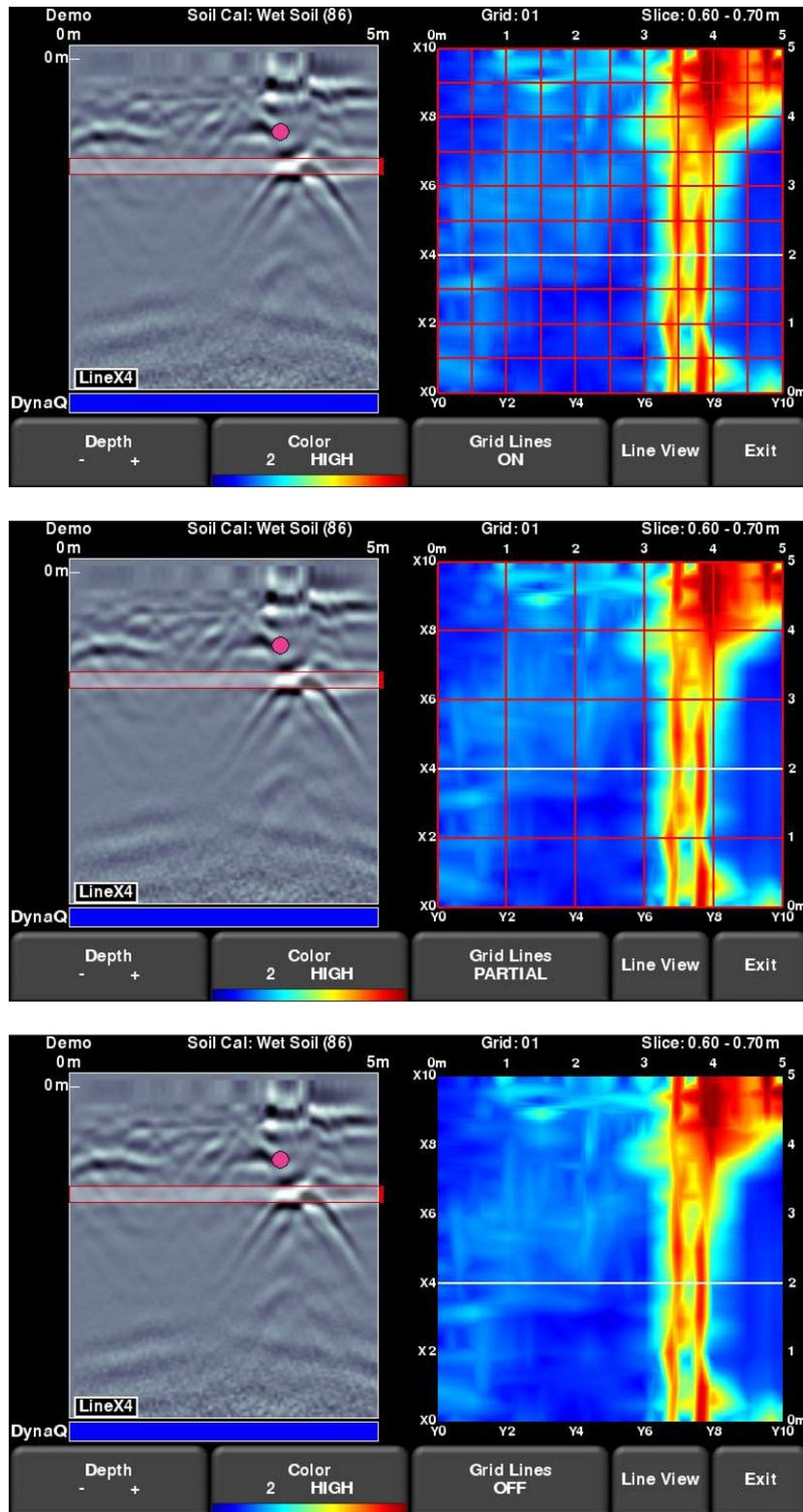


Figure 8-3: Varying the Grid Lines, from top to bottom: ON, PARTIAL and OFF settings.

8.4. Line View

Pressing this button displays the currently selected GPR line as a full screen image. All the functionality of Line Scan (such as depth, color, filter, gain, DynaT, Soil Cal, interps) are available here. Use the **4-way directional keypad** to change to a different line.

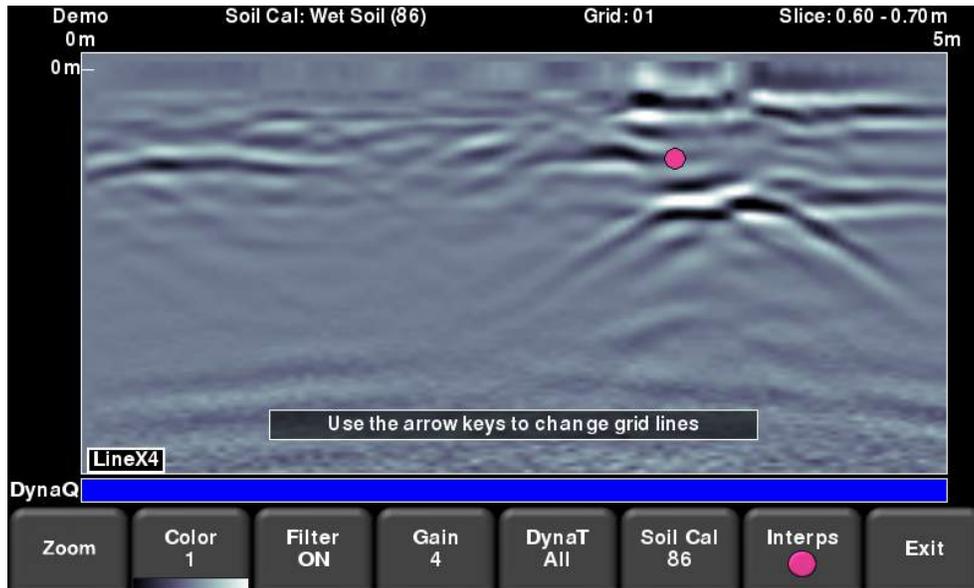


Figure 8-4: Changing Line View settings from within Slice View.

Press **Exit** to return to Slice View. Any changes made will be reflected on the GPR line in Slice View mode. If you change the Soil Cal or Zoom (depth), this will cause the depth slices to be re-processed.

Users may want to change these display settings to make it easier to correlate line scan data with depth slices.

8.5. Recollecting lines

After looking at the grid data in Slice View you may discover that one or more grid lines need to be recollected (for example, maybe the starting position was offset). If so, you will need to enter the Grid Scan menu again and select the appropriate grid number and press Start (the grid number will be in red, since data exists).

Select the grid line that needs to be recollected. When you press **Start**, it will display a prompt confirming if you want to overwrite the line. After recollecting the grid line(s), press the **Slice View** button to re-process the grid data.

9. Map View

Map View is a unique feature that allows the user to graphically view the path travelled by the system, and any flags or interpretations made. This is helpful in determining the linearity and consistency of buried objects. It will also display a view showing the lines collected as part of a grid.

A common use of this feature is to snake back and forth over a given area. Each time you cross a target producing a hyperbola, back up to the top of the hyperbola and add an interpretation. If the object is a linear feature, all the interpretations will line up when viewed in Map View.

Map View only works if GPS data is collected with the GPR data. This is what allows the lines and/or grids to be positioned correctly (with the right orientation).

If you use the internal GPS, only grid data will be shown in Map View. If an external GPS is connected, both line and grid data will be shown.

9.1. Accessing Map View (LMX200)

You will only see Map View when you enter either a line or grid

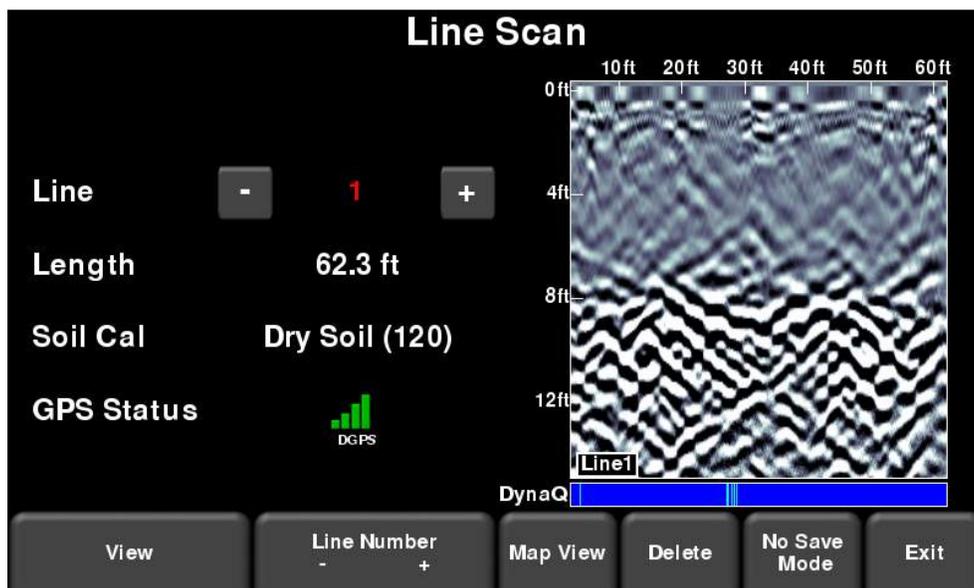


Figure 9-1: Accessing Map View from LMX200

9.2. Accessing Map View (LMX200 Enhanced)

Map View can be accessed from the File Management menu or from the main screen. Remember that in the Enhanced configuration, Map View is *project* based, meaning it will display all lines and grids that are present in a given project.

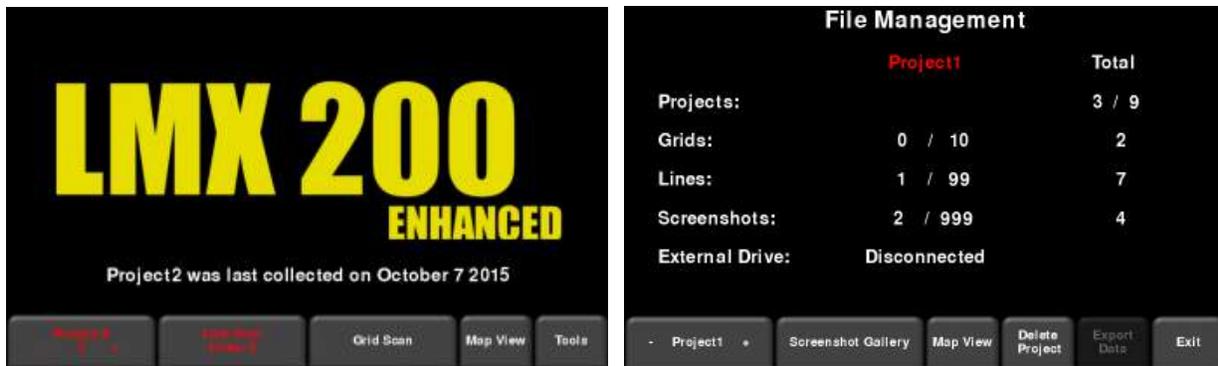


Figure 9-2: Accessing Map View from LMX200 Enhanced, either from the a) Main screen or b) File Management menu

9.3. Map View screen

Irrespective of the system configuration, entering **Map View** will show an image similar to the one in Figure 9-3. You will always have the same options in Map View which are described below:

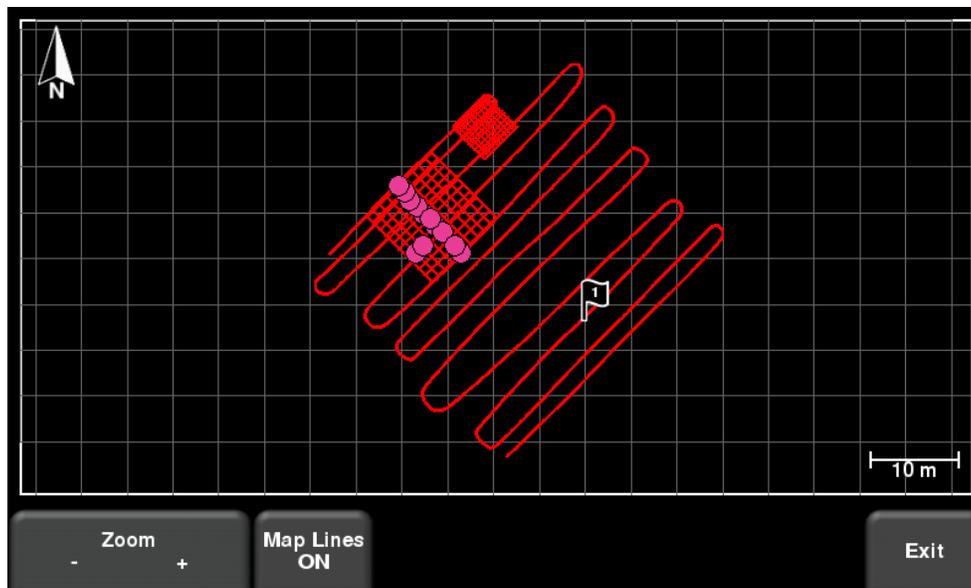


Figure 9-3: Map View showing the position of two grids and one line

- Pressing **Zoom +/-** will zoom accordingly. To reposition the image in the middle of the screen, simply swipe the screen until the image is positioned properly.
- Pressing **Map Lines** will turn the grid lines on or off.
- Pressing the **Camera** button saves the screen as a screenshot

10. Capturing Screens & E-mailing mini-reports

10.1. Capturing Screens

If you would like to save an image of the current screen in Line Scan, Grid Scan, Slice View or Map View, press the **Camera** button on the Display Unit. This saves the screen as a Screenshot image (.JPG), which can be viewed in any third-party viewing software. If any GPS is enabled, the screenshot image (only for Line Scan and Slice View screens) will contain also a geo-tagged reference.

If you are not connected to a WiFi network, a message appears confirming the filename of the saved image (Figure 10-1).

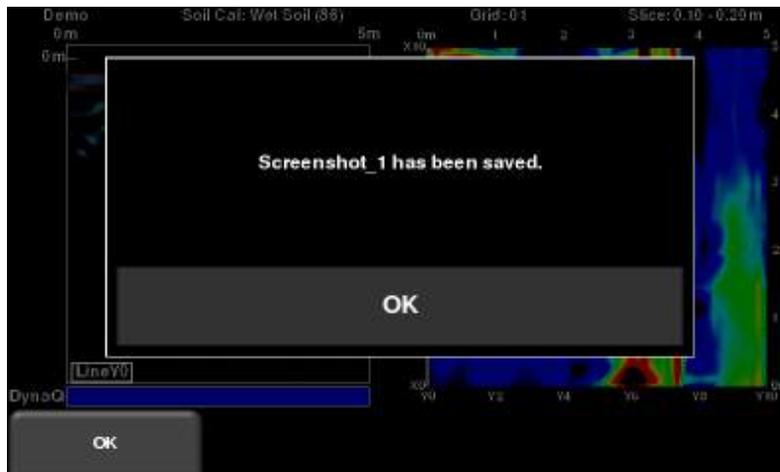


Figure 10-1: Message displayed after pressing the camera button on the Display Unit to capture the screen (no WiFi present).

If you are connected to a wireless network and have a sending e-mail address configured, the user will see the message in Figure 10-2, asking if you would like to email the screenshot and prompts you to enter the email address. The email address defaults to the last one entered. Pressing the “...” button to the left of the e-mail address displays the last 5 e-mail addresses used, allowing the user to easily select a recent email, rather than re-entering it.

Screenshots can always be e-mailed at a later time from the Screenshot Gallery (Section 4.3.1).

|

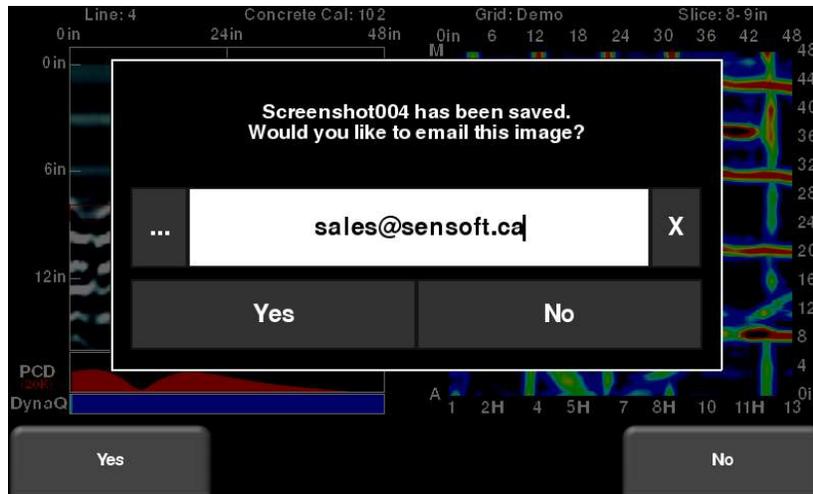


Figure 10-2: Message after pressing the Camera button on the Display Unit to capture the screen with WiFi enabled and a connection to a wireless network. The user can enter an email address to send the mini-report to.

10.2. Mini-Reports

When a screenshot is e-mailed, it is sent as part of a mini-report. This mini-report also contains a table with information about the collected data including the settings used, date & time (Figure 10-3)

LMX 200 Mini Report

Project	Demo
Screen Capture Number	14
Date Collected	September 23 2015 10:52 AM
Mode	Line Scan
Depth	3.0 m
Line Color Palette	1
Filter	ON
Gain Level	4
DynaT	All
Soil Cal	Dry Soil (120)



Your screen capture is attached to this email.

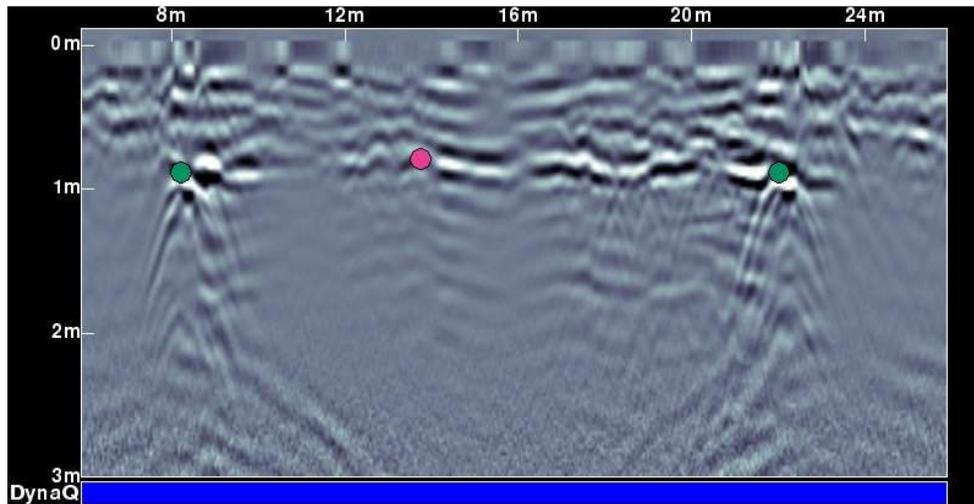


Figure 10-3: Example of a Mini-Report

11. Transferring Data to a PC

Screenshot images (and data if you have the Enhanced system) can be exported to a PC, via a USB memory stick.



Figure 11-1: Insert a USB memory stick into the USB port on the Display Unit to export data.

Insert a USB drive into the USB port (Figure 11-1). Once the USB drive is recognized, a message will appear telling you that a drive has been inserted and if you wish to export your data to it (Figure 11-2). Click **Yes**.

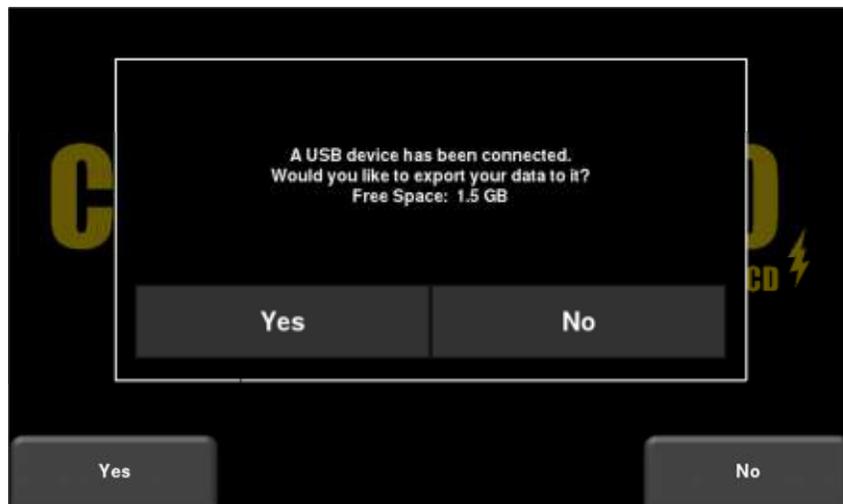


Figure 11-2: When a USB drive is connected to the Display Unit, a message opens asking if you would like to export all your data to it. Select **Yes** to transfer immediately. If you select **No**, you can export the data later by going to the **Setup > File Management** menu option.

Alternatively, if you want to export the data later, you can select No for the time being. Later on, when you are ready to export your data, from the main menu select **Setup > File Management** and press **Export Data** (Section 11)

The directory structure on the USB drive can be viewed on your PC, and will look as follows:

- GPR Data
 - LMX200
 - Export01
 - Project1
 - Screen Shots
 - All Screenshots as .JPG files
 - Project1.GPZ file
 - Project1.KMZ file
 - Field Interp Report.CSV
 - Project2
 - Screen Shots
 - All Screenshots as .JPG files
 - Project2.GPZ file
 - Project2.KMZ file
 - Field Interp Report.CSV
 - System Info
 - Exportxx
 - Projectx
 - Screen Shots
 - All Screenshots as .JPG files
 - .GPZ file
 - .KMZ file
 - Field Interp Report.CSV
 - System Info

All screenshot files are saved as .JPG files

The actual GPR data files are all contained in a .GPZ file. This can be opened by the EKKO_Project software.

If data was collected with GPS (internal or external), a .KMZ file is also generated. This contains positional information and can easily be opened in Google Earth™.

If any Interpretations were made, these are saved in a .CSV file. This is a spreadsheet file, which shows the positional information of any interps made.

The System Info folder contains log files and a system summary diagnostic report.

Each successive export of data will create a new directory called ExportXX, where XX is incremented by 1 from the previous directory.

12. Troubleshooting

The LMX200 system is designed to minimize user problems; however, all electronic devices are subject to possible failure. The following are troubleshooting hints which can be referred to if your system fails to operate.

12.1. Power Supply

The most common problem that can occur while trying to run the system is insufficient power. The battery may be dead, have a low voltage or the fuse may be blown.

Once boot up is complete, the colour of the LED will indicate the amount of battery power remaining:

- 100% to 20% = green
- 20% to 10% = orange
- 10% to 0% = red

You can check the battery voltage with a voltmeter. Try to do this while the system is still attached to the Cart to get a true measure of the voltage while under load (it will be necessary to open the Cart battery case and connect the voltmeter to the positive and negative battery terminals). A fully charged battery will show a voltage of 13.8V, whereas a voltage of 10.8V or lower will not power the system. If the battery has a low voltage or seems dead, try using another battery (if available), or give the battery a good 12-14 hour charge and try running the system again.

If the battery does not charge up to 12 Volts or more, it should be replaced.

Batteries are fused to protect the system. Open the battery case and check that the 10 Amp fuse is OK. If necessary, replace it with one of the spare fuses available inside the battery case.

If the battery seems OK but the system still does not power up, check the battery cable connections and inspect the battery cable for damage.

12.2. System Communications

If the battery is OK and the Display Unit turns on but the GPR sensor does not scan, there may be a communication failure between the Display Unit and the GPR sensor. If an error occurs, an error message will appear. Power Off the system and disconnect the battery.

Make sure the display cable is not damaged, all pins are straight, and there is no dirt or debris in the connector. Ensure that the cable connections are tightly secured. Sometimes vibrations cause the cable connections to slightly loosen and break contact leading to errors.

Disconnecting the cable and reconnecting it may provide a better contact and solve the problem. Plug in the battery, turn on the system and try scanning again.

If the Battery, Battery Cable and Display Cable are OK, the problem is either a failure of the Display Unit or the GPR sensor. These units have no user-serviceable parts so they will have to be returned to the vendor for inspection and repair.

12.3. System Overheating

The GPR system is designed to operate to a maximum *internal* temperature of 70 C or 158 F. In situations of high ambient temperatures or long exposure to direct sun, this maximum internal temperature may be exceeded and cause the system to fail.

If you suspect that the GPR sensor is overheating, shut it off and give it a chance to cool down in a shady location before trying to run it again.

If the situation is such that the high temperatures or direct sun cannot be avoided, it may be a good idea to put some sort of shade over the GPR sensor.

12.4. Display Unit Problem

The Display Unit is weatherproof and rugged, it should be handled in much the same way a notebook computer is. If the Display Unit does not power up, check the battery power and all cable connection. If that doesn't work, contact the manufacturer.

12.5. Wobbly Wheels

If, over time, a wheel becomes wobbly, the wheel nut will need to be manually tightened.

For the rear right wheel only (which is connected to the direct drive odometer), insert a large slotted screwdriver into the end of the axle (there's already a slot there for it) and use a large wrench to slightly tighten the wheel nut. The nut only has to be turned slightly, 1/8th - 1/16th of a turn is usually enough. Spin the wheel to make sure it's still free and not too tight.

12.6. Creating a Test Line for Data Quality

After receiving the system and getting comfortable with its operation, one of the best ways of detecting any problems is to collect a line of data at a convenient, easily accessible location. The line does not have to be too long but one screen is a good guide. This data line should be saved electronically and perhaps plotted out on paper and dated. If there is a suspected problem with the system, this test line could be collected and compared with earlier tests. When comparing data, take into account weather and environmental conditions, which could skew the comparisons slightly.

12.7. Contacting the Vendor for Service

When returning the system to the Vendor, have the following information available:

- 1) GPR sensor Serial Number displayed at the top of the **System Settings Screen**.
- 2) A brief description of when the error is happening and the operating conditions (temperature, humidity, sunshine, system settings, etc.).
- 3) System log files downloaded to your computer

12.8. Using the Hotspot on your Smartphone

If you are experiencing difficulty connecting to a cell phone Personal Hotspot, ensure that the phone is in discovery mode while connecting. On iPhone (iOS 9.0), for example, this involves going to **Settings - Personal Hotspot**. Ensure that the Personal Hotspot setting is turned on, and wait on this screen until the LMX200 connection has been established. Once you have received confirmation on the Display Unit, the cell phone can resume normal use.



Note that when setting up a Personal Hotspot, you may be disconnected from any WiFi networks. Vice-versa, if you have a Personal Hotspot setup, attempting to connect to a WiFi network may disconnect your personal hotspot.

13. Care and Maintenance

13.1. Battery Care

The LMX200 uses a 9-Amp-hour, 12-Volt sealed lead acid battery. It is fused with a 10 Amp fuse to protect it from short circuit damage.

The battery unit should run the LMX200 continuously for 6 hours before recharging is necessary. If long days of data surveying are typical, a second battery unit may be useful.

The battery is strapped onto the cart base and is normally recharged without removing it from the cart. However, the battery can be easily removed for maintenance or for recharging, if required.

If batteries are maintained in a charged condition they will give long life and reliable service. Improper use and lack of maintenance will greatly reduce their life.

Sealed lead acid batteries should **NEVER** be left in a discharged condition for any period of time. Charge the batteries as soon as possible after use.

Charge the battery at room temperature whenever possible.

The LMX200 has a voltage monitoring circuit that will turn off the unit when the input voltage drops below 10.8 volts.

If a battery has been deeply discharged or left in a discharged condition for some period of time it may not accept charge immediately when it is connected to the charger (the fast charge light will not illuminate). If the fast charge light does not come on within 6 hours the battery should be considered damaged and should be discarded.

Do not assume that a battery that is still charging after 8 hours is nearing the end of its charge cycle. Typical charging time for an empty battery is 12-14 hours from the start of fast charge.

Ensure that the batteries are fully charged before storing. If practical, store the batteries in a cool place, 10°C (a refrigerator is ideal), but make sure the temperature is not likely to drop below -30°C or the electrolyte may freeze and possibly split the case.

13.2. Cable Care

- 1) The cable connectors as well as the connectors on the GPR Sensor and Display Unit 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) When the system is not being used, make sure the connections are protected to prevent dust and moisture from collecting inside. If the connectors are exposed, cover them with some sort of dust cap.
- 3) Cables are designed to be as tough as practical.
- 4) Careless use of cables like making them carry loads that they are not designed for can cause internal damage.
- 5) Connectors are weak points in any system. 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.
- 6) Cables and connectors are not designed to suspend or tow or otherwise carry the weight of systems. They are part of the electronic circuit and should be treated accordingly. When not in use they should be placed in their storage box.

13.3. Skid Pads

The bottom of the GPR Sensor is covered with one large wear-resistant skid pad. The skid pad is designed to take the majority of the abrasive wear. If the pad wears down enough, the less-resistant plastic housing may start to wear. If this occurs, it is best to replace the skid pad. It is easily removed with a screwdriver and a new one can be purchased from the vendor.

13.4. Odometer

The odometer should be periodically calibrated (refer to Section 4.4.3) to ensure accuracy.

13.5. Storage Cases

Equipment that is transported and stored loosely is more susceptible to damage. All equipment should be stored in its shipping case or a storage box. Sensors & Software has optional shipping cases available for all LMX200 systems.

14. Technical Specifications

Specifications	Values
GPR Sensor size	630 x 410 x 230 mm (25 x 16 x 9 in)
GPR Sensor weight	5 kg (11 lbs)
Display Unit weight	2.83 kg (6.24 lbs)
Display Unit screen	8.0" high-visibility, sunlight-readable diagonal LCD display with touch screen Adjustable backlighting 1500 NIT and 800:1 contrast ratio
Battery weight	4 kg (8.8 lbs)
Wireless	Integrated modules: Wi-Fi (IEEE 802.11 b,g,n) GPS/GLONASS
Audio	Built-in speaker - 85dBA speaker w/volume control
Battery	Lead acid gel cell Battery Life: 4-6 hours Battery Capacity:9.0 Ah
Charger	Built-in charger with status indicator Universal AC mains charger input: 100-240V \sim , 1.5A, 50/60Hz Output: 12 Volts @ 3 Amps
DVL-500N Display Unit Input	11-18V \equiv , 4A maximum
Temperature & Environmental 	Ruggedized, environmentally sealed unit and connections. Ingress protection (IP) rating: DVL-500N Display Unit is rated to IP65 under IEC 60529 Relative Humidity operation (non-condensing): 10 – 90% GPR Sensor and DVL-500N operating temperature range: -40 to 50°C Do not use touch screen below -20°C. Use battery charger between 0 and 30°C.
Regulatory Specifications	EMC-FCC, CE, IC, ACA, RSM Safety-TUV, CE

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 and the web sites listed below.

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 graphically in Figure B-1.

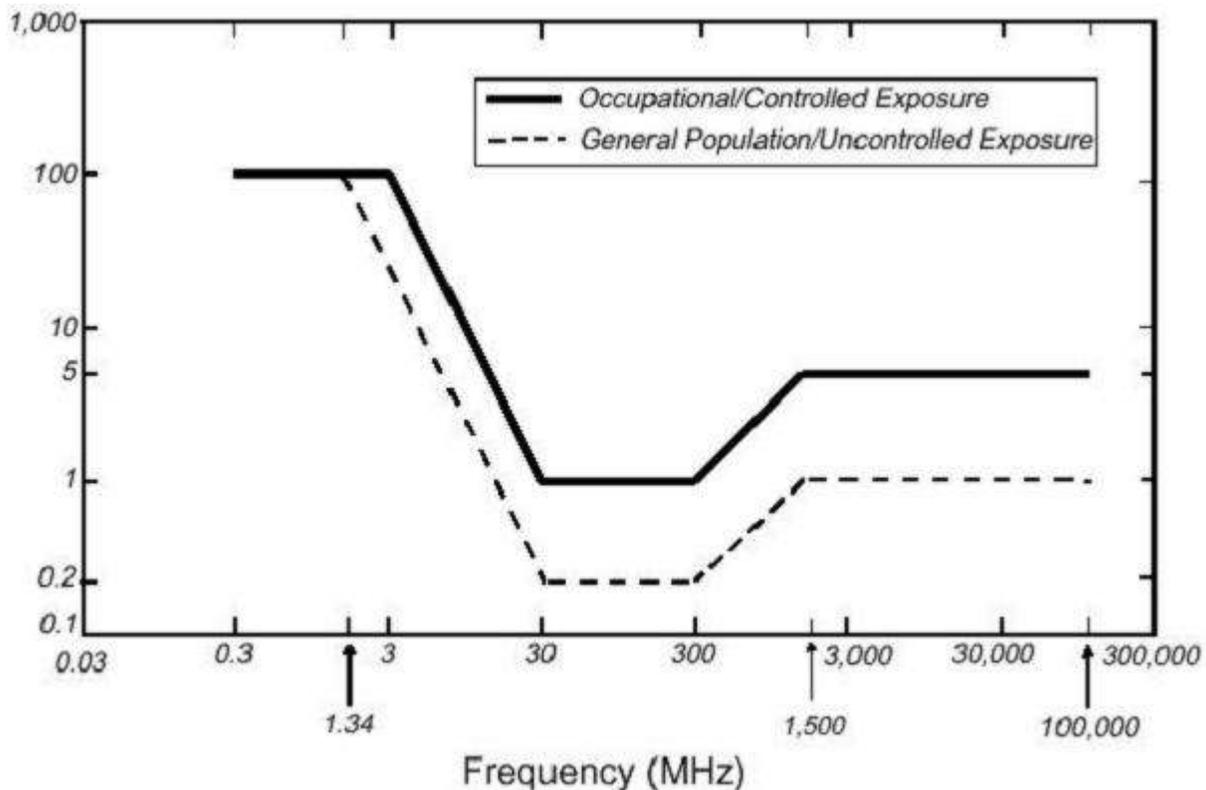


Figure B-0-1: FCC limits for maximum permissible exposure (MPE) plane-wave equivalent power density mW/cm^2 .

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.

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 test 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.

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: QJQ-NG250

EQUIPMENT NOMENCLATURE: NG250

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 its 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 dispositif

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: WiFi 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.