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EKKO_Project™ Pavement Structure Report Module

Ground Penetrating Radar Software

User Guide

2016-00071-02

SPX TECHNOLOGIES

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1 Introduction

EKKO_Project was designed to simplify the display, editing, processing, and interpretation of Ground Penetrating Radar (GPR) data.

The Pavement Structure Report module allows you to process polyline interpretations on subsurface layers and output a PDF report with cross-sections and statistics about the layers.

To use the Pavement Structure Report module, it is necessary to be familiar with the EKKO_Project software as well as the LineView and Interpretation modules; see the EKKO_Project and LineView Module User Guides.

2 Procedure for Creating Pavement Structure Reports

This section describes the procedure for creating Pavement Structure reports.

2.1 Opening Data

1. Open the EKKO_Project software.

2. From the **Getting Started** screen:

    a. If the GPR data was collected with a GPR system that outputs a GPZ file, open the GPZ file by selecting **Browse for Project File** and navigate to the folder containing the GPZ file and select it.

    b. If the GPR data was collected as lines with an older GPR system (pre 2012) that does not output a GPZ file, open the grid data by selecting **Add all Lines in Folder** and navigate to the folder and select it.

2.2 Correcting GPS

1. If GPR lines were collected on a high speed platform such as a SmartChariot, check all the GPR Line names in the **Project Explorer** and then use the **Tools > GPS > Latency** routine to correct the GPS positioning of the data. See the EKKO_Project manual for more information on how to calculate GPS latency.

2. If GPR lines were collected with a GPS that is offset from the center of the GPR sensor, check all the GPR Line names in the **Project Explorer** and then use the **Tools > GPS > Offset** routine to correct the GPS positioning of the data. See the EKKO_Project manual for more information on GPS offset.

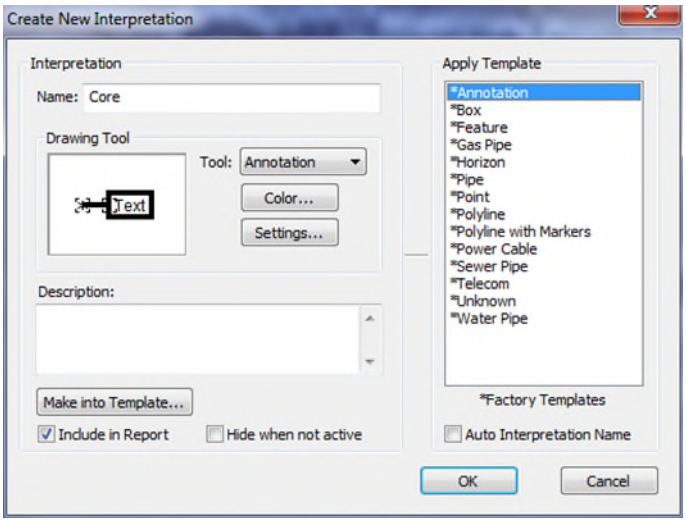
2.3 Opening a GPR Line

Display a GPR line in **LineView** by double-clicking on the name in the **Project Explorer.**

2.4 Adding Core Information

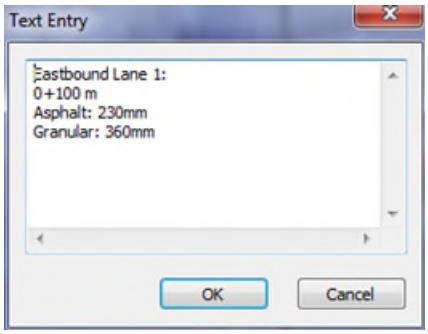
1. Add details from any cores close to the line. Having core information available before picking layers is optional but helps with data interpretation and the calibration of GPR velocity for the final report.

    a. Create a new interpretation for the cores under the **Interpretation > Create New Interpretation** using the “Annotation” template. Name the interpretation “Core1”.

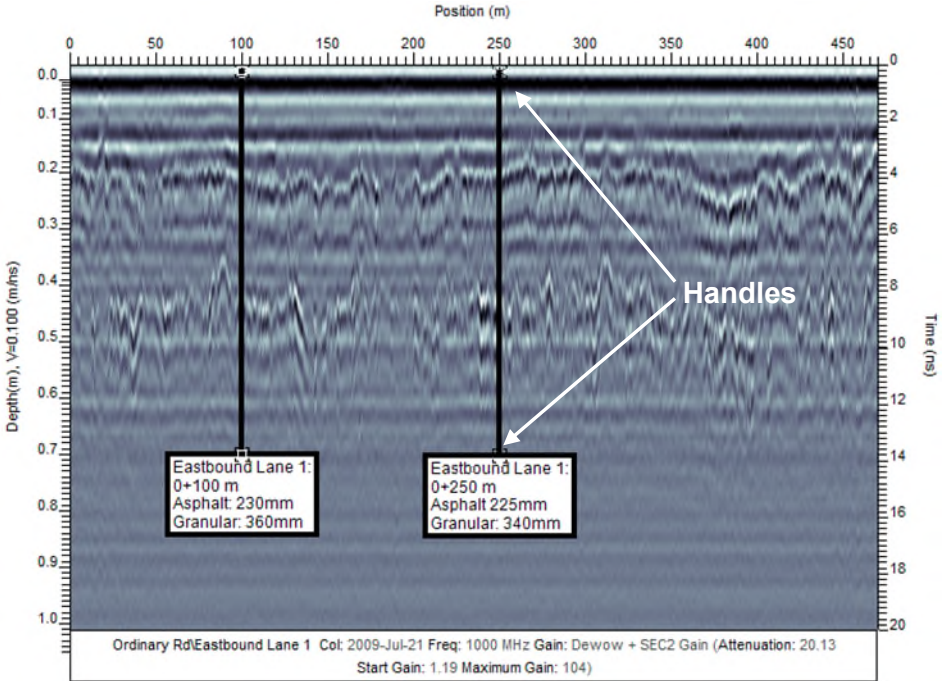


    b. When a new interpretation is created, **LineView** will automatically enter **Add Observations** mode. Place a new core log by clicking near the top of the cross-section at the correct line position, and dragging down so the text box will not cover boundaries in the data.

    c. In the text box that appears, enter the core details and press OK. Note that in the example below the thickness of each layer is given. The depth the layer occurs is the sum of that layer thickness and the thickness of all the layers above.

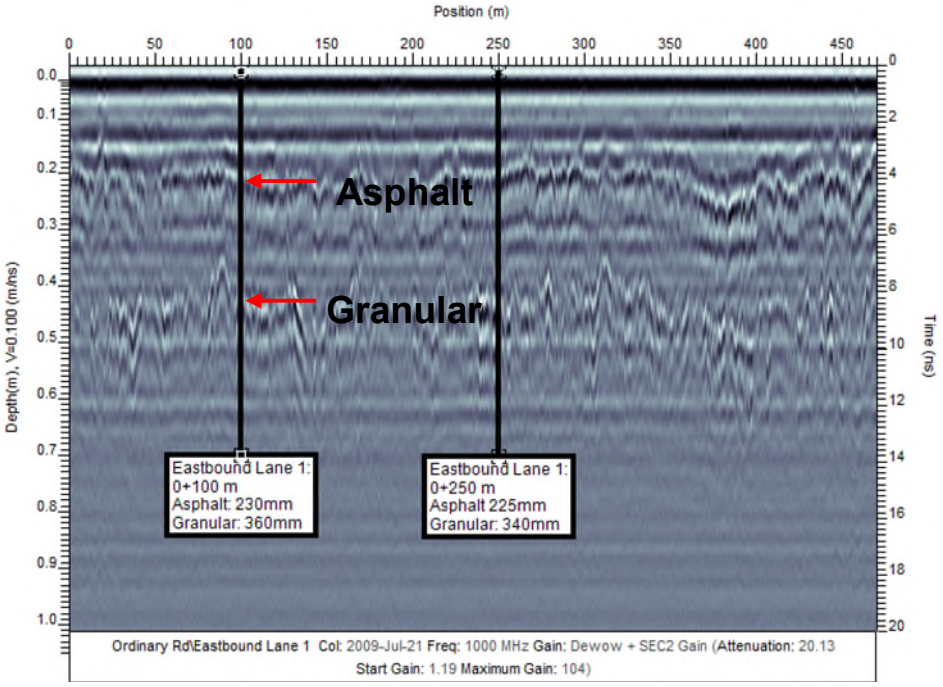


d. To move the annotation line, exit 'Add Observations mode by clicking the' button (). Then both the anchor point and the text box can be moved by clicking and dragging either handle on the annotation. Ensure that the black line is straight up and down, and at the correct line position for that core.



e. Repeat this process for all core data on the GPR line.

2. Looking at the cross-section image near a core will help to determine not only the order of the boundaries, but also the general appearance of each. Zoom in on one of the cores using the **Zoom Window** tool  and use the reported depth to determine which GPR boundary response corresponds to the bottom of the asphalt layer. Keep in mind that the core was likely not collected right on the GPR line so the core thickness may not correlate exactly to a GPR boundary response; pick the most likely one.



2.5 Setting the Background Subtraction Filter

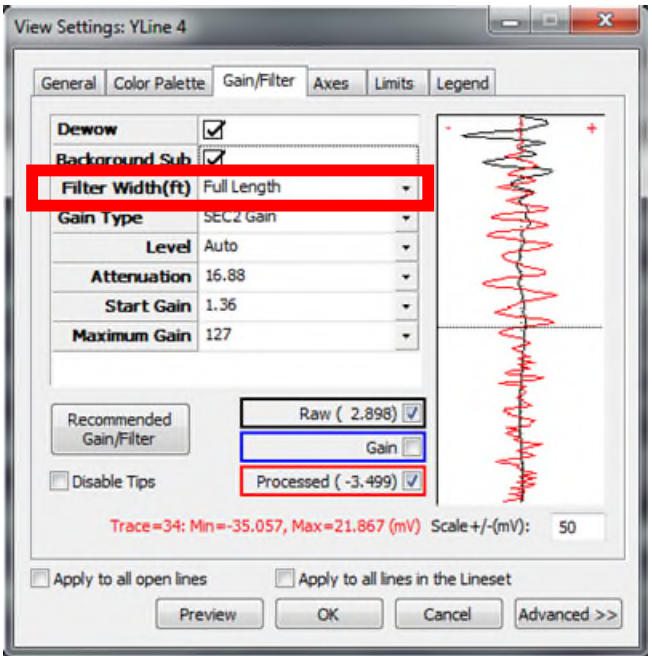
Depending on the data, it may be helpful to turn on the **Background Subtraction** filter to remove flat-lying bands in the GPR line that interfere with the boundary you are trying to pick; press the BKG SUB button.

If necessary, change the length of the filter:

a. Go to **View Settings > Gain/Filter Tab**.

b. Turn on **Background Subtraction** by checking the box next to the process.

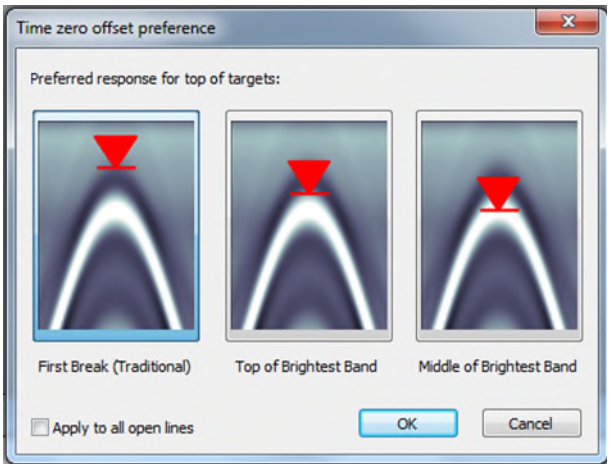
c. Set the **Filter Length** to “Full Length” and press **Preview** to see the effect. If banding is still present, reduce the Filter Length and Preview again. Be cautious of setting the Filter Length to a small value as this may filter out the boundaries you are trying to pick; experiment with different values.



d. Click **OK** to accept.

2.6 Setting the Boundary Pick Location

Use the **View > Time Scale Offset** option to set where on the boundary response you would like to pick.



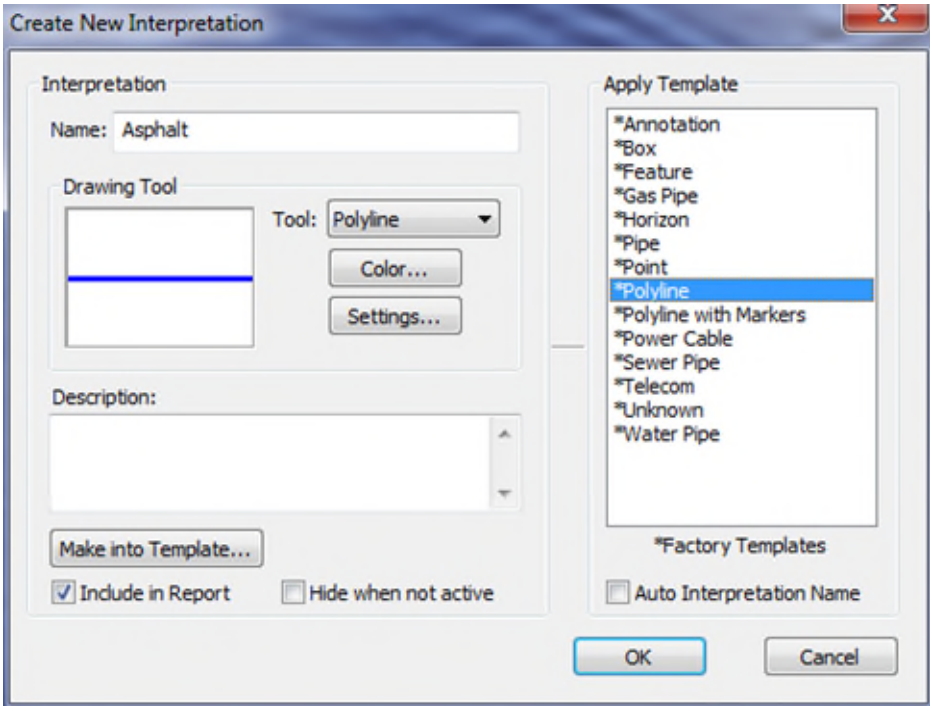
The options are:

a. First Break – at the very top of the highest band
b. Top of the brightest band
c. Middle of brightest band

Option C is used for the remainder of the images in this document but select the option you prefer.

2.7 Adding Boundary Interpretations

1. Create new interpretations for the subsurface boundaries under **Interpretation > Create New Interpretation**.
    a. Select the “Polyline” template and name the interpretation, for example, “Asphalt”.

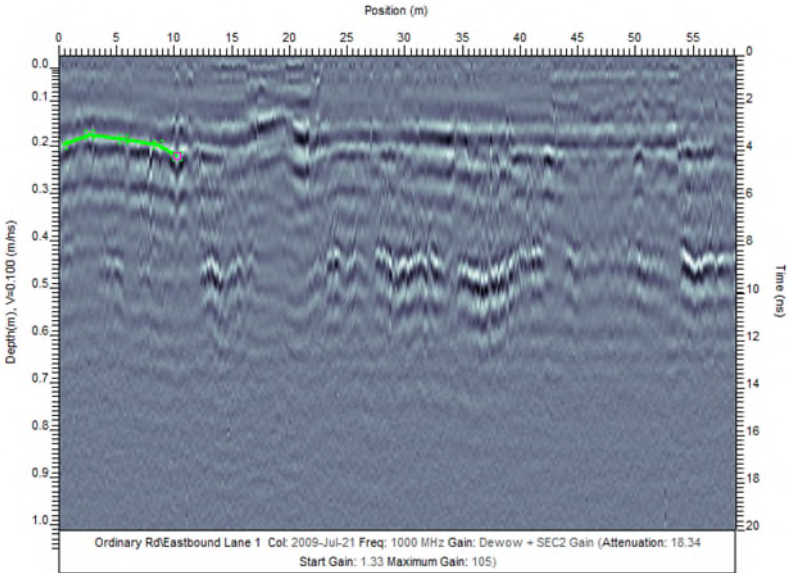


    b. Click **OK** to accept.

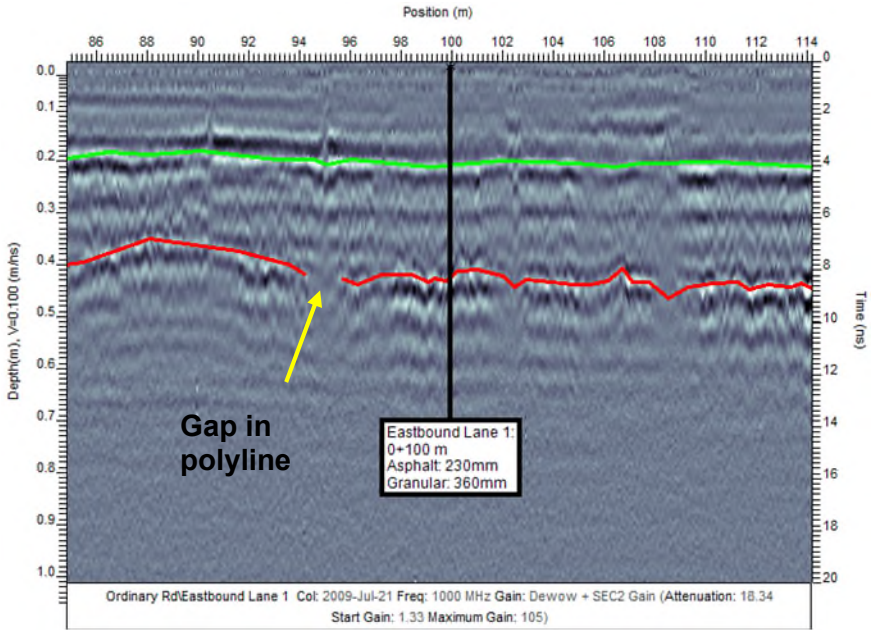
    c. Repeat this step for any additional boundaries to be picked in the data (i.e. Granular, PCC etc.)

2. When a new interpretation is created, **LineView** enters **Add Observations** mode automatically.

Now, starting at the beginning of the GPR line, place interpretations along the asphalt layer by clicking in the location selected above (2.4) The interval between clicks will depend on the amount of variation in the boundary (less picks in flat, consistent areas and more picks in areas with more variability), as well as the horizontal resolution desired. Generally, picking at roughly 2 to 5 meter intervals is sufficient to follow the interface.



3. A gap in the polyline can be placed at any locations where the interface is too faint to pick or where interference with other GPR responses makes it too difficult to follow the boundary by double clicking the last point. Then move the cursor to the next position where the boundary is identifiable and continue picking from there.



4. If a point is added at the wrong position, remove it by pressing “Delete” on the keyboard and trying again.

5. Once the bottom of Asphalt boundary has been picked, repeat the steps above for the Granular layer. This boundary is often more difficult to pick, with multiple areas needing to be skipped. To start working on a new boundary, select that interpretation from the interpretation drop down list.

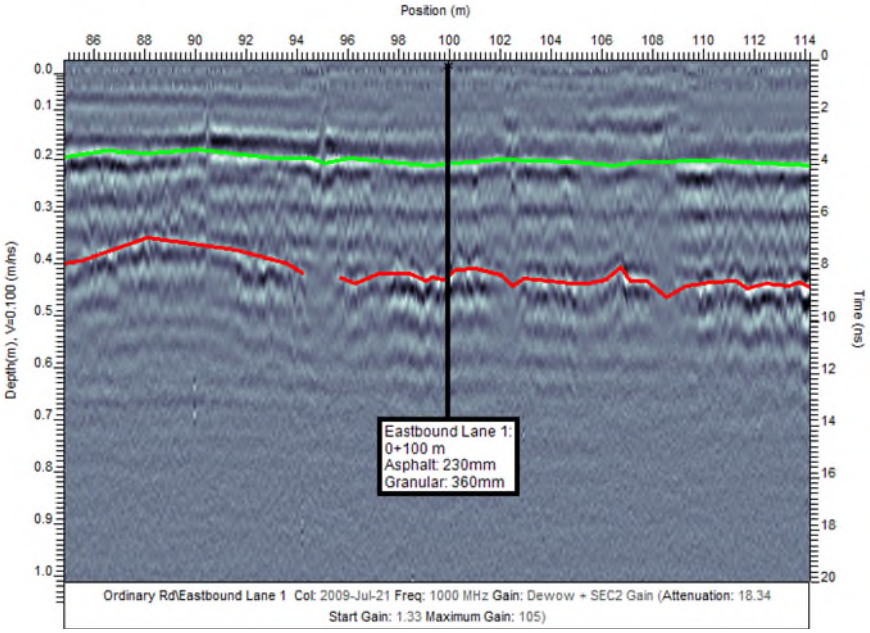
6. Open the next GPR line using the **Line Selection** drop down list, or close **LineView** and double-click the next line in **Project Explorer**. It is also possible to open all the GPR lines in the project by pressing the button  and then tile them all on the screen by pressing one of the tile buttons . Then select each one in turn and add observations.

2.8 Determining Velocity

1. To determine the layer depths accurately, the average signal velocity must be calculated for each layer.

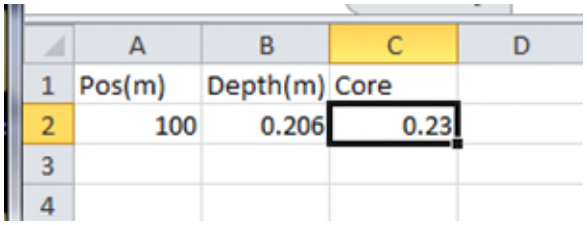
    a. Under **View > Settings > Axes** tab, set the velocity for the depth axis to 0.10 m/ns if the position units are **Metric** or 0.328 ft/ns if position units are **US Standard**.

    b. Zoom in on the first core location using the **Zoom Window** button .



2. Place the cursor directly on the Asphalt interpretation at the core location and press **Shift+F8** to copy the cursor coordinates to the clipboard. Open a Microsoft® Excel® spreadsheet and press **Ctrl+v** to paste the coordinates (including depth).

3. In the spreadsheet, delete all columns except Position and Depth, then beside the Depth add the measured depths from the core. Make sure that the granular depth is calculated by adding together both the asphalt and granular thicknesses:



	A	B	C	D
1	Pos(m)	Depth(m)	Core	
2	100	0.206	0.23	
3				
4				

4. Now, in cell D2, enter the following formula to calculate the velocity:
   =C2/B2*0.10 (if using Metric position units)
   =C2/B2*0.328 (if using US Standard position units)

5. Repeat this process for the remaining asphalt and granular cores on all GPR lines.

	A	B	C	D	E
1	Asphalt				
2	Pos(m)	Depth(m)	Core	Velocity	
3	100	0.206	0.23	0.11165	
4	250	0.2	0.22	0.11	
5	200	0.154	0.16	0.103896	
6	410	0.216	0.25	0.115741	
7					
8	Granular				
9	Pos(m)	Depth(m)	Core	Velocity	
10	100	0.431	0.59	0.136891	
11	250	0.445	0.55	0.123596	
12	200	0.452	0.6	0.132743	
13	410	0.416	0.52	0.125	
14					

6. Calculate the average of all asphalt velocities, and the average of all granular velocities.

7. Close **LineView** by pressing the X in the top right corner of the window and return to the main EKKO_Project screen.

2.9 Generate Pavement Structure Report

The Pavement Structure report requires:

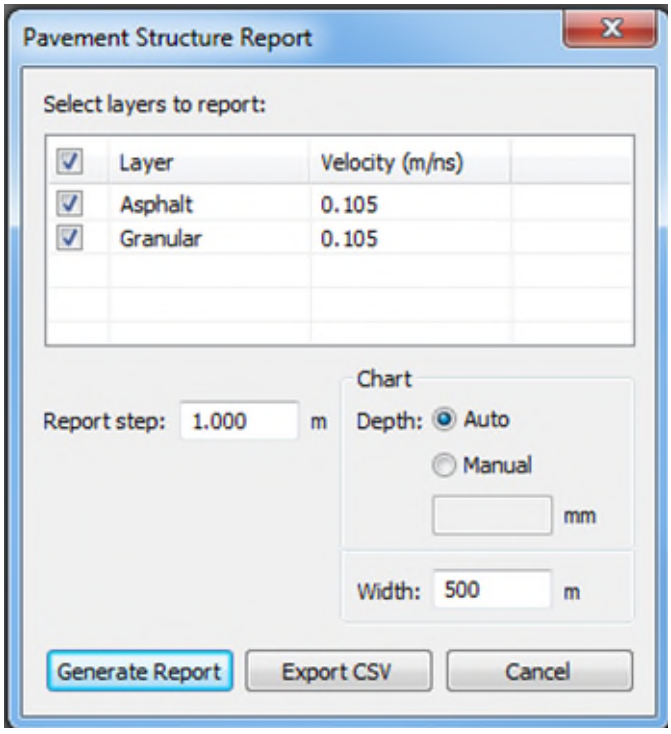
- The polylines placed in the GPR lines must not change order (shallow to deep)
- The report will not plot the thickness of layers under areas where portions of the shallower layers have not been picked

In **Project Explorer**, select the lines to include in the report by checking all the GPR lines with boundary interpretations. They will have a small "i" beside their names. If no GPR lines are selected, all the lines in the project with point interpretations are included in the report.

Select **Tools > Report > Pavement Structure Report** or select the Pavement Structure Report button from the Toolbar:



The Pavement Structure dialog opens:



Field	Description
Layers to Report	The dialog lists the names of all the polyline interpretations added to the GPR line(s). The default is to include all layers in the report but the user can uncheck any layers to ignore. Each layer has a velocity value. This is the average velocity from the surface to the bottom of the layer. An error message is generated if a velocity is used that is impossible, that is, it causes layers to switch the order they appear from shallow to deep.
Report Step	The distance between reported depth measurements along the GPR line. The smaller this value, the more detail there is in the charts in the report.
Chart Depth	The total depth to plot in the chart. **Auto** sets the maximum depth in the chart to the deepest point of the deepest layer. **Manual** allows the user to set the maximum value to plot. A manual value is often used so all GPR line structure charts are plotted to the same depth for easier comparison.
Chart Width	The total horizontal distance depicted in each Pavement Structure chart. Setting this distance allows all the data to be displayed on one chart or broken up into several charts with the specified width. Defaults to 500 meters or 1000 feet.
Generate Report	Select to generate the Pavement Structure Report.
Export CSV	Export the pavement layer depths to a .csv file. One csv file is created for each GPR line. This allows the user to import the data into third-party software for image generation and further analysis. If the thickness of a layer cannot be determined because the layers above were not picked, then those cells are blank.

Position(m)	Asphalt1(m)	Layer2(m)	Layer3(m)	Layer4(m)	Latitude	Longitude	UTM Easting (10S)	UTM Northing (10S)
0	0.18				37.4957	-122.3101	560988.261	4150084.267
1	0.181	0.202	0.31	0.287	37.4957	-122.3101	560987.151	4150084.654
2	0.183	0.204	0.296	0.297	37.4957	-122.3101	560986.115	4150085.017
3	0.185	0.205	0.294	0.296	37.4957	-122.3101	560984.968	4150085.411
4	0.187	0.203	0.311	0.283	37.4957	-122.3101	560983.945	4150085.764
5	0.186	0.204	0.322	0.278	37.4957	-122.3101	560982.807	4150086.152
6	0.185	0.203	0.337	0.267	37.4957	-122.3101	560981.681	4150086.537
7	0.184	0.2	0.353	0.259	37.4957	-122.3101	560980.602	4150086.905
8	0.184	0.198	0.356	0.266	37.4957	-122.3102	560979.555	4150087.28
9	0.183	0.196	0.353	0.267	37.4957	-122.3102	560978.411	4150087.67
10	0.18	0.196	0.345	0.267	37.4957	-122.3102	560977.38	4150088.036
11	0.175	0.199	0.336	0.27	37.4957	-122.3102	560976.298	4150088.419
12	0.17	0.206	0.345	0.262	37.4957	-122.3102	560975.244	4150088.785
13	0.175	0.204	0.356	0.252	37.4957	-122.3102	560974.079	4150089.203
14	0.184	0.196	0.368	0.243	37.4957	-122.3102	560972.994	4150089.591

After generating a report, a preview is displayed. There are several fields the user can add information and options to modify the amplitude image map. The Pavement Structure Report includes:

1. Road name and description including:
    a. number of lanes
    b. surface material
    c. surface condition
    d. additional information
2. GPR survey details including:
    a. GPR system
    b. GPR system configuration
    c. type of GPS
3. Overall Pavement Structure Summary listing:
    a. Layer Names
    b. GPR Velocities
    c. Minimum, maximum and average layer thicknesses for all GPR lines included in the report.
4. Individual GPR line pavement structure report
    a. Layer Names
    b. GPR Velocities
    c. Minimum, maximum and average layer thicknesses for that particular GPR line.

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GPR Pavement Structure Report

Save
Print

Road Name:

Pavement Example Data

Road Description

Number of Lanes:	2
Surface Material:	Asphalt
Surface Condition:	Fair
Additional Information:	

GPR Survey

GPR System:	NOGGIN
System Configuration:	SmartChariot
GPS System:	

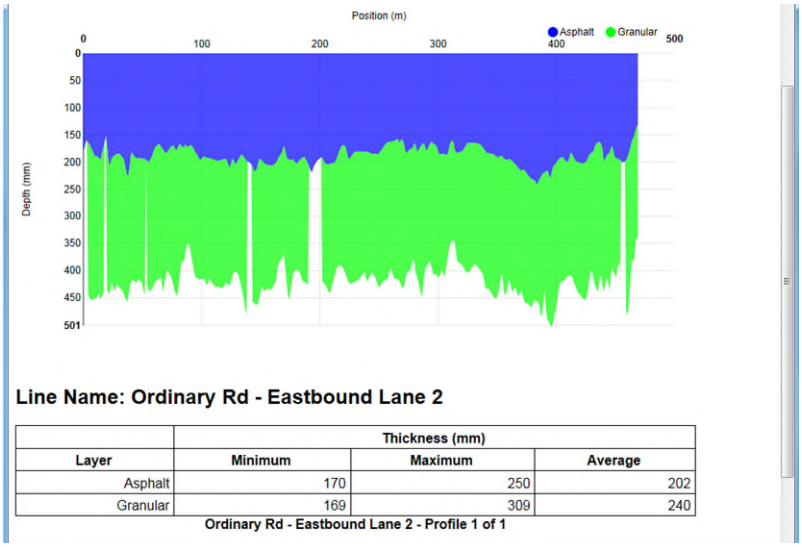
Pavement Structure Summary:

		Thickness (mm)		
Layer	Signal Velocity (m/ns)	Minimum	Maximum	Average
Asphalt	0.105	133	250	195
Granular	0.105	169	309	236

Line Name: Ordinary Rd - Eastbound Lane 1

	Thickness (mm)		
Layer	Minimum	Maximum	Average
Asphalt	133	240	188
Granular	170	289	233

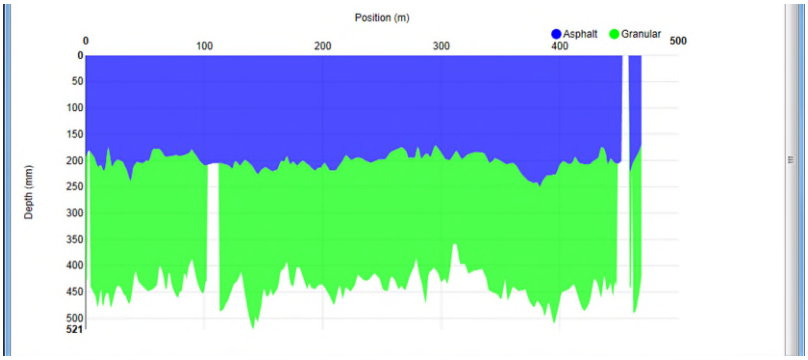
Ordinary Rd - Eastbound Lane 1 - Profile 1 of 1



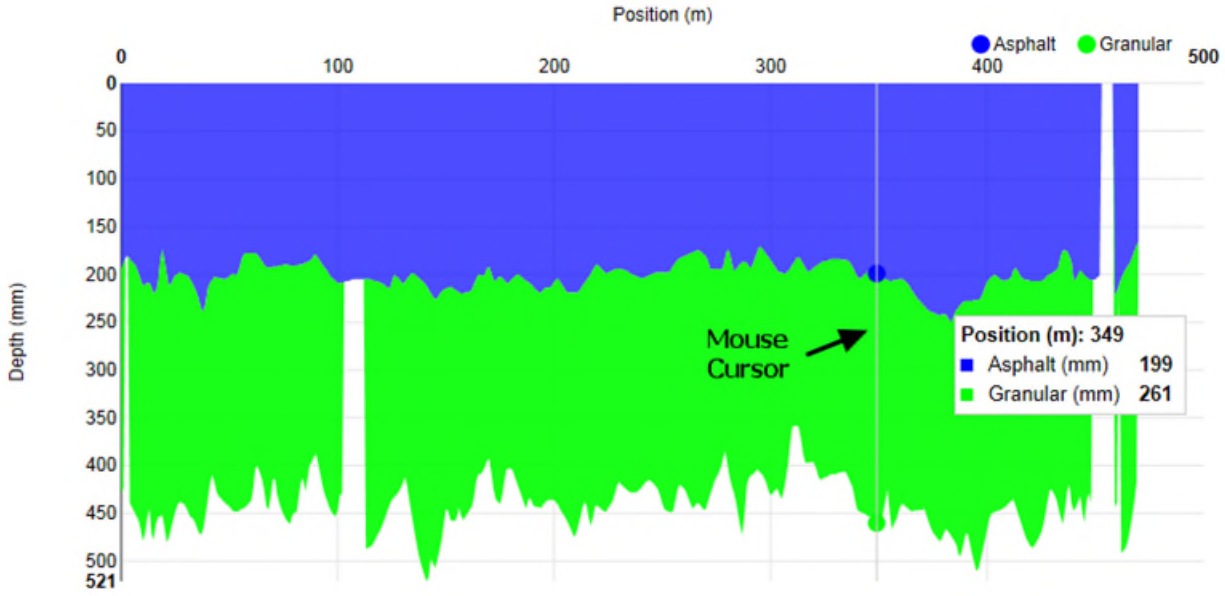
Line Name: Ordinary Rd - Eastbound Lane 2

	Thickness (mm)		
Layer	Minimum	Maximum	Average
Asphalt	170	250	202
Granular	169	309	240

Ordinary Rd - Eastbound Lane 2 - Profile 1 of 1



Field	Description
Save	Save the current report to an Adobe Acrobat PDF file.
Interactive Chart	Charts of layer thicknesses are interactive. Place the mouse cursor anywhere on the chart to display the position along the line and depth of each layer at that position.



Appendix A Glossary

1. Definitions

Term	Description
Attenuation	Represents the radar wave attenuation given in decibels/meter. The higher the attenuation value, the faster the exponential function rises the more gain applied at earlier times on the GPR Line.
Attributes	Characteristics derived from original data. Examples are the average amplitude of the dominant frequency between two times or depths.
Automatic Gain Control (AGC)	The Automatic Gain Control (AGC) gain attempts to equalize the amplitudes of all GPR signals by applying a gain which is inversely proportional to the signal strength. This type of gain is most useful for defining continuity of reflecting events.
Average Frequency Spectrum (AFS)	Use AFS plots to determine the frequency of a signal on which to base processing and filtering, similar to band-pass.
Average Trace Amplitude (ATA)	The Average Trace Amplitude (ATA) plot displays the average signal amplitudes (in microvolts) for an entire data file. This plot is a good way to display how rapidly the signal amplitude decays to the background level, giving you an idea of the maximum penetration for the data file.
Background Average Subtraction (BAS)	Use BAS to subtract the average trace of the entire GPR line from every trace in the line. This process enhances dipping events (such as hyperbolas from point targets) and removes horizontal responses common to all traces in the line. It is also used to remove the direct air and direct ground waves (transmit pulse) visible at the top of the line. BAS also removes horizontal bands in the data present throughout the length of the line.
Background Subtraction	Use Background Subtraction to apply a running-average background subtraction to the data set. This process enhances dipping events (such as hyperbolas from point targets) and suppresses or completely removes horizontal responses. This can be very useful for removing localized flat-lying events.
Bandpass Filter	Use bandpass filtering when the GPR signal is contained in a defined band of frequencies and there is "noise" energy in the remainder of the spectrum. Applying bandpass filtering enhances the desired signals at the expense of the out-of-band noise (Dewow). Bandpass is based on Fourier transform filtering concepts.
Dewow	The process of removing a very low frequency component from GPR data. These low frequency data components are associated with either inductive phenomena or possible instrumentation dynamic range limitations.

Term	Description
DynaQ	DynaQ is an advanced, patented technology that dynamically adjusts stacking as system speed varies. In most situations, moving the system at a comfortable speed stacks enough to generate good quality data.
Enveloping	Enveloping converts a trace from a wavelet with both positive and negative components to a monopulse wavelet with all positive components. The process removes the oscillatory nature of the radar wavelet and shows the data in its true resolution. Enveloping can also simplify radar section display making it easier to interpret.
Filter Type	Dictates the weighting the traces on the edges of the Filter Width have on the average trace calculation.
First Break Offset	The number of nanoseconds from the start of the trace to the first break.
GPS Files	Attaching a GPS file adds Latitude and Longitude, UTM coordinates, and GPS elevation to every trace in the GPR line. A GPS file is created by attaching a GPS system to the GPR system during data collection. GPS files contain lines of standard GPS positional output text (called NMEA strings) and the associated GPR trace number. When the GPS file is attached, latitude, longitude, and GPS elevations for every GPR trace are saved into the GPR file.
GPZ Files	Compressed files containing GPR lineset and grid data
Grid	A square or rectilinear set of straight lines which cover an area. Acquiring data on a grid means acquiring data along each line forming the grid. Acquiring data on a grid is a pre-requisite for creating depth or time slice images. Conventional notation is to use a Cartesian coordinate system with X and Y axes.
Highpass Filter	Removes frequencies below a cut-off frequency. Used for removing low frequency content in the GPR data; sometimes used instead of the Dewow filter. High Pass is a recursive filter designed for filtering GPR lines in the time domain. It is an infinite impulse response zero phase filter.
Interpretation Module	Interpretation module in LineView to create interpretations of Points, Polylines, Boxes, and Annotations, view them in GPR lines, and then output the interpretational information in reports.
KMZ Files	The KMZ files generated by a Noggin contain GPS information describing the path travelled during line collection. These files can be configured to display depth measurements along the line, making the data easier to interpret. Noggin enables you to export KMZ files which can be opened in Google Earth™.
Lineset	All GPR lines in a project contained in one folder; collections of GPR lines that may or may not be related to one another. Linesets can be edited to add or delete GPR lines. GPR lines in linesets can also be cut and/or copied and pasted into other linesets.

Term	Description
LineView	Shows GPR line data cross sections. Uses EKKO_View/Interp application modified to work with and get launched from EKKO_Project.
Lowpass Filter	Removes frequencies above a cut-off frequency - useful for removing high frequency noise in GPR data. Low pass is a recursive filter designed for filtering GPR lines in the time domain. It is an infinite impulse response zero phase filter.
Migration	The migration process applies a synthetic aperture image reconstruction process to the GPR line.
nanosecond	A nanosecond is 10^{-9} seconds (one billionth of a second).
Overlap	Overlap (% of slice thickness) between the adjacent depth/time slices.
picosecond	A picosecond is 10^{-12} seconds (one trillionth of a second).
Polylines	A polyline is a list of points, where line segments are drawn between consecutive points.
Polyline Output Interval	The horizontal distance (meters or feet) between points on any polylines in the project. To interpolate and list more points than just the input observation points, enter them text box. A common interval is the step size for the GPR line
Project Explorer	The Project Explorer is similar to Windows Explorer, which lists folders and files. In Project Explorer, grids and linesets are used just like folders in Windows, and GPR lines are similar to Window Explorer files.
Processing Module	The optional Processing module allows you to edit and process data, including cropping data, time filters, migration and gain. Popular processing streams can be saved as Recipes and applied to other GPR projects.
Properties Window	Displays details of each GPR line including acquisition parameters and associated files
Slice	Describes the GPR data in a depth slice when the data is displayed as a computer generated image. Normally shortened to slice.
SliceView (EKKO_Mapper)	SliceView creates and displays GPR depth slice maps quickly and easily. Using the systematic grid data acquisition process common to pulseEKKO PRO, Noggin, or Conquest systems, images at multiple depths are generated in minutes.
Spatial Filter	Spatial filters act on radar data in the spatial (or positional) direction. These filters use adjacent traces during the filtering procedure and alter the shape of the trace through various mathematical manipulations designed to enhance or eliminate certain features.
Spreading & Exponential Calibrated Compensation (SEC2)	SEC2 gain is a composite of a linear time gain and an exponential time gain which attempts to compensate for the spherical spreading losses and the exponential ohmic dissipation of energy in the GPR Line.

Term	Description
Time Window	The maximum time selected for viewing, processing or data acquisition along a line. The length of the time window in nanoseconds (ns).
Time Sampling Interval	The time in picoseconds at which the GPR signal is sampled. Often set automatically by the system based on GPR frequency.
Topography Files	A topography file is a text file containing GPR line positions and the elevations at those positions. When a topography file is attached to a GPR line, elevations for every GPR position are saved into the elevation field of the GPR trace header.
Trace Plot	View Traces when you want to display subtle features in the data file or view the effect of different editing and processing types have on individual traces. Viewing traces can help you determine whether time-zero point needs to be edited. Normally the time-zero point should occur at the first large deflection in the signal. If not, time scales and depth scales on section plots will be inaccurate.
Universal Transverse Mercator (UTM)	UTM is a geographic coordinate system that uses a 2-dimensional Cartesian coordinate system to give locations on the surface of the Earth. It is a horizontal position representation, i.e. it is used to identify locations on the Earth independently of vertical position, but differs from the traditional method of latitude and longitude in several respects.
UTM Zone	The UTM system divides the Earth between 80°S and 84°N latitude into 60 zones, each 6° of longitude in width.
UTM Zone Number	Zone 1 covers longitude 180° to 174° W; zone numbering increases eastward to zone 60 that covers longitude 174 to 180 East.
UTM Letter	Each zone is segmented into 20 latitude bands. Each latitude band is 8 degrees high, and is lettered starting from "C" at 80°S, increasing up the English alphabet until "X", omitting the letters "I" and "O" (because of their similarity to the numerals one and zero). The last latitude band, "X", is extended an extra 4 degrees, so it ends at 84°N latitude, thus covering the northernmost land on Earth. Latitude bands "A" and "B" do exist, as do bands "Y" and "Z". They cover the western and eastern sides of the Antarctic and Arctic regions respectively.
Velocity	Speed at which GPR signals travel. Velocity is a critical parameter when creating depth slice images and estimating target depth since velocity is used to convert travel-time to depth.
Vertical Filter	Applies a running average filter vertically (down the trace) to a GPR line. The signal is averaged by replacing the data value at a given point by the average data value over a window centered about that point. Its primary purpose is to reduce random or high frequency noise by acting as a low pass temporal filter.

2. Abbreviations

Abbreviation	Full Phrase
AFS	Average Frequency Spectrum
ATA	Average Trace Amplitude
AGC	Automatic Gain Control
BAS	Background Average Subtraction
GPR	Ground Penetrating Radar
GPZ	GPR Project Zip file
MAPI	Messaging Application Programming Interface
MHz	Megahertz
ns	nanoseconds
ps	picoseconds
SEC2	Spreading & Exponential Calibrated Compensation
UTM	Universal Transverse Mercator

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