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EKKO_Project™ Bridge Deck Condition Module

Ground Penetrating Radar Software

User Guide

2016-00070-02

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 Bridge Deck Condition Report module allows you to process point interpretations on the rebar in a bridge deck or other concrete structure and output a PDF report with an amplitude map image and statistics about the rebar in the structure.

To use the Bridge Deck Condition 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 Bridge Deck Condition Reports

This section describes the procedure for creating Bridge Deck Condition reports.

The report requires positioning information so it will only run if the GPR lines were collected in a grid or with GPS.

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 in a grid format with an older GPR system (pre 2012) that does not output a GPZ file, open the grid data by selecting **Add Grid** and navigate to the folder containing the GFP file and select it.

    c. 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 to Pick

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

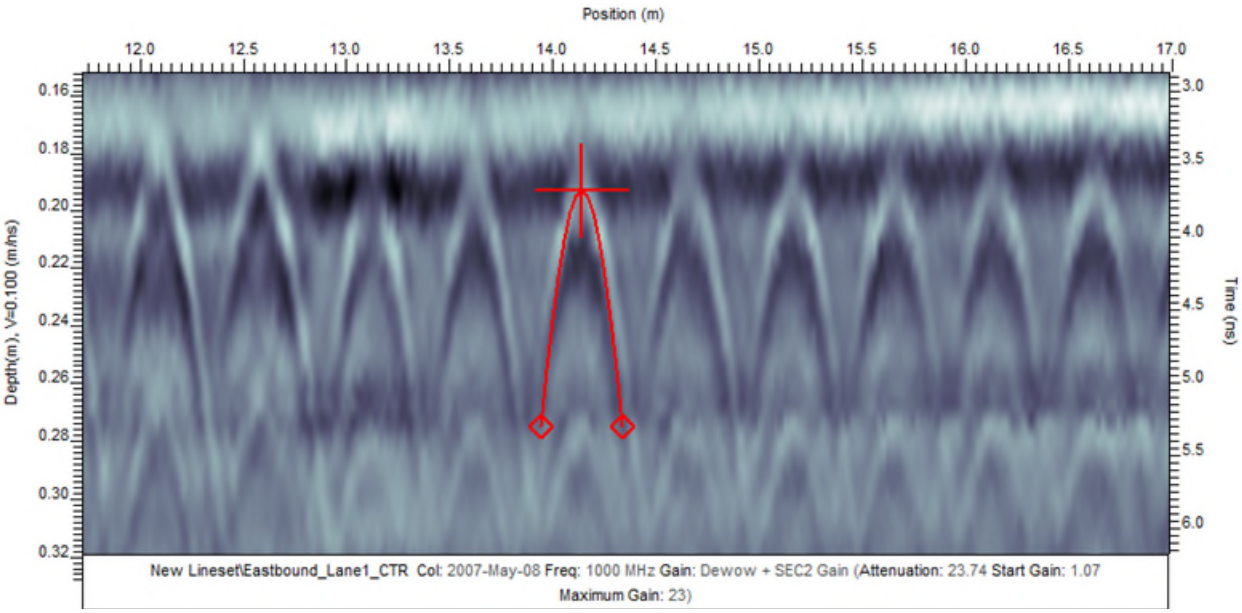
2.4 Determining Velocity

Determine the best velocity for the GPR line:

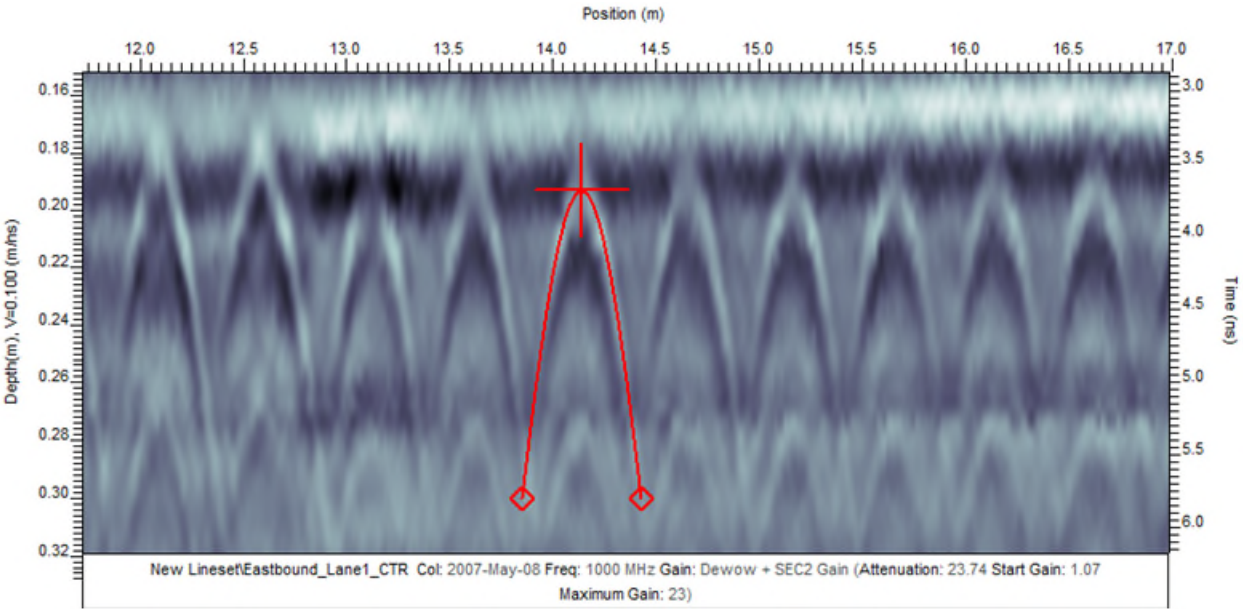
a. Zoom in on a section of reinforcing hyperbolic responses using the **Zoom Window** tool .

b. Turn on the **Hyperbola Velocity Calibration** tool .

c. Place the red hyperbola over a reinforcing bar hyperbola in the GPR line. Keep the cross-hair near the center of the strongest band, in this case the white one.

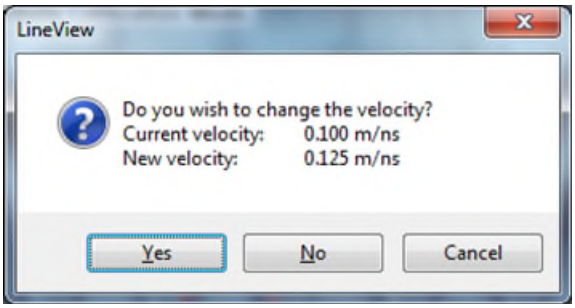


d. Click and drag the handles on the ends of the red hyperbola until it best fits the white band in the GPR line.



e. Move the red hyperbola to other targets to make sure the one you picked is representative of the rest of the reinforcing bars.

f. When you think the velocity is correct, click the **Hyperbola Velocity Calibration** button  to turn it off and accept the new velocity by clicking **Yes**.



g. Zoom back out to display the entire GPR line clicking the **Fit to Window** button 

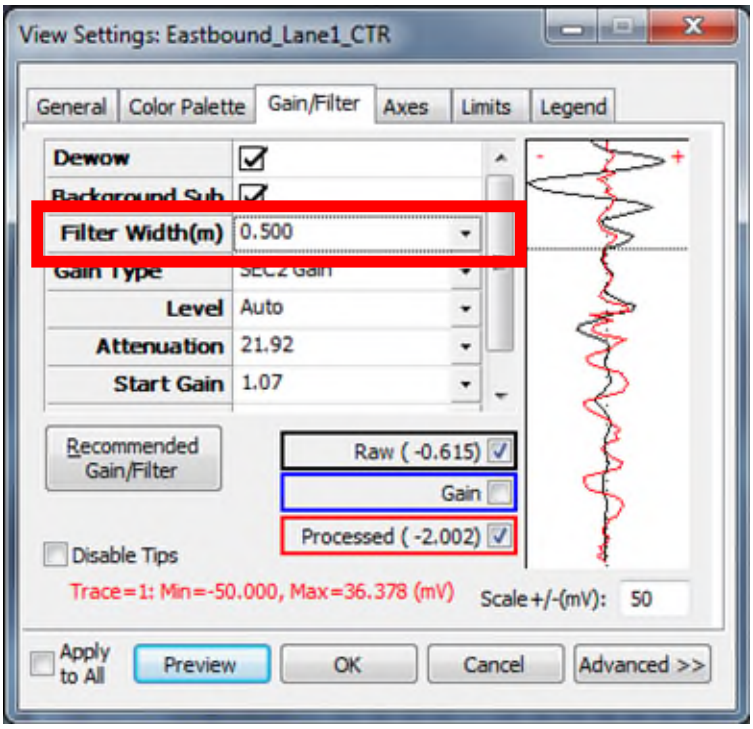
2.5 Setting the Background Subtraction Filter

Turn on **Background Subtraction** to remove flat-lying boundaries such as the bottom of asphalt.

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

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

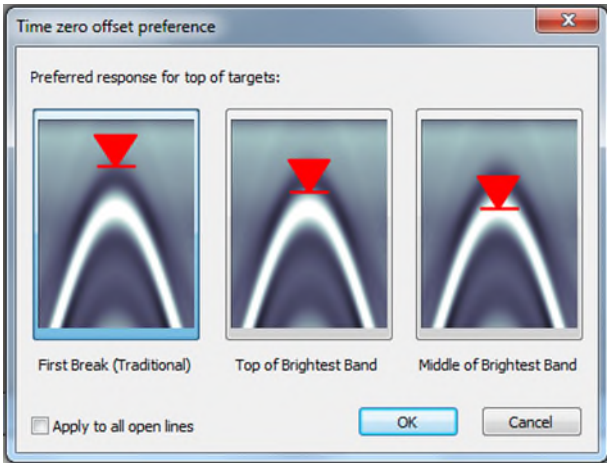
c. Set the **Filter Length** to a value small enough to make the hyperbolas stand out from the boundaries; 0.5 to 1 meter (1.5 to 3 feet) often works well but experiment with different values and select **Preview** to see the effect of the Filter Length.



d. Click **OK** to accept.

2.6 Setting Pick Location

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



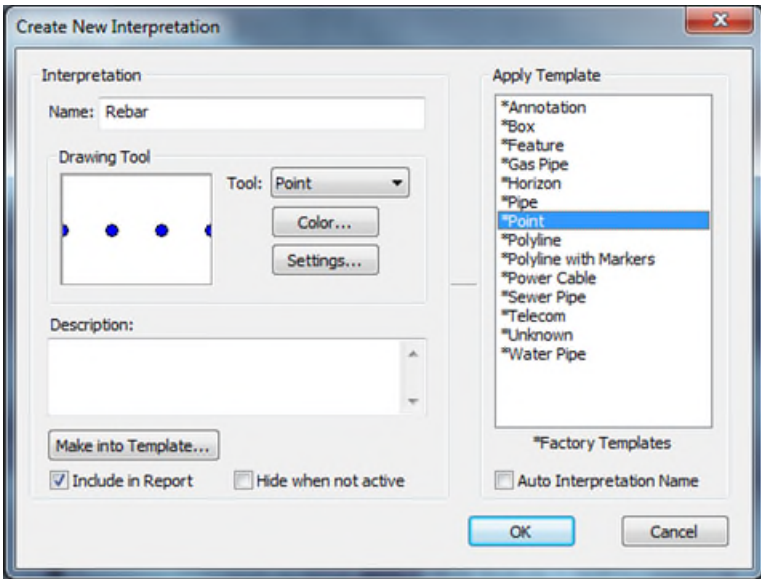
The options are:

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

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

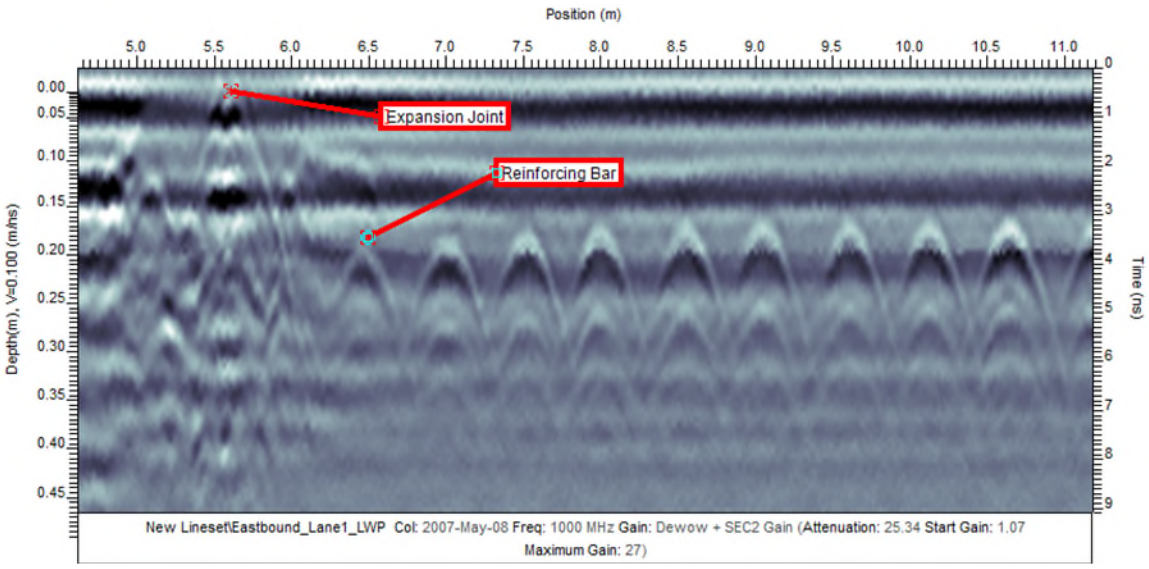
2.7 Adding Rebar Interpretations

1. Create a new interpretation for rebar under **Interpretation > Create New Interpretation**.
    a. Select the “Point” template and name the interpretation “Rebar”.

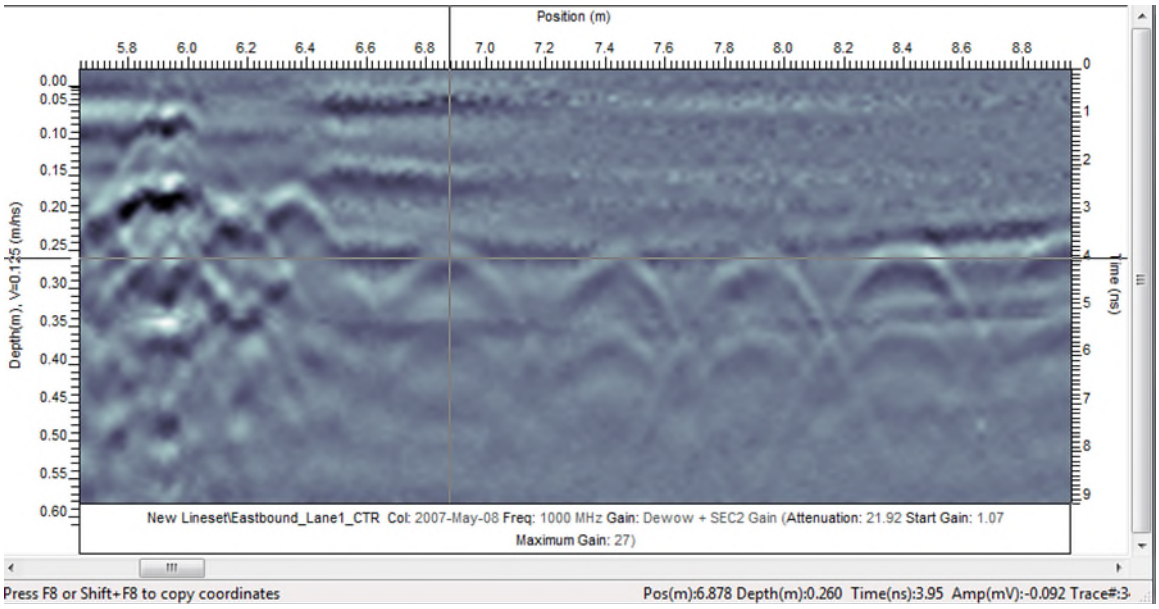


    b. Click **OK** to accept.

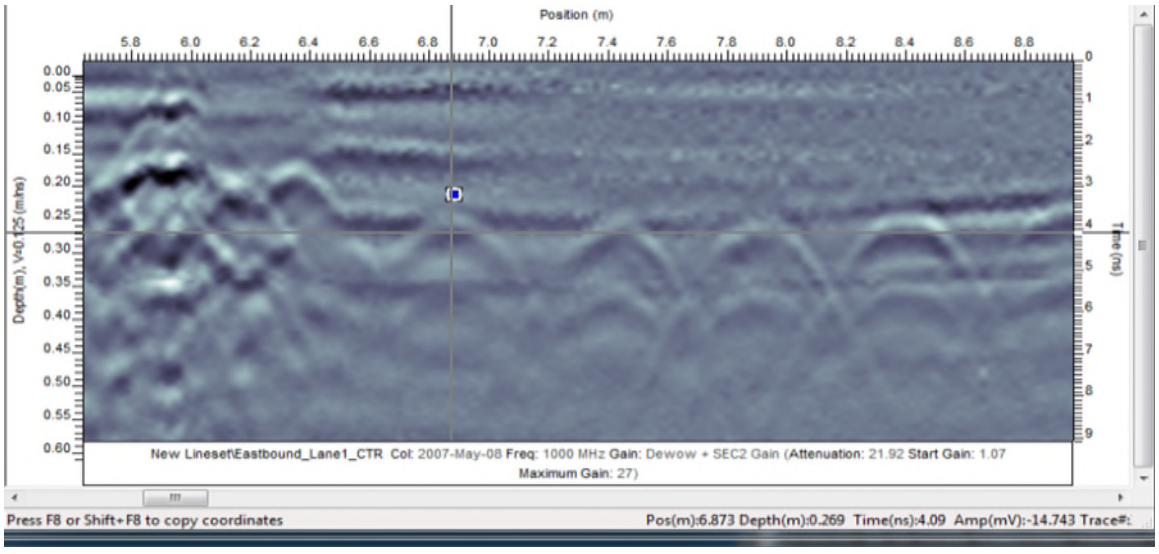
2. **LineView** enters **Add Observation** mode automatically. Turn on Smart Point mode by clicking the **Add Observation** button with the “**A**” on it . For bridge decks, pick the hyperbolic responses from rebar between the expansion joints.



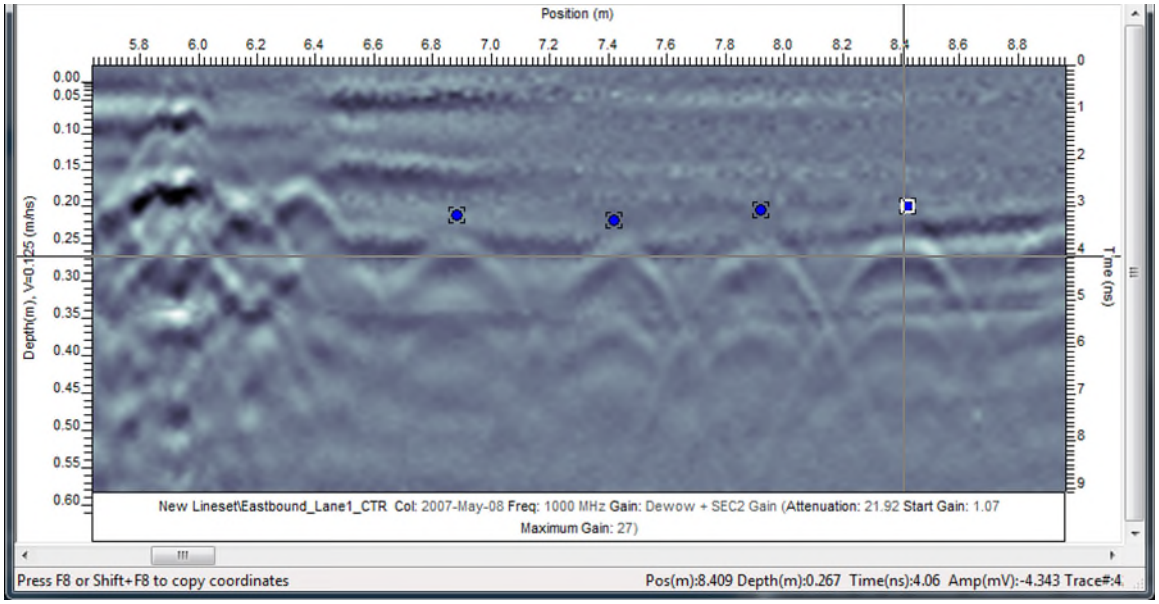
3. To pick a hyperbola, align the cursor with the center of the hyperbola, the white to black transition usually works well, and click.



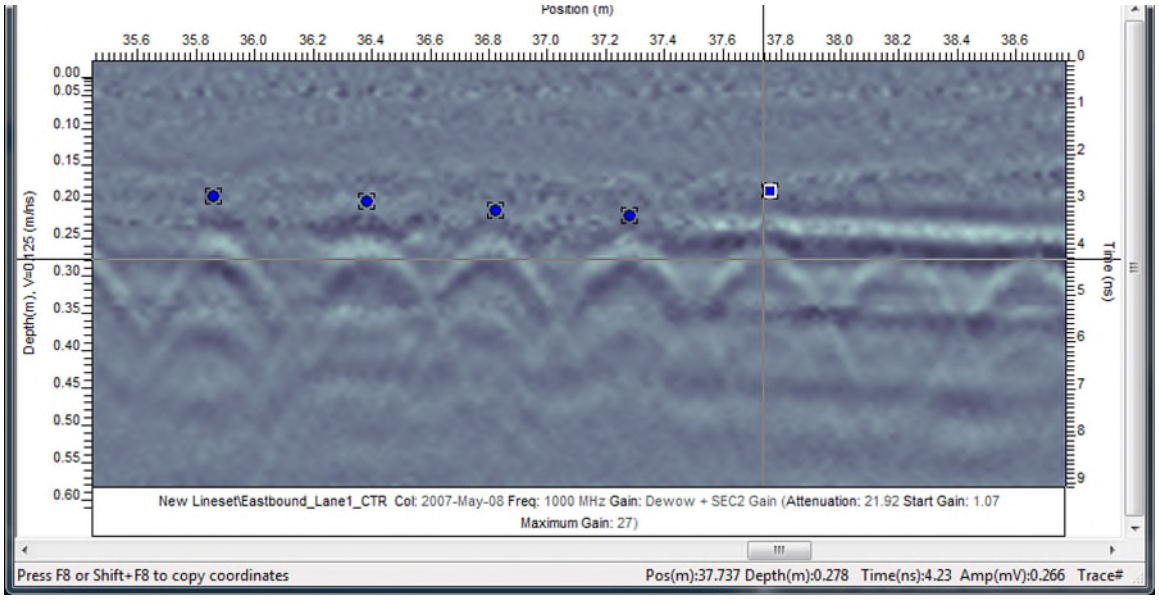
4. An observation is added at the very peak of the hyperbola. This observation represents the top of the target. The position of the Smart Pick on the hyperbola depends on the Time Offset Scale selection in step 8 above.



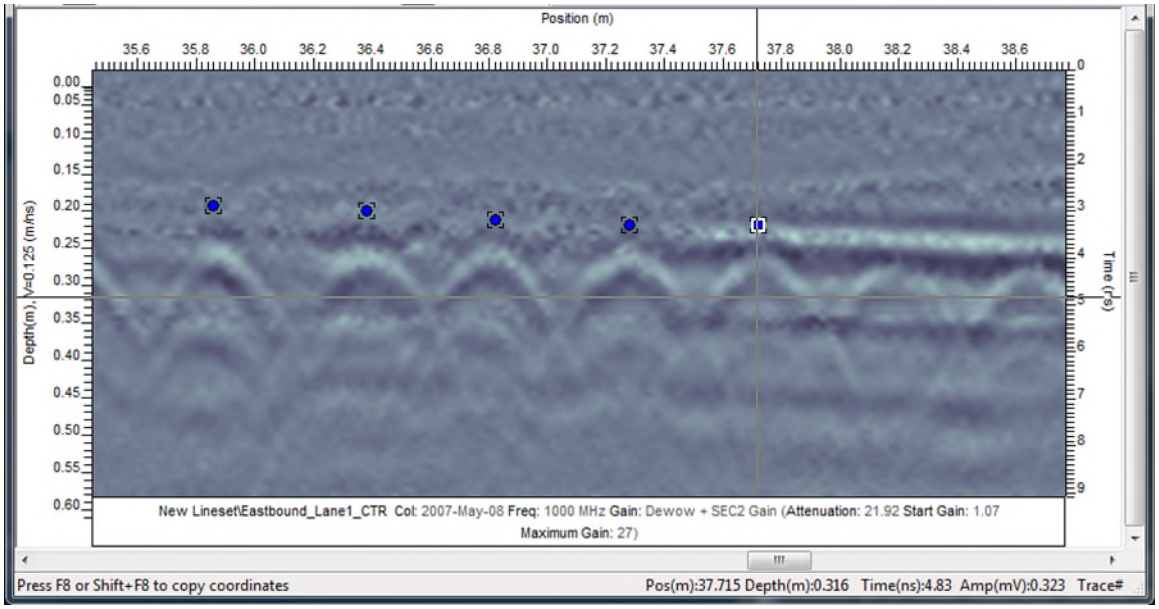
5. Continue picking each hyperbola from a rebar on the GPR line.



6. If an observation appears in the wrong position, remove it by pressing “Delete” on the keyboard and trying again in a slightly different location. You may find you need to pick some hyperbolas lower or higher depending on what other types of reflections are nearby. Here is an example of an observation which appears too high, probably due to interference of the layer above it:

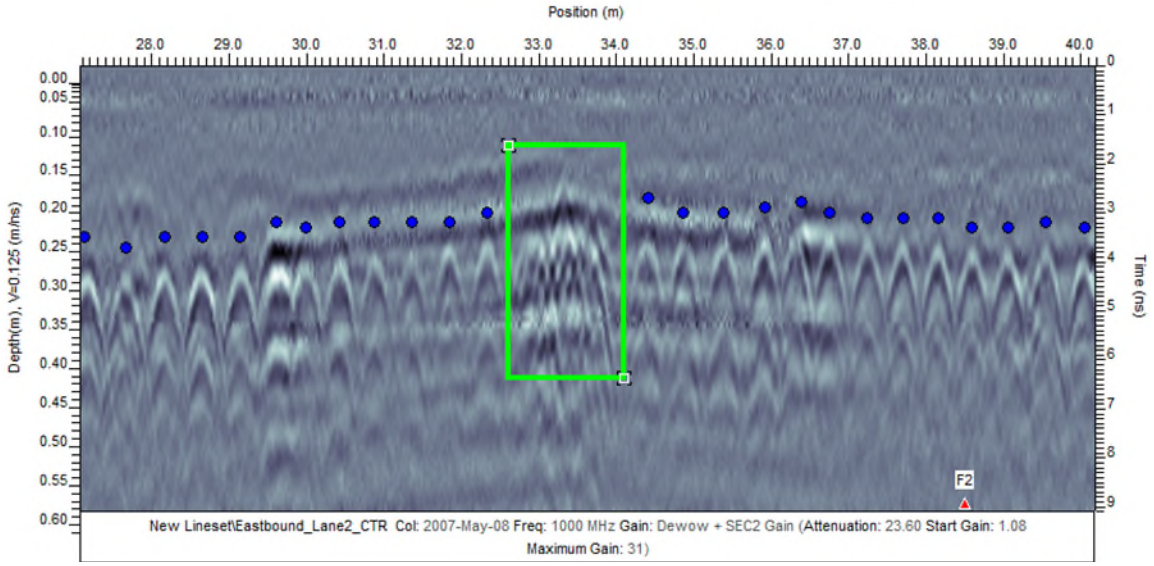


Press the **Delete** key to remove it, move the cursor down slightly and try again:



7. If the Smart Point has too much trouble with a hyperbola, switch to the normal **Add Observation** mode by selecting the  button and add the point manually. Try to add it at a location consistent with where the Smart Point tool picked on other hyperbolas.

8. Areas with rebar spacing much smaller than the surrounding rebar should NOT be picked; it is an area of the bridge deck with additional reinforcing.

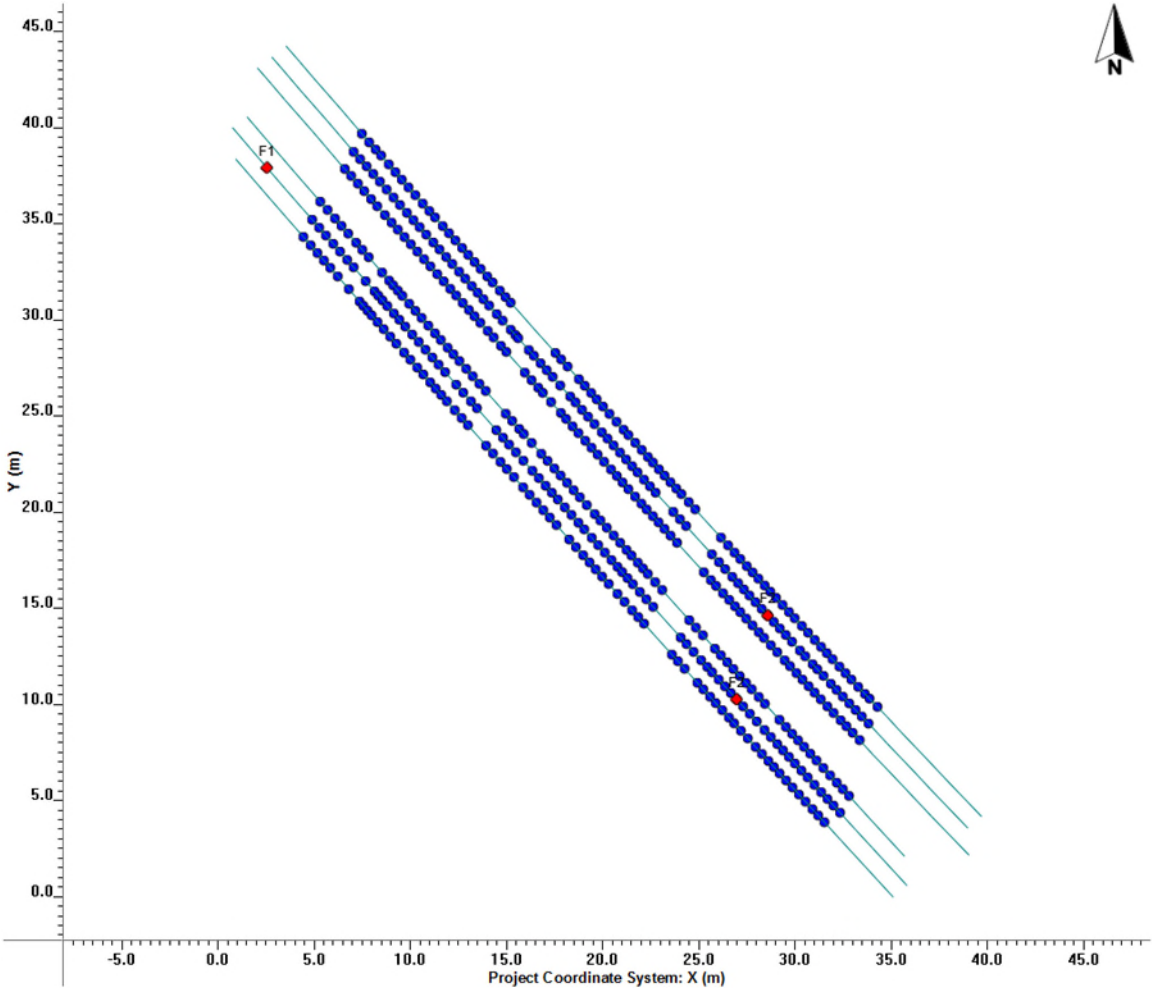


9. Once all hyperbolas on a GPR line are picked, open the next GPR line using the **Line Selection** drop down list, or close **LineView** and double-click the next line in **Project Explorer**. It is also possible to open all the GPR lines in the project by

pressing the button  and tile them all on the screen by pressing one of the tile buttons .

10. Follow the same procedures for setting the **Velocity** (Step 6) and the **Background Subtraction** filter (Step 7) on the new GPR line. Then pick the hyperbolas in the same way as described above.

11. Once all bars are picked close **LineView** and inspect the results in **MapView**:



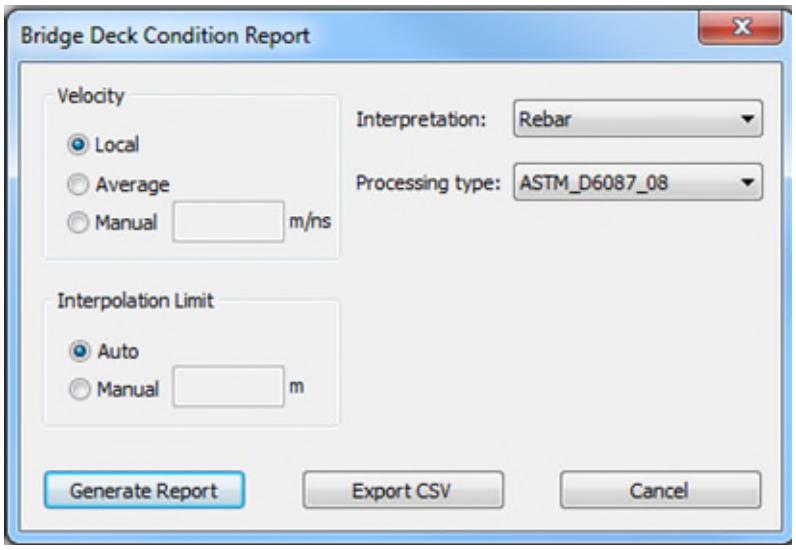
2.8 Generate Bridge Deck Condition Report

In **Project Explorer**, select the lines to include in the report by checking all the GPR lines with rebar 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 > Bridge Deck Condition Report** or select the Bridge Deck Report button from the Toolbar:



The Bridge Deck Condition dialog opens:



An error message "There is insufficient data to generate the bridge deck condition report" usually means that there are too few picked points in the data or they are too widely scattered to generate an amplitude map image and good statistics.

Field	Description
Velocity	Velocity used to migrate the rebar hyperbolas to point responses for amplitude analysis. Also used to calculate rebar depths. **Local** uses the GPR line velocities set in LineView (step 6 above). If not set in LineView, the default is 0.10 m/ns or 0.328 ft/ns. **Average** uses the average velocity of all the GPR line velocities set in LineView. **Manual** uses a velocity entered by the user for all GPR lines. If the velocity was set in each GPR line then **Local** is recommended.

Field	Description
Interpolation Limit	The Bridge Deck Condition Report generates an amplitude map image by interpolating data into the gaps between GPR lines. As the GPR line separation increases, interpolating data into the gap is less desirable as artifacts may be created in the image. If set to **Auto**, the value is calculated based on the average rebar spacing in the data set to provide a "solid" map image with few or minimal gaps. **Manual** uses an interpolation limit value input by the user. The interpolated Limit calculated by **Auto** is listed in the report. The user can regenerate the report using a **Manual** interpolation limit, if desired. It should normally be set slightly larger than half the line spacing.
Interpretation	Select the name of the Point Interpretation to process for the report (in this procedure it is "Rebar"). The dropdown lists all the "Point" interpretation names added to GPR lines in the project (or selected lines). Only one interpretation is used to generate the report.
Processing Type	**Absolute Amplitude** produces a map image plotted in signal amplitude values of millivolts (mV). Higher values indicate higher GPR signal amplitudes. **ASTM D6087-8** produces a map image of relative signal attenuation plotted in decibels (dB) based on the processing outlined in ASTM D6087-8 –"*Standard Test Method for Evaluating Asphalt-Covered Concrete Bridge Decks Using Ground Penetrating Radar*". Higher values indicate higher GPR signal attenuation. The ASTM based map image plots the relative attenuation in dB using the median of the top 10% of picked rebar amplitudes as a reference level.
Generate Report	Select to generate the Bridge Deck Condition Report.
Export CSV	Export the calculated amplitude value (in mV or dB), Latitude-Longitude and UTM coordinates for each picked rebar to a .csv file. This allows the user to import the data into third-party software for interpolation, image generation and/or further analysis.

X(m)	Y(m)	Amplitude(mV)	GPS Latitude	GPS Longitude	UTM Easting (17T)	UTM Northing (17T)
32.995	9.298	3.534	43.6236586	-79.6589786	608192.956	4830948
32.659	9.654	3.703	43.6236619	-79.6589827	608192.62	4830949
32.337	9.994	3.467	43.623665	-79.6589866	608192.298	4830949
32.015	10.335	3.285	43.6236681	-79.6589905	608191.975	4830949
31.678	10.691	2.904	43.6236713	-79.6589946	608191.639	4830950
31.324	11.07	2.608	43.6236748	-79.6589989	608191.285	4830950
30.984	11.435	2.383	43.6236781	-79.6590031	608190.945	4830951
30.675	11.767	1.691	43.6236812	-79.6590068	608190.636	4830951
30.369	12.096	1.518	43.6236842	-79.6590106	608190.33	4830951
30.058	12.432	1.532	43.6236872	-79.6590143	608190.019	4830952
29.727	12.789	1.793	43.6236905	-79.6590184	608189.688	4830952
29.437	13.102	0.803	43.6236934	-79.6590219	608189.398	4830952
29.076	13.496	2.15	43.623697	-79.6590263	608189.036	4830953
28.714	13.891	2.835	43.6237006	-79.6590307	608188.675	4830953
28.415	14.215	1.944	43.6237035	-79.6590343	608188.376	4830953

After generating a report, a preview is displayed. There are several fields in the report that are auto-filled with known information or the user can add information. There are also options to modify the amplitude image map. The Bridge Deck Analysis Report includes:

1. Bridge deck name and description including:
    a. number of lanes
    b. surface material
    c. surface condition
    d. expansion joints
    e. divided center median
    f. additional information
2. Bridge deck location description (user input) and the GPS coordinates of the center of the bridge deck
3. GPR survey details including:
    a. type of GPS
    b. GPR system
    c. GPR system configuration
4. Processing Summary listing:
    a. Processing Type (Absolute Amplitude or ASTM D6087-8)
    b. GPR Velocity
    c. Analysis Date
    d. Total number of rebar responses picked and processed to generate the amplitude image
    e. Interpolation Type (Auto or Manual with value listed)
5. Bridge deck rebar amplitude image:
    a. With user-selectable Color Palette
    b. Export to .png, .bmp or .jpg graphic file formats
    c. Amplitude range plotted can be set to Automatic (full range) or Manual (user sets the range)
6. Statistical summary of the rebar measurements including:
    a. Minimum, maximum and average amplitude
    b. Minimum, maximum and average rebar depth
    c. Minimum, maximum and average rebar spacing

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Bridge Deck Condition Report

Exit | Save | Export Image | Export to Google Earth

Color Palette: jet reversed
Range: Automatic / Manual
Min: 0.049 mV
Max: 5 mV
OK

Bridge Deck Name:

Main Street Bridge

Bridge Deck Description

# of Lanes:	6
Surface Material:	Asphalt
Surface Condition:	Fair
Expansion Joints:	Yes, 2
Divided Center Median:	Yes
Additional Information:	Dry and Sunny, 20 C

Location Description

Town of Smithville

GPR Survey:

GPS System:	TopCon SGR-1
GPR System:	NOGGIN
System Configuration:	SmartChariot

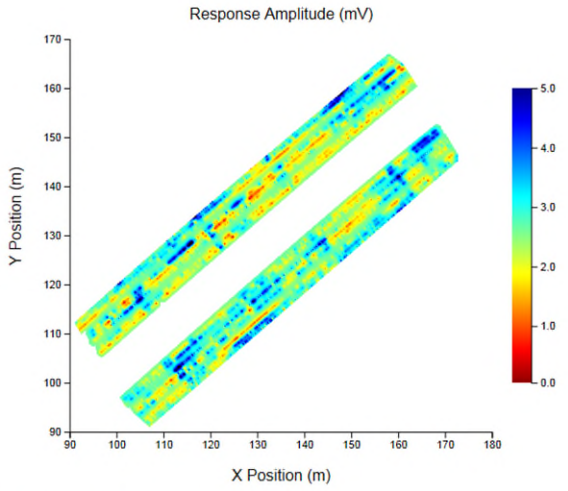
GPS Location(Center of bridge deck):

Easting: 601907
Northing: 4831788
Zone: 17T

Processing Summary:

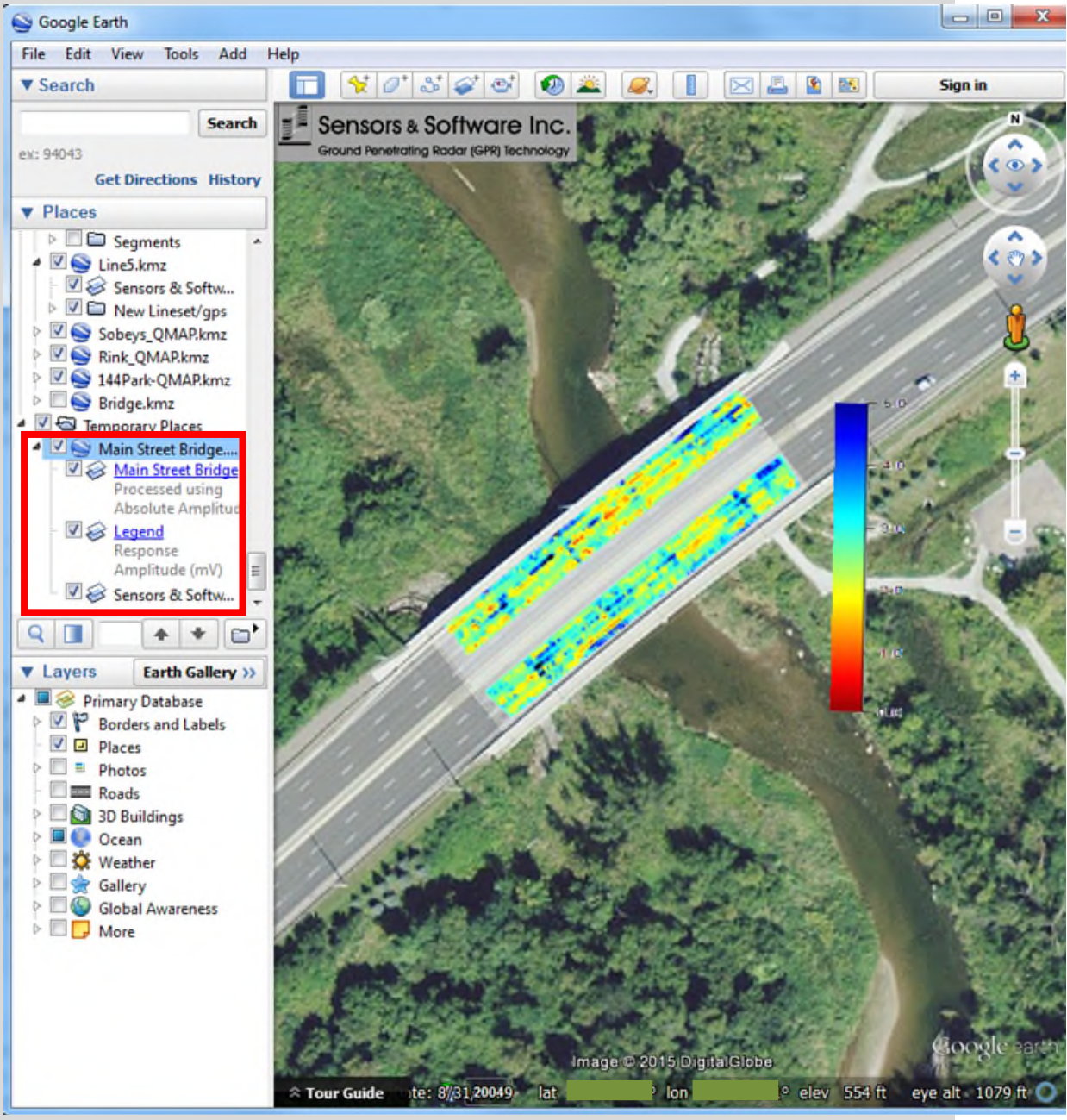
Processing Type: Absolute Amplitude
GPR Signal Processing Velocity: Local (0.083 - 0.100 m/ns)
Analysis Date: Friday, April 10, 2015
Number of measurements: 5480
Interpolation Type: Auto (1.021 m)

Bridge Deck Amplitude Image:



Statistical Summary:

	GPR Amplitude (mV)	Reinforcement Depth (m)	Reinforcement Spacing (m)
Minimum	0.049	0.120	0.147
Maximum	7.923	0.206	2.010
Average	2.634	0.164	0.255

Field	Description
Save	Save the current report to an Adobe Acrobat PDF file.
Export Image	Export Response Amplitude map image to .png, .bmp or .jpg graphic file formats
Export to Google Earth	Export Response Amplitude map image to a .kmz file format so the image can be displayed in Google Earth™ at the survey location. The image elements can be modified in Google Earth™ using the checkboxes and other options under **Places > temporary Places**. 
Color Palette	Select a color map from the dropdown list to display the response amplitude image in various colors.

Field	Description
Color Palette Range	The range of amplitude values to display in the map image. **Automatic** uses the full range of calculated of response amplitudes in the data set. **Manual** uses the range set by the user. Changing the range is often used to emphasize high or low amplitude areas of the map or, if you want to compare maps from more than one bridge deck, setting a fixed range. The range can be narrowed to emphasize areas with low amplitudes in mV or high attenuations in dB. Typically, low amplitudes in mV or high attenuations in dB are displayed with strong colors such as red.

3 Bridge Deck Condition Interpretation

The degree of salt-induced corrosion of reinforcing is a major concern with concrete decks and similar structures in northern climates where salt is used for de-icing bridges. The presence of saline water and corrosion causes strong attenuation of GPR signals.

Two types of Response Amplitude displays are available in the Bridge Deck Condition Report:

- Raw amplitude displays GPR signal strength in millivolts (mV)
- Normalized display presents the data in decibels (dB).

The latter map is often referred to as a Deterioration Index map.

Map areas with low raw amplitudes (mV) or high attenuation (dB) indicate possible bridge deck deterioration.

The rebar data also provide useful statistics including the minimum, maximum and average amplitudes, rebar depth and rebar spacing.

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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