


SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Advanced Methods to Identify Asphalt Pavement Delamination (R06D)

Minnesota DOT Evaluation

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U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

Acknowledgement

FHWA/SHRP2 (3D GPR equipment)
MnDOT District Offices

SHRP2 R06D Project Goal (2009-2012)

Identify and develop NDT technology that can:

- Detect delamination in HMA
- Operate at reasonable traveling speed
- Cover full lane width

Two devices (three methodologies) were identified:

- 3DGRP from 3D Radar
- Sonic Surface Scanner – S^3 from Olson Engineering

Impact Echo (IE) test and Spectral Analysis of Surface Waves (SASW)

GPR by 3D Radar

SASW-IE Rolling Meter

R06D Implementation Assistant Program(IAP) (2016-2019)

- Objective
  - Help state departments of transportation (DOTs), metropolitan planning organizations (MPOs), and other interested organizations deploy SHRP2 Solutions.
- 6 State DOTs Selected
  - Caltrans; FLDOT; MNDOT; NMDOT;TXDOT; KYDOT
  - 3DGPR: All DOTs
  - SASW/IE: Caltrans; KYDOT; NMDOT; TXDOT

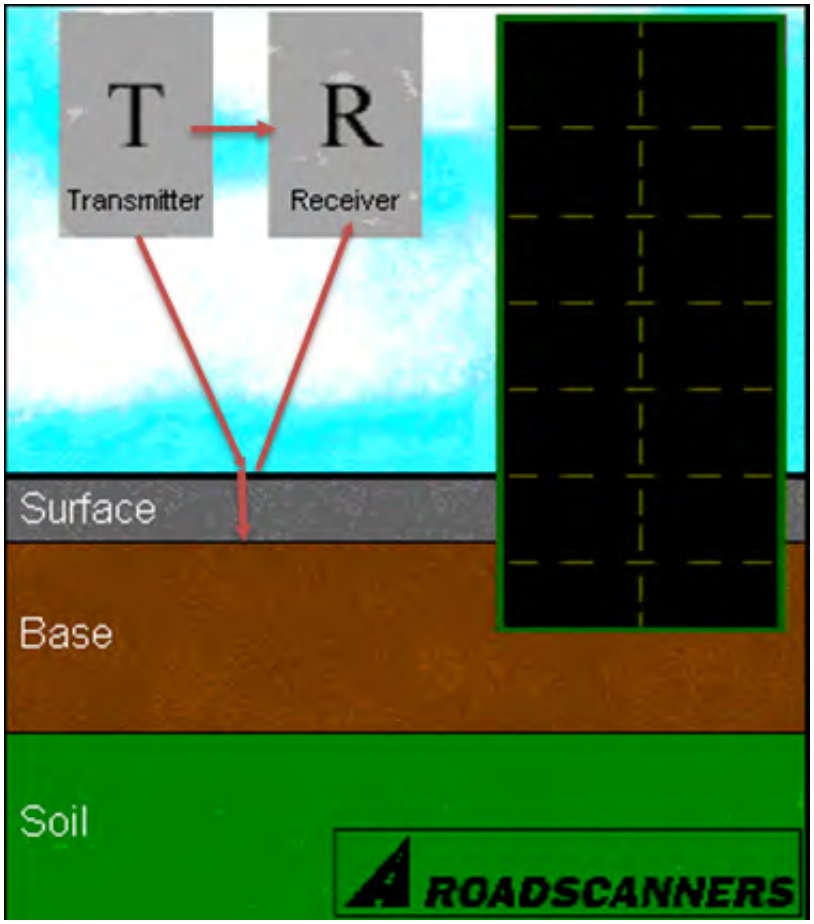
FHWA provided funding and technical assistance

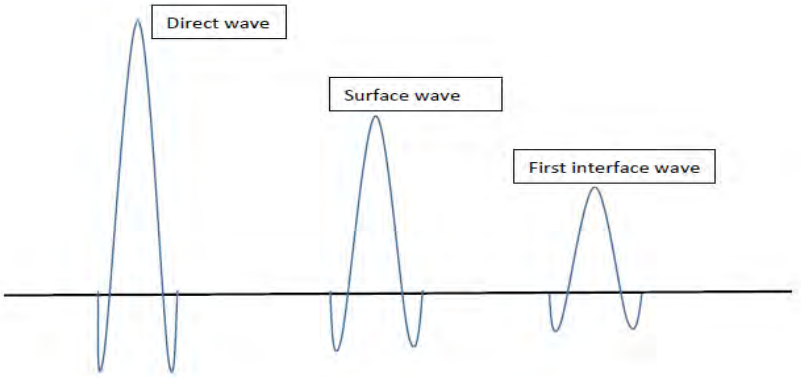
Background

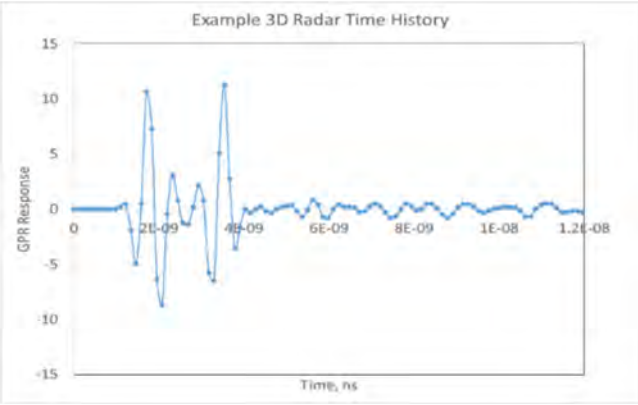
- Stripping in asphalt pavements a major problem in MN
  - Server freeze-thaw cycles
- Traditionally use cores to assess
  - Isolated locations, not full pavement assessment
  - Need a full coverage method: GPR has great potential.
- Important to locate stripping areas
  - Pavement rehabilitation strategy
    - FDR or M/O
  - Milling depth

Basic principal of GPR

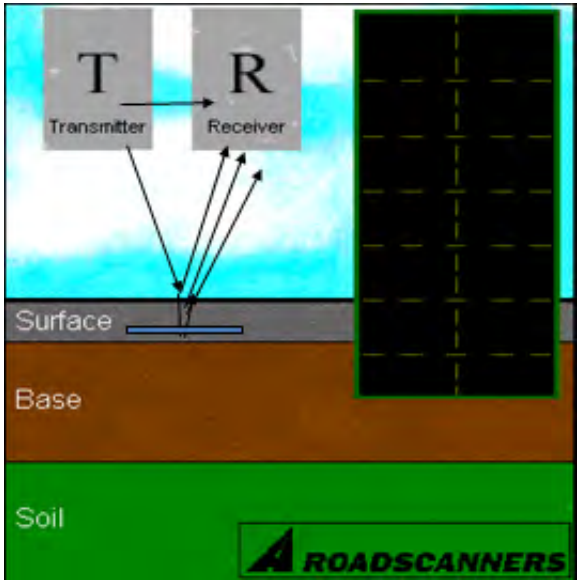
- Wave propagation in solids

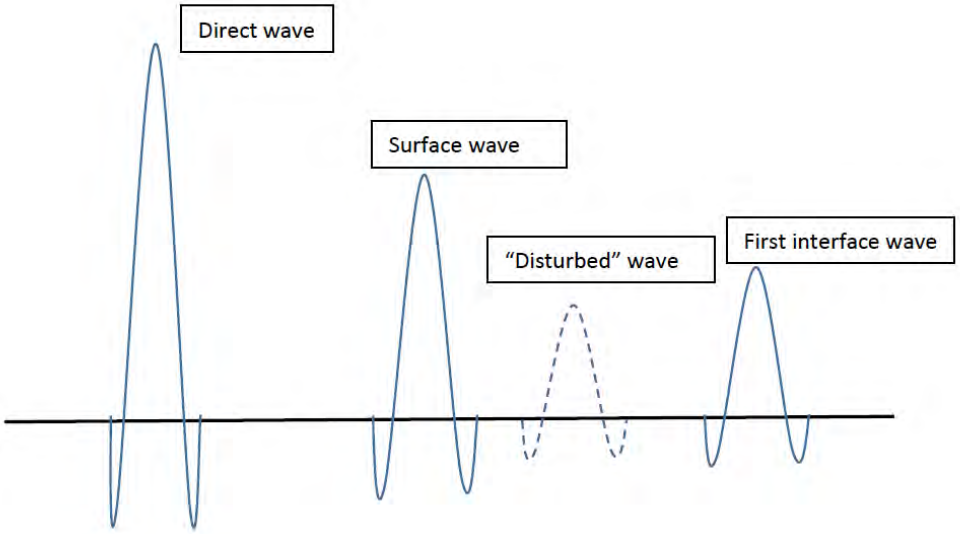




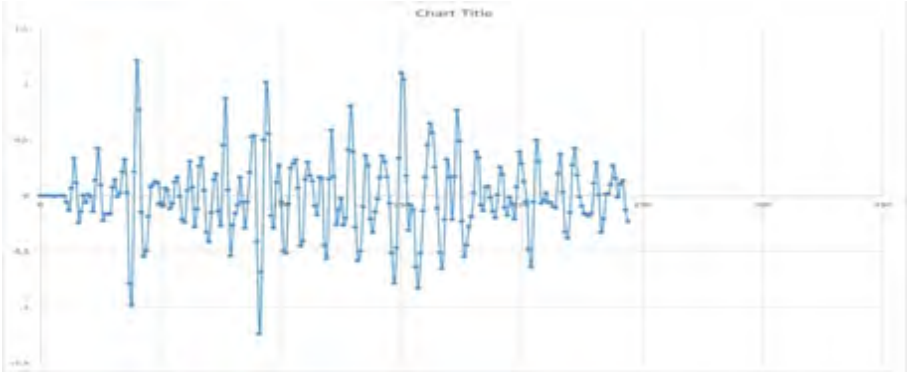


A Layered System with Defect (Stripping)





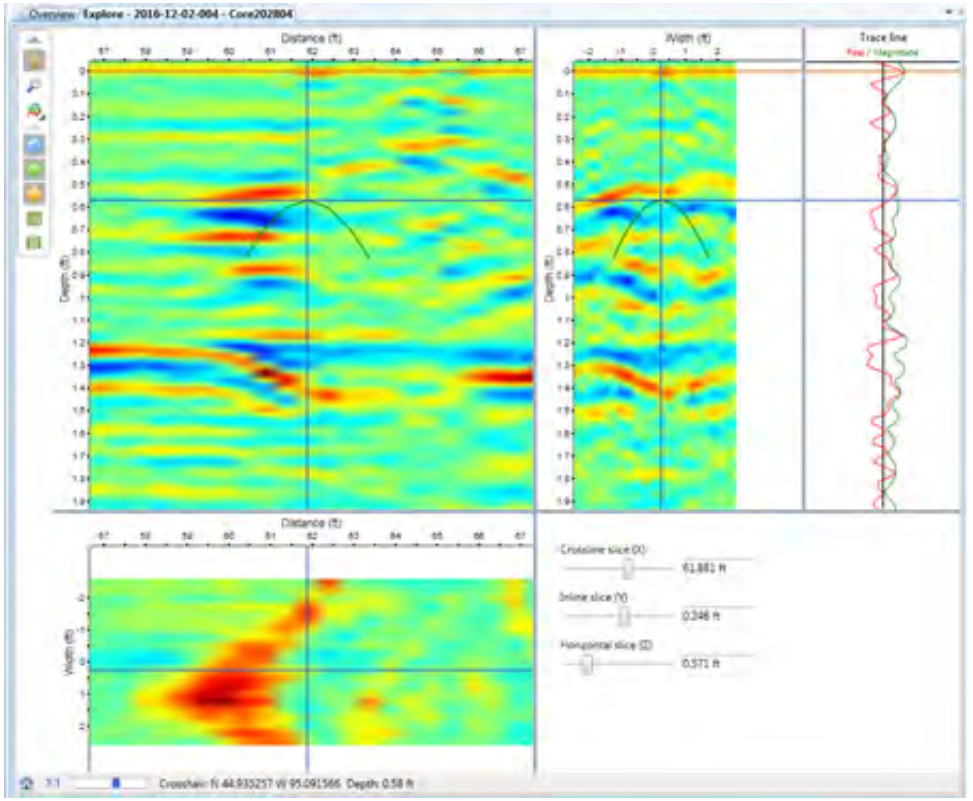
- **Real Signal Contains Noise**
  - Noise makes "disturbed" waveform less visible



3D-GPR --- FHWA (3D-Radar)

- Multiple Antenna

Software -- Examiner



Calibration/Validation

- Controlled Laboratory Tests: Antenna Variation
  - Air Calibration
  - Metal Calibration
  - High Density Polyethylene(HDPE) plastic:

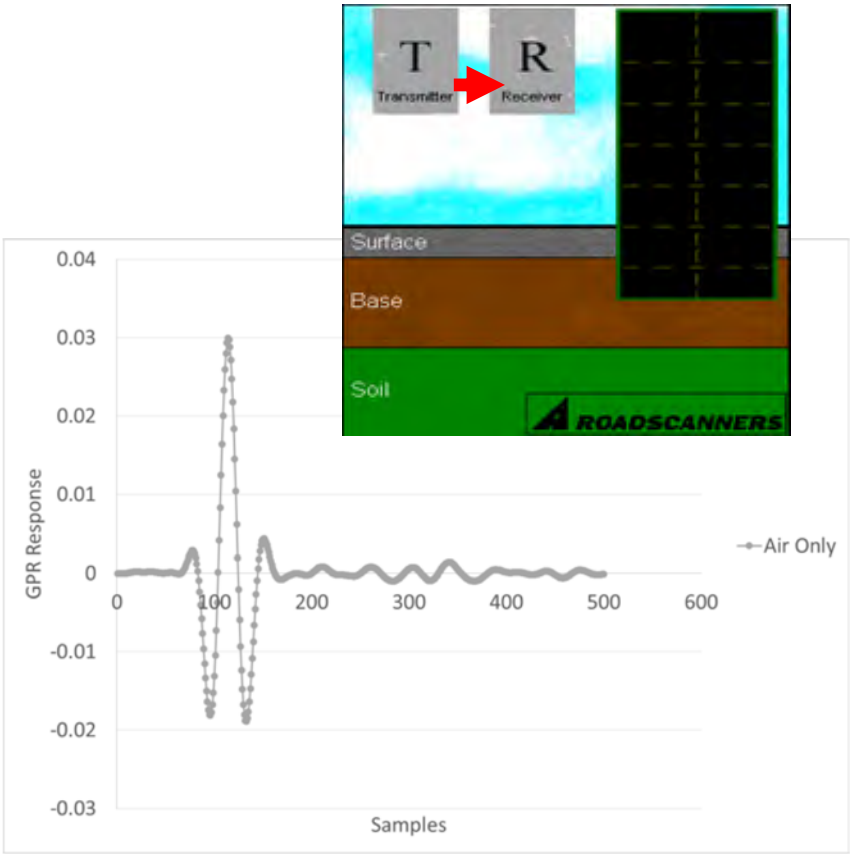
    e=2.3-2.35

Controlled Laboratory Tests: Air Calibration

Extract “Air Wave”

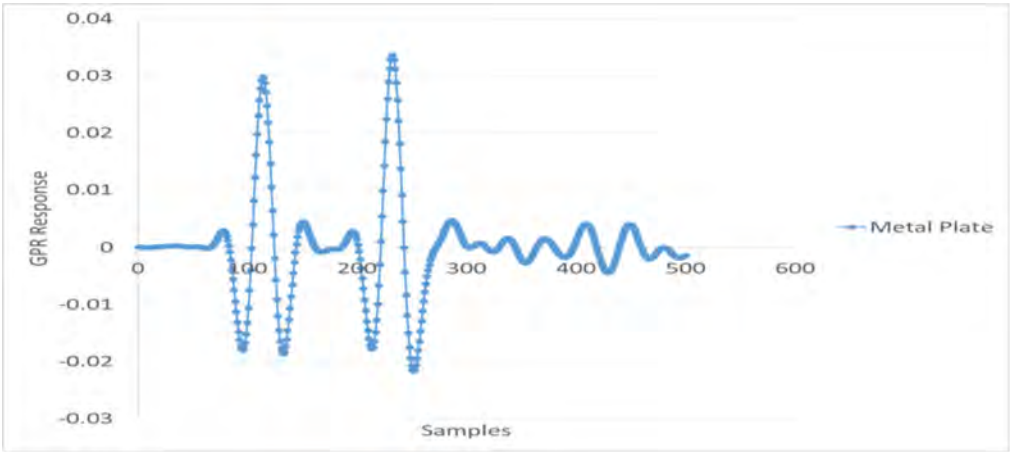
– Face antenna away from the surface

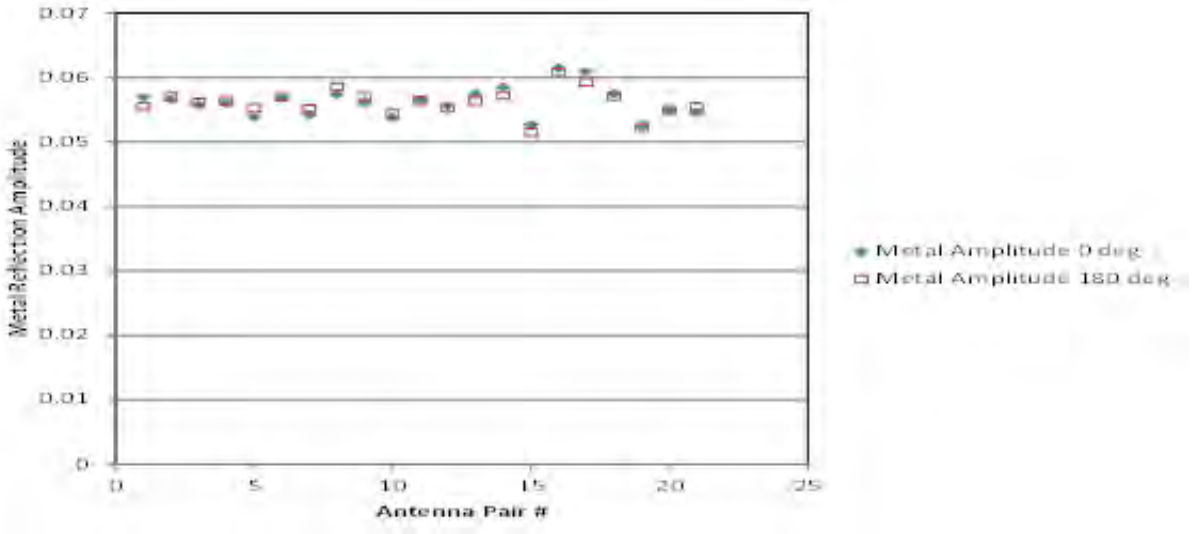
– Eliminate portion of the signal that is only affected by the antenna



Controlled Laboratory Tests: Metal Calibration

4'x8' Metal Surface Reflection Amplitude
– Use the amplitude of the surface reflection to characterize the signal magnitude



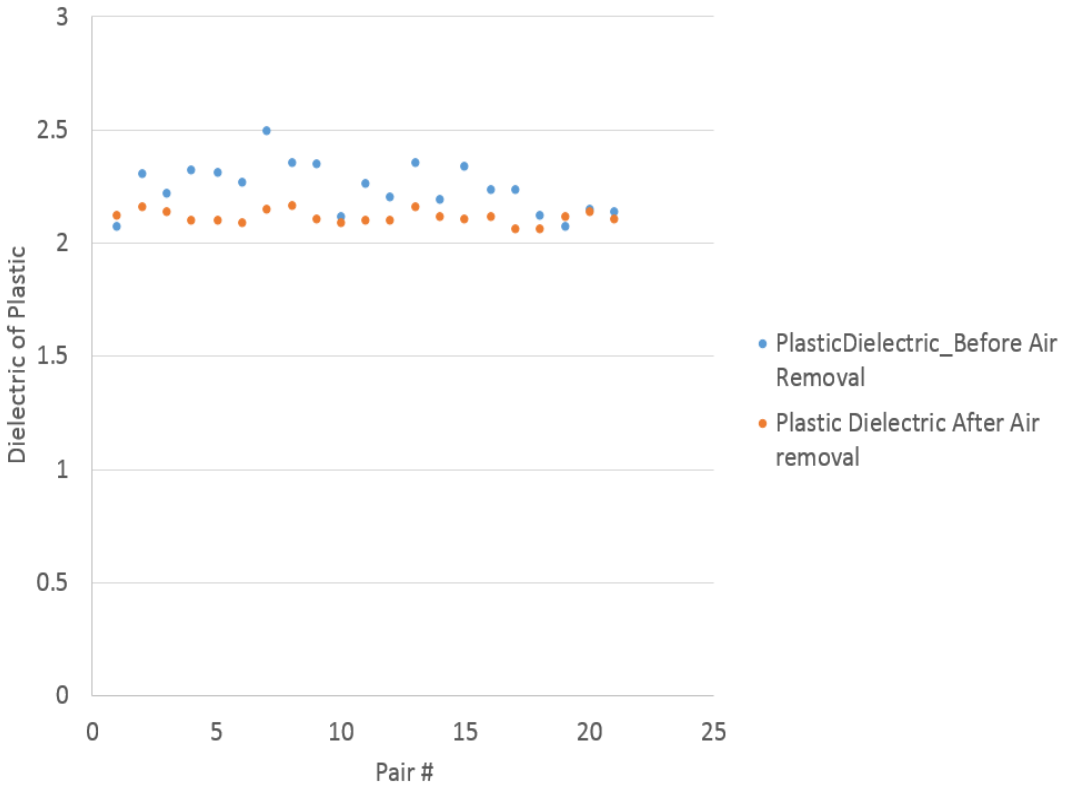


$$\varepsilon_{HMA} = \left(\frac{1 + \frac{A_0}{A_P}}{1 - \frac{A_0}{A_P}} \right)^2$$

Controlled Laboratory Tests: HDPE Plastic

$$\varepsilon_{HMA} = \left(\frac{1 + \frac{A_0}{A_P}}{1 - \frac{A_0}{A_P}} \right)^2$$

HDPE Surface Reflection Amplitude
- Manufacturer Dielectric Listed: 2.30 – 2.35
- Known Dielectric can be used to evaluate the system



Field Trials

- **Evaluate If the 3D GPR and Examiner Can Detect HMA Stripping**
- **Collected 3D Radar data on several projects:**

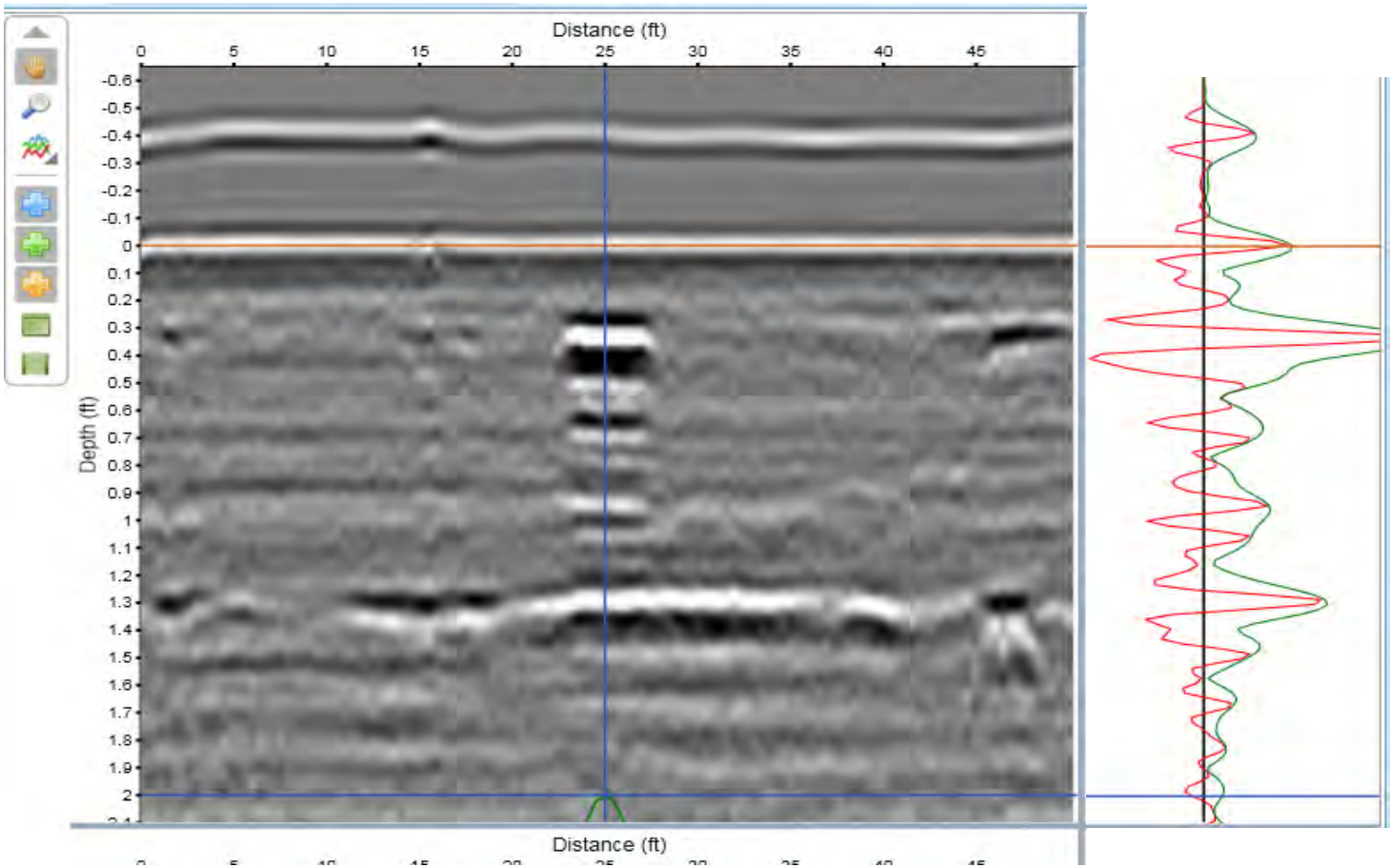
  MnROAD cells: 1 and 15 (cores taken after GPR data)

  Highway 7 (cores taken before GPR data collection)

  70th and 80th streets near MnROAD (cores after GPR data)

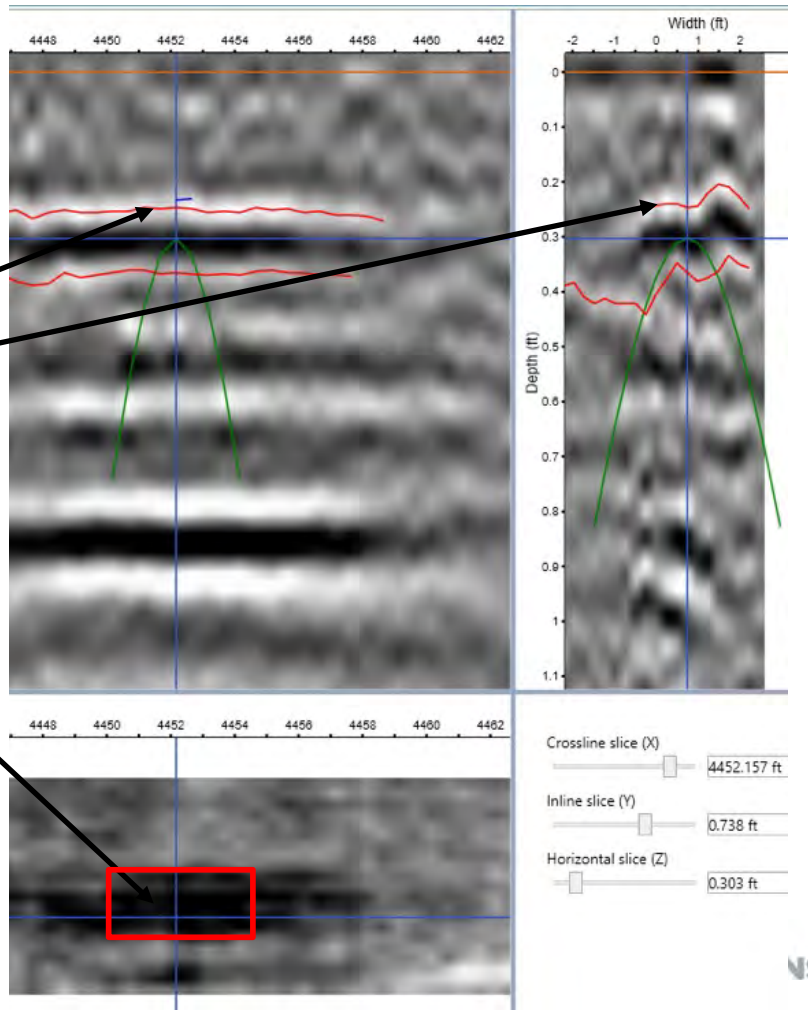
Example 1 (Cell15; Core 2) (core was taken after GPR data collection)

Each of the GPR waveforms contain information of pavement features, such as stripping and delamination. Typically, GPR signal raises when it detects a defect in pavement due to a change of dielectric constant of materials



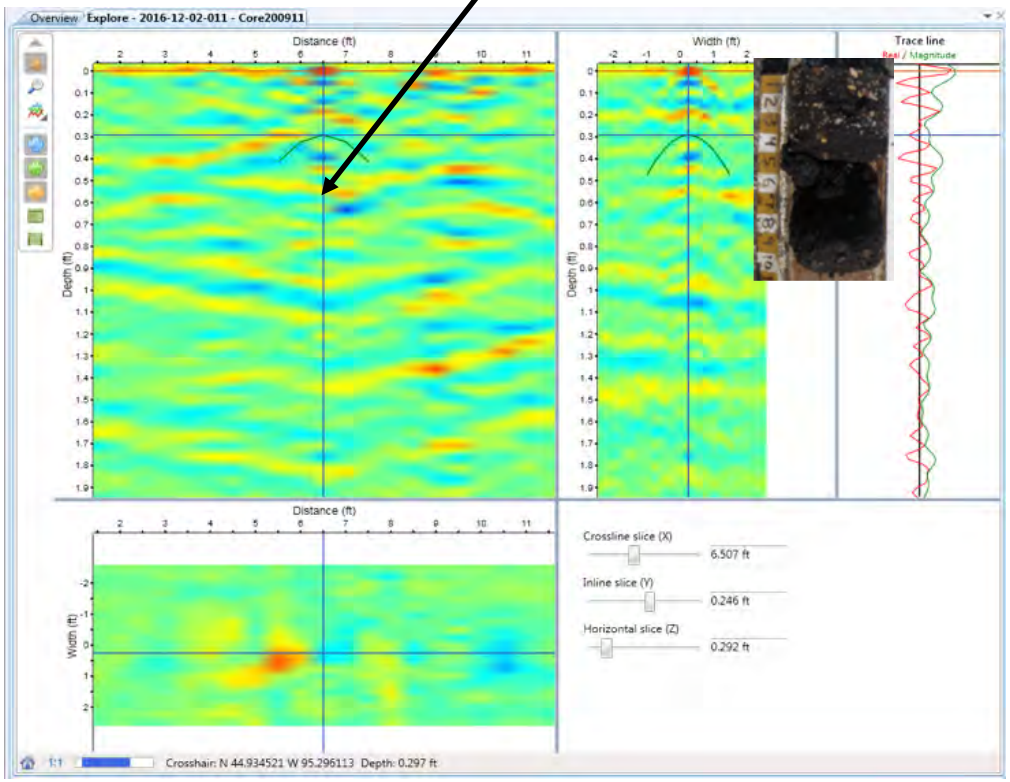
Example 3 (80th Street)

Example Stripping Detection: 80th WB Section 1 Core 12

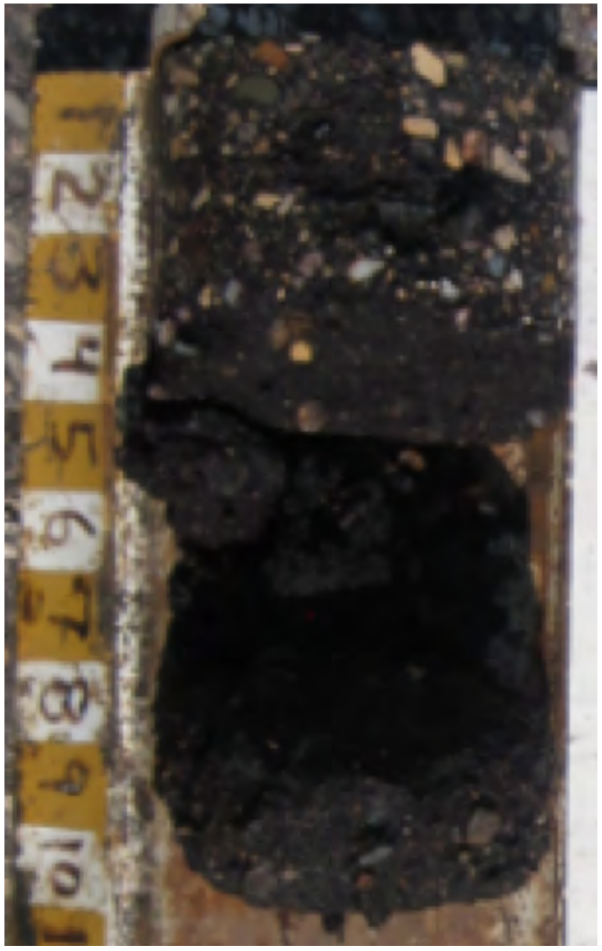


Example 4 (TH7)
Bottom stripping not shown well (Not clear)

Unclear

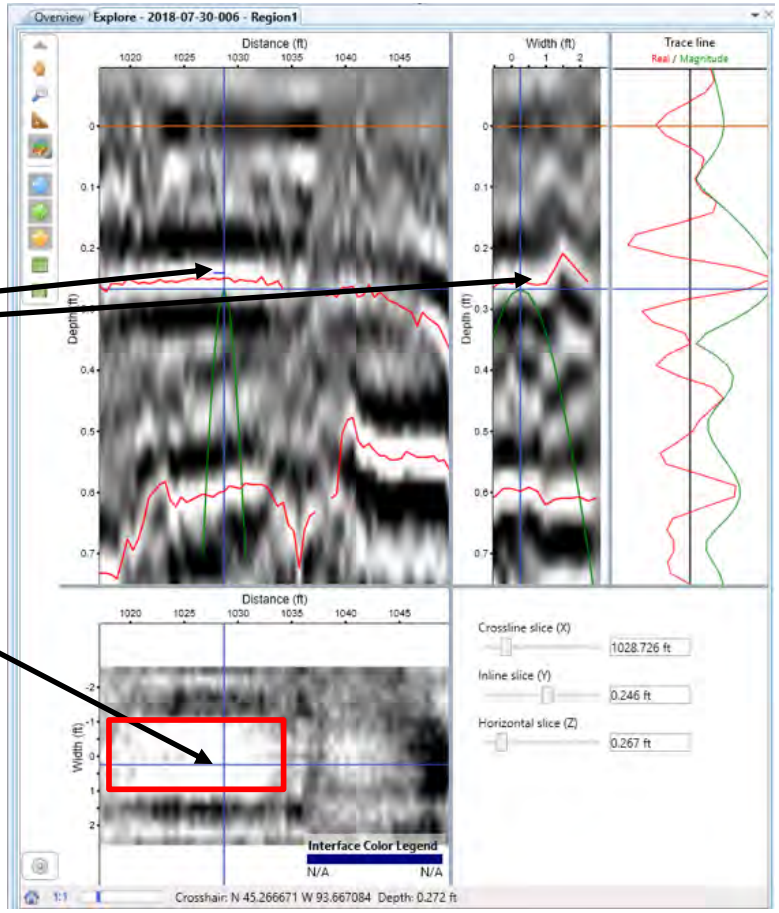


Core2033
(On Crack)



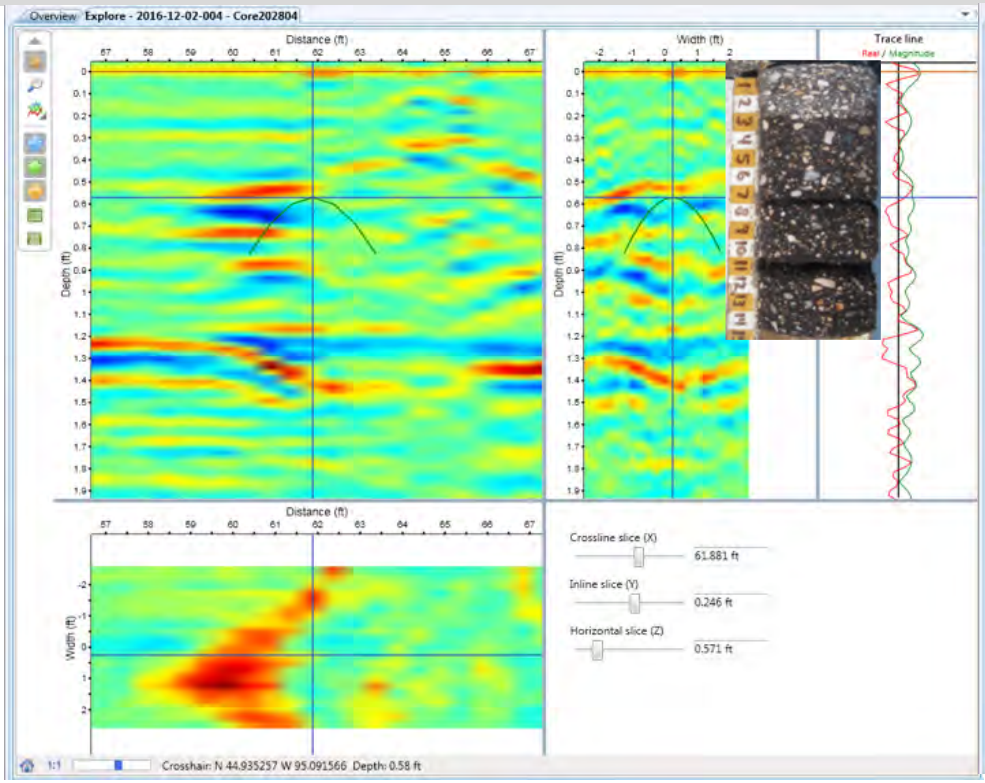
Example 5 (80th Street)

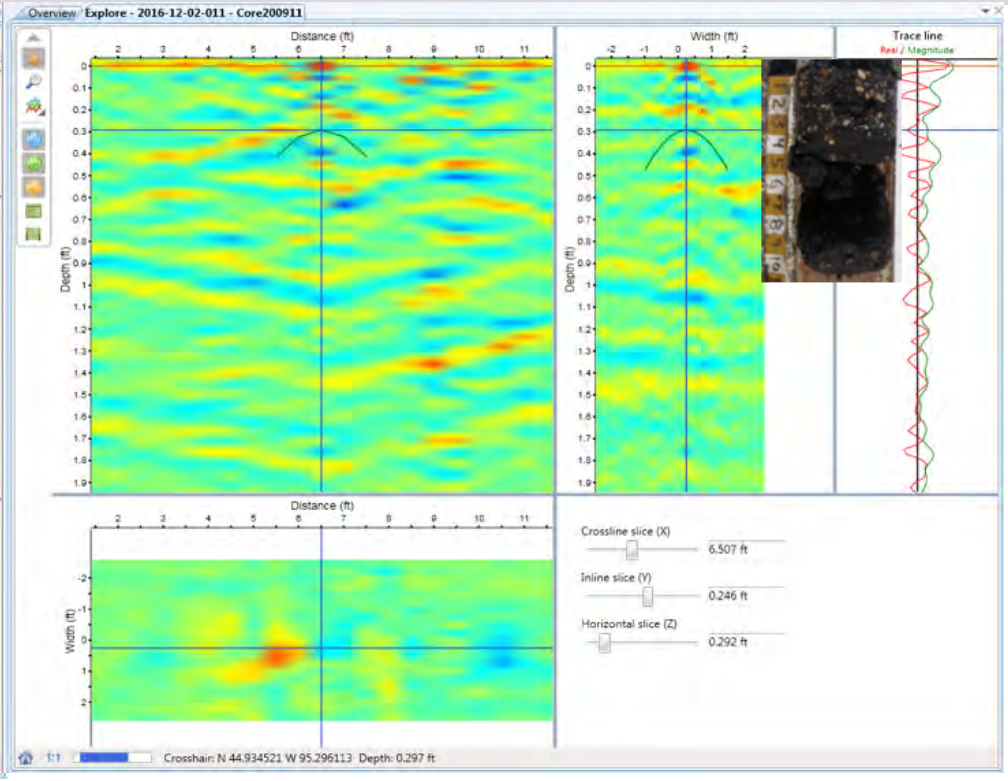
Example False Stripping Detection: 80th WB Section 4 Core 17



Advanced Data Analysis

- Looking at GPR images
  - Very subjective to the person analyzing the image
  - Time-consuming and labor intensive
- GPR can not definitively identify stripping

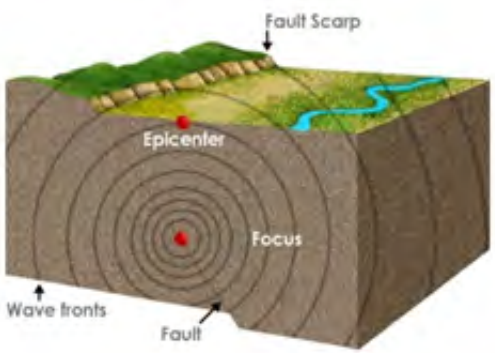


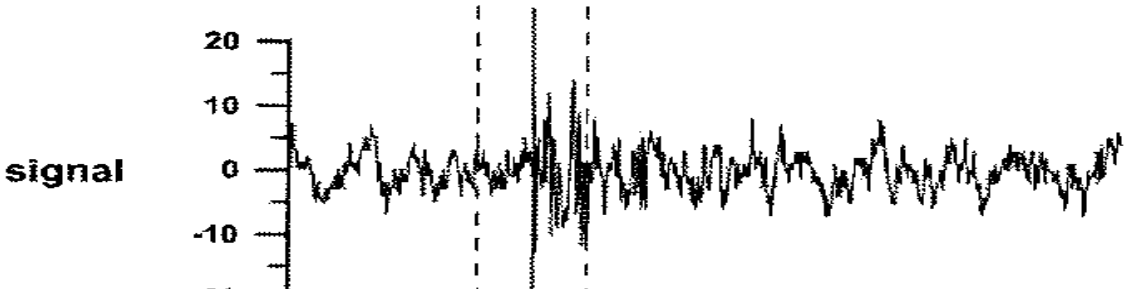


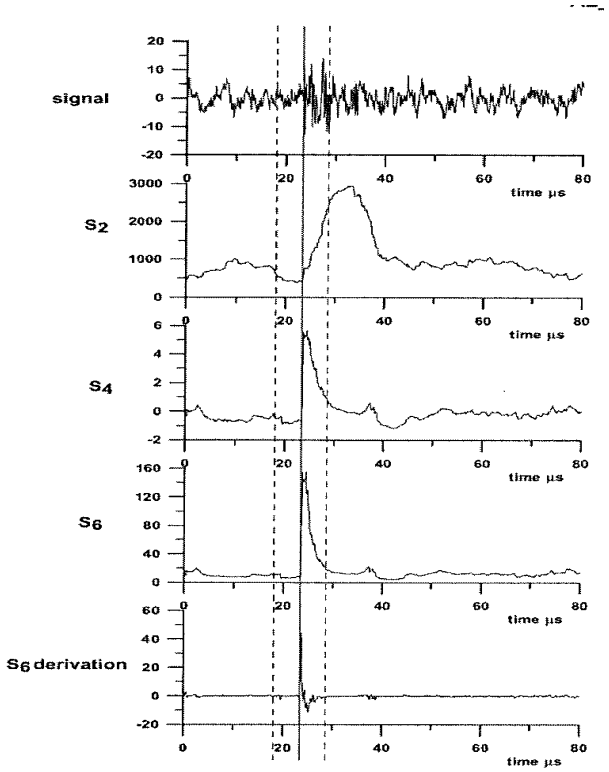
Maximum Energy Ratio

- **AE is used for detecting earthquake**
- **First arrival of P wave used to estimate hypocenter location**
  - Energy before and after the first arrival in a small time window has a large difference

$$R_p = \frac{\sum_{i=p+1}^{p+M} Y_i^2}{\sum_{i=p-M}^{p-1} Y_i^2}$$







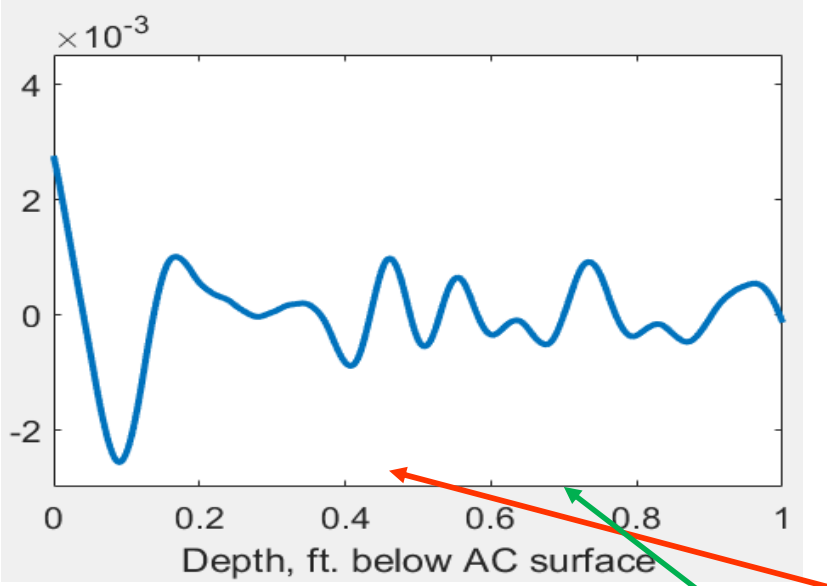
(Shah and Labuz, 1995)

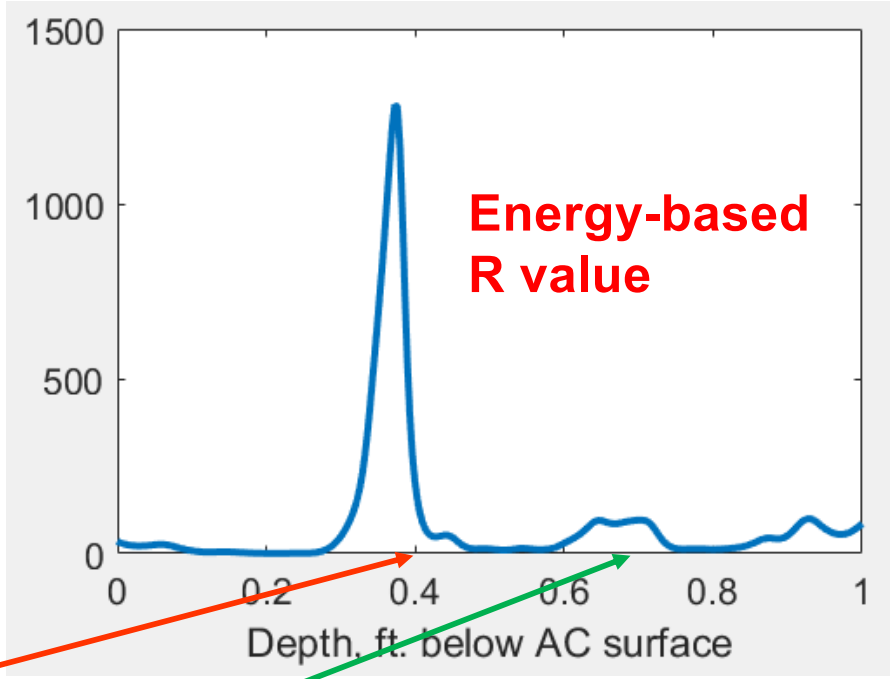
NCAT Test Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10
Top 2-inch lift	Full bond	Full bond	Full bond	Partial No bond	No bond	partial stripping	Full bond	Full bond	Full bond	Full bond
Bottom 3-inch lift	no bond	Full bond	Full bond	Full bond	Full bond	Full bond	Full bond	partial Stripping	partial No bond	No bond
Existing surface	PCC	PCC	HMA	HMA	HMA	HMA	HMA	HMA	HMA	HMA

Stripped Location

Original Signal

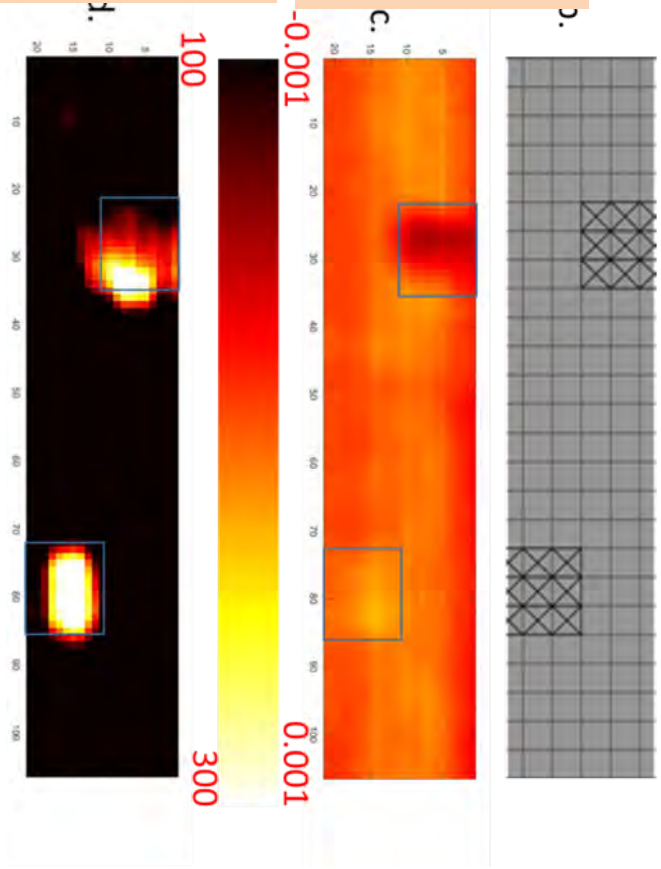




Raw signal c-scan compared to the filtered data c-scan

C-scan of Energy-filtered Data

C-scan of Raw Data



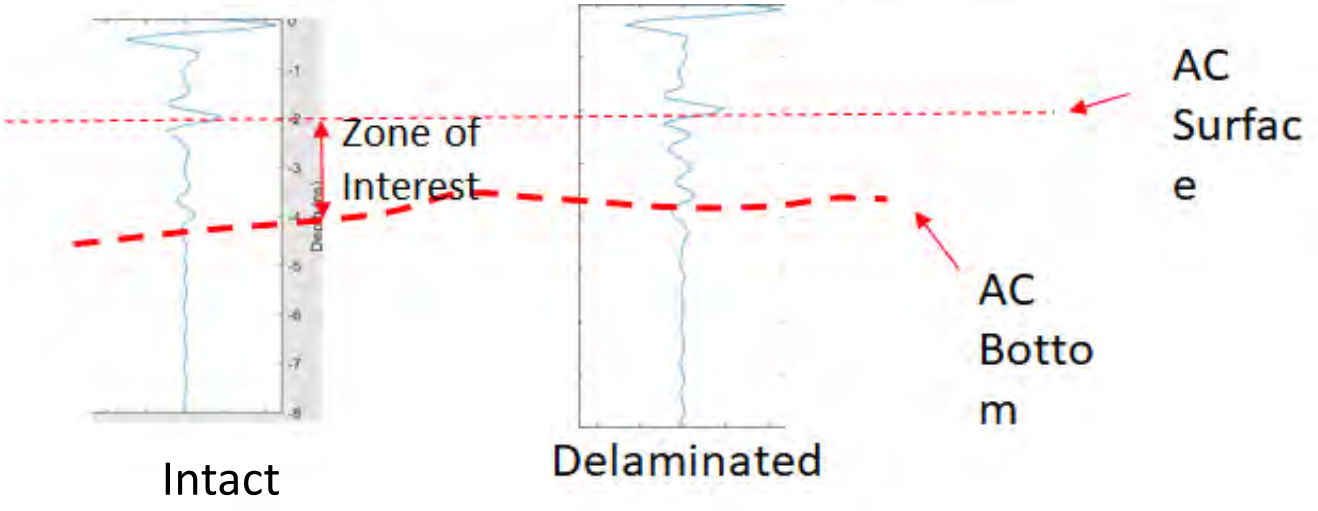
C-scan at design depth (~0.4 ft)

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7			
Top 2-inch lift	Full bond	Full bond	Full bond	Partial No bond	No bond	partial stripping	Full bond	Full bond	Full bond	Full bond
Bottom 3-inch lift	no bond	Full bond	Full bond	Full bond	Full bond	Full bond	Full bond	partial Stripping	partial No bond	No bond
Existing surface	PCC	PCC	HMA	HMA	HMA	HMA	HMA	HMA	HMA	HMA

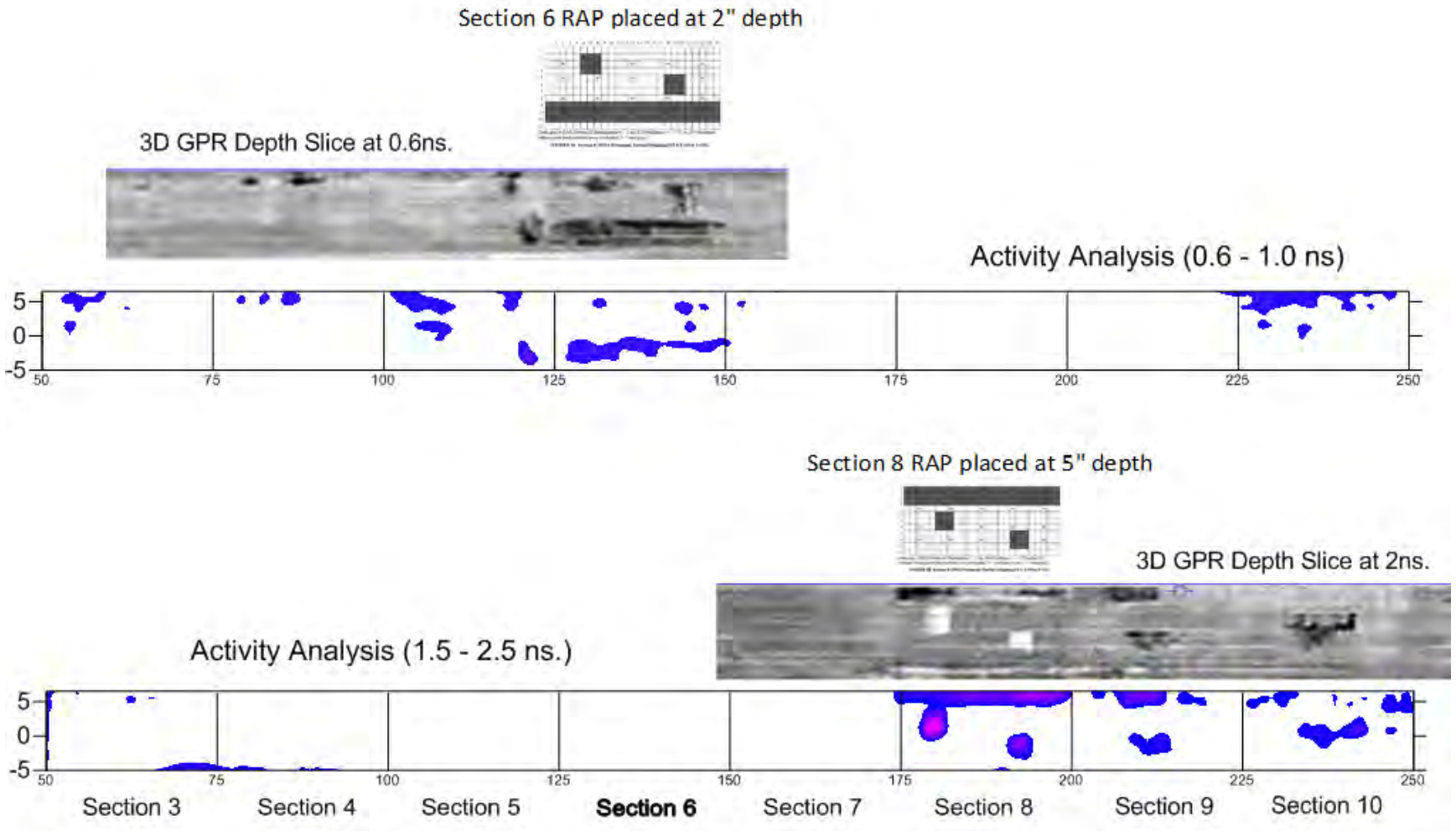
Activity Index Method

- ExploreGPR (Dr. Ken Maser from Infrasense)
  - **Conducts quantitative analyses using data generated by "Examiner"**
  - **Activity Index**

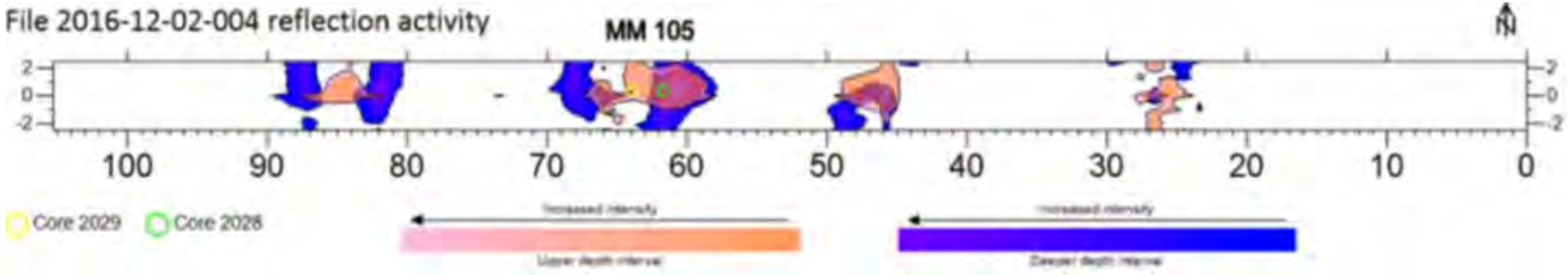
$$AI(x,y) = \sum_{n1}^{n2} |A(x,y,i)| \Big/ (n2 - n1)$$



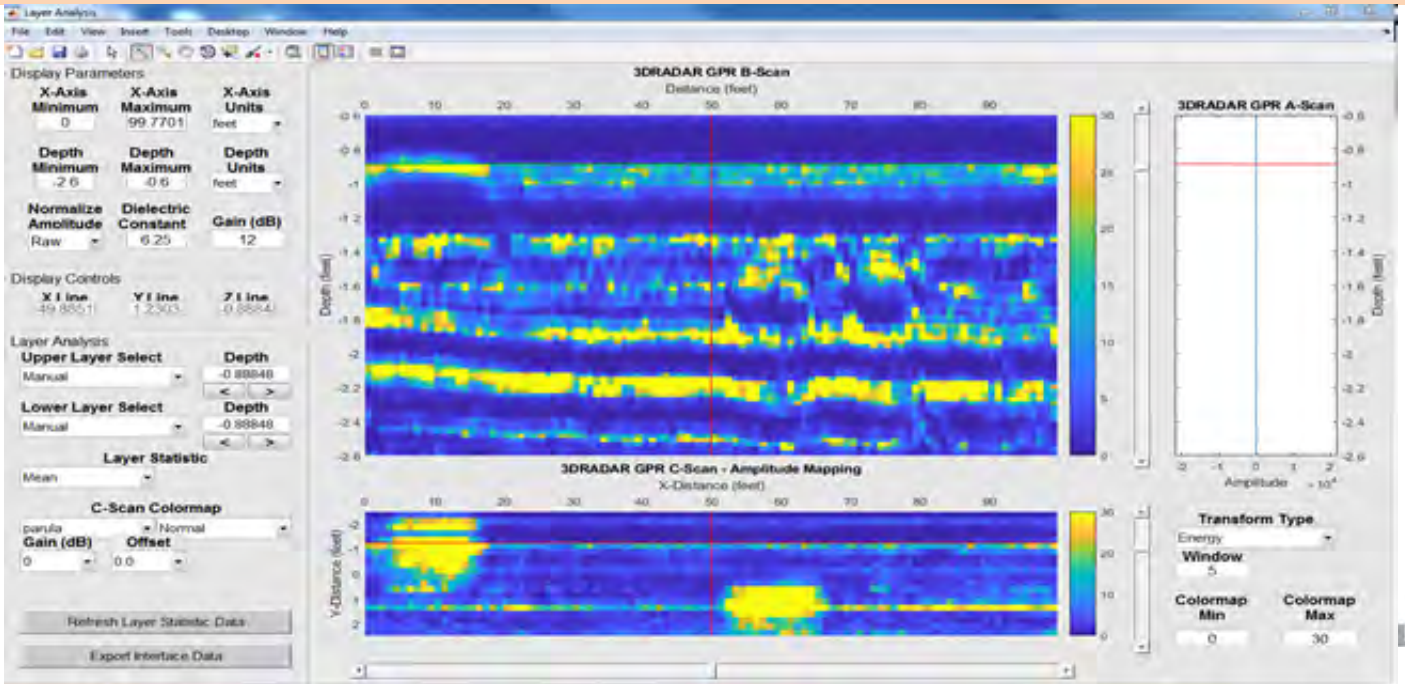
Activity Analysis on NCAT Test Sections



ExploreGPR Integration

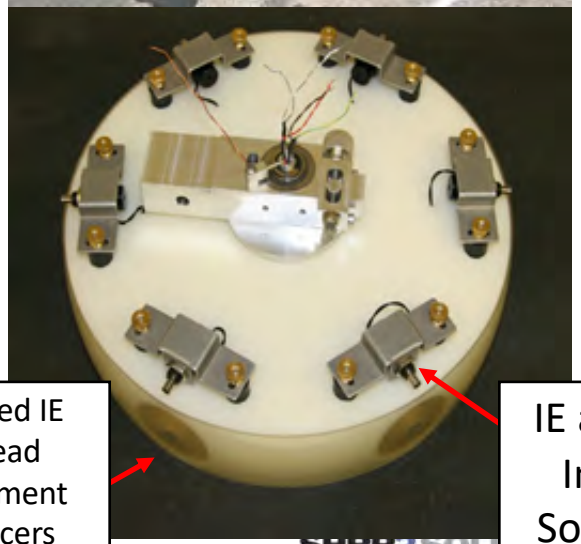


- Energy method in ExploreGPR



Sonic Surface Scanner - S^3 (SASW/IE) (KY, NM, TX).

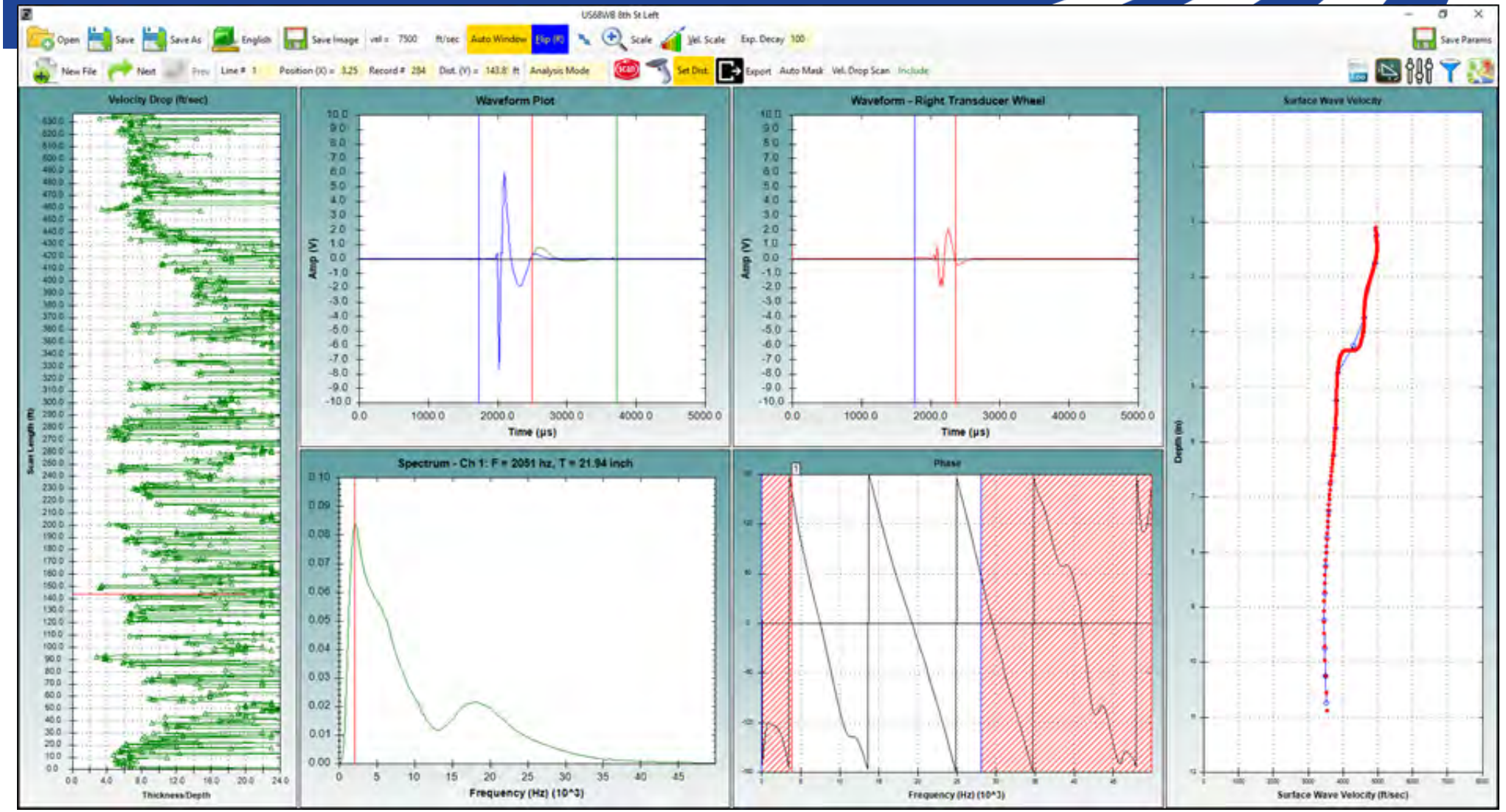
- Slow-rolling (1 mph) scanner for delamination mapping of asphalt pavements and bridge decks
- 6 Displacement transducers on two wheels lined up 6 to 9 inches apart
- Impacts surface every 6 inches for
  - Impact Echo (IE) test
  - Spectral Analyses of Surface Waves (SASW) test



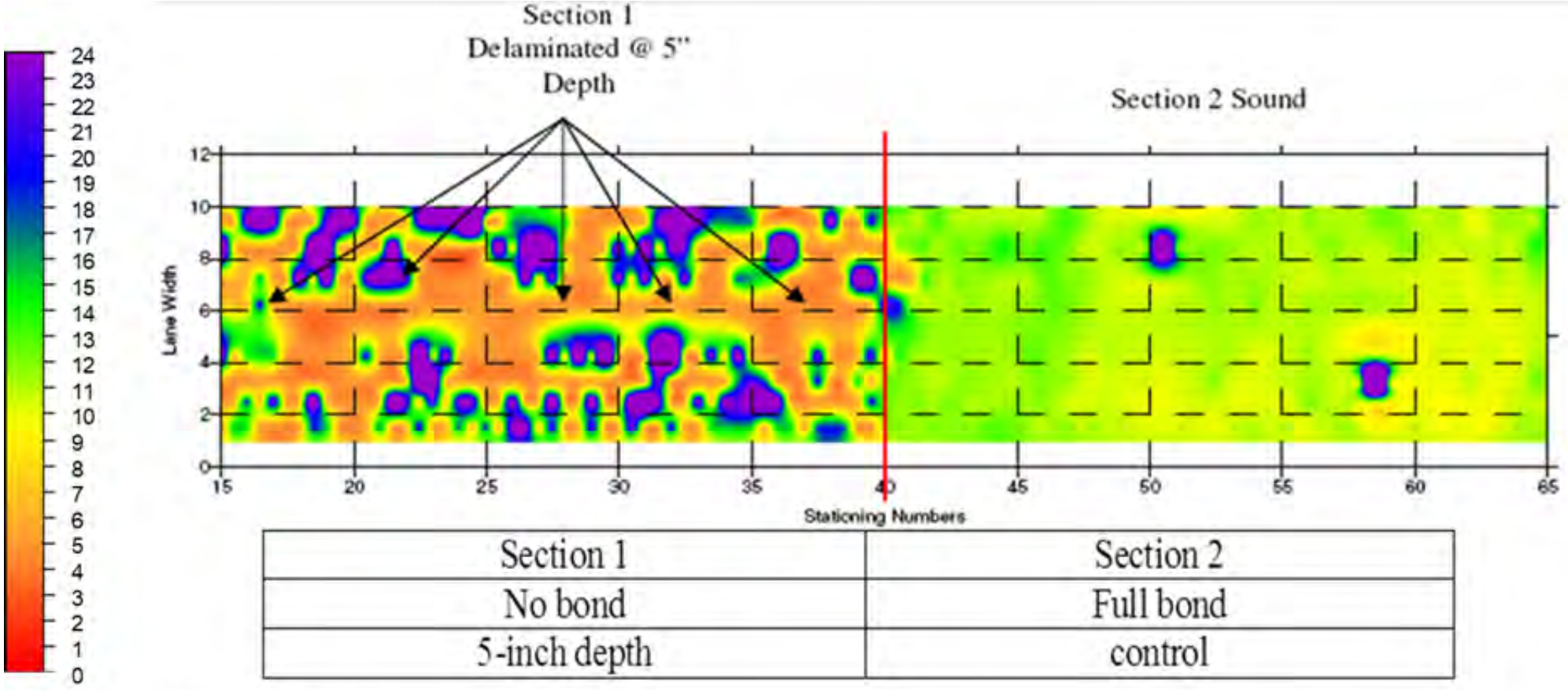
Embedded IE Test Head Displacement Transducers

IE and SW Impact Solenoids

Standard S³ Data Analysis View

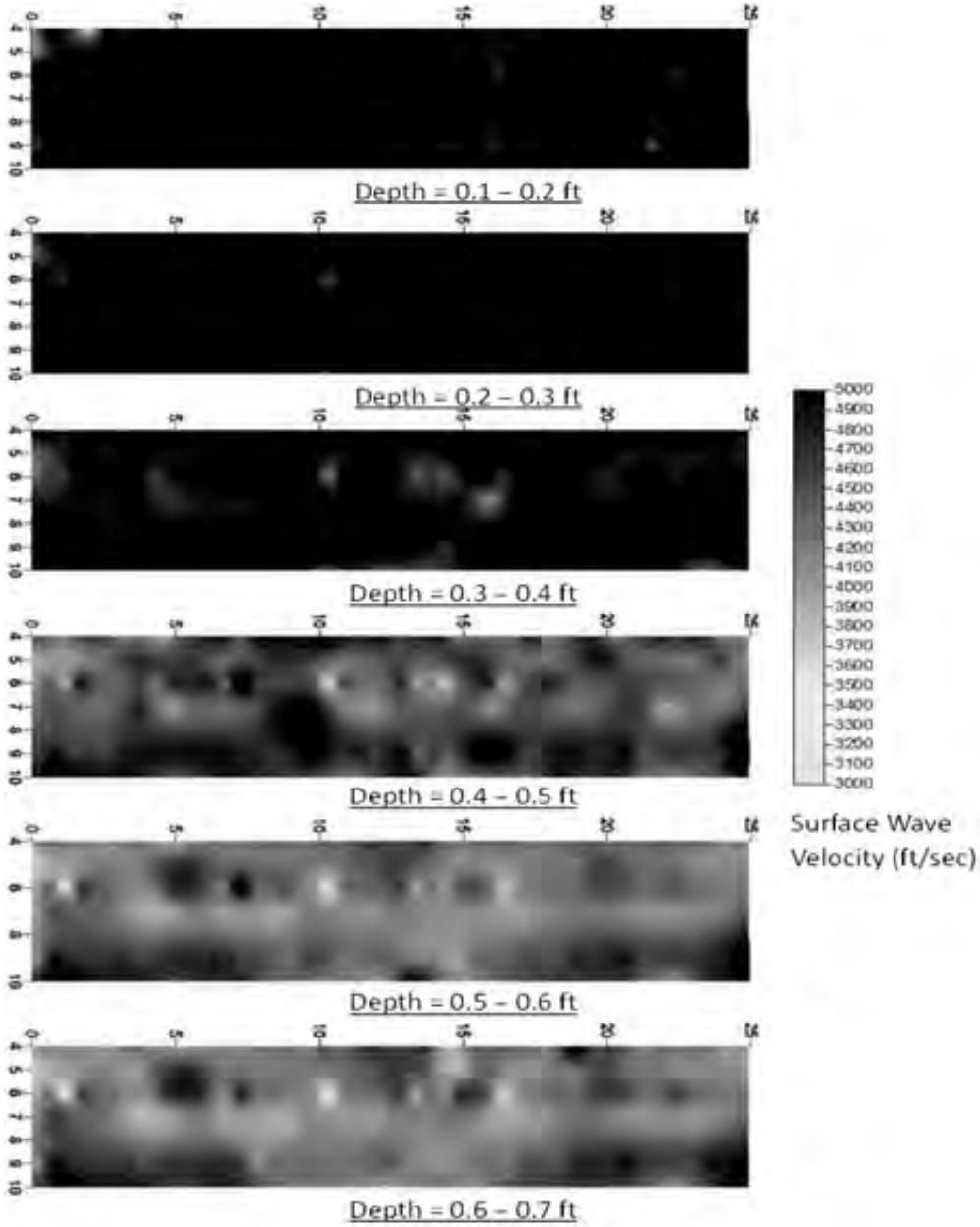


IE Data Display (NCAT test track section)

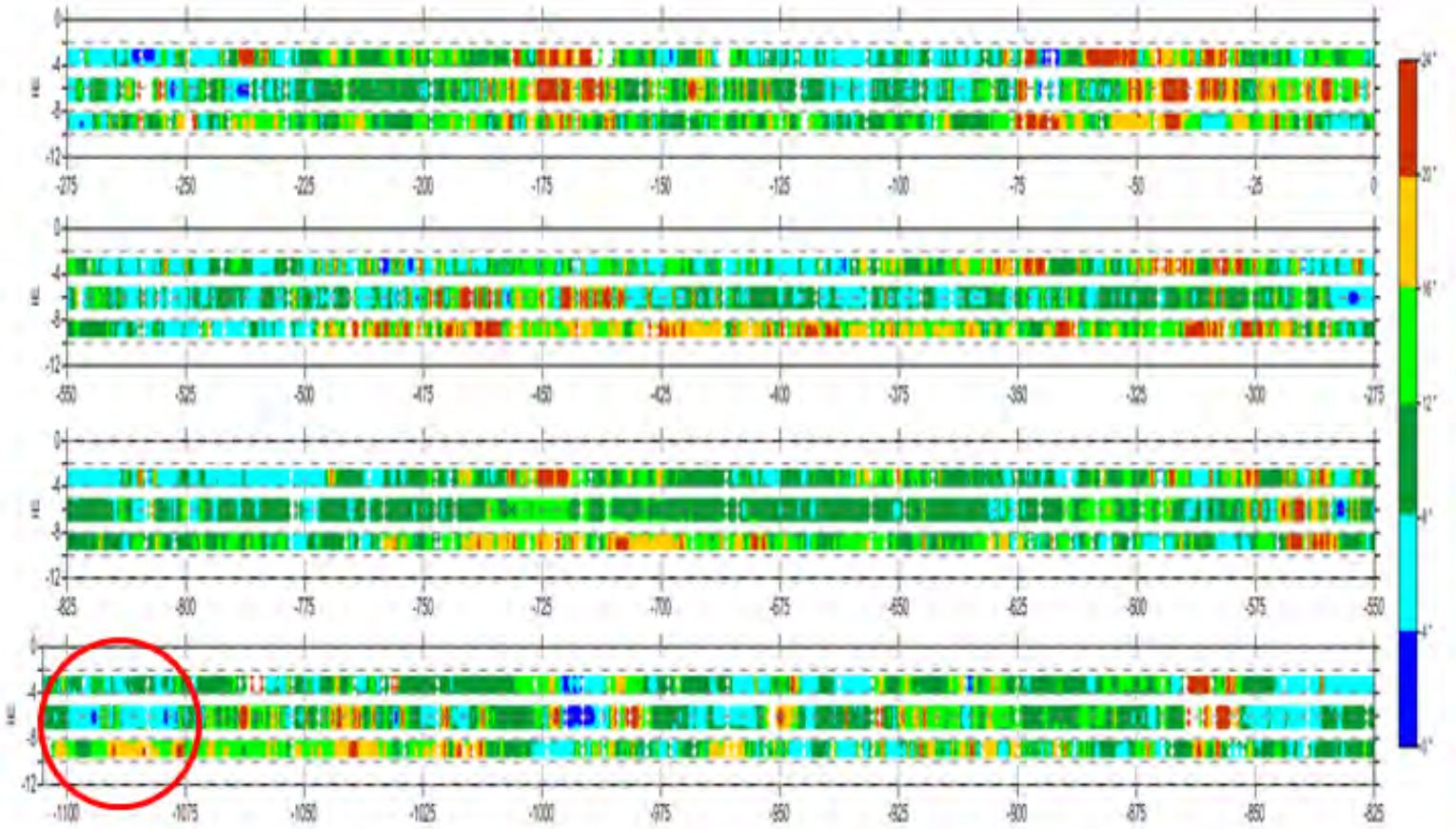


Section 1	Section 2
No bond	Full bond
5-inch depth	control

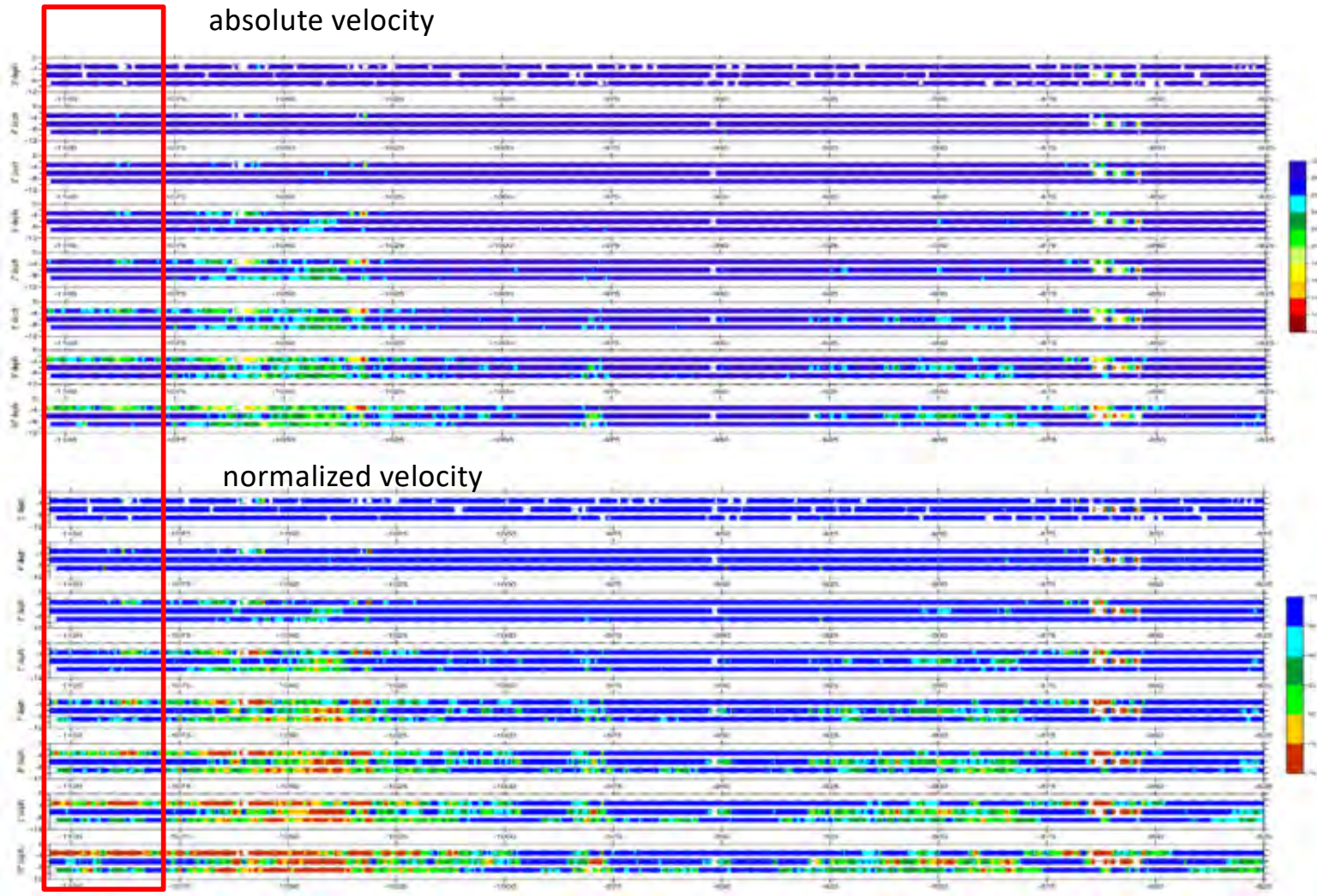
SASW Data Display (NCAT test track section)



Impact Echo: core IE5, section three, CWP--1084.6 feet



SASW: core IE5, section three, CWP--1084.6 feet



Summary on Sonic Surface Scanner – S^3

- Technologies (SASW best) correctly identify depth to pavement change (distress)
- Slow-rolling (1 mph) scanner for delamination mapping of asphalt pavements and bridge decks
- Field testing still requires lane closure, but testing is much faster than single point testing
- Data analysis is still very labor intensive. Automated data analysis will make analysis turn-around much faster (1 week down to 1 hour)

Summary on GPR

- 3D GPR Is a Great Tool to Assist On HMA Stripping Detection
  - Provides continuous coverage
- 3D GPR Alone Can Not Definitively Identify Stripping
  - Sometimes successful; sometimes not
  - May need additional tool: such as FWD, Traffic Speed Deflectometer (TSD)
- Important to Remove Air Calibration Data
  - Minimize system effects on actual data
- Need Automatic Data Analysis Tools for Future Implementation
  - Activity Method and Energy Ratio Method are promising, but need further evaluation/validation
  - Goal: Use different methods to analyze signal. If all or most methods indicate a common area with “unusual” activity, the area is worth to be investigated further, could be “stripping”.