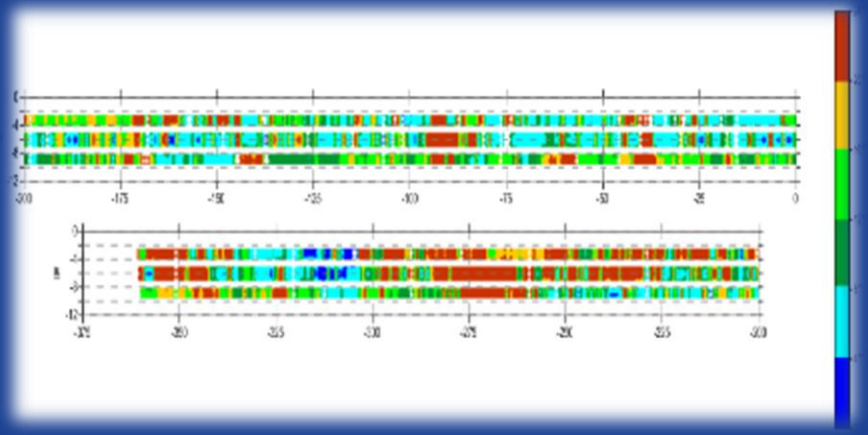
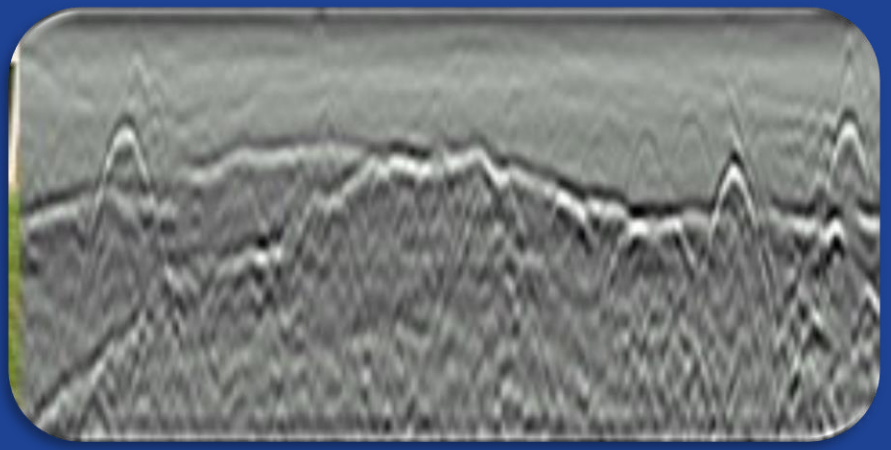
Evaluation of 3D Radar and Sonic Surface Scanner (SSS) Technology for Pavement Forensics (a.k.a. pavement delamination RO6D)

KENTUCKY

Brad Rister P.E.
Brad Frazier P.E.
Jamie Creech Eng. Tech.
Joe Tucker P.E.
Kate Kurgan
Michael Heitzam P.E.





AASHTO

KENTUCKY TRANSPORTATION CABINET

SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD

Outline: Why - Where - What - How

Evaluation of 3D Radar and Sonic Surface Scanner (SSS) Technology
for
Pavement Forensics (a.k.a. pavement delamination RO6D)

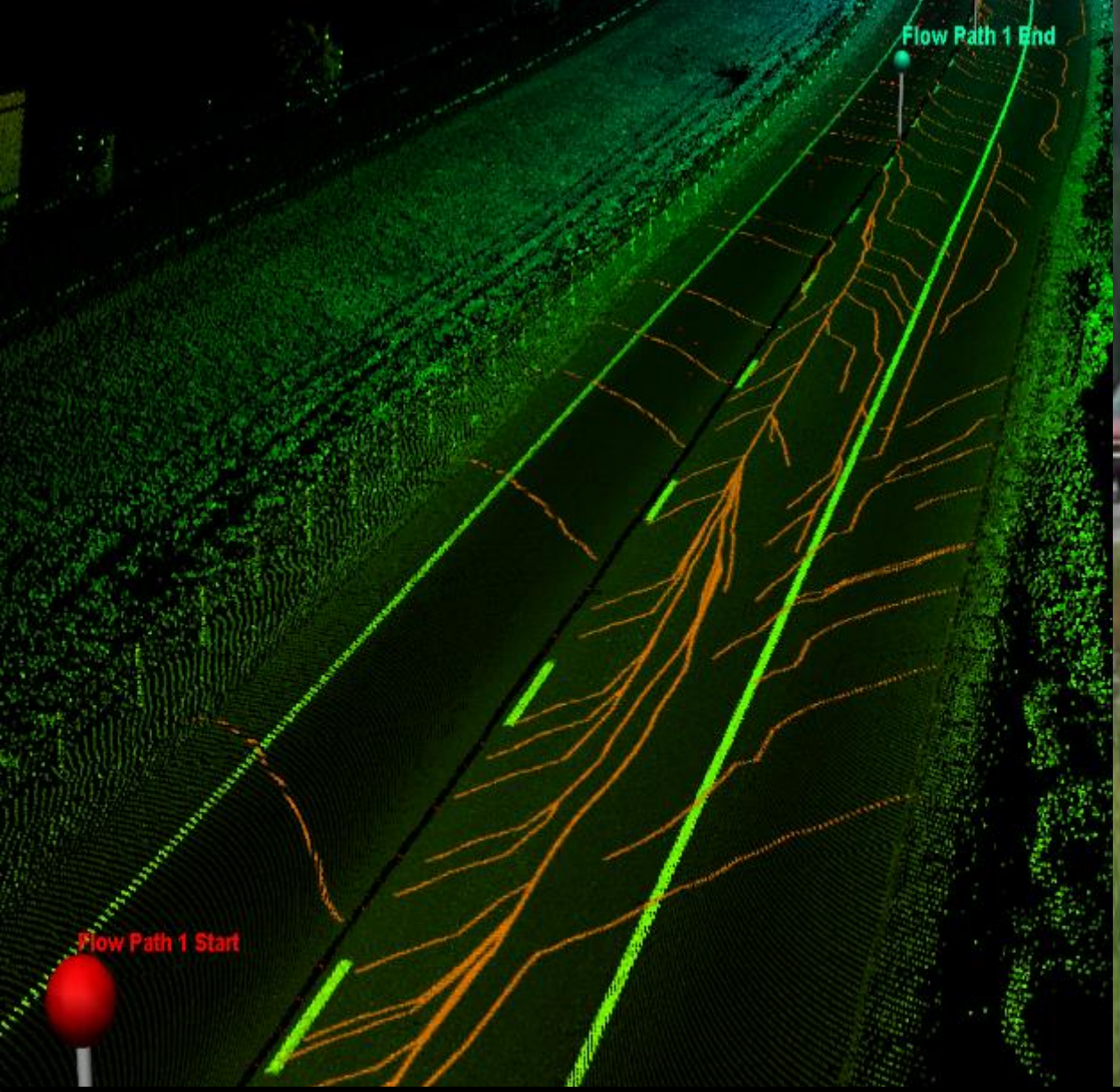
- Why evaluate new technologies for pavement delamination/forensics—RO6D

  - Pavements are an asset to our transportation network in Kentucky.
  - Kentucky has approximately 79,857 miles of roads.
  - Approximately 27% of Kentucky's economy is in the "goods-producing industries" which highly depend on transportation for movement of those goods.
    - IE: UPS international, Ford truck plant, Toyota's North American head quarters, Amazon distribution, Corvette plant, aggregates, farm products, thoroughbred horses, coal, bourbon, aluminum, oil, and 2nd most navigable in-land water ways state behind Alaska.
    - 500 mile radius (8 hour drive) from central KY—120 million people / 40% of US population.
  - Essentially, almost every person in Kentucky uses the road network sometime throughout their lifetime, if not every day along with many others.
  - But—Pavements fail and we have to fix them.

pavement failure could look like this?

KENTUCKY TRANSPORTATION CABINET

KTC
EXCELLENCE IN MOTION



Identification of pavement rutting

TRB 1984: ¼ inch water @ 45 mph on average tires will cause hydroplaning

On average, there are over 5,760,000 vehicle crashes each year. Approximately 1,259,000 are weather related "USDOT"

When we choose to fix these pavements

Pavement designers need good field data to support their pavement rehabilitation plans

Choosing the right fix can save both time and money

AASHTO
"more quality data can translate into better results and solutions for highway projects"

Use Pavement Forensics

Pavement Forensics is….

- Utilizing non-destructive technology (NDT) to better understand what might be causing a pavement to fail and using that information to assist in the pavement rehabilitation design process.

Where: Forensic Project Site--Bourbon Co. US 60

- https://kytranscenter.maps.arcgis.com/home/index.html

Avoid First Change Order

all cores came from the same project
over a 1.5 mile area

Estimated Pavement Forensics Savings to Date

August 2018: $3.7 million

KENTUCKY TRANSPORTATION CABINET

KTC
EXCELLENCE IN MOTION

What – How

Looking at the technology: Sonic Surface Scanner (SSS), 3D Radar and Impulse Radar

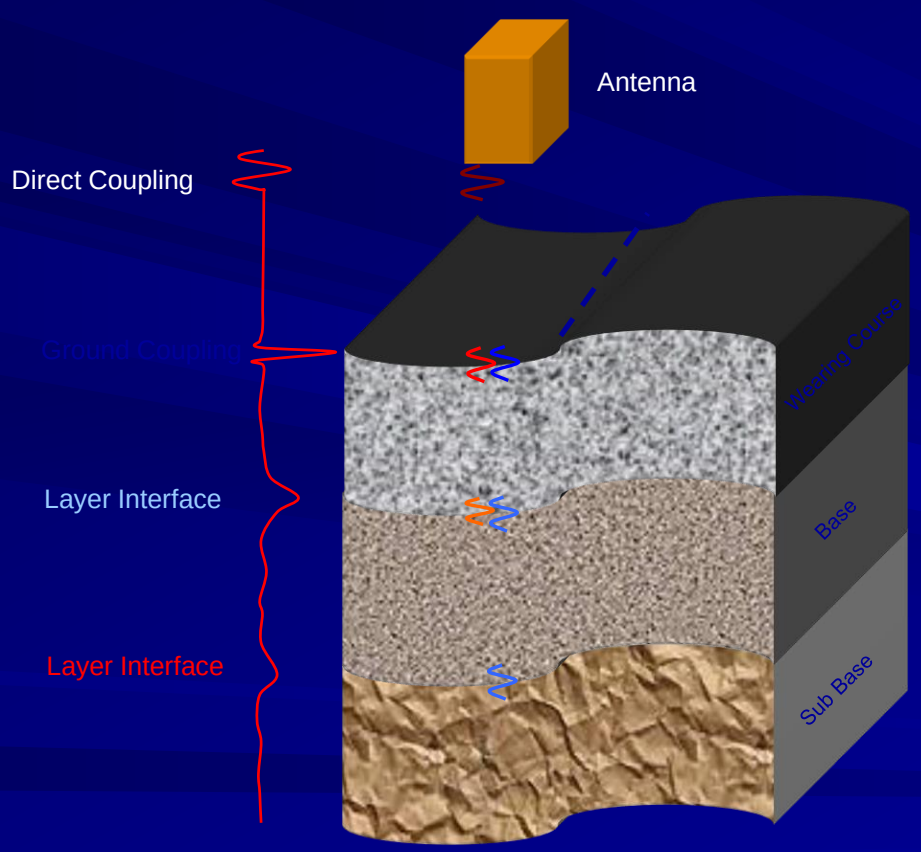
3D Radar

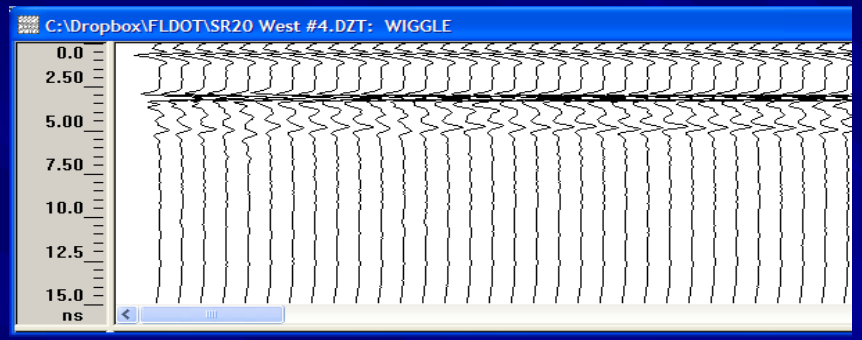
KENTUCKY TRANSPORTATION CABINET

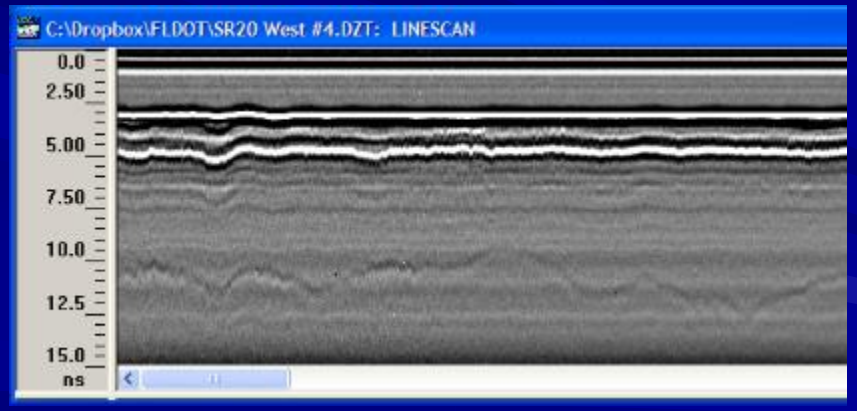
EXCELLENCE IN MOTION

How are we trying to use the GPR data to determine delamination / deterioration

GPR: Theory of Operation

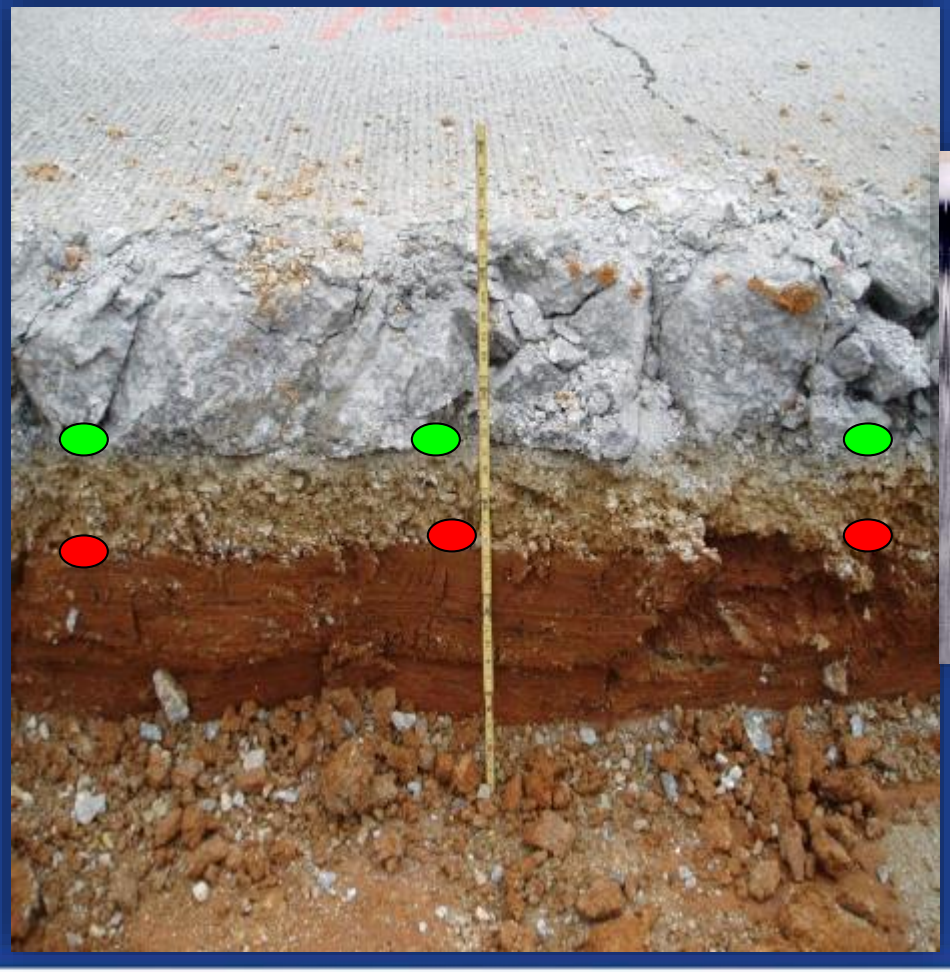


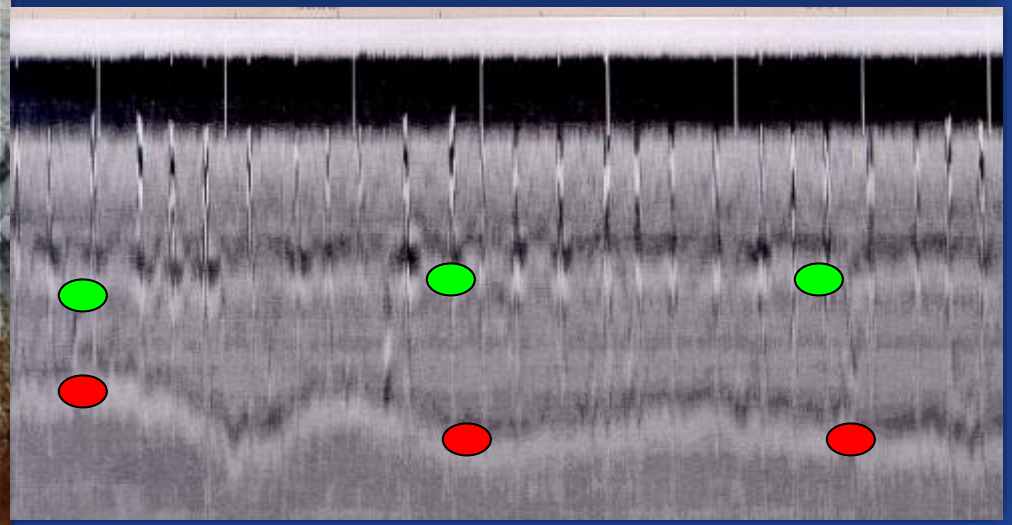




Reflections are produced when the pulse encounters a material with different dielectric constant
Dielectric Constant: Air = 1 Asphalt = 3-5 Concrete = 6-8

Comparison of GPR data to field conditions

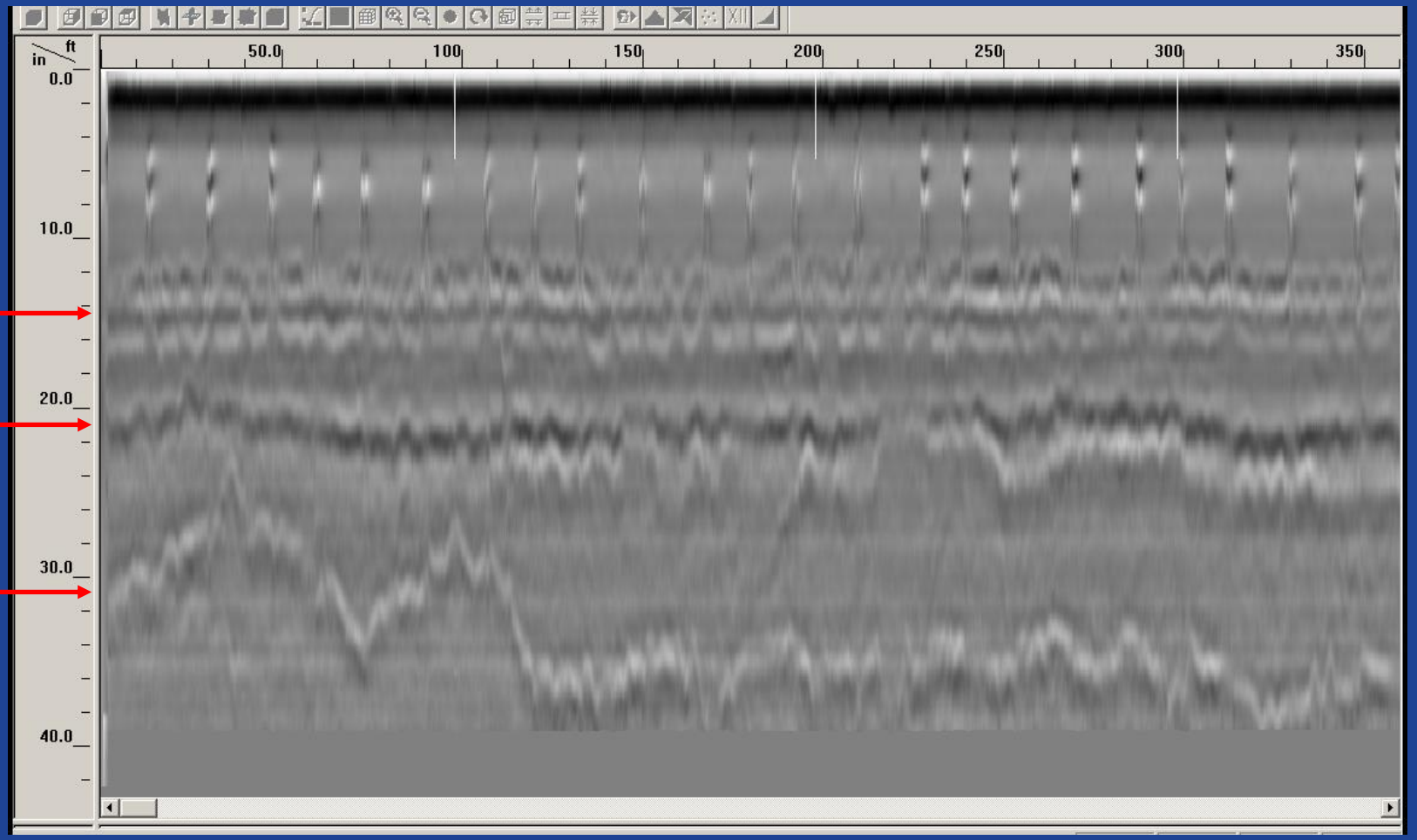




Conventional coring is one core per 1,000 ft. alternating lanes

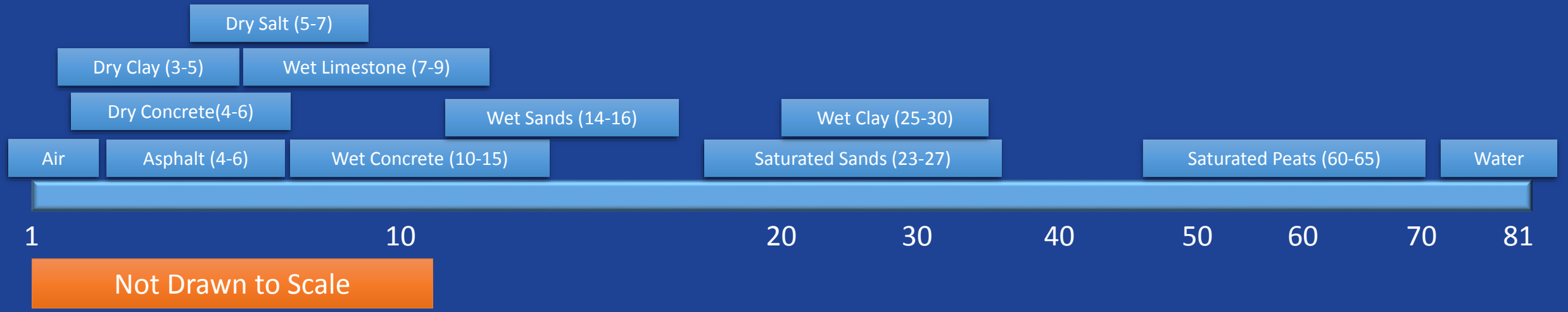
GPR is scanning every six inches at 20 mph.

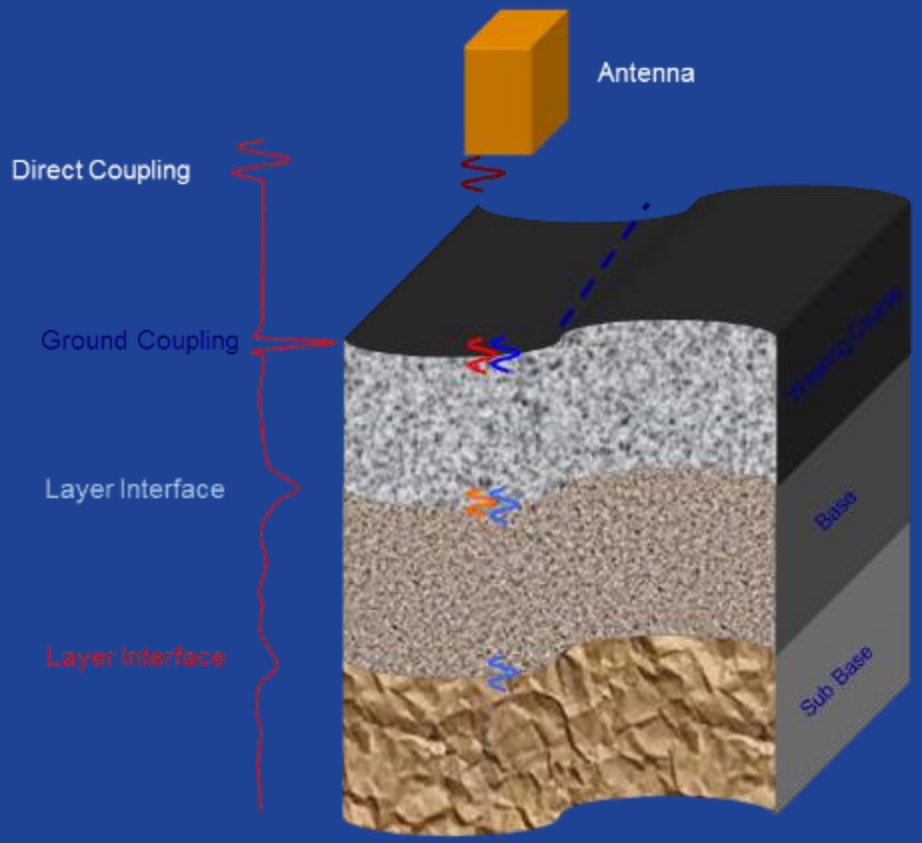
GPR identifying different pavement layers

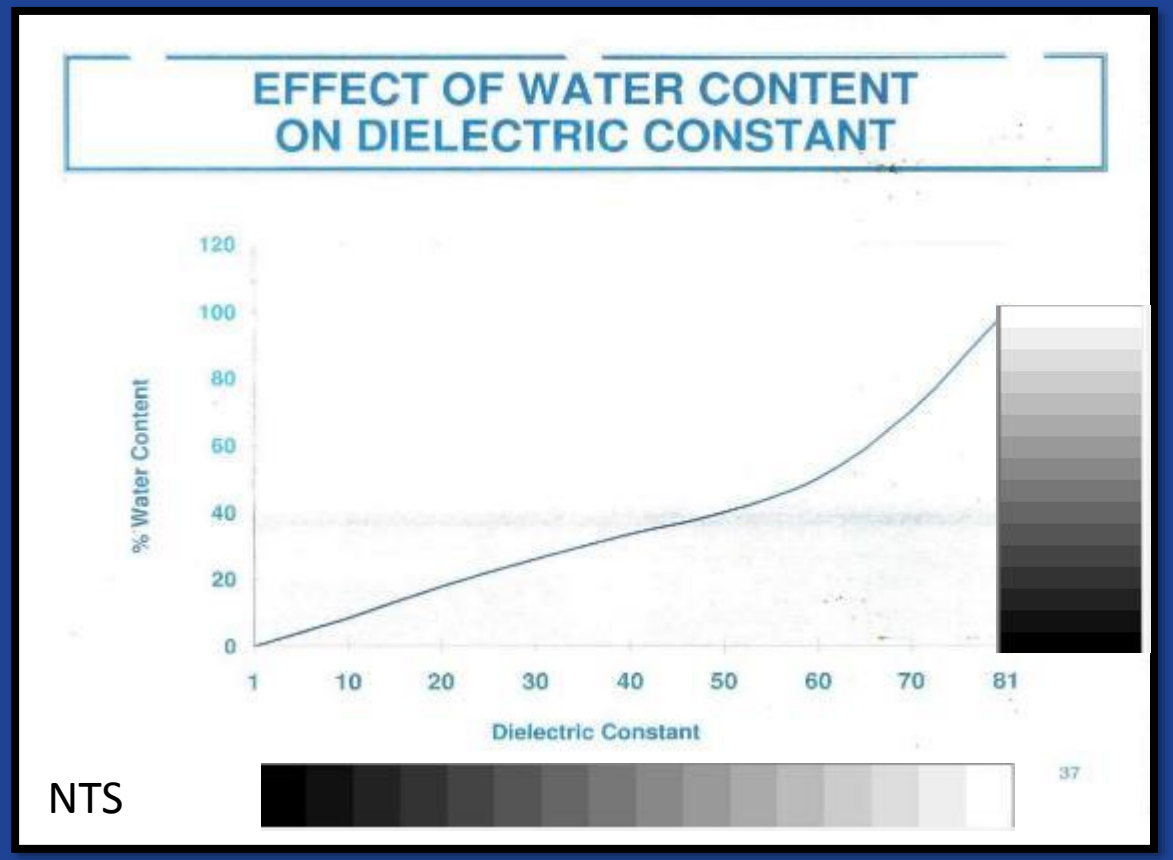


How can we figure Dielectric?

- Published references
- Noting target in data and drilling/digging to it for a measurement: Ground Truth
- Hyperbola matching: Migration
- *Unless the material is the same all the way through (concrete) the dielectric is only a "best guess!"*

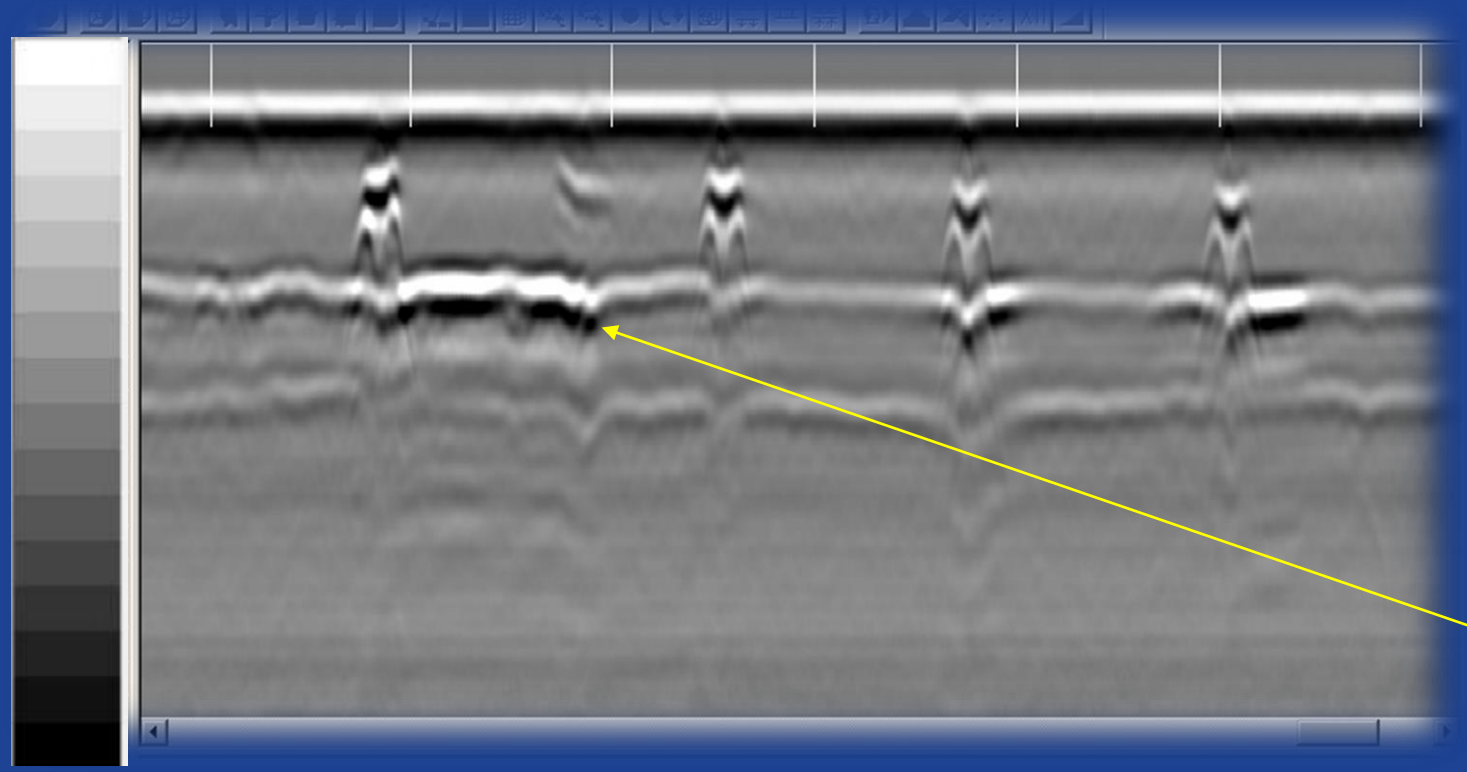






When looking for delaminations: We are looking for the abnormal dielectric values and/or variation in the signal amplitudes

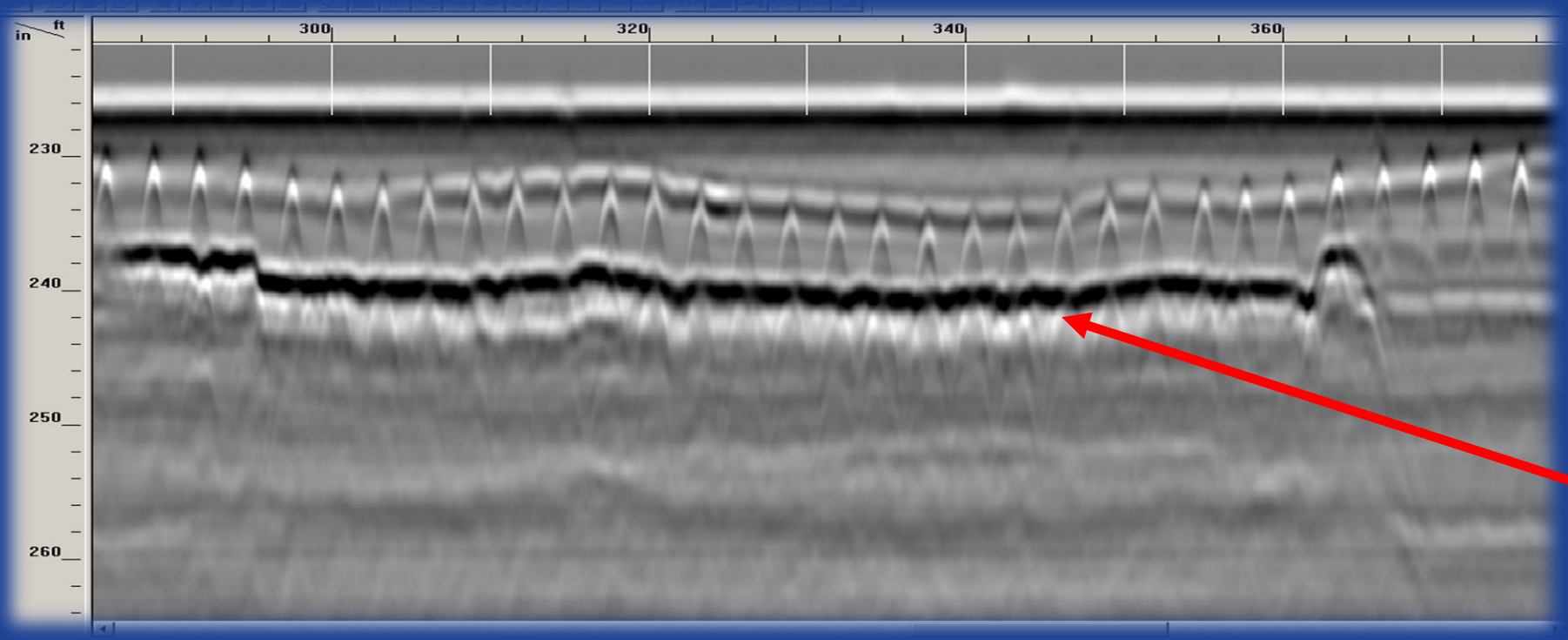
Voids can be field with
Air (low dielectric/low amplitude)
Water (high dielectric/high amplitude)



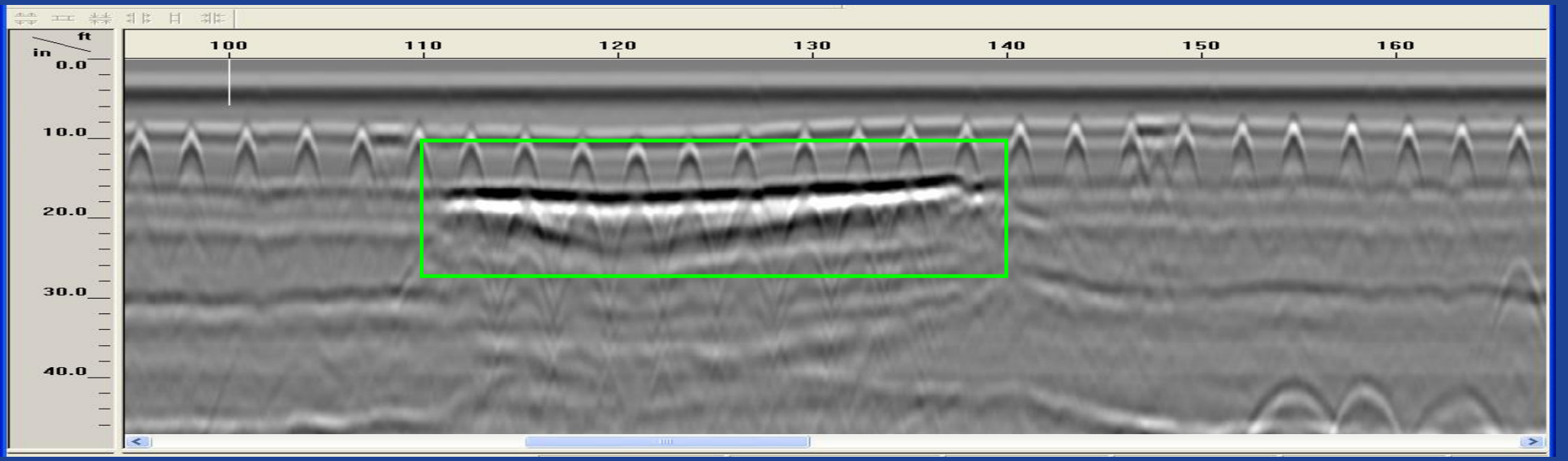
KENTUCKY TRANSPORTATION CABINET

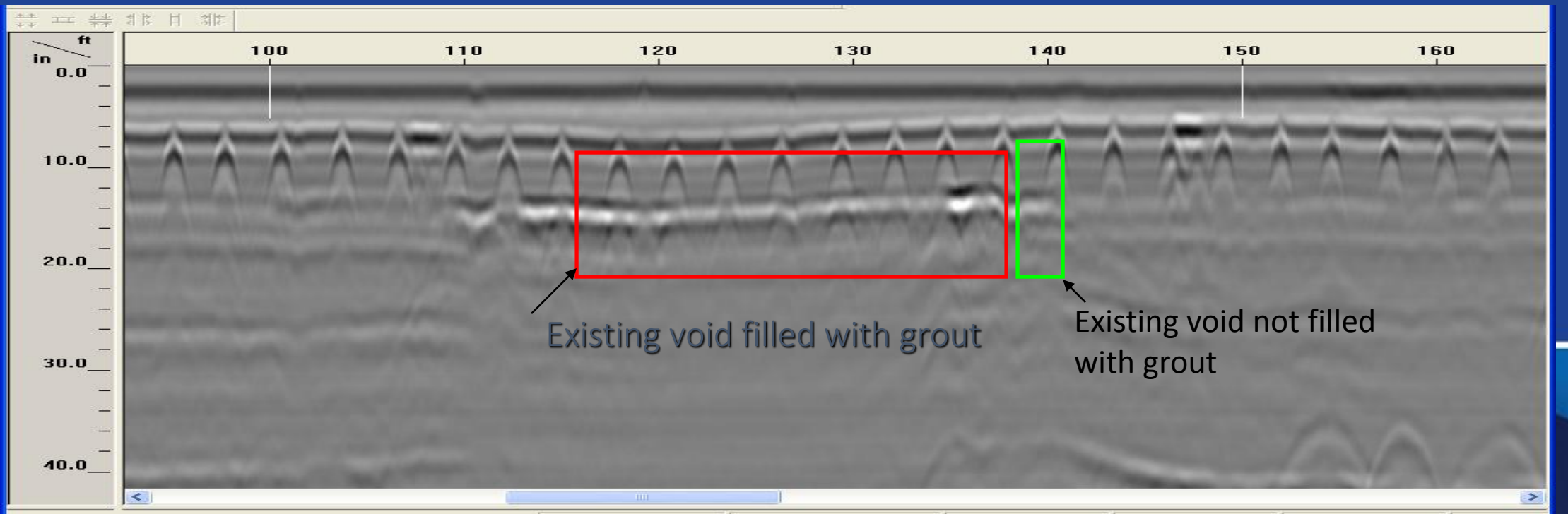
EXCELLENCE IN MOTION

Void area beneath concrete pavement southbound tunnel



GPR signal has negative amplitude (noted as black space) because it doesn't have anything to bounce off of (namely air).


ft
in
0.0
10.0
20.0
30.0
40.0
100
110
120
130
140
150
160


ft
in
0.0
10.0
20.0
30.0
40.0
100
110
120
130
140
150
160
Existing void filled with grout
Existing void not filled with grout

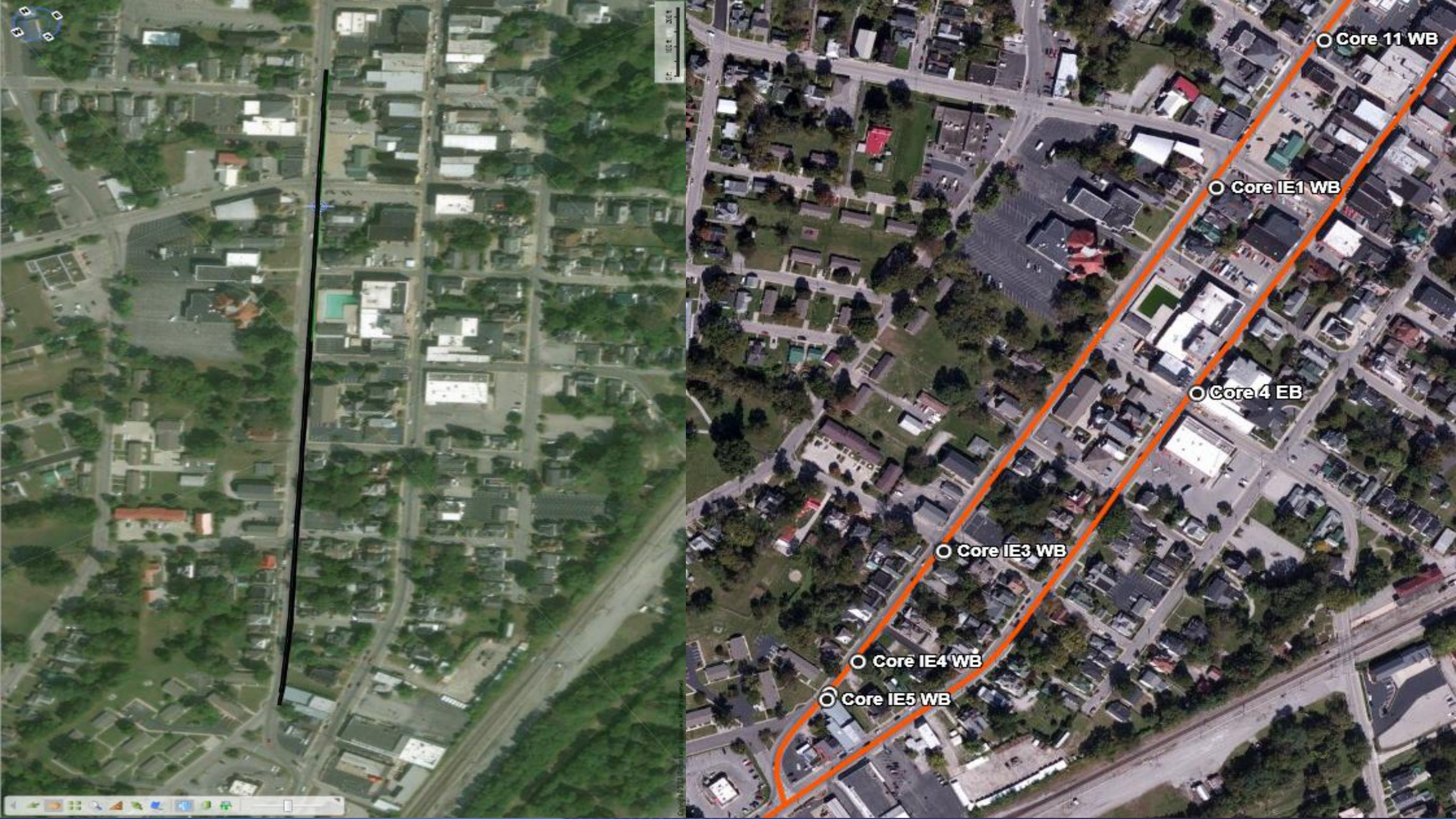
3D Radar collection (apply what we know about amplitudes and dielectrics)

Safety First

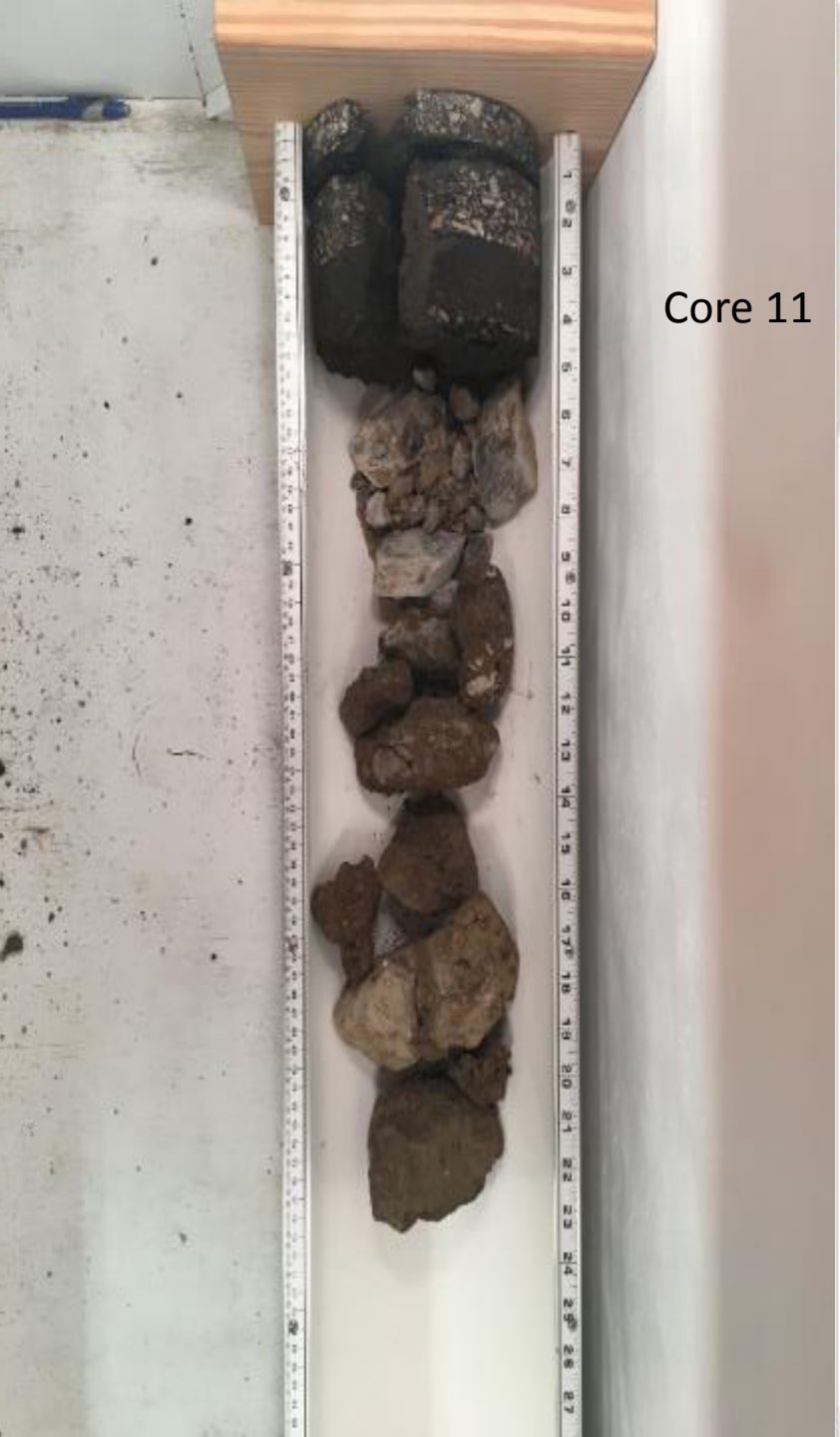
$1,600

KENTUCKY TRANSPORTATION CABINET

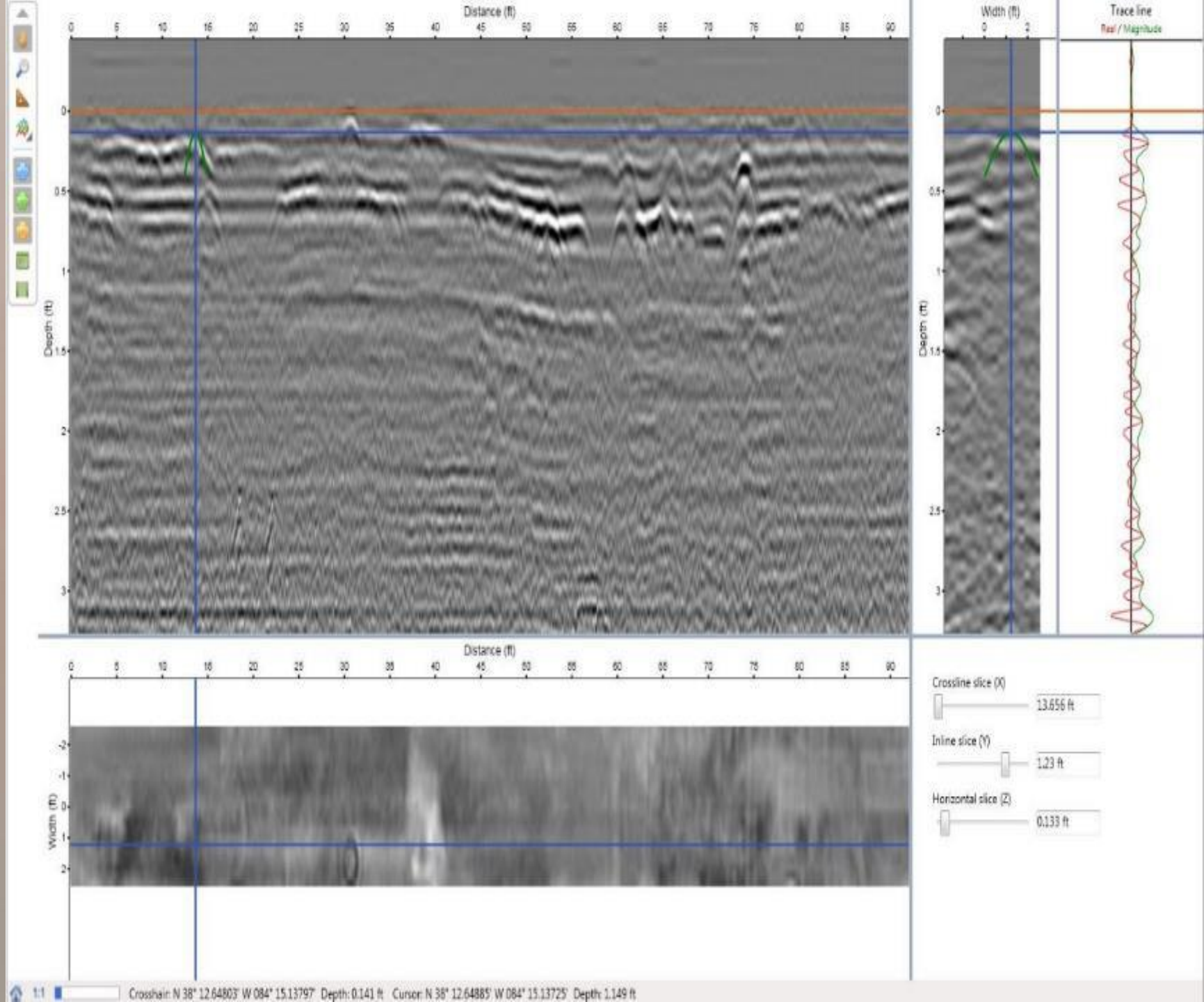
KTC EXCELLENCE IN MOTION

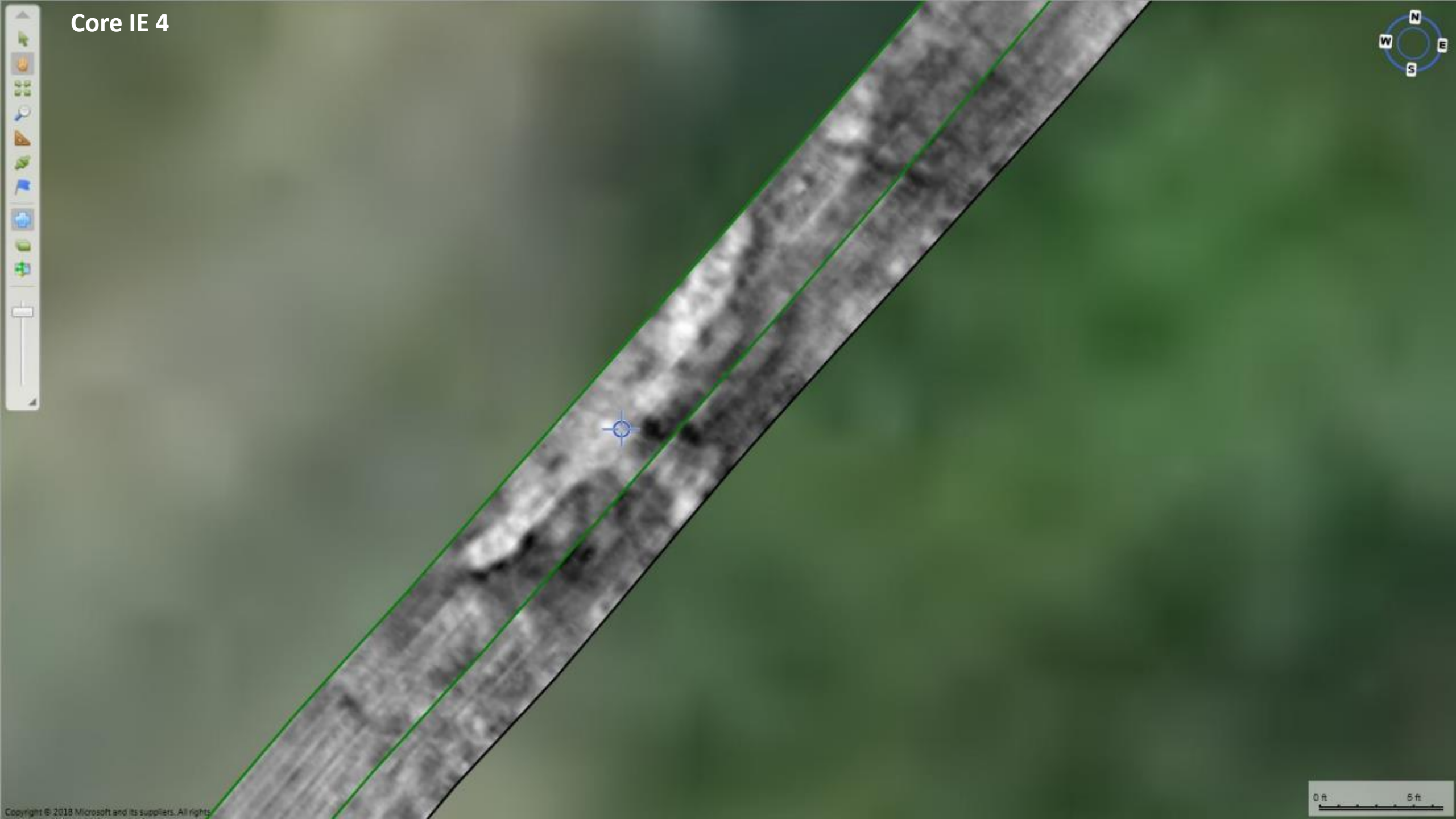

Core 11 WB
Core IE1 WB
Core 4 EB
Core IE3 WB
Core IE4 WB
Core IE5 WB


Core 11
N
W
E
S
0 ft
5 ft
10 ft
Copyright © 2018 Microsoft and its suppliers. All rights reserved.

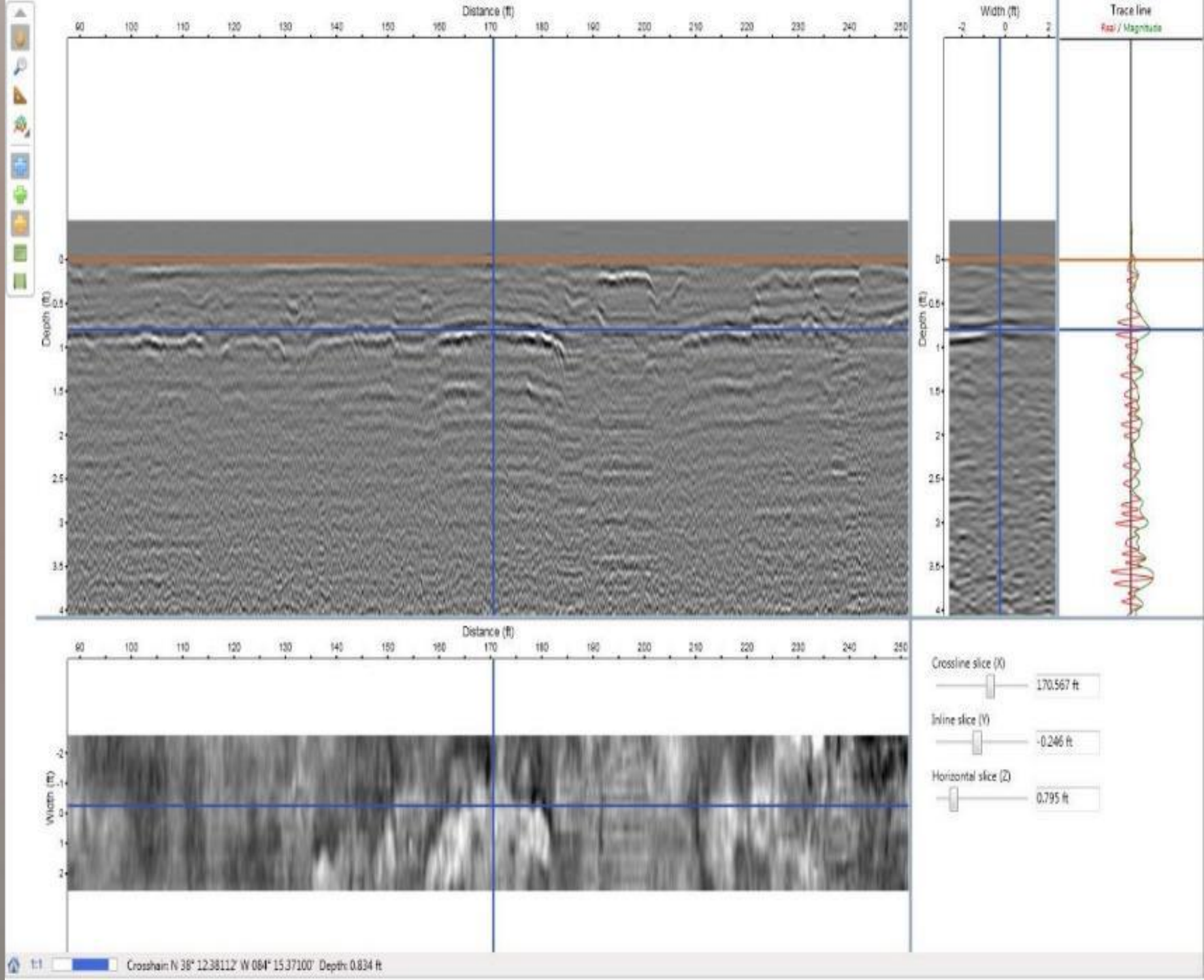


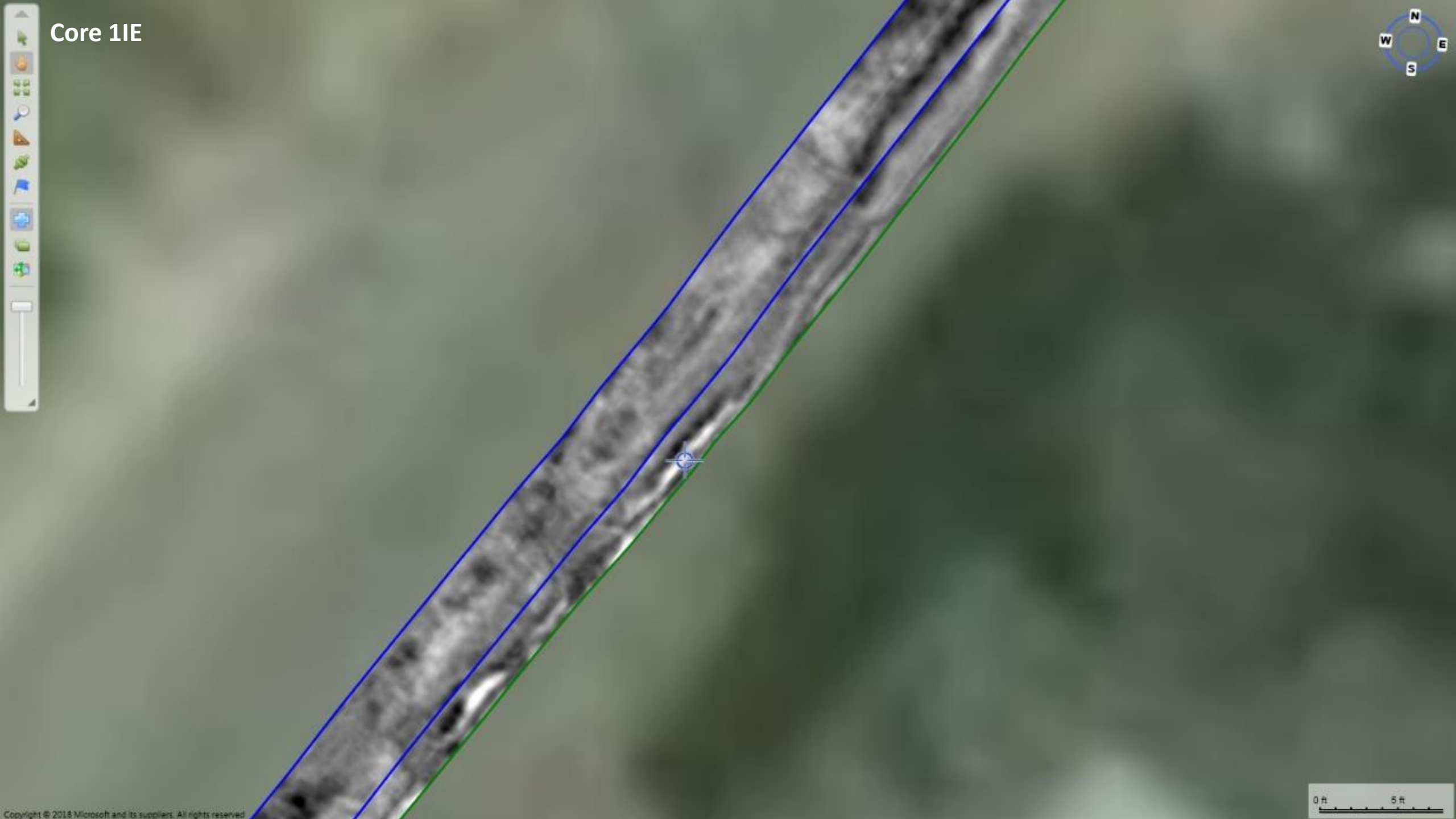
Core 11


Distance (ft)
Depth (ft)
Width (ft)
Trace line
Real / Magnitude
Distance (ft)
Width (ft)
Crossline slice (X)
13.656 ft
Inline slice (Y)
1.23 ft
Horizontal slice (Z)
0.133 ft
Crosshair: N 38° 12.64803' W 084° 15.13797' Depth: 0.141 ft Cursor: N 38° 12.64885' W 084° 15.13725' Depth: 1.149 ft

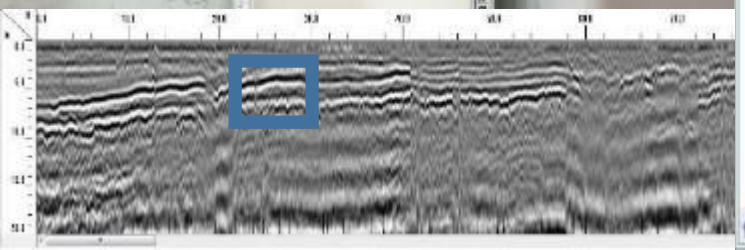

Core IE 4
N
W
E
S
0 ft
5 ft
Copyright © 2018 Microsoft and its suppliers. All rights

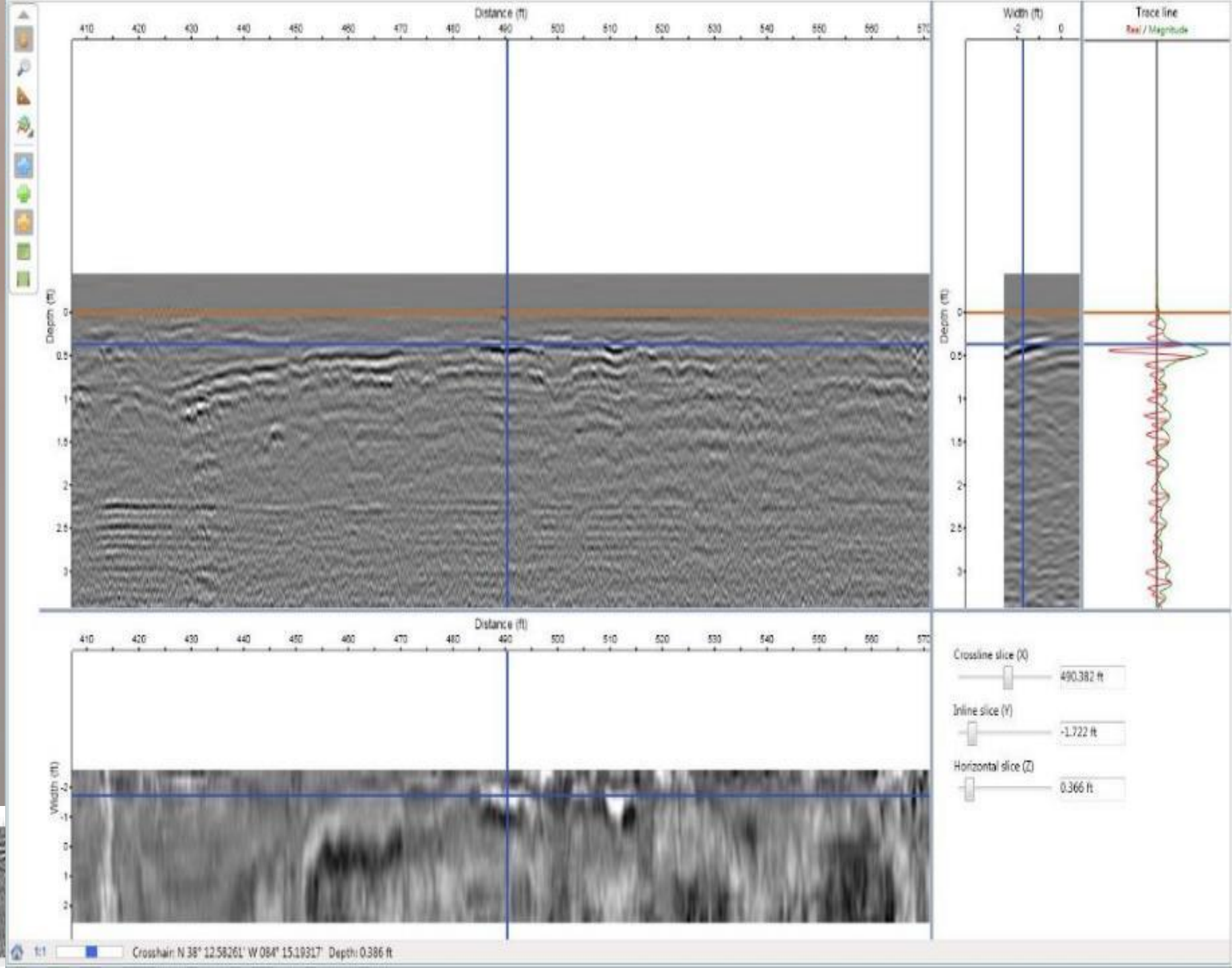
IE 4


Distance (ft)
Width (ft)
Trace line
Real / Magnitude
Depth (ft)
Distance (ft)
Width (ft)
Crossline slice (X)
170.567 ft
Inline slice (Y)
-0.246 ft
Horizontal slice (Z)
0.795 ft
Crosshair: N 38° 12.38112' W 084° 15.37100' Depth: 0.834 ft

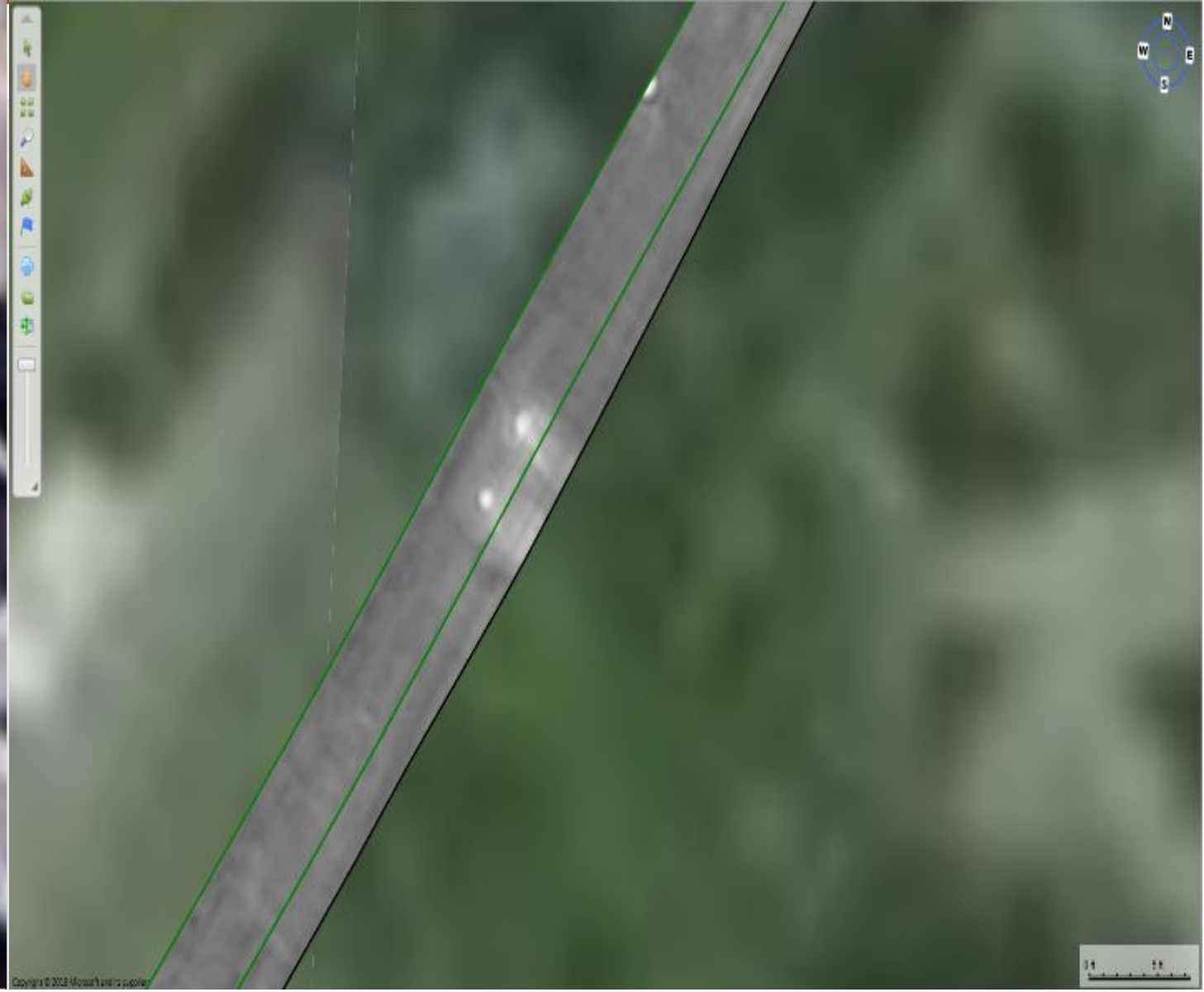

Core 1IE
N
W
E
S
0 ft
5 ft
Copyright © 2018 Microsoft and its suppliers. All rights reserved

Core 1 IE



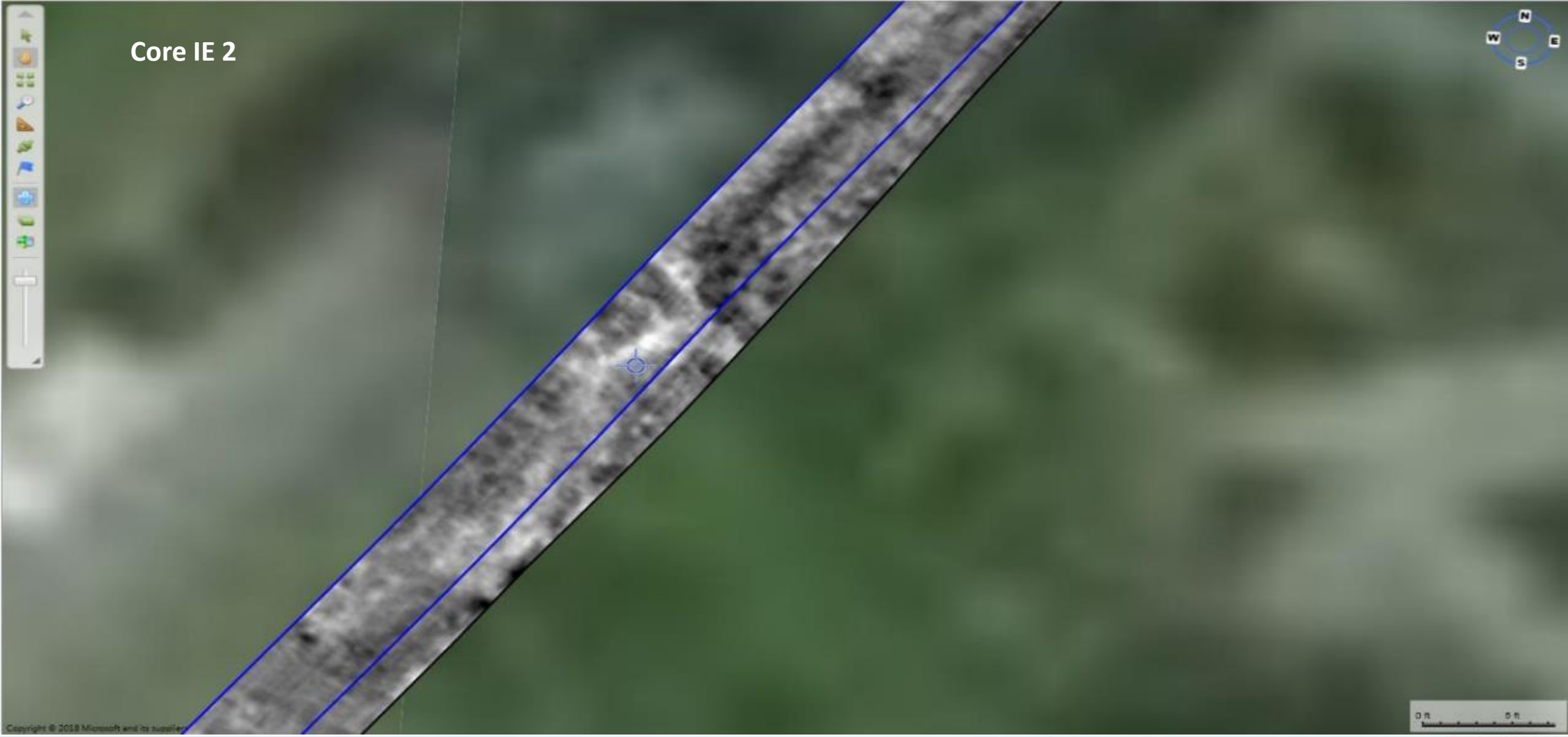

Distance (ft)
Depth (ft)
Width (ft)
Trace line
Real / Magnitude
Crossline slice (X)
490.382 ft
Inline slice (Y)
-1.722 ft
Horizontal slice (Z)
0.366 ft
Crosshair: N 38° 12.58261' W 084° 15.19317' Depth: 0.386 ft

Cores IE 3 and IE 2

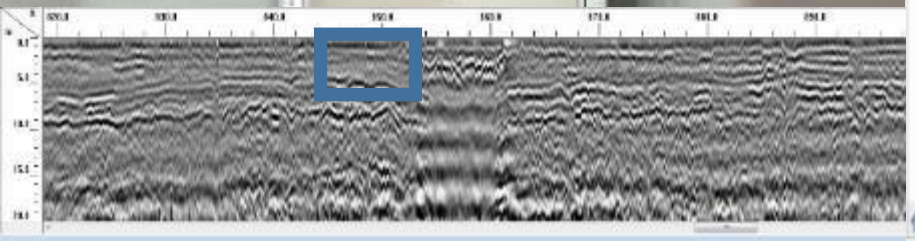


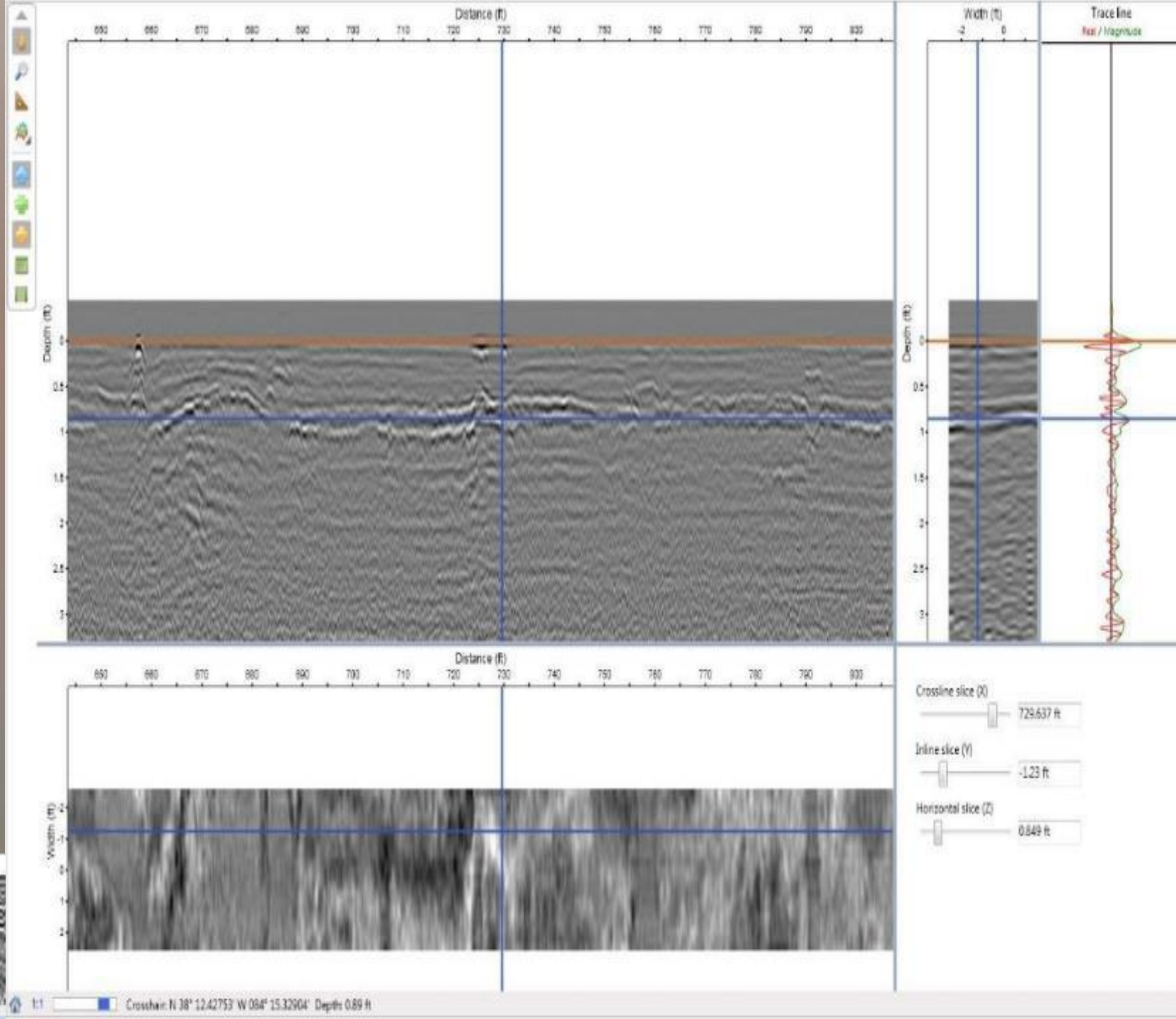
KENTUCKY TRANSPORTATION CABINET

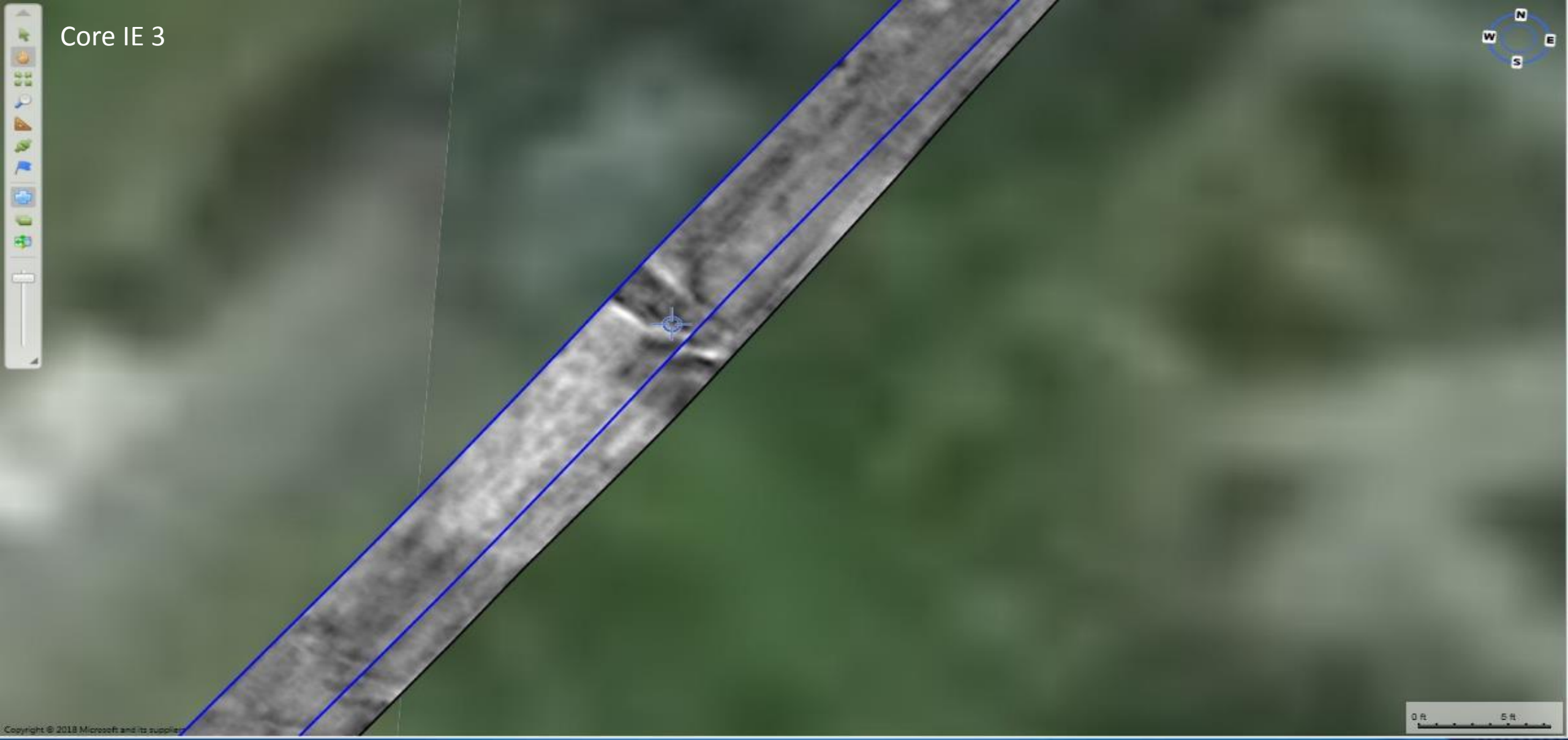
KTC EXCELLENCE IN MOTION


Core IE 2

IE 2



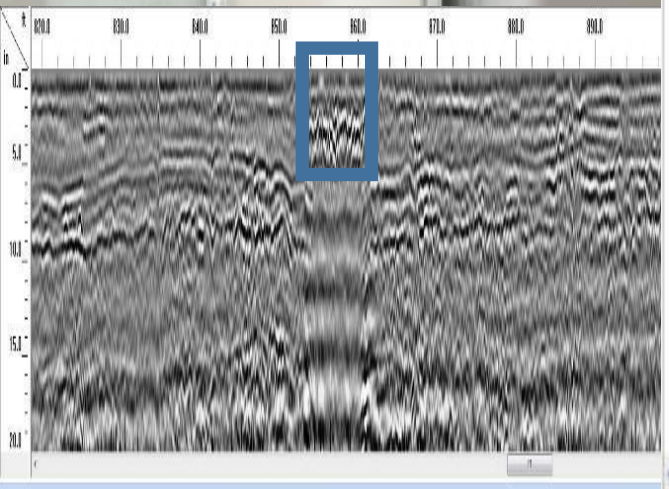

Distance (ft)
Width (ft)
Trace line
Real / Magnitude
Depth (ft)
Crossline slice (X)
729.637 ft
Inline slice (Y)
-1.23 ft
Horizontal slice (Z)
0.849 ft

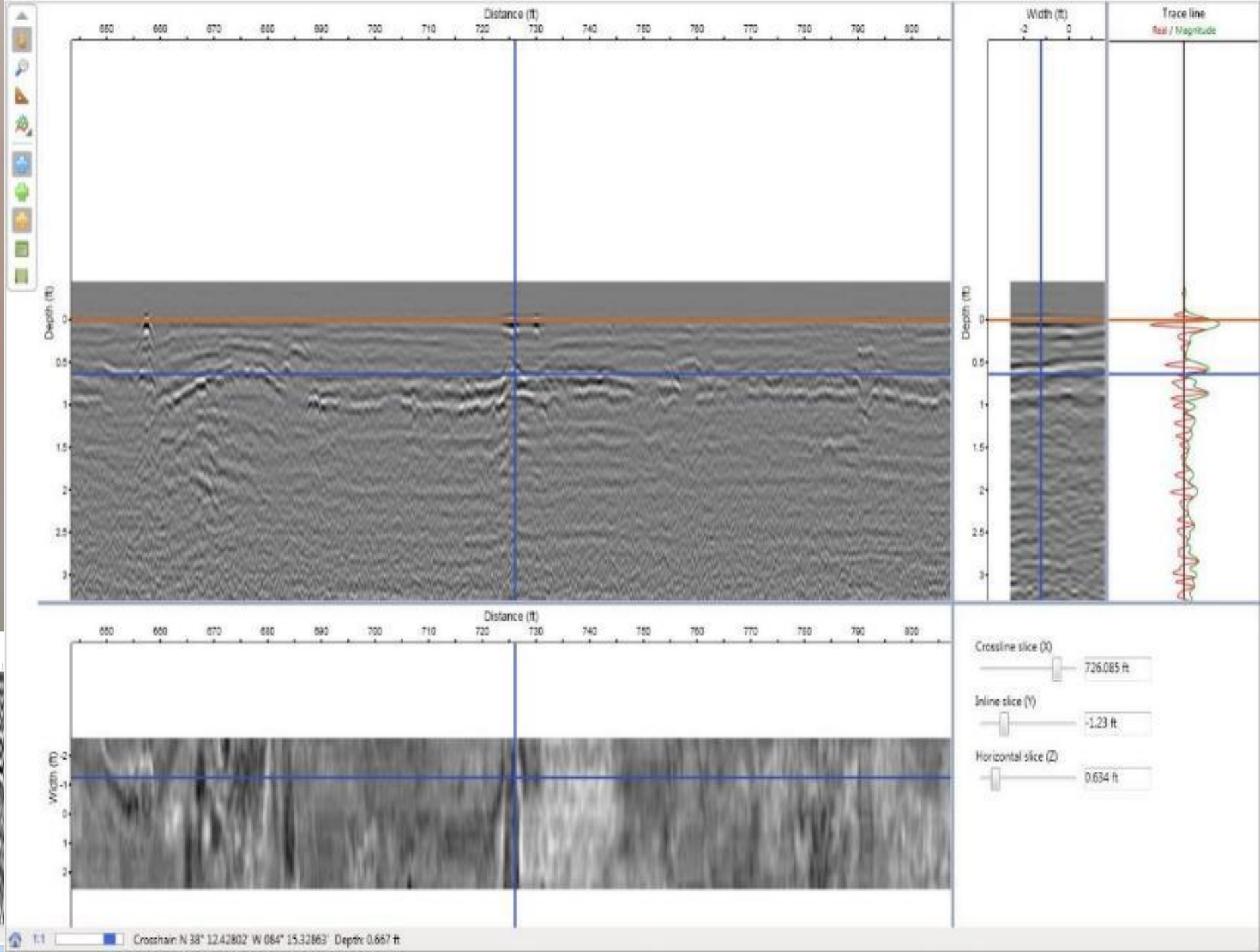


KENTUCKY TRANSPORTATION CABINET

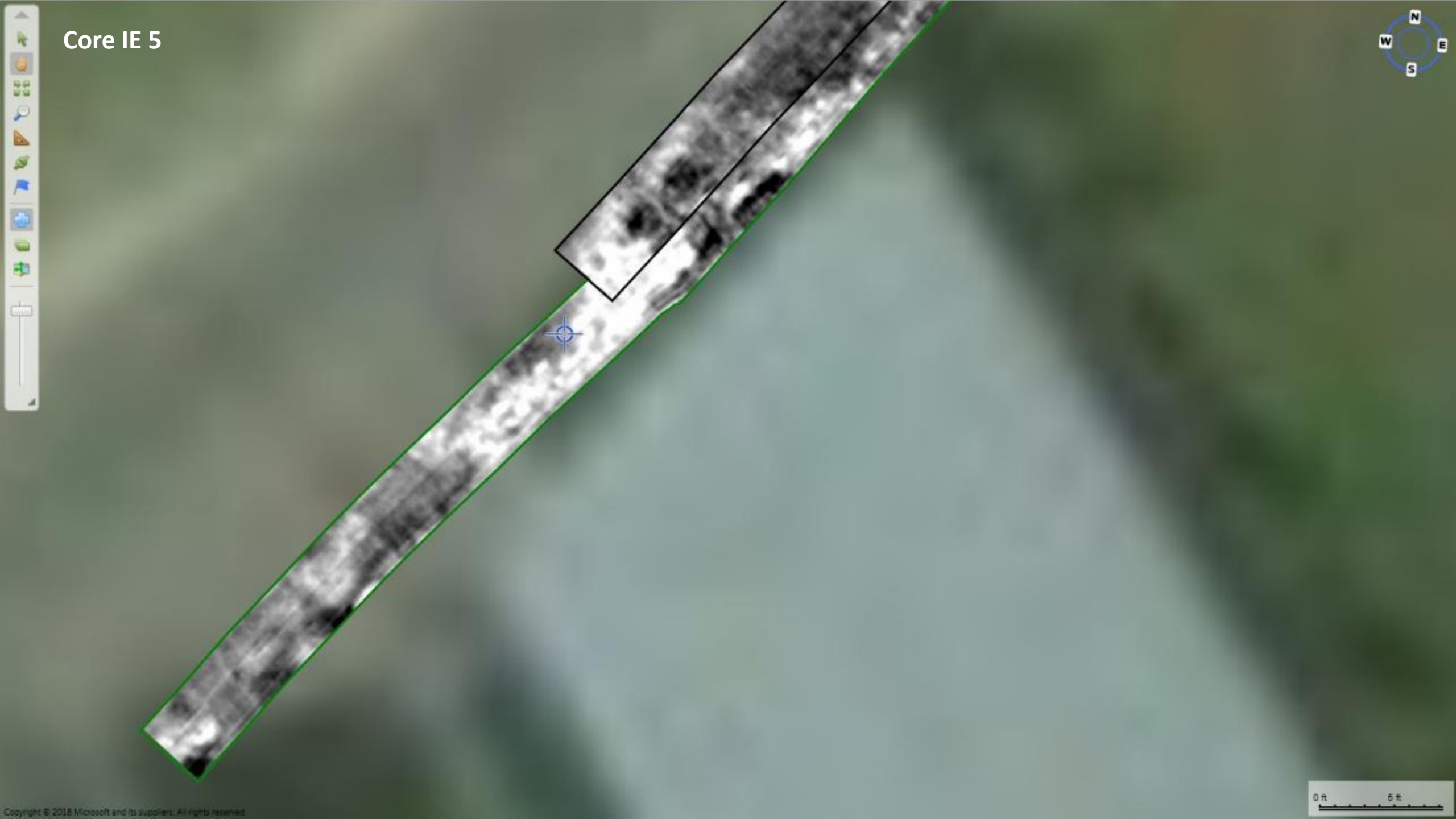
KTC
EXCELLENCE IN MOTION

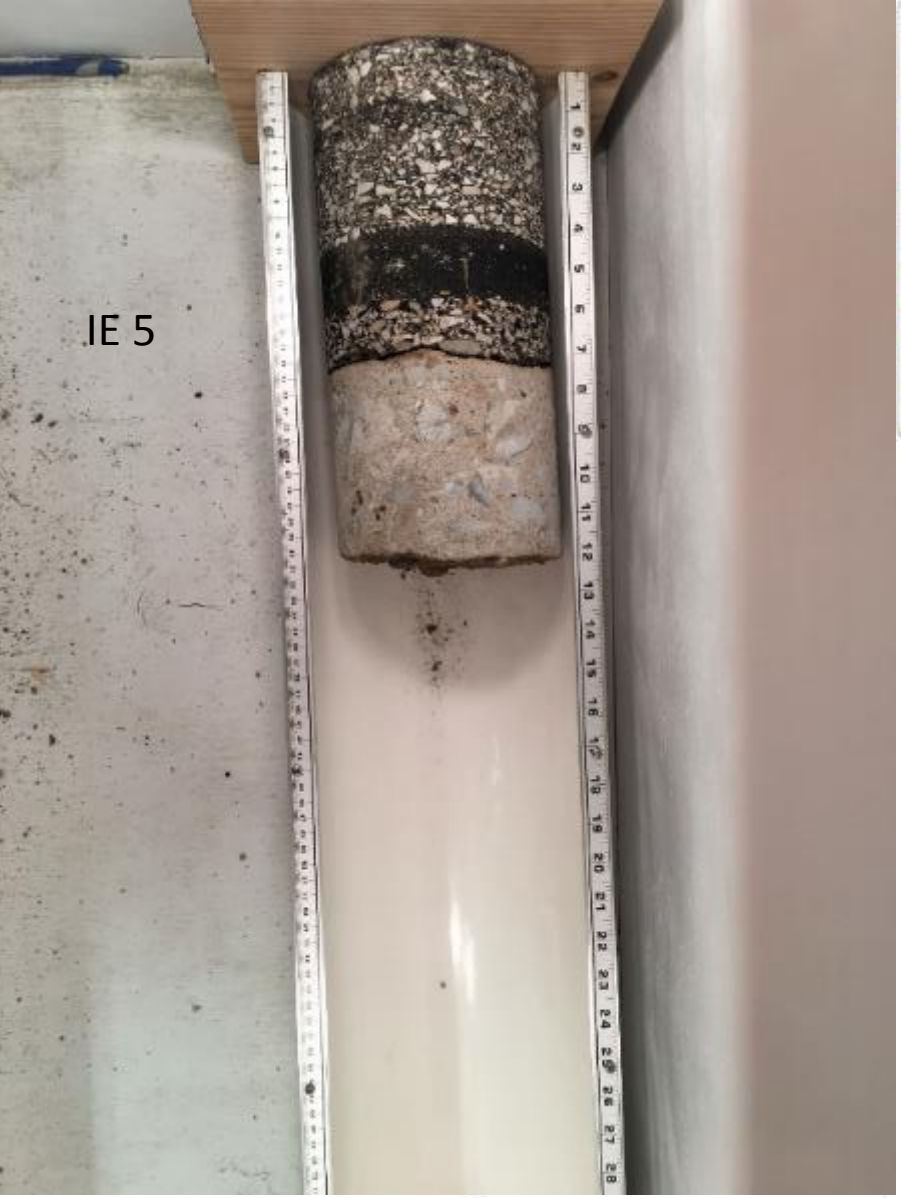
IE 3

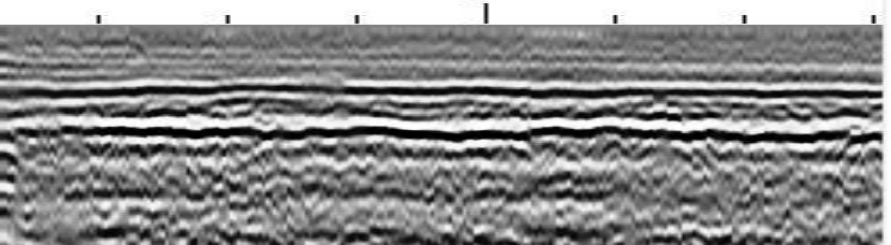


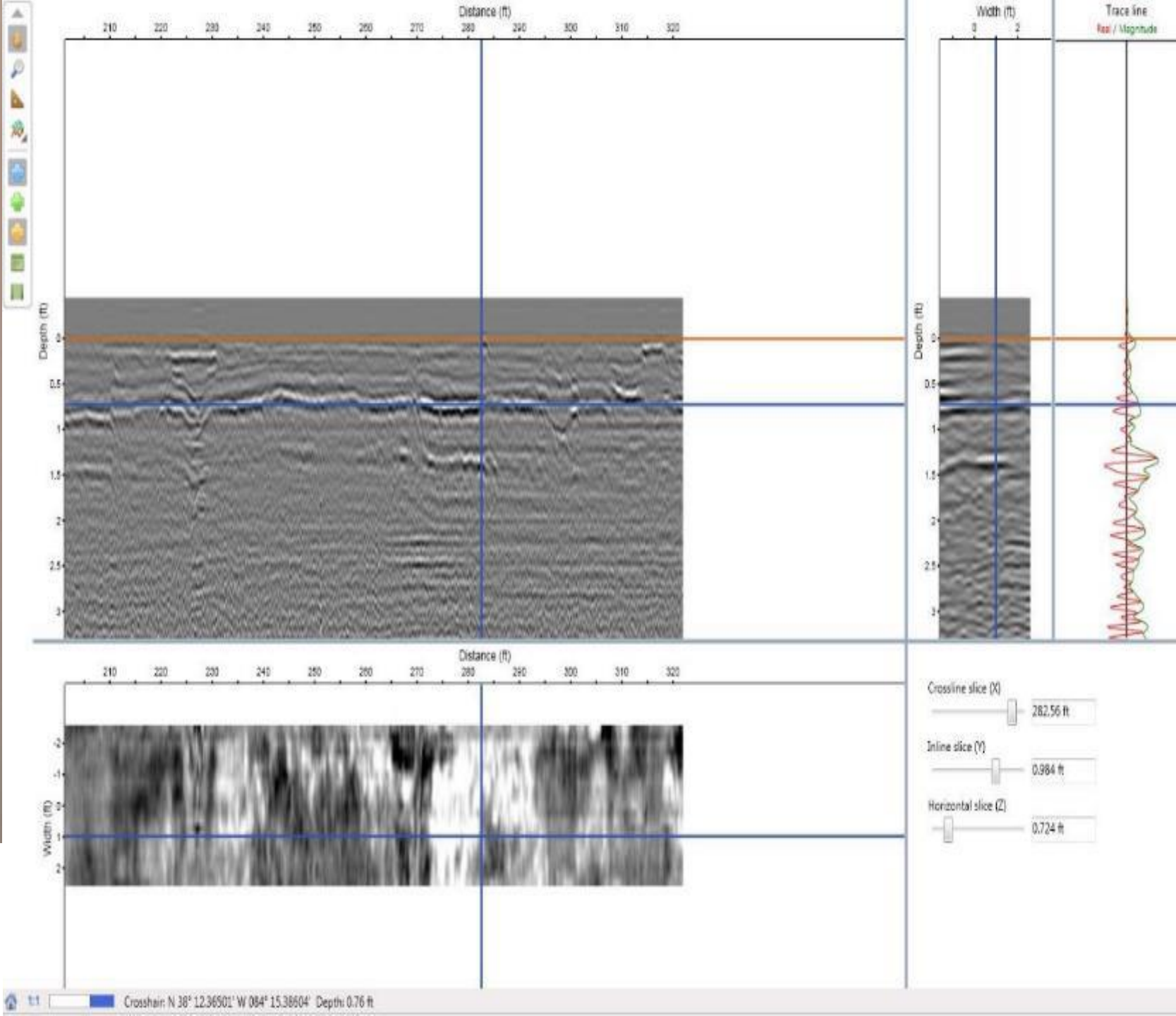

Distance (ft)
Depth (ft)
Width (ft)
Trace line
Real / Magnitude
Crossline slice (X)
726.085 ft
Inline slice (Y)
-1.23 ft
Horizontal slice (Z)
0.634 ft
Crosshair: N 38° 12.42802' W 084° 15.32863' Depth: 0.667 ft

Core IE 5




IE 5

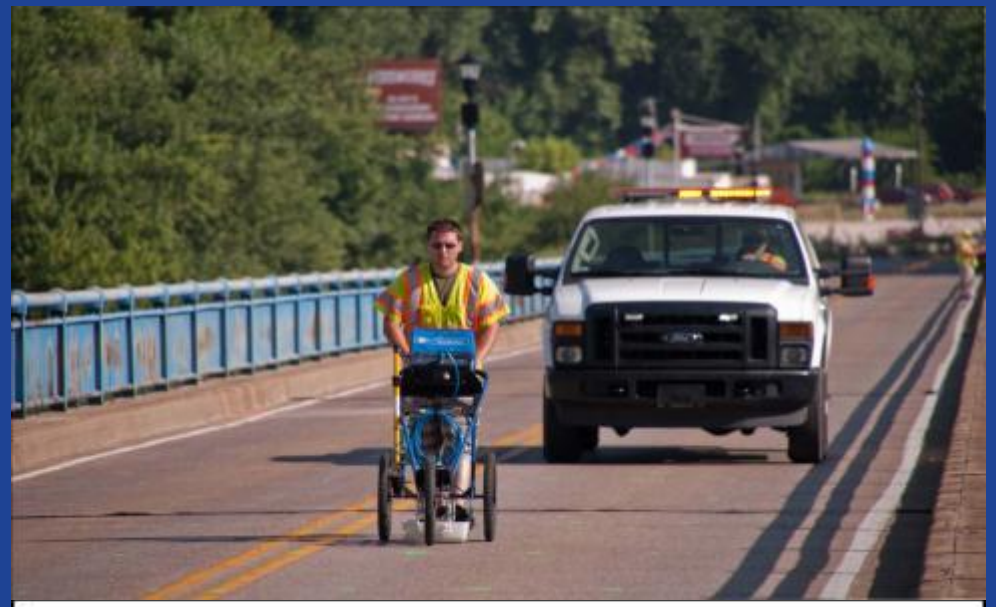


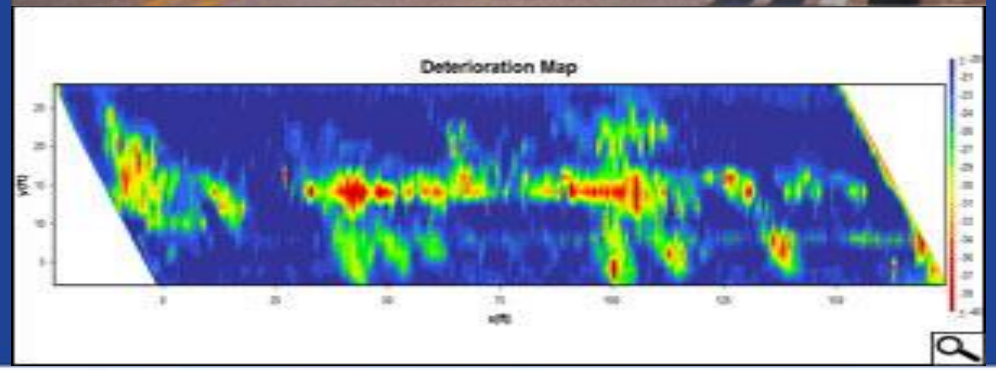

Distance (ft)
Depth (ft)
Width (ft)
Trace line
Real / Magnitude
Crossline slice (X)
282.56 ft
Inline slice (Y)
0.984 ft
Horizontal slice (Z)
0.724 ft
Crosshair: N 38° 12.36501' W 084° 15.38604' Depth: 0.76 ft

Maybe consider a bridge deck deterioration approach for finding delaminations in pavements?

- Use the high and low amplitudes to identify if voids are air/water filled

Similar to Bridge Deck Deterioration
Use amplitudes of return signals at interface to determine if voided or not

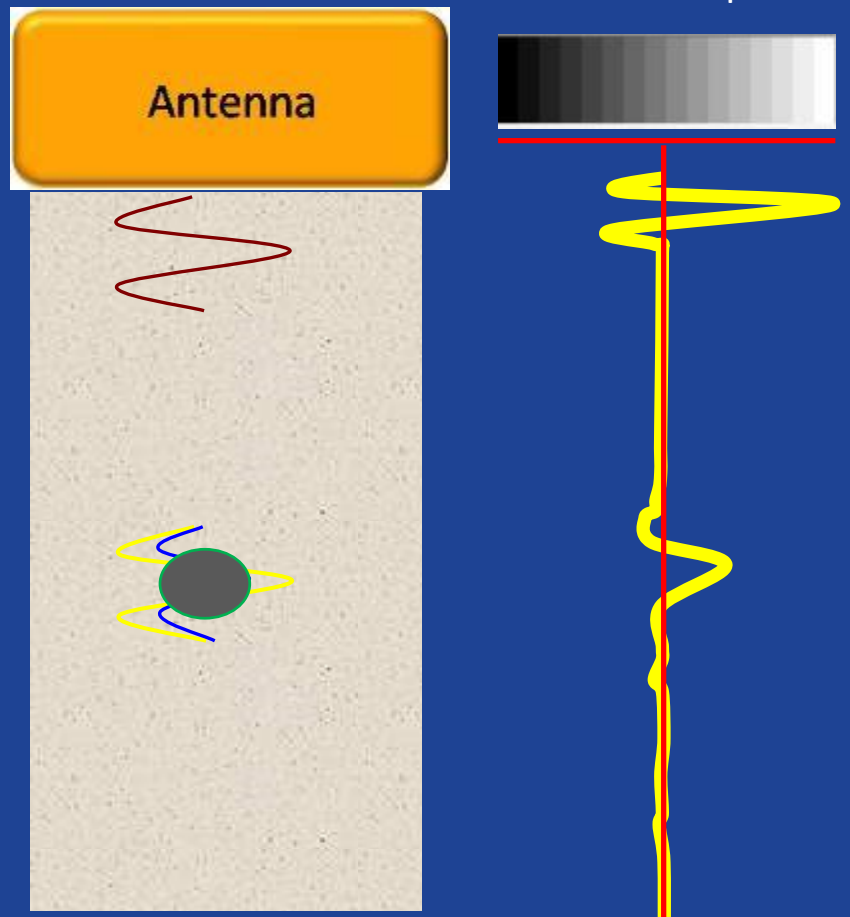


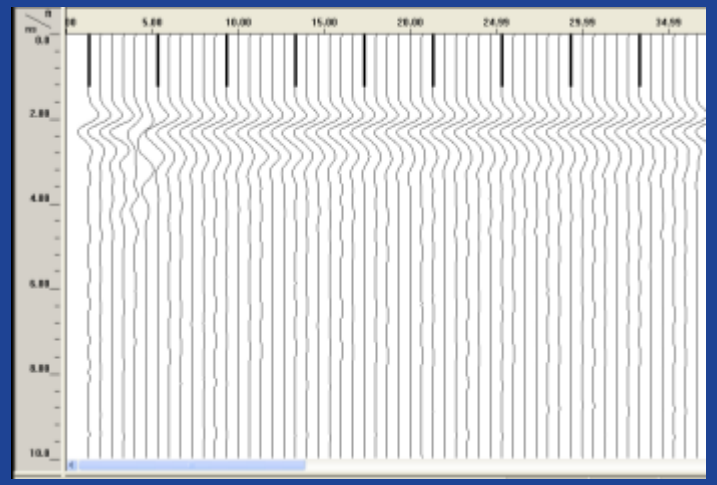


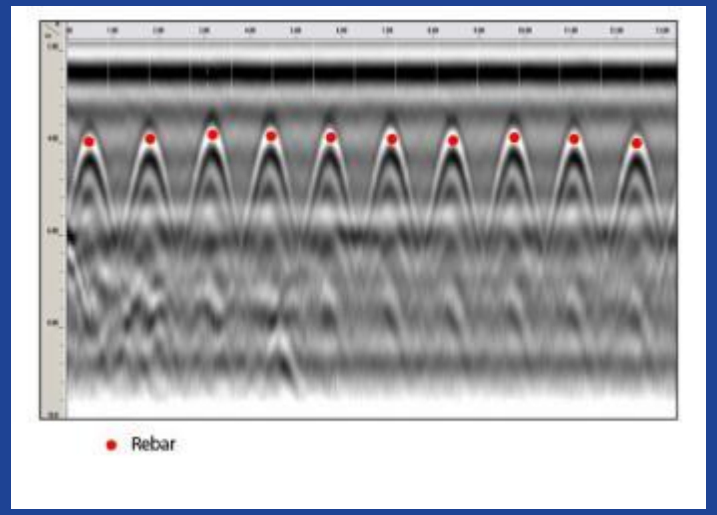
KENTUCKY TRANSPORTATION CABINET

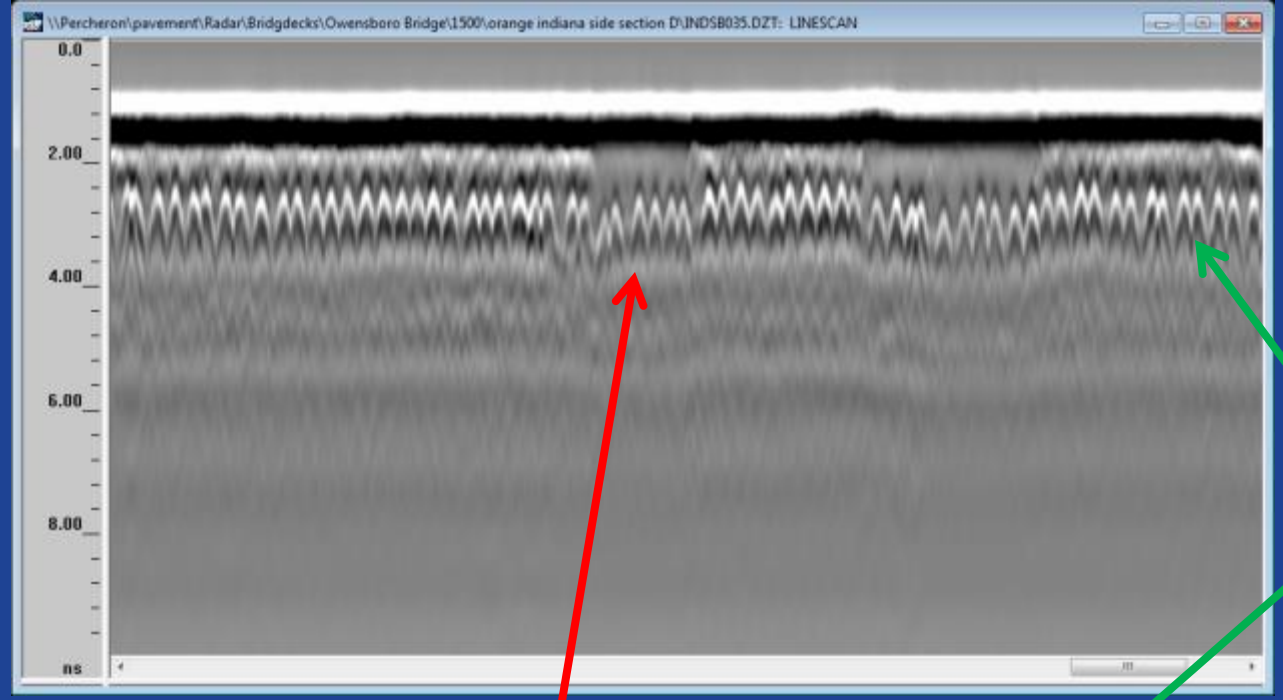
KTC
EXCELLENCE IN MOTION

Producing multiple scans to image reinforcement





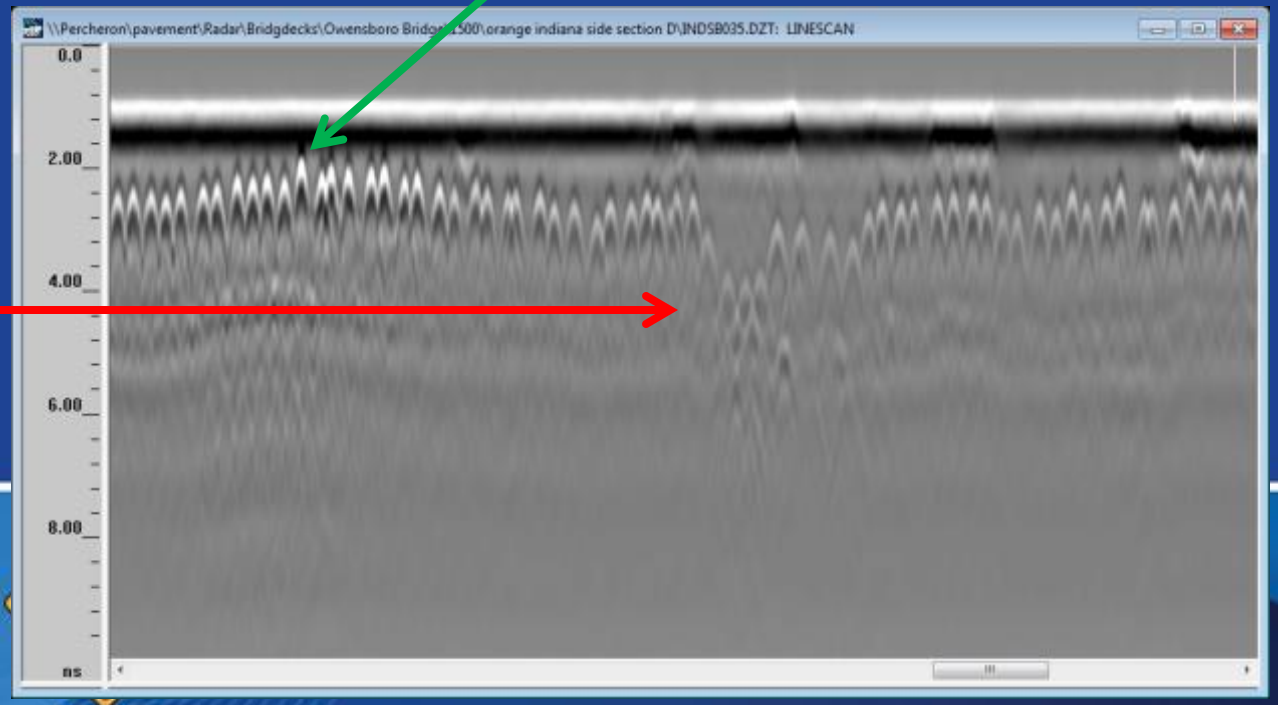




Change in reinforcement corrosion and delaminated concrete affects amplitude of radar signal

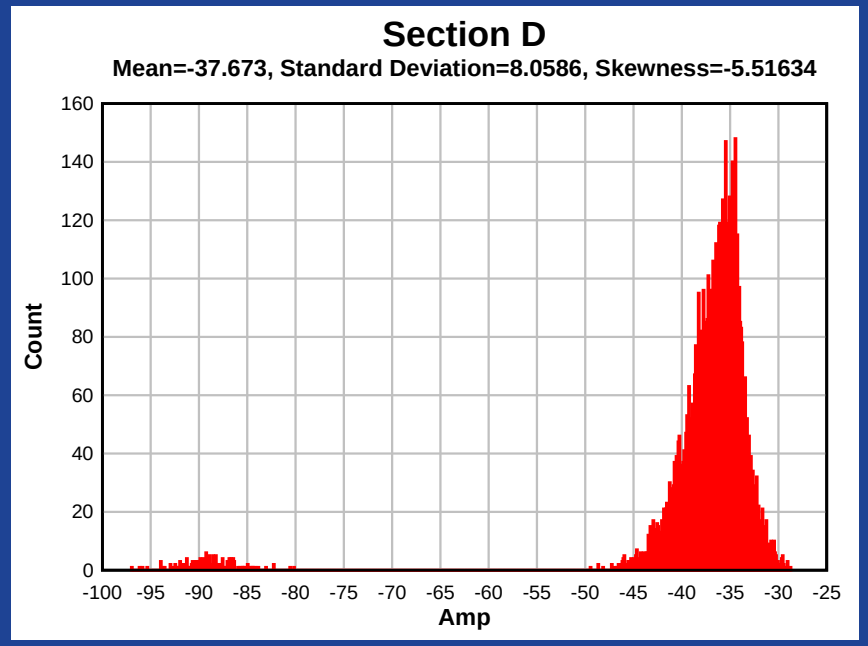
Good reflections high amplitudes

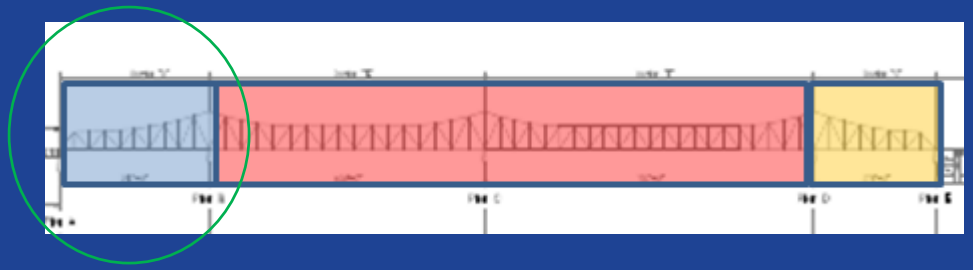
Weak reflections low amplitudes

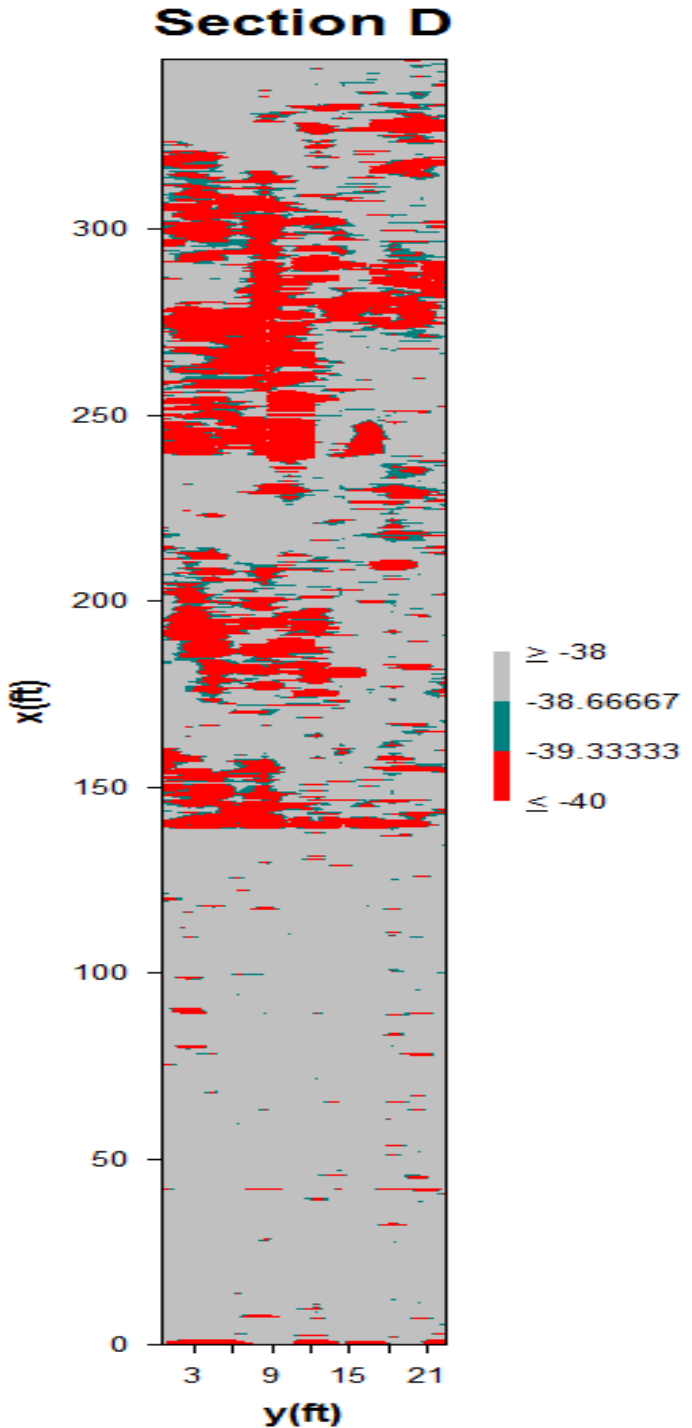


EXCELLENCE IN MOTION

Section D: 25% +/- 5% deteriorated



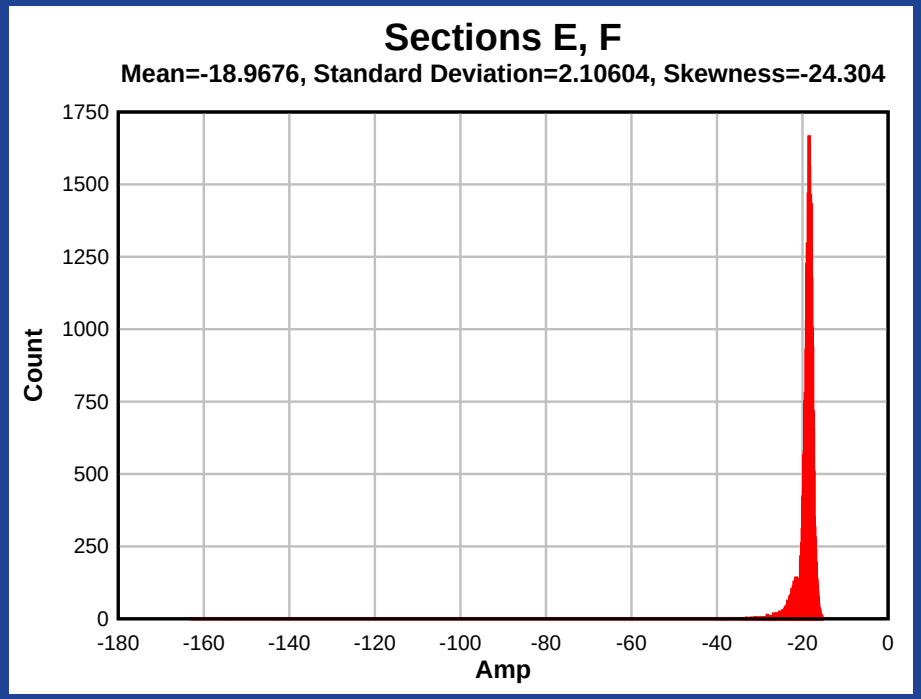


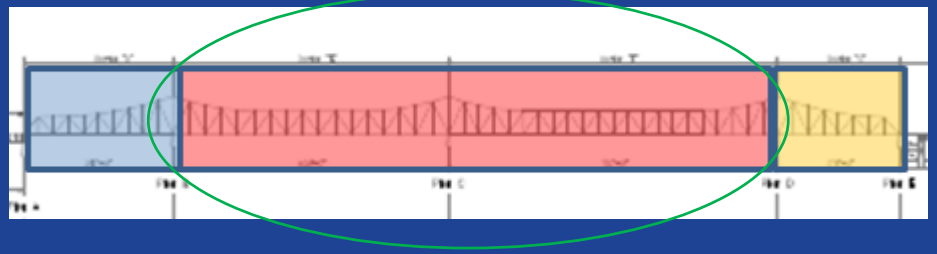


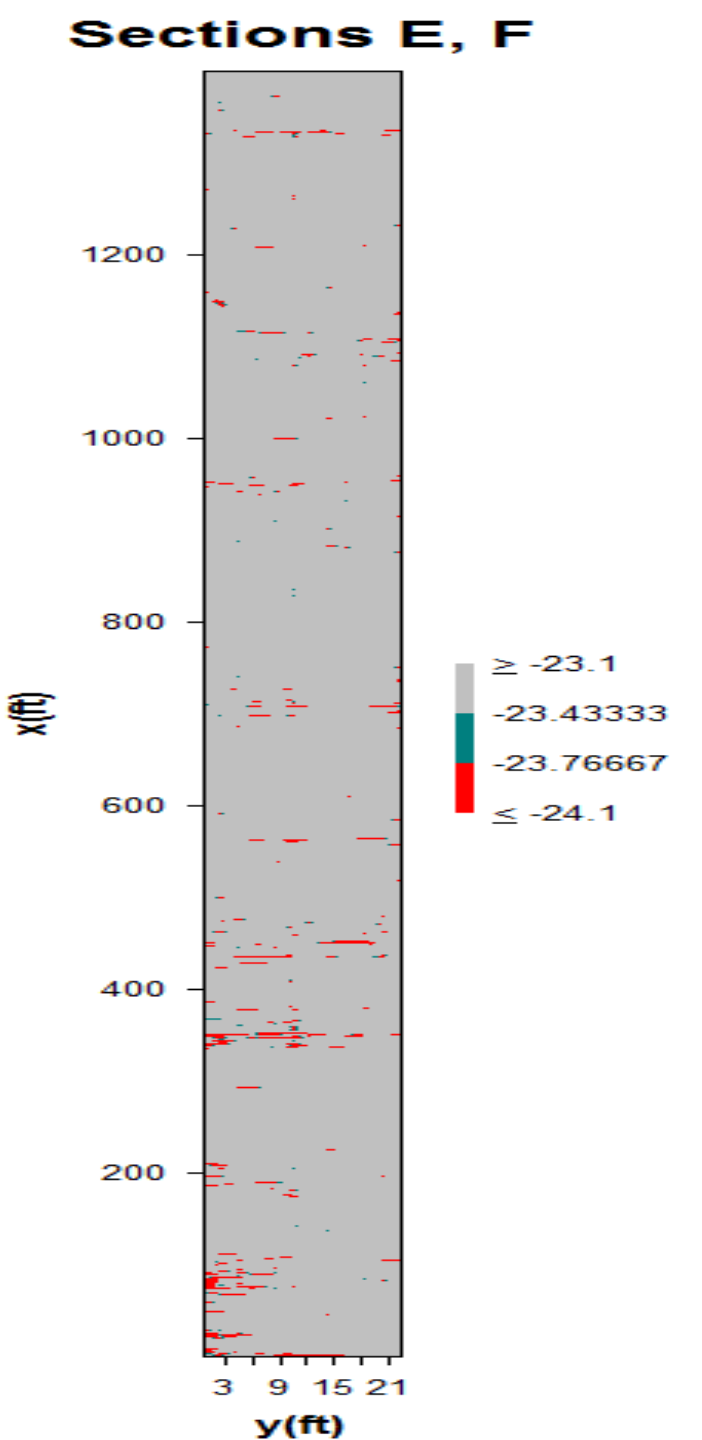
KENTUCKY TRANSPORTATION CABINET

KTC
EXCELLENCE IN MOTION

Section E, F: 3.5% +/- 5% deteriorated

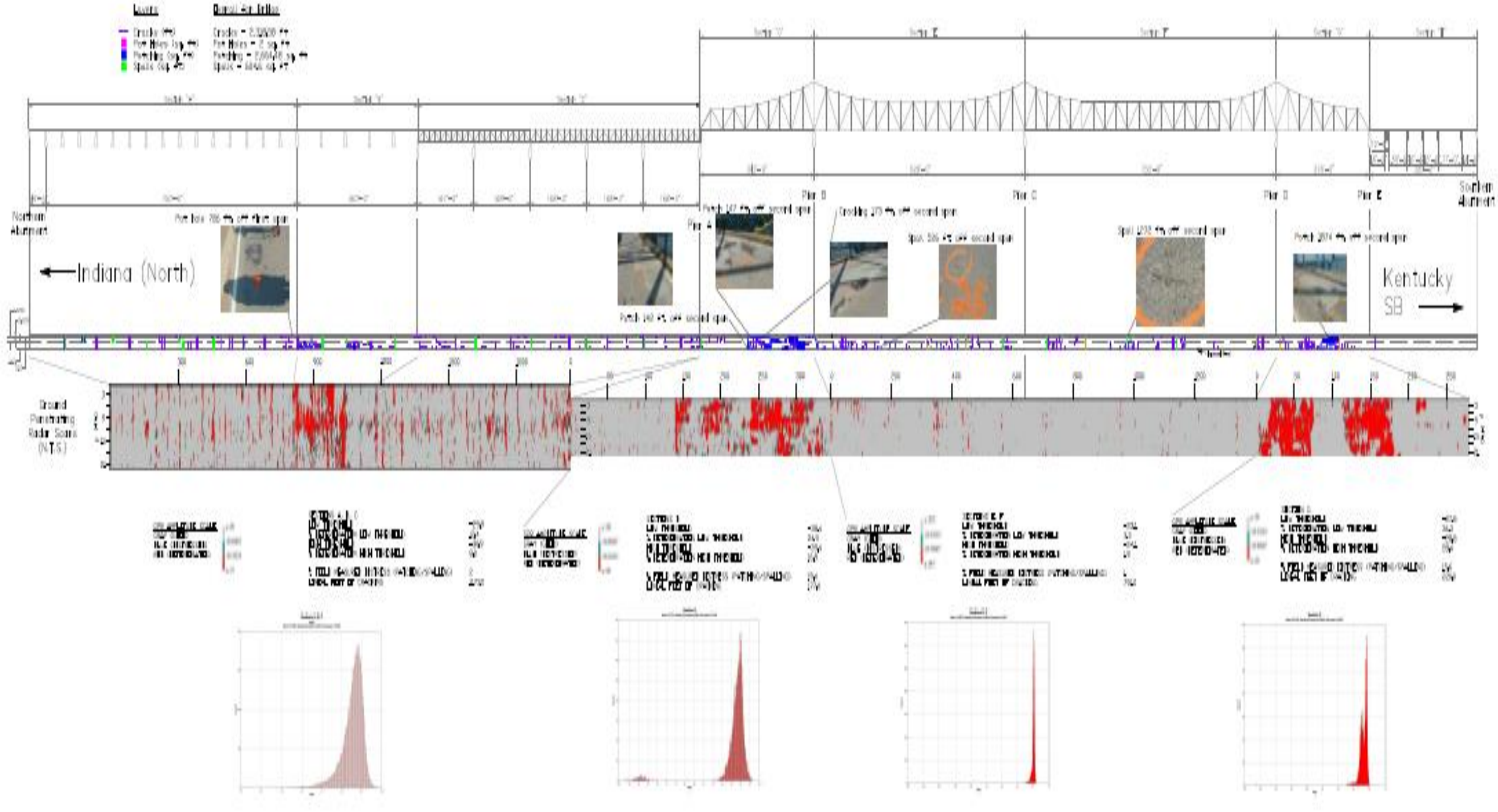


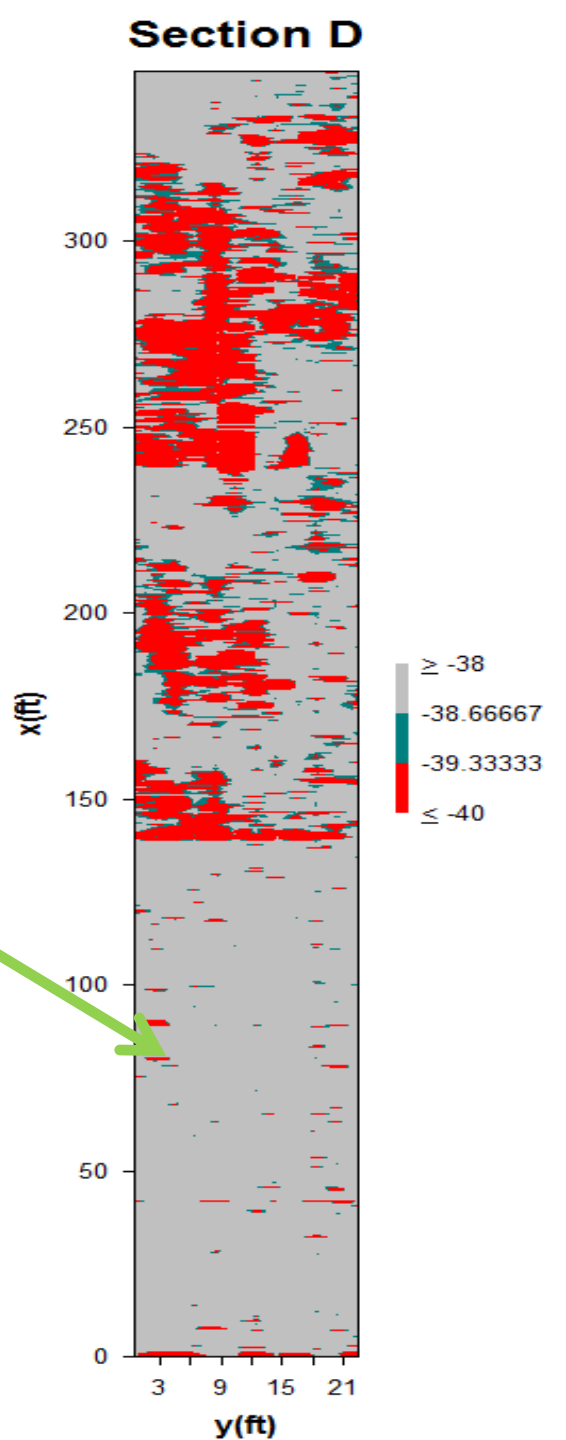




KENTUCKY TRANSPORTATION CABINET

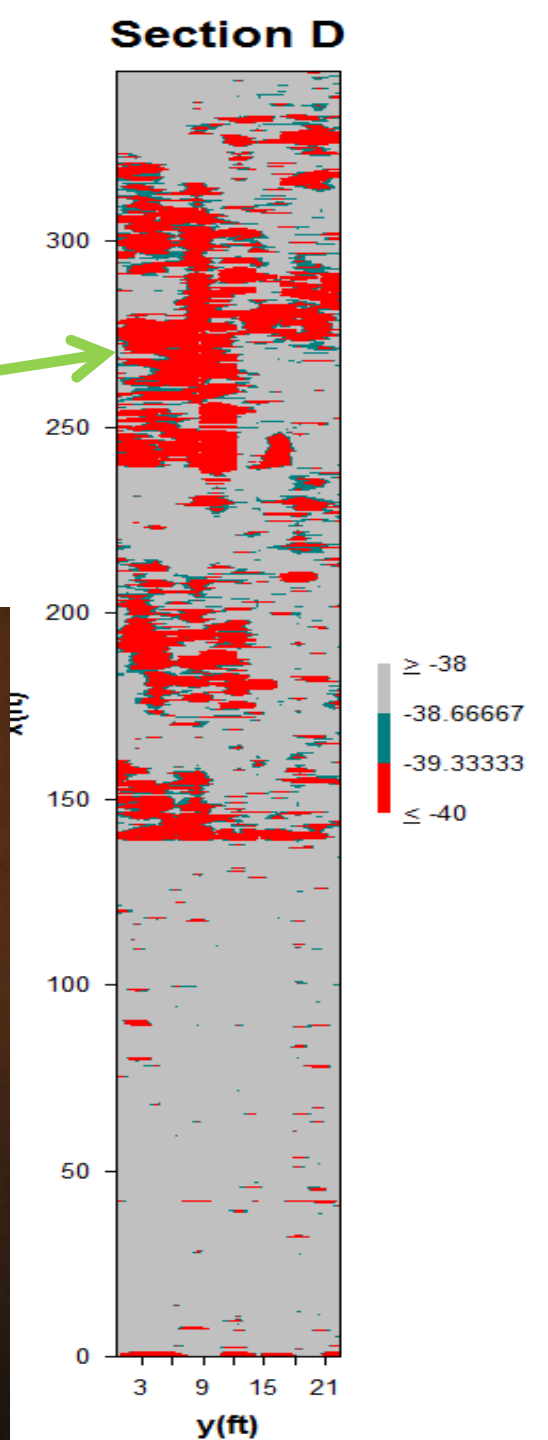
KTC
EXCELLENCE IN MOTION


Indiana (North)
Kentucky
SB
Northern Abutment
Pier A
Pier B
Pier C
Pier D
Pier E
Southern Abutment
Ground Penetrating Radar Scans (N.T.S.)

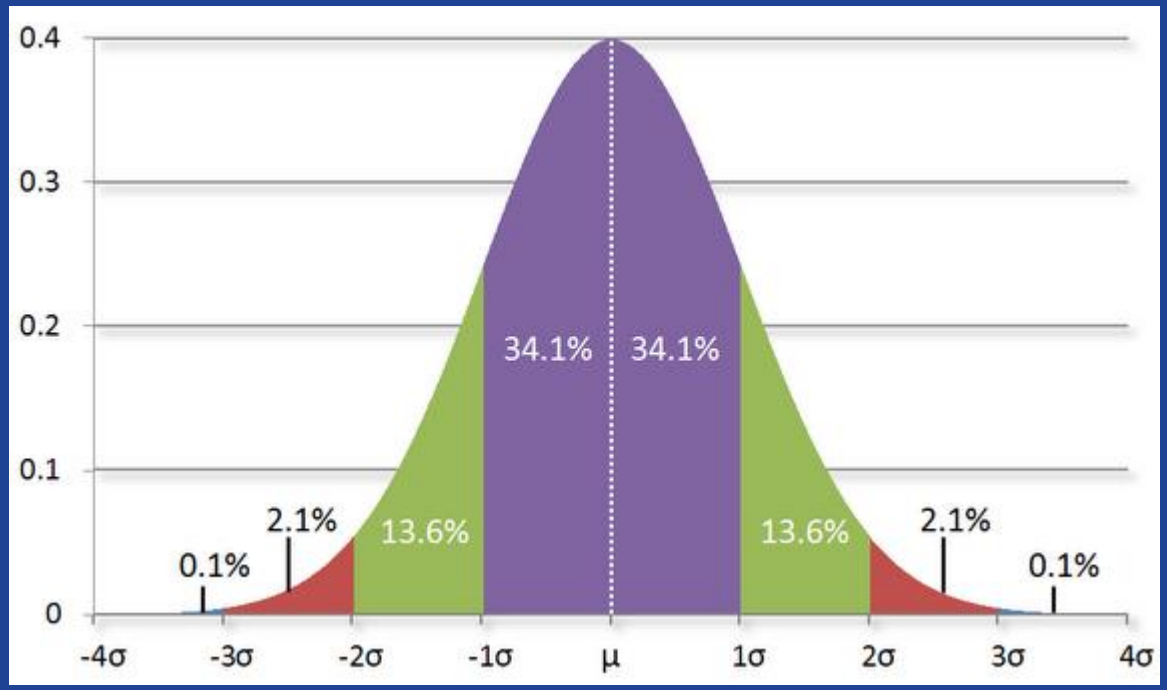


EXCELLENCE IN MOTION


50%
Loss


Section D
300
250
200
150
100
50
0
3
9
15
21
y(ft)
≥ -38
-38.66667
-39.33333
≤ -40

Maybe a statistical approach, with a percent within limits, could be used to find air/water filled voids within pavements



Other uses of 3D Radar

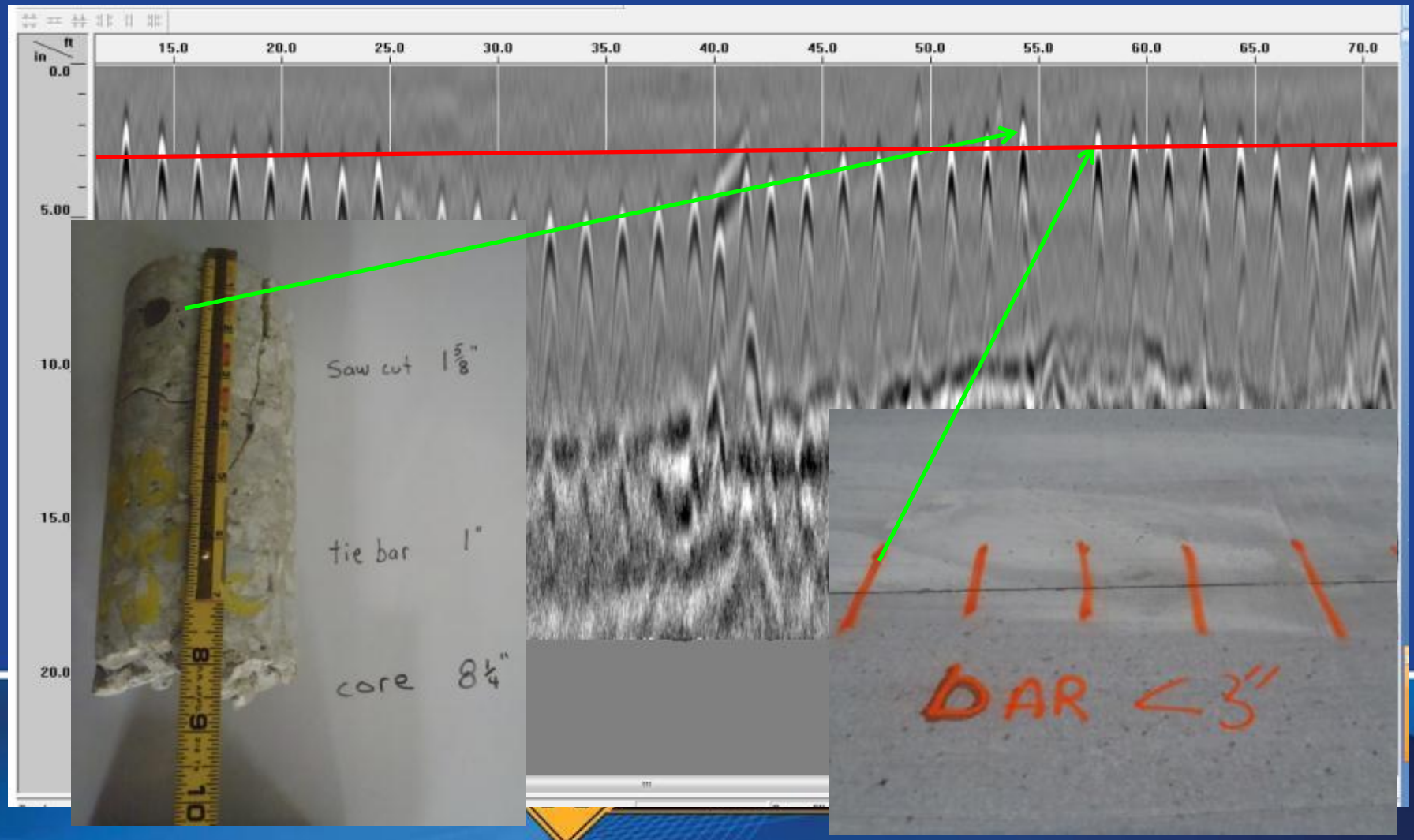
Determining placement of dowel baskets and tie bars in PCCP

Shelbyville Bypass: after diamond grinding to achieve ride acceptance—Longitudinal Tie Bars were exposed

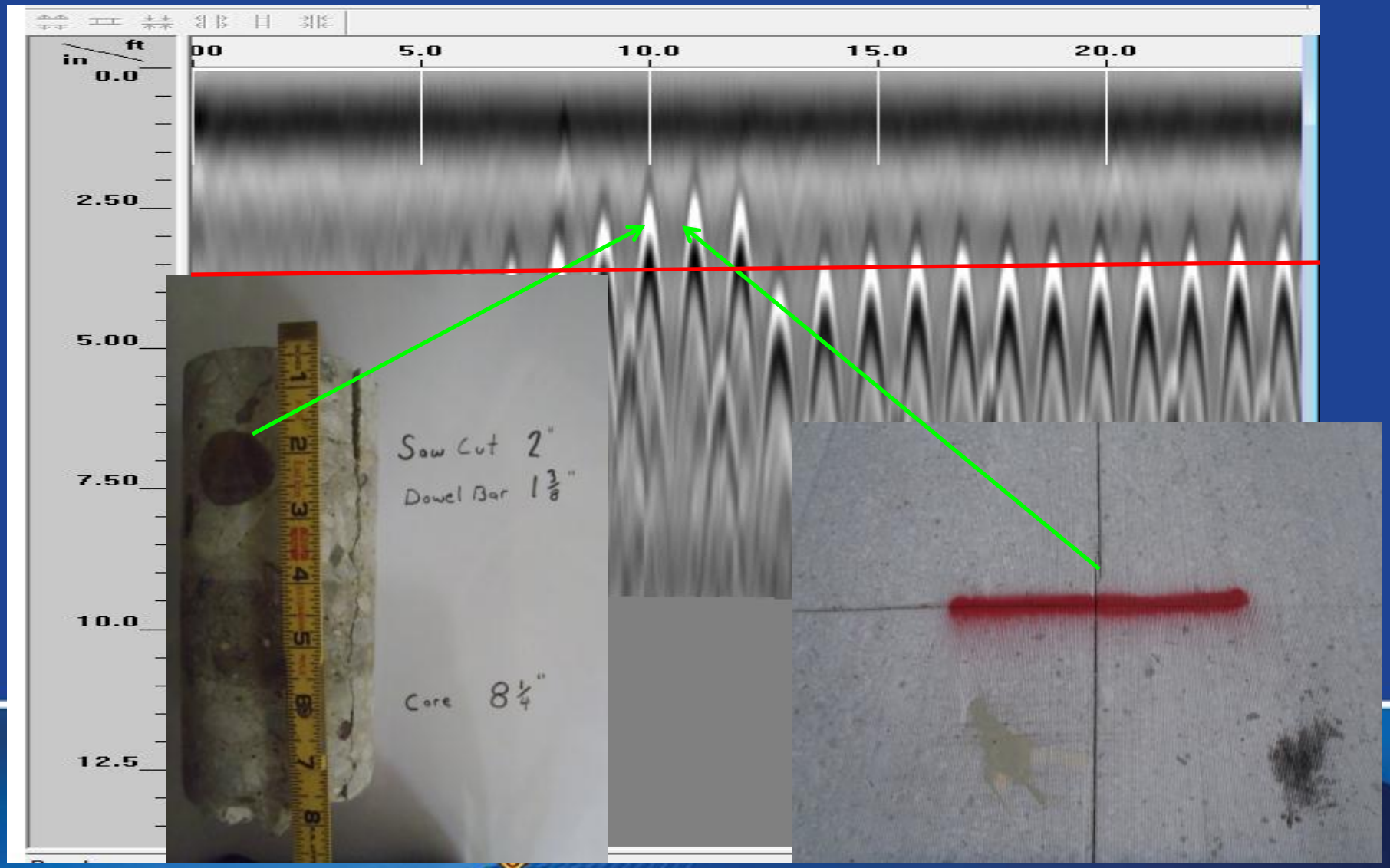
KENTUCKY TRANSPORTATION CABINET

KTC EXCELLENCE IN MOTION

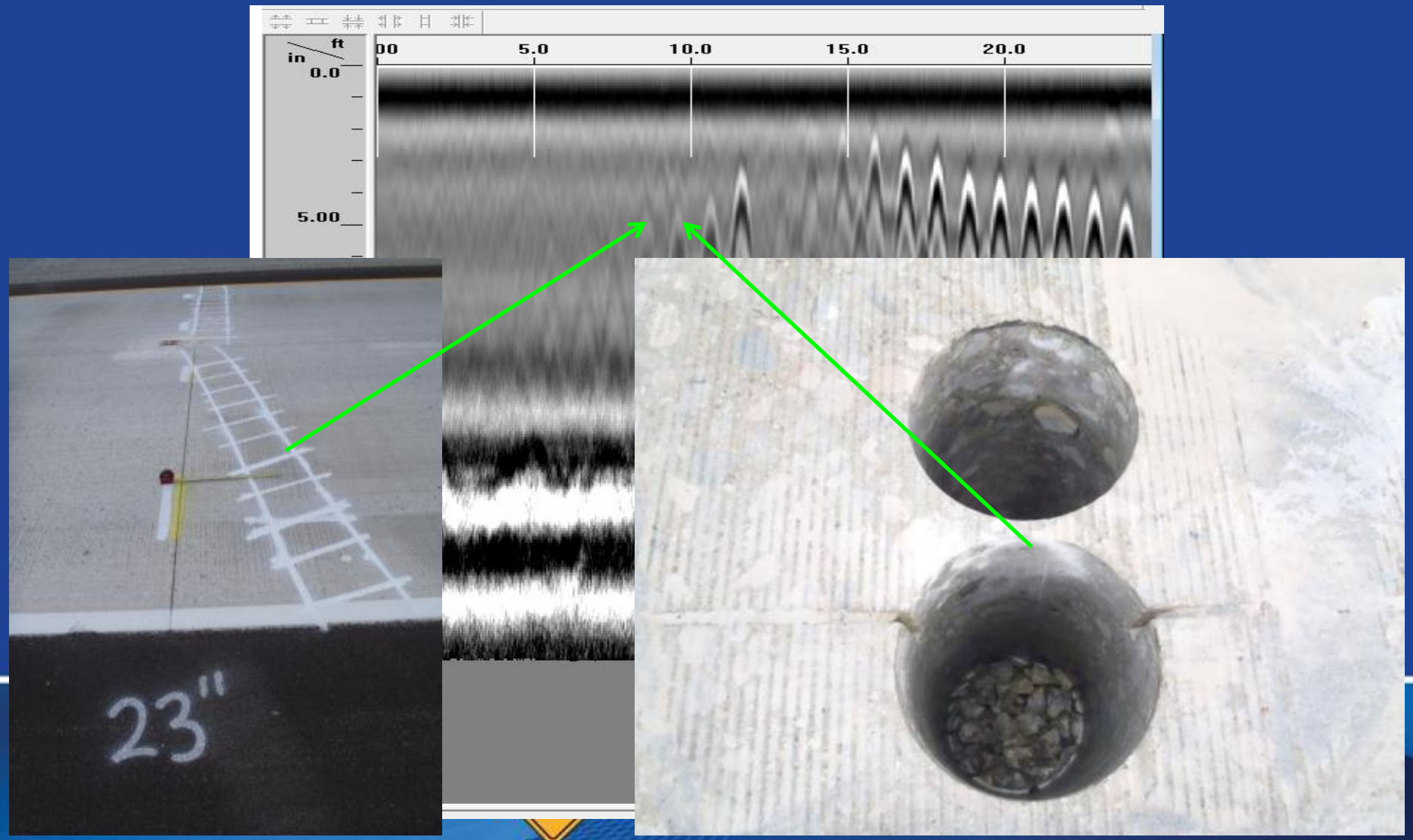
High Tie Bars



High Dowel Baskets



Misaligned Dowel Baskets



How much affected Pavement

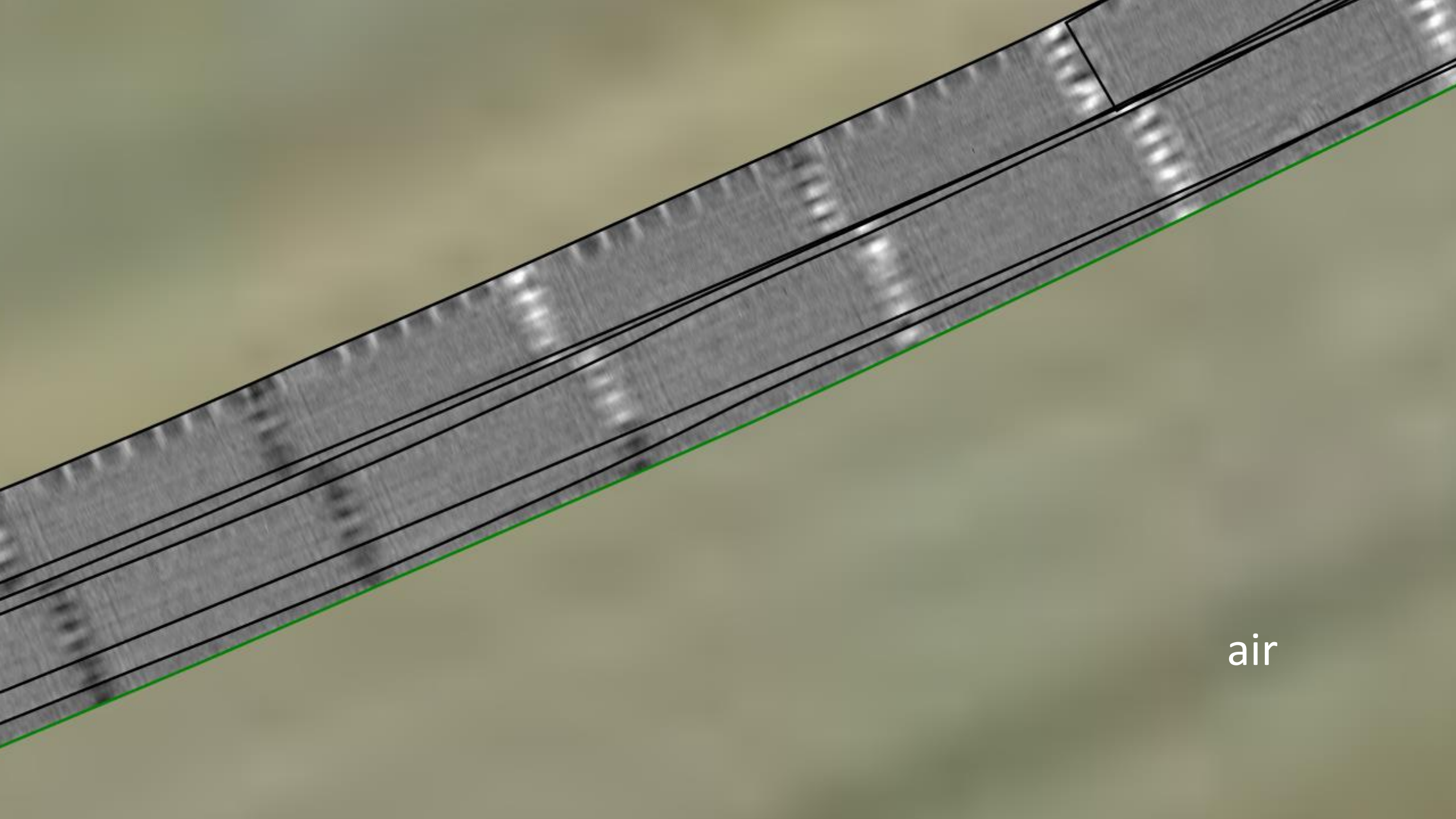
- Tie Bars: 2,388 ft.
- Dowel Bar Baskets: 3.25 lane miles
- Approximate cost of 3.7 lane miles of 10 inch concrete pavement (PCCP)
  - $59/SQYD (2010 average unit bid price)

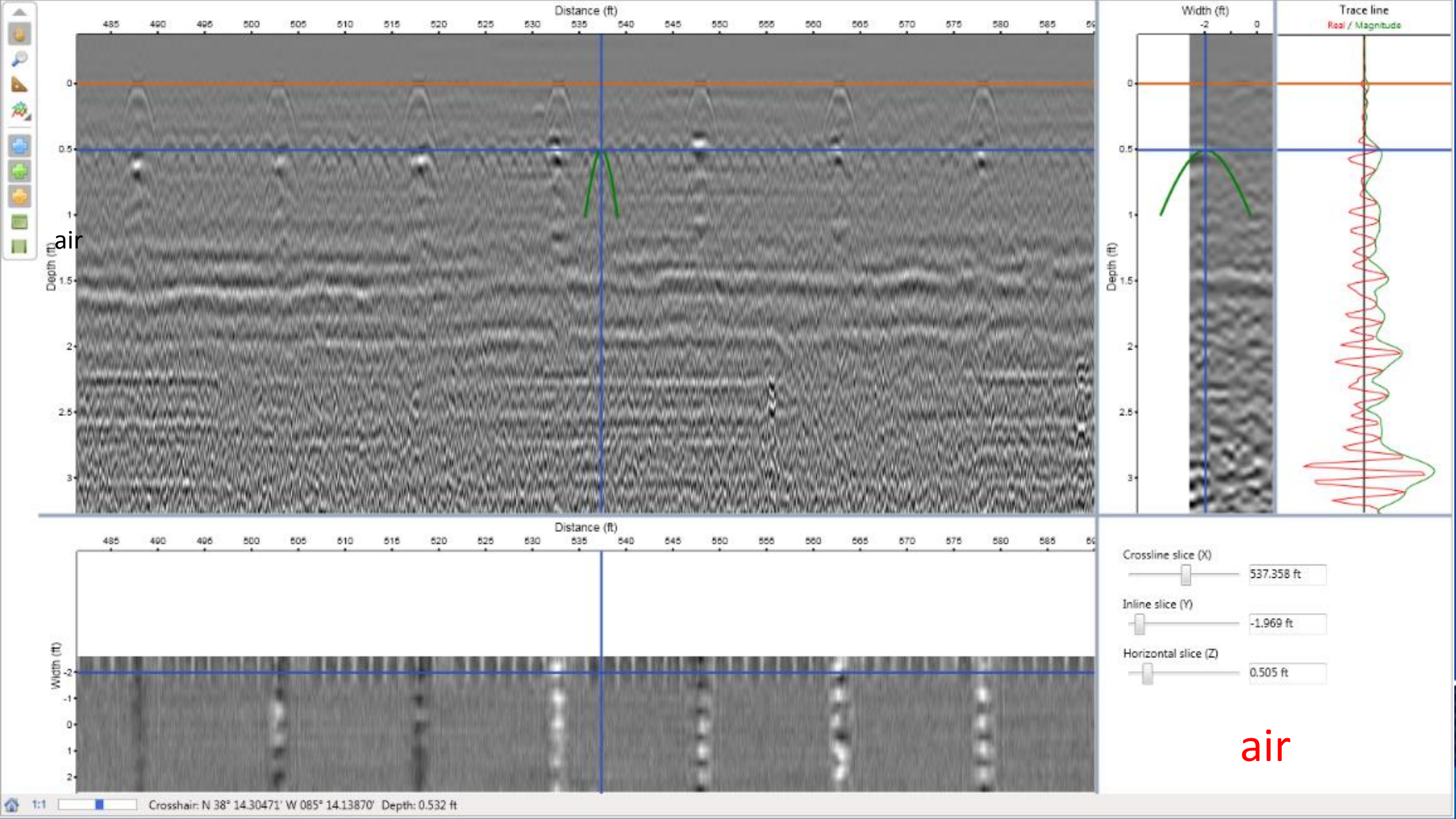
Total Replacement Costs: $1,537,776

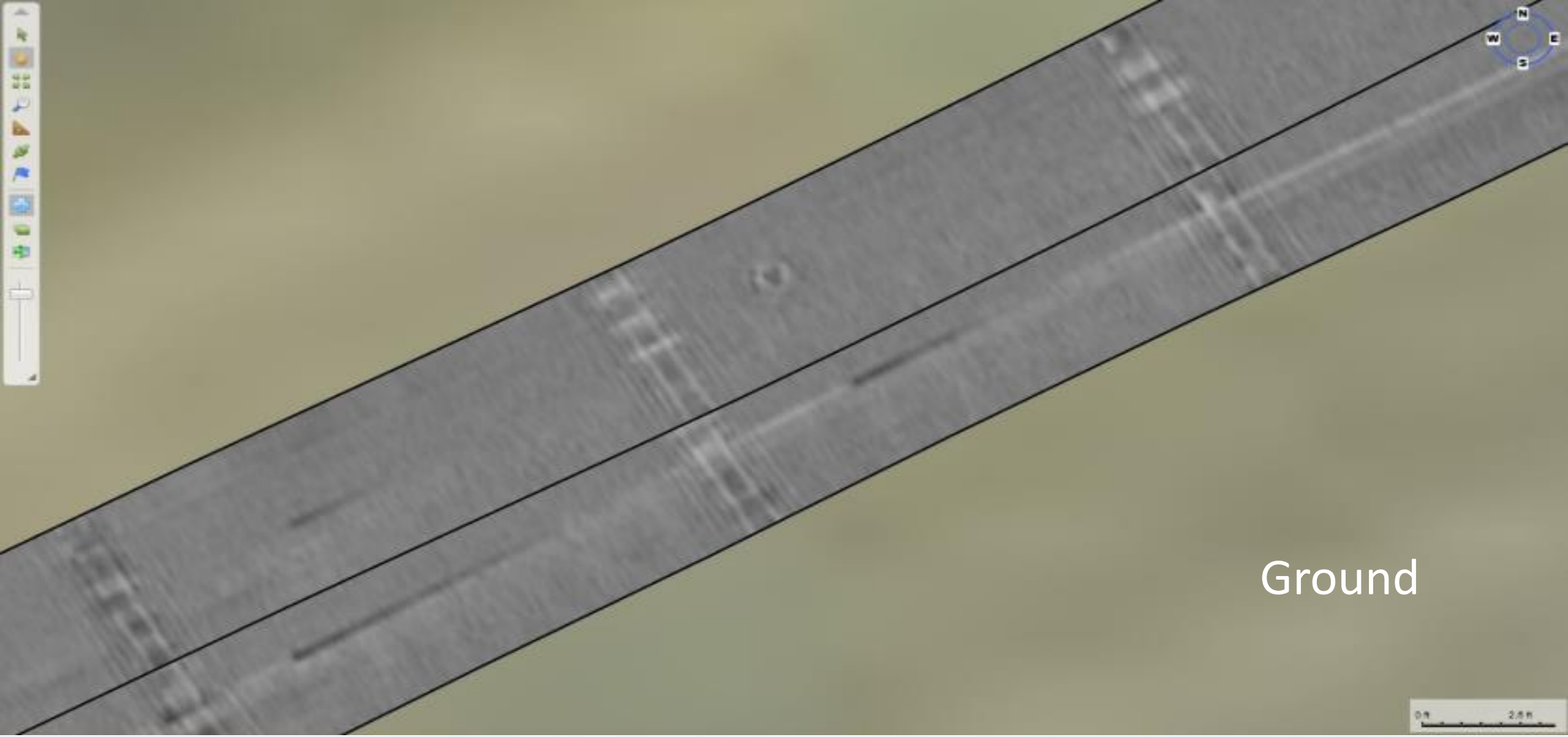
Tried both air coupled and ground coupled 3D Radar units for locating dowel baskets and tie bars in PCCP


Google Earth


air


air


Distance (ft)
Depth (ft)
air
Width (ft)
Trace line
Real / Magnitude
Distance (ft)
Width (ft)
Crossline slice (X)
537.358 ft
Inline slice (Y)
-1.969 ft
Horizontal slice (Z)
0.505 ft
air
1:1
Crosshair: N 38° 14.30471' W 085° 14.13870' Depth: 0.532 ft

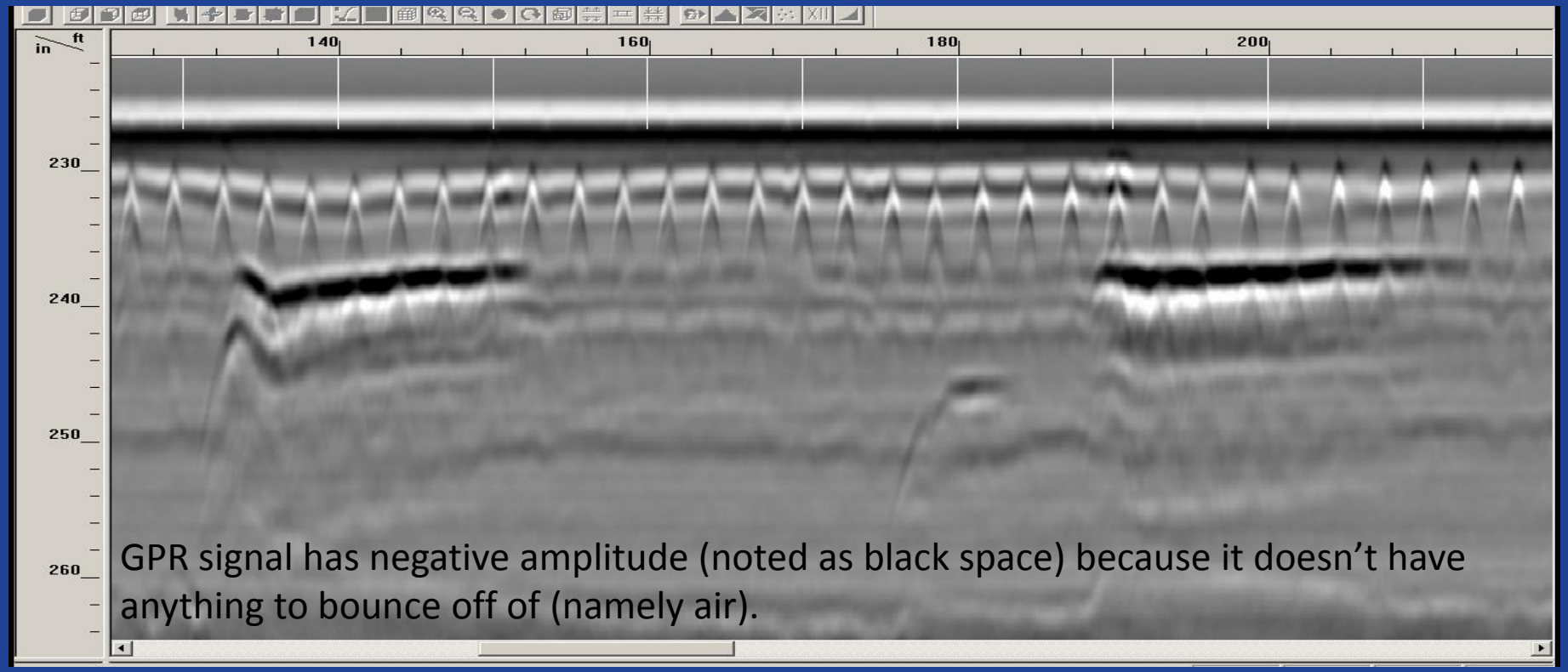

Ground

Using GPR to Identify Voided Areas Beneath Pavements

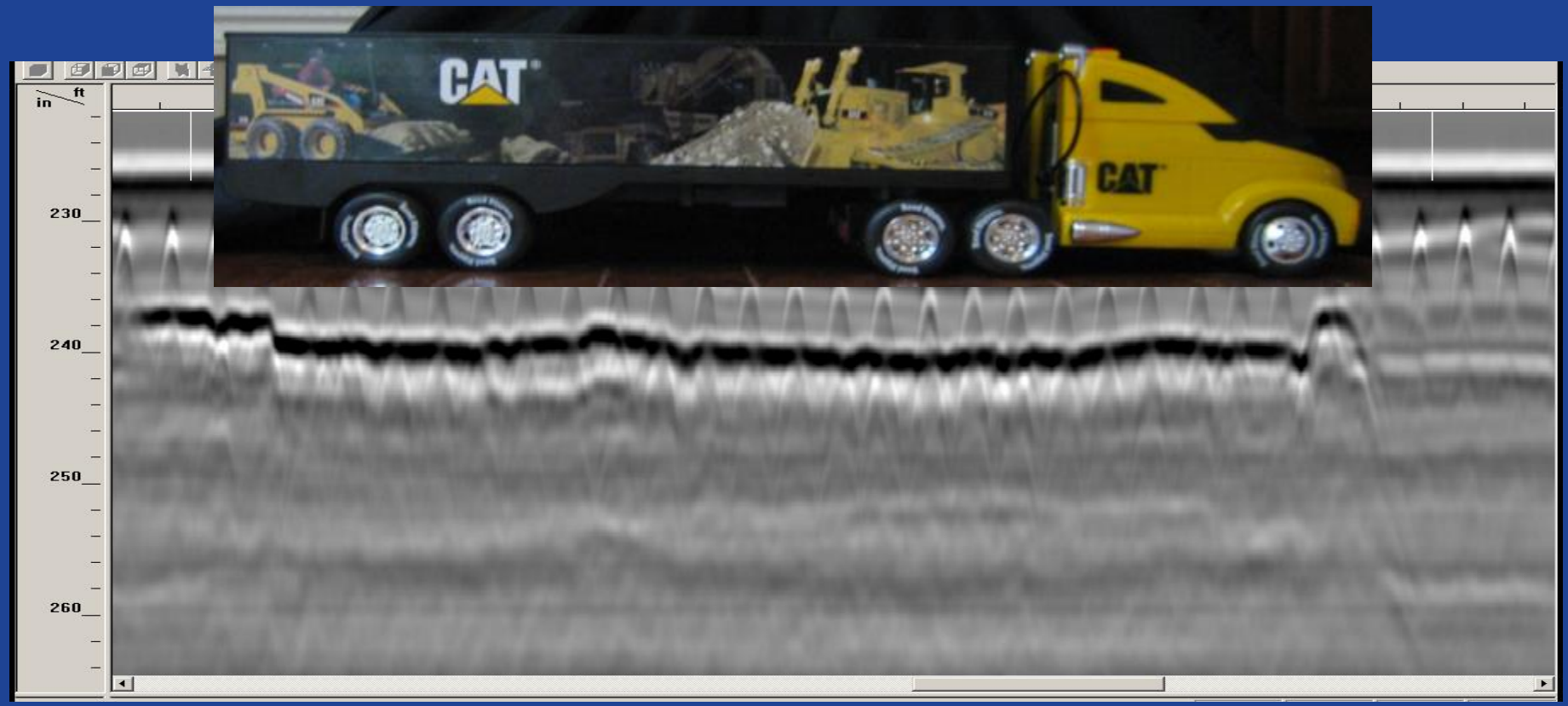
KENTUCKY TRANSPORTATION CABINET

KTC
EXCELLENCE IN MOTION

Multiple Void Areas Beneath Concrete Pavement



GPR signal has negative amplitude (noted as black space) because it doesn't have anything to bounce off of (namely air).



KENTUCKY TRANSPORTATION CABINET

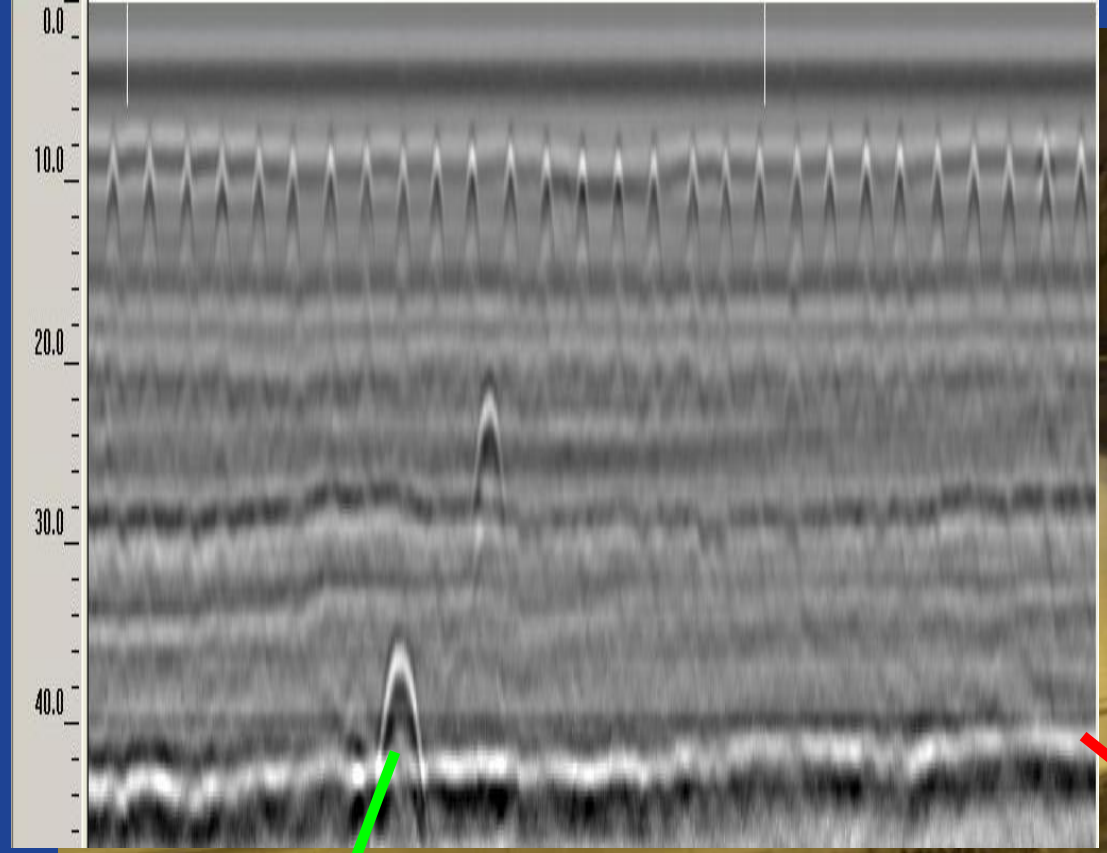
KTC
EXCELLENCE IN MOTION

Void depth beneath 10 inch concrete pavement

40 inch deep void

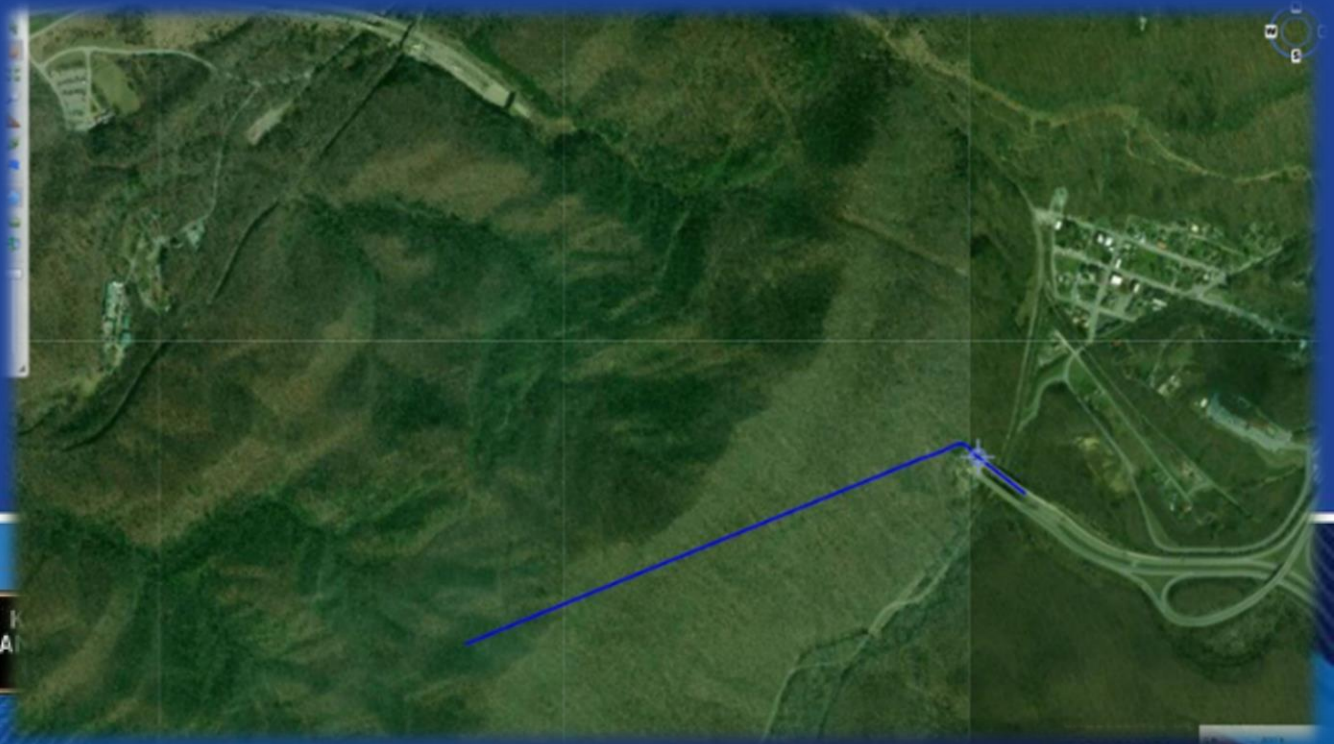
10,000 s.f. of voided areas found

Rate of void growth:
75-100 S.F. per month

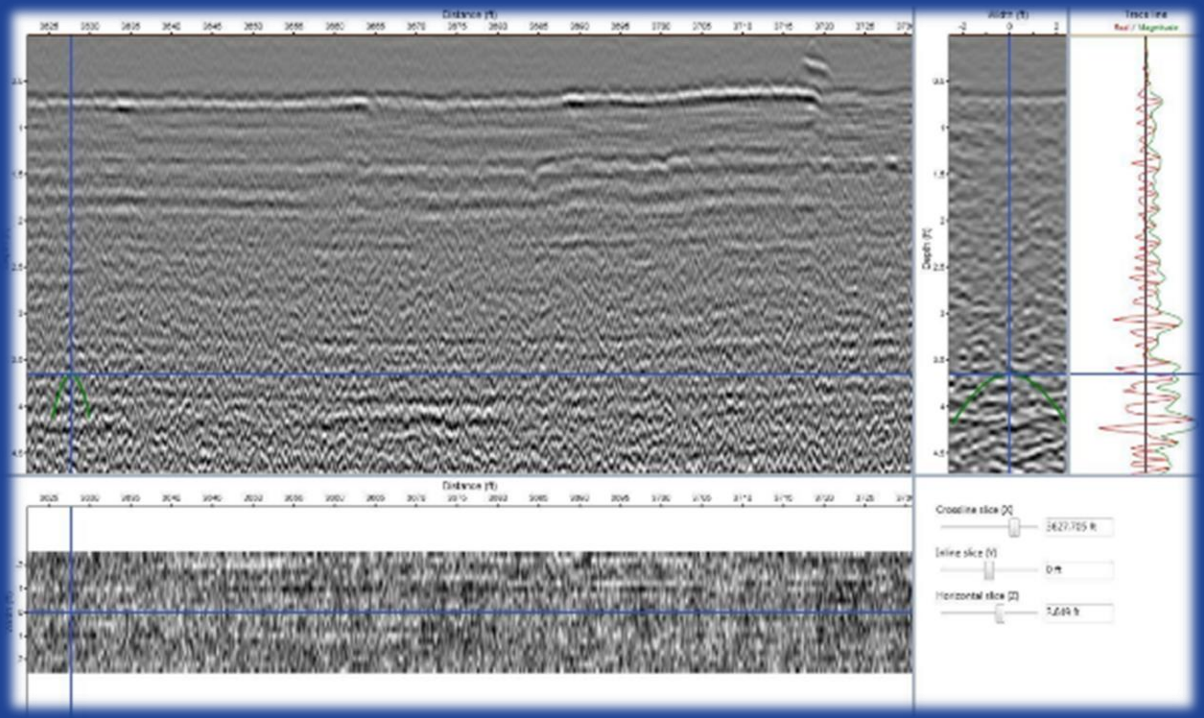


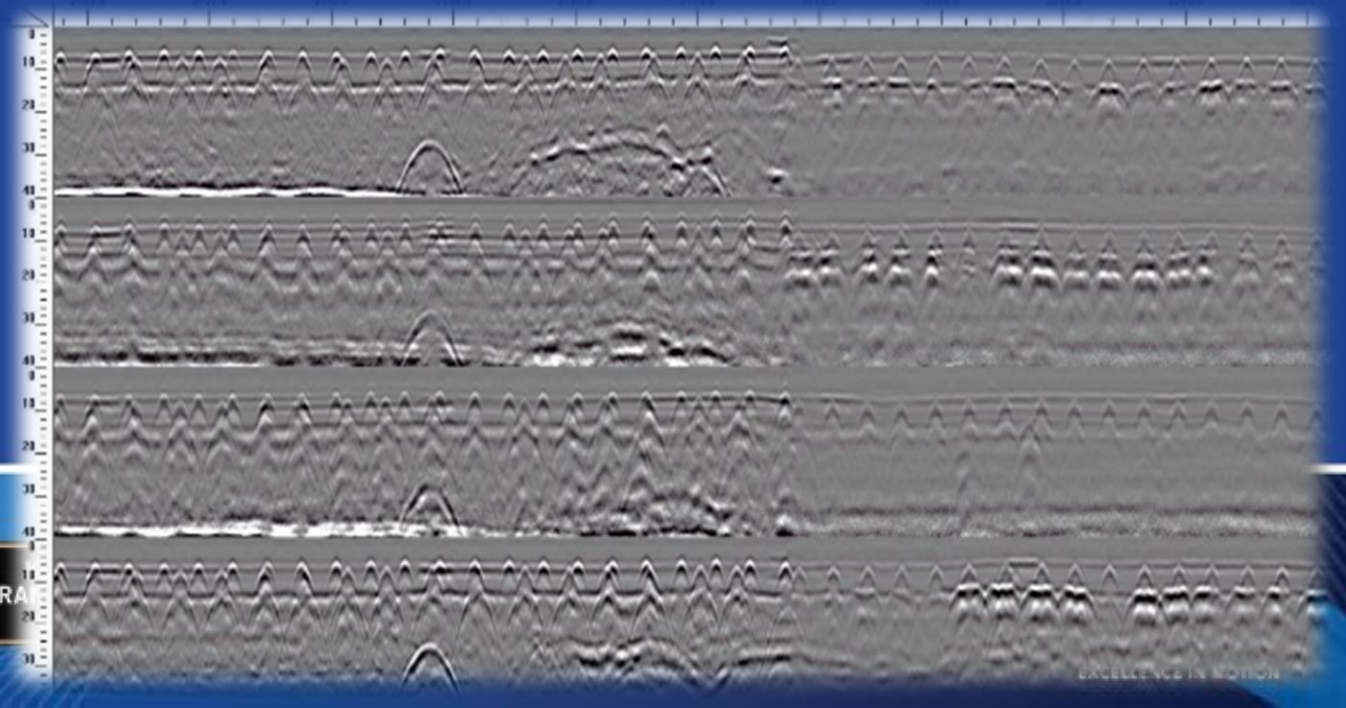
EXCELLENCE IN MOTION


CUMBERLAND GAP TUNNEL

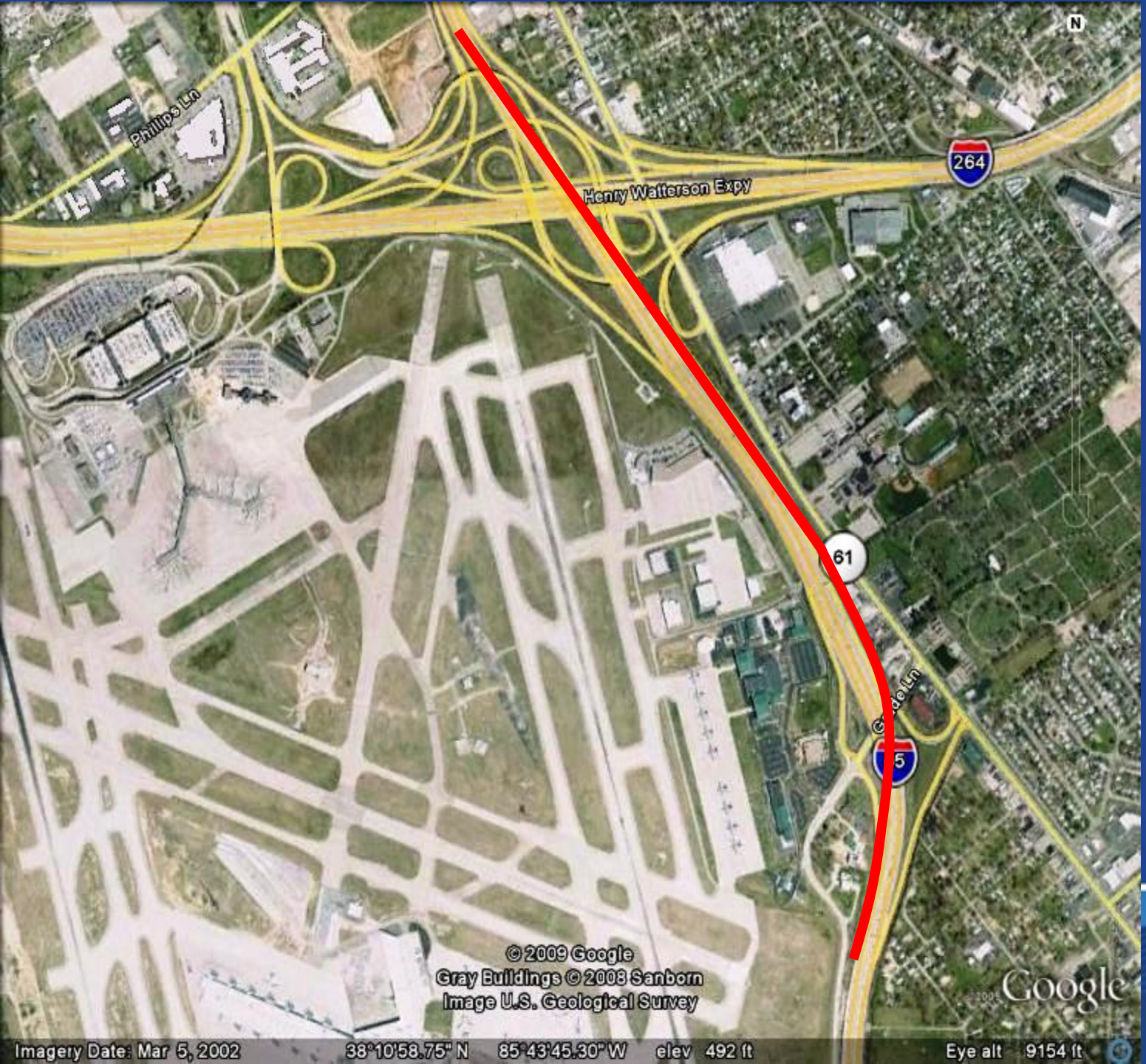


3D Radar and Impulse Radar



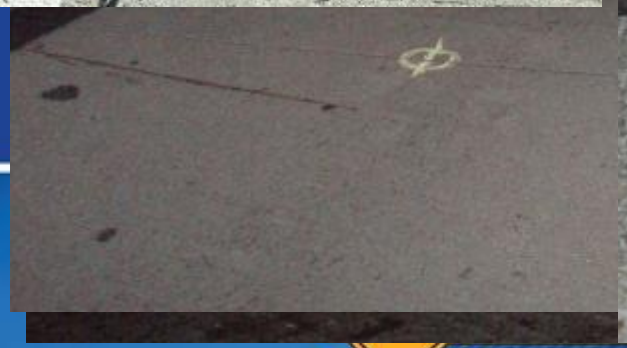


I-65
differential settlement in the longitudinal joint

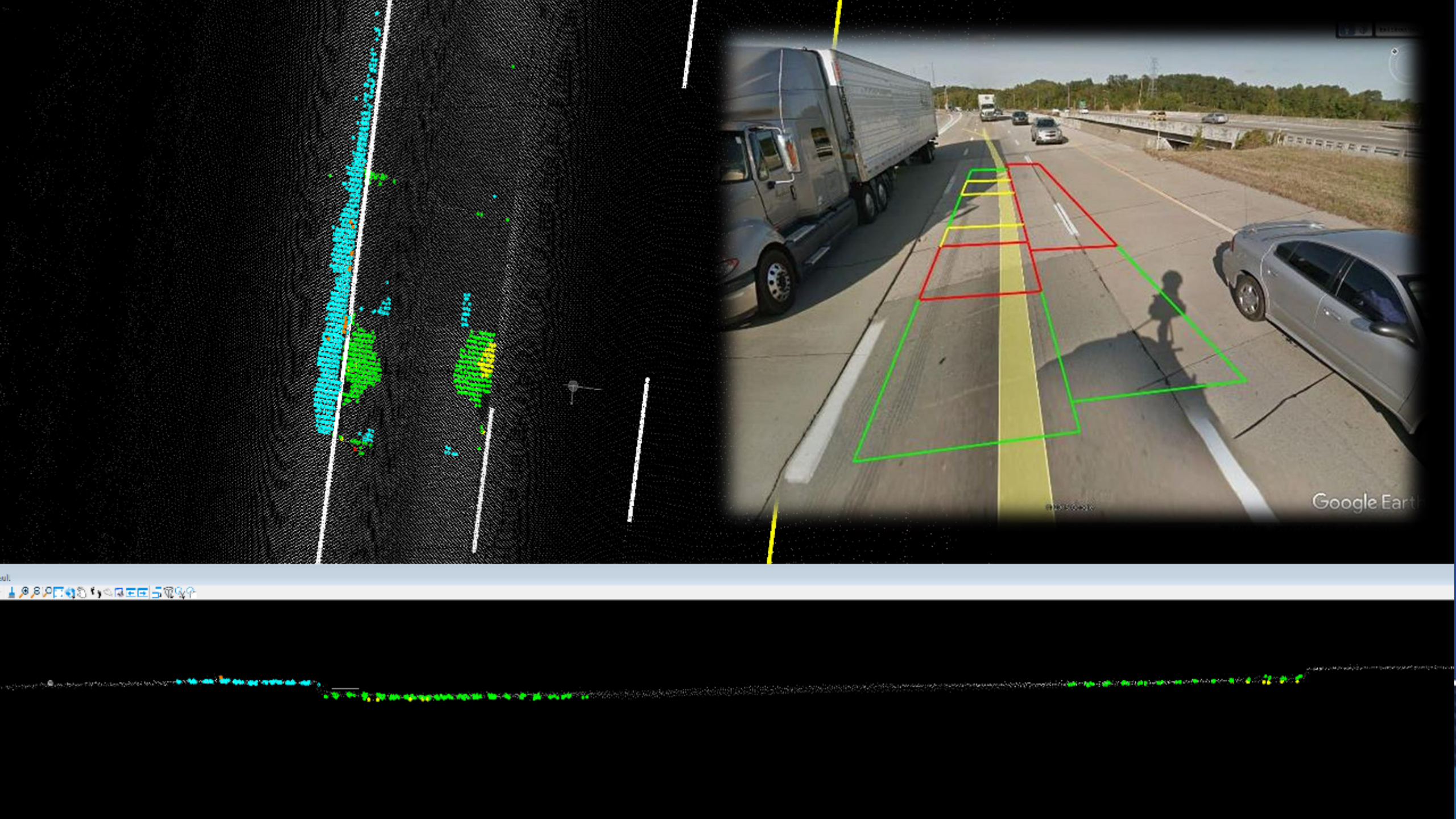


KTC
EXCELLENCE IN MOTION

Longitudinal Joint: tie bars

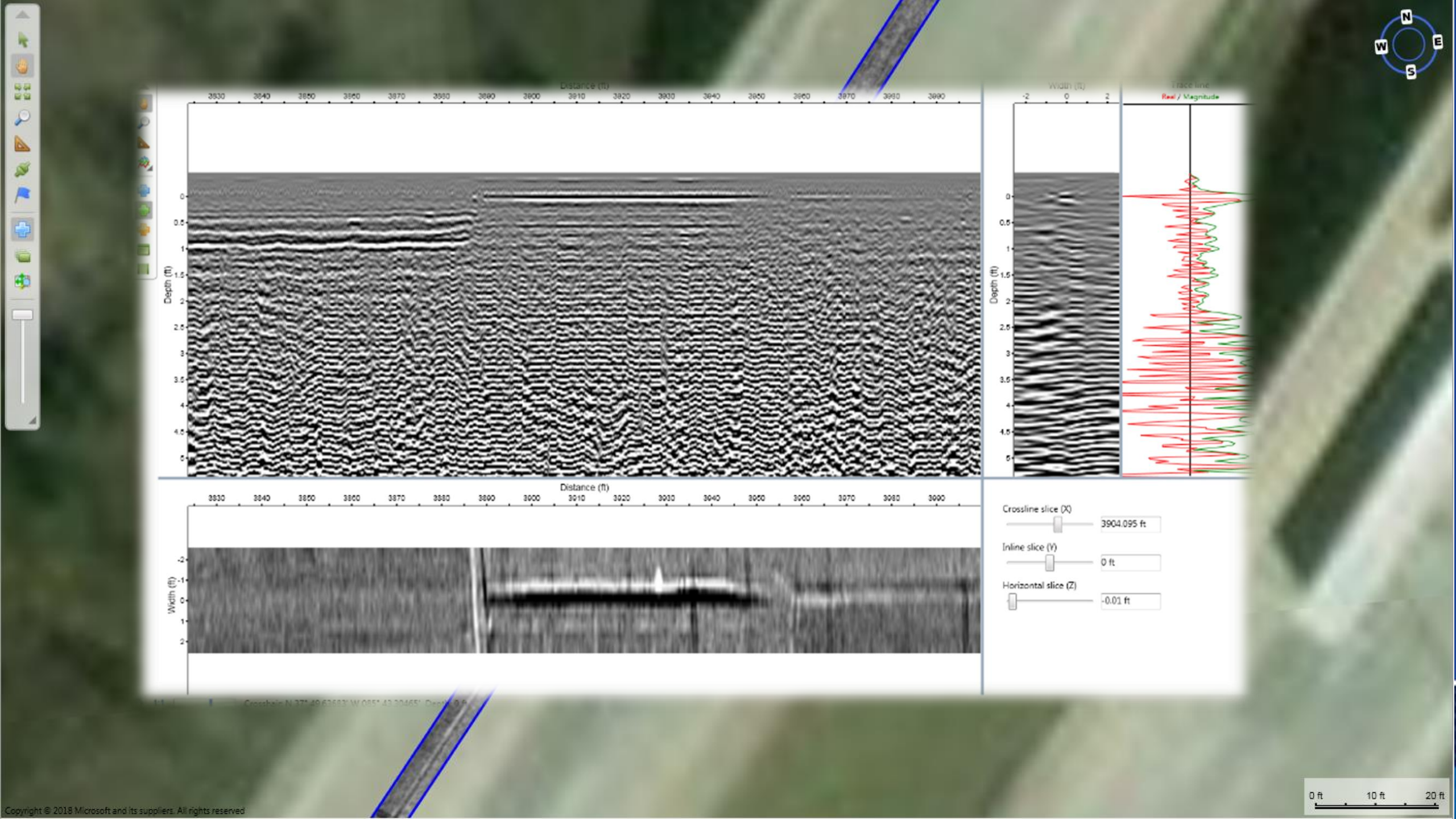


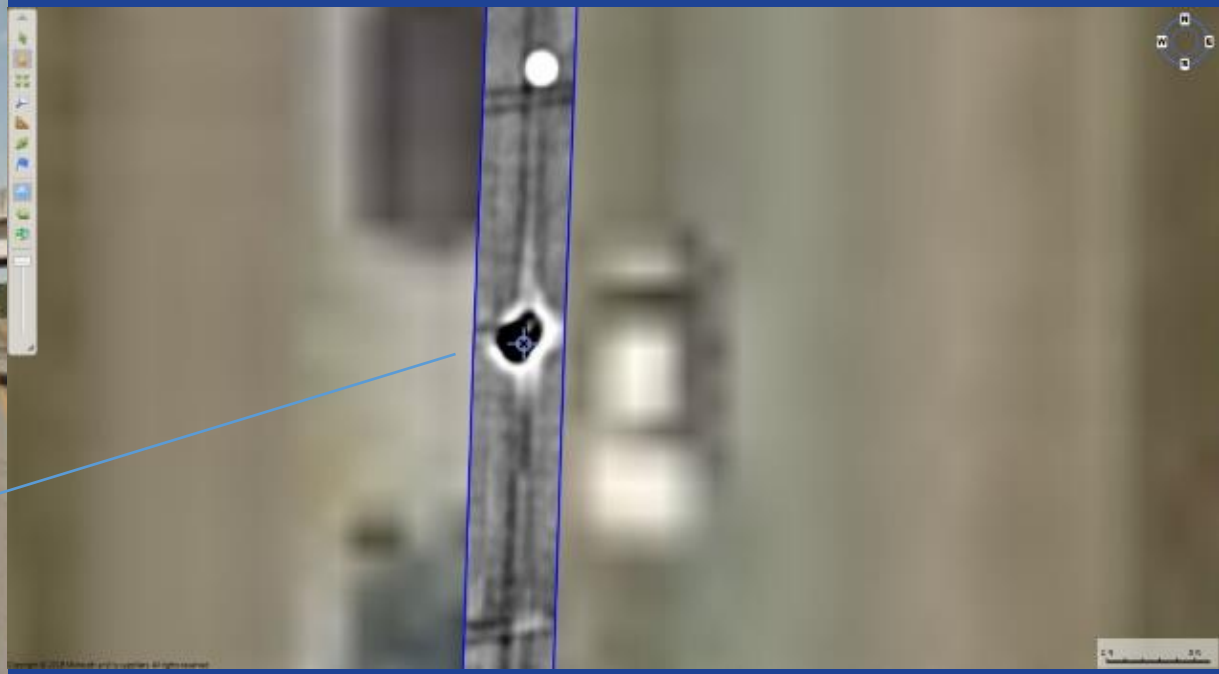
I65 Longitudinal Joint Settlement with Mobile Lidar


Google Earth

I65 Longitudinal Joint Settlement with 3D Radar

EXCELLENCE IN MOTION





TION

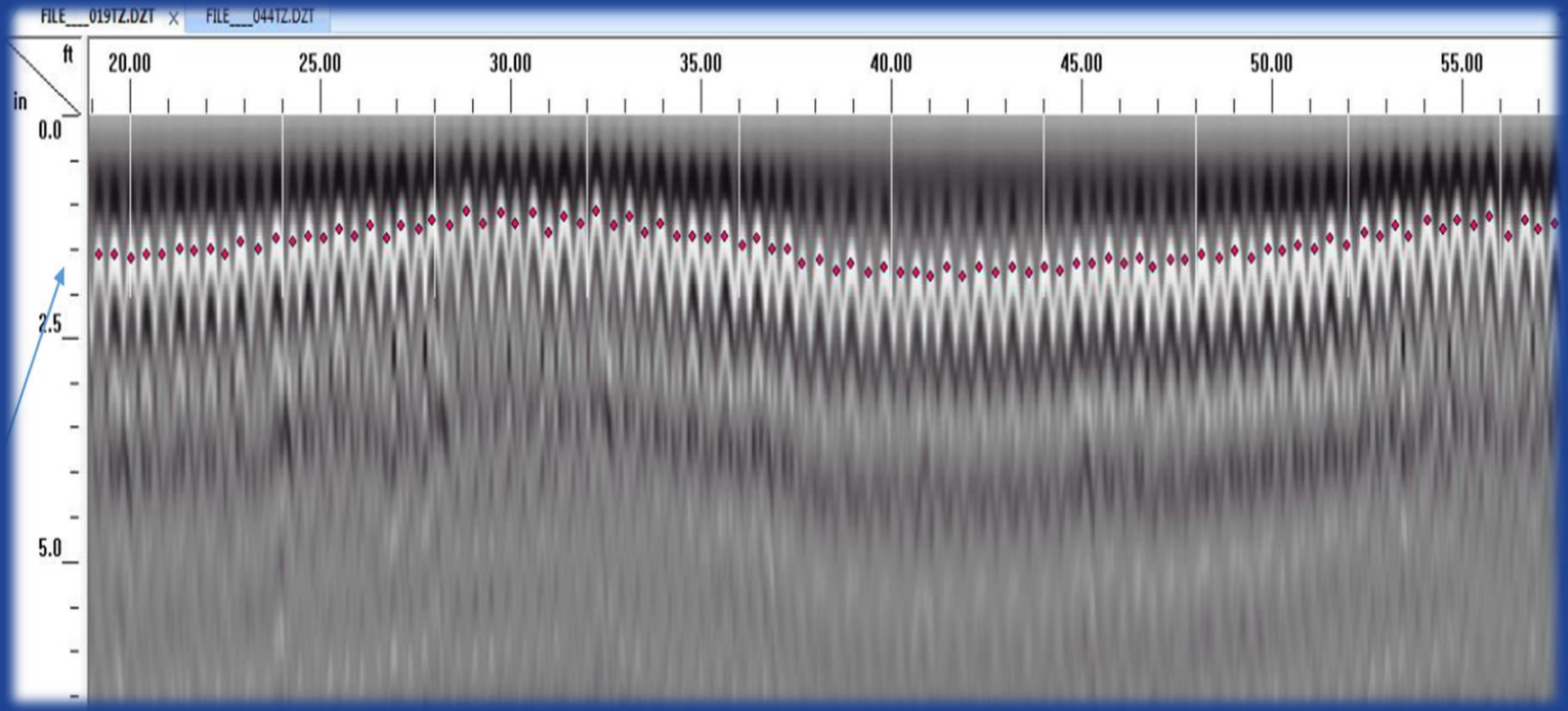
KTC
EXCELLENCE IN MOTION

KENTUCKY TRANSPORTATION CABINET

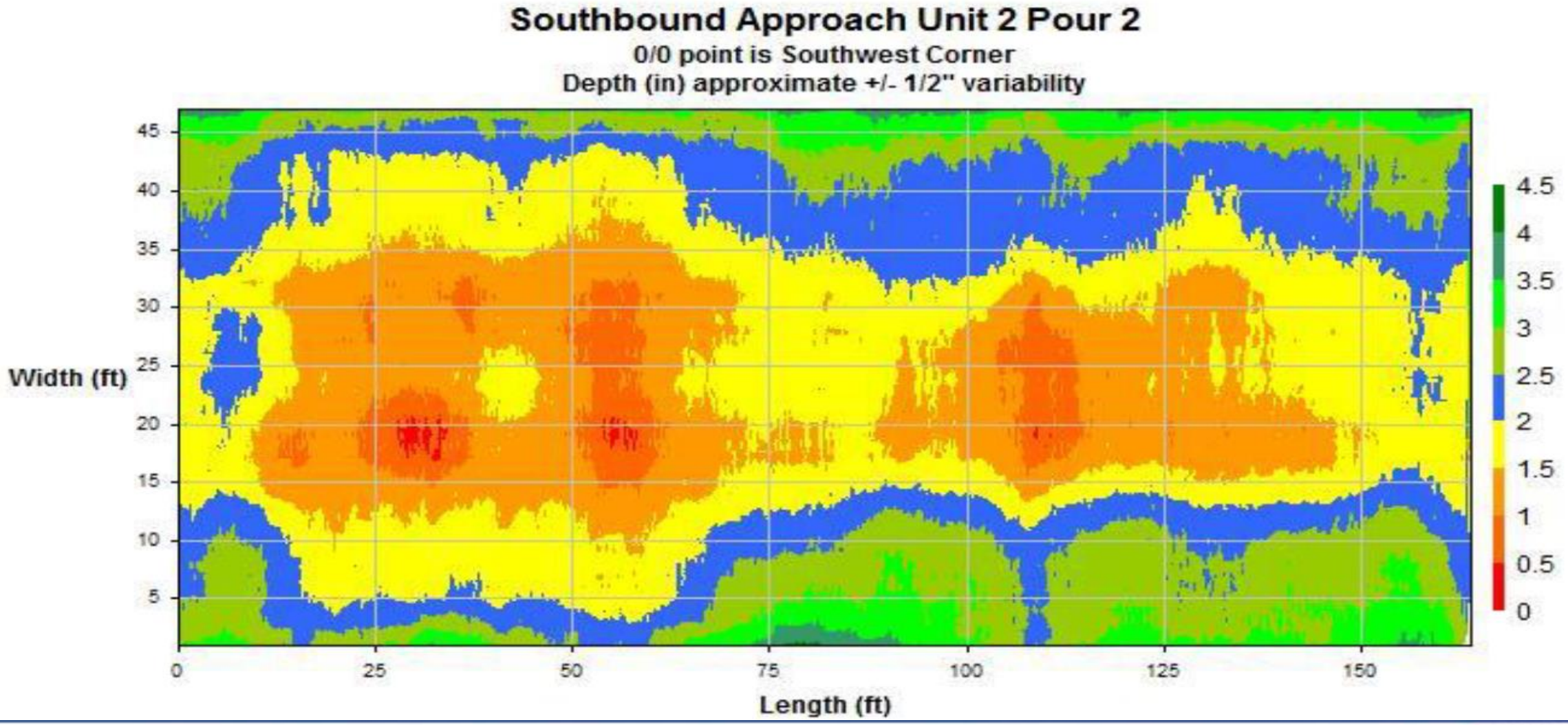
KTC
EXCELLENCE IN MOTION

How much concrete cover is over the top layer of steel

Process GPR data using a known dielectric value



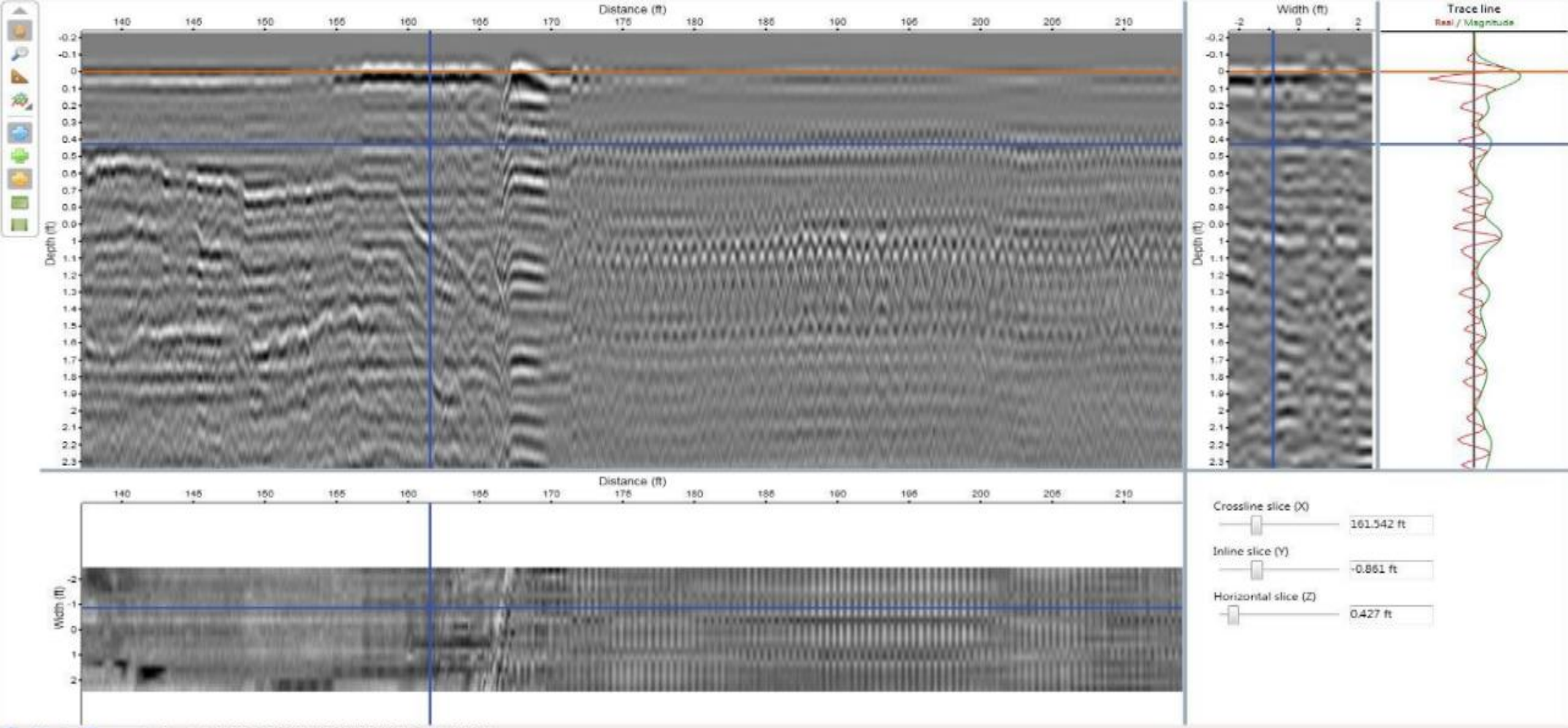
DPlot Results



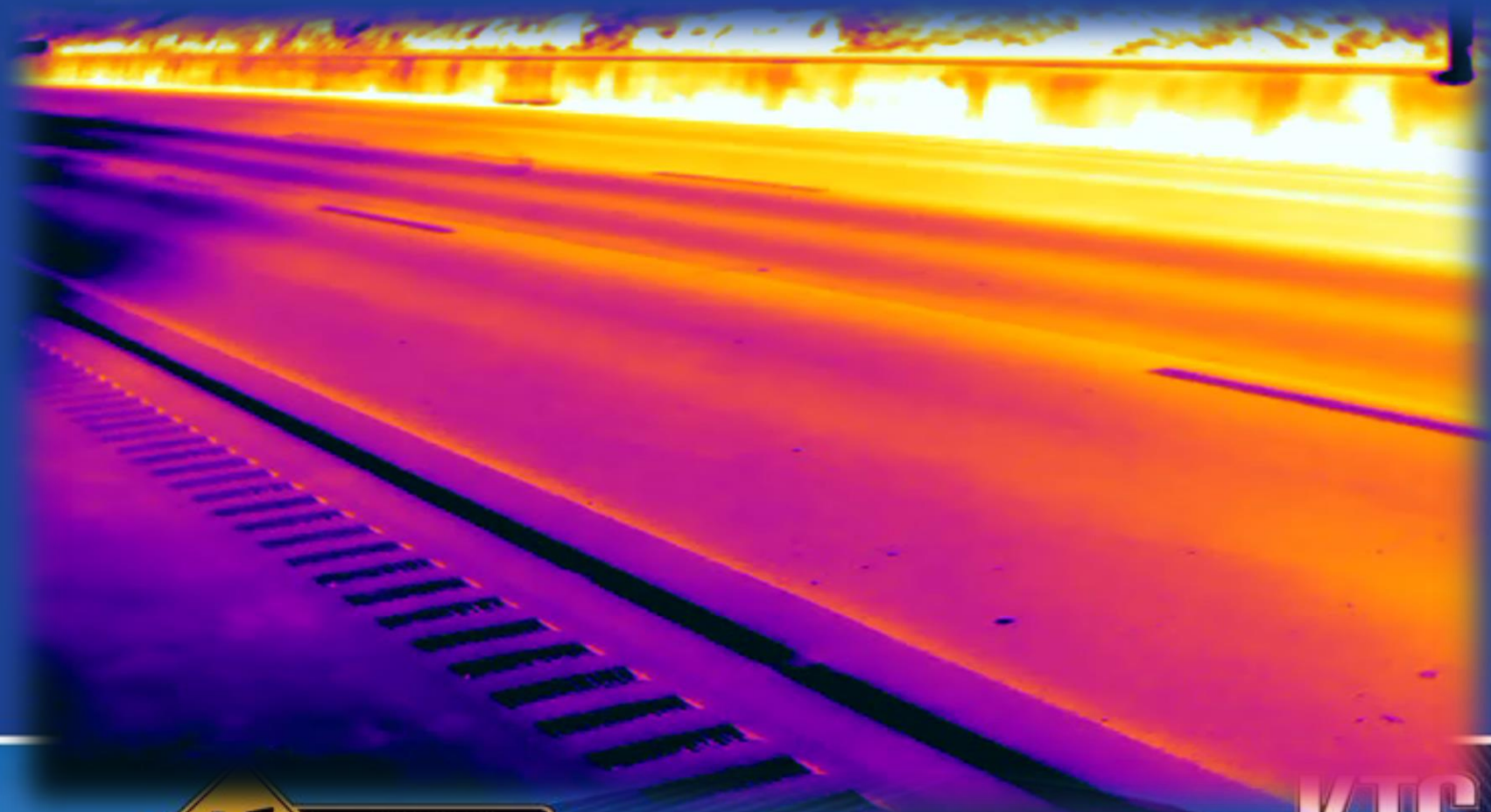
KENTUCKY TRANSPORTATION CABINET

KTC
EXCELLENCE IN MOTION


UK


Distance (ft)
Depth (ft)
Width (ft)
Trace line
Real / Magnitude
Distance (ft)
Width (ft)
Crossline slice (X)
161.542 ft
Inline slice (Y)
-0.861 ft
Horizontal slice (Z)
0.427 ft

Identify water trapped within roadways



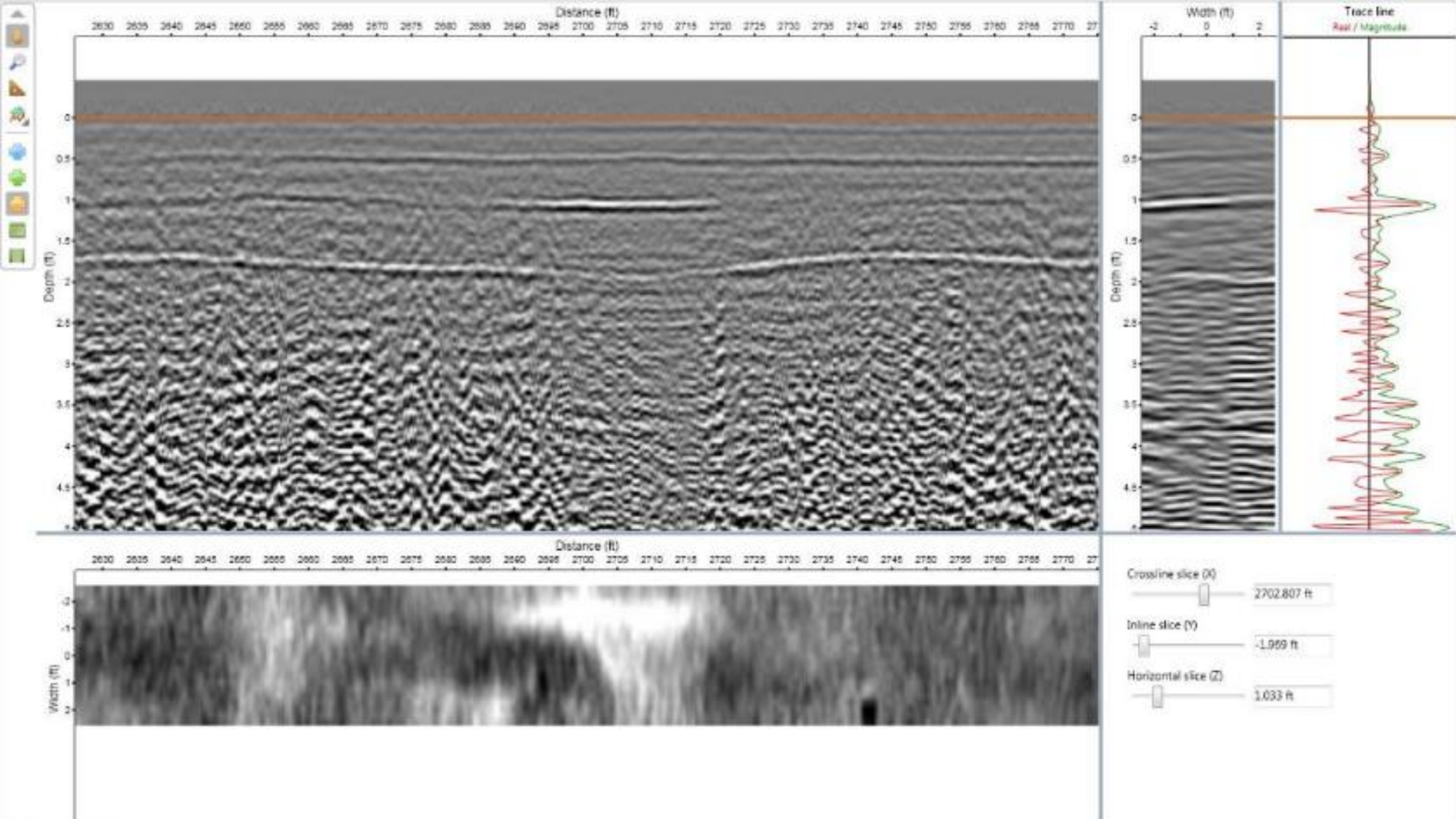
KENTUCKY TRANSPORTATION CABINET

KTC
EXCELLENCE IN MOTION

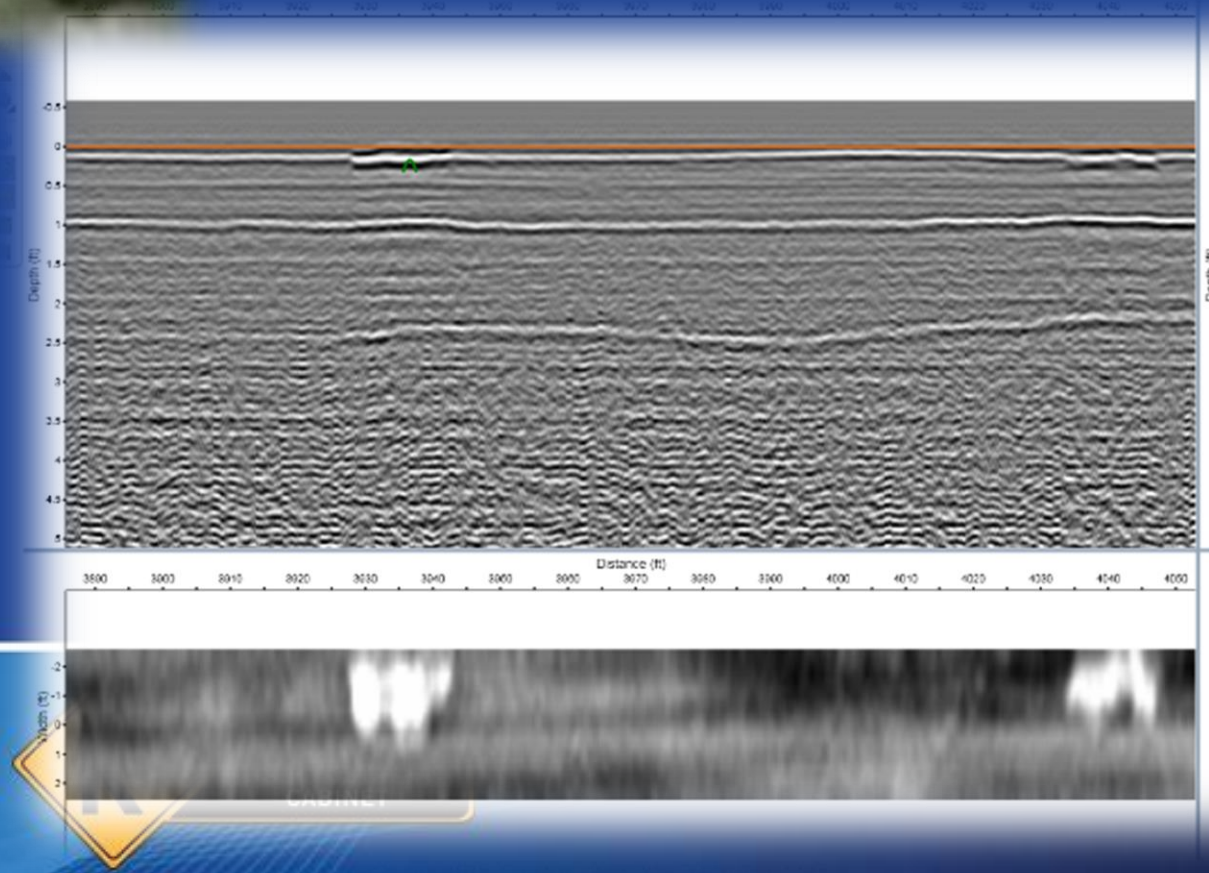
Water trapped within the pavement due to a layer of impermeable clay

KENTUCKY TRANSPORTATION CABINET

KTC
EXCELLENCE IN MOTION


Distance (ft)
Depth (ft)
Width (ft)
Trace line
Real / Magnitude
Distance (ft)
Width (ft)
Crossline slice (X)
2702.807 ft
Inline slice (Y)
-1.969 ft
Horizontal slice (Z)
1.033 ft

Pavement surface distress



EXCELLENCE IN MOTION

KENTUCKY TRANSPORTATION CABINET

KTC

EXCELLENCE IN MOTION