Virtual Surface for Runway, Multi-Lane Highways, Bridge Decks at 1mm Resolution

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September 17, 2014

Pavement Evaluation 2014
September 15-18, 2014 ▼ Blacksburg, Virginia

RPUG
Road Profile Users' Group

Outline

- PaveVision3D Ultra (3D Ultra) system
- Airport runway evaluation
- Multi-lane highway evaluation
- Virtual bridge deck

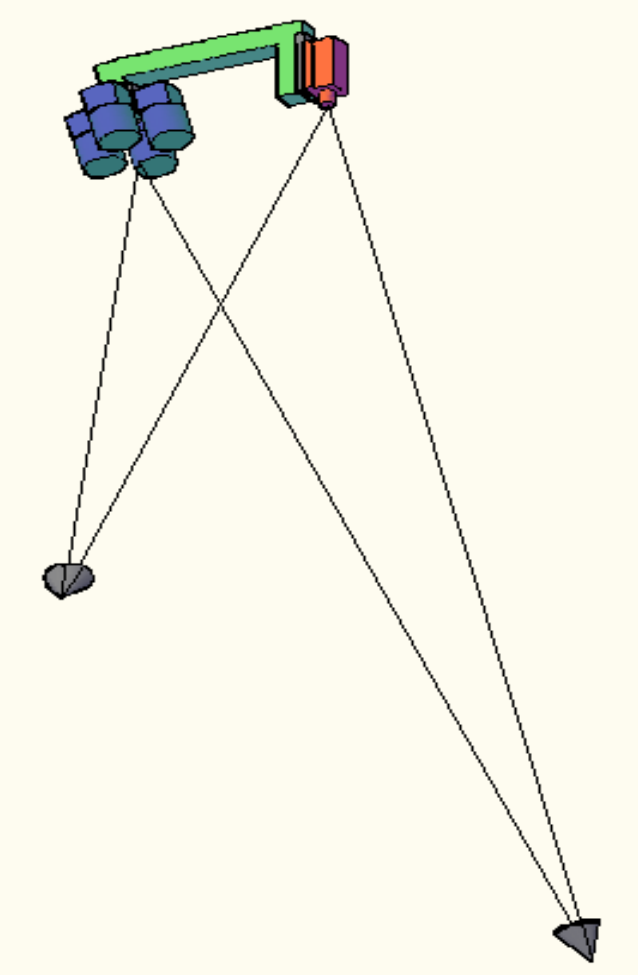
Common Problems

- Accurate and timely pavement surface characteristics: critical for performance evaluation and safety
- Poor quality of field condition data
  - Particularly cracking
- Operating 3D Profile Line Rate
  - 4000 -8000/sec: 4mm to 6mm (¼'') resolution at 60MPH
  - Good enough for some purposes; not sufficient

PaveVision3D Ultra

- Use multiple sensors
- Increase 3D profile line rate to 30,000/second
- Complete coverage of pavement lane
  - 1mm resolution in 3D at collection speed up to 60MPH
- High-precision IMU
  - Grades, curves, cross slope

PaveVision3D Ultra - Existing



PaveVision3D Ultra - New

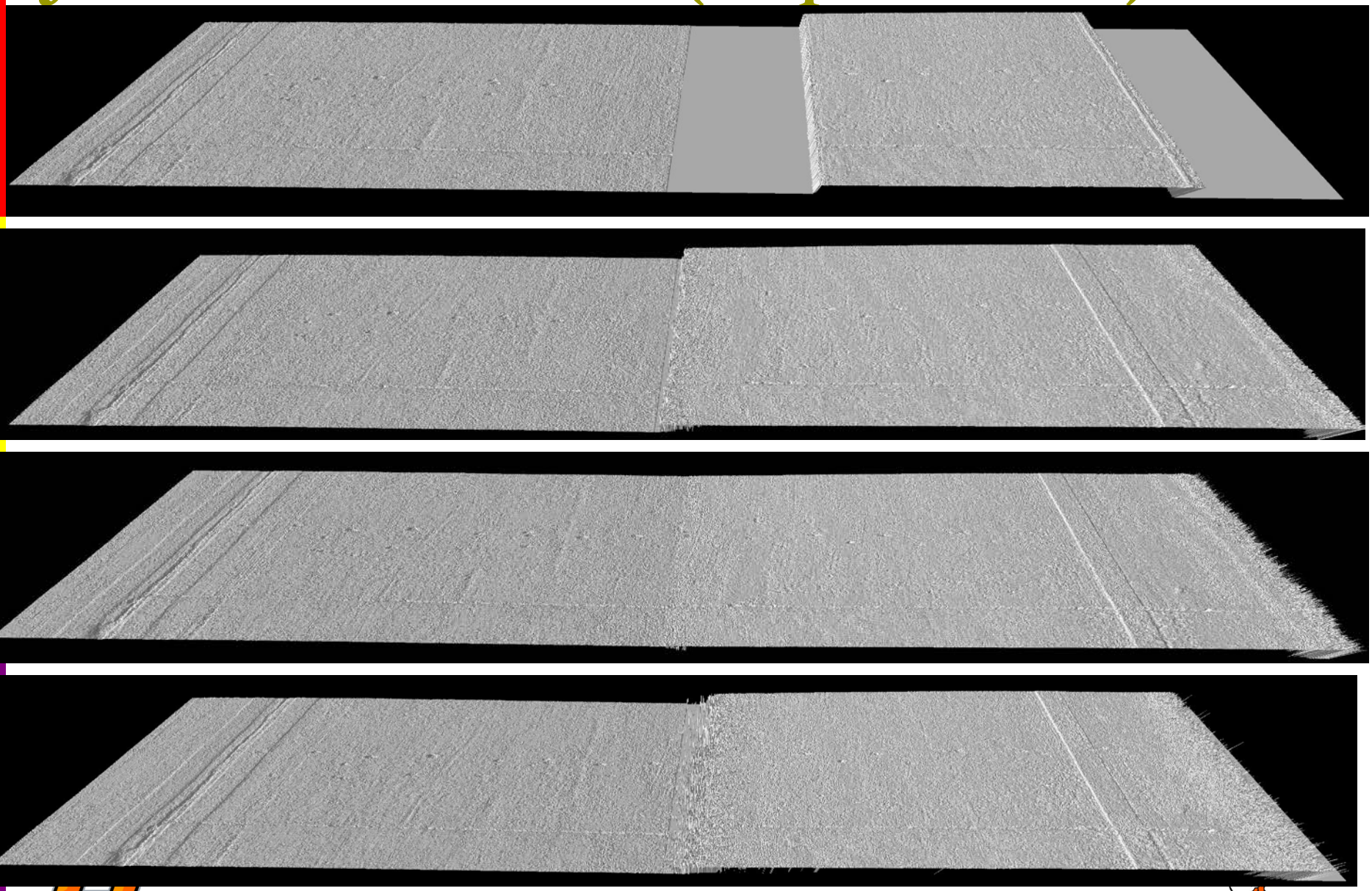
PaveVision3D Ultra - New

- Green lasers: previous red lasers
  - More uniform illumination
  - Substantially better sensitivity for 3D cameras
  - Consistently higher quality data, regardless of ambient light condition changes and pavement color variations
- 3D Ultra: simultaneously acquire both 3D "Range" and "Intensity" data
  - Totally synchronized with pixel-to-pixel accuracy
  - Complement each other for cracking detection and rutting measurement

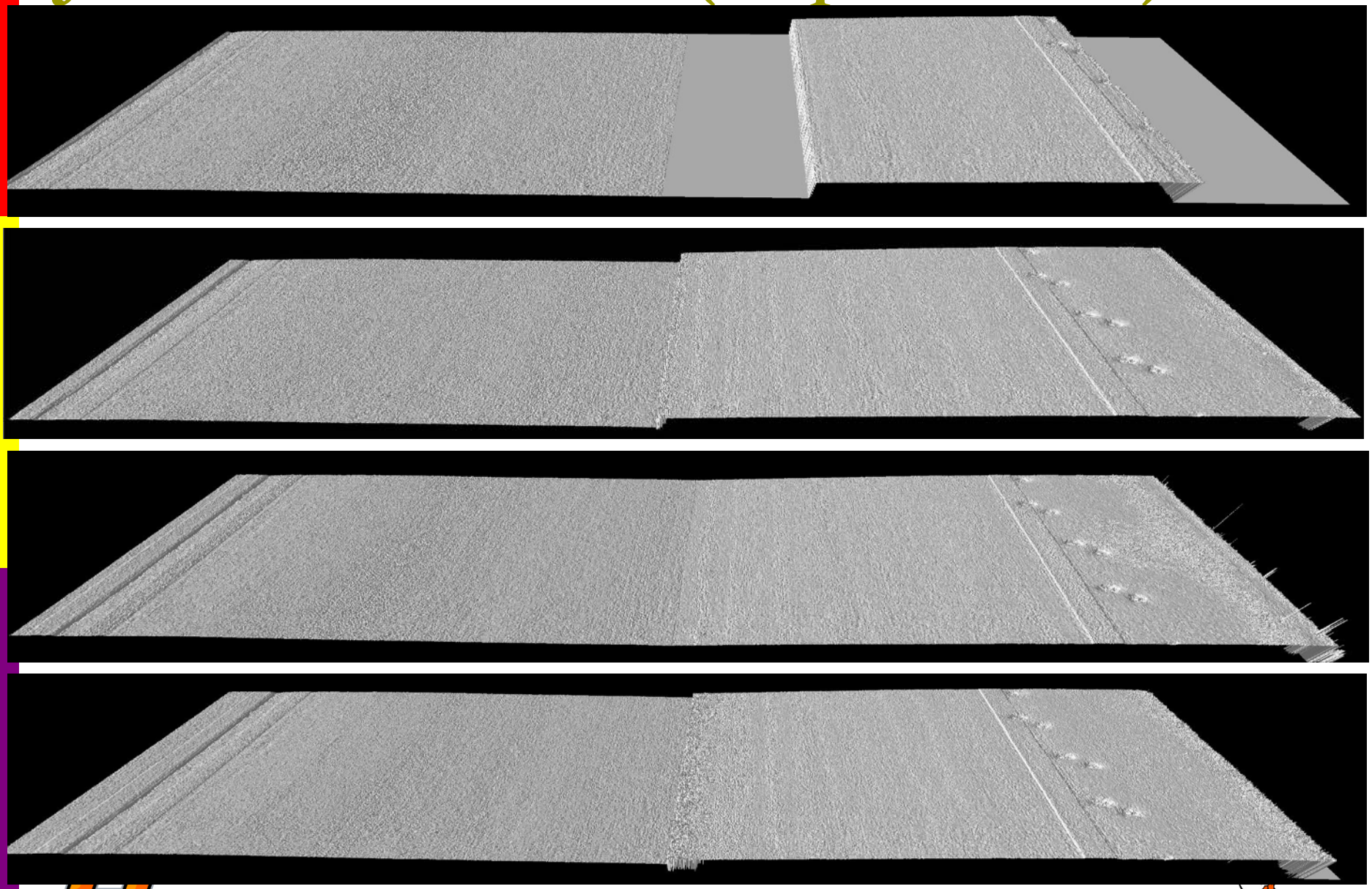
Green Laser Testing

- Left: red laser; Right: green laser
- Field Testing
  - Brand New Asphalt (Husband Rd)
  - Brand New PCC (Jardot St)
  - Typical Surface at High Speed (US51)
- Various exposure time setting

Jardot – New PCC (Exposure #1)

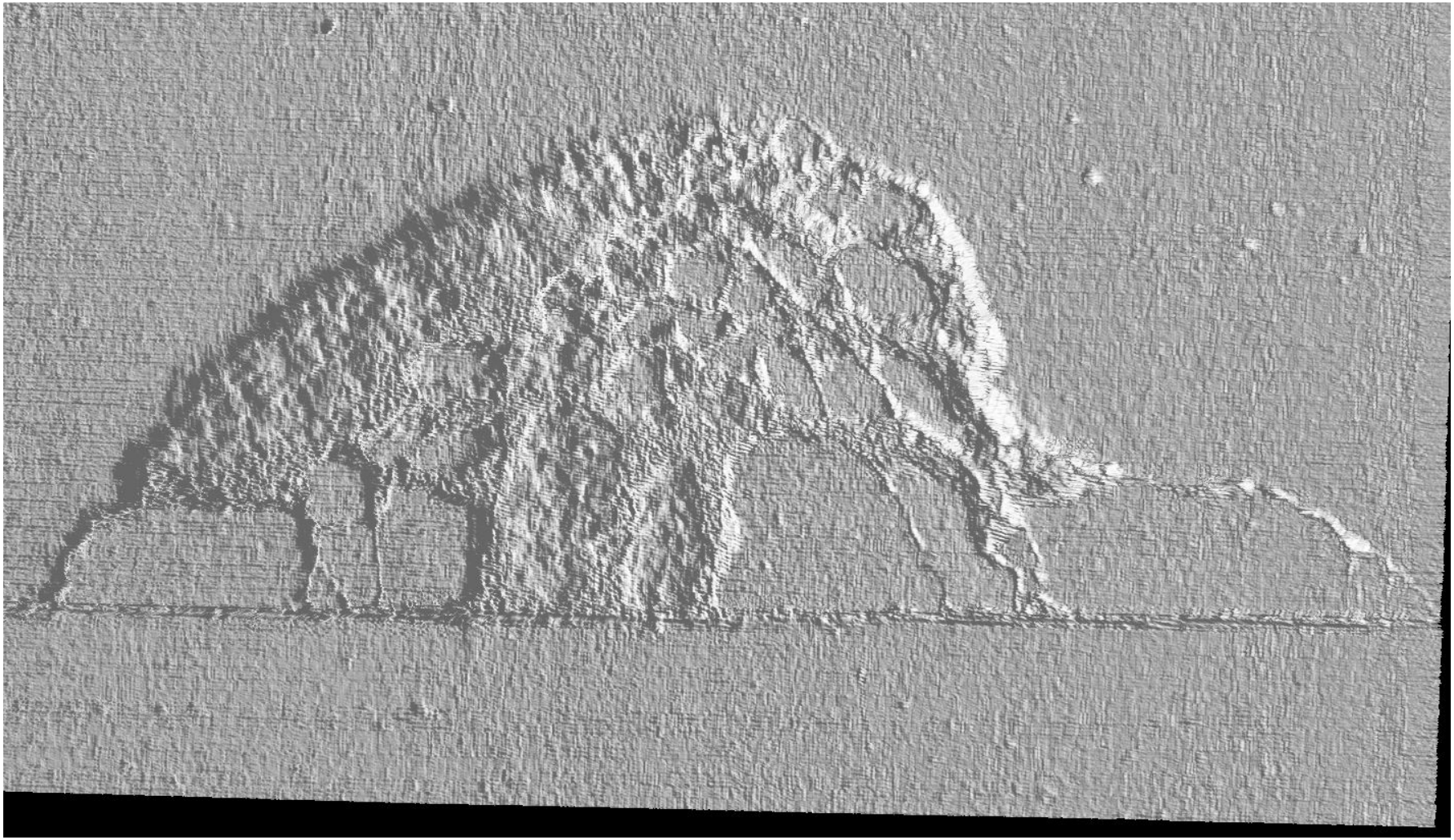


Jardot – New PCC (Exposure #2)

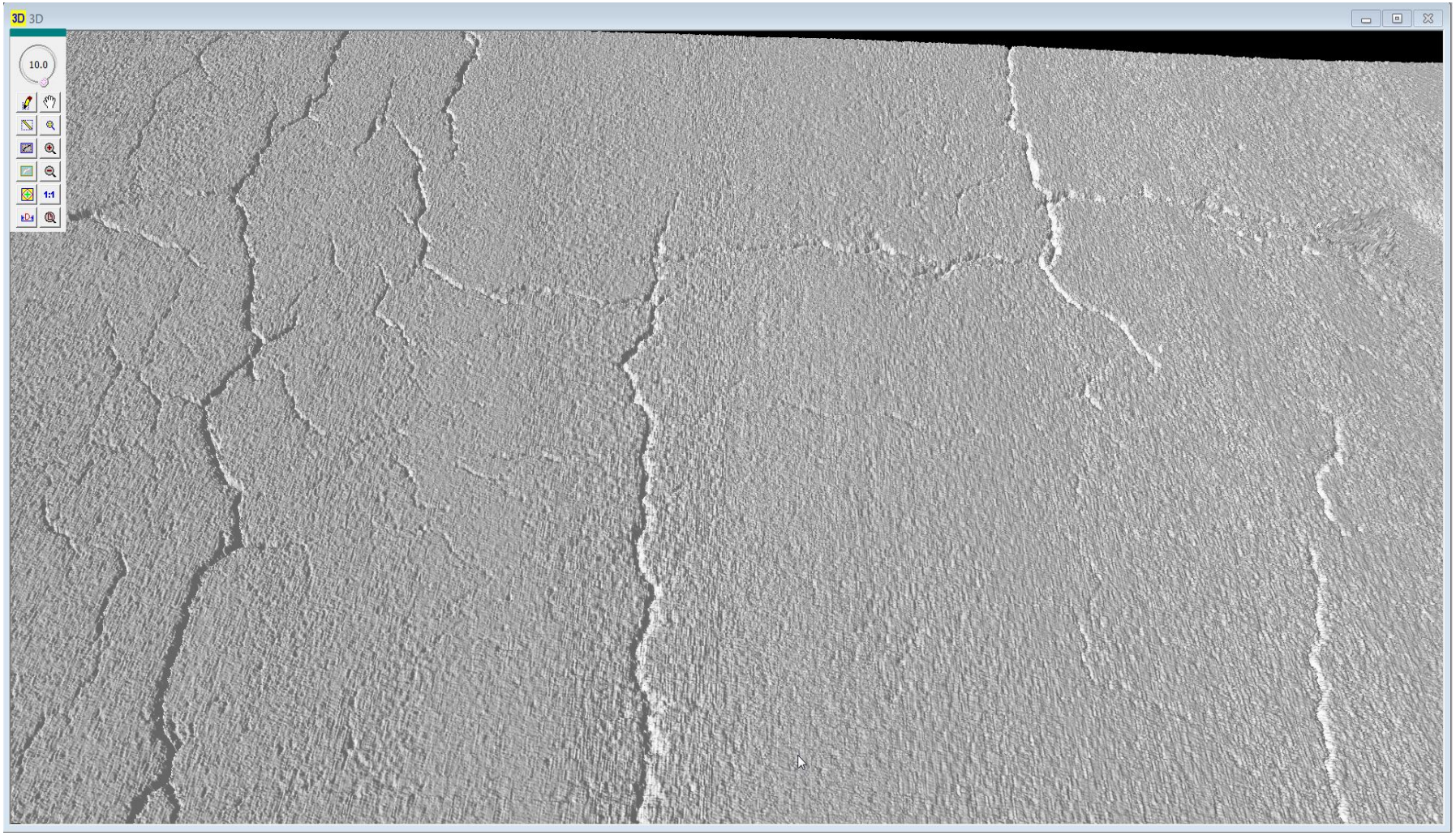


Jardot – New PCC (Exposure #3)

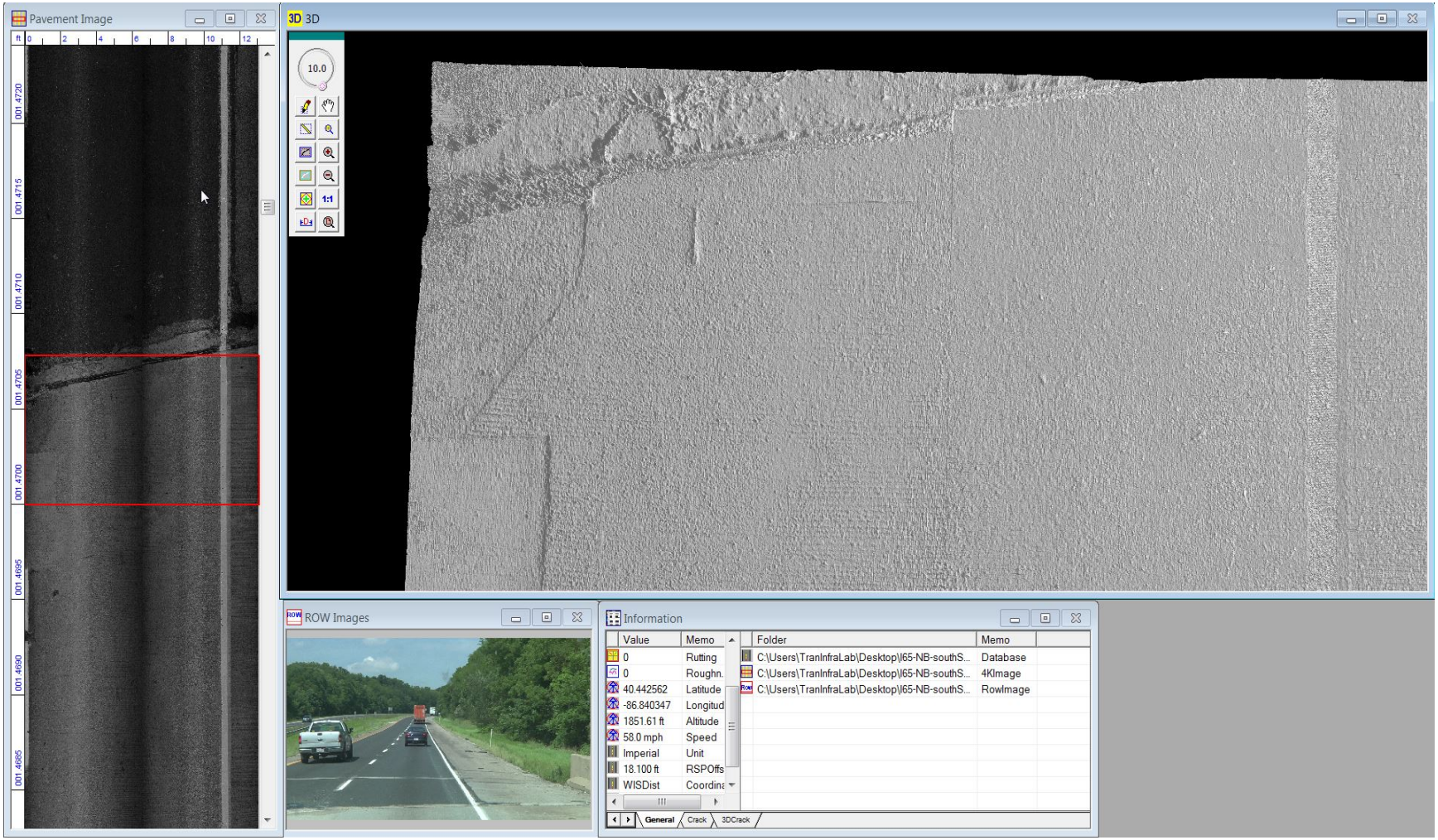
New 3D Data - Example



New 3D Data - Example



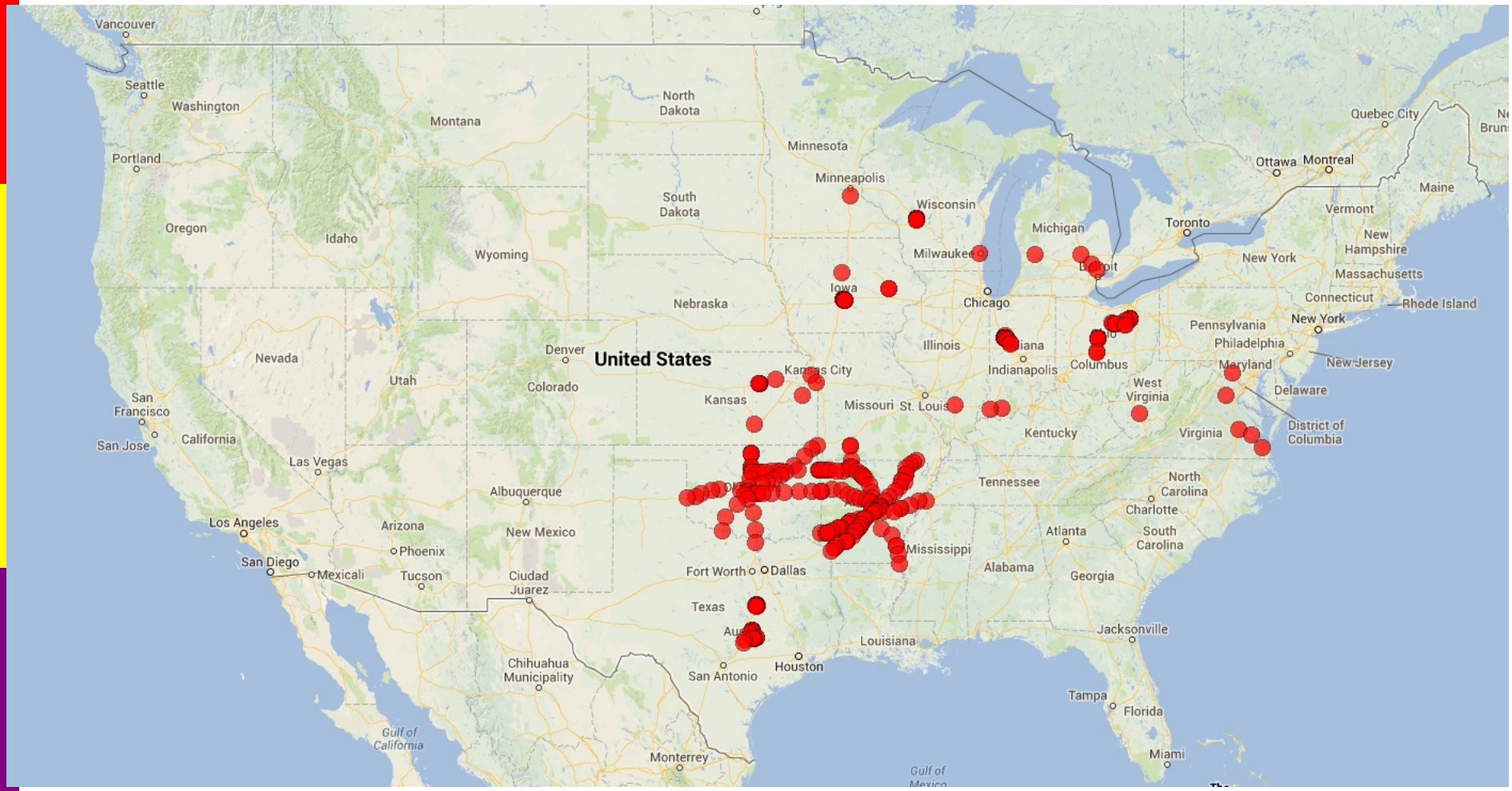
New 3D Data - Example



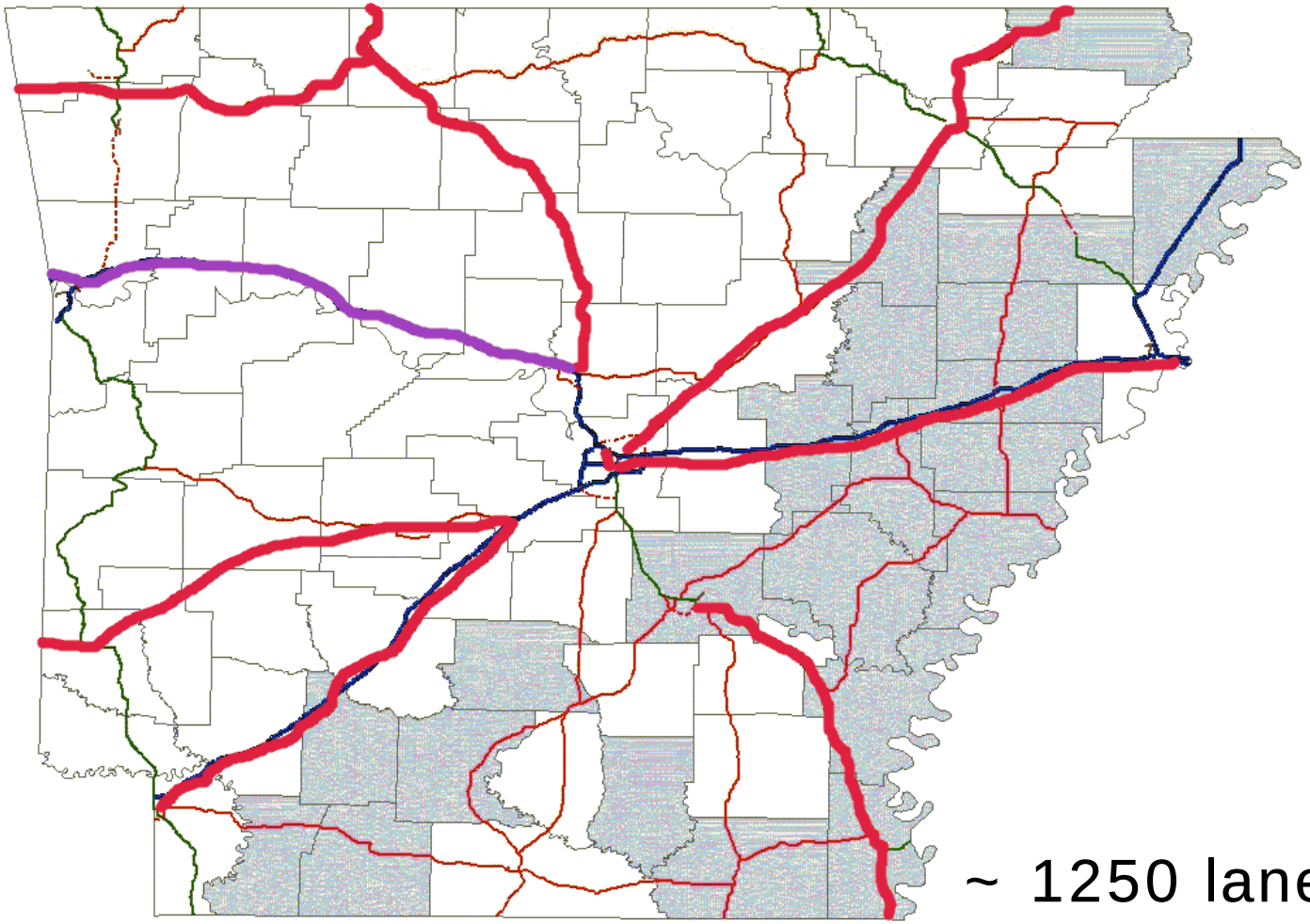
3D Ultra Applications

- Virtual surface for visualization
  - Multi-lane highway
  - Airport runway
  - Bridge deck
- Cracking: 1mm cracks at 60mph
- Safety analysis: macro-texture (MPD), hydroplaning, grooving
- Transverse profiling for rutting
- Longitudinal profiling for roughness & faulting

Multi-Lane Highway Evaluation

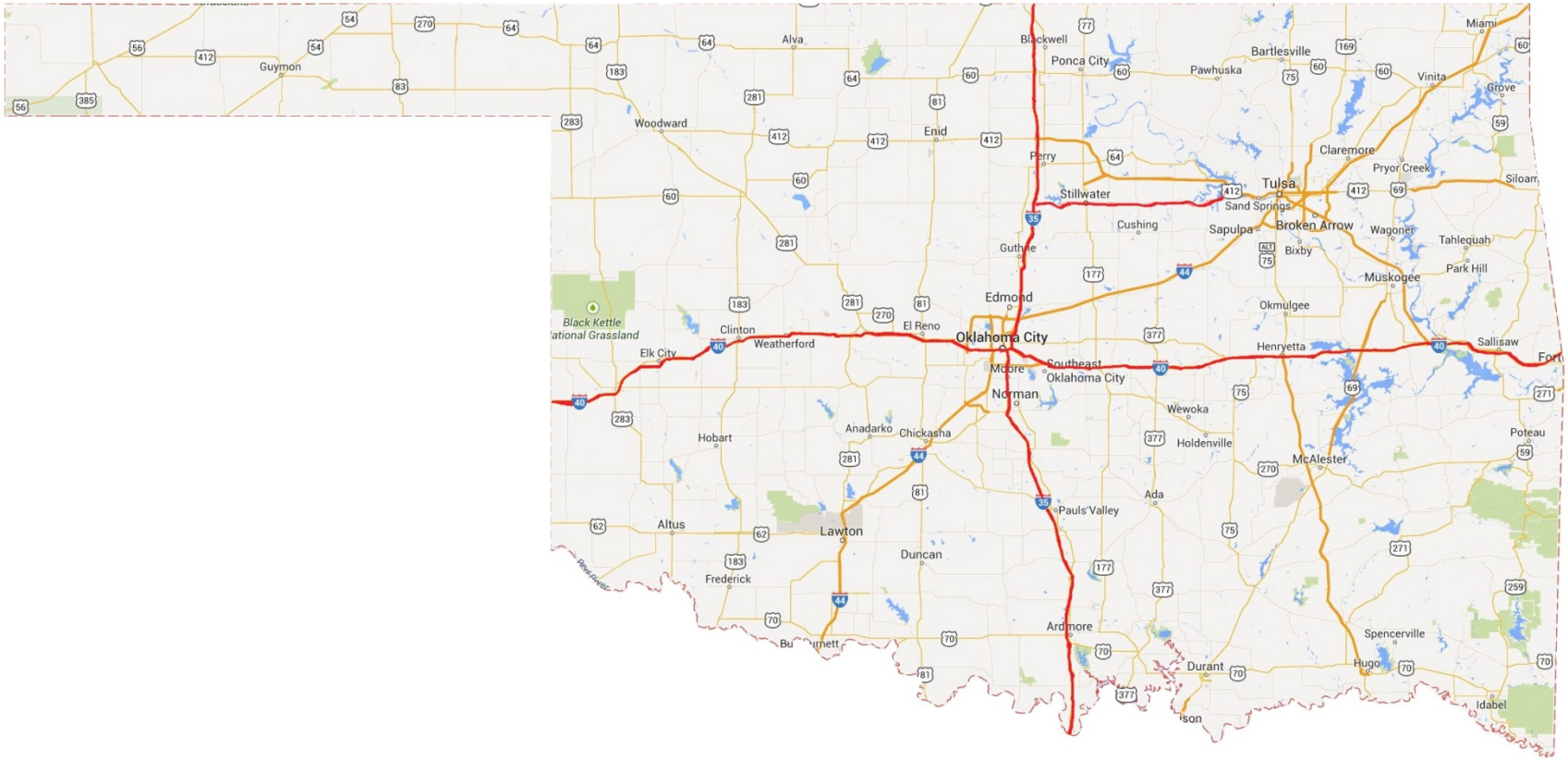


AHTD NHS Survey



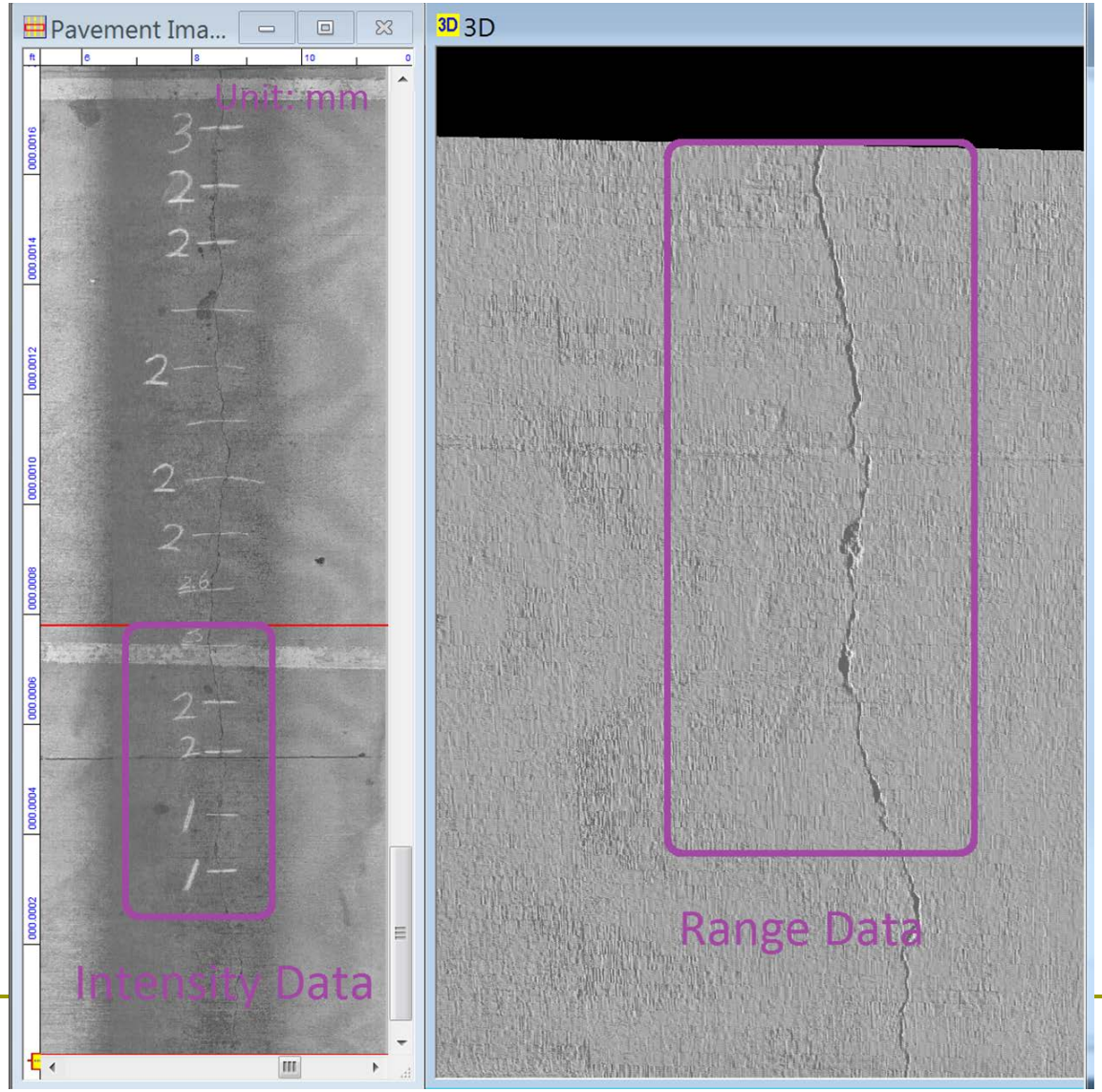
~ 1250 lane miles

ODOT Interstate Survey

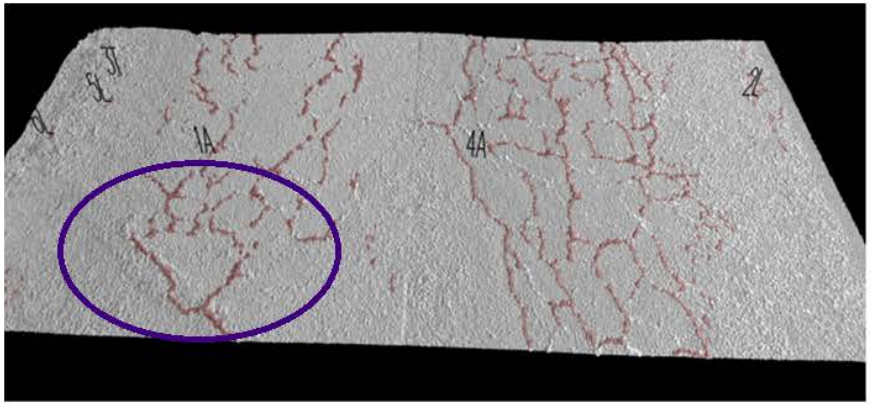


~ 1628 lane miles

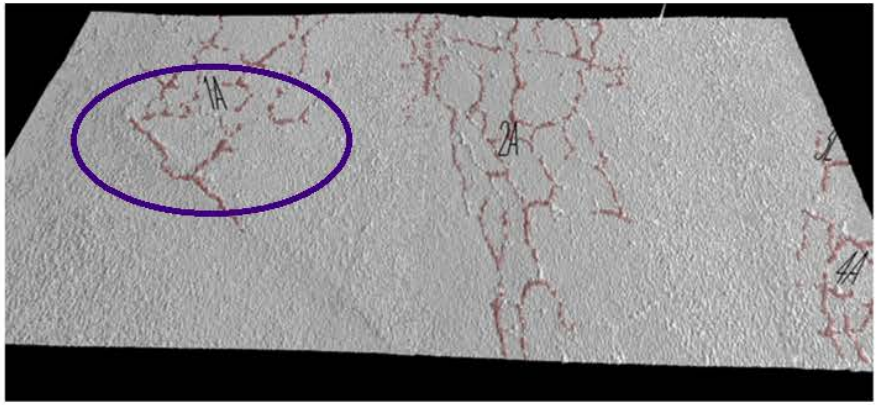
Crack Data Validation



Crack Data Validation



(a) Elephant Road #1 40km/h



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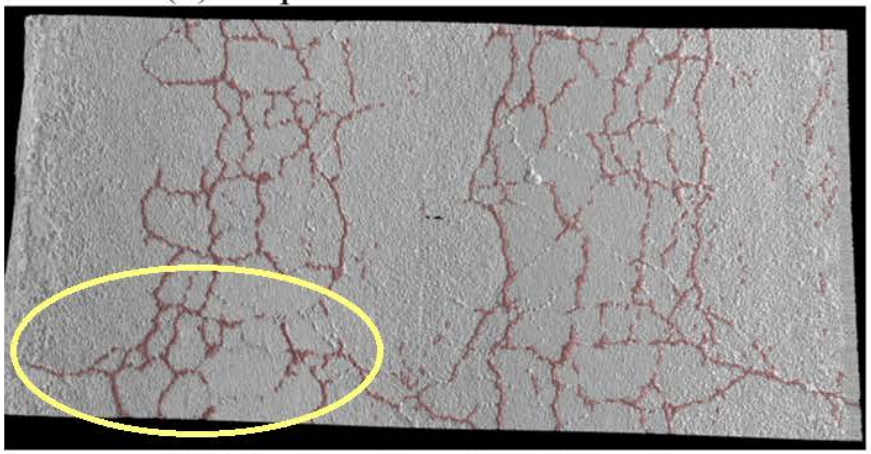
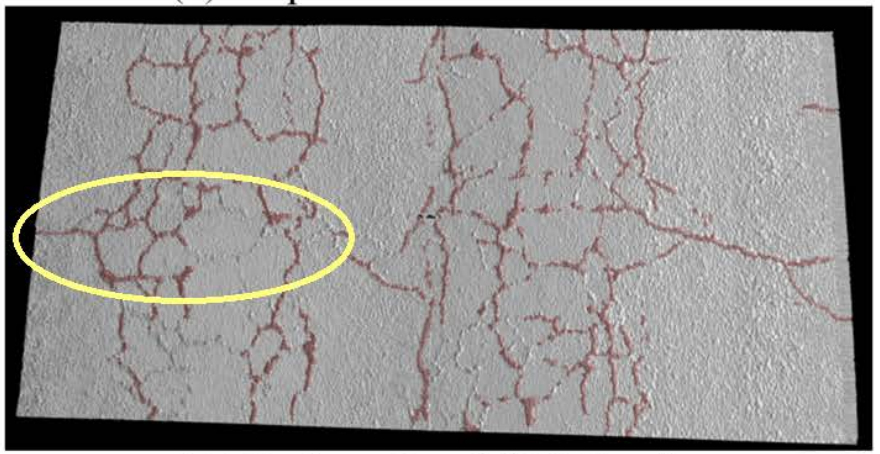


(b) Elephant Road #2 40km/h

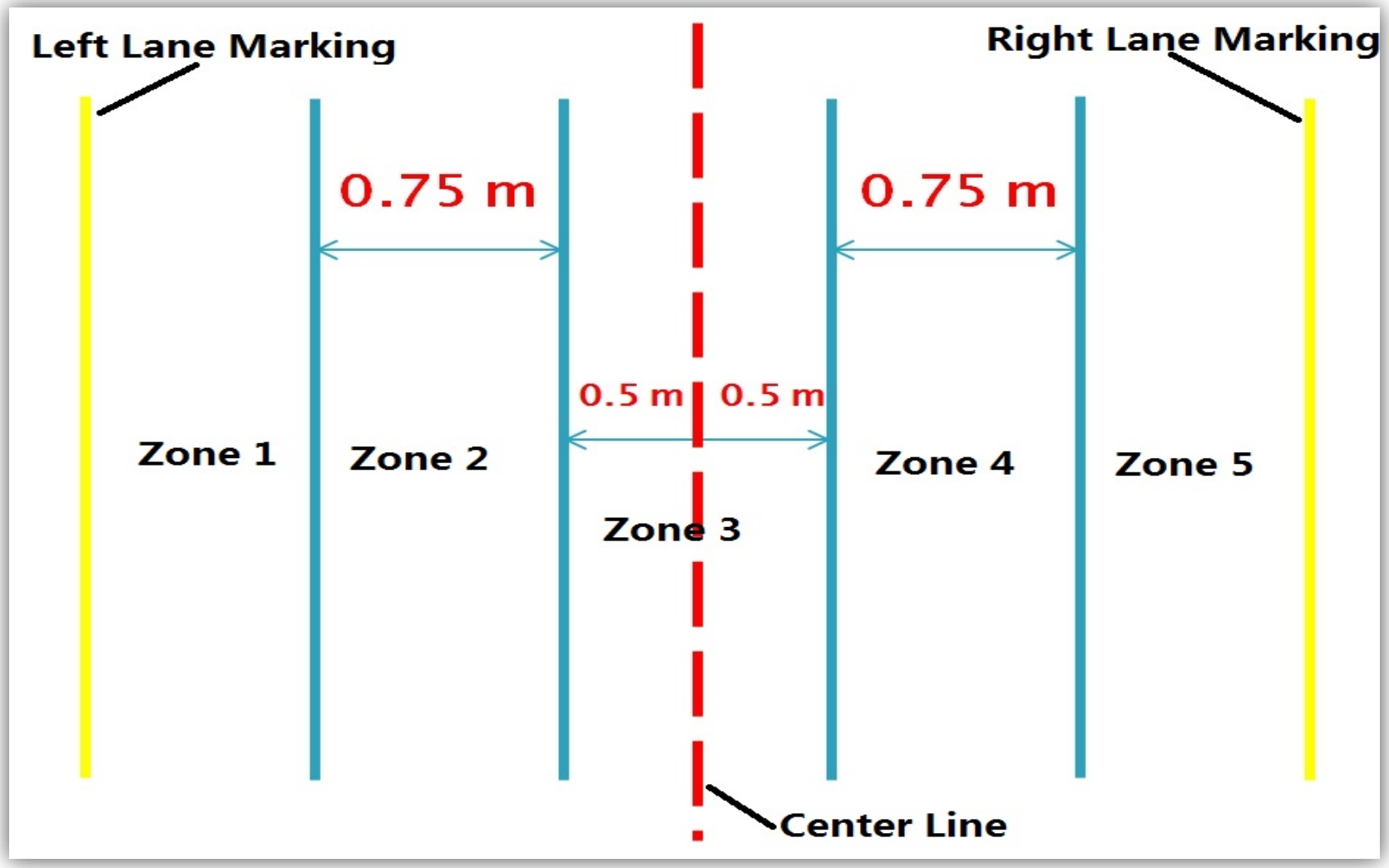


(b) Elephant Road #2 80km/h

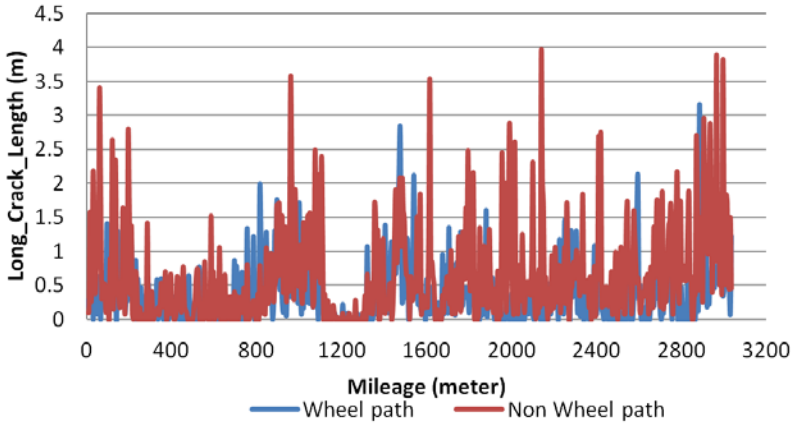
AASHTO PP67-10 Protocol

- Two cracking properties
  - Cracking length & width
- Three cracking types (by orientation)
  - Transverse, longitudinal & pattern cracking
- Five zones
  - Defined by WP & NWP

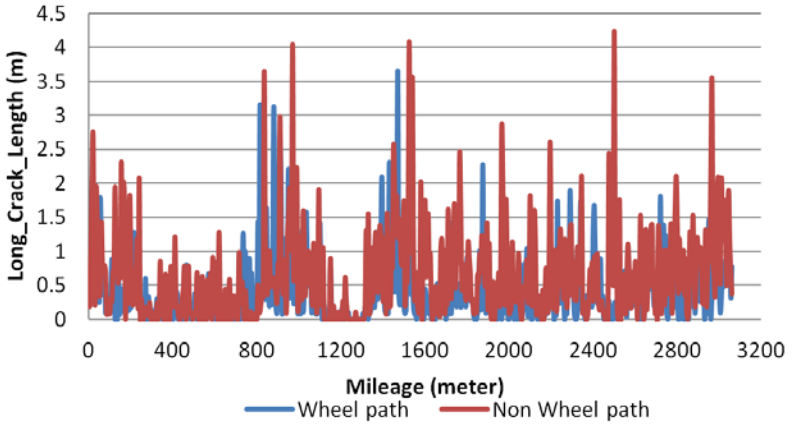
Wheelpath (WP) Definition



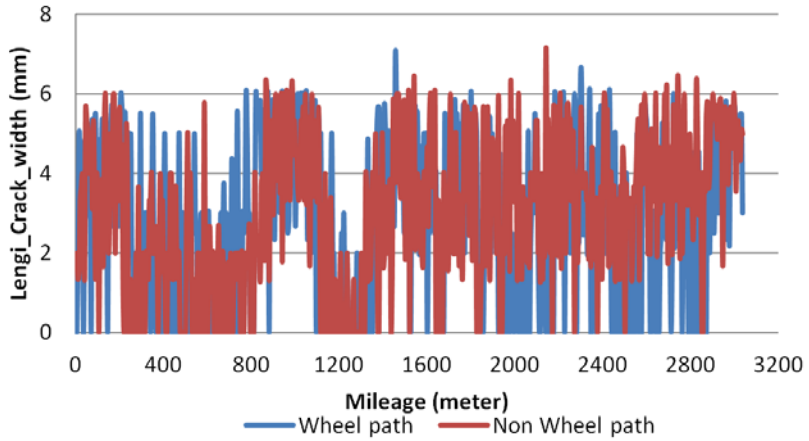
Longitudinal Cracking



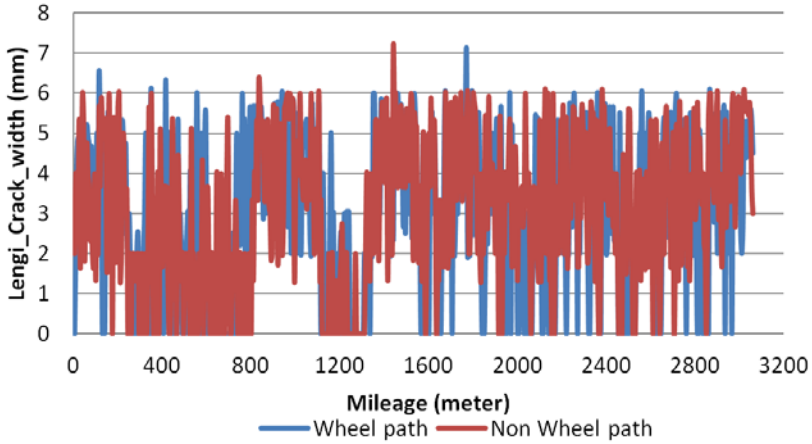
(c) West Bound 80km/h



(d) West Bound 40km/h

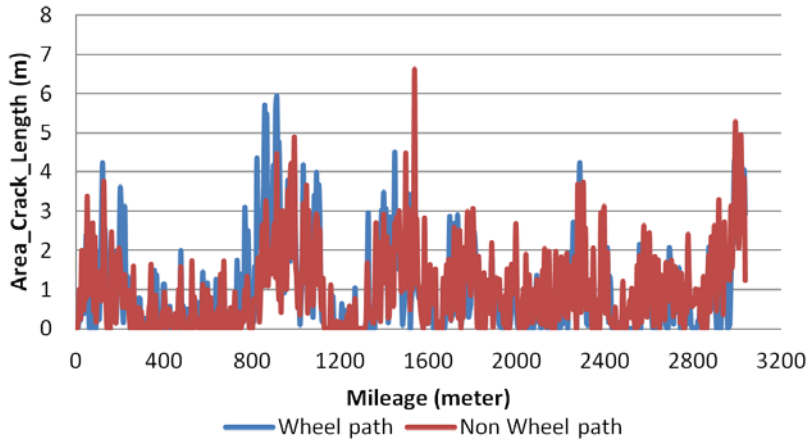


(c) West Bound 80km/h



(d) West Bound 40km/h

Area Cracking



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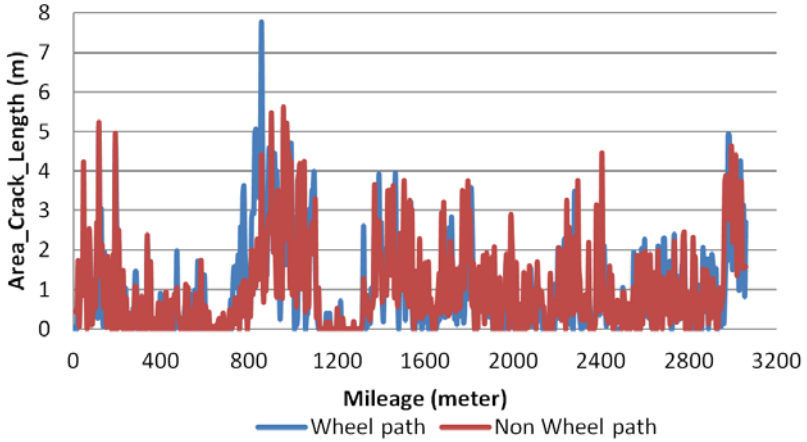

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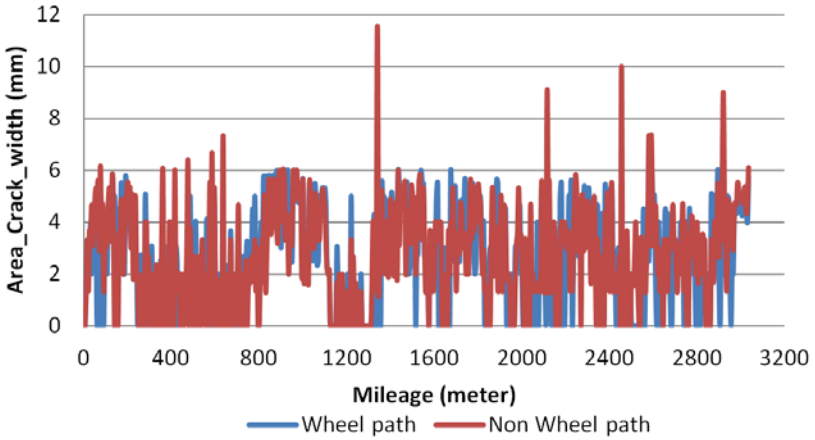

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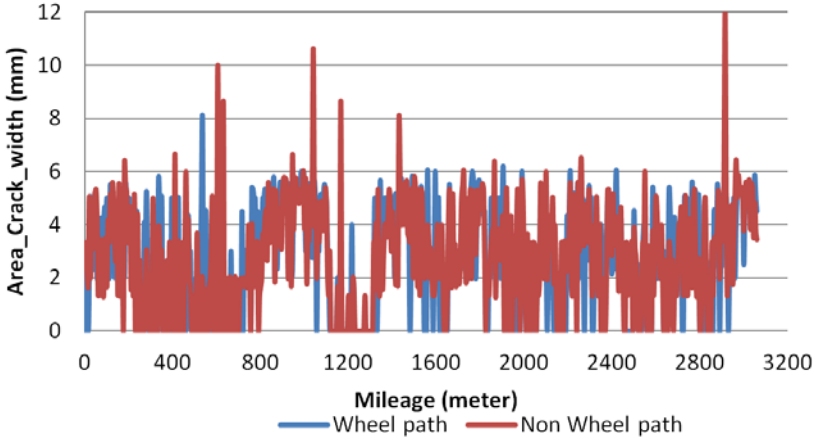
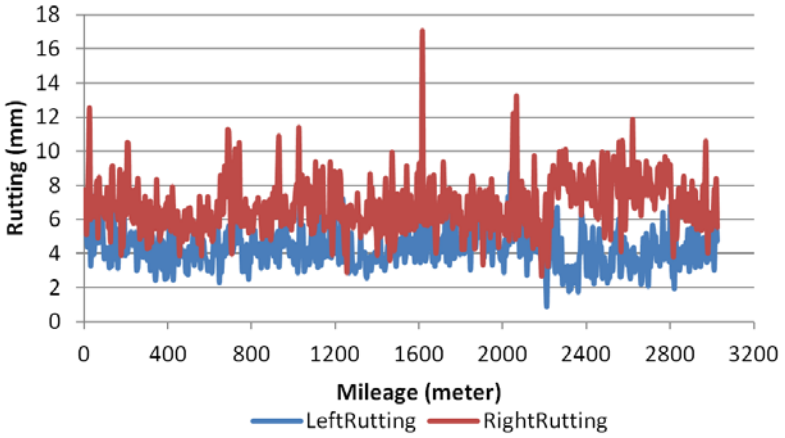
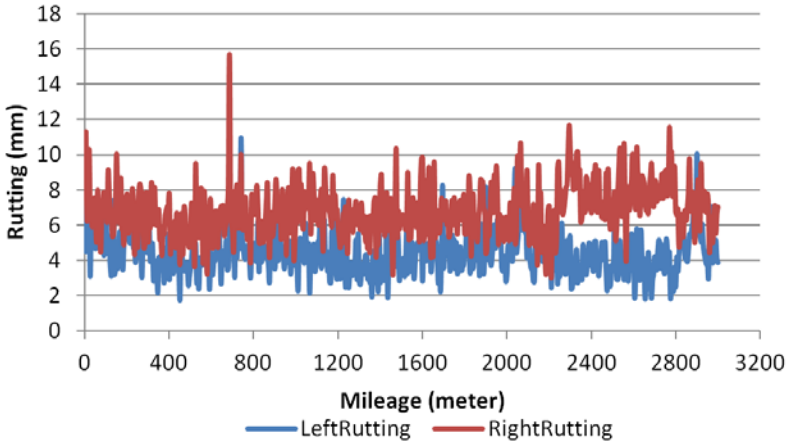


(d) West Bound 40km/h

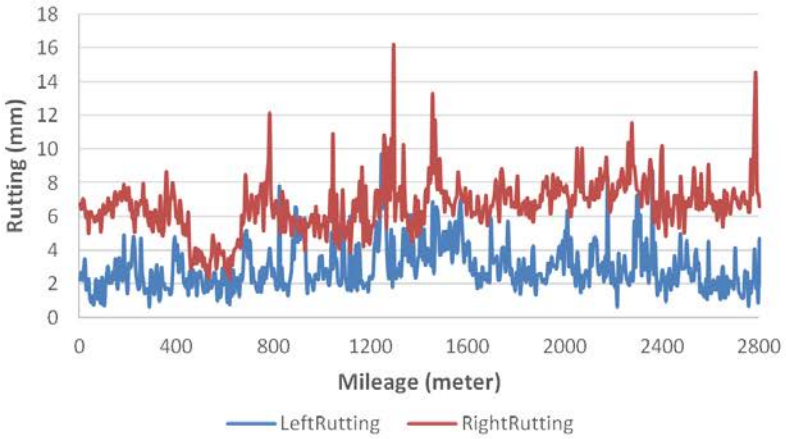
Rutting



(a) East Bound 80km/h



(b) East Bound 40km/h



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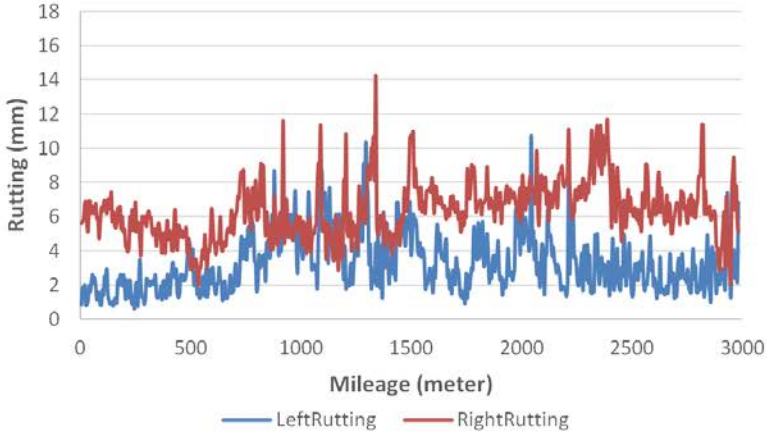
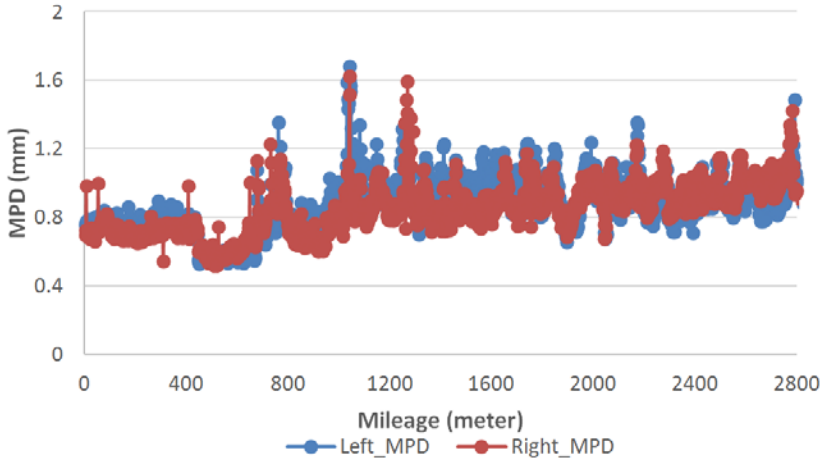


(b) East Bound 80km/h

Macro-Texture



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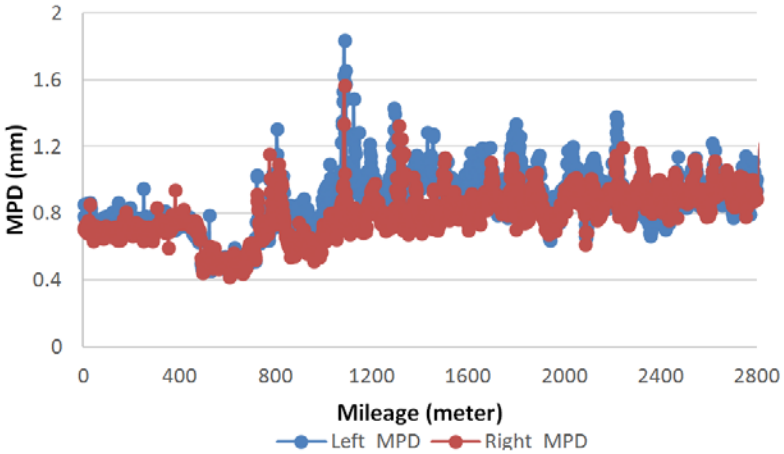
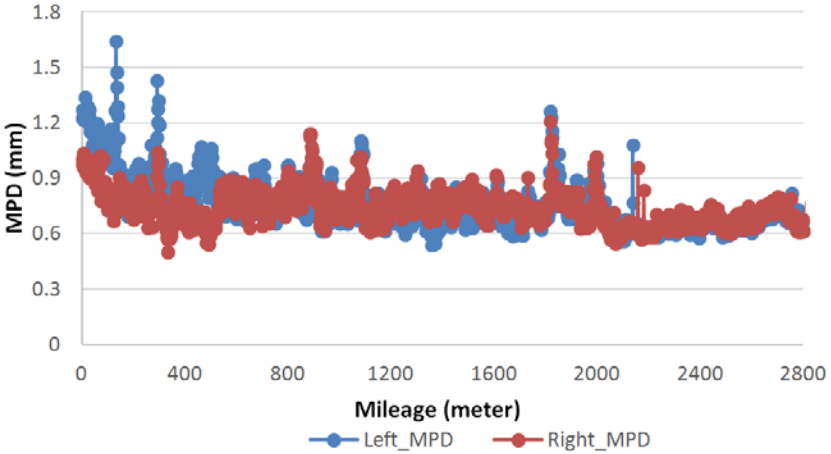
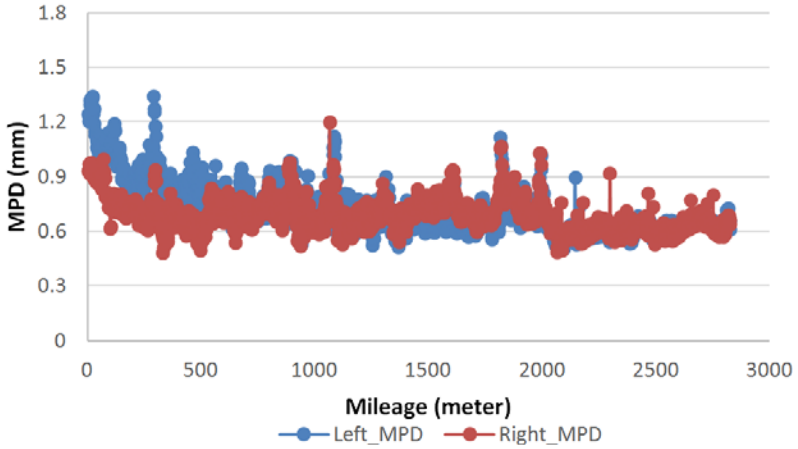


(b) East Bound 80km/h



(c) West Bound 40km/h



(d) West Bound 80km/h

Hydroplaning Evaluation

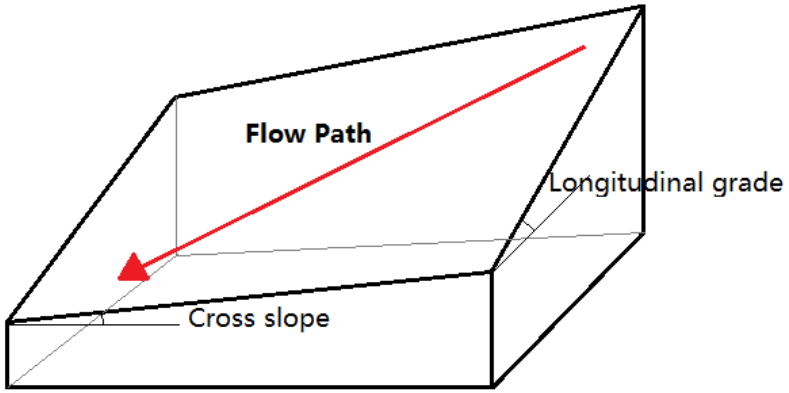
- Inertial Measurement Unit (IMU) Data
  - Positioning, cross slope and vertical slope
- PaveVision3D texture data
- Hydroplaning speed model
  - Water film depth: pavement texture, pavement type, cross slope, vertical grade, rain intensity
  - Hydroplaning speed: FHWA PAVDRN model

PAVDRN Model

$$WFD = \left[\frac{nL_f I}{36.1 S_f{}^{0.5}}\right]^{0.6} - MTD$$

$$S_f = (S_l{}^2 + S_c{}^2)^{\frac{1}{2}}$$

$$L_f = W\frac{S_f}{S_c}$$

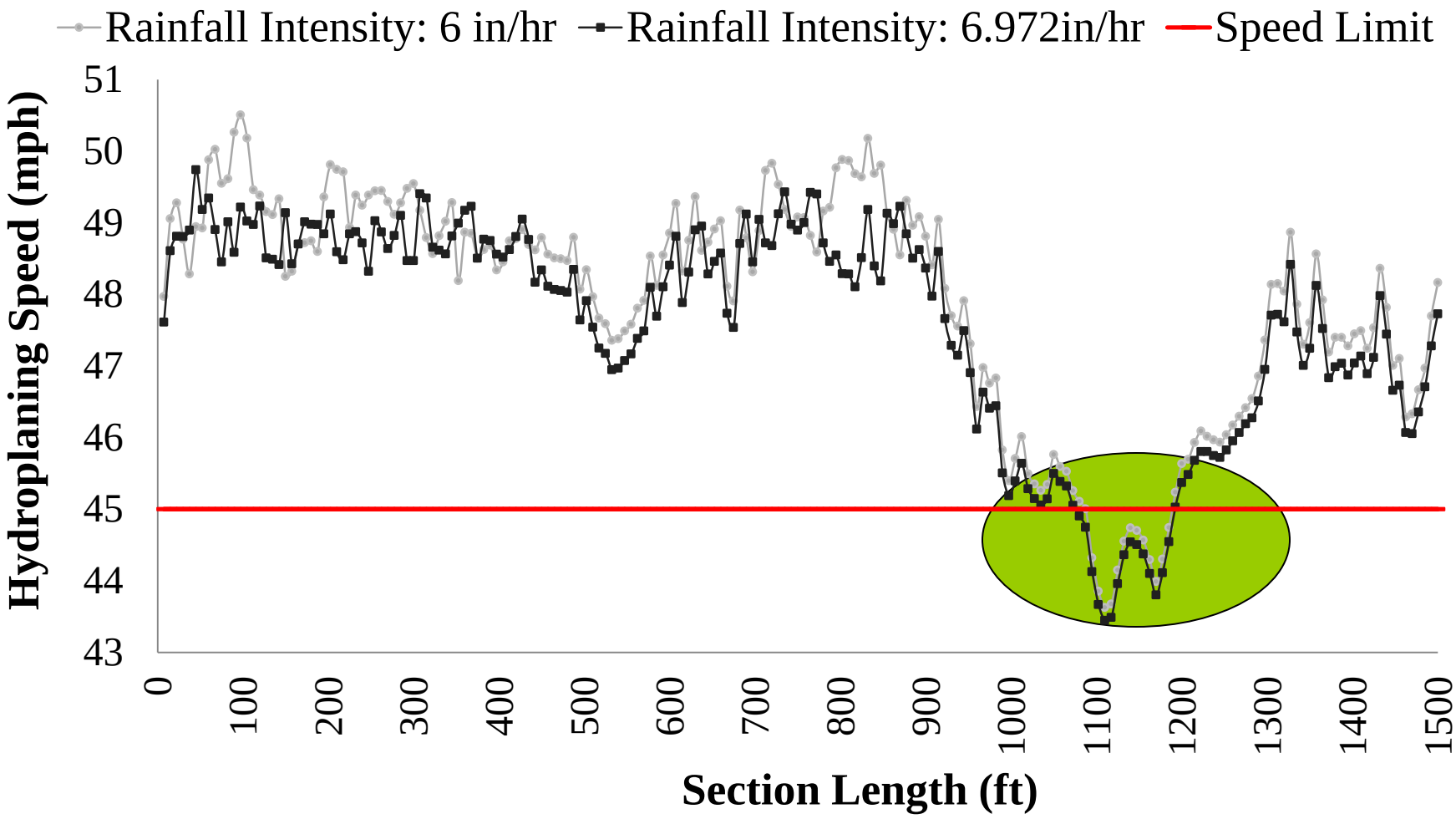


$$HPS = 26.04 WFD^{-0.259} \; (WFD\,(in) < 0.095)$$

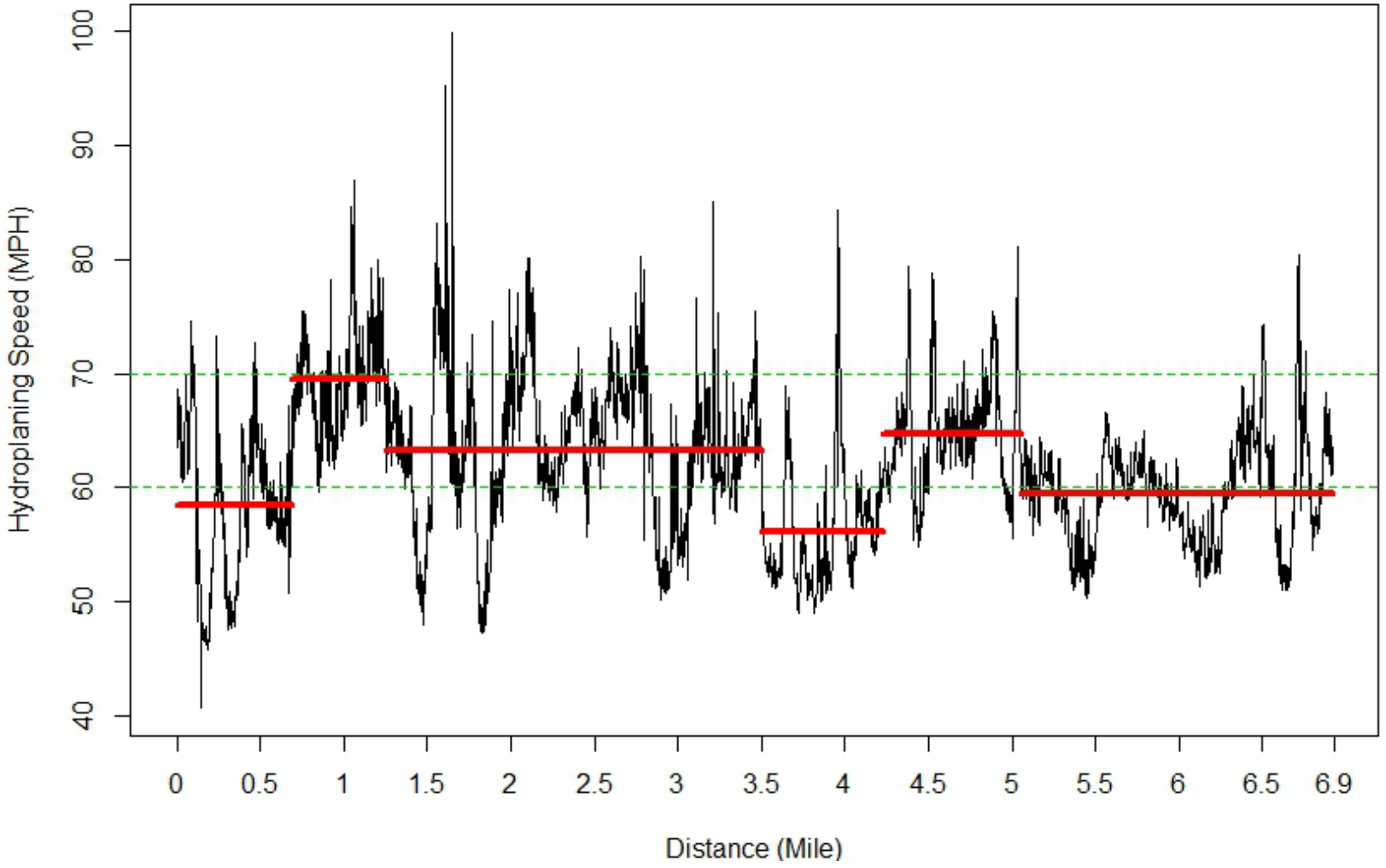
$$HPS = 3.09\,A \;\; (WFD\,(in) \geq 0.095)$$

WFD: Water Film Depth (in)	*Sc:* Cross slope
MTD: Mean Texture Depth (in)	*I:* (i – f) = Excess rainfall rate (in/hr)
HPS: Hydroplaning (Hydroplaning) Speed (mph)	*i:* Rainfall intensity (in/hr)
Lf: Flow path length (in)	*f:* Infiltration rate or permeability of pavement (in/hr)
Sf: Flow path slope (mm/mm)	*n:* Manning's roughness coefficient
Sl: Longitudinal grade	

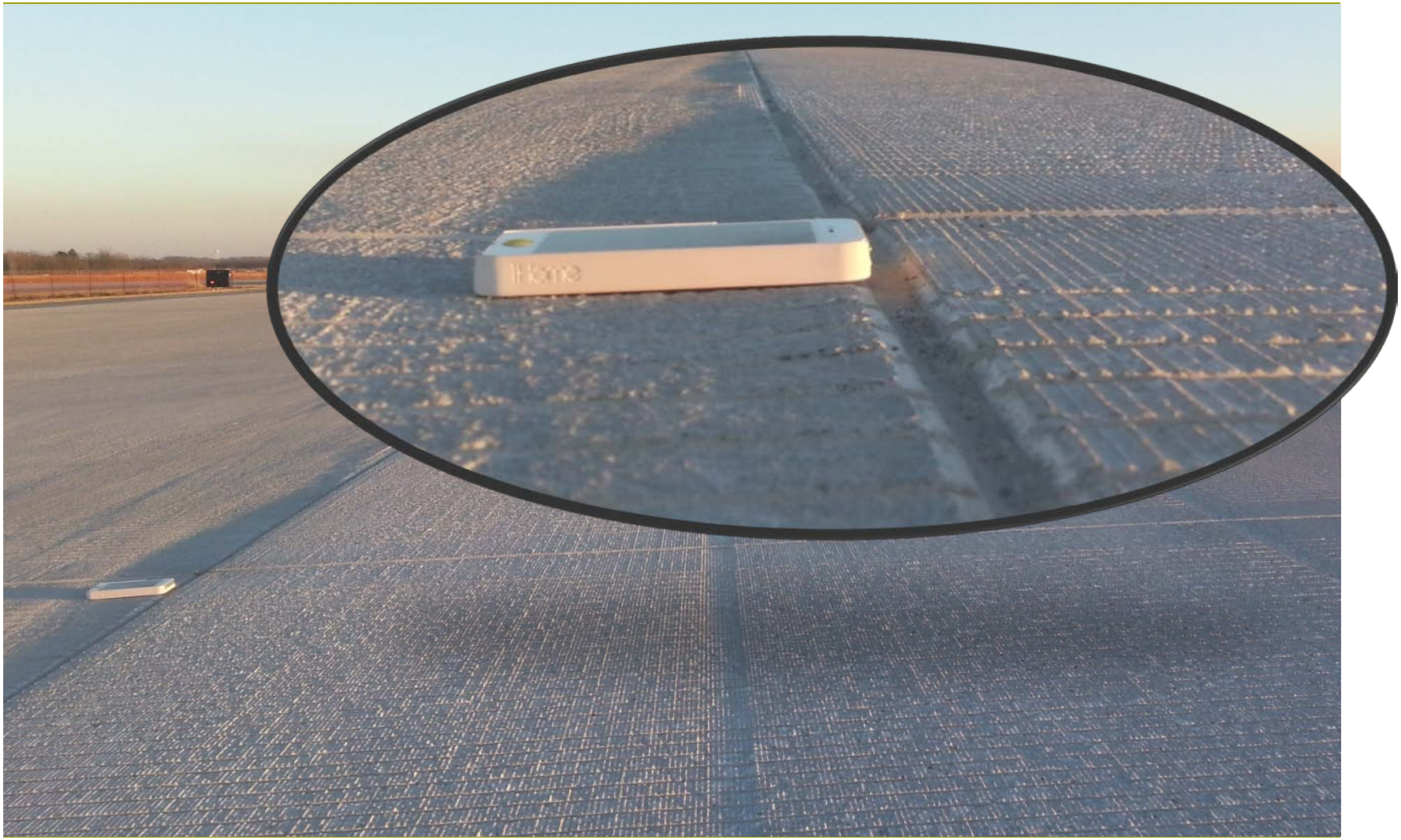
Hydroplaning Evaluation



Hydroplaning Segmentation



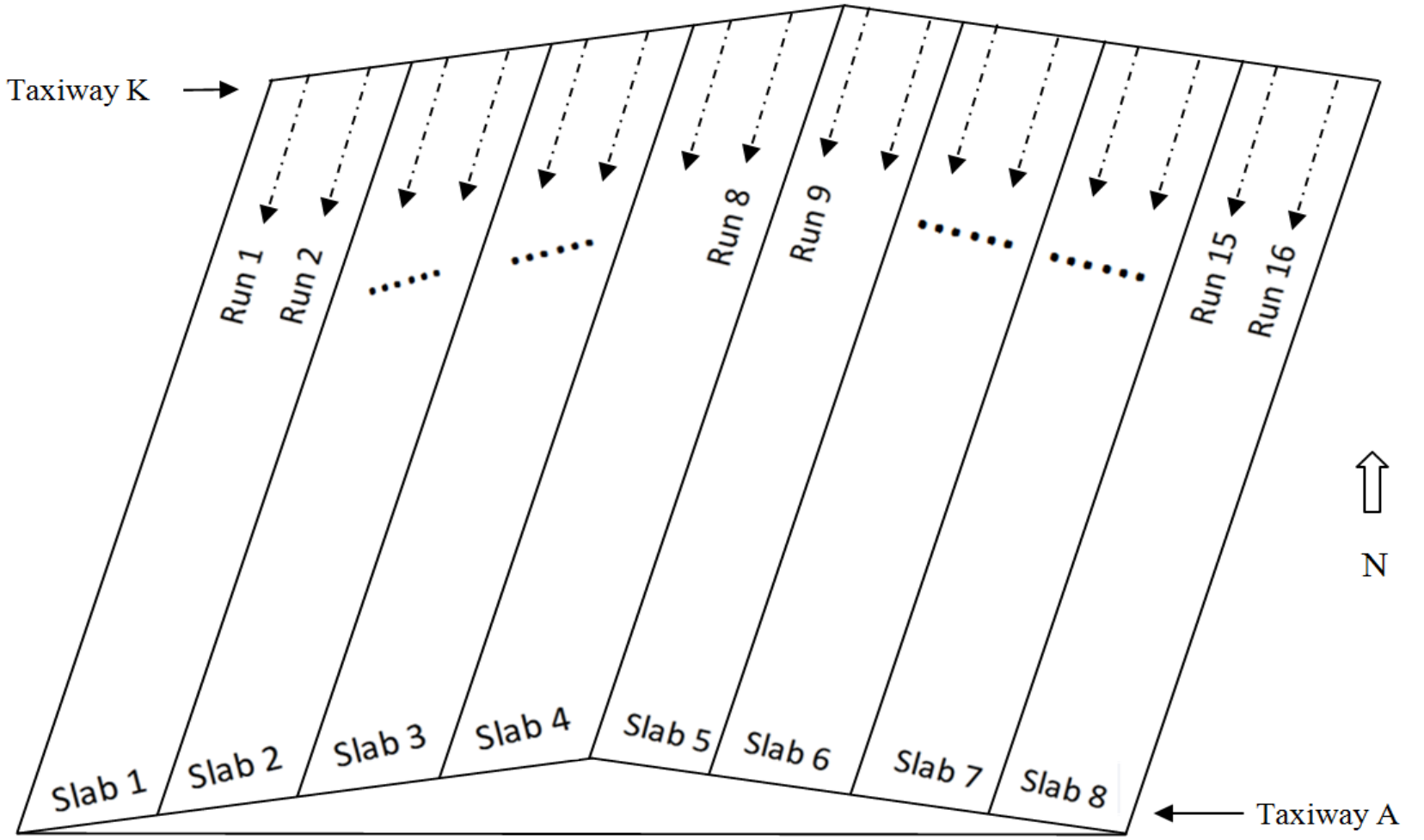
Full Size Runway Evaluation



Evaluation Objectives

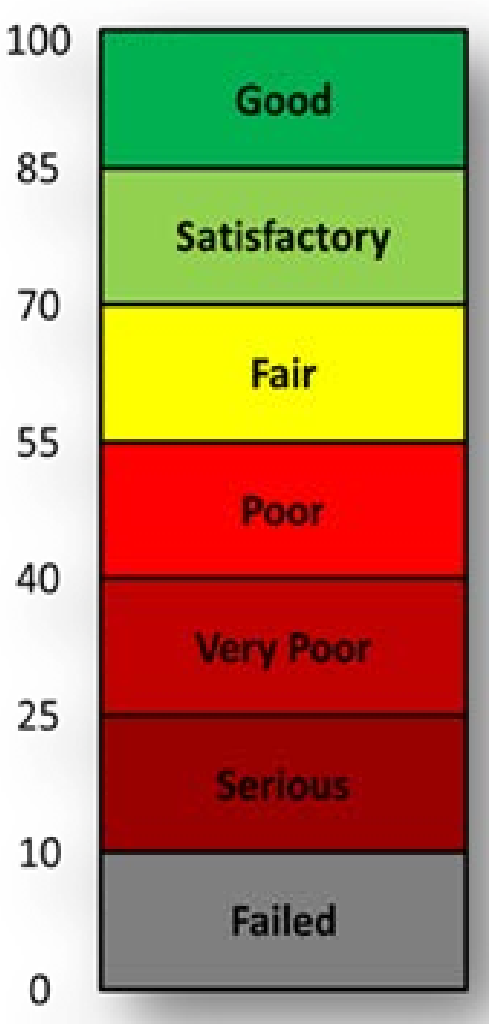
- PaveVision3D Ultra imaging of runway and taxiways at 1mm resolution
- PCI analysis
- Longitudinal profiling
  - Boeing Bump Index (BBI)
- Runway groove identification, measurement, evaluation
- Transverse profiling

Runway Data Collection

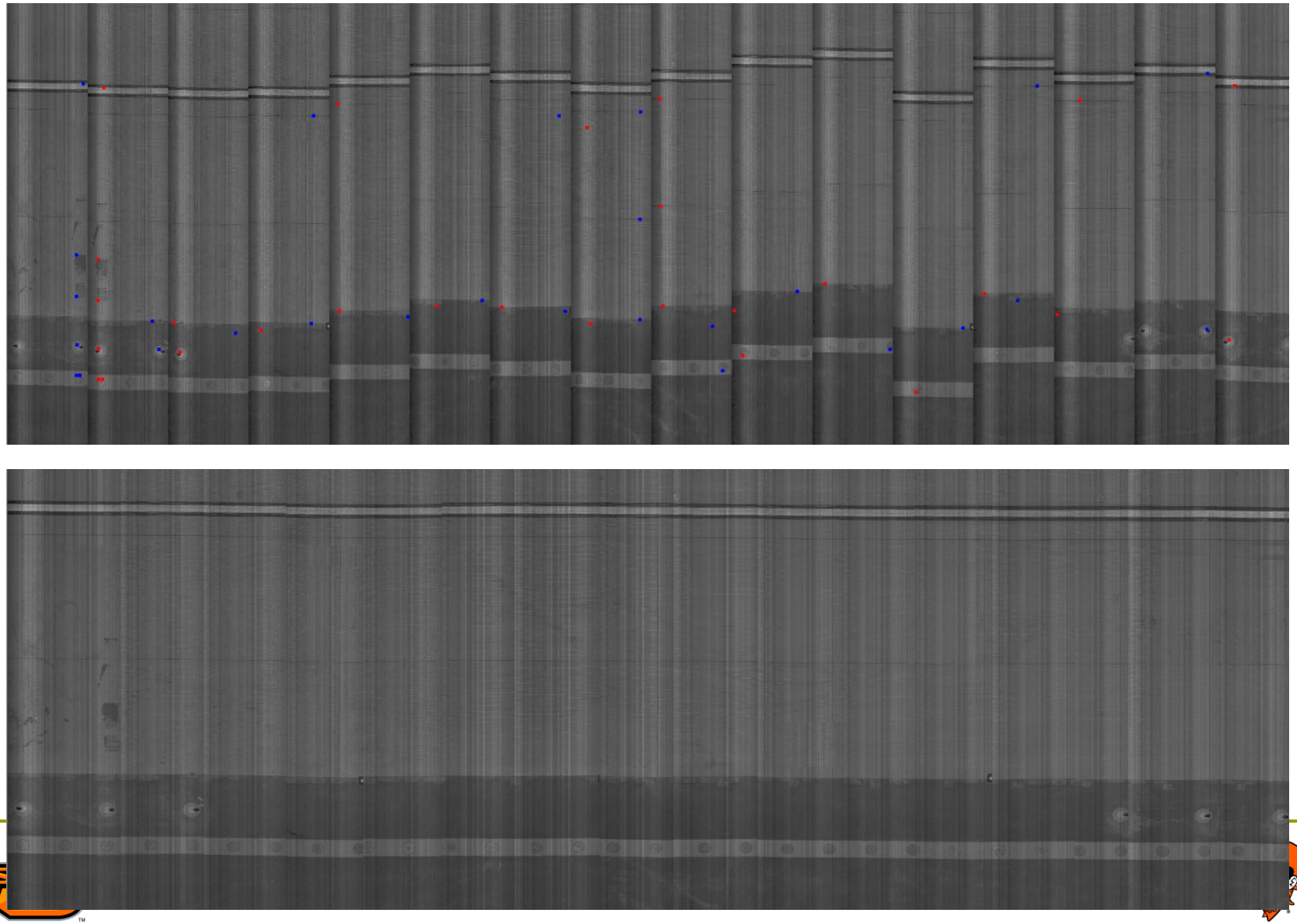


Airport PCI Analysis

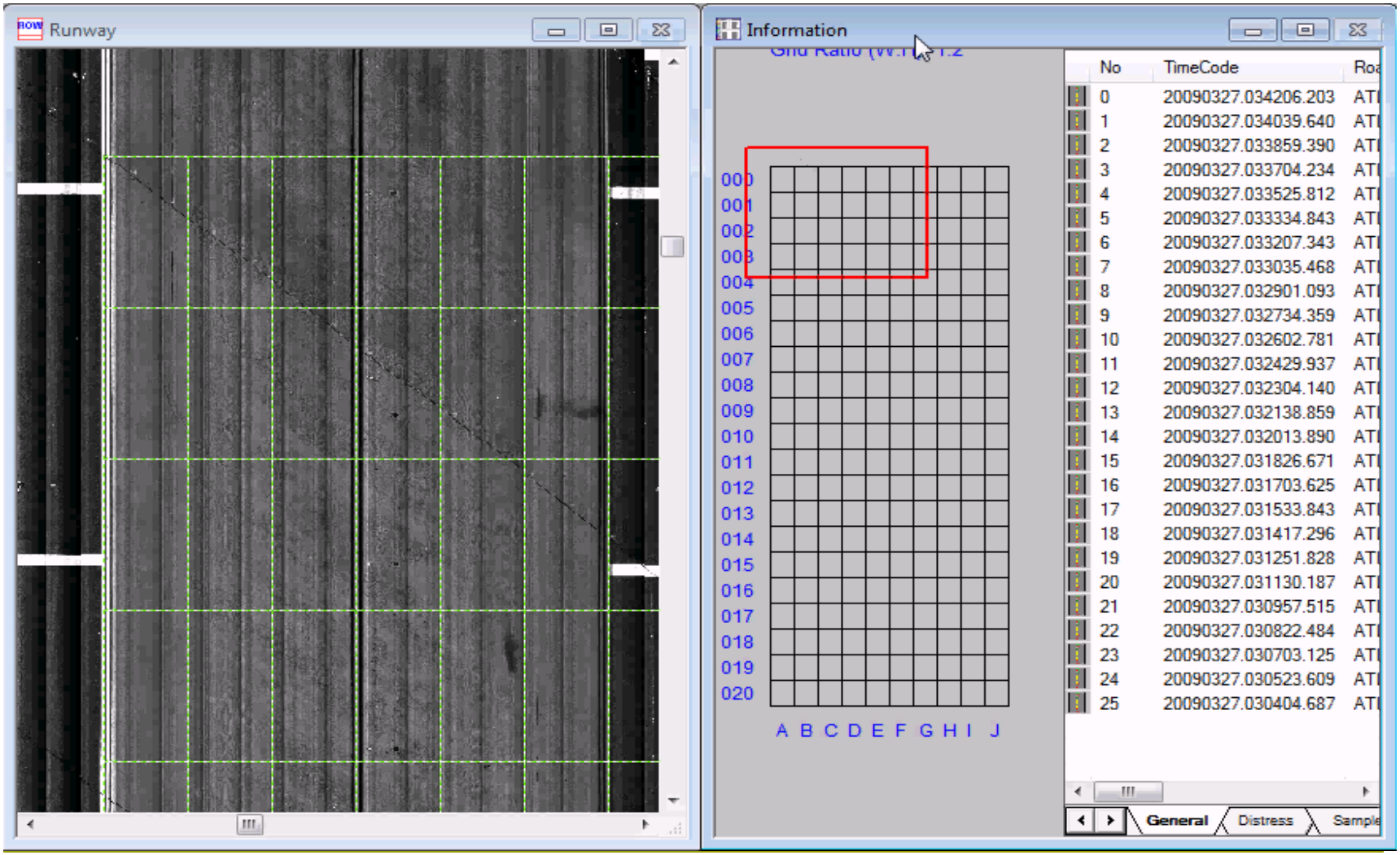
- PCI – Pavement Condition Index
- Quantitative Measure of Pavement Condition
- FAA AC 150/5380-6A (ASTM D5340-03)
- Pavement distress
  - Type
  - Quantity
  - Severity



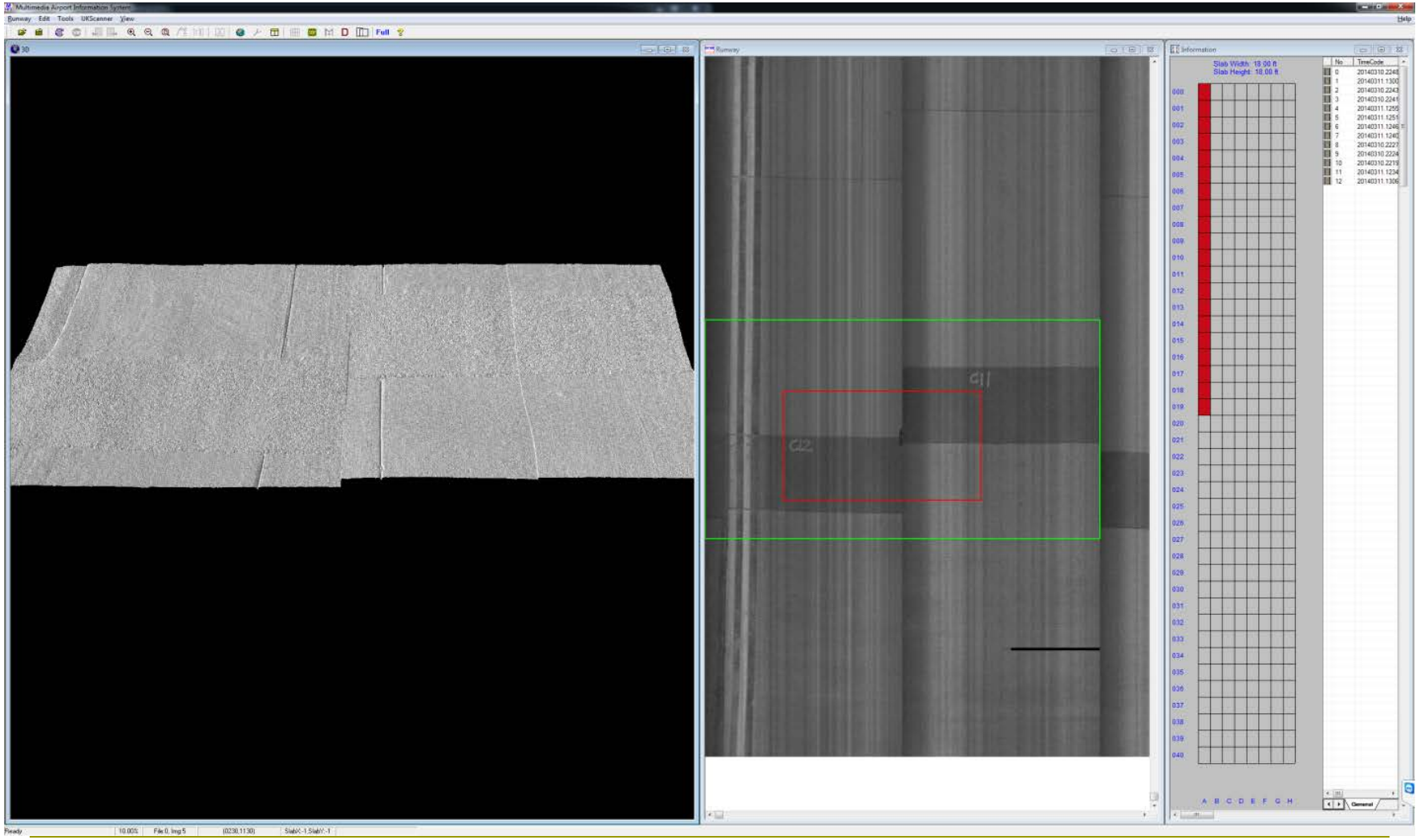
MHIS-Airport2D: Stitching



MHIS-Airport2D: PCI Analysis



MHIS-Airport3D Interface



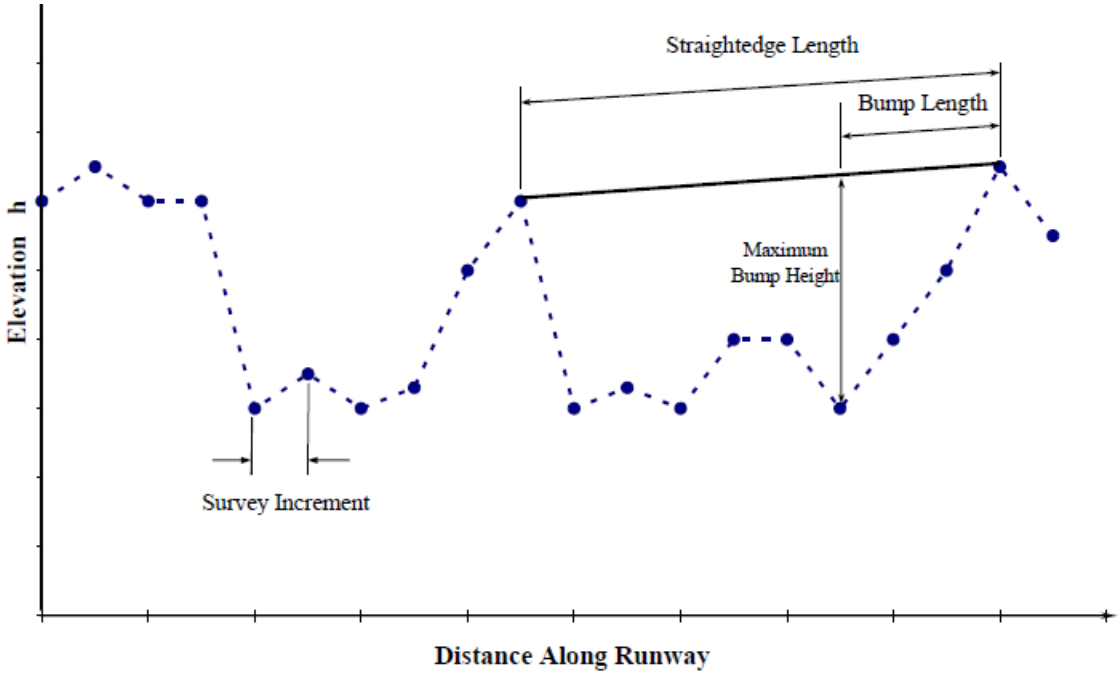
PCI Results

Location		PCI
Runway Overall		91
Runway Segment	Taxiway K-C	92
	Taxiway C-E	89.3
	Taxiway E-F	92.8
	Taxiway F-A	90.7

- PCI: excellent condition
- Many surface issues: not in PCI procedure
  - Surface irregularity
  - Groove problems
  - Surface grinding
  - Construction problems

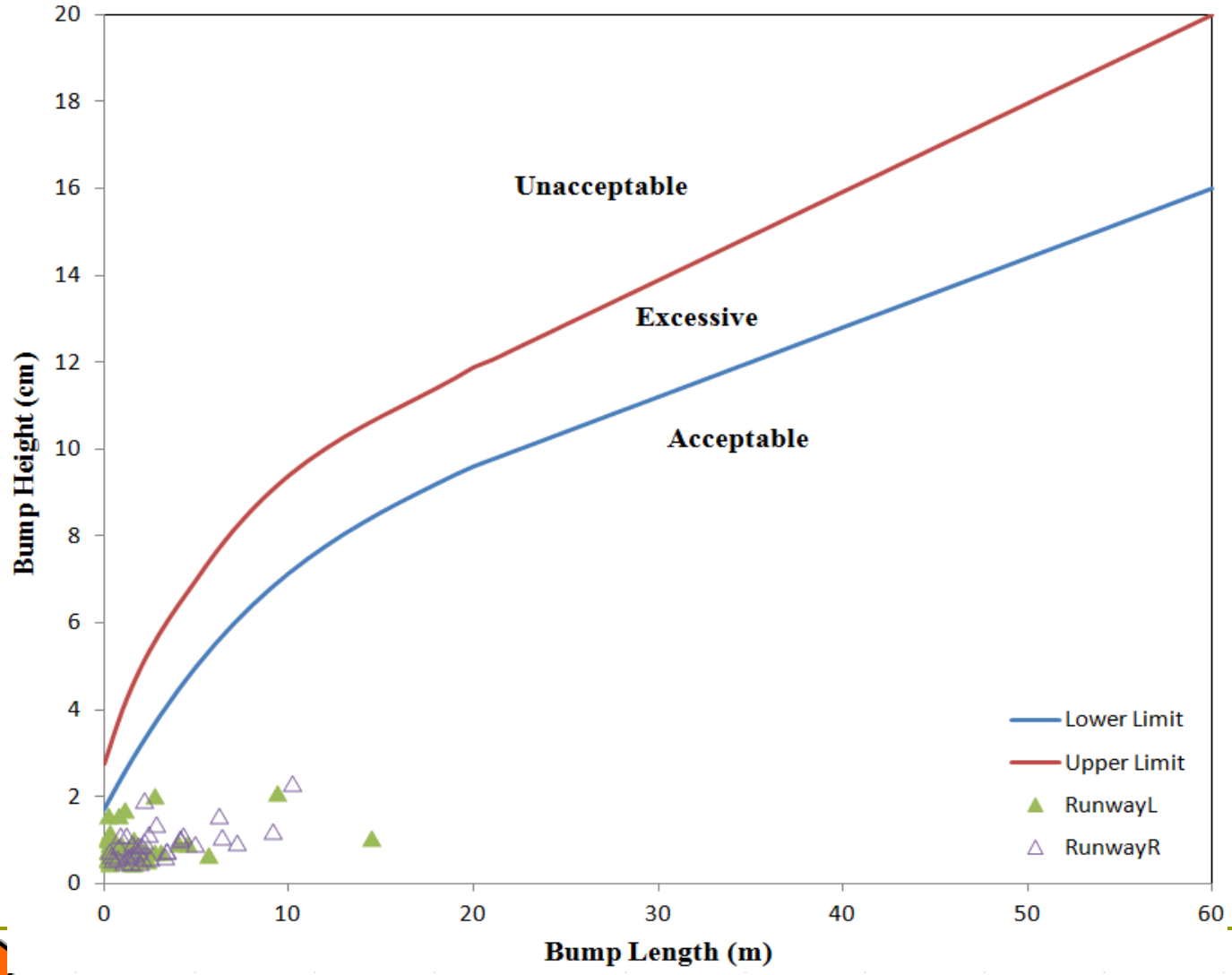
Runway Longitudinal Profiling

- Boeing Bump Methodology
  - FAA AC 150/5380-9

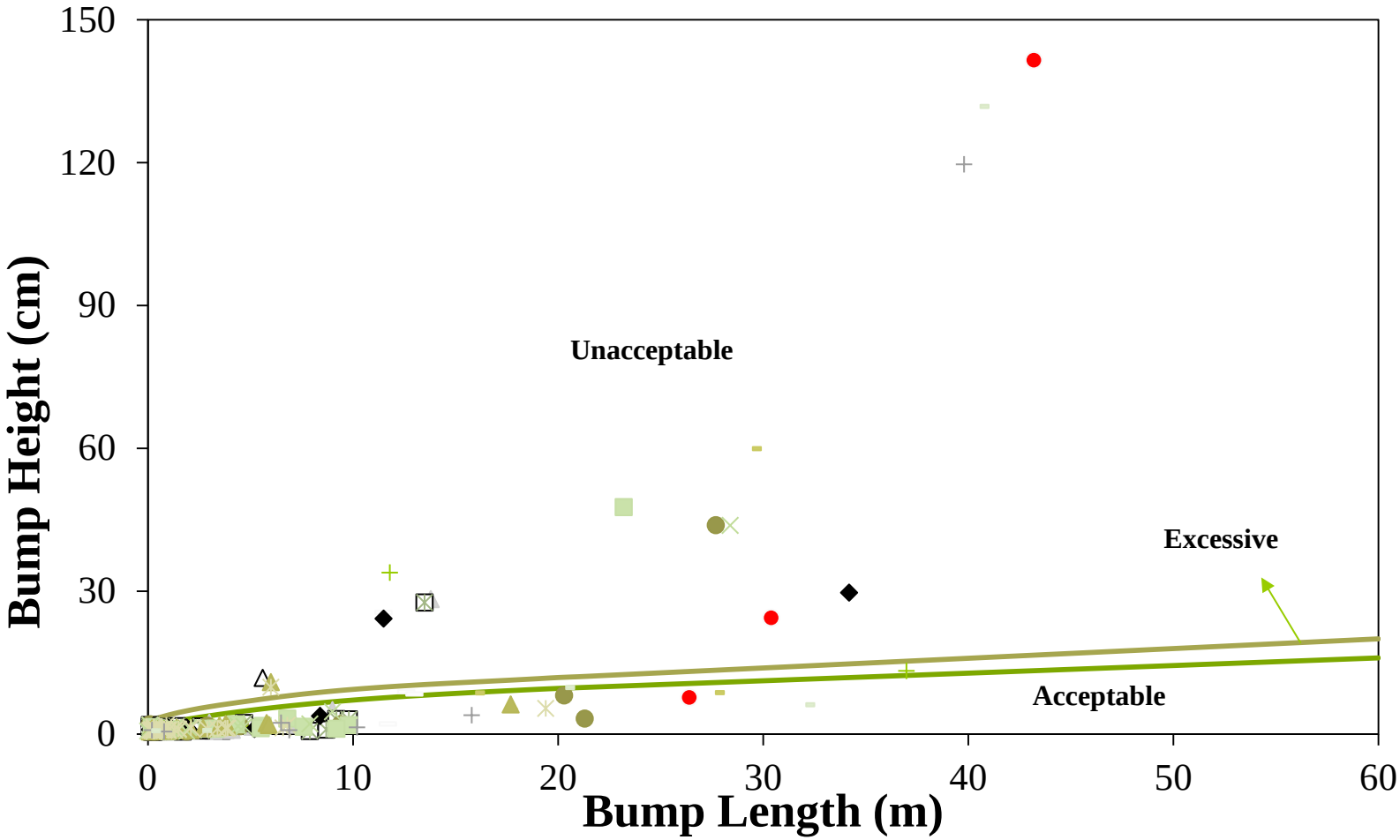


BBI = (measured bump height) / (limit of acceptable bump height)

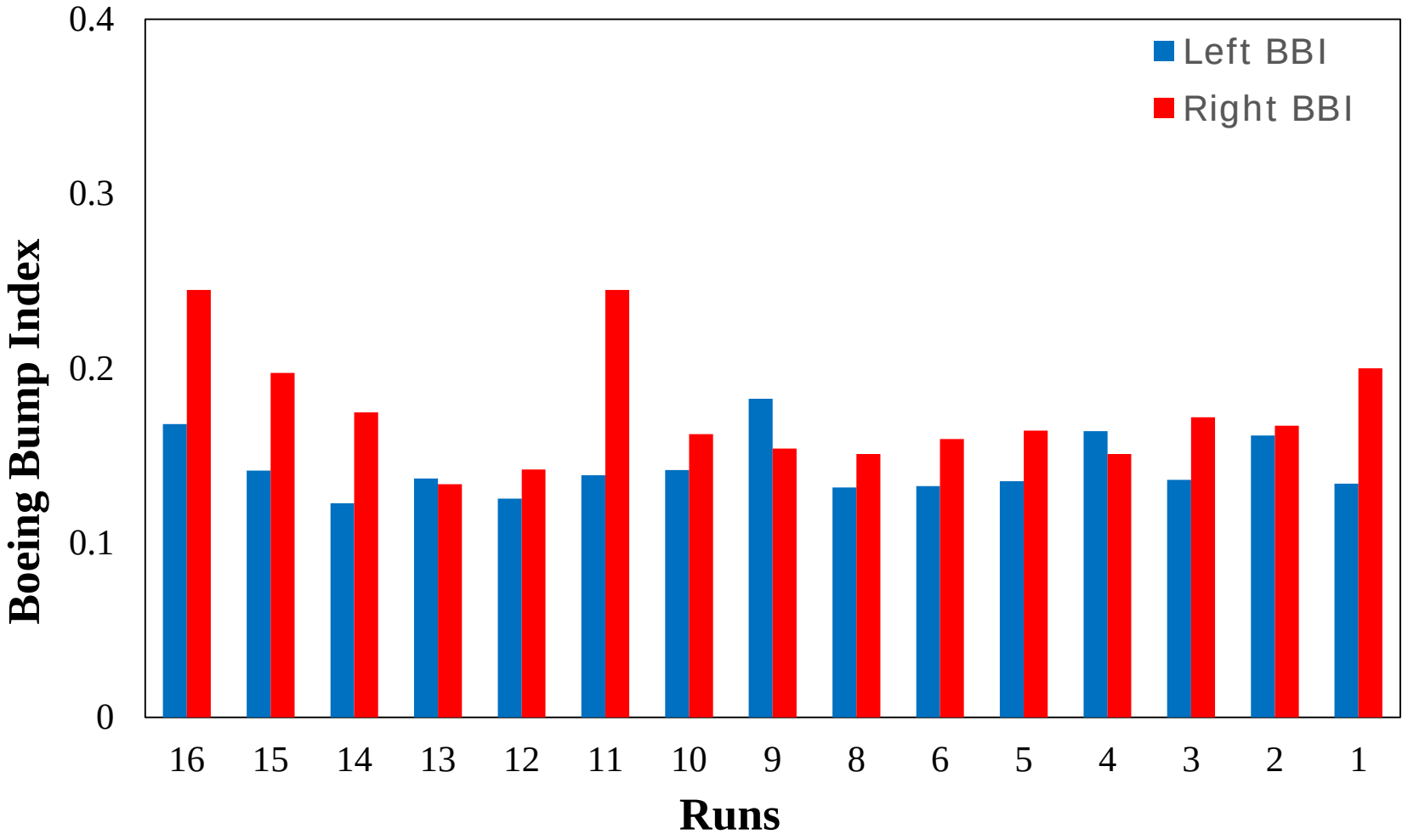
Runway Boeing Bumps



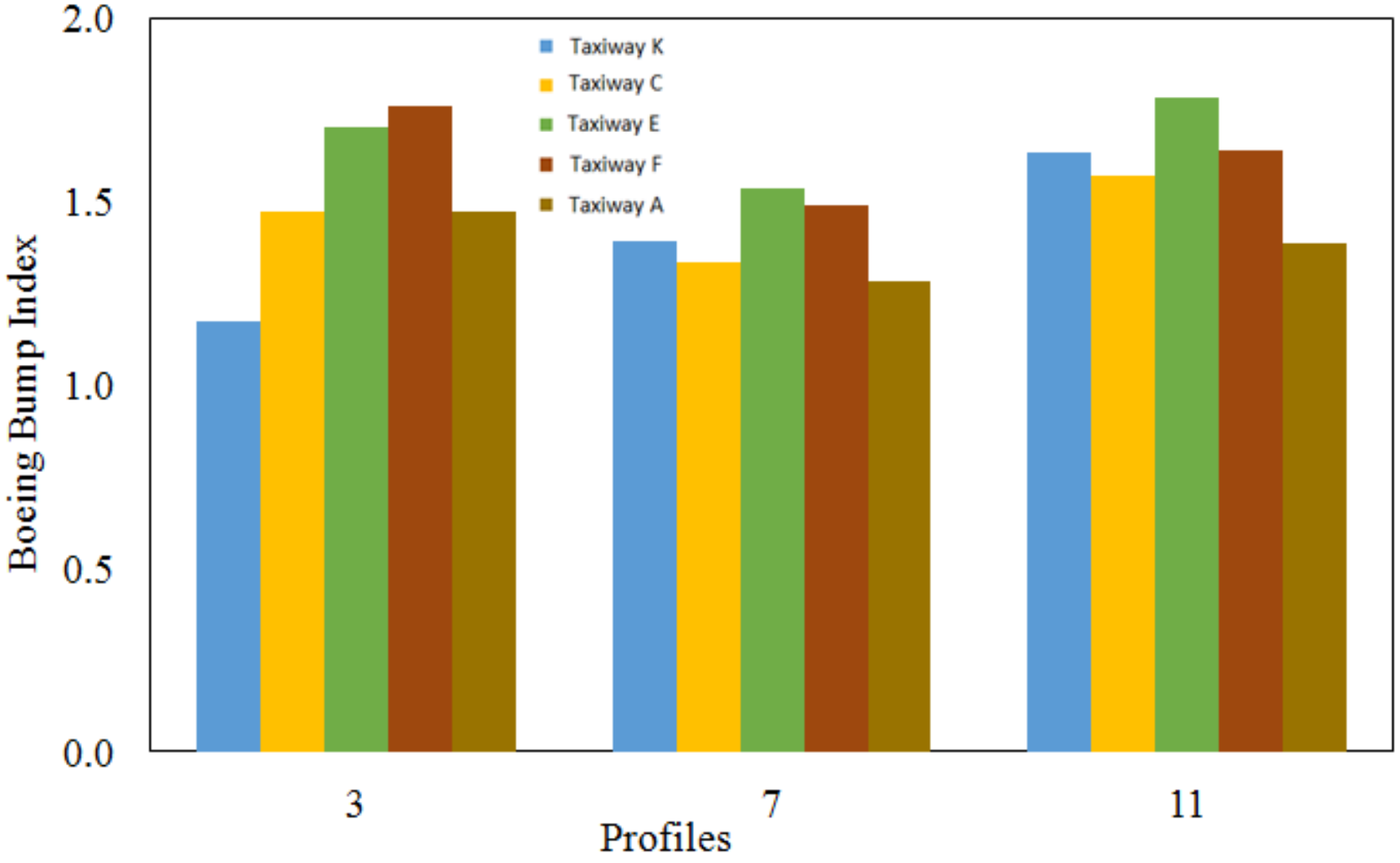
Taxiway Boeing Bumps



Runway BBI

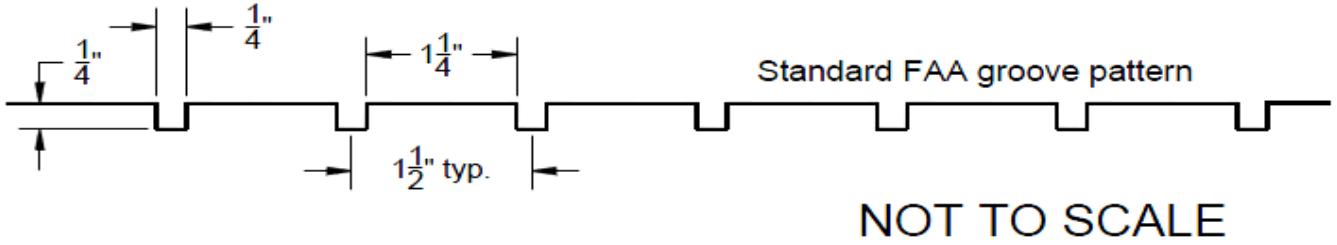

0.4
0.3
0.2
0.1
0
Boeing Bump Index
Left BBI
Right BBI
16
15
14
13
12
11
10
9
8
6
5
4
3
2
1
Runs

Taxiway BBI


2.0
1.5
1.0
0.5
0.0
Boeing Bump Index
Taxiway K
Taxiway C
Taxiway E
Taxiway F
Taxiway A
3
7
11
Profiles

Runway Groove Evaluation

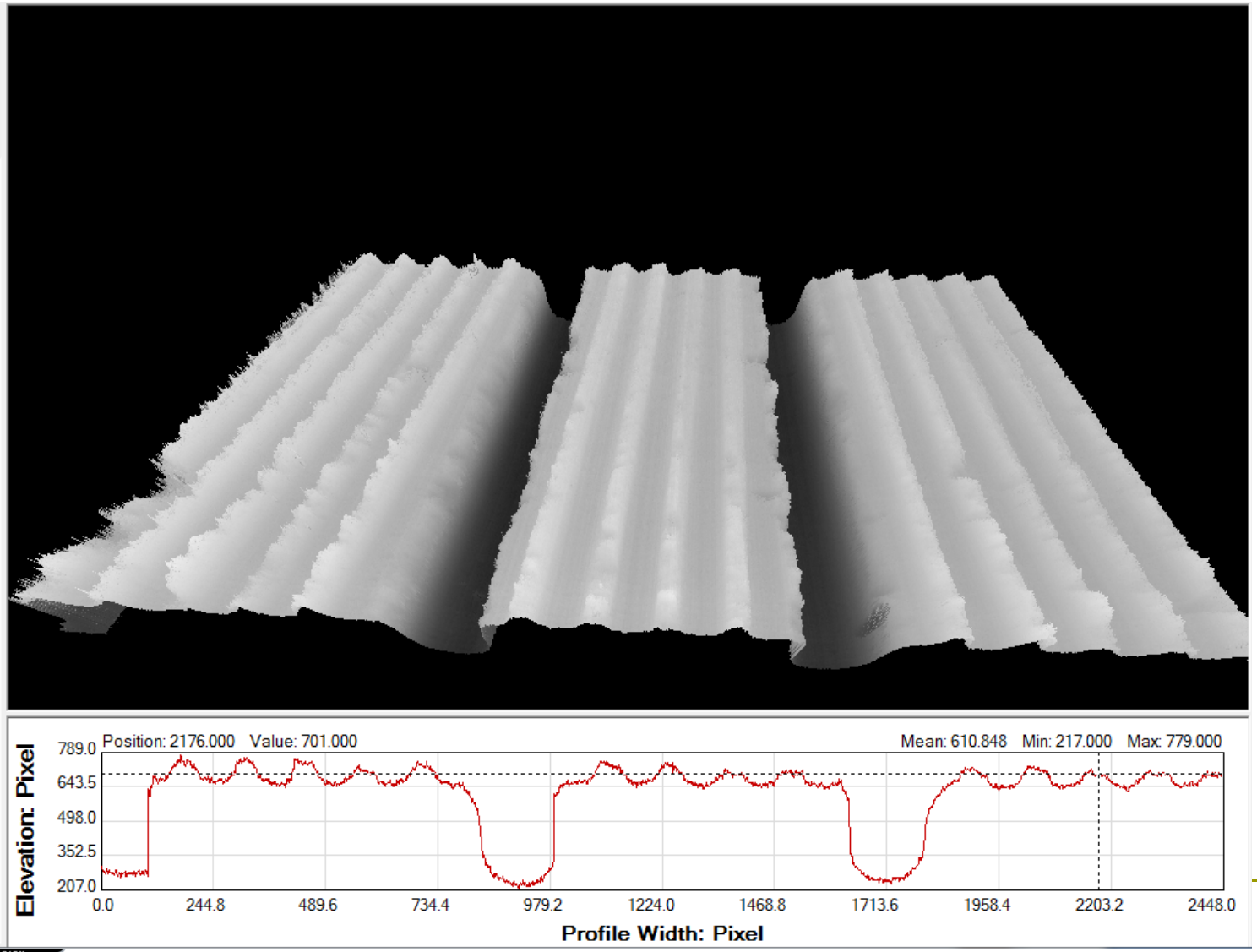
- Standard Rectangle Groove (AC 150/5320-12C)



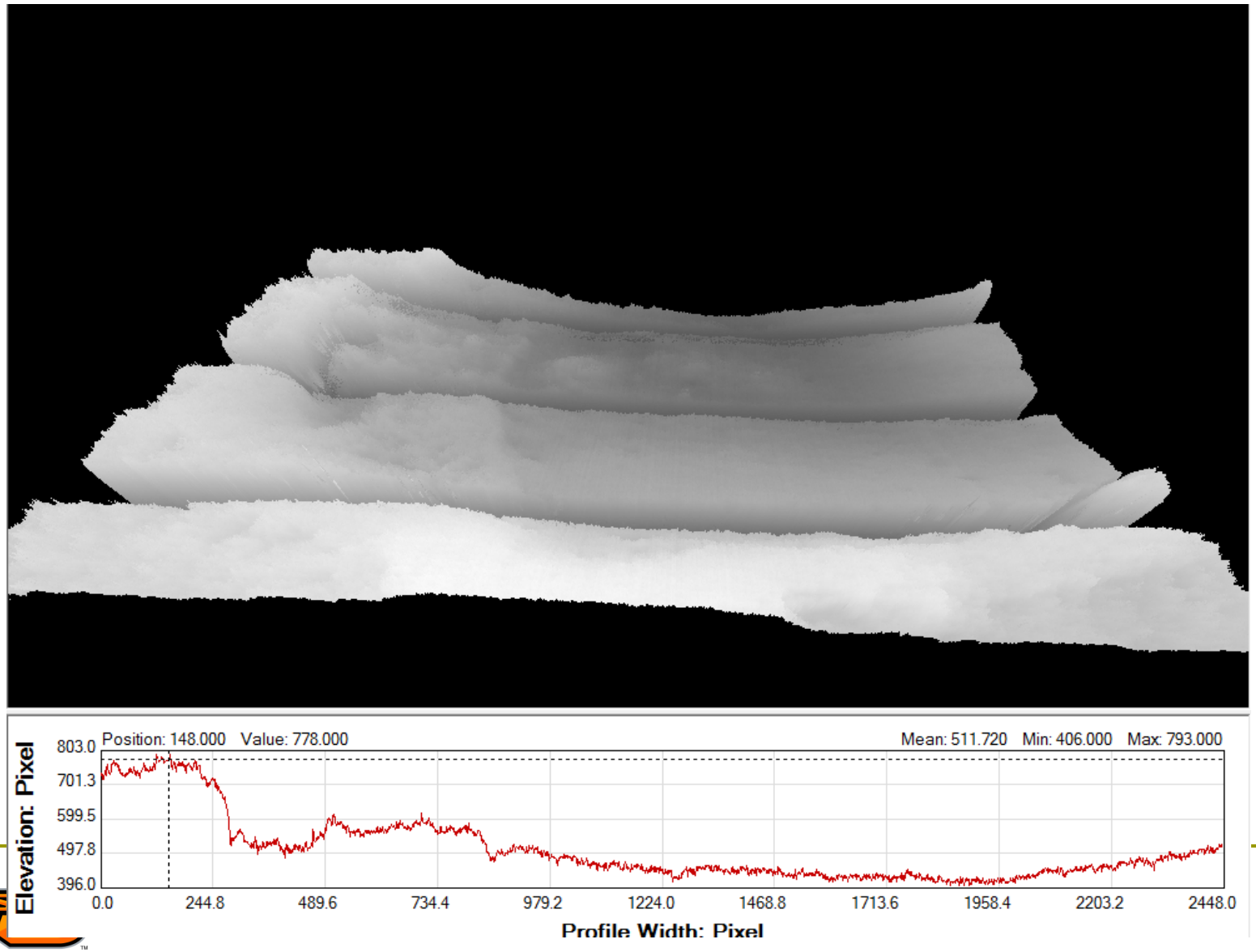
- Groove Tolerance

Groove type	Recommended configuration (Unit: in)		Tolerance (Unit: in)		Acceptable range			
			Lower limit	Upper limit	Unit: inch		Unit: mm	
Rectangular	Depth	1/4	-1/16	1/16	0.19	0.31	4.76	7.94
	Width	1/4	0	1/16	0.25	0.31	6.35	7.94
	Spacing	1 1/2	-1/8	0	1.38	1.5	34.9	38.1

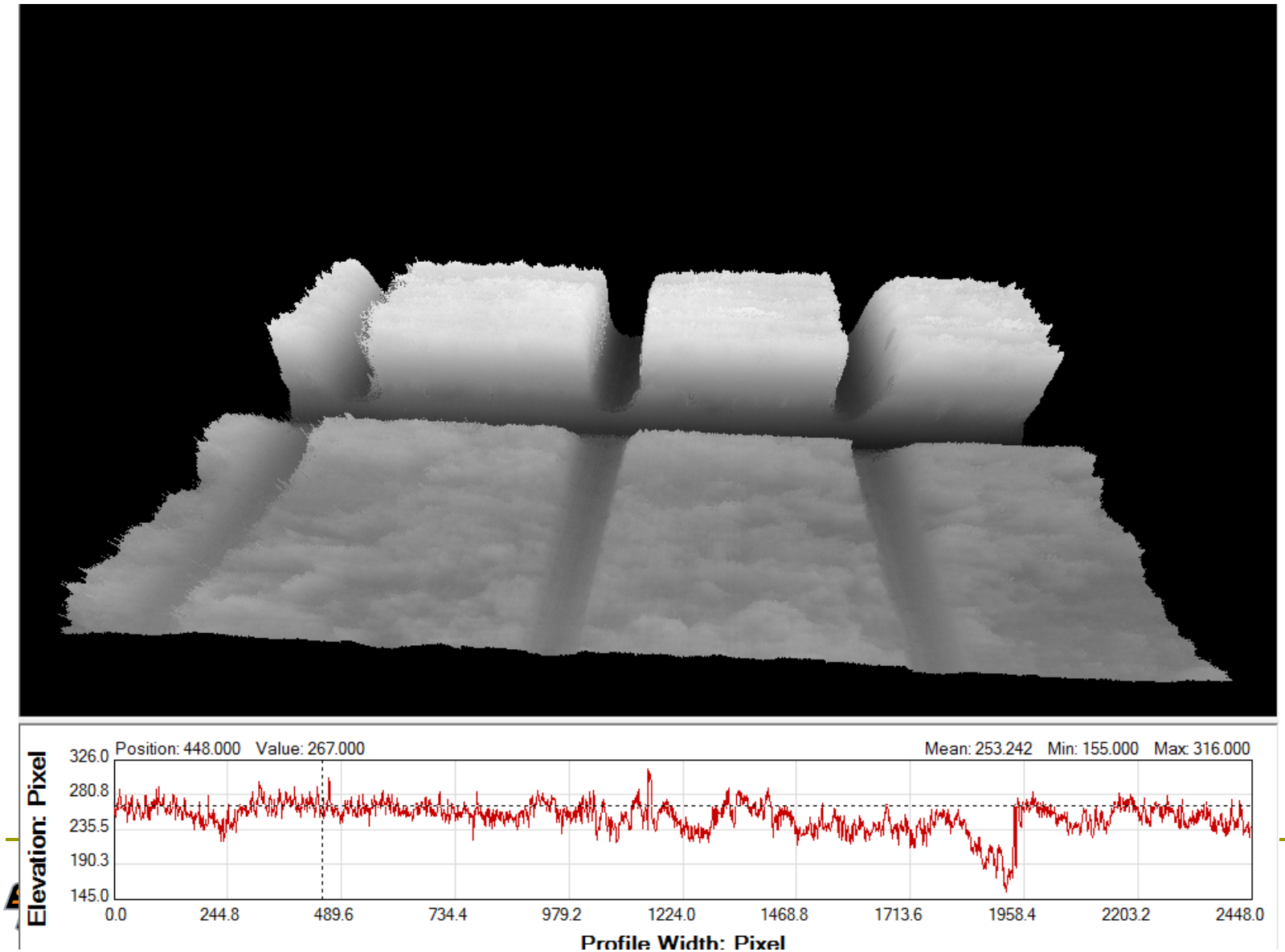
Grinded Surface



Grinded Surface

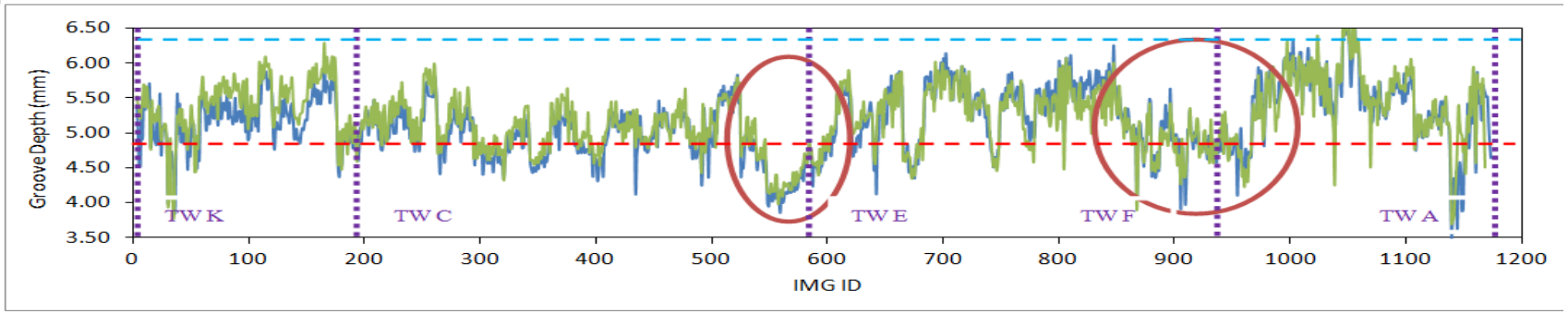


Uneven Surface

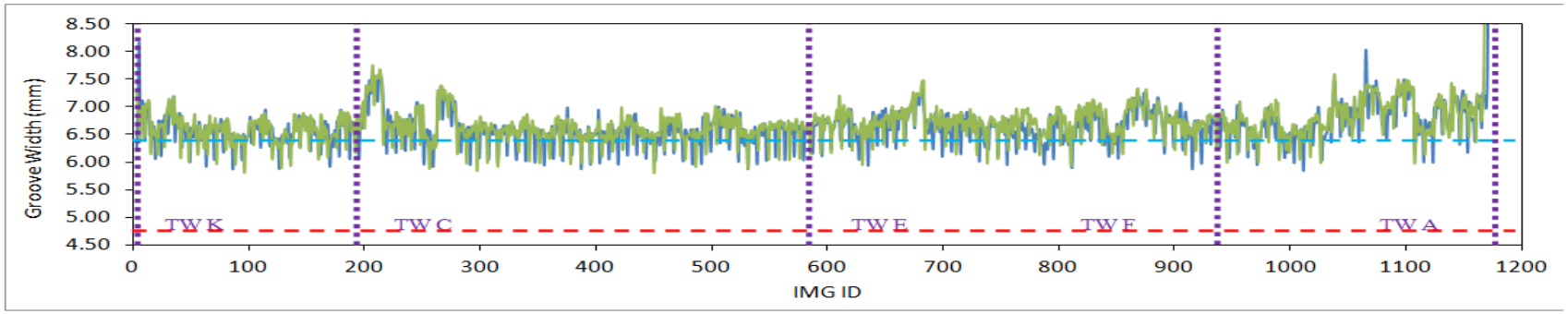


ProGroove3D Interface

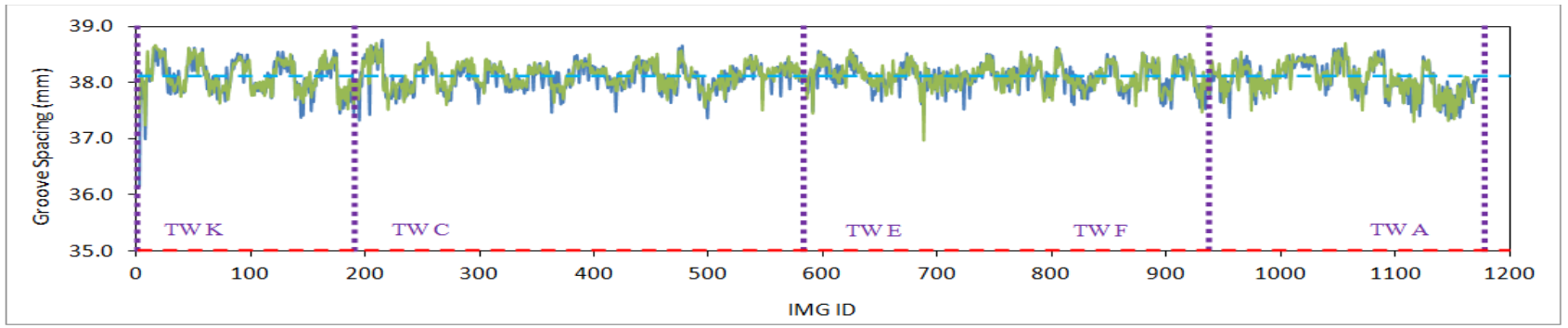
Groove Evaluation (Keel Runs 7&8)



(a) Groove Depth

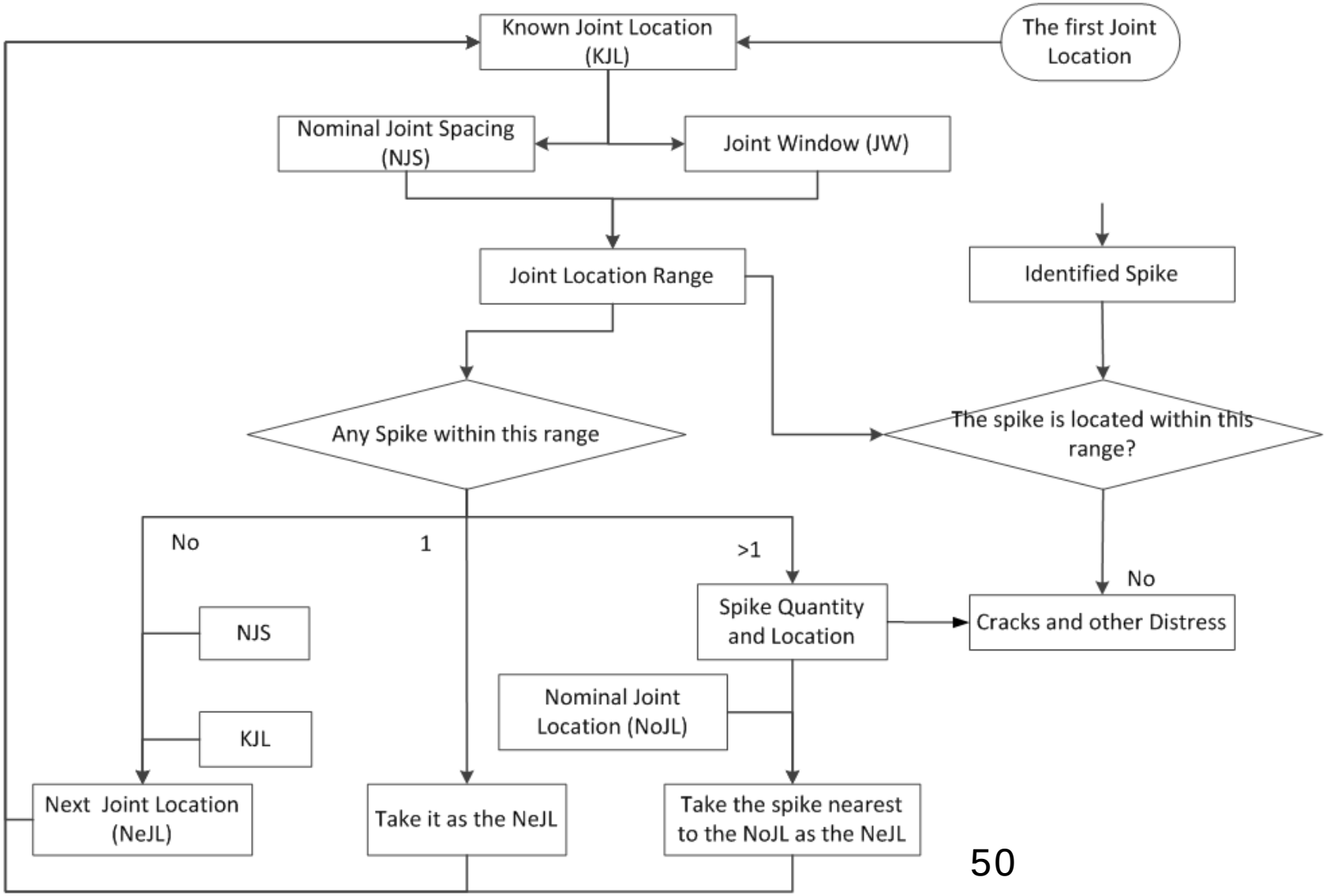


(b) Groove Width

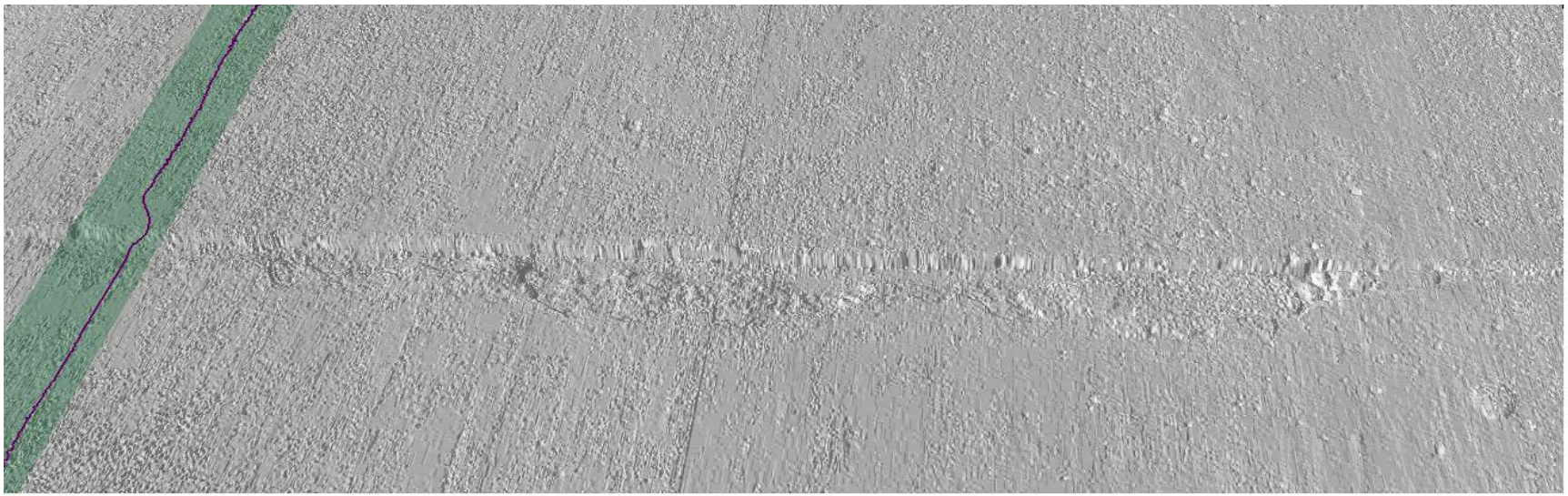


(c) Groove Spacing

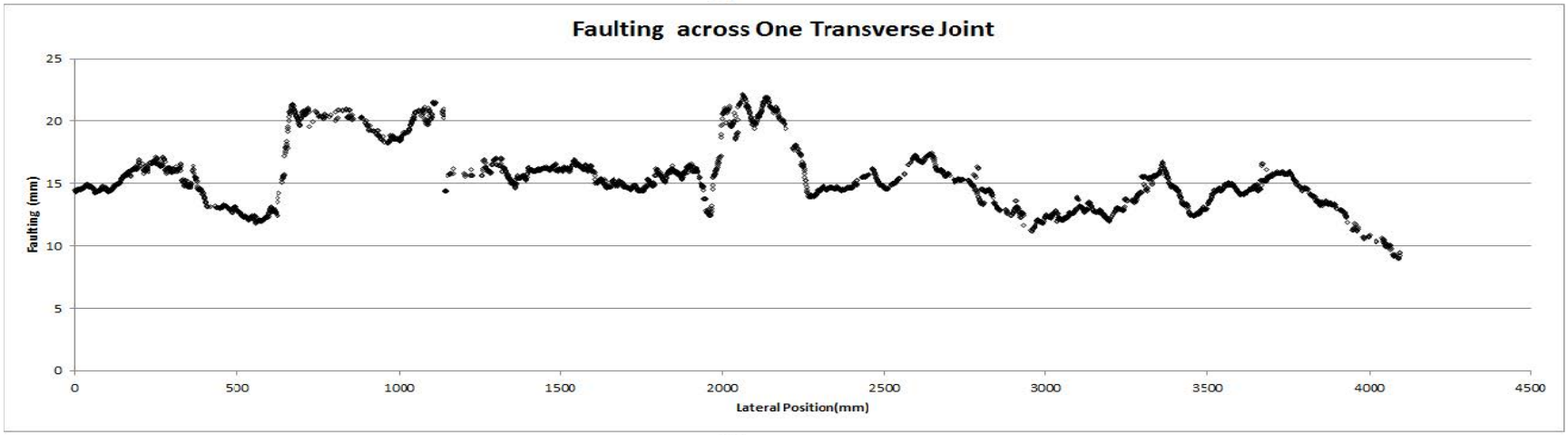
Automated Faulting Measurement



Example Faulting Results

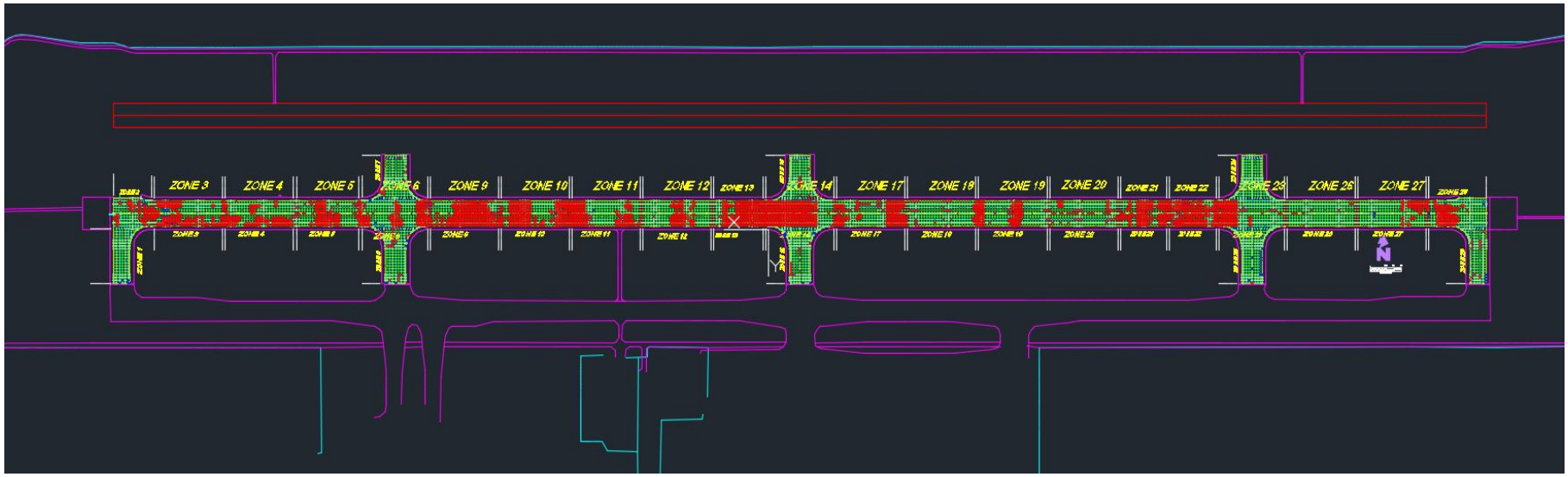


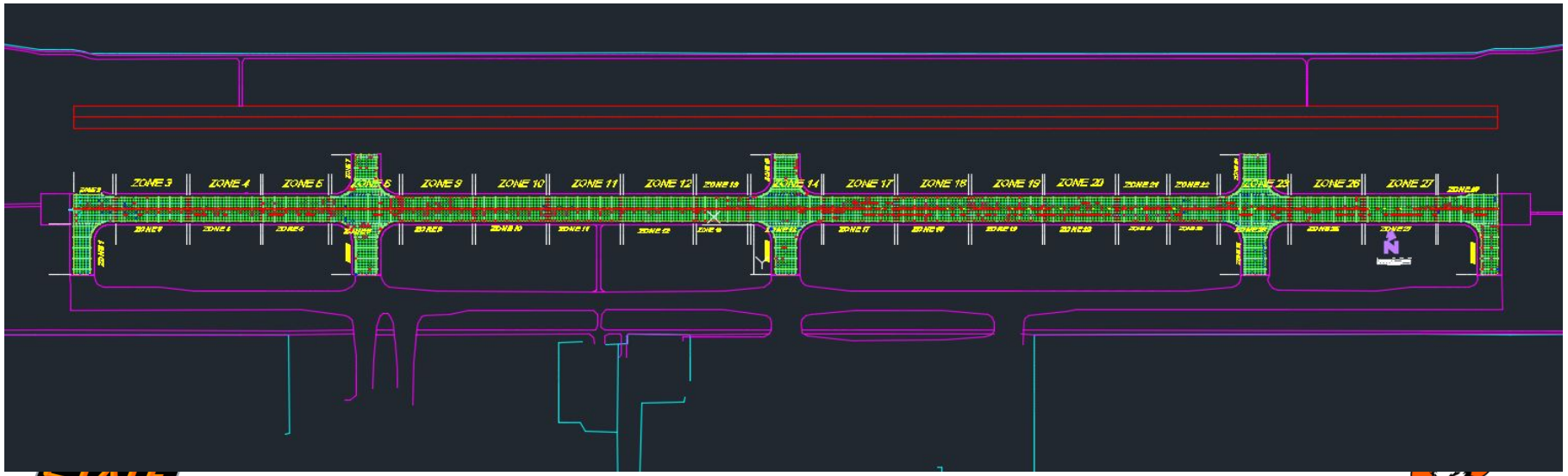
(a)



(b)

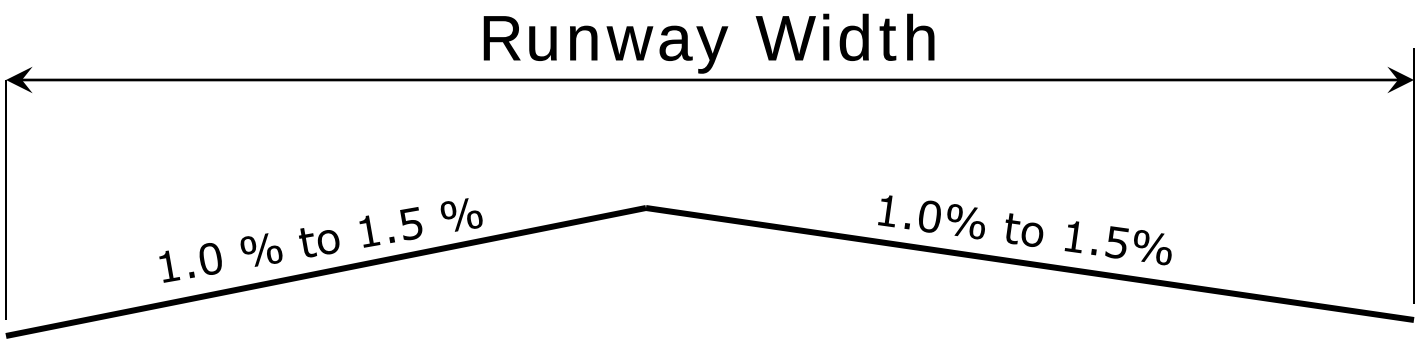
Groove/Joint Evaluation



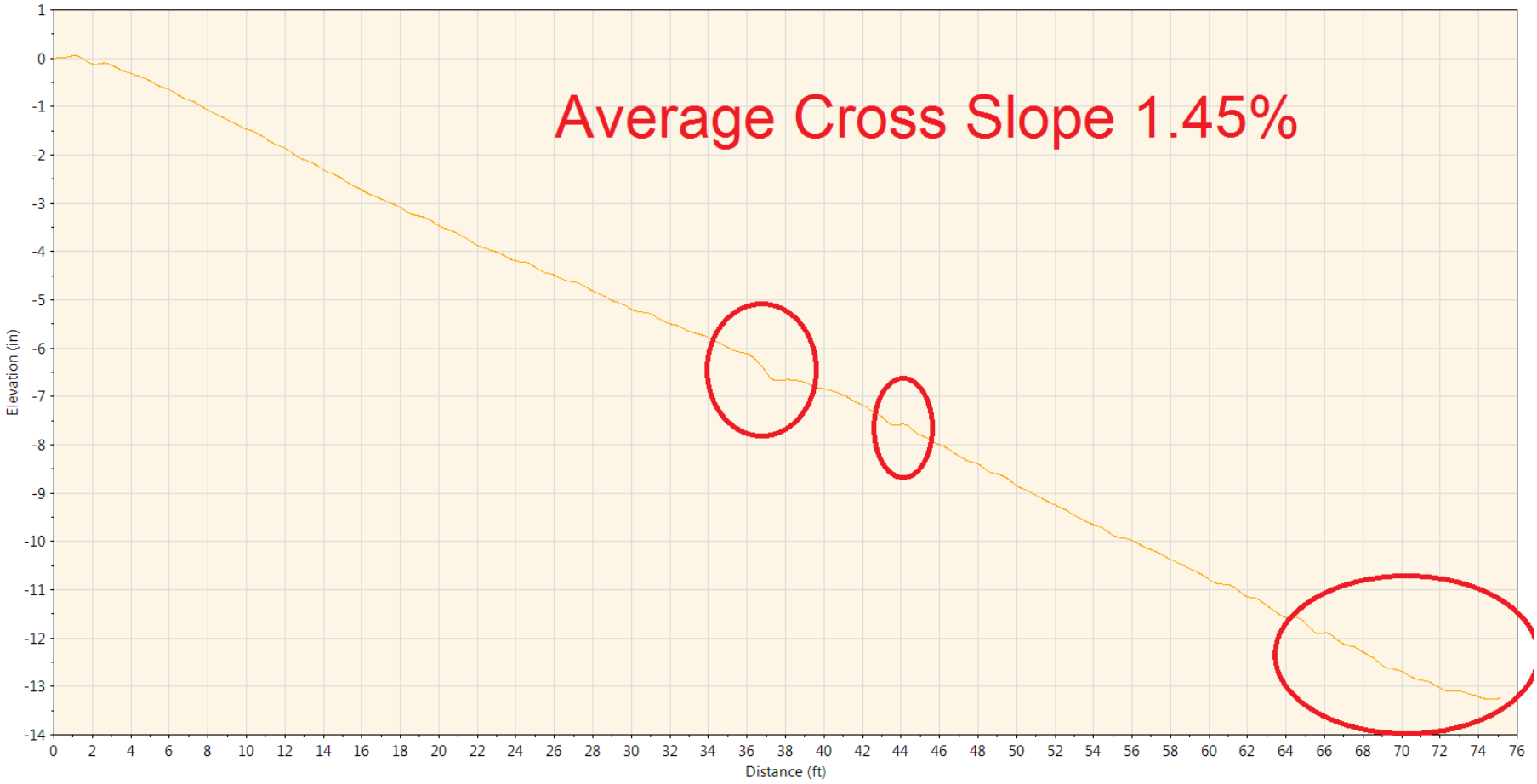


Transverse Profiling & Cross Slope

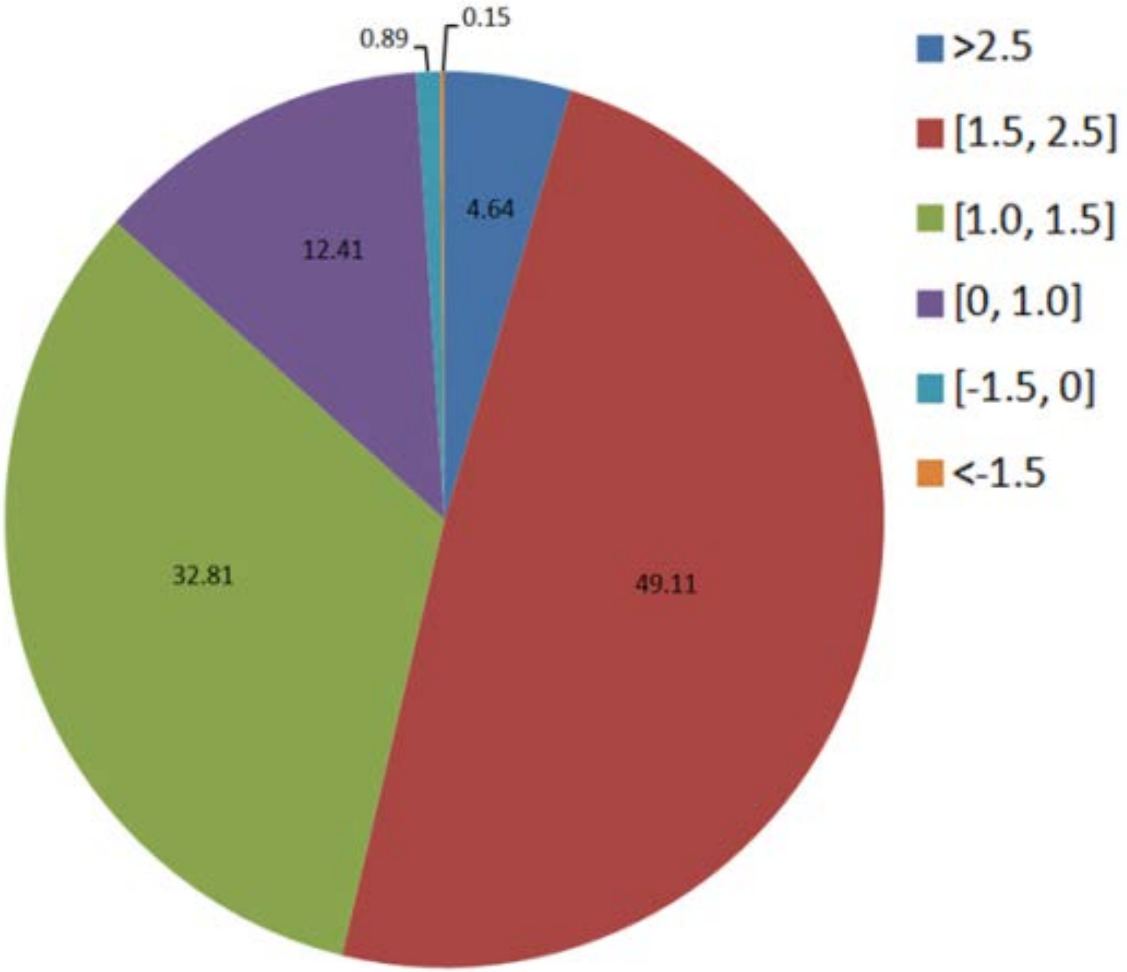
- Cross Slope Calculation
  - AASHTO method
  - TxDOT method
  - Linear regression method
- Transverse Grade – Category C & D Airports (FAA Guidance)



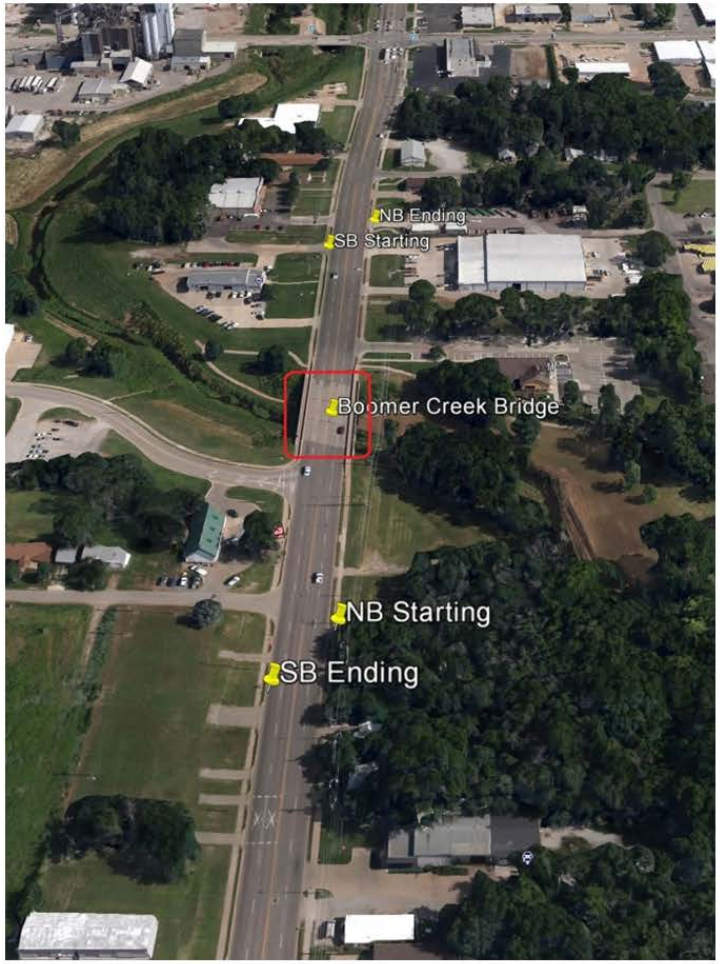
Example Cross Slope (West-Half)



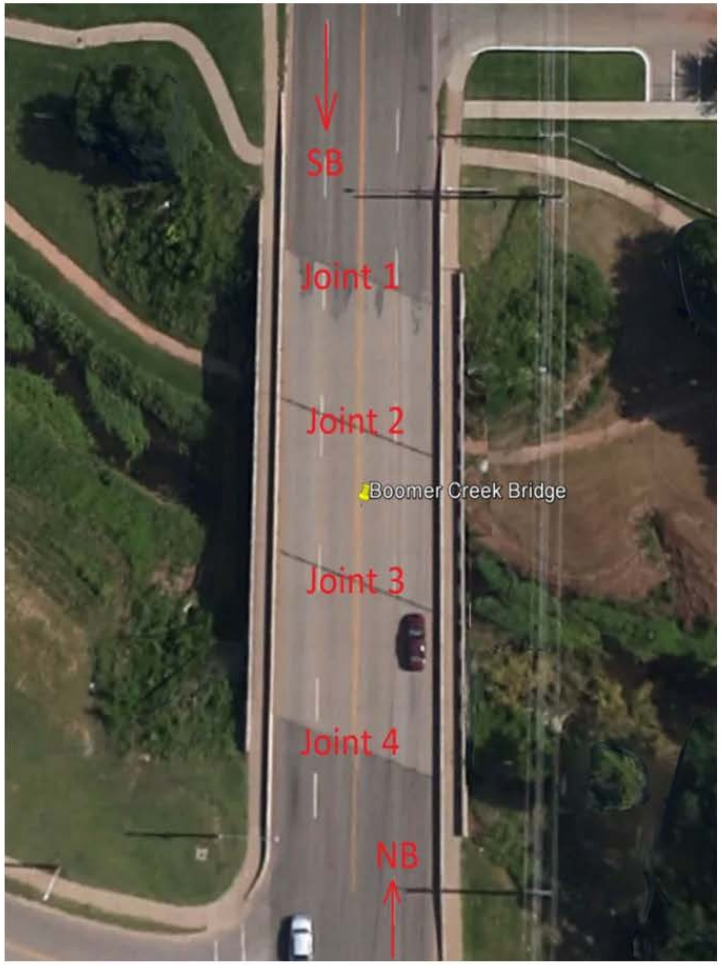
Cross Slope Evaluation



Bridge Deck Evaluation



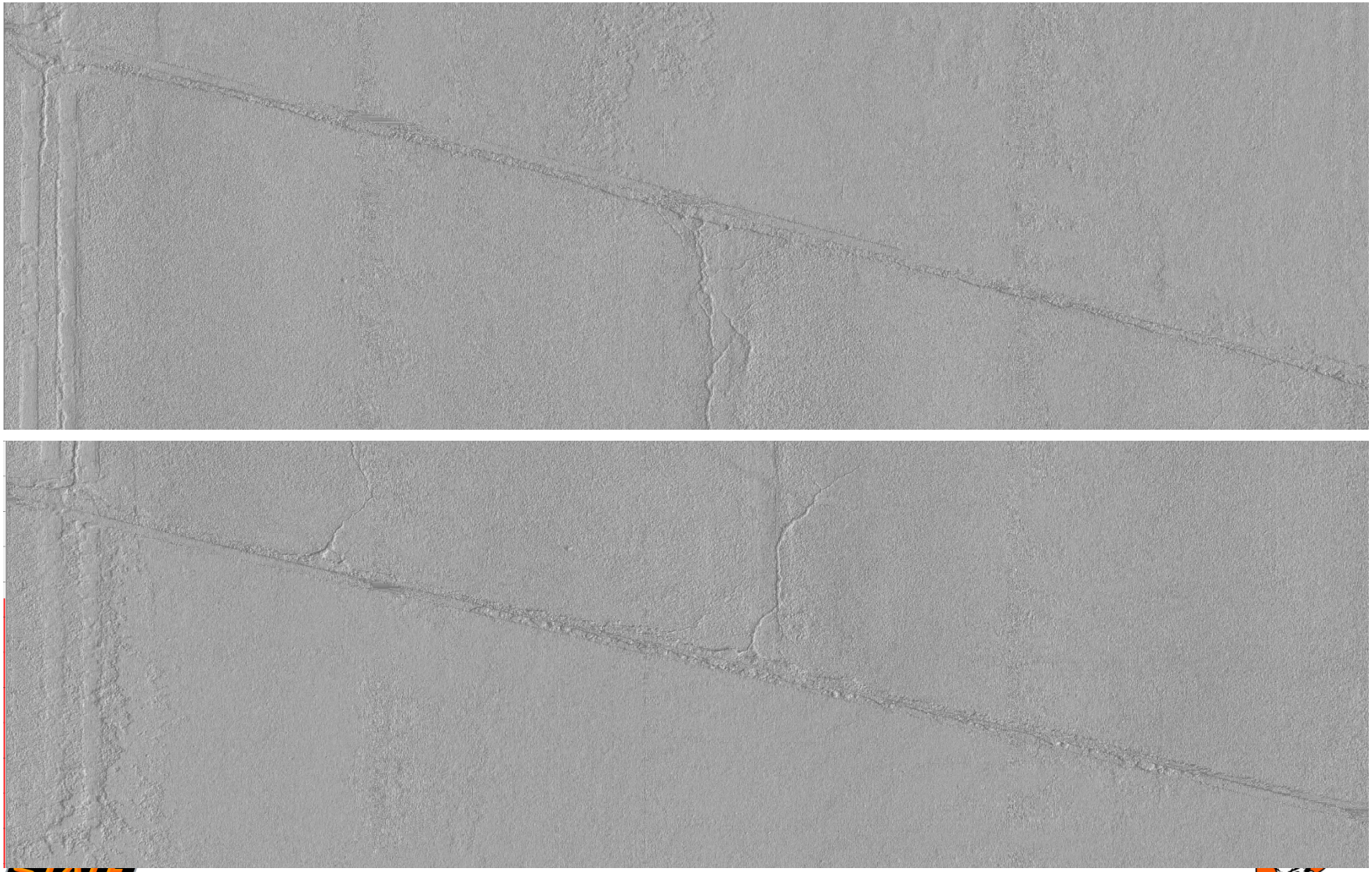
(a) Bridge Location



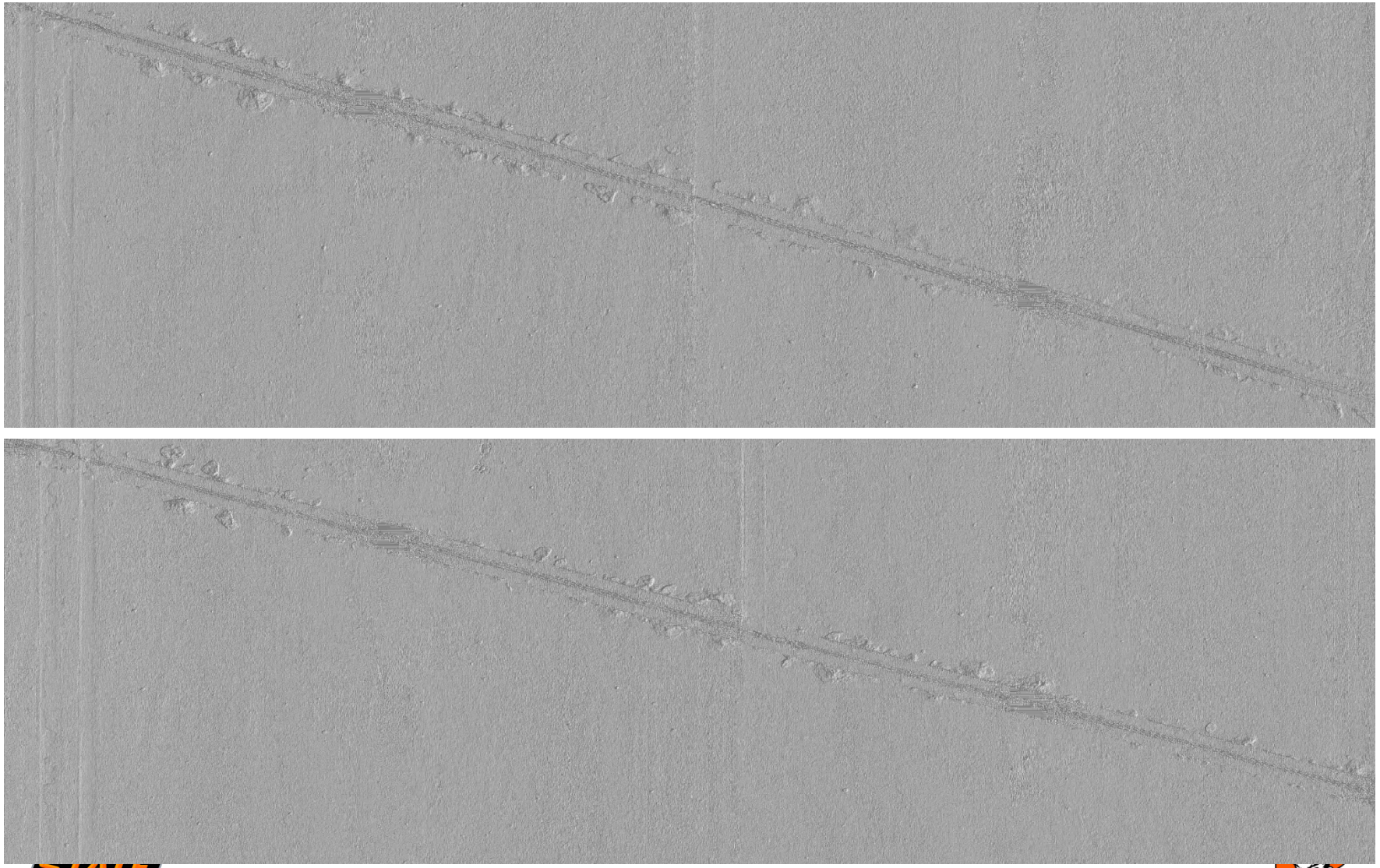
(b) Bridge Deck

Bridge Deck (Joint #1 & #2)

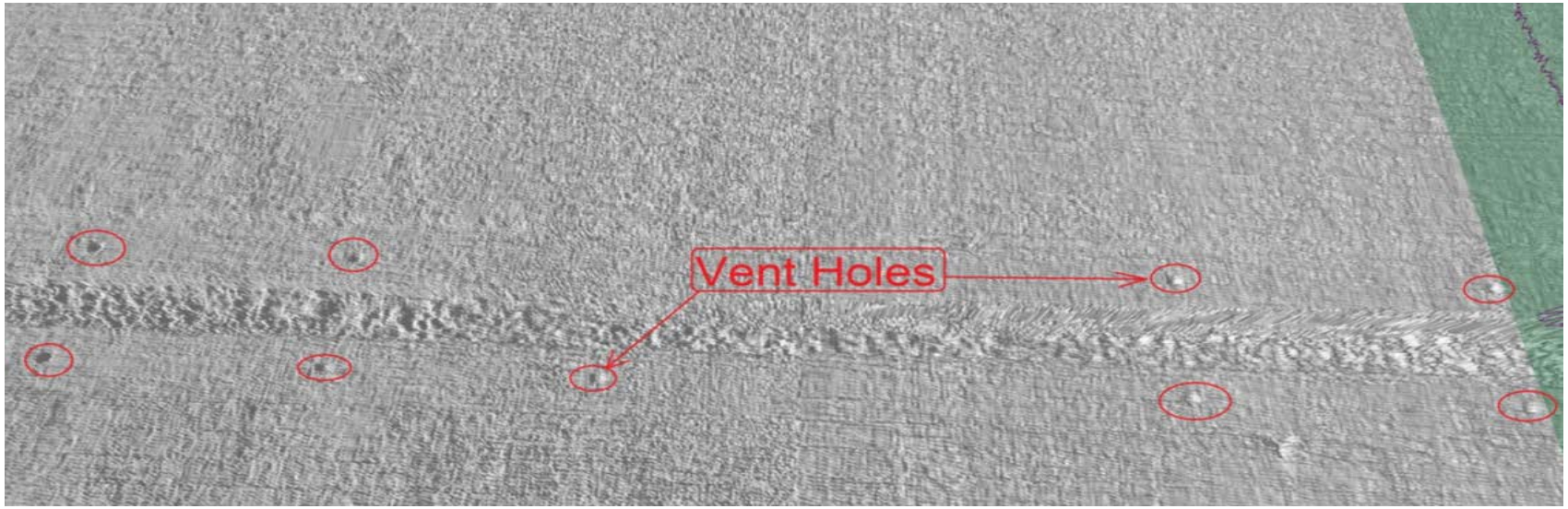
Virtual Bridge Deck (Joint #1)

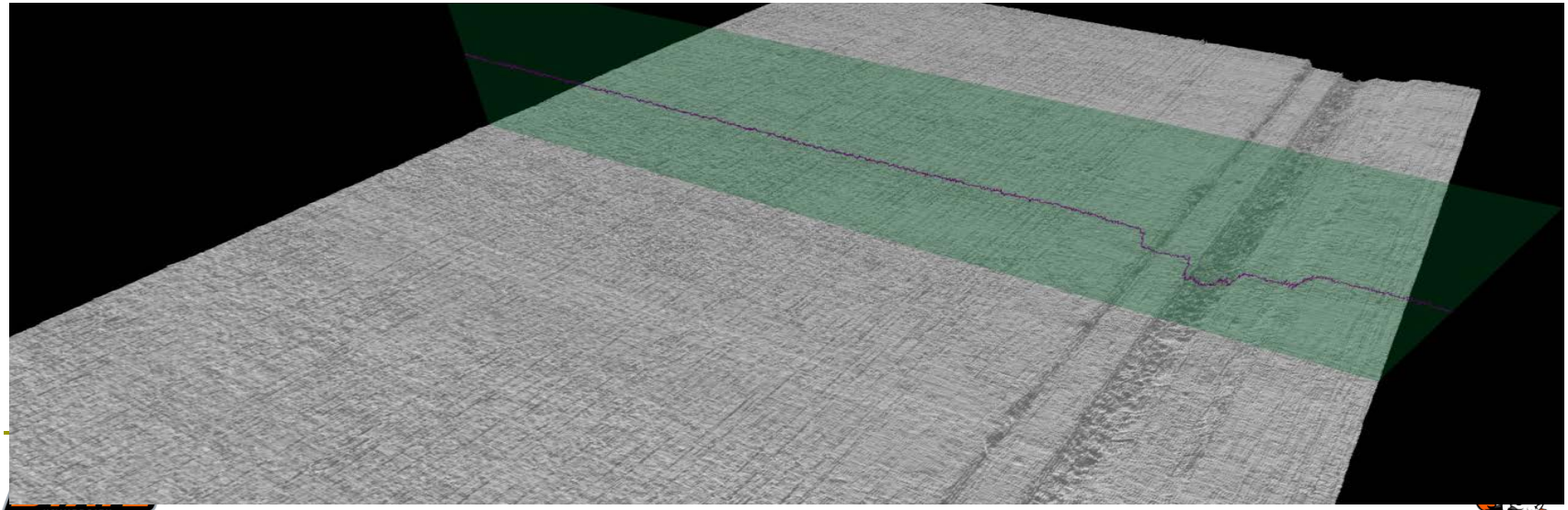


Virtual Bridge Deck (Joint #2)



Virtual Bridge Deck





Conclusions

- PaveVision3D Ultra system
  - 1mm surface data at 60mph
  - Stitch images from multiple passes to establish virtual surface
- Various applications
  - Multi-lane highway
  - Airport runway
  - Bridge deck