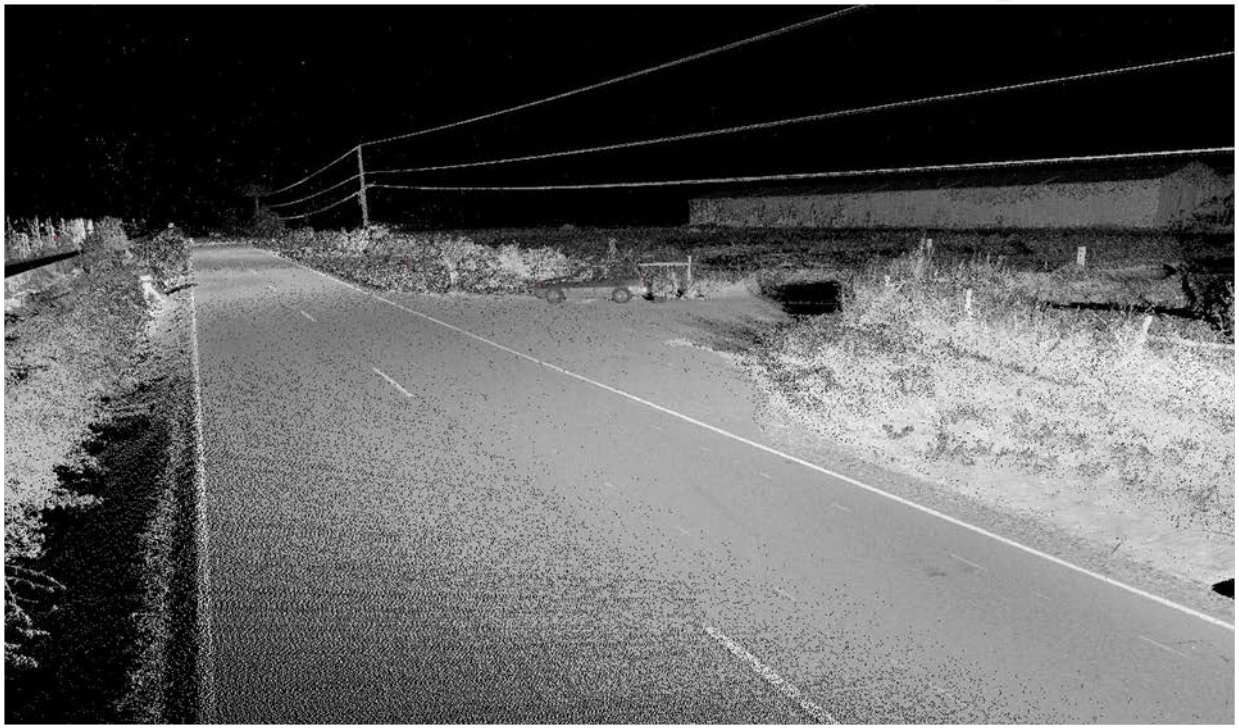
Paving the Way for Terrestrial Laser Scanning Assessment of Road Quality



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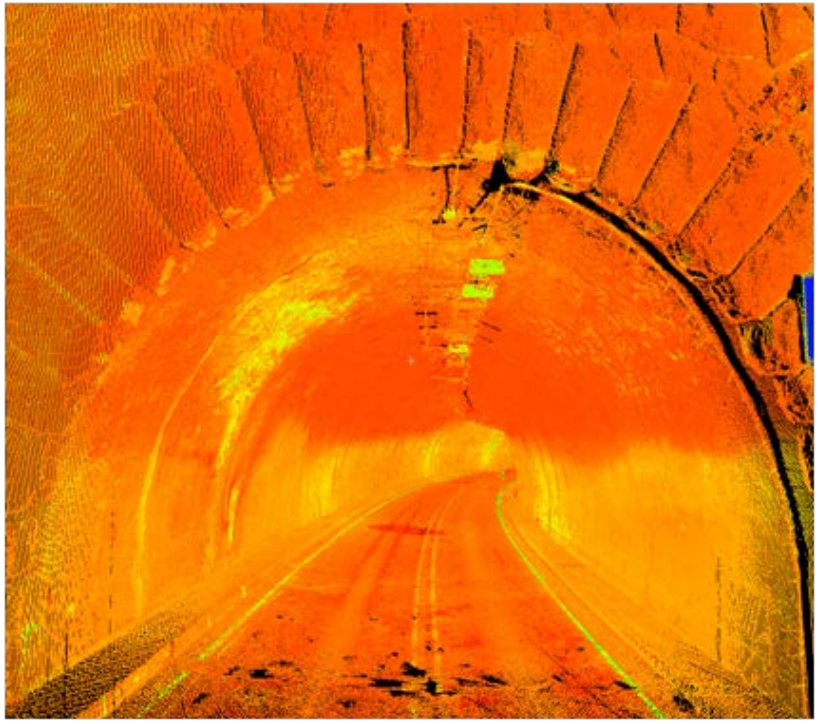
RPUG: September, 26, 2012

School of Civil and Construction Engineering

Presentation Outline

- Project background and objectives
- Terrestrial Laser Scanning (TLS)
- Testing Results
- Conclusions
- Lessons learned and future work



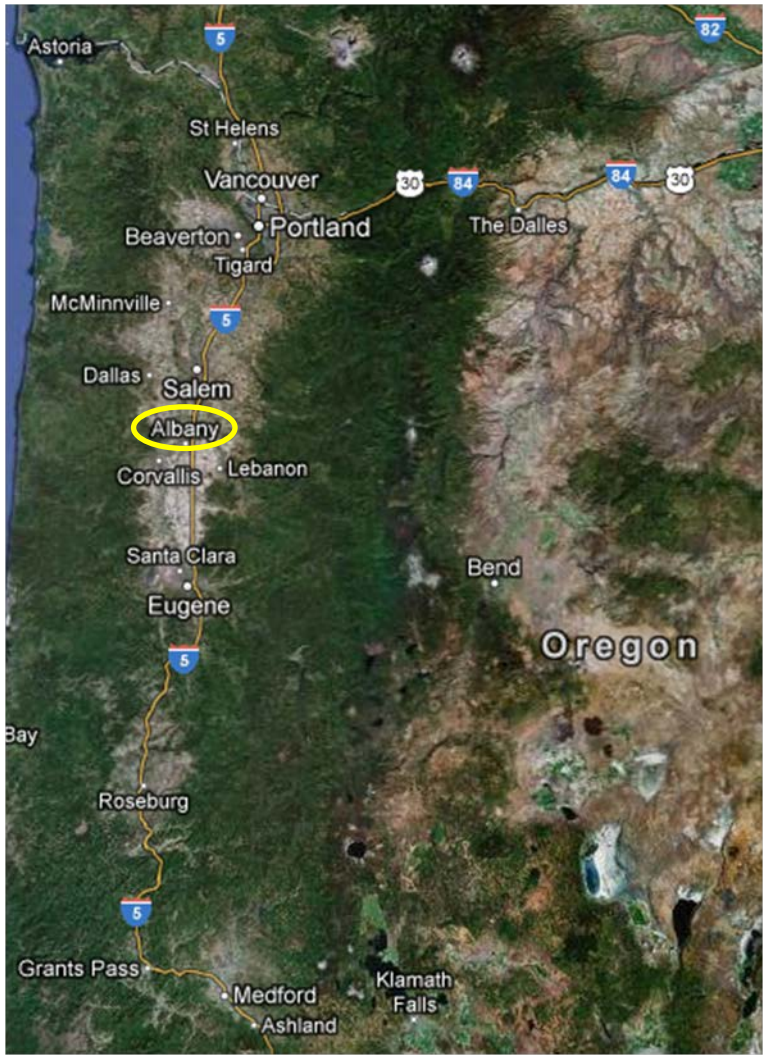
Project Background

- ODOT is implementing IRI-based incentive/disincentive program
- Can AASHTO standards be achieved by Oregon DOT when comparing an inclinometer and inertial profiler?
- Previous difficulties with certification
  - Great repeatability results
  - Not meeting AASHTO accuracy requirements

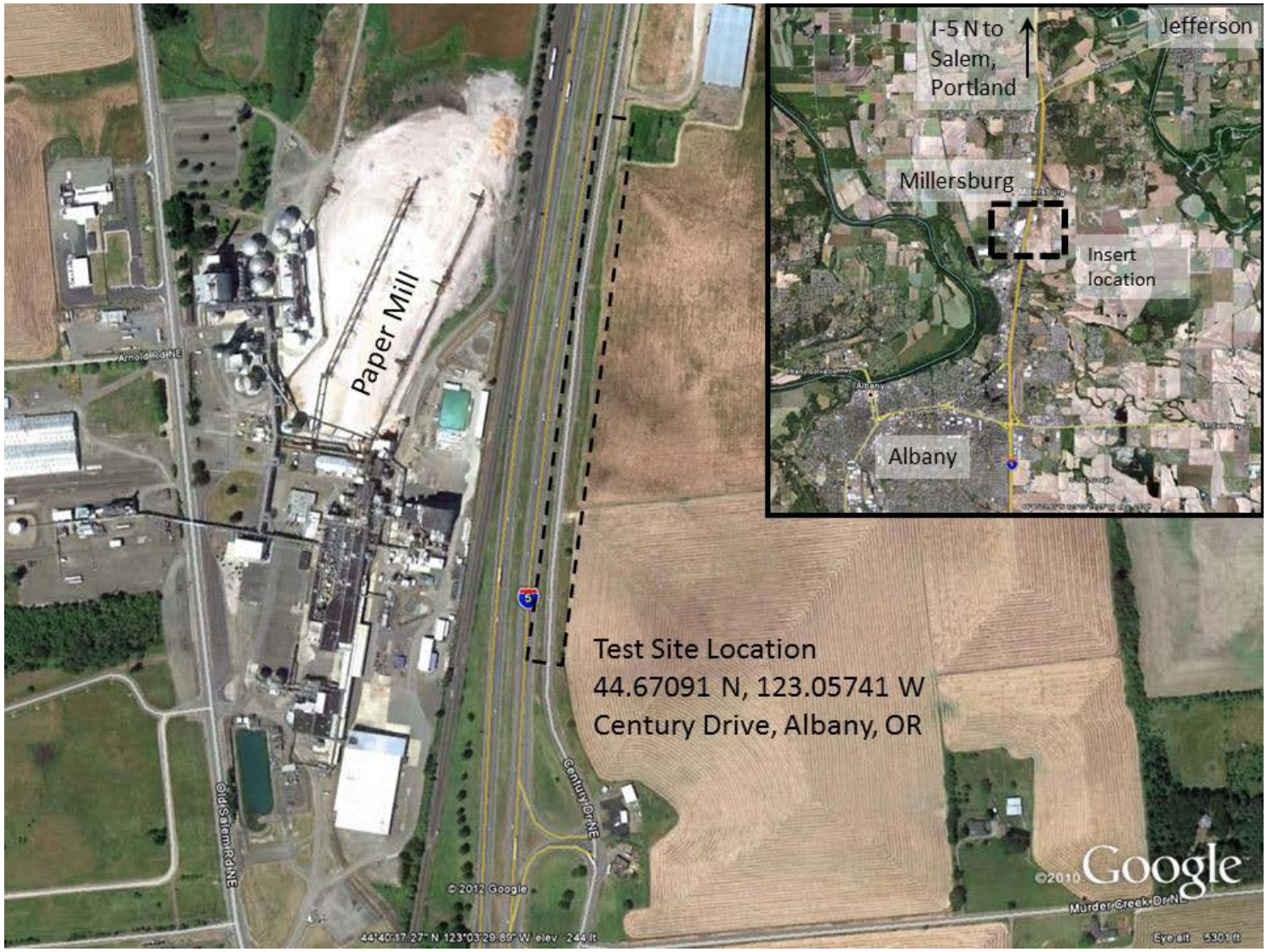
Objectives

- Verify that the test site is appropriate for certification
- Determine repeatability and accuracy of reference profiler (inclinometer)
- Recommend improvements to certification procedure
- Evaluate applicability of terrestrial laser scanning

Test Site – Albany, OR



Test Site


I-5 N to Salem, Portland
Jefferson
Millersburg
Insert location
Albany
Paper Mill
Arnold Rd NE
Old Salem Rd NE
Century Dr NE
Murder Creek Dr NE
Test Site Location
44.67091 N, 123.05741 W
Century Drive, Albany, OR
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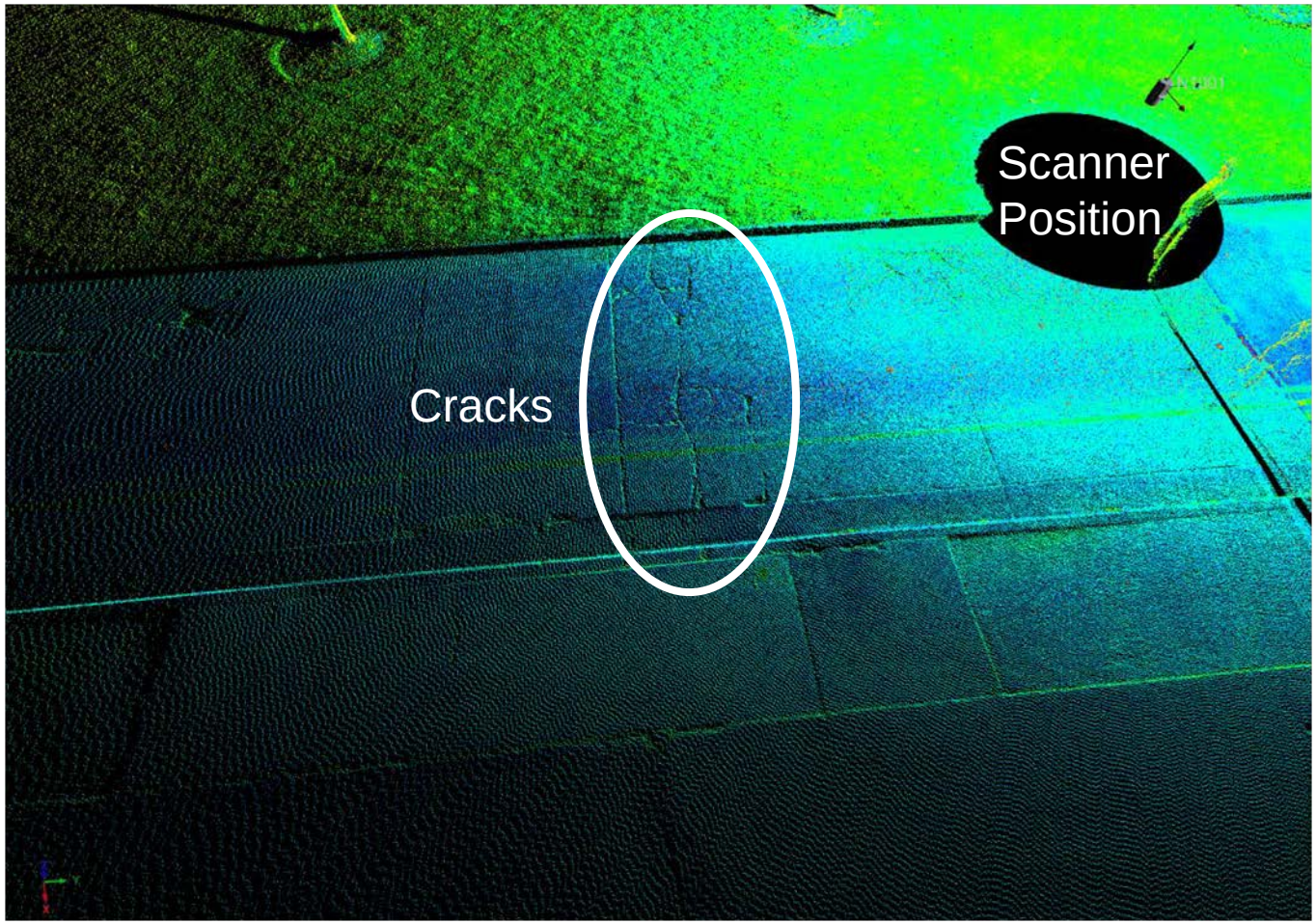
Terrestrial Laser Scanning (TLS)

- LiDAR – Light Detection and Ranging
- Time of flight system
- 0.2 in accuracy at 164 ft range
- Produces 3D point cloud
- Geo-referenced data

Point Cloud Example

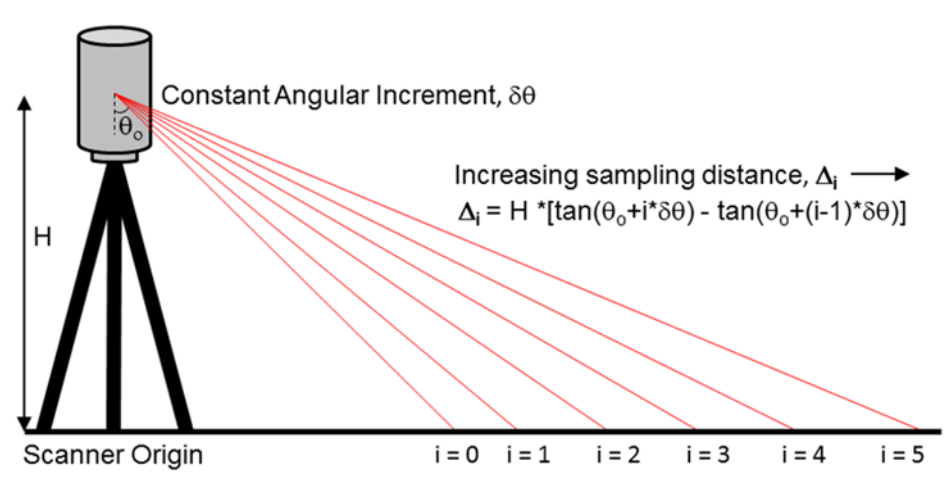


Advantages of TLS

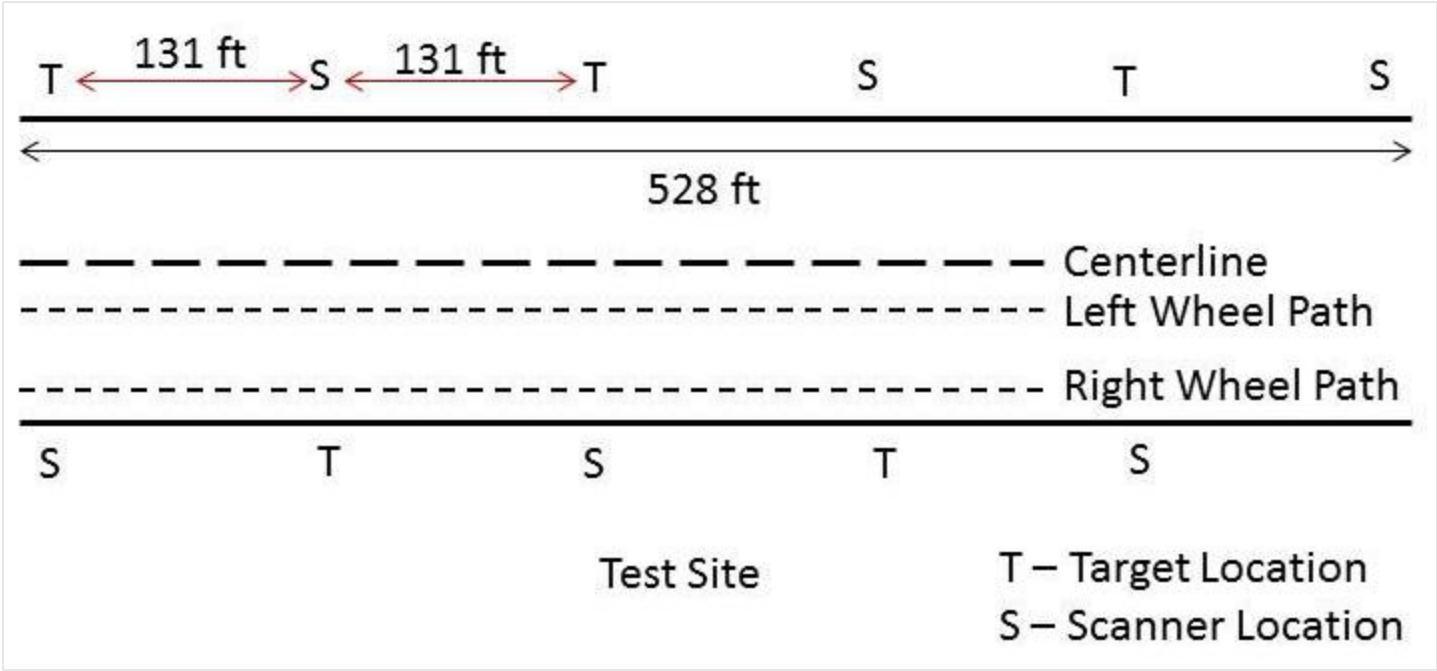
- Data is collected across the entire roadway
  - Provides a full, as-built record
  - Enables analysis of:
    - Cross slopes
    - Localized depressions
    - Variations in roughness across the entire road
- Data is collected from the side of the road
  - Improves safety
  - Road can remain open

Disadvantages of TLS

- Objects can block line of sight of the scanner
- Increased field time
- Data processing requires training and time
- Individual measurements accurate to ± 0.2 in
- Dark pavement does not reflect light well

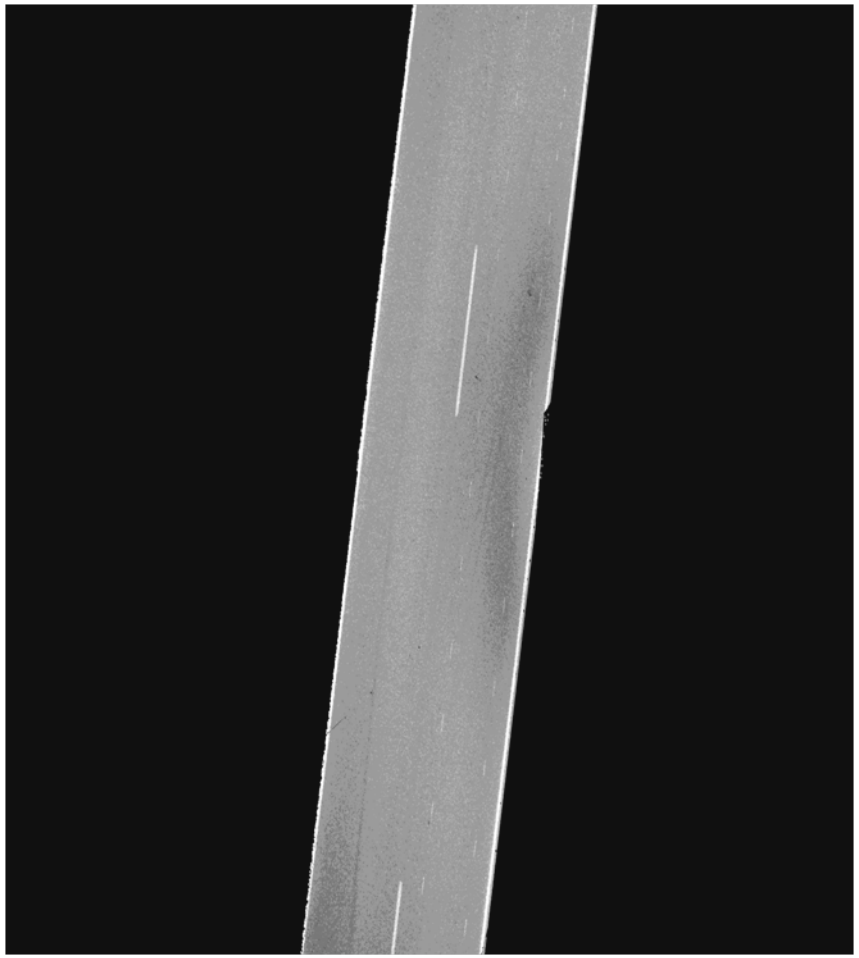


Test Set Up for TLS



TLS Workflow

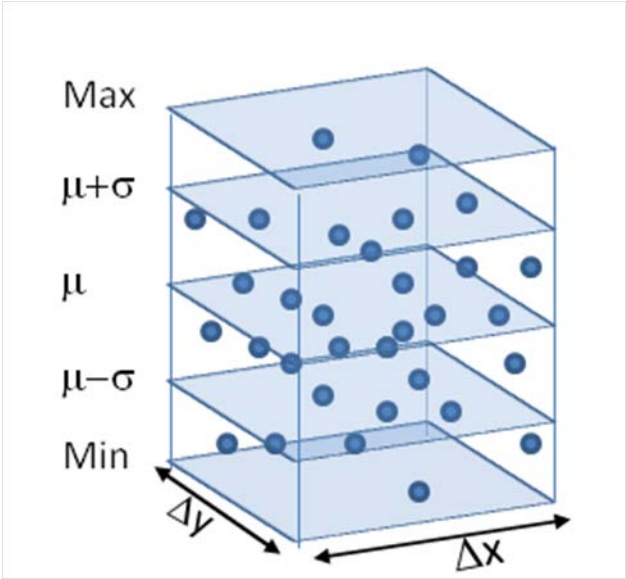
- Obtain 3D point cloud
  - Prune data to roadway
- Statistically filter data to specified spacing intervals
- Extract profile using tools in ArcGIS
- Input data into ProVAL

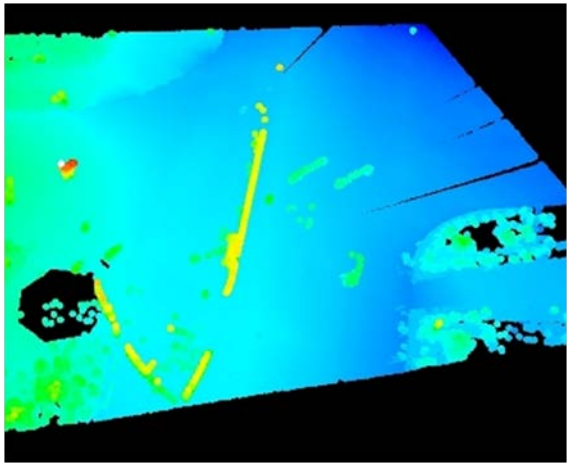


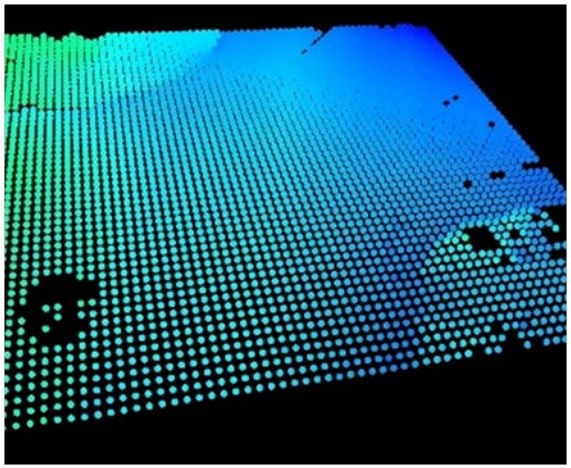
Statistical Filtering Process "Bin and Grid"

Sampling Intervals:

1-12, 16, 20, 24 in



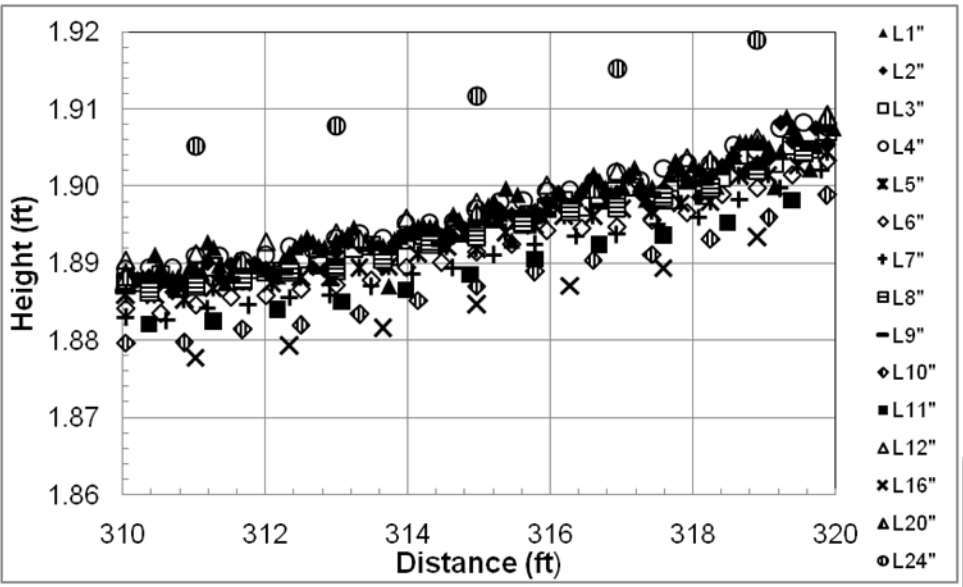




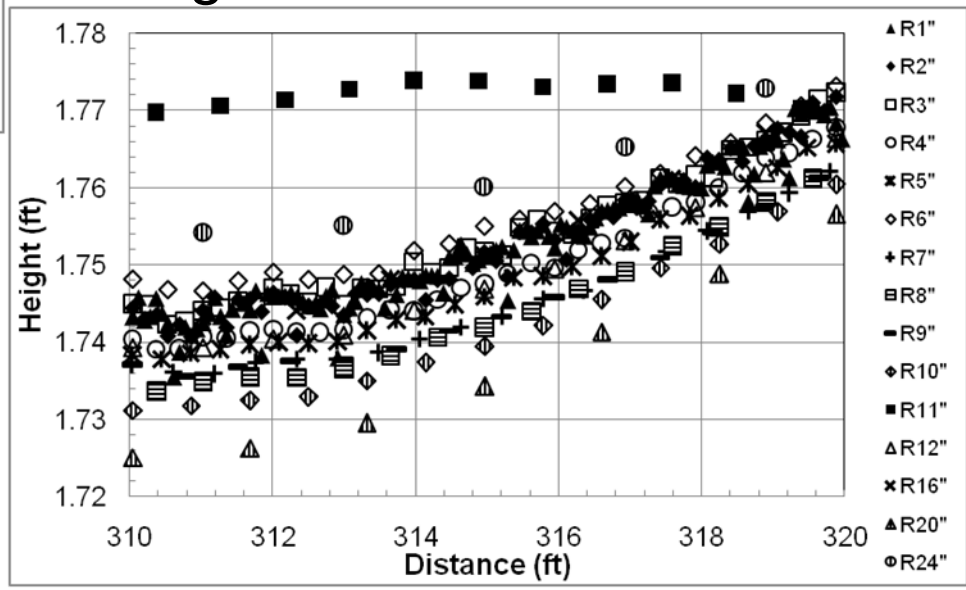
http://www.lidarnews.com/content/view/8378/136/

TLS Profile Comparison

Left Wheel Path

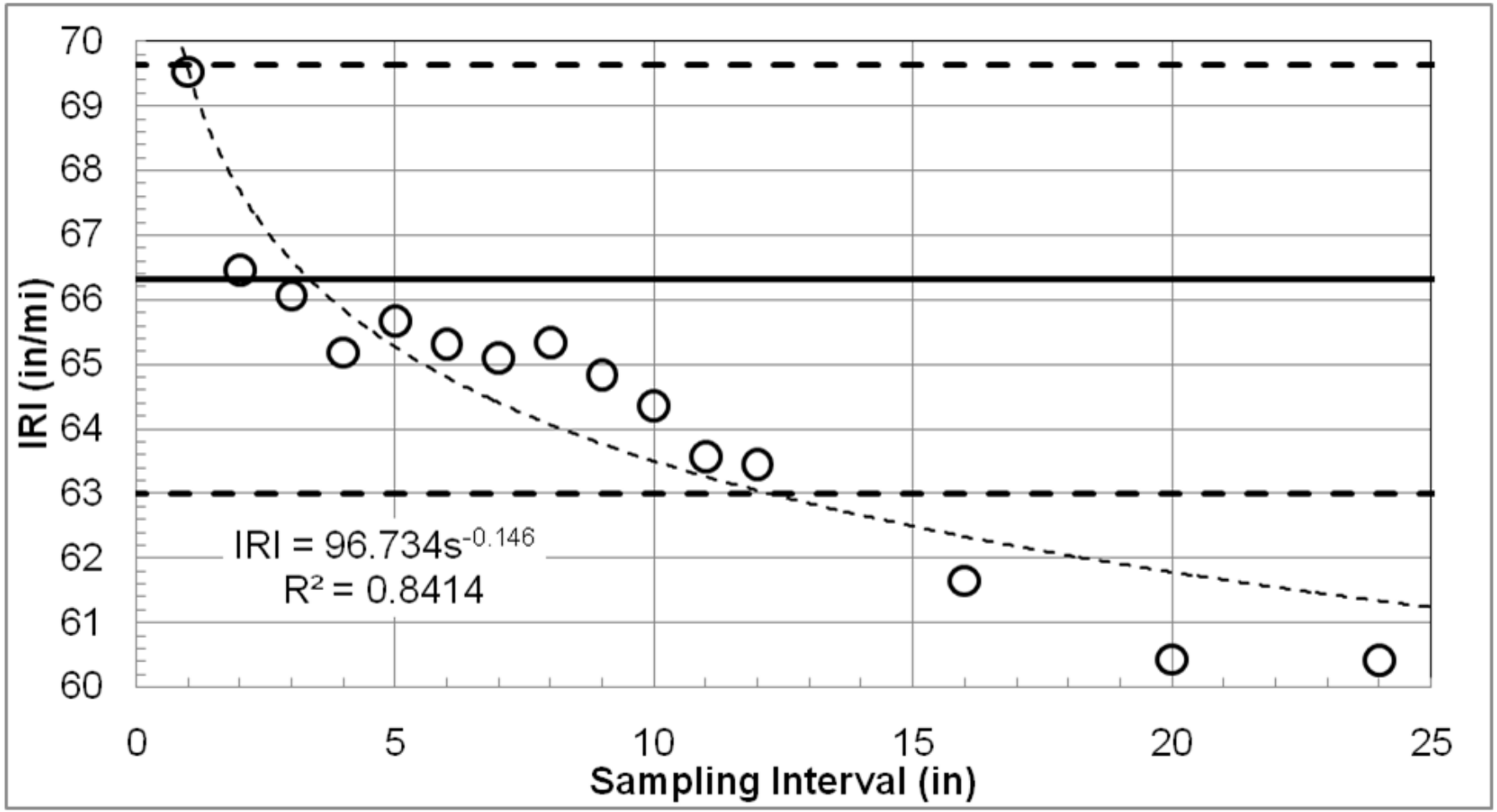


Right Wheel Path

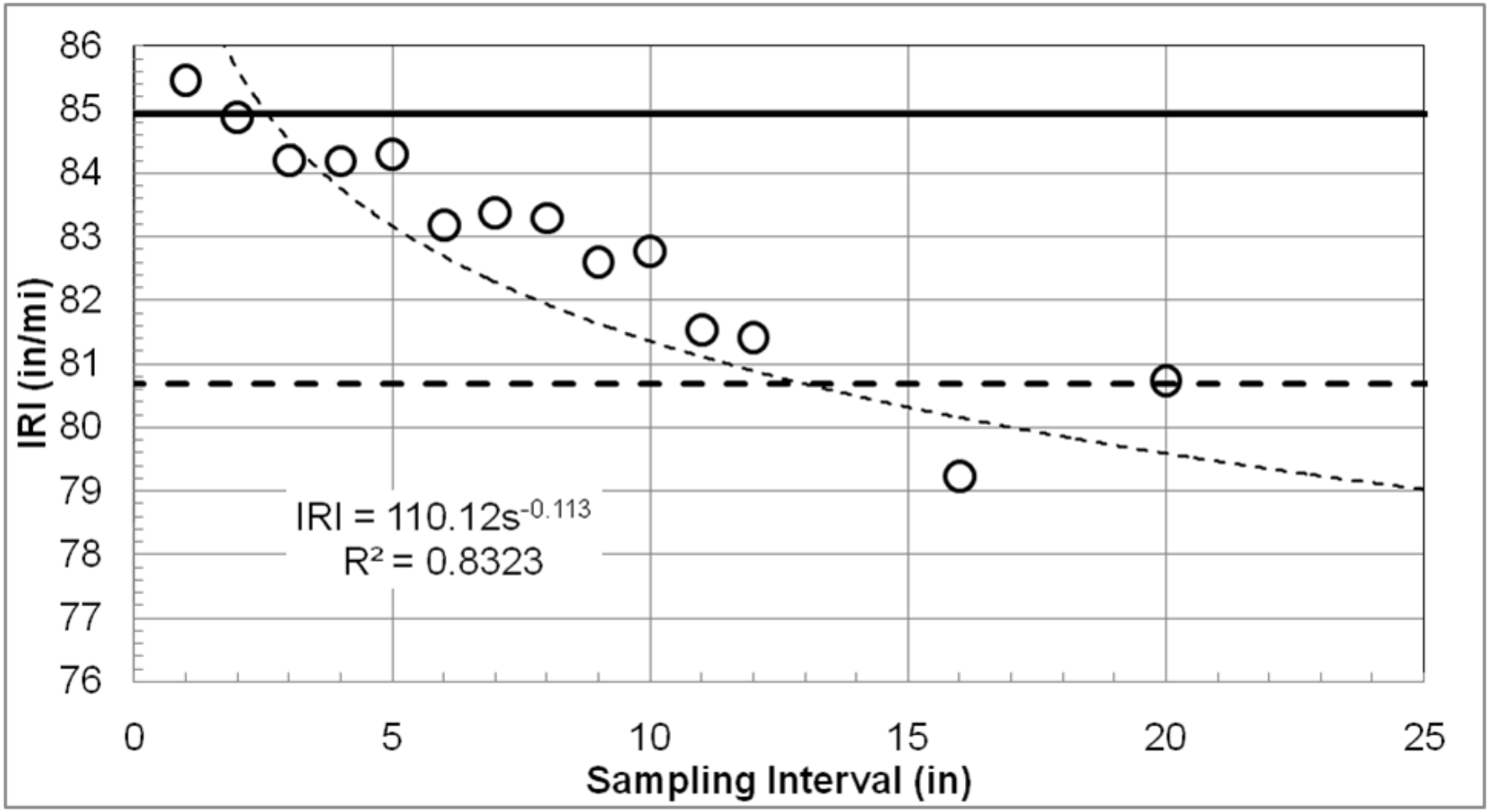


Compares profiles obtained from different sampling intervals

Left IRI Comparison from TLS

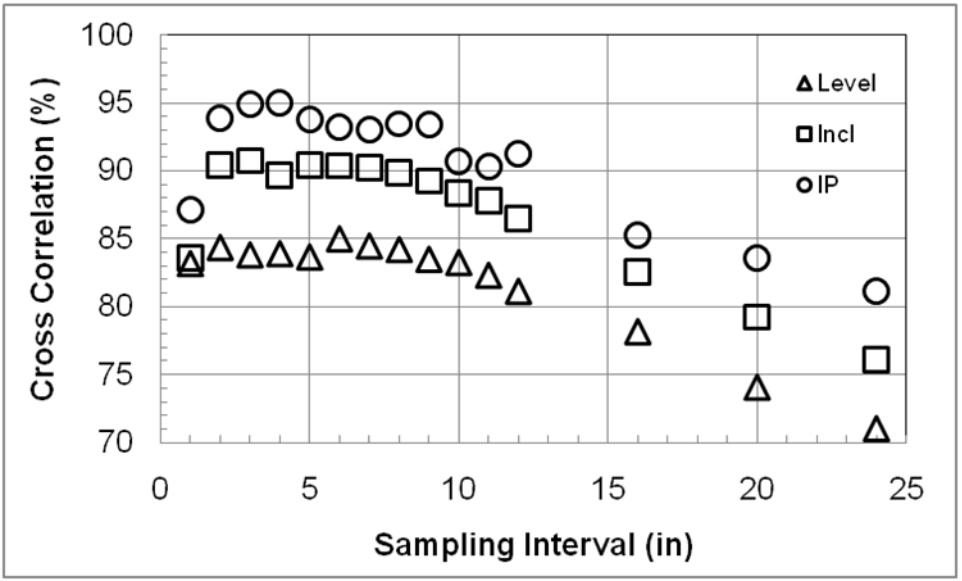


Right IRI Comparison from TLS

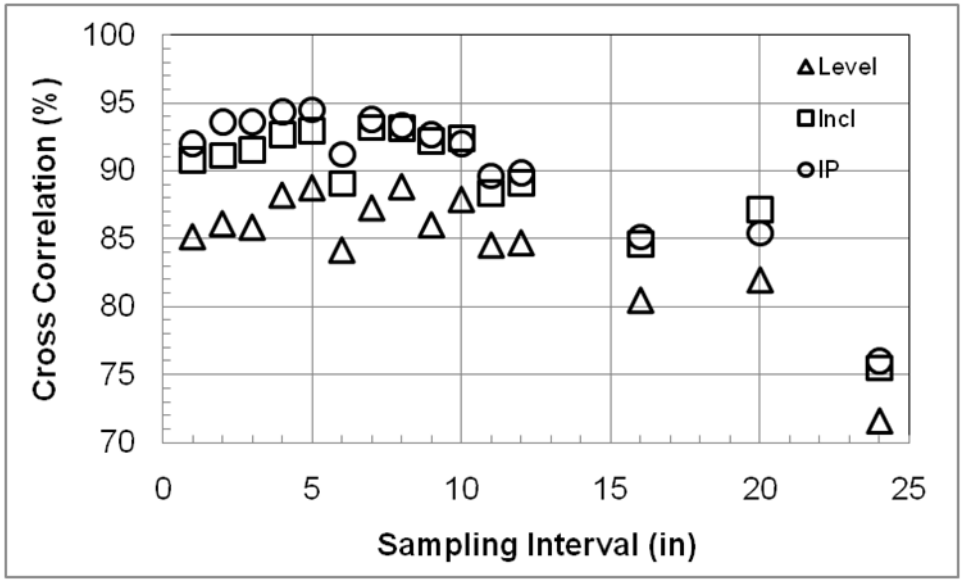


Cross Correlations from TLS

Left Wheel Path

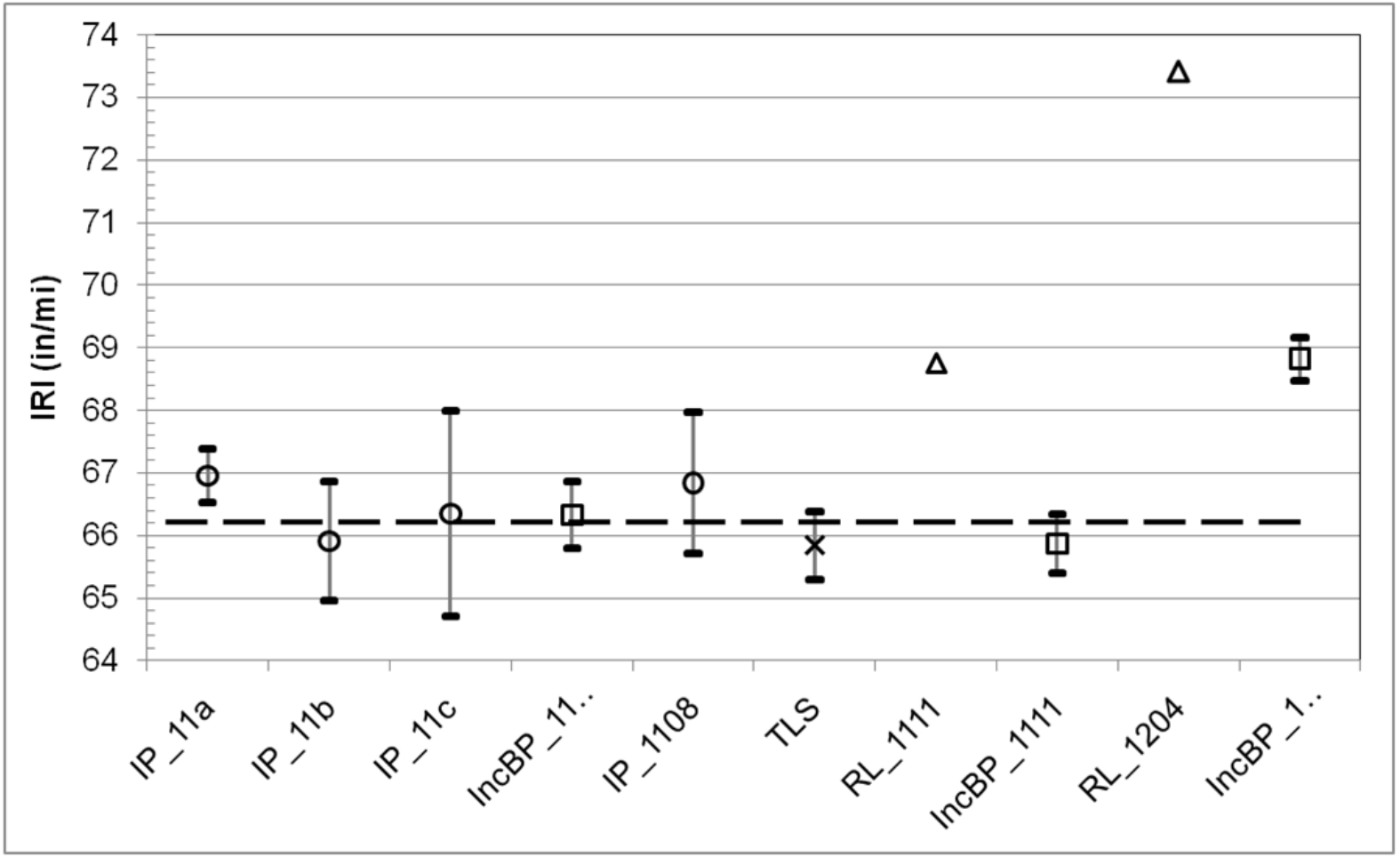


Right Wheel Path

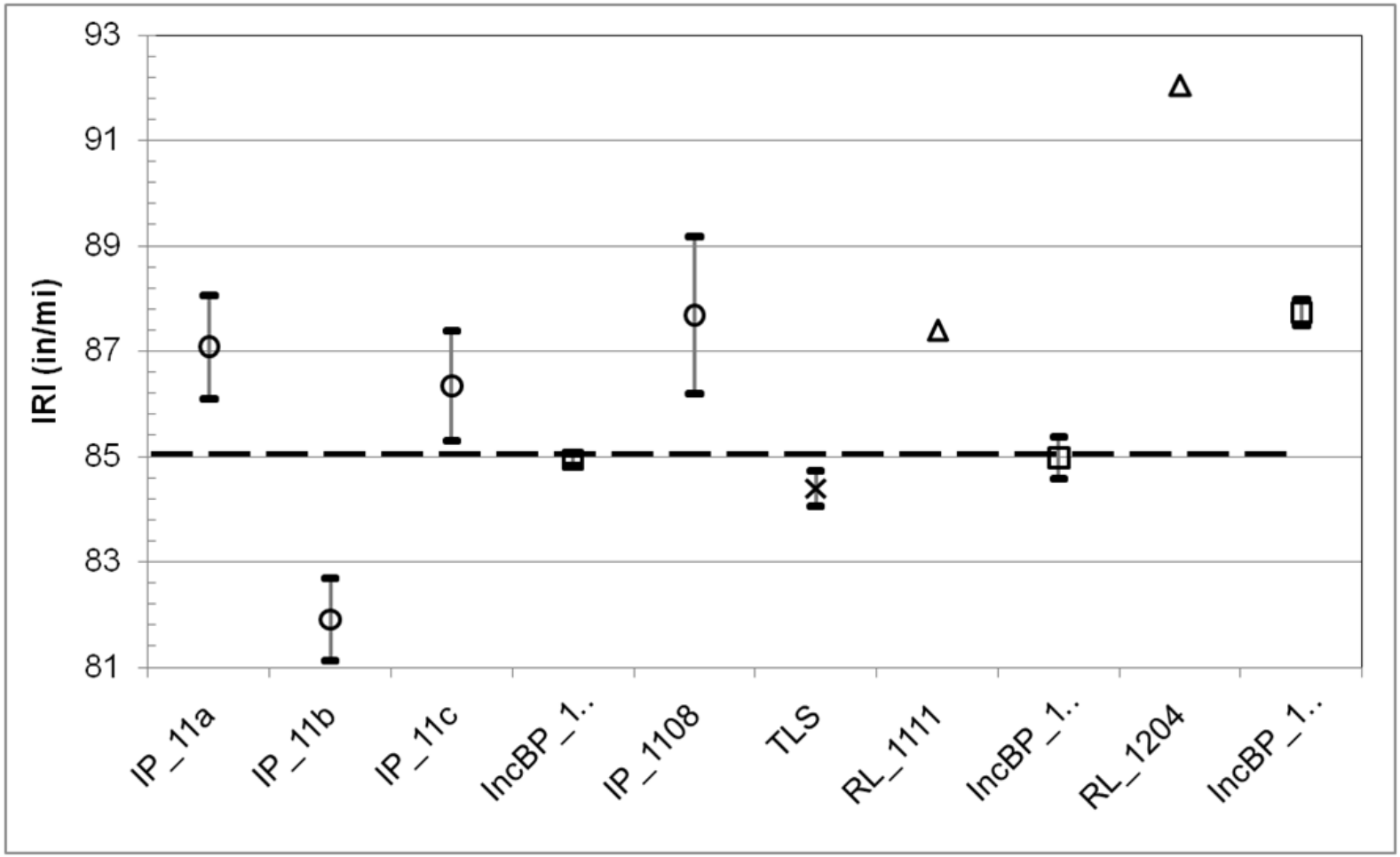


Determined an optimal sampling interval:
2-5 inches

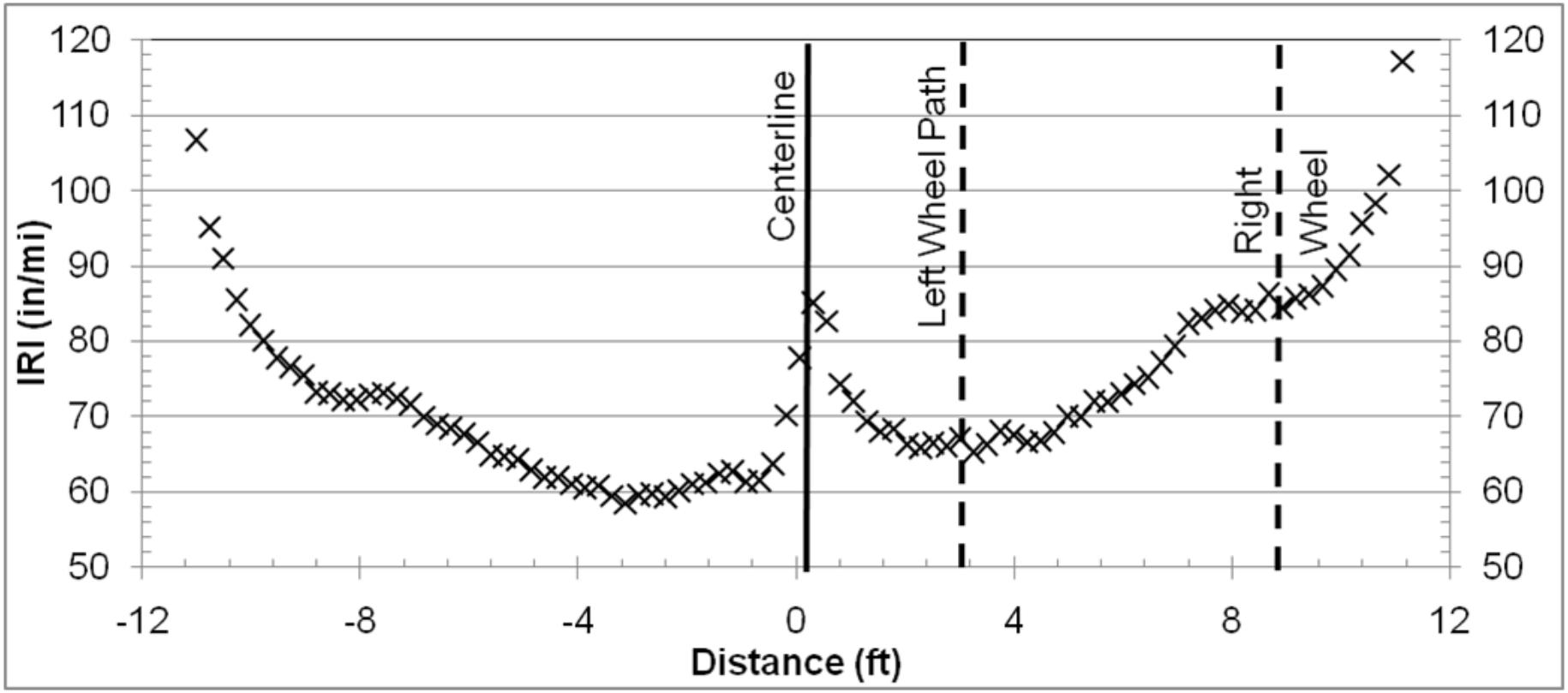
Left Wheel Path IRI Comparison



Right Wheel Path IRI Comparison



IRI Across the Roadway



IRI determined across the roadway for profiles spaced every 3” using a 3” point spacing

Cross Correlations

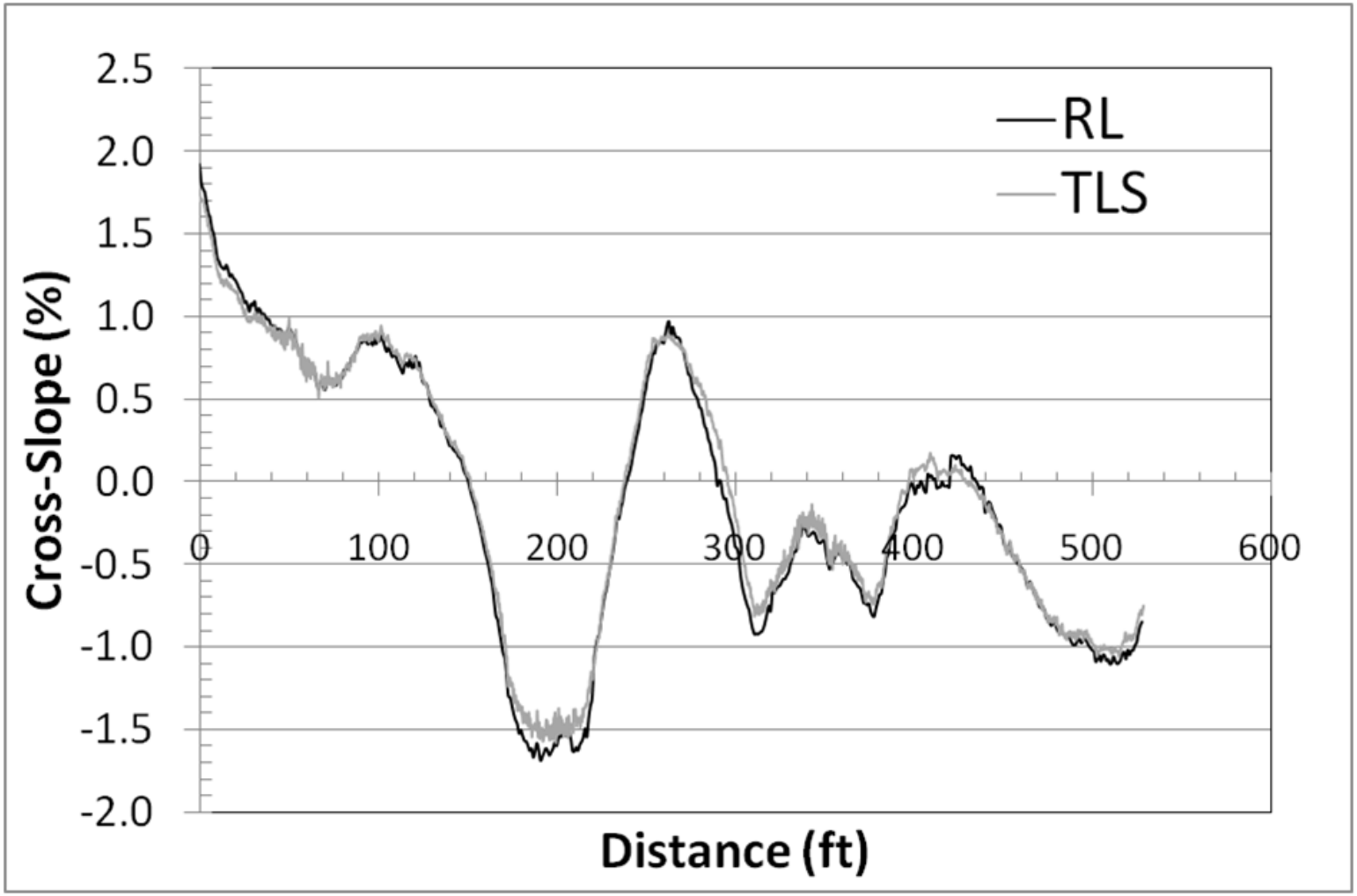
Left Wheel Path REFERENCE -->

Reference / Profile	IBP_1106		IBP_1111		IBP_1206		RL_1111		RL_1204		TLS_1110		IP1		IP2		IP3		IP4	
IBP_1106	**98.20**	**(0.32)**	**91.65**	**(0.76)**	87.61	(1.19)	83.27	(1.30)	75.52	(0.54)	**90.57**	**(0.60)**	87.54	(0.69)	**91.13**	**(0.74)**	72.01	(0.65)	**96.34**	**(0.79)**
IBP_1111	**92.19**	**(0.68)**	**99.00**	**(0.46)**	73.55	(0.98)	74.35	(0.79)	65.38	(0.85)	80.51	(0.80)	77.03	(0.75)	79.05	(1.02)	62.44	(0.98)	89.23	(0.82)
IBP_1206	86.78	(3.19)	72.10	(3.22)	**97.37**	**(1.49)**	85.70	(2.71)	84.26	(1.18)	86.79	(2.54)	86.40	(2.38)	**90.84**	**(2.16)**	69.47	(1.82)	87.56	(2.74)
RL_1111	88.44	-	77.99	-	86.21	-	-	-	83.87	-	88.48	-	88.36	-	**90.84**	**-**	67.30	-	87.74	-
RL_1204	80.73	-	68.93	-	72.46	-	83.87	-	-	-	82.37	-	81.98	-	84.59	-	64.21	-	80.32	-
TLS_1110	**90.32**	**(0.45)**	80.52	(0.52)	87.33	(0.84)	83.91	(0.30)	77.40	(0.56)	**97.63**	(0.69)	**94.40**	**(0.66)**	**93.54**	**(0.55)**	74.85	(1.27)	**92.03**	**(0.49)**
IP1	88.50	(1.15)	76.65	(0.72)	88.31	(1.06)	84.13	(0.62)	77.23	(0.90)	**94.56**	**(1.19)**	**98.06**	**(0.49)**	**94.52**	**(1.17)**	71.20	(1.58)	**90.76**	**(1.17)**
IP2	**90.84**	**(0.92)**	78.49	(1.59)	**90.48**	**(1.29)**	84.12	(1.09)	77.70	(1.55)	**93.79**	**(0.94)**	**94.55**	**(2.56)**	**95.14**	**(0.16)**	74.70	(1.43)	**92.49**	**(1.55)**
IP3	71.66	(2.29)	60.98	(2.00)	70.46	(2.44)	63.78	(1.76)	59.96	(1.73)	74.11	(2.67)	71.18	(2.62)	75.06	(2.58)	**94.12**	**(2.09)**	75.10	(2.76)
IP4	**93.88**	**(2.77)**	86.19	(2.94)	87.08	(3.62)	74.06	(1.92)	82.46	(1.67)	**90.75**	**(1.76)**	88.80	(1.91)	**91.29**	**(2.92)**	74.19	(1.05)	**94.40**	**(2.49)**

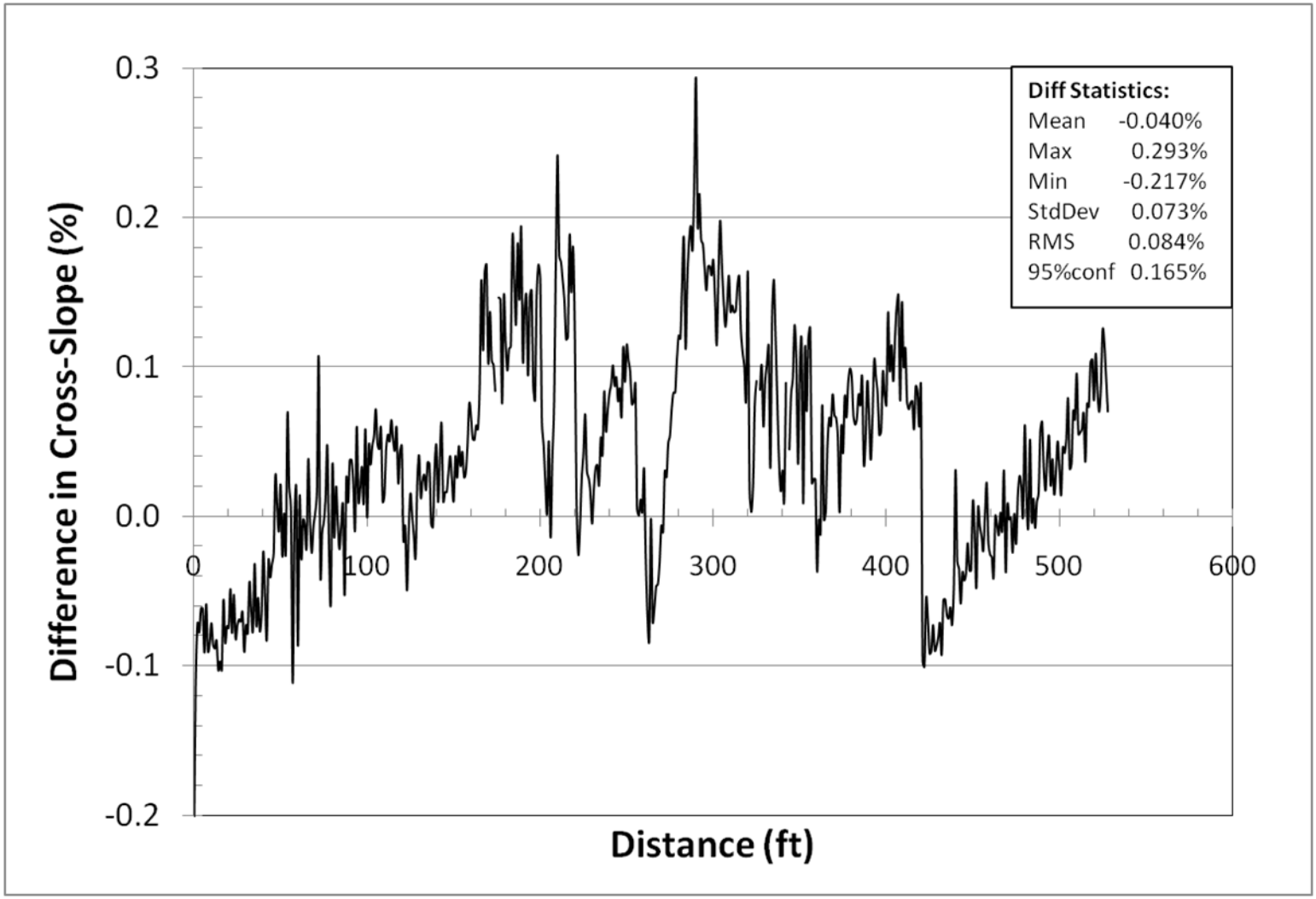
Right Wheel Path REFERENCE -->

Reference / Profile	IBP_1106		IBP_1111		IBP_1206		RL_1111		RL_1204		TLS_1110		IP1		IP2		IP3		IP4	
IBP_1106	**99.02**	**(0.16)**	**92.38**	**(0.21)**	**92.23**	**(0.17)**	**93.37**	**(0.36)**	83.93	(0.66)	**91.42**	**(0.14)**	**94.22**	**(0.17)**	**96.92**	**(0.29)**	69.39	(0.40)	**98.00**	**(0.40)**
IBP_1111	**92.42**	**(0.72)**	**99.32**	**(0.19)**	79.75	(0.85)	84.90	(0.70)	77.94	(0.64)	84.15	(0.58)	83.40	(0.71)	87.39	(0.69)	62.48	(0.46)	**93.87**	**(0.50)**
IBP_1206	**92.39**	**(1.06)**	80.04	(1.30)	**99.24**	**(0.28)**	**92.90**	**(0.75)**	86.58	(0.33)	86.61	(0.99)	**91.90**	**(0.93)**	**95.37**	**(0.93)**	66.30	(0.63)	**90.33**	**(1.08)**
RL_1111	**95.82**	**-**	87.81	-	**91.18**	**-**	-	-	83.17	-	89.89	-	**92.47**	**-**	**94.73**	**-**	67.29	-	**93.90**	**-**
RL_1204	87.45	-	81.32	-	89.48	-	83.17	-	-	-	80.22	-	84.81	-	89.27	-	61.55	-	86.57	-
TLS_1110	**92.07**	**(0.88)**	84.67	(0.96)	86.37	(0.88)	87.21	(1.46)	78.34	(1.47)	**98.56**	**(0.10)**	**94.02**	**(0.50)**	**90.85**	**(0.80)**	72.12	(0.84)	89.39	(0.72)
IP1	**92.80**	**(2.29)**	81.86	(2.26)	**91.99**	**(1.22)**	**91.27**	**(0.94)**	81.69	(1.00)	**92.91**	**(0.84)**	**97.51**	**(1.46)**	**92.76**	**(1.67)**	72.26	(0.82)	**90.63**	**(1.53)**
IP2	**94.22**	**(2.99)**	84.91	(3.14)	**93.80**	**(1.24)**	**92.15**	**(2.28)**	84.76	(0.85)	**90.14**	**(1.70)**	**94.98**	**(1.65)**	**95.66**	**(3.40)**	70.41	(2.29)	**93.26**	**(2.64)**
IP3	69.64	(0.63)	62.33	(1.32)	65.92	(0.59)	64.36	(1.10)	58.19	(0.85)	70.48	(2.43)	71.98	(2.43)	76.81	(1.14)	**95.58**	**(1.41)**	69.18	(0.77)
IP4	**95.49**	**(1.81)**	**92.07**	**(3.06)**	**90.61**	**(2.19)**	**90.94**	**(0.87)**	82.94	(1.96)	87.47	(1.31)	89.56	(2.02)	**92.27**	**(2.81)**	68.20	(1.95)	**96.94**	**(1.64)**

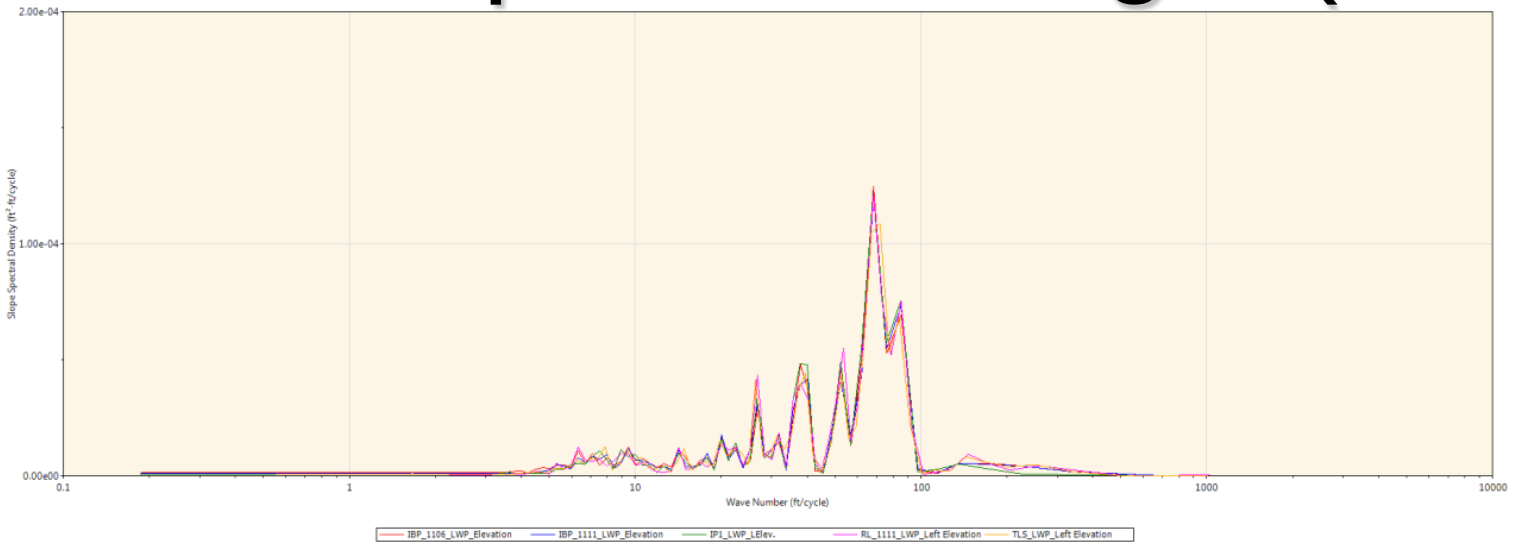
Cross Slope Comparison



Cross Slope Comparison



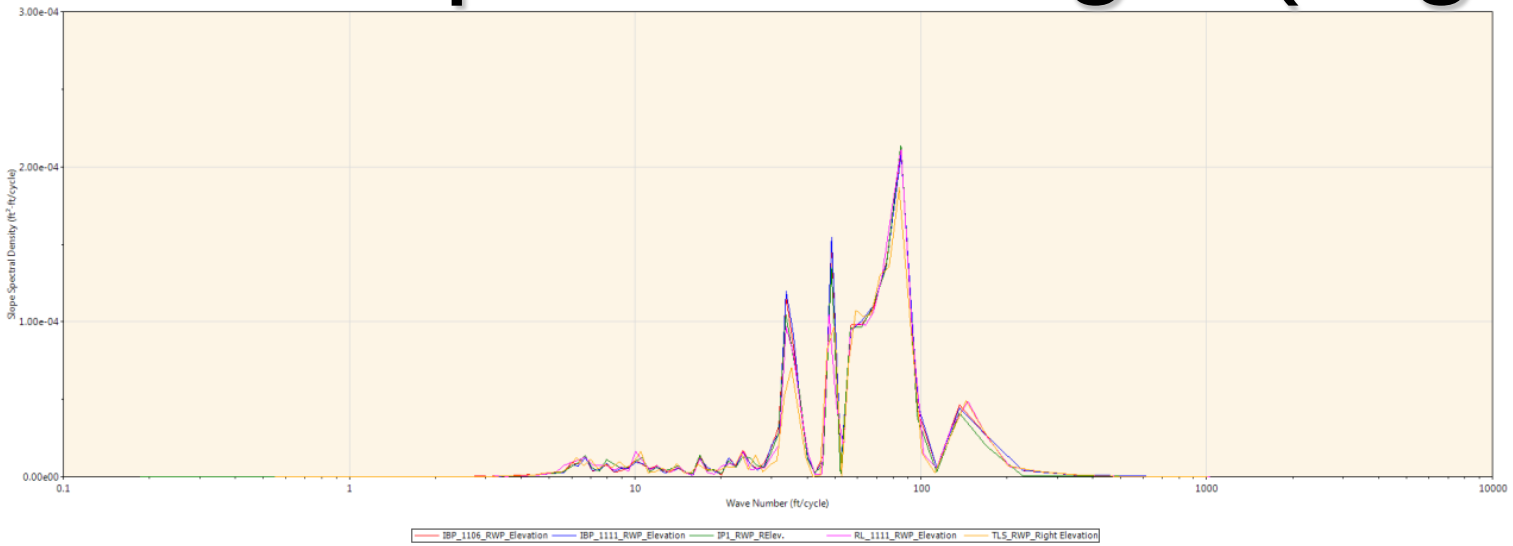
Slope Wavelength (Left)



No averaging filter used

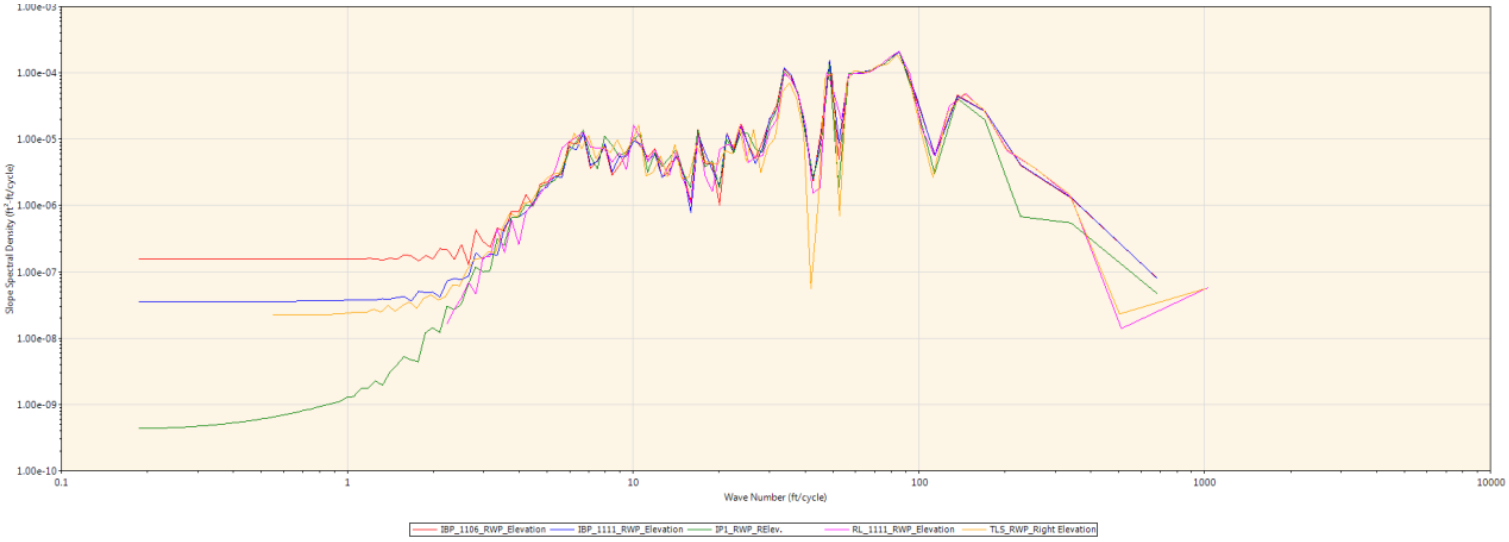
Deviations below 4 ft/cycle and above 120 ft/cycle

Slope Wavelength (Right)

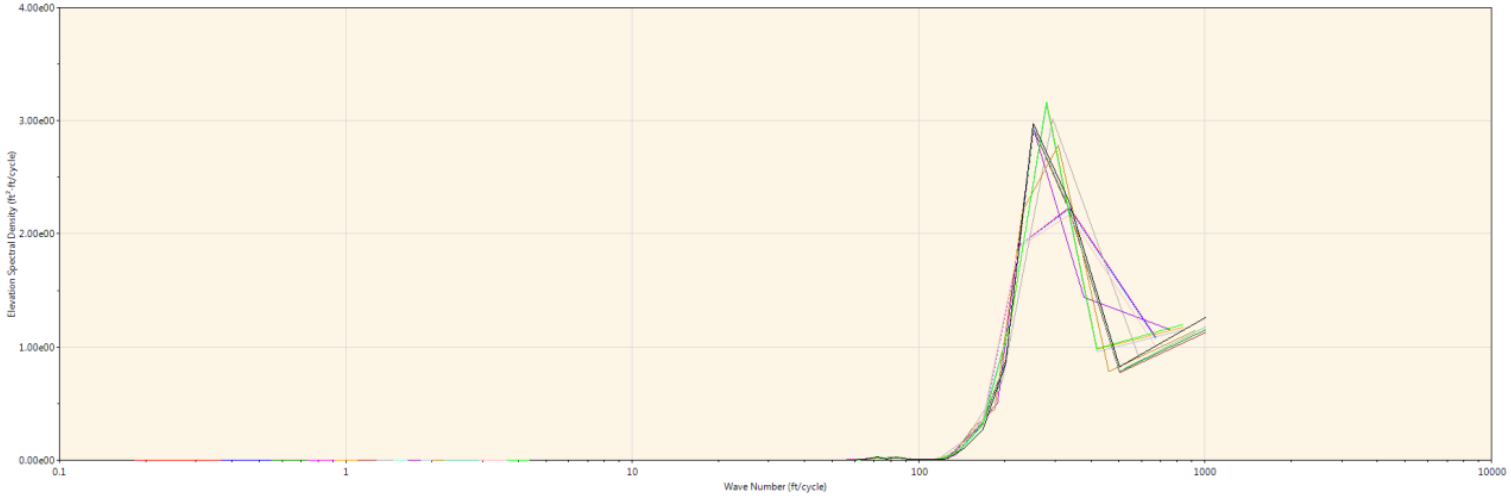


No averaging filter used

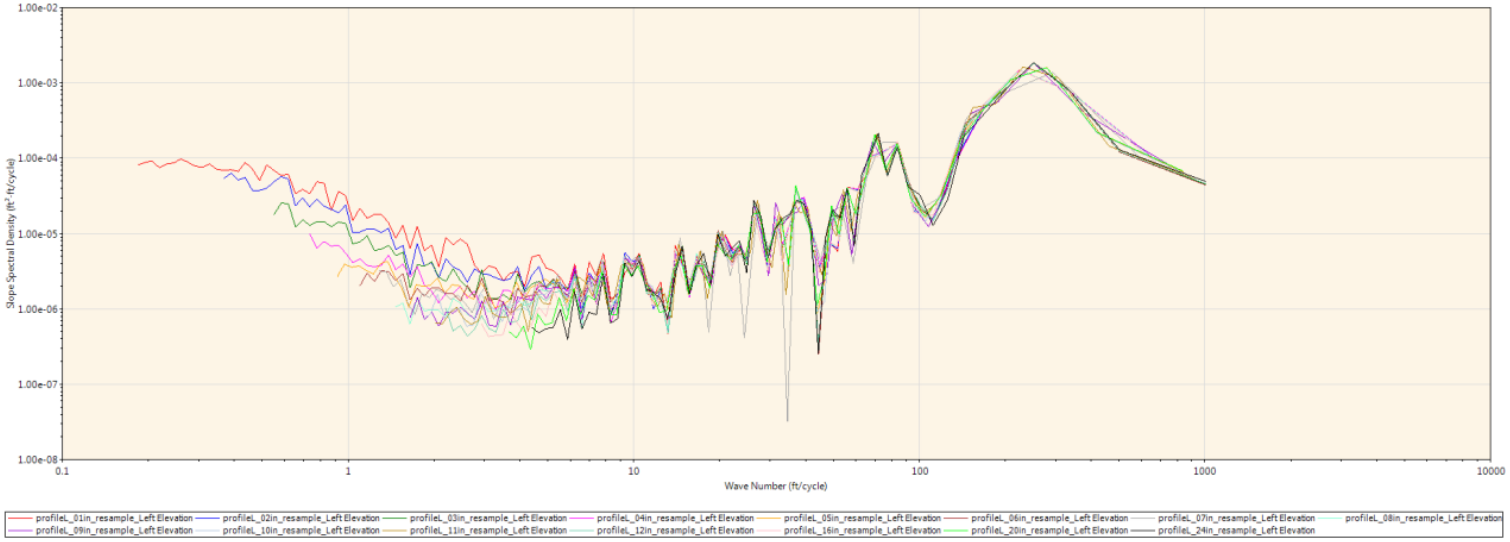
Deviations below 3 ft/cycle and above 200 ft/cycle



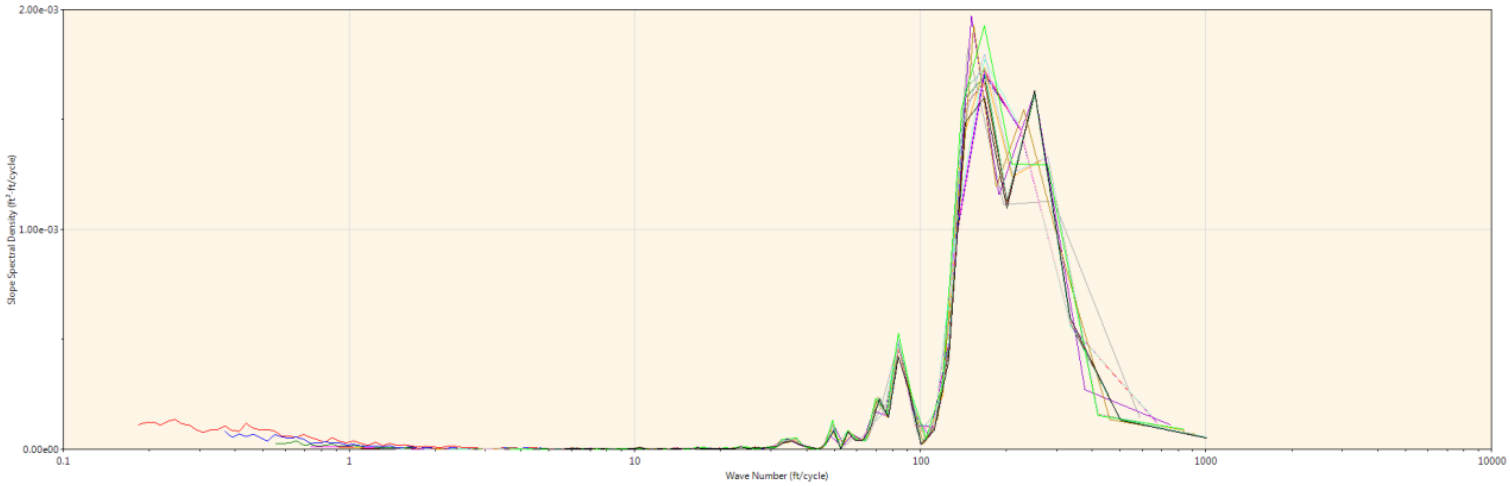
TLS Slope Wavelength (Left)



No averaging filter used



TLS Slope Wavelength (Right)



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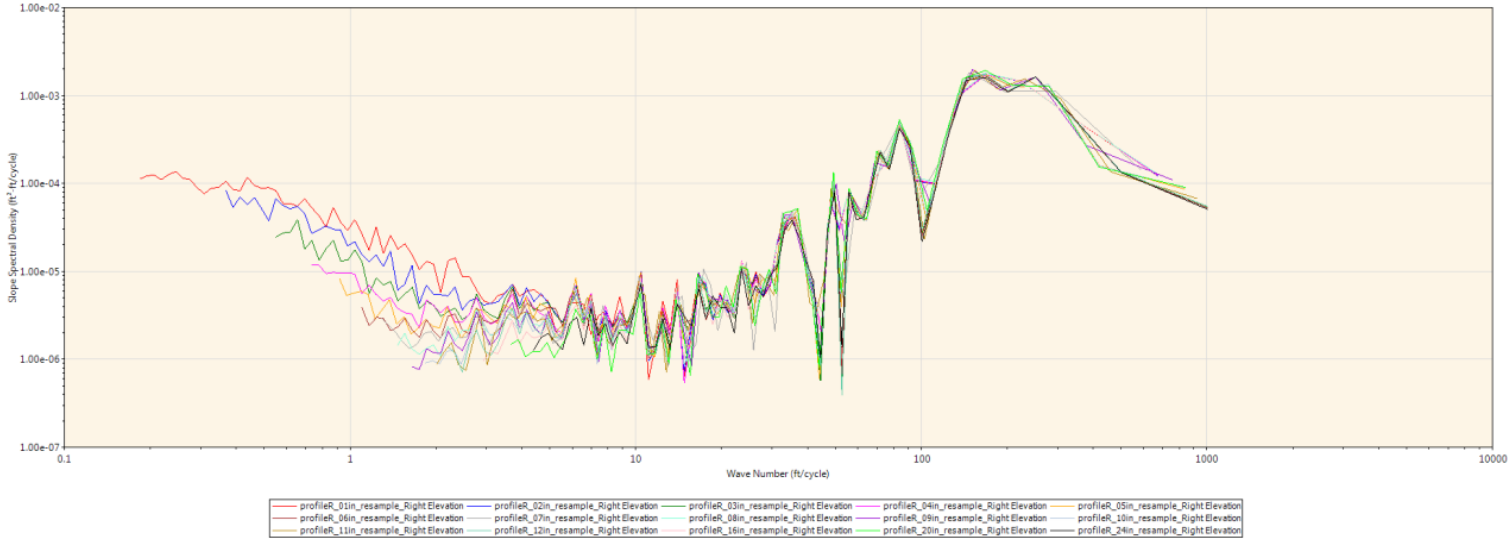


Conclusions

- TLS is able to measure cross slopes and multiple profiles across the roadway
- Methods measure same wavelengths
- Optimal spacing interval for TLS: 2-5 in
    - More scans allow closer spacing, but increase time
    - Profiler and Inclinometer read at 1 in
  – Requires additional time and software

Conclusions (cont.)

- Repeatability is met (AASHTO 92%, ODOT 90%)
- Accuracy is difficult to meet but achievable (AASHTO, 90%ODOT 88%)
  - More difficult for left wheel path

Scanning Considerations Learned

- Data Processing:
  - Data should be checked to avoid truncation
  - Relative and vertical accuracy are more important than network and horizontal accuracy
- Profile Extraction:
  - Intensity values should be used not RGB color values
  - Extraction is easiest if painted wheel paths are straight

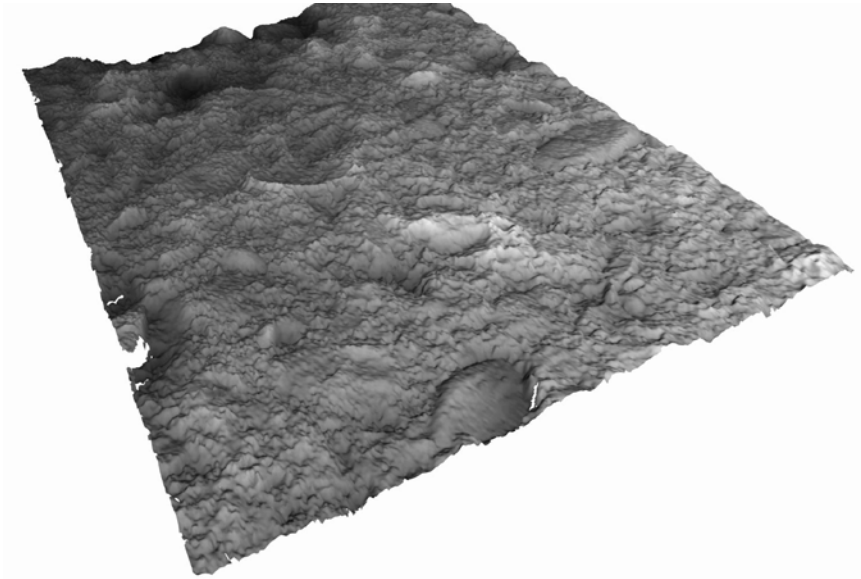
Future Work

- Effects of time and weathering
- Road wear from studded tires
- Use of mobile laser scanning
- Use of one high resolution scan instead of multiple scans

Additional Work Done

- Micro Texture Analysis
  - Fine scale 3D laser scanning
  - Evaluated texture of asphalt pavements with varying predominant aggregate sizes
    - ¼, ½, ¾ inch aggregates
  - Measured the texture using three different methods
  - Tested various scanner settings

Micro Texture Analysis



Acknowledgments

- Funding Organization:
  Oregon Department of Transportation
  FHWA
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- George Chang
- Equipment, training and software:

Questions