Welcome to Oregon

And a Look at Our R06A Experience

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Image 1:
R1 Inspection Team

TRIMET

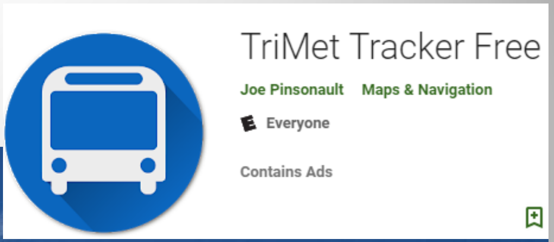
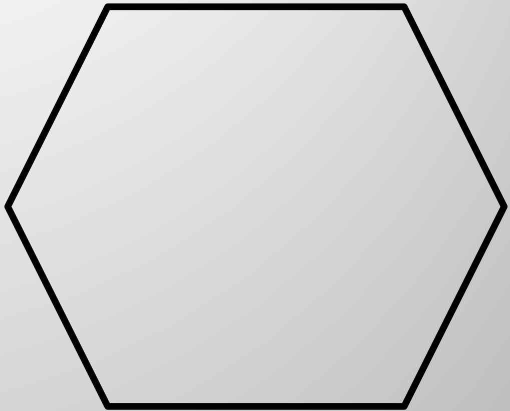
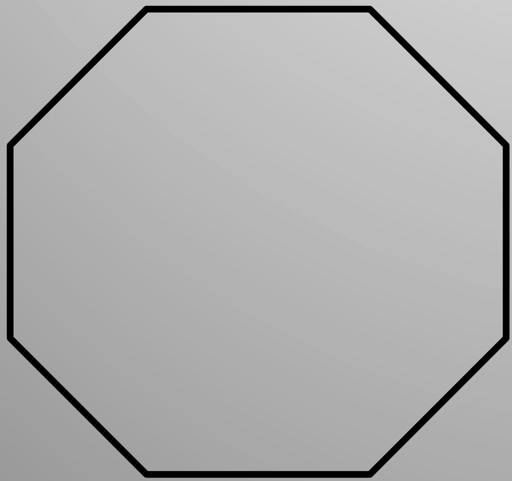


Image 2: Steve Morgan CC BY-SA 4.0

Pentagon



Hexagon



Octagon

~~Oregon~~

Thank You

Bruce Johnson State Bridge Engineer
Kevin Chesnik, Applied Research Associates
FHWA, AASHTO and their representatives in attendance
Mike Goff, ODOT Region 2 Bridge Inspector,
Jeff Swanstrom, ODOT Senior Bridge Inspector (Ret.)
John Adkins, ODOT Region 4 Bridge Inspector,
Debera-Jean Murdoch, Procurement Coordinator,
Andrew Blower, ODOT Corrosion Protection Engineer
Liantao Xu, Region 1 Senior Bridge Designer,
George Bornstedt, Region 5 Senior Bridge Designer,
Bryan Mast, Region 3 Bridge Maintenance Manager
Benjamin King, Region 3 Senior Construction Coordinator
Our maintenance crews, and D&H Flagging.
Our contracting Partners, especially
Adam Carmichael at Infrasense
Paul Fuchs at ThermalStare
Dennis Sack, Yajai Tinkey, from Olson Engineering
The Reader/ Listener

Introduction

1. **Background & our inventory**
2. **Our initial strategy**
3. **Results and case studies**
4. **How that initial strategy has changed during this process**
5. **The near future of NDE on bridge decks**
6. **Potential applications on tunnels**

Image 3: FC inspection of NB Interstate Bridge

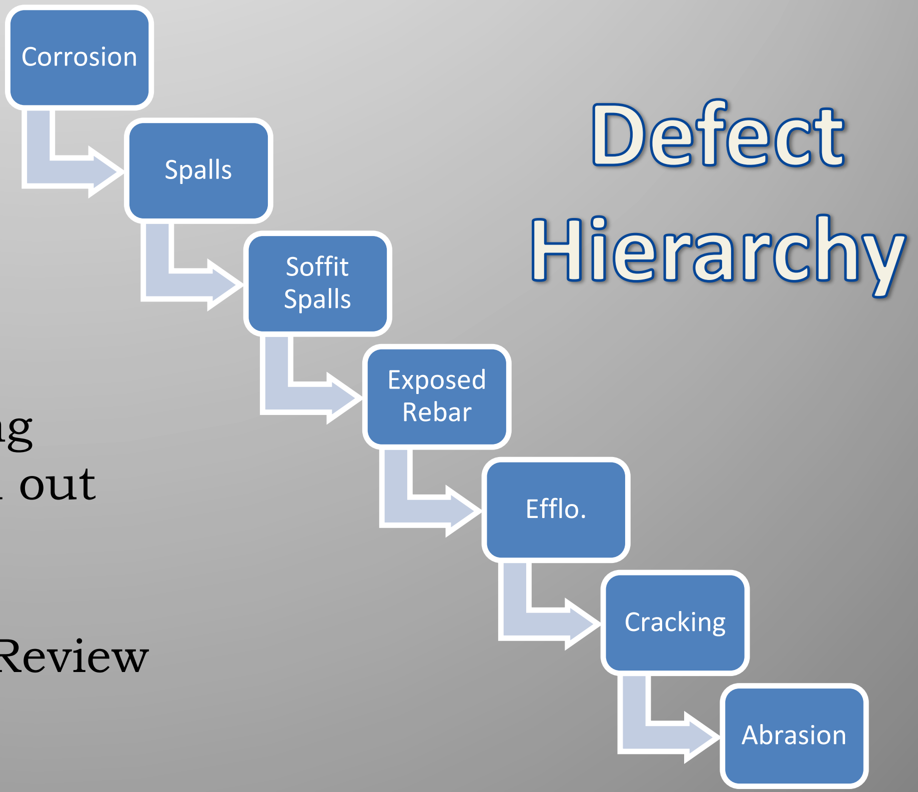
OREGON DOT Bridge Inspection coding guide

DECK SURVEY GUIDELINES[2]

Corrosion Related-

Determine whether the defects are in fact, "Corrosion Related". If any of the following conditions exist, the bridge inspector needs to instigate the specified actions:

1. Concrete Deck Element is in **condition state 3**, chain drag and map the bridge deck.
2. Concrete Deck Element is in **condition state 4**, take cores and test quality of deck materials.



Condition state 3:

1. Delams/ Spall > 1"
2. Cracks: > 0.009" or < 1' apart
3. Exposed rebar w/ measureable section loss
4. Rutting causing > 1" deep ponding
5. Coarse aggregate loose or popped out

Condition State 4:

1. Anything Warranting Structural Review

OREGON DOT Bridge Design Manual

QUANTITY ESTIMATES[3]

Class 2 Deck Preparation (SC Overlays only)

A deck survey is recommended to confirm the estimated quantity of both Class 2 and Class 3 Deck Preparation. Chain drag, ***infrared scan, impact echo or ground penetrating radar*** (GPR) [are] acceptable methods of performing a deck survey.

- **When at least the bottom half of deck is still sound**
- **~$270/ yd^2 (2017 cost data)** [4]

Class 3 Deck Preparation (SC Overlays only)

- **When concrete beyond mid-depth needs removal**
- **~$650/ yd^2**

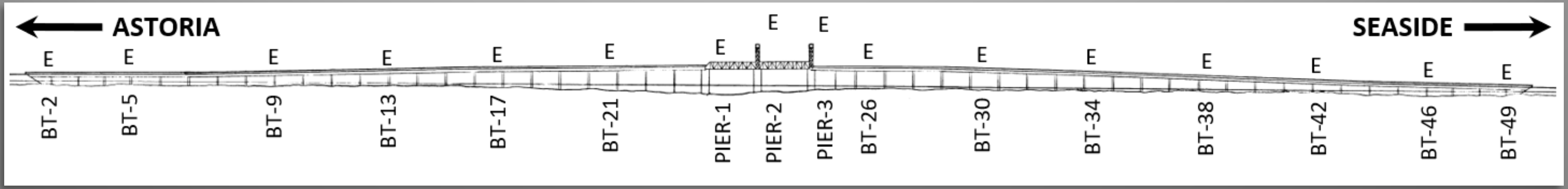


Figure 1 New Youngs Bay Elevation

Background

	Deck			Superstructure			Substructure			Culvert#		
NBI Rating	*N*	μ	σ	*N*	μ	σ	*N*	μ	σ	*N*	μ	σ
Years at 8	1899	8.72	6.49	1970	11.45	7.55	2031	10.92	7.30	35	5.35	3.24
Years at 7	1354	12.12	6.55	1308	11.49	6.50	1372	11.51	7.05	91	6.49	3.23
Years at 6	230	9.13	5.75	154	9.20	5.35	232	9.28	5.69	85	6.80	3.05
Years at 5*	18	9.44	5.86	6	8.50	4.11	14	9.71	5.26	21	4.35	0.00
Years at 4*	21	5.52	3.38	10	2.70	5.50	18	6.33	4.29			

*Included if 4 is current rating

As of 2017 Federal Submittal

Table 1

only 10 years of data and included if current rating

Included in *N* only if dropped

Those still at 5 or below

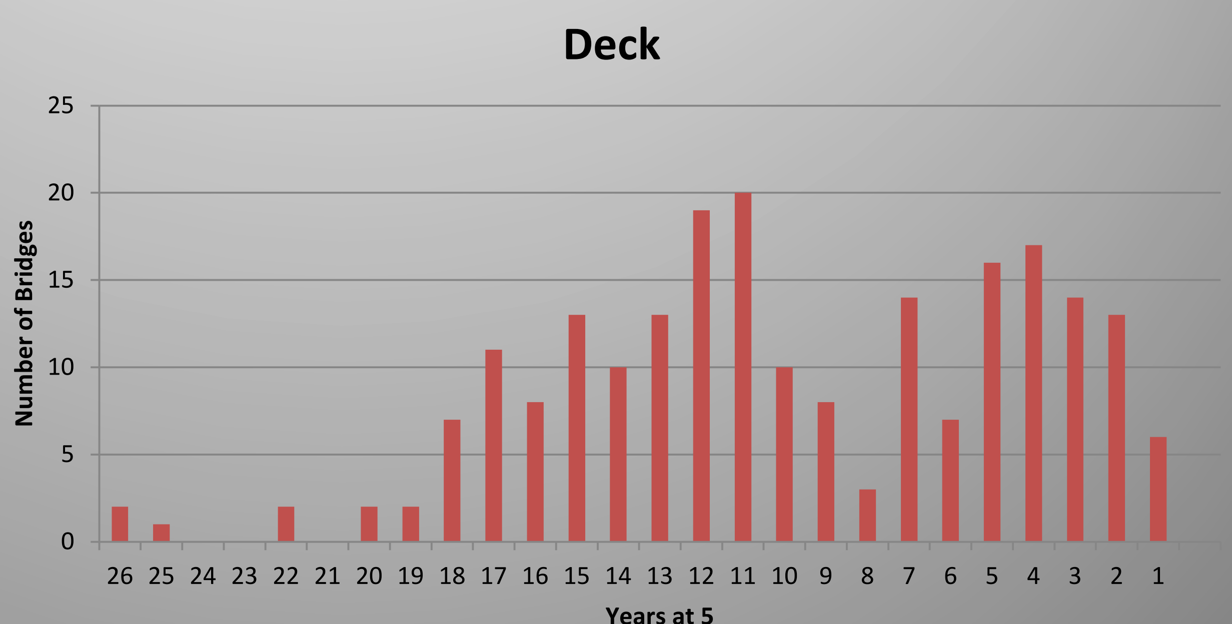


Chart 1

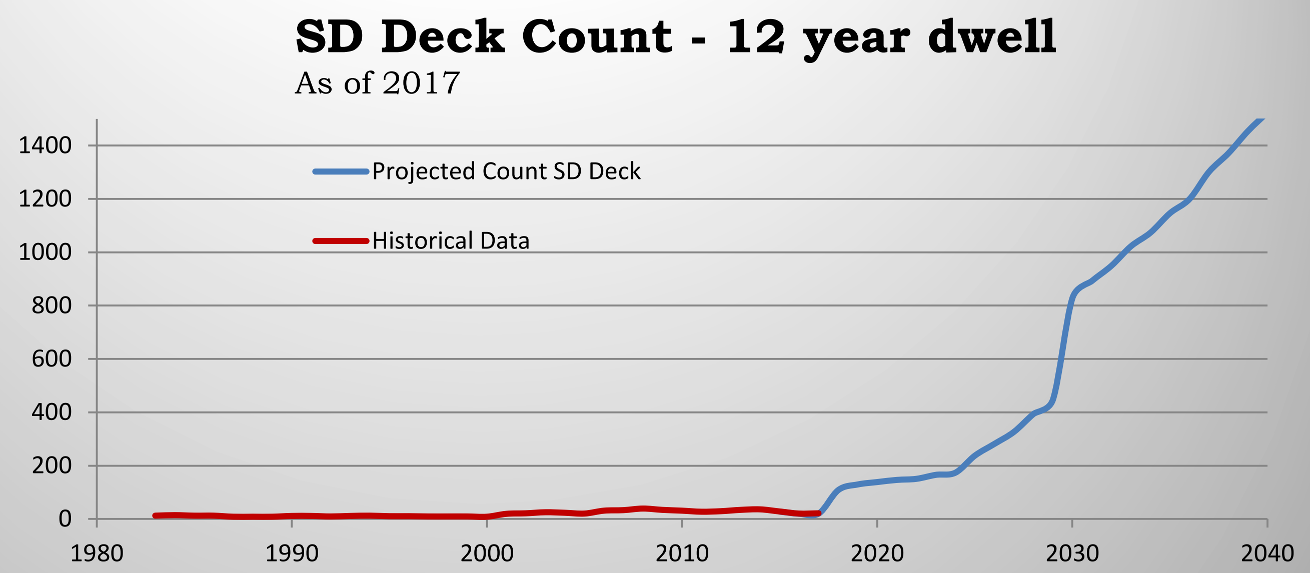


Chart 2

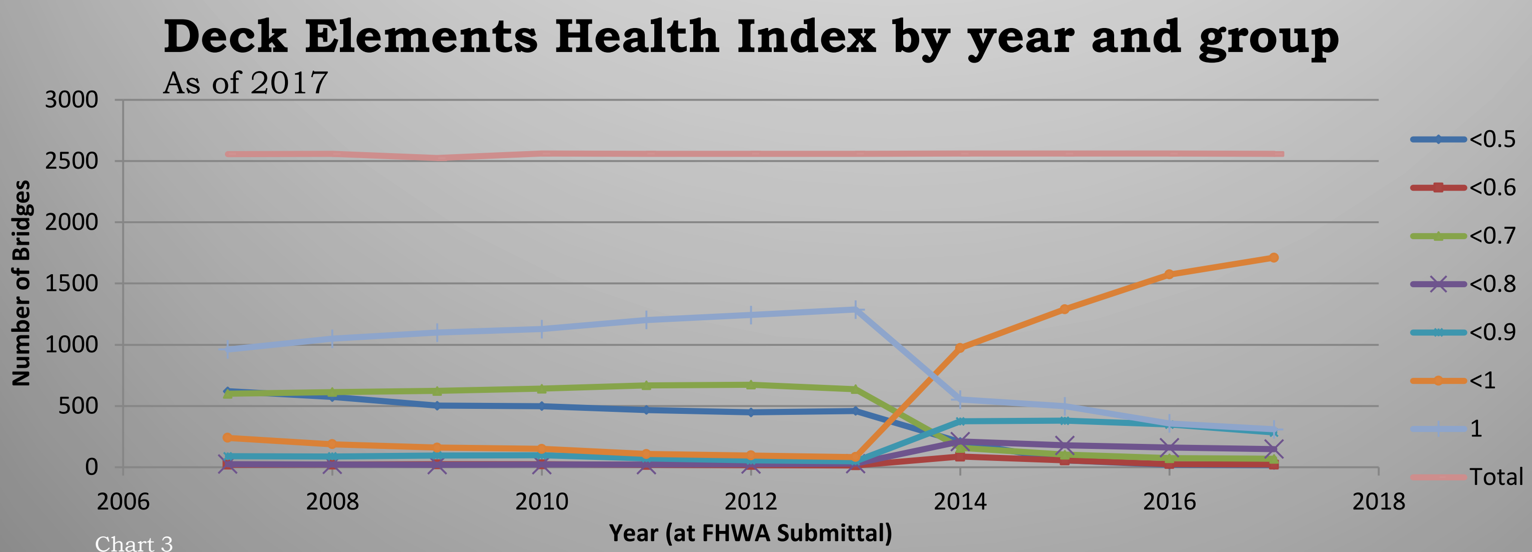


Chart 3

Figure 2

HI for Deck or Superstructure or Substructure

$$= \frac{\sum \{\text{Element Quantity CS-1}*(1)+\text{Quantity CS-2}*(2/3)+\text{Quantity CS-3}*(1/3)\}*\text{Element Wt}}{\sum\{\text{Total Element Quantity}*\text{Element Weight}\}}$$

Background

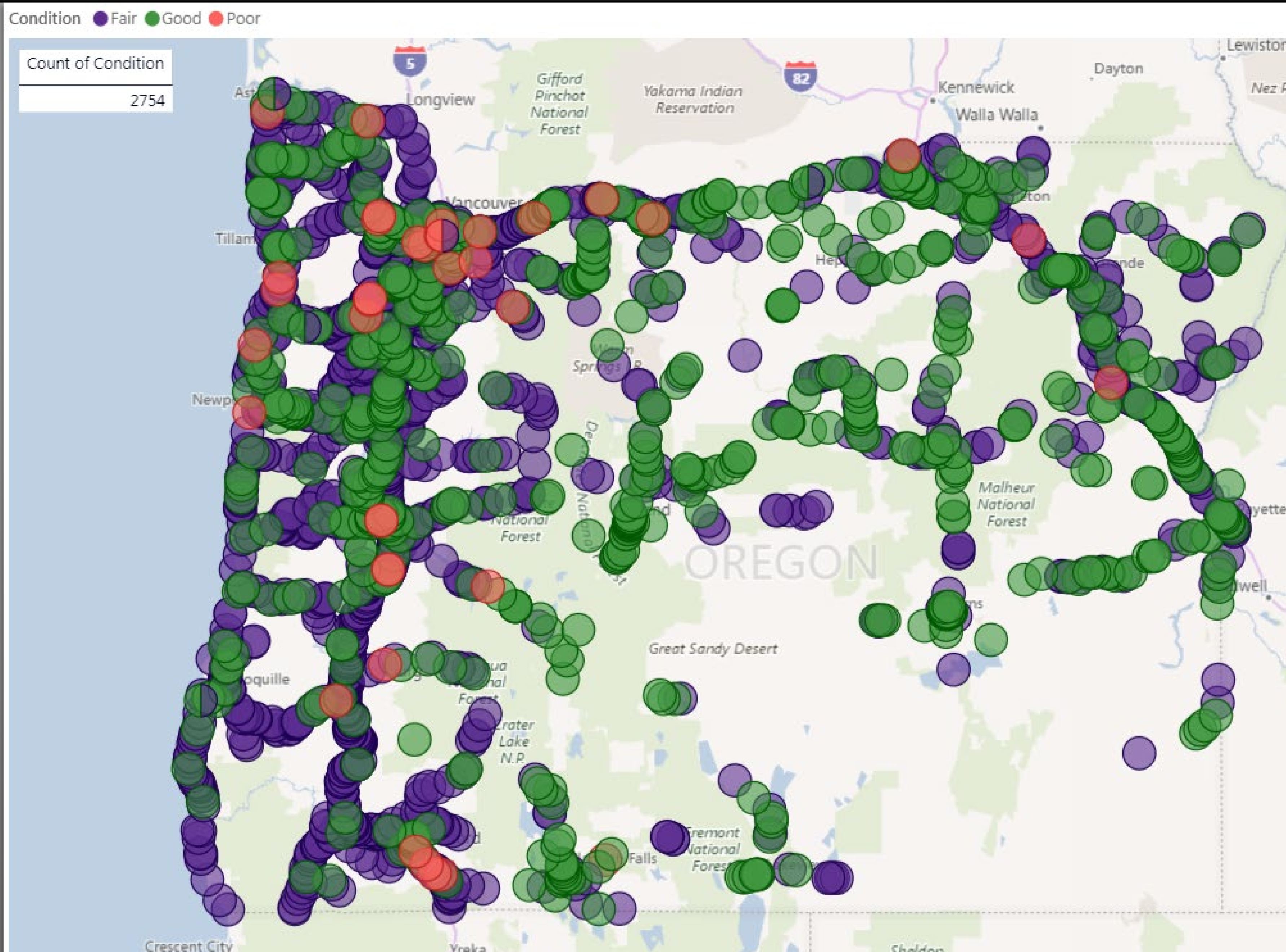


Figure 3

“Project Level” Impact Echo & Chain Drag (with lane closure)

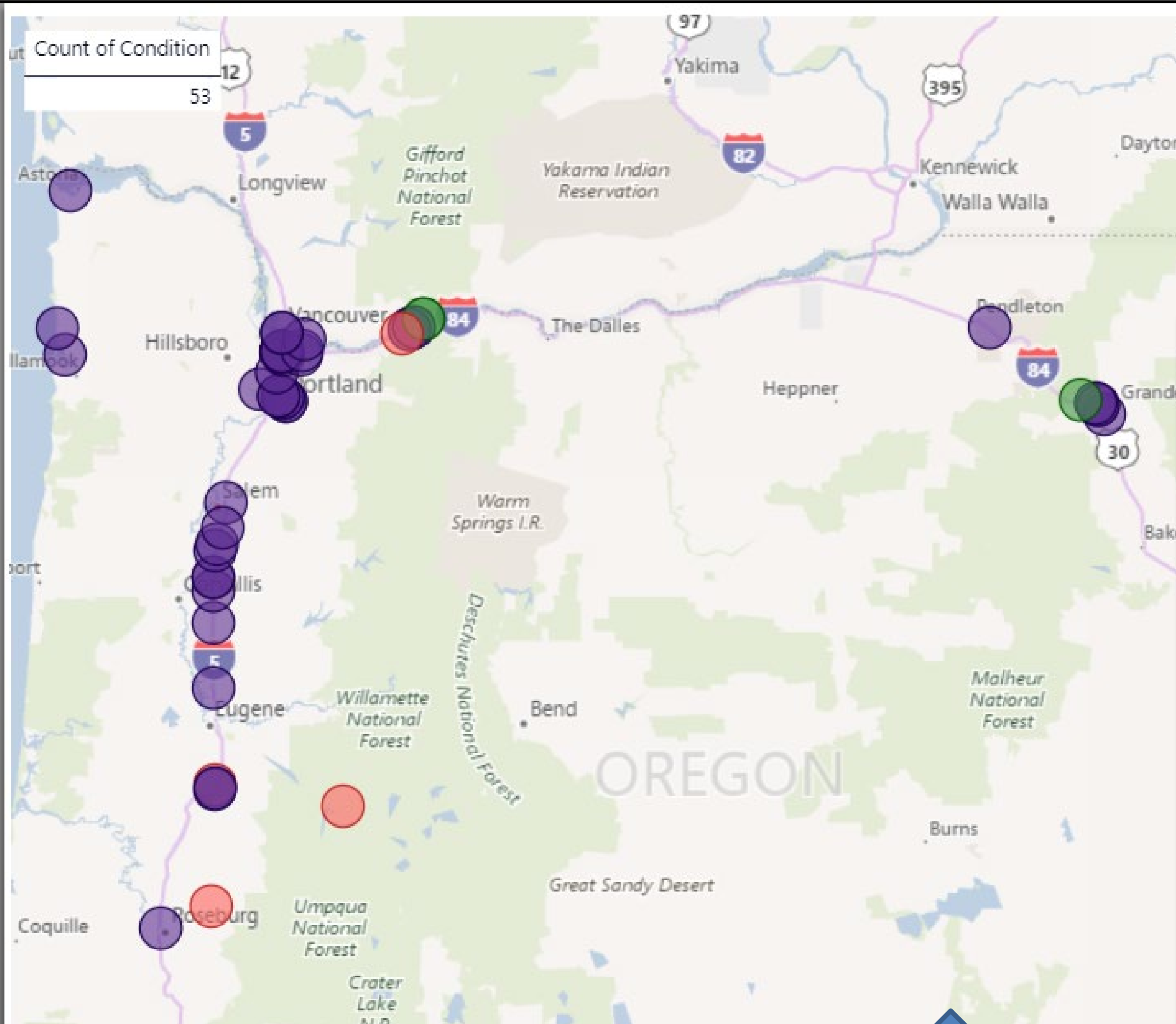


Figure 4

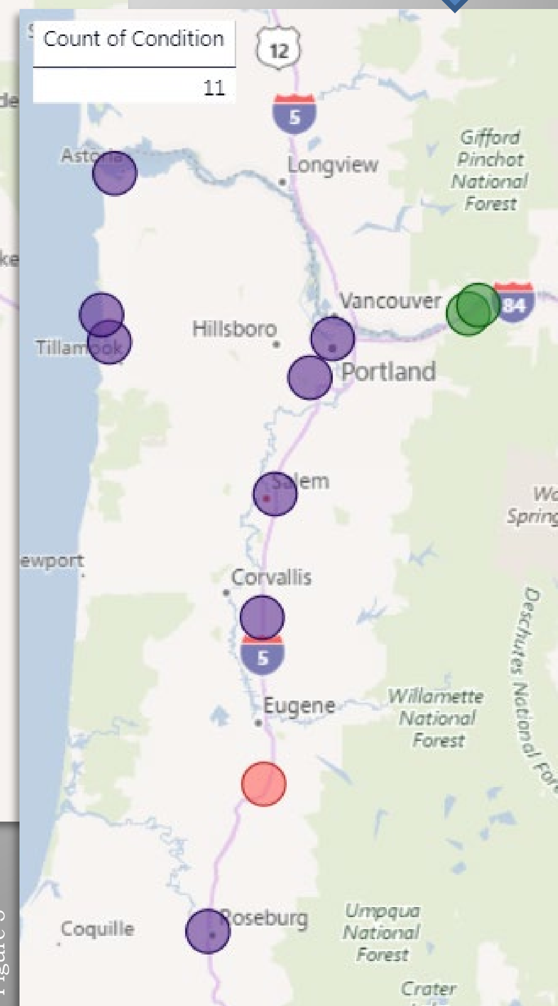


Figure 5

“Network Level” High-Speed, GPR, IR, HD Video

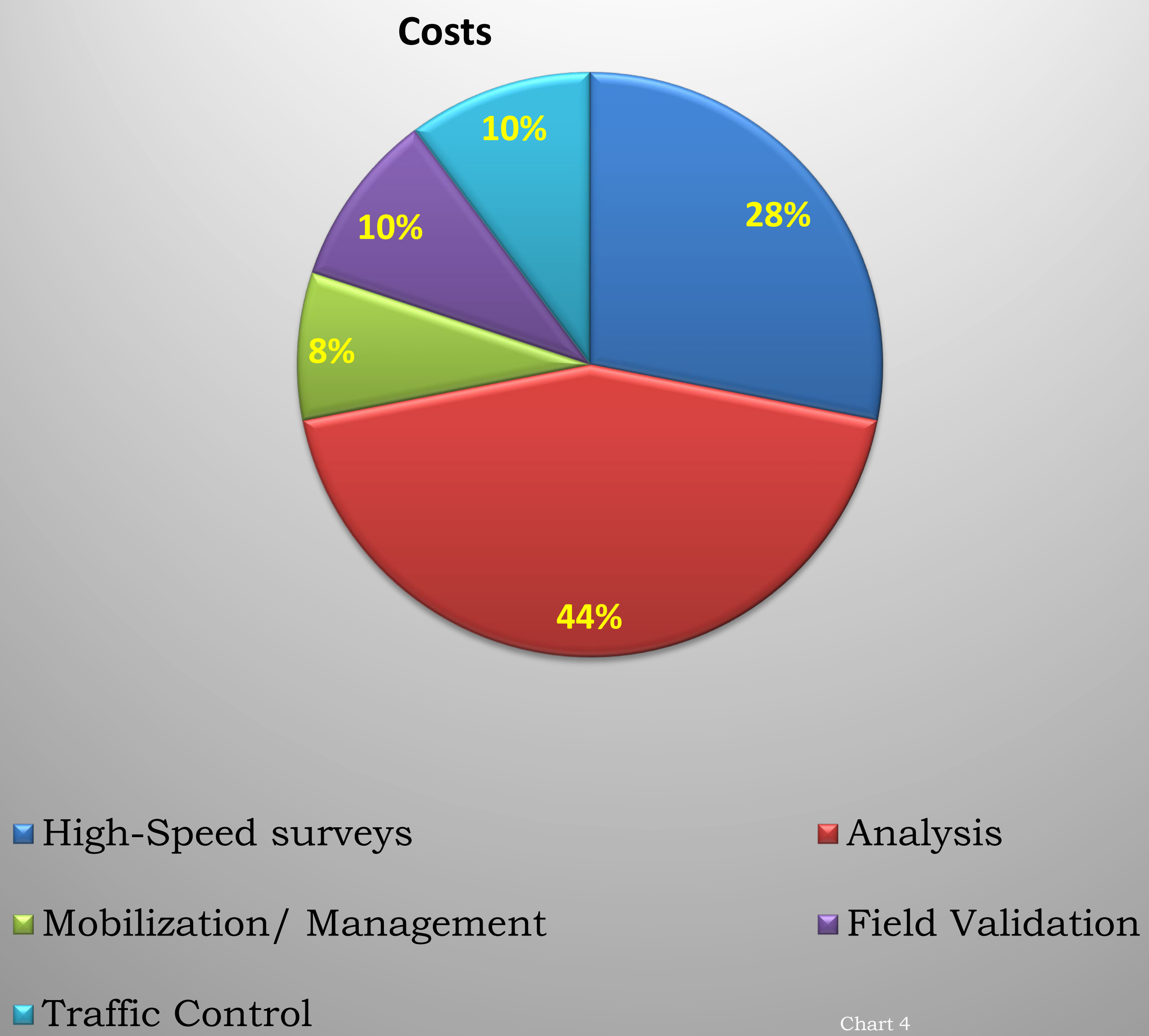
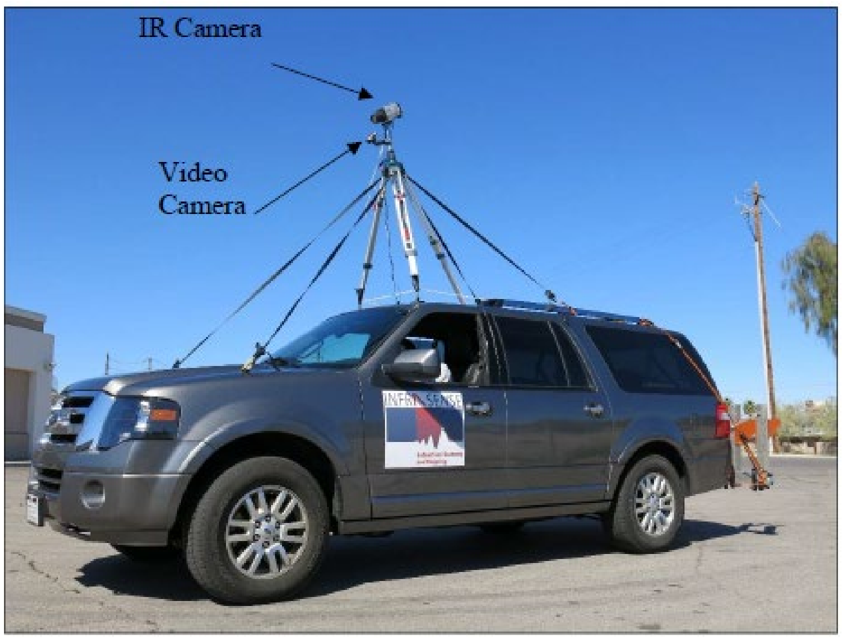

Costs
10%
28%
10%
8%
44%
High-Speed surveys
Analysis
Mobilization/ Management
Field Validation
Traffic Control

Chart 4

Equipment used for Deck Evaluations

GPR Antennas DMI

GPR Equipment



IR Equipment

Figure 6

GPR:

- ASTM D6087-08
- Dual 2Ghz Horns, GSSI, Inc.
- 3' Transverse incriments
- 40' = 13 lines
- May, July 2017
- 70°-87° F;
- 11:00AM – 6:30 PM
- 4 passes/ 2 lanes + shoulder
- ≤ 60 mph

IR:

- ASTM D4788-03 (2013)
- 640x480 FLIR Model A655sc
- Sony a7 4K camera
- May, July 2017
- 70°-87° F;
- 11:00AM – 6:30 PM
- 4 passes/ 2 lanes + shoulder
- ≤ 50 mph

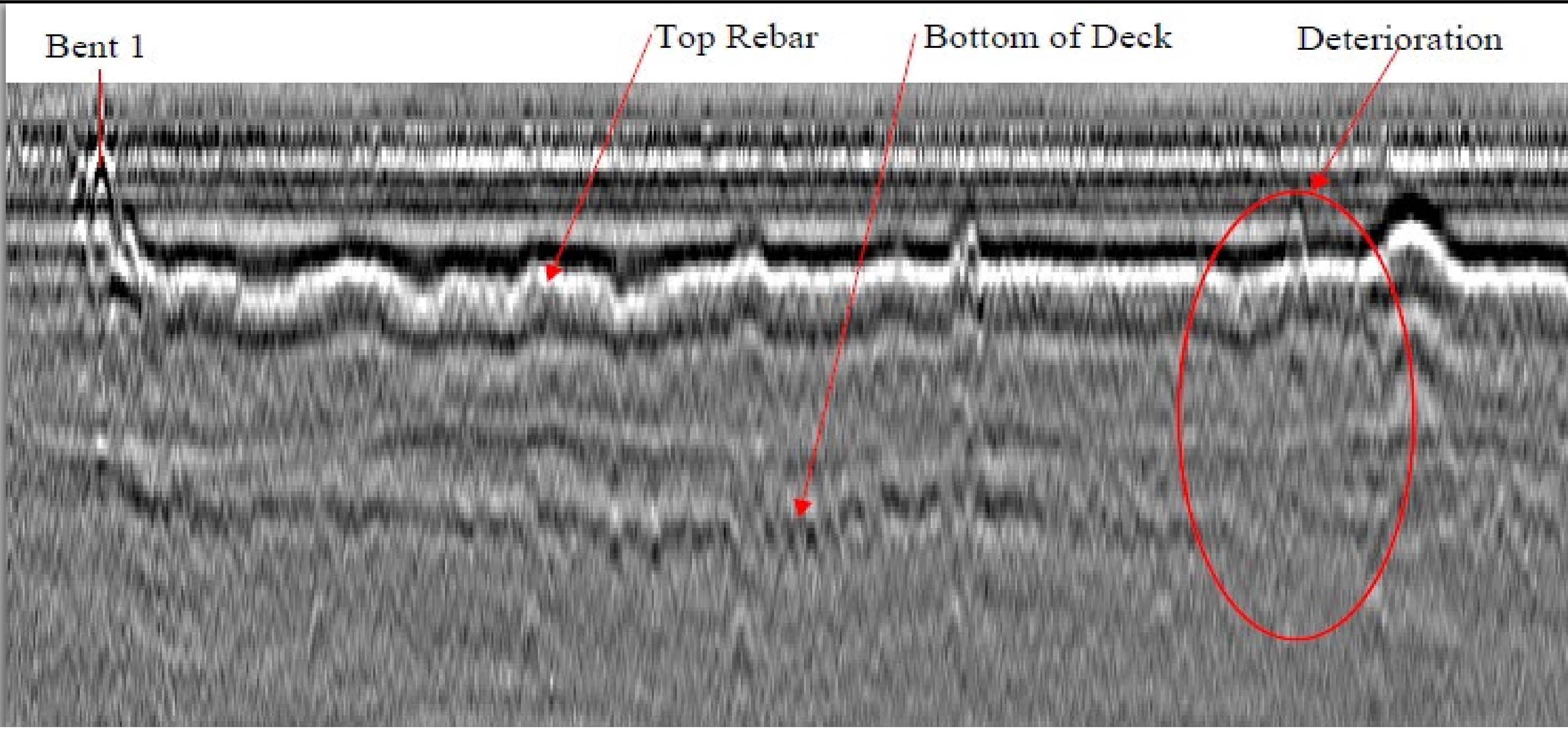


Figure 7

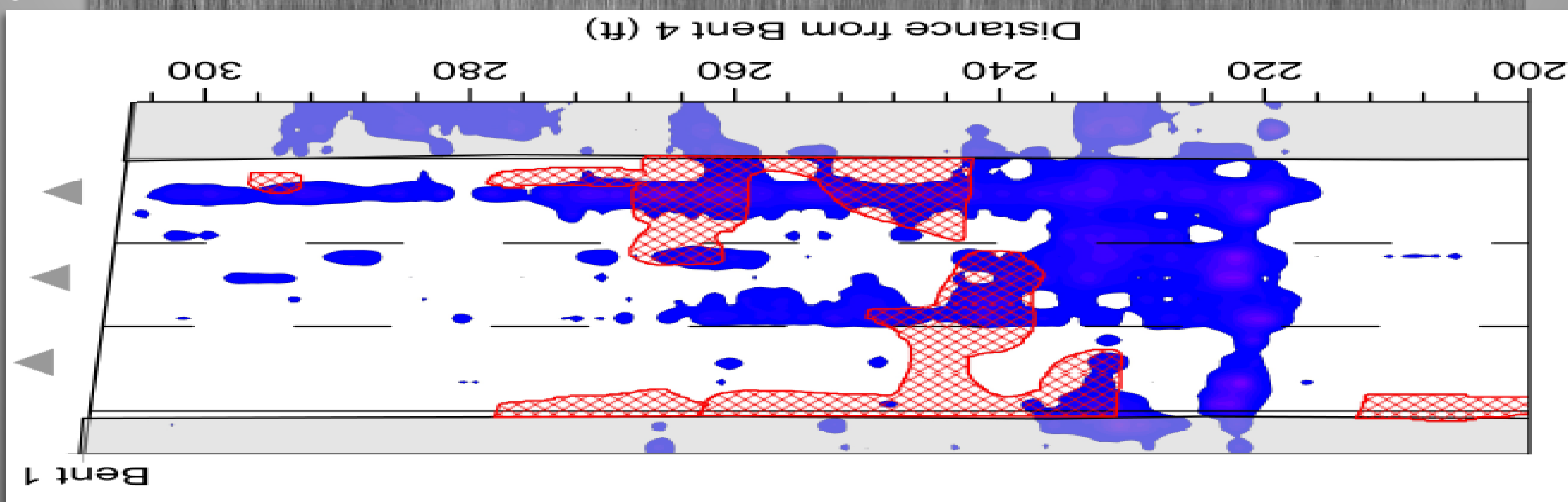


Figure 8

Initial Results – Thin Decks

BRIDGE_ID	YEARBUILT	MATERIALMAIN	DESIGNMAIN	DKSURFTYPE	DKRATING	Notes	INF_Del	INF_GPR	CS2	CS3	DK_HI
07832	**1956**	2 Concrete Continuous	04 Tee Beam	1 Monolithic Concrete	**4**	Severe transverse cracking throughout	16%	16%	83%	3%	71%
02193B	**1962**	5 Prestressed Concrete	02 Stringer/Girder	1 Monolithic Concrete	**4**		3%	14%	19%	0%	94%
08306	**1964**	3 Steel	15 Movable - Lift	1 Monolithic Concrete	**5**		6%	29%	40%	1%	86%
09567	**1971**	6 P/S Conc Continuous	05 Multiple Box Beam	1 Monolithic Concrete	**6**		7%	22%	55%	1%	83%
08114	**1958**	2 Concrete Continuous	04 Tee Beam	5 Epoxy Overlay	**6**	Large shadow from tree at west end of deck	3%	21%	70%	16%	
08363	**1958**	2 Concrete Continuous	04 Tee Beam	1 Monolithic Concrete	**6**	IR data limited due to extensive tree shadows.	10%	10%	3%	0%	
08254	**1958**	2 Concrete Continuous	04 Tee Beam	1 Monolithic Concrete	**6**		8%	14%	37%	2%	
07404	**1955**	3 Steel	09 Truss-Deck	1 Monolithic Concrete	**6**	Extensive cracking throughout	5%	7%	2%	0%	99%
17225	**1993**	5 Prestressed Concrete	05 Multiple Box Beam	1 Monolithic Concrete	**6**		6%	13%	50%	0%	85%
08167	**1960**	5 Prestressed Concrete	02 Stringer/Girder	1 Monolithic Concrete	**6**		6%	8%	42%	0%	

Table 2

CS2 > GPR Defects, IR Delams > CS3

Initial Results – I-84 Chlorides

BRIDGE_ID	YEARBUILT	MATERIALMAIN	DESIGNMAIN	DKSURFTYPE	DKRATING	Notes	INF_Del	INF_GPR	CS2	CS3	DK_HI
09635A	**1972**	4 Steel Continuous	02 Stringer/Girder	1 Monolithic Concrete	**5**		8%	12%	58%	21%	78%
09632	**1972**	4 Steel Continuous	02 Stringer/Girder	5 Epoxy Overlay	**6**		9%	11%	1%	0%	100%
09632A	**1972**	4 Steel Continuous	02 Stringer/Girder	5 Epoxy Overlay	**6**		3%	9%	2%	0%	99%
02063	**1969**	4 Steel Continuous	02 Stringer/Girder	1 Monolithic Concrete	**6**		5%	20%	12%	0%	
02062B	**1962**	2 Concrete Continuous	05 Multiple Box Beam	3 Latex Concrete/Similar	**7**		5%	26%	25%	0%	
09631A	**1972**	2 Concrete Continuous	01 Slab	5 Epoxy Overlay	**7**		6%	26%	7%	0%	
09382	**1969**	4 Steel Continuous	02 Stringer/Girder	5 Epoxy Overlay	**7**		6%	17%	13%	0%	
19865	**2004**	4 Steel Continuous	02 Stringer/Girder	1 Monolithic Concrete	**7**		11%	10%	18%	0%	
20743	**2009**	5 Prestressed Concrete	05 Multiple Box Beam	1 Monolithic Concrete	**7**	Infrared effectiveness limited due to depth of rebar >4.5 inches	2%	10%	1%	1%	97%
20742	**2009**	5 Prestressed Concrete	05 Multiple Box Beam	1 Monolithic Concrete	**7**	Significant amount of debris along both shoulders	8%	5%	14%	5%	93%

Table 3

GPR Defects, IR Delams > CS2

09635A – Outlier, (CS2 cracking/ CS3 Rutting)

Initial Results – Others w/ Overlay

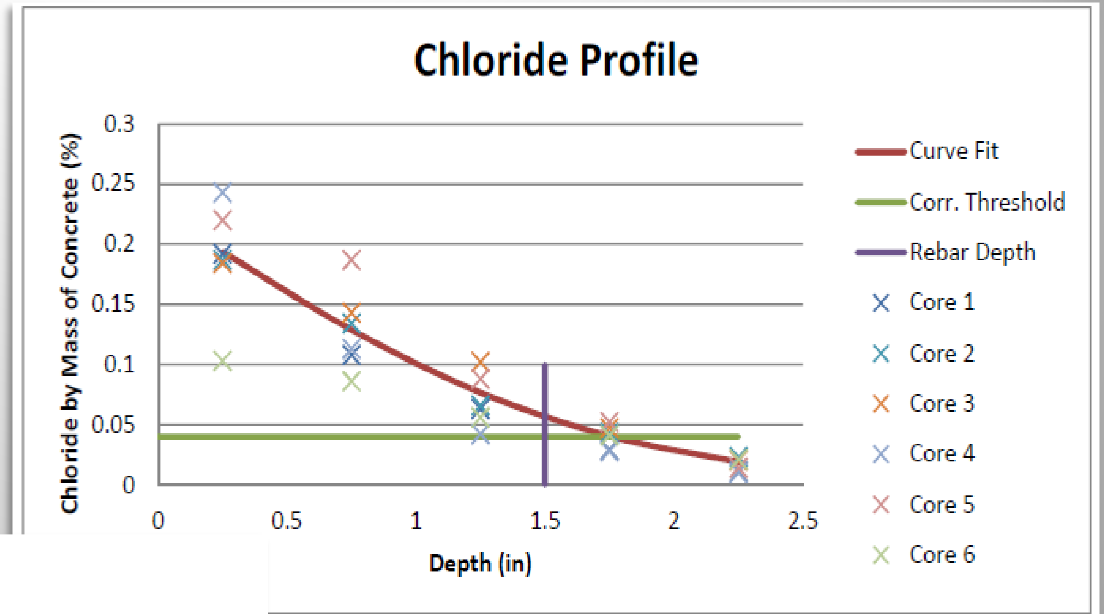
BRIDGE_ID	STRUCNAME	YEARBUILT	MATERIALMAIN	DESIGNMAIN	DKSURFTYPE	DKRATING	Notes	INF_Del	INF_GPR	CS2	CS3	DK_HI
17477	Hwy 1 over Turner-Sunnyside Rd	**1997**	6 P/S Conc Continuous	01 Slab	3 Latex Concrete/Similar	**5**		5%	6%	7%	1%	
01417N	Tualatin River, Hwy 1W NB	**1955**	2 Concrete Continuous	03 Girder-Floorbeam	3 Latex Concrete/Similar	**5**	A few large shadows from trees	10%	14%	6%	44%	69%
01377A	Columbia R & N Hayden Isl Dr, Hwy1 NB (Interstate)	**1916**	3 Steel	15 Movable - Lift	3 Latex Concrete/Similar	**5**	Patching primarily concentrated in the inside lanes of both directions.		19%	32%	2%	90%
07864A	Hwy 1 over 16th Street (Landess Rd)	**1956**	2 Concrete Continuous	04 Tee Beam	3 Latex Concrete/Similar	**6**		6%	9%	1%	14%	
08221A	Hwy 1 NB over Knox Butte Rd (North Albany Intchg)	**1958**	2 Concrete Continuous	04 Tee Beam	5 Epoxy Overlay	**6**		4%	9%	4%	1%	
08221B	Hwy 1 NB over Hwy 58 NB (North Albany Intchg)	**1958**	2 Concrete Continuous	04 Tee Beam	5 Epoxy Overlay	**6**		3%	10%	17%	5%	
07865A	Hwy 1 over Taylor Ave	**1956**	2 Concrete Continuous	04 Tee Beam	5 Epoxy Overlay	**6**		7%	9%	2%	45%	75%
08828	Hwy 9 over POTB RR at MP 59.32	**1962**	2 Concrete Continuous	04 Tee Beam	5 Epoxy Overlay	**6**	IR data limited due to extensive tree shadows.	7%	14%	11%	0%	
02349	Lake Lytle Outlet, Hwy 9	**1938**	7 Wood or Timber	02 Stringer/Girder	3 Latex Concrete/Similar	**6**	Large shadow from tree in southbound lane	12%	13%	4%	0%	98%
07333	Columbia R & N Hayden Isl Dr, Hwy1 SB (Interstate)	**1958**	3 Steel	15 Movable - Lift	3 Latex Concrete/Similar	**6**	Truss structure obstructs deck from obtaining consistent solar heating	NA	8%	18%	9%	
08583	Hwy 1 over NE Hassalo St & NE Holladay St	**1963**	5 Prestressed Concrete	02 Stringer/Girder	5 Epoxy Overlay	**6**		5%	14%	16%	4%	99%
08203B	Hwy 1 over SW 26th Ave	**1959**	2 Concrete Continuous	04 Tee Beam	3 Latex Concrete/Similar	**6**		7%	13%	31%	15%	
08227N	Oak Creek, Hwy 1 NB	**1958**	2 Concrete Continuous	04 Tee Beam	5 Epoxy Overlay	**6**		2%	7%	5%	0%	
02062A	Tanner Creek, Hwy 2 WB	**1950**	2 Concrete Continuous	02 Stringer/Girder	3 Latex Concrete/Similar	**7**		4%	20%	36%	15%	79%

Table 4

CS2 > GPR Defects, IR Delams > CS3

Initial Results – Bridge 02071A

Coring indicates chloride content *above* initiation threshold—not indicated with high-speed GPR scans



hloride Concentrations (Curve Fit, 6 Cores)

Chart 5 *Evaluation of in-service Bridge Decks using Chloride Analysis*[5]

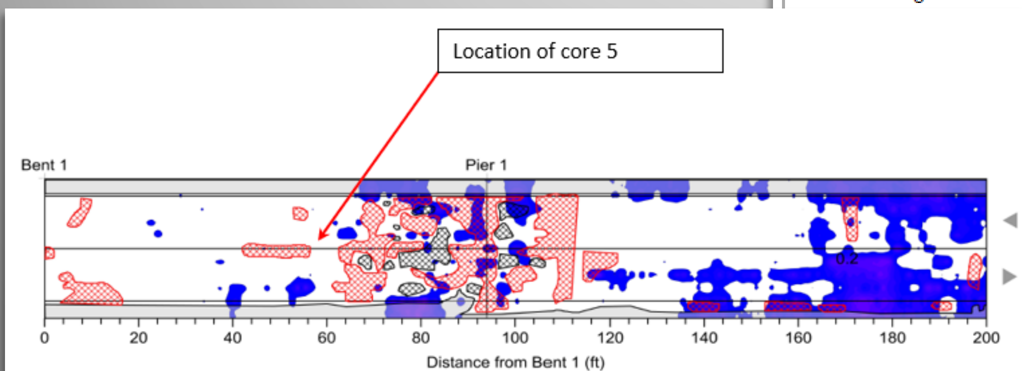


Figure 9

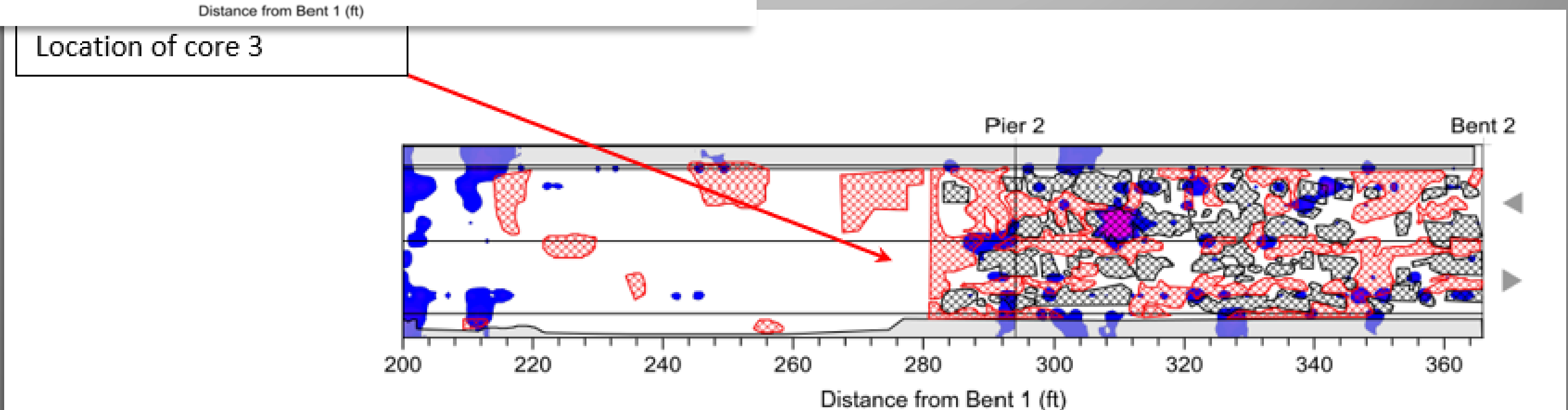


Figure 10

Image 4: Coring the NB Interstate Bridge

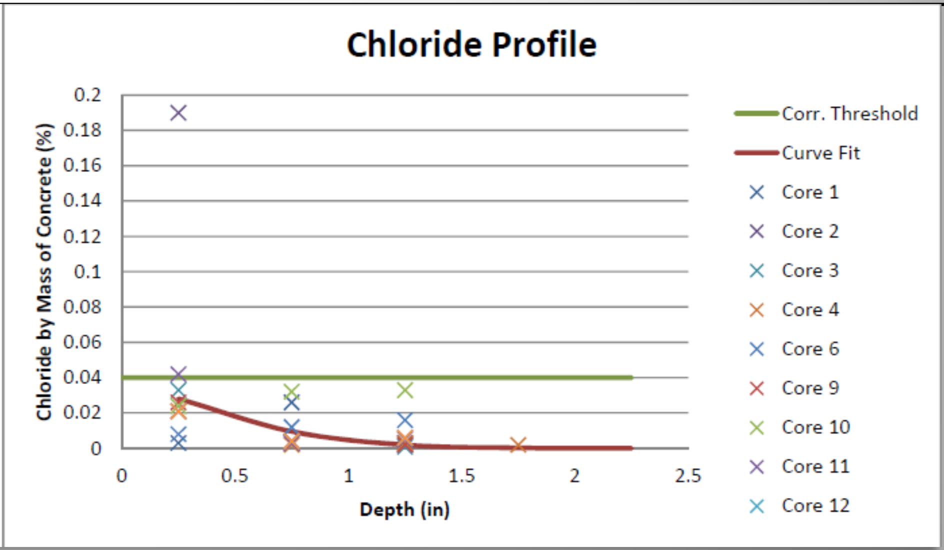


Chart 6 *Evaluation of in-service Bridge Decks using Chloride Analysis*[5]

Cores 3 & 4

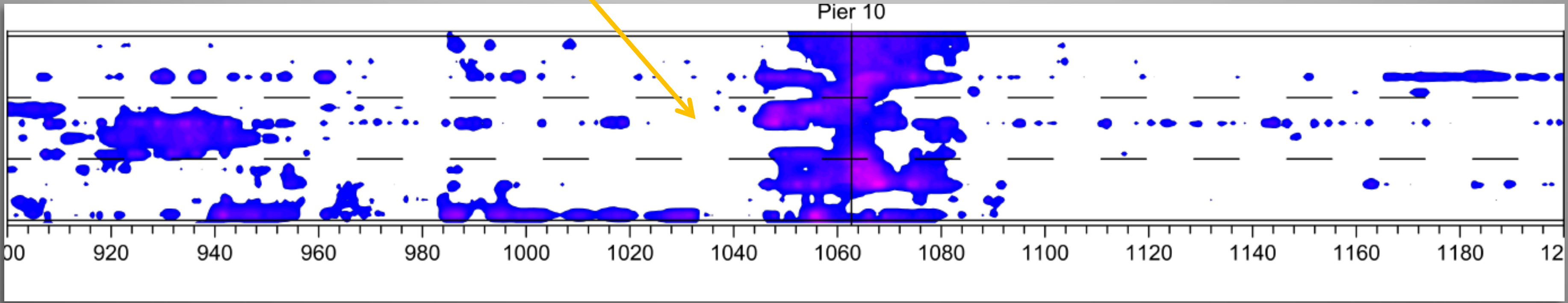


Figure 12

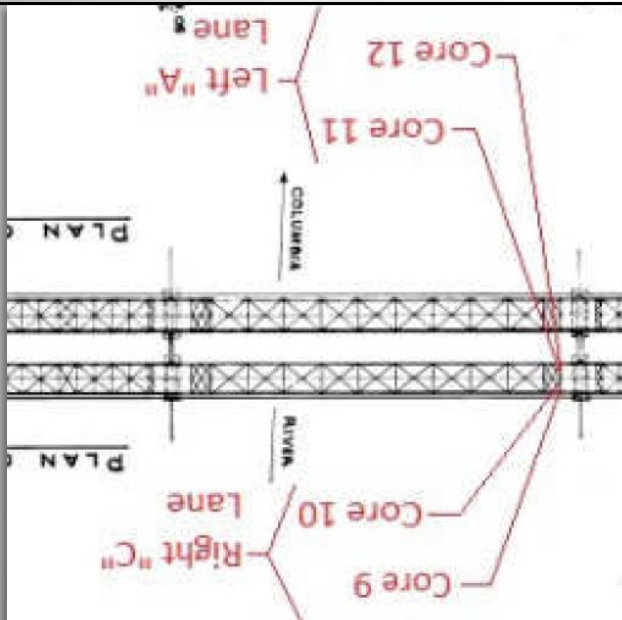


Figure 13

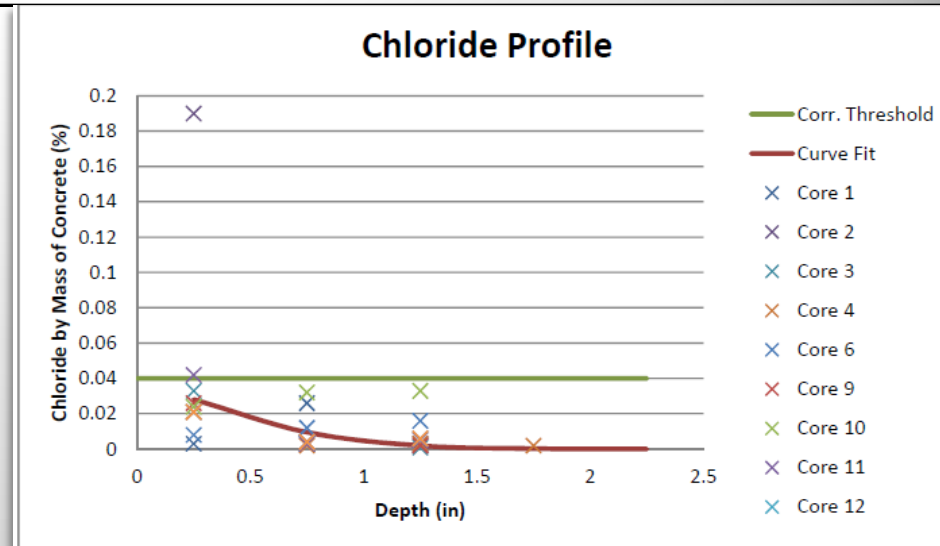


Chart 6 *Evaluation of in-service Bridge Decks using Chloride Analysis*[5]

Cores 11,12

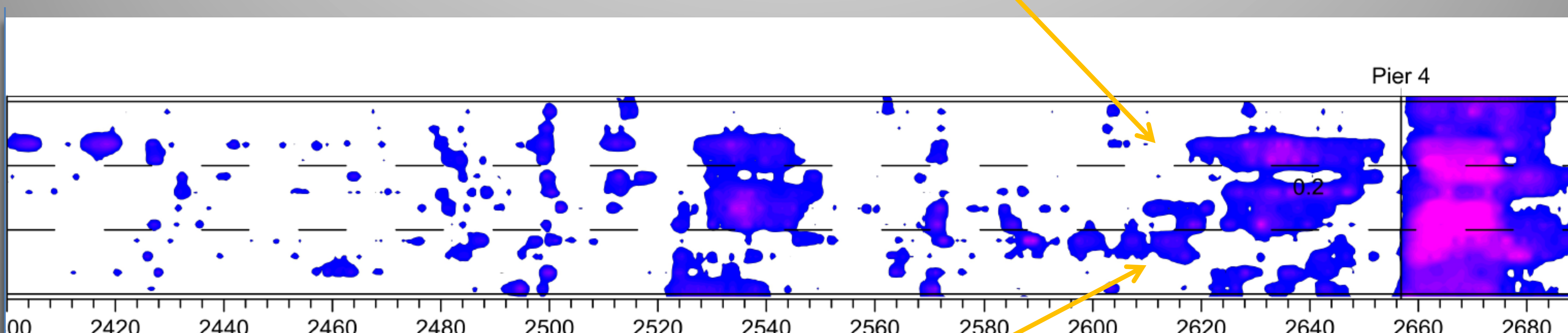


Figure 14

Cores 9,10

Coring indicates chloride content *below* initiation threshold—not indicated with high-speed GPR scans

4 samples (locations unknown)

ADT: 66,150 (NB Only)

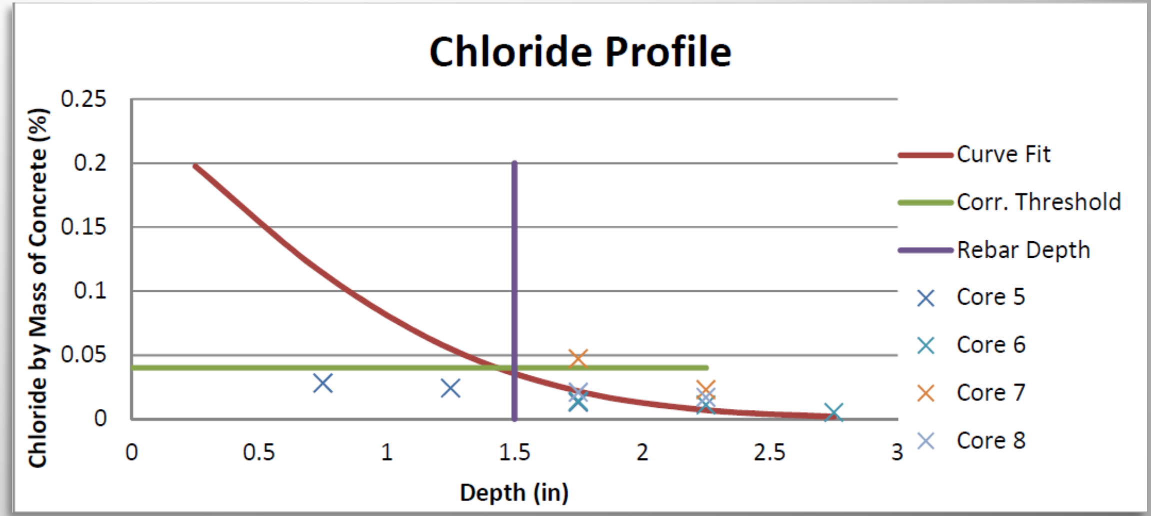


Chart 7 *Evaluation of in-service Bridge Decks using Chloride Analysis*[5]

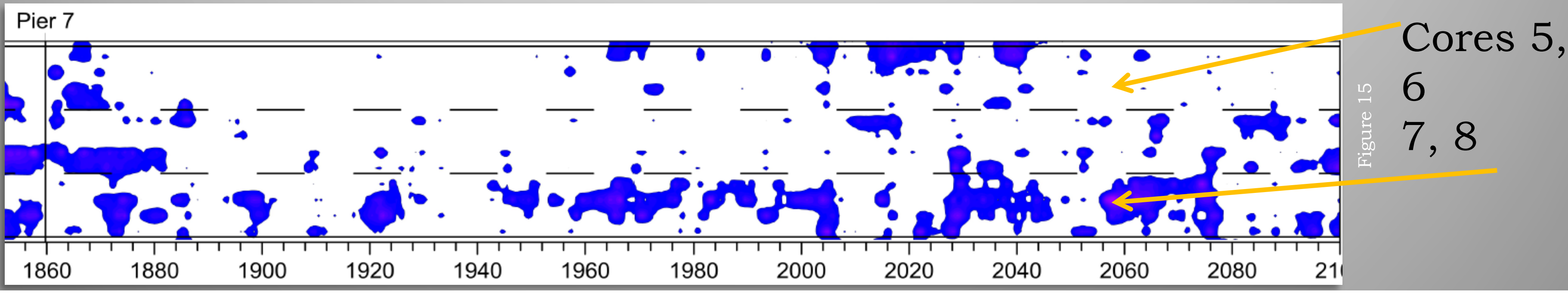


Figure 15

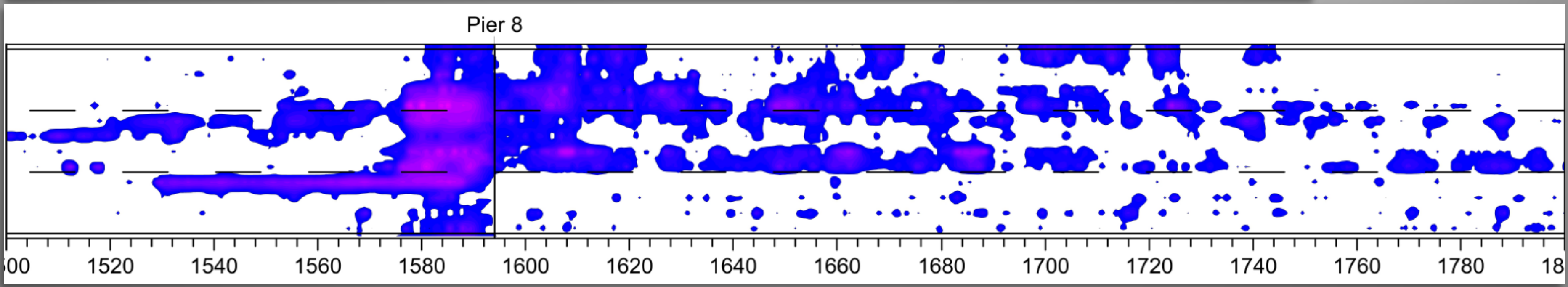


Figure 16

Results – Field Validation – Bridge 02349

Image 5: chain drag and impact echo on Br 023948

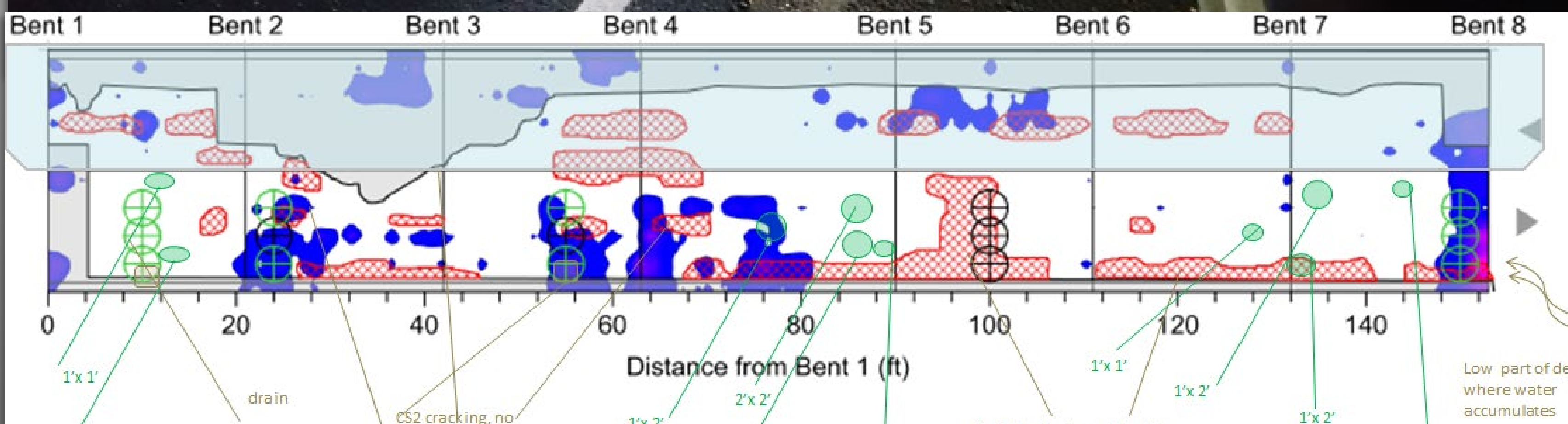


Figure 17

Results – Field Validation – Bridge 07832

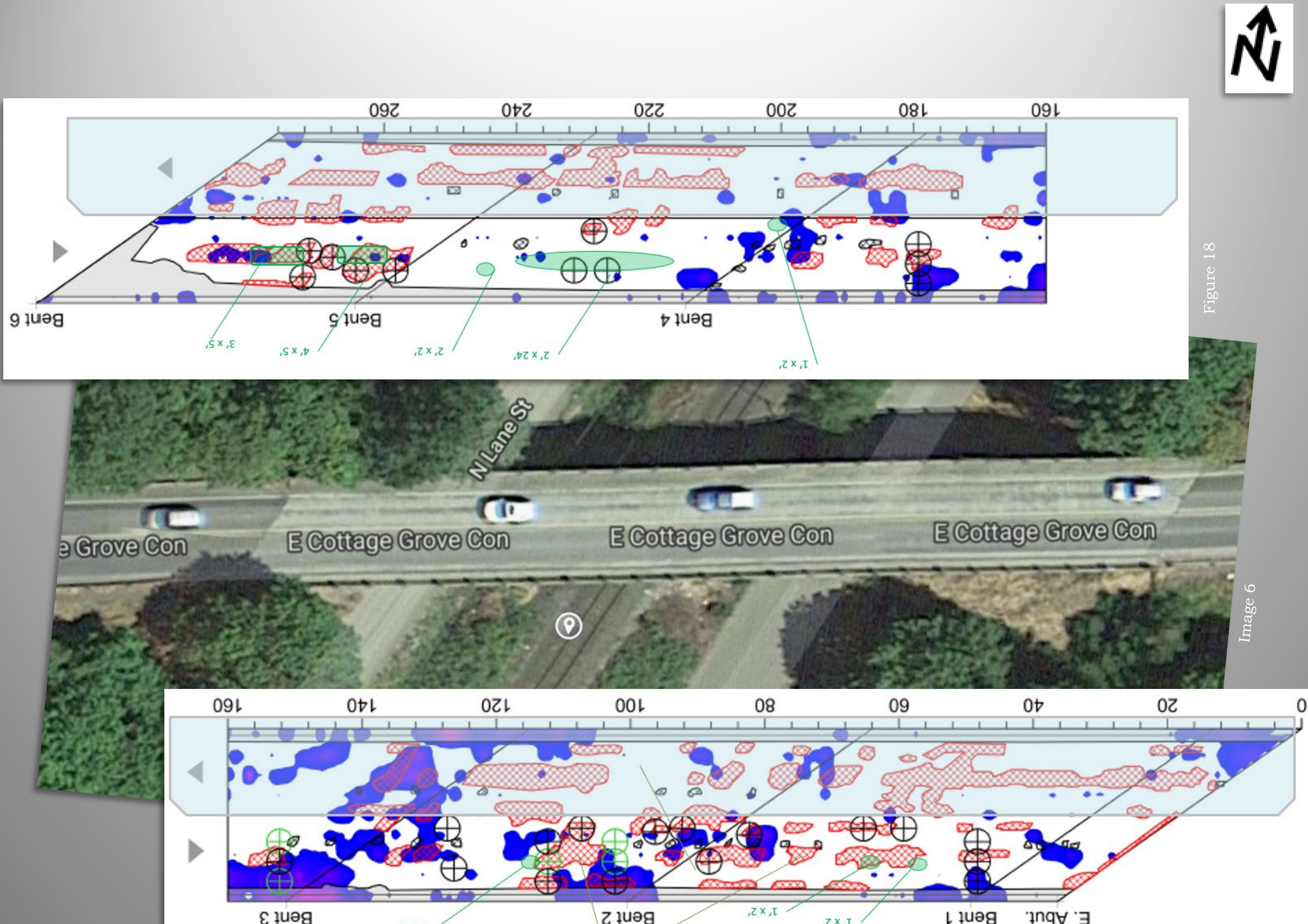


Figure 18

Image 6

Figure 19

Results – Field Validation – Bridge 01417N

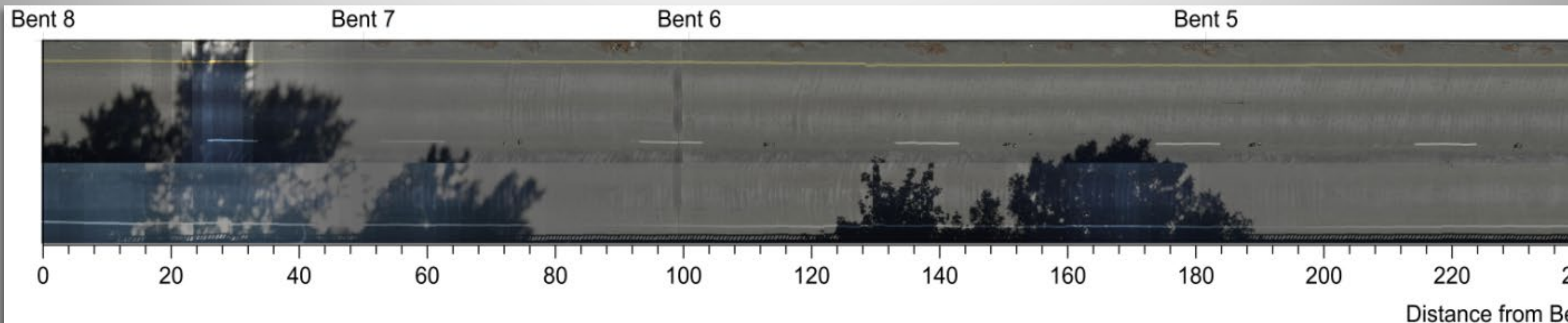


Image 7

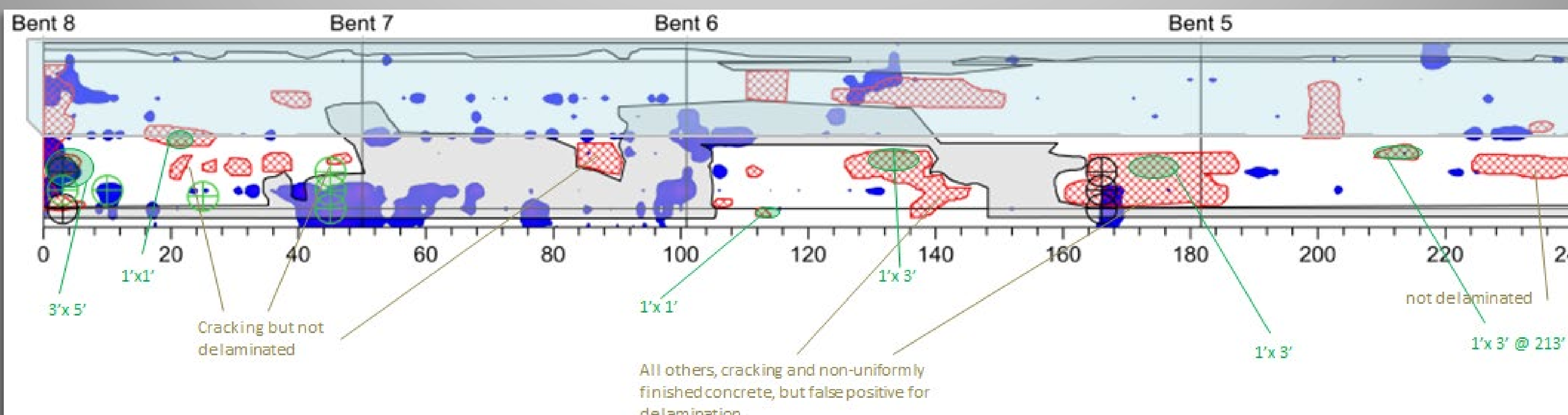


Figure 20

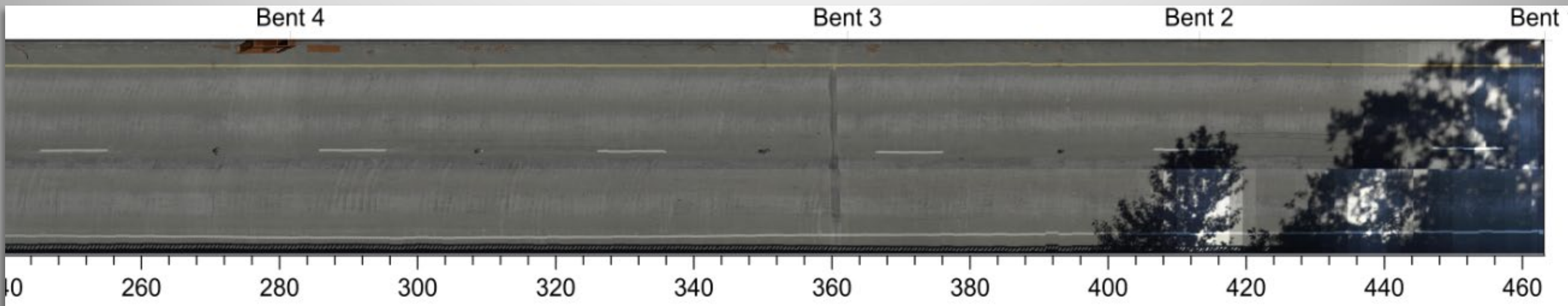


Image 8

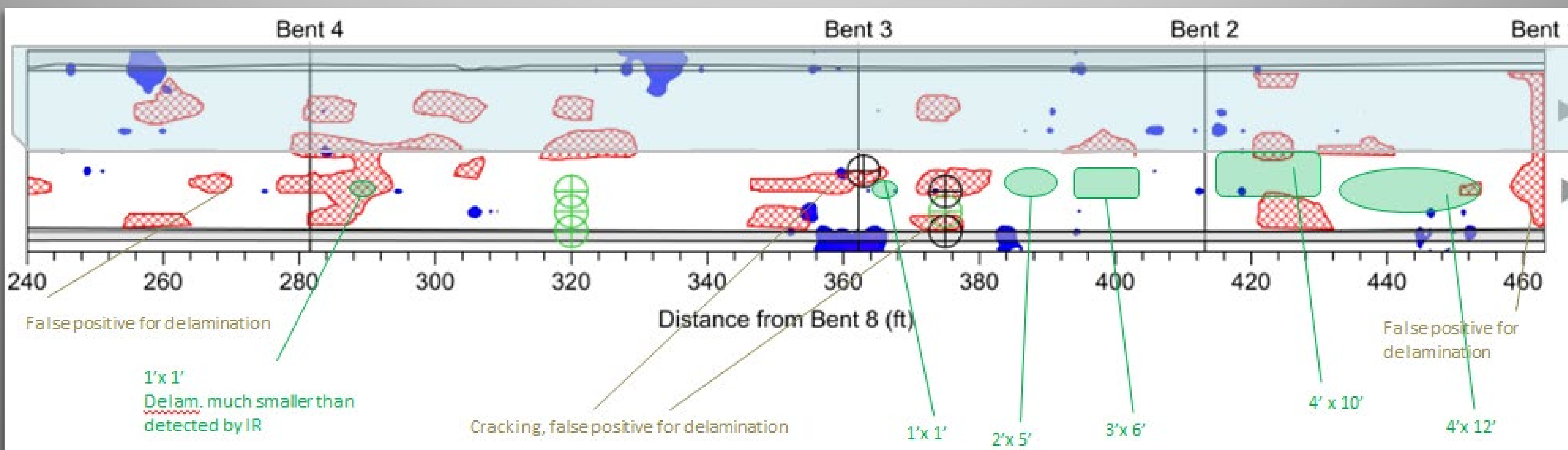


Figure 21

Results – Impact Echo Tools

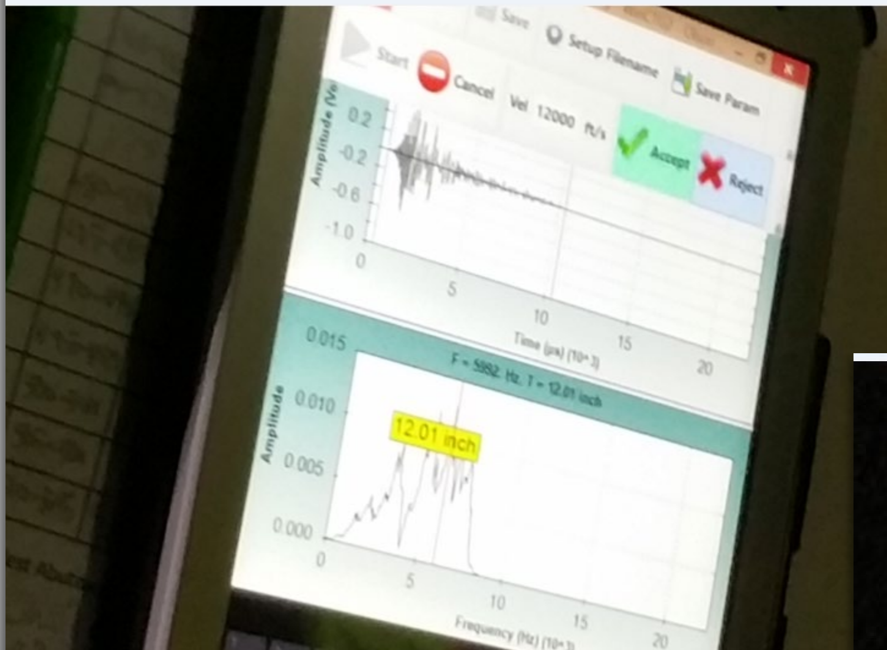


Image 9

ASTM C1383-15
P-Wave speed/ Thickness Measurement in concrete slabs

Olson Instruments NDE 360 unit and CTG-2 unit

$$Thickness := \frac{C_{p\_plate}}{2f}$$

Figure 22

"A typical velocity [C_{p_plate}] for concrete (12,000 ft/s)"

$C_{p\_plate} = 0.96\ C_p$

$= 0.96 * \text{P-wave speed}$

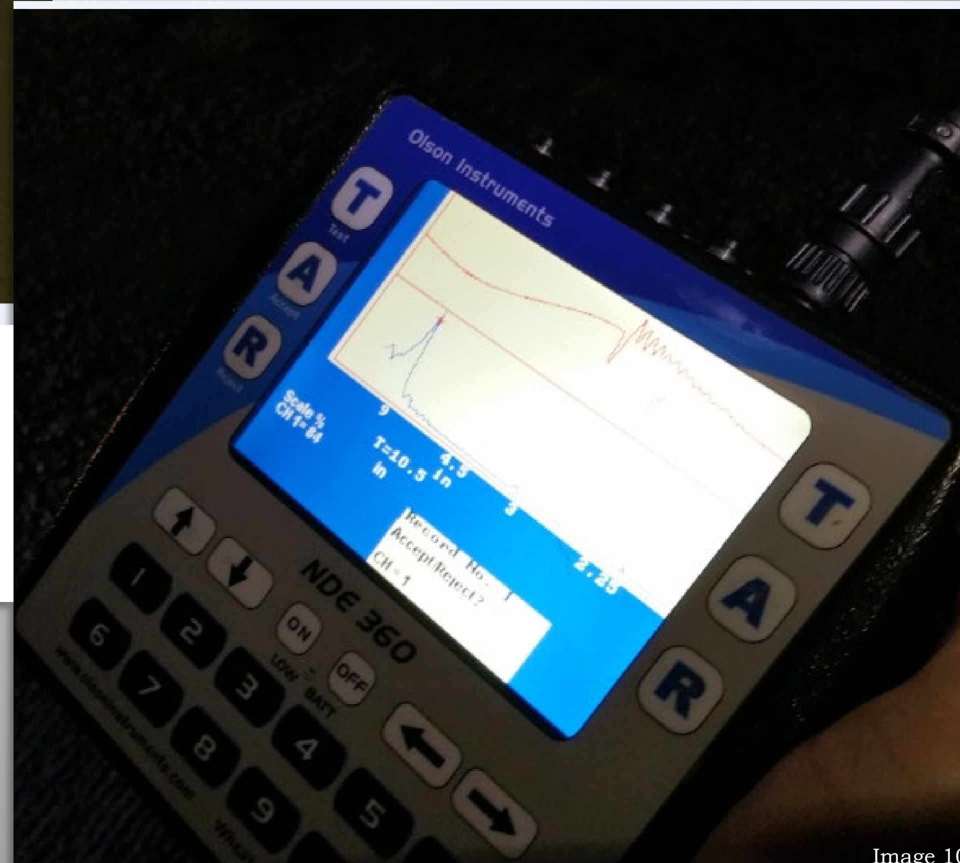


Image 10

Results – Field Validation

Bridge	Area surveyed (ft^2)	ODOT DELAM (ft^2)	% delam'ed	Matches Infrasense (ft^2)	% matching	% False negative	Infrasense Delam. (ft^2)	% delam'ed	Matches ODOT (ft^2)	% matching	% False Positive
01417N	6496	173	2.66%	64.8	37.5%	62.5%	740	11.39%	65	8.8%	91.2%
08958F	17340	40	0.23%	29	72.5%	27.5%	1018	5.87%	29	2.8%	97.2%
02349	1836	15	0.82%	3	20.0%	80.0%	268	14.60%	3	1.1%	98.9%
08828	2880	65	2.26%	54	83.1%	16.9%	288	10.00%	54.4	18.9%	81.1%
09382	27000	1629	6.03%	1284.4	78.8%	21.2%	3132	11.60%	1283.9	41.0%	59.0%
20742	2200	2	0.09%	0	0.0%	100.0%	150	6.82%	0	0.0%	100.0%
08254	2238	115	5.14%	69.4	60.3%	39.7%	96	4.29%	70.1	73.0%	27.0%
17225	4830	2	0.04%	0.5	25.0%	75.0%	278	5.76%	1	0.4%	99.6%
07832	3312	102	3.08%	14	13.7%	86.3%	261	7.88%	14.8	5.7%	94.3%
07404	13200	75	0.57%	12	16.0%	84.0%	596	4.52%	11.2	1.9%	98.1%

Table 5

Chain Drag Results vs Infrared Scanning to determine delamination quantities/ location
November 27- December 2, 2017

Measurements ±10%

Routine Inspection:
Thin Overlay Recommended
(CS2 Efflorescence
Polished aggregates in wheel paths
Extensive CS1 Cracking)

SOUTH UMPQUA RIVER (VETS) - BR# 07404 - HWY 1 SB - MP: 124.54 SIDE ELEVATION

SOUTH UMPQUA RIVER (VETS) - BR# 07404 - HWY 1 SB - MP: 124.54 ON-LINE ROADWAY VIEW

Deck sealed previously

Results – Vets Bridge (07404) I-5 over S. Umpqua River

Conditions: 42°, foggy, moderate fast traffic

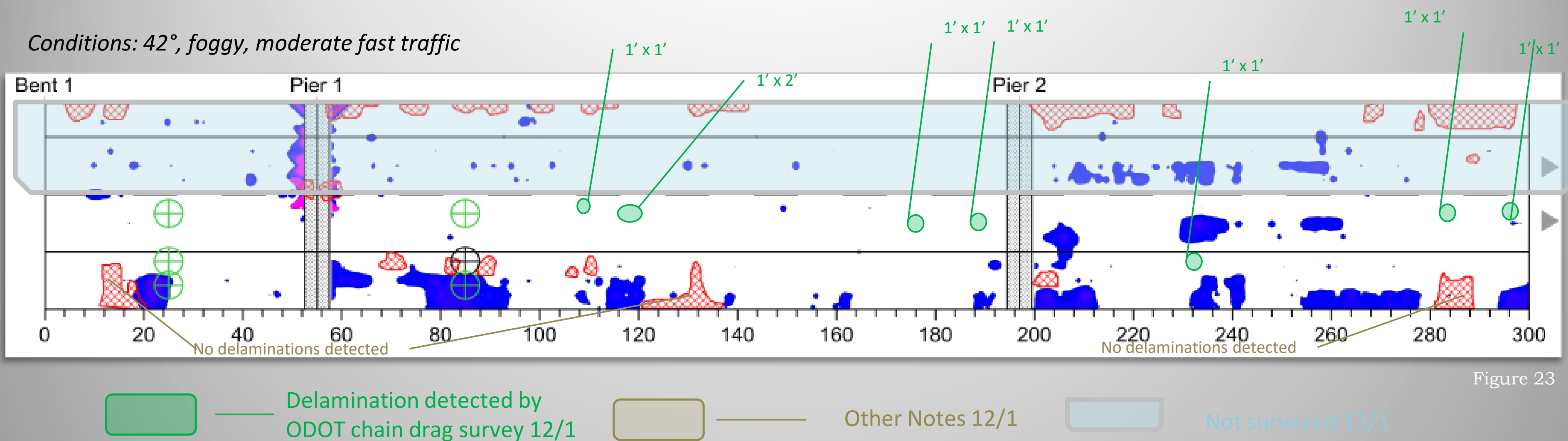


Figure 23

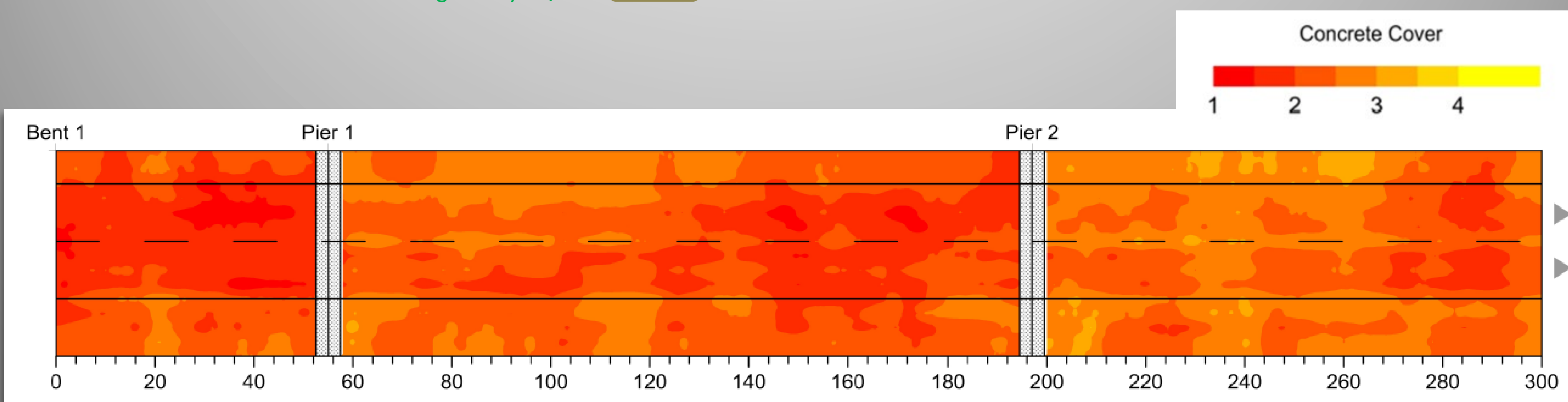


Figure 24

Concrete Condition Legend		Orientation	Quantity Summary			General Information
Deterioration detected by GPR	Delamination detected by IR		Condition	sq. ft.	%	Bridge ID: 07404 I-5 SB over S Umpqua R
IE (delam)	Patching		Delamination (IR)	1611	5.5	Analyzed by: GC/JC Reviewed by: EG Completed: 1 of 3
IE (no delam)	Not detectable by IR / GPR	Direction of traffic	Deterioration (GPR)	2084	7.1	Sheet 1 of 1
			Patching (Visual)	NA	0.0	INFRASENSE

Conditions: 42°, foggy, moderate fast traffic

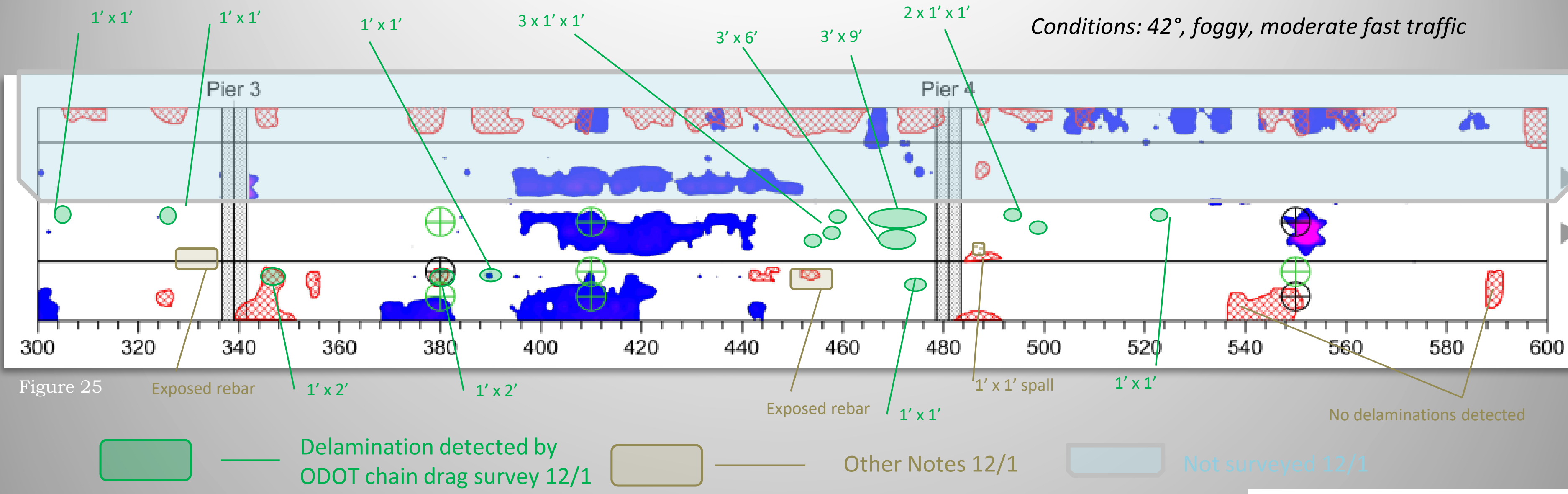


Figure 25

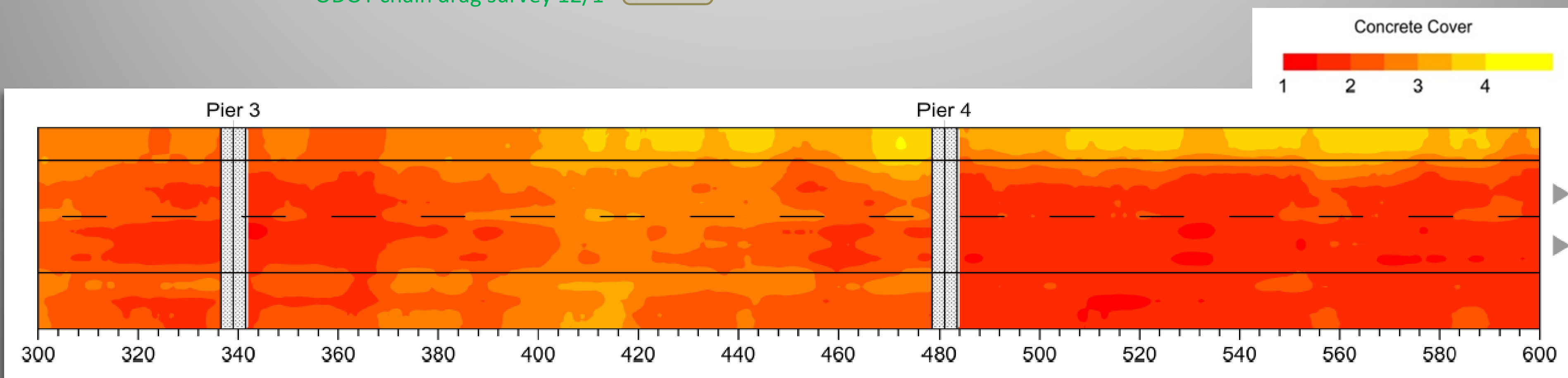


Figure 26

Concrete Condition Legend

- Deterioration detected by GPR (severity →)
- Delamination detected by IR
- IE (delam)
- Patching
- IE (no delam)
- Not detectable by IR / GPR

Orientation

Direction of traffic

Quantity Summary

Condition	sq. ft.	%
Delamination (IR)	1611	5.5
Deterioration (GPR)	2084	7.1
Patching (Visual)	NA	0.0

General Information

Bridge ID: 07404
I-5 SB over S Umpqua R

Analyzed by: GC/JC
Reviewed by: EG
Completed: 8/30/17

Sheet 2 of 3

INFRASENSE

Results – Vets Bridge (07404) I-5 over S. Umpqua River

What is this?

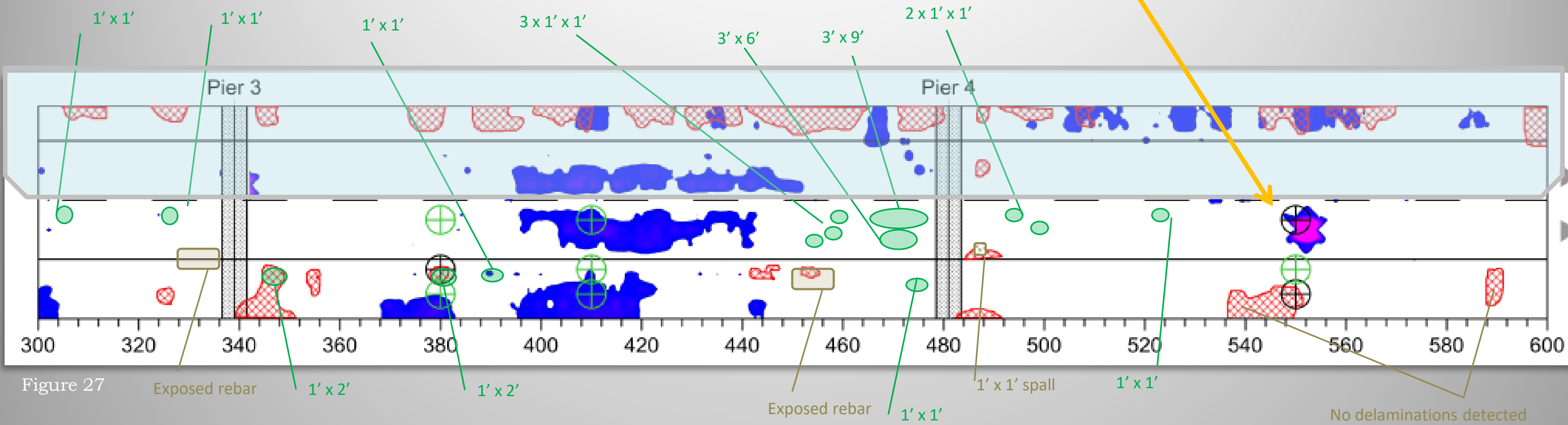


Figure 27

Delamination detected by ODOT chain drag survey 12/1

I didn’t see anything on the surface. I dragged my chain over it several times,

Although this isn’t the exact spot, this could be what’s going on (report recommended patching several like it)

Conditions: 42°, foggy, moderate fast traffic

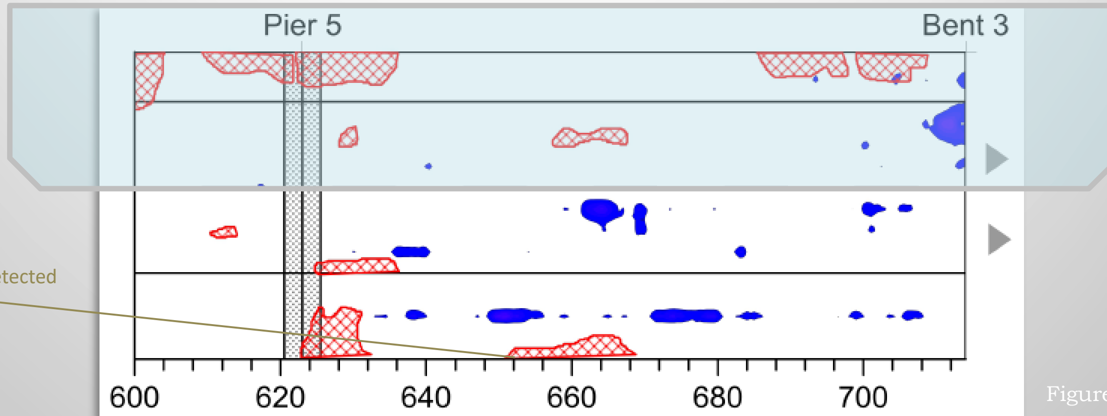


Figure 28

Delamination detected by ODOT chain drag survey 12/1

Other Notes 12/1

Not surveyed 12/1

Vets Bridge (I-5 near Roseburg) Monolithic Concrete – Deck Truss

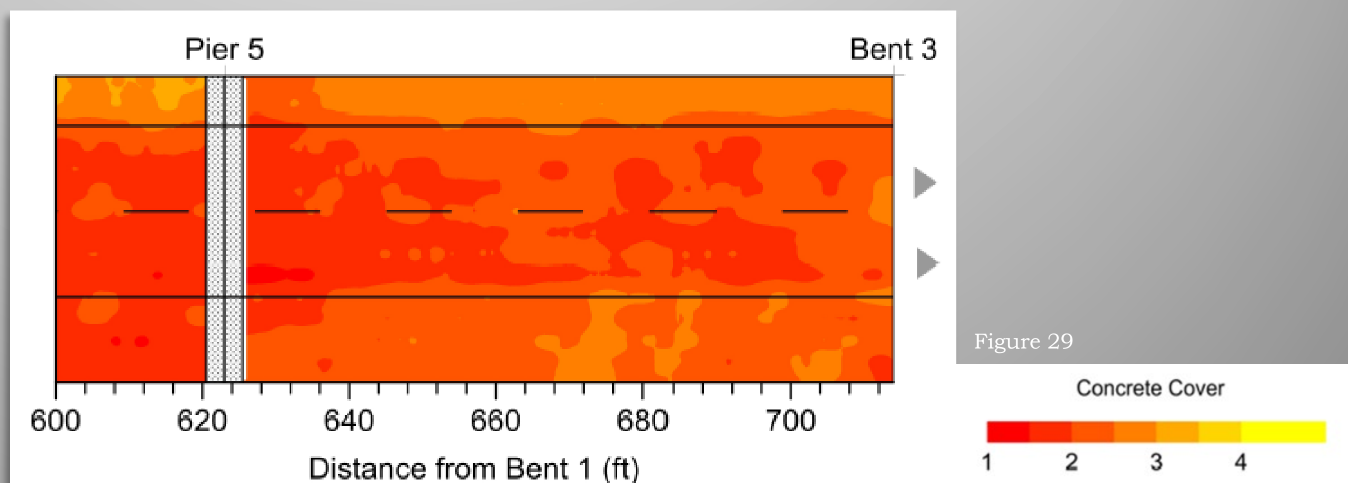


Figure 29

Concrete Condition Legend		Orientation	Quantity Summary			General Information
Deterioration detected by GPR	Delamination detected by IR		Condition	sq. ft.	%	Bridge ID: 07404 I-5 SB over S Umpqua R
IE (delam)	Patching		Delamination (IR)	1611	5.5	Analyzed by: GC/JC Reviewed by: EG
IE (delam)			Deterioration (GPR)	2084	7.1	Comple 3 of 3
IE (no delam)	Not detectable by IR / GPR	Direction of traffic	Patching (Visual)	NA	0.0	Sheet 1 of 1

INFRASENSE

Image 12

Shade from a Cottonwood (?)
South end
~ 6pm summertime

Image 13

Hairline map cracking prior to seal

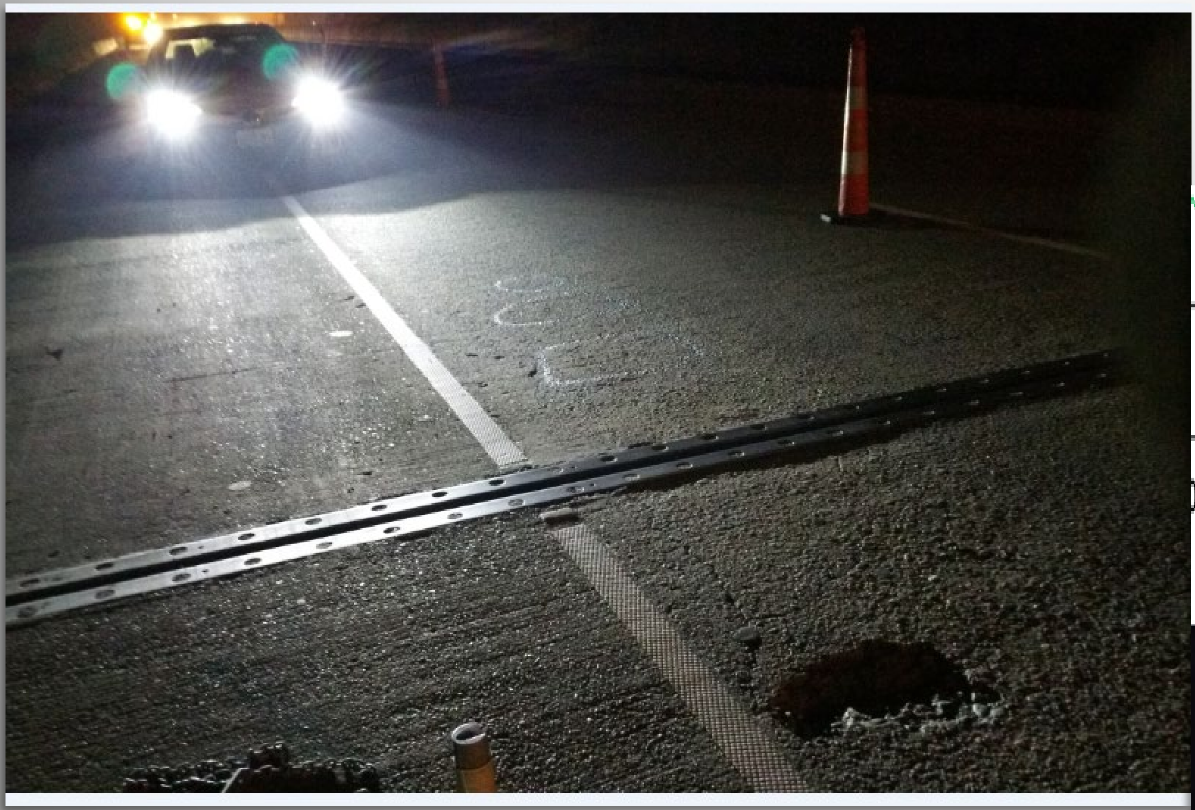


Image 14

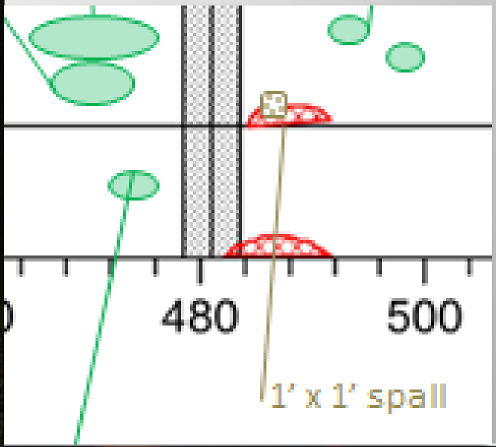


Figure 30

Image 15

Spall with exposed rebar appears as Delam of different shape on map

Results – Vets Bridge (07404) I-5 over S. Umpqua River

VETS Bridge	ODOT$_1$	ODOT$_2$	Vendor$_1$				Final Repair ODOT$_3$
Southbound Only	Chain Drag SB	Routine	Infrared		GPR		SB
Bridge 08203B	Field Data	Inspection	Field Data	Calibrated	Field Data	Calibrated	
Area Surveyed	13200	37039	29300	13200	29300	29300	37039
Delam/Deteriorated	75	15	1573.6	596	2084	2084	390
% Delam/ Deteriorated	0.57%	0.04%	5.37%	4.52%	7.1%	7.1%	**1.05%**
Match	12			11.2			
% Matching	16.0%			1.9%			
False Negative	84.0%						
False Positive				98.1%			
							Table 6

Most repairs on south side of bridge, no class 3 prep

Vets Bridge (07404) I-5 over S. Umpqua River

Image 16

Image 17

Conclusions:

NDE estimates >

actual quantities >

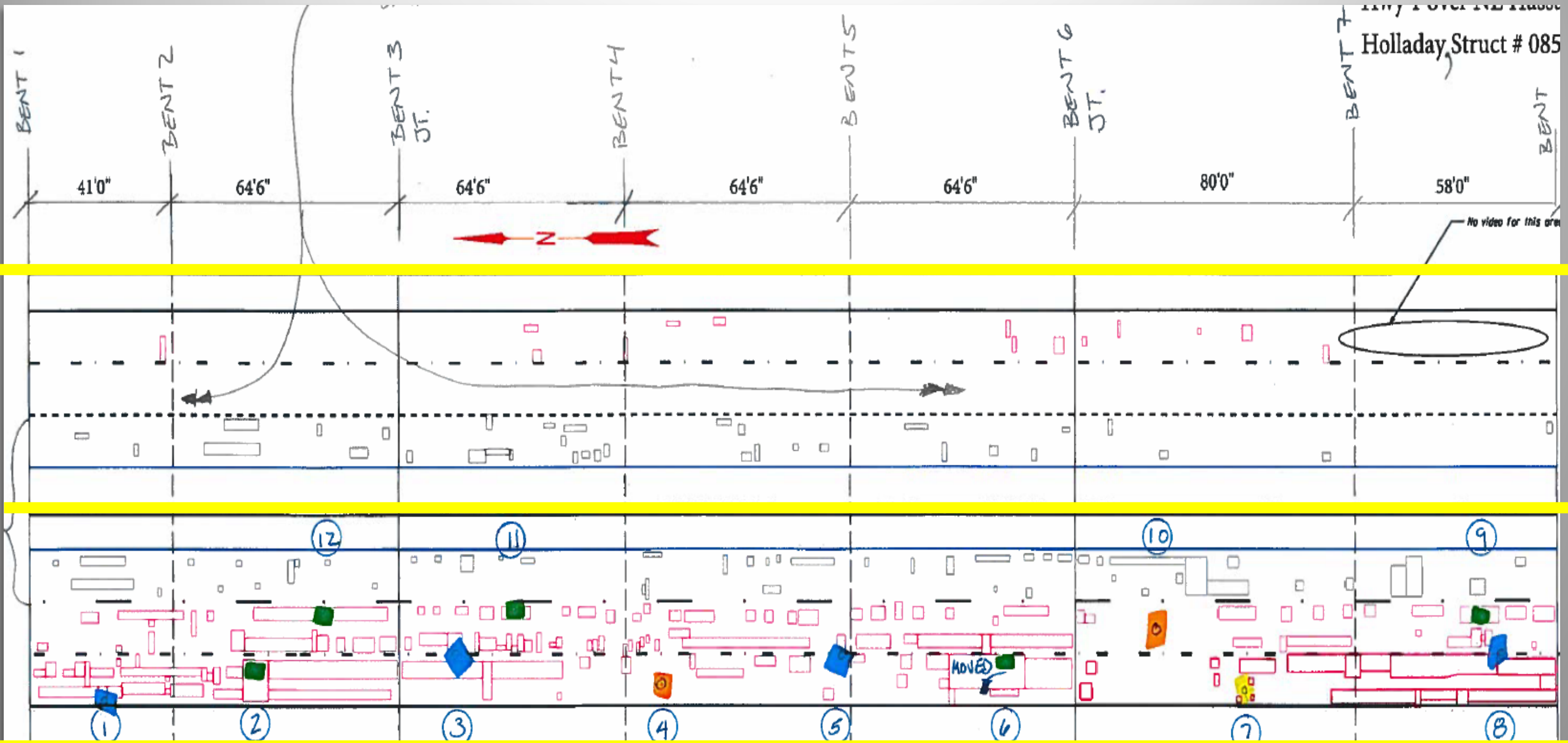
chain drag

Thin wearing surface (25% CS3)
40 ft^2 of CS2 Spalls
1985 overlay
PPC overlay sometime since

Image 18: Looking west toward Moda Center

Image 19

Figure 31



Test location - Distressed area	TOT	5
Test location - Edge of Distressed area	TOT	4
Test location - Non-Distressed area	TOT	2
Test location - Between cluster of markings	TOT	1

TOTAL 12 TESTS

1. Epoxy failed
2. Core broke during drilling ~2" below overlay
3. 146 psi Core broke ~2" below overlay
4. 158 psi
5. Core broke during drilling ~2" below overlay
6. 74 psi Core broke ~1 3/4" below surface
7. 128 psi
8. Core broke during hand tightening of rod into puck
9. 47 psi
10. 143 psi
11. Core broke during drilling ~1 1/2" below overlay
12. 16 psi

Bridge (08583) I-5 over Hassalo & Holladay

Better Delamination Correlation
14% Delamination

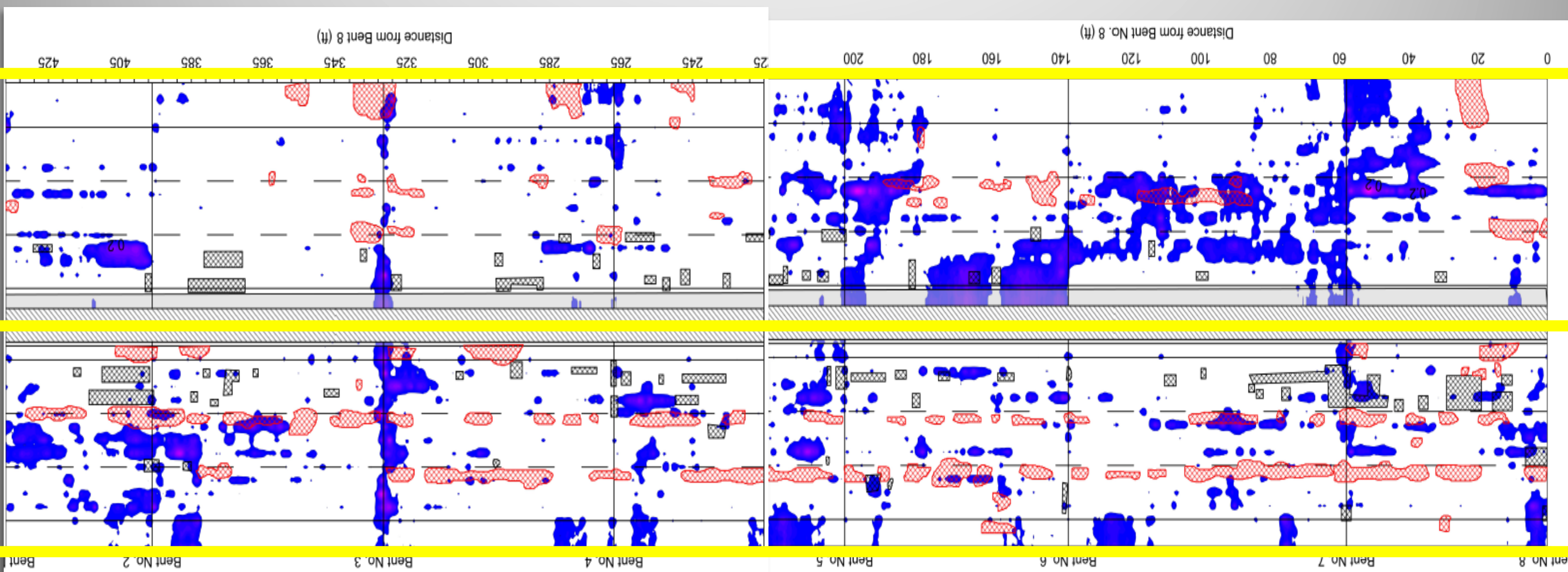


Figure 32

Note slight shifting of well-established patching locations

<u>Conclusions</u>: SB Deck to be replaced (2021)

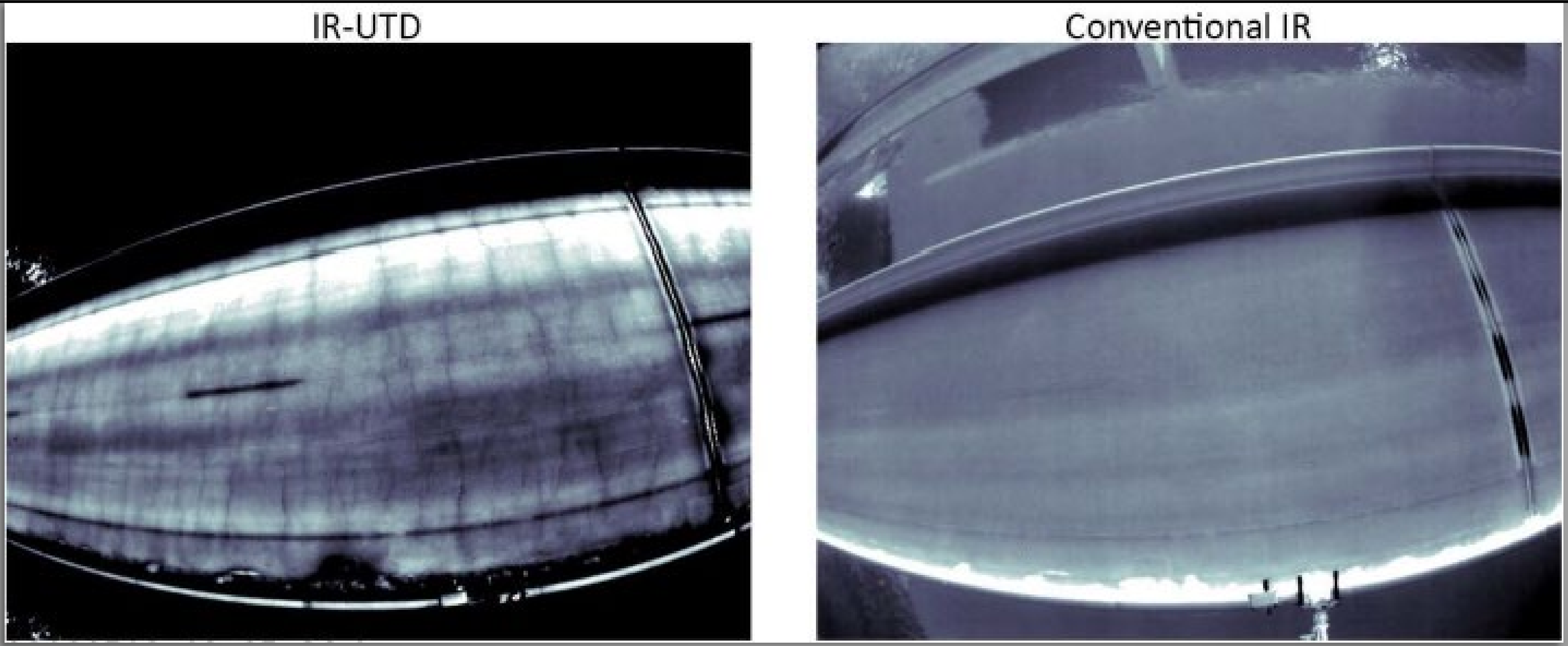


Figure 33

Conventional (static) Infrared vs Long-term Infrared

I-5 over SW 26th Avenue (08203B)

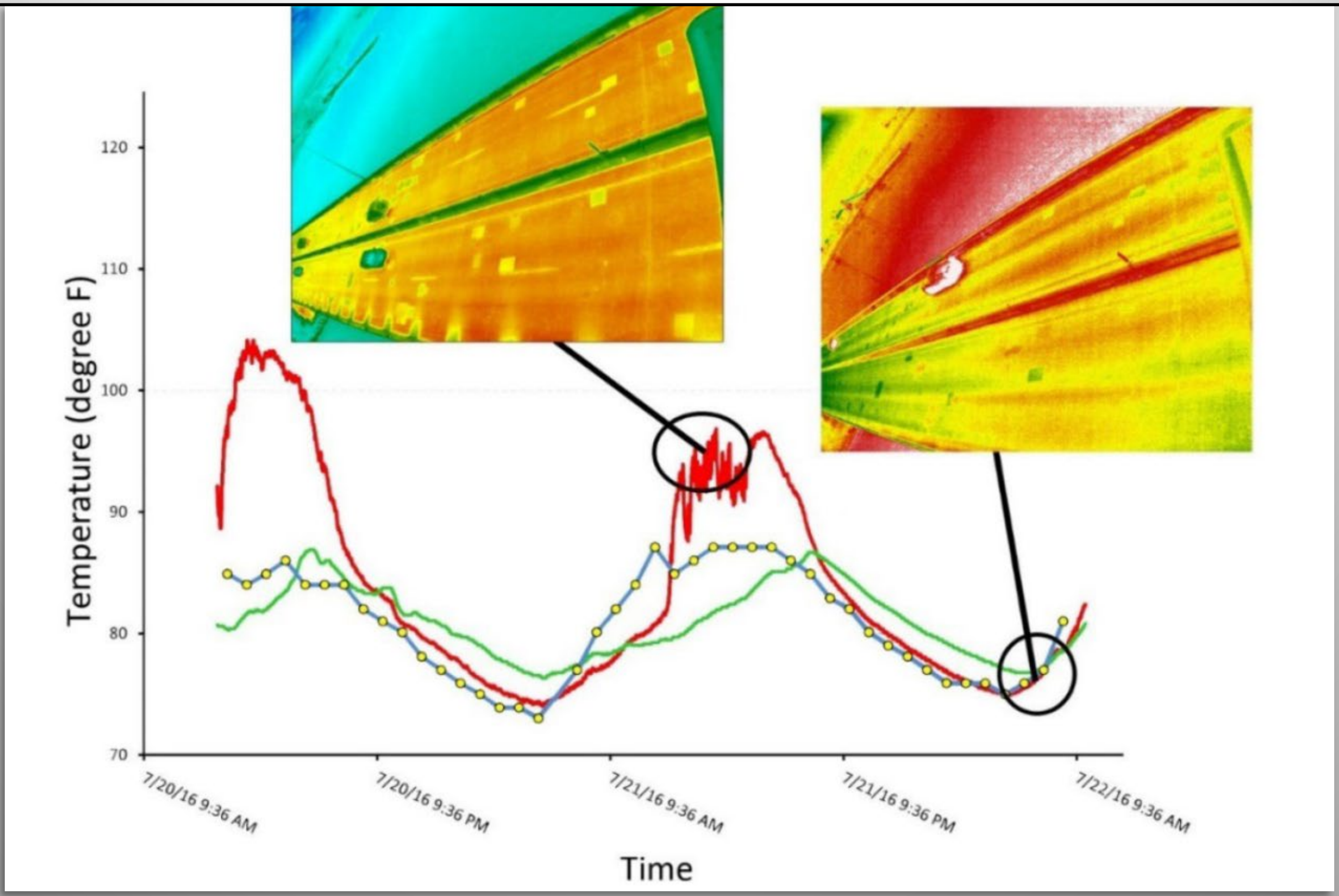


Figure 34

Infrared- “Ultra Time Domain”
Principle: two day/night cycles rather than a sliver of time
To create time-lapsed thermal measurements

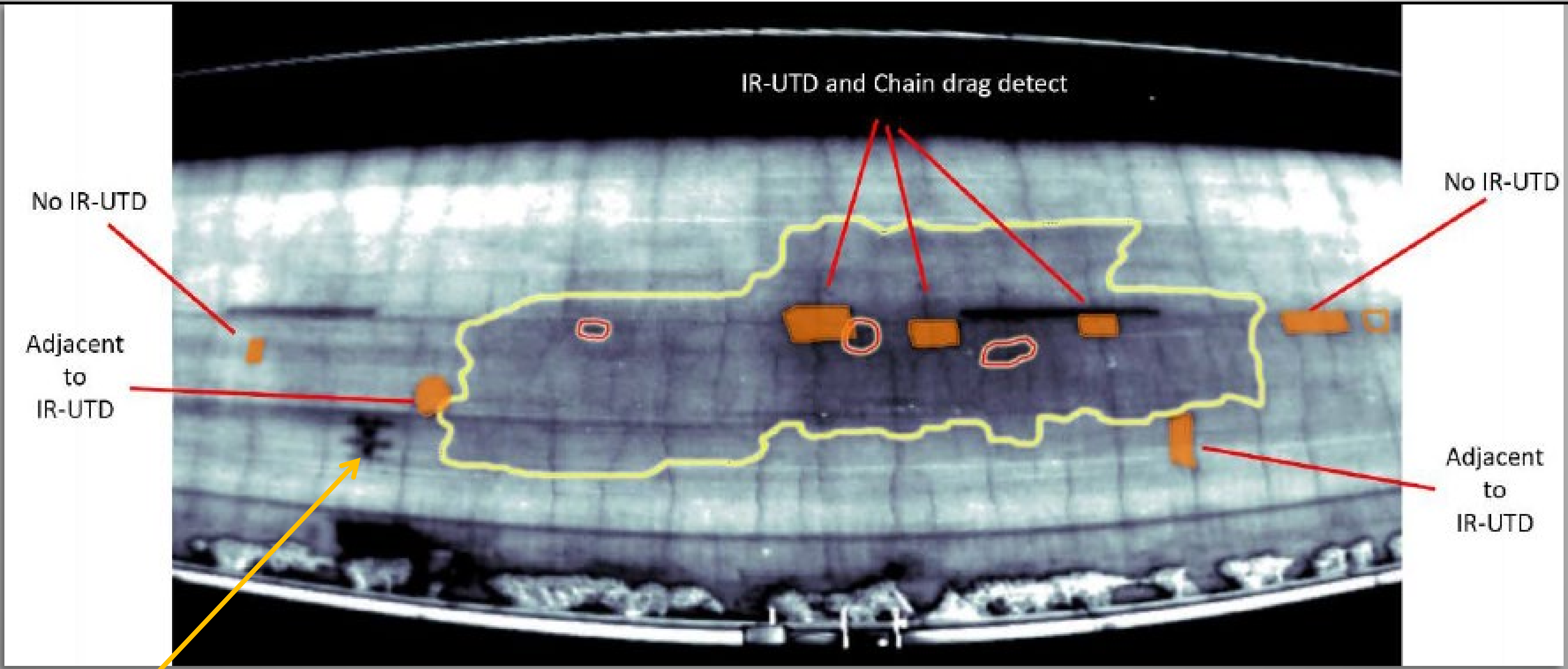


Figure 35

Core locations

- **Chain drag dramatically under-detects defects**
- **Intact cores agreed with IR results**

I-5 over SW 26th Avenue (08203B)

Image 20

Routine Inspection: Top Flange

- 3% CS3 (rust staining)
- 12% CS2 (soffit cracking)
- Spalls, exposed rebar
- LMC overlay Sealed (2104)
- Column spalls & cracks

Three options for bridge based (in part) on NDE results

1. Replace the overlay if deck is sound
2. Apply PPC overlay to extend life 15-20 years
3. Replace the entire bridge

I-5 over SW 26th Avenue (08203B)

- Two, 2-3 hour shoulder closures
  - $1800
- 48 Hour duration

Image 21

Image 22

- Significantly more expensive than high-speed
- ~$1.75/ft²
  vs
- ~¢1.75/ft²

I-5 over SW 26th Avenue (08203B)

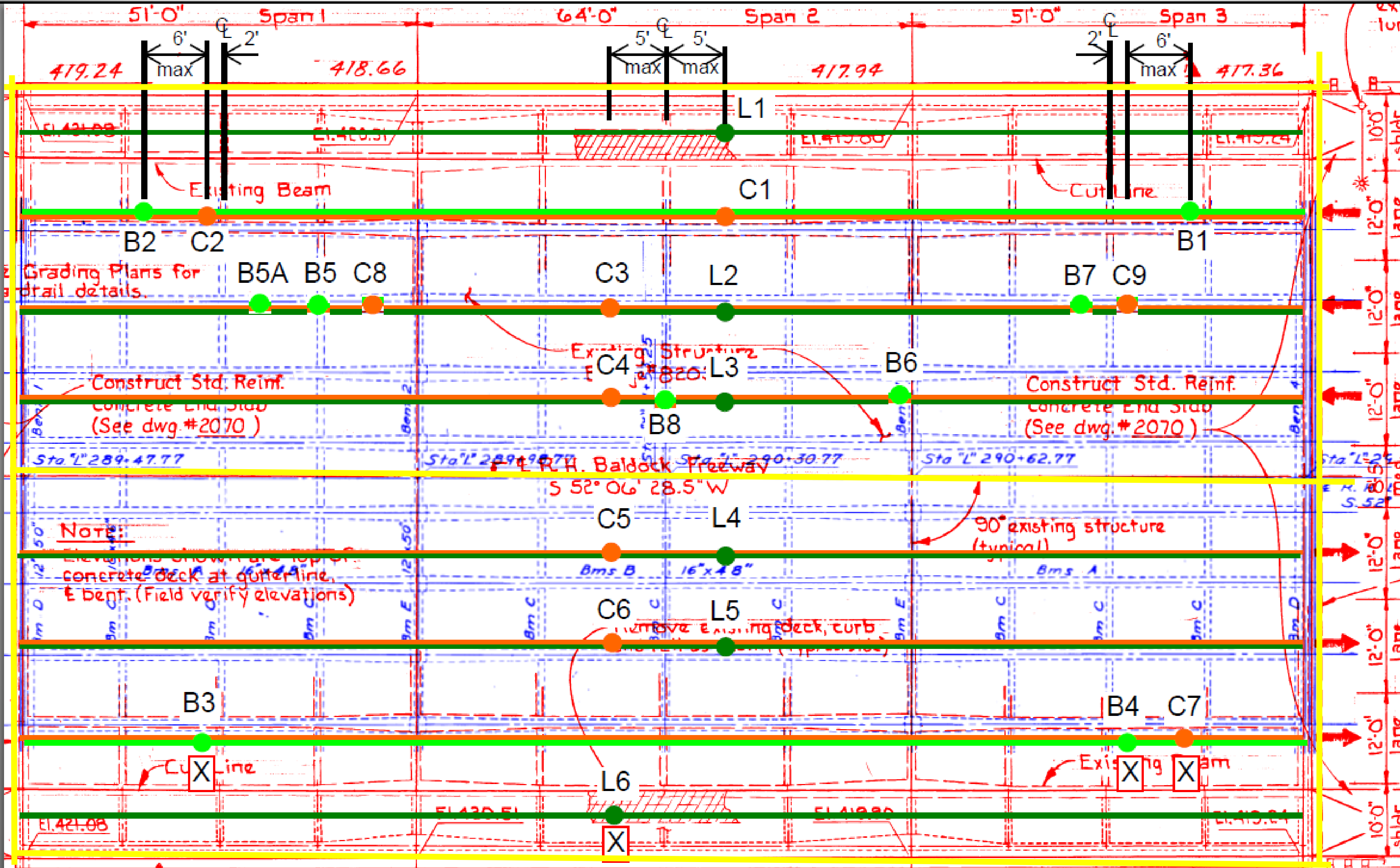


Figure 36

- **Chain drag, coring also performed (outside R06A)**
- **One sample used to calibrate IR-UTD**

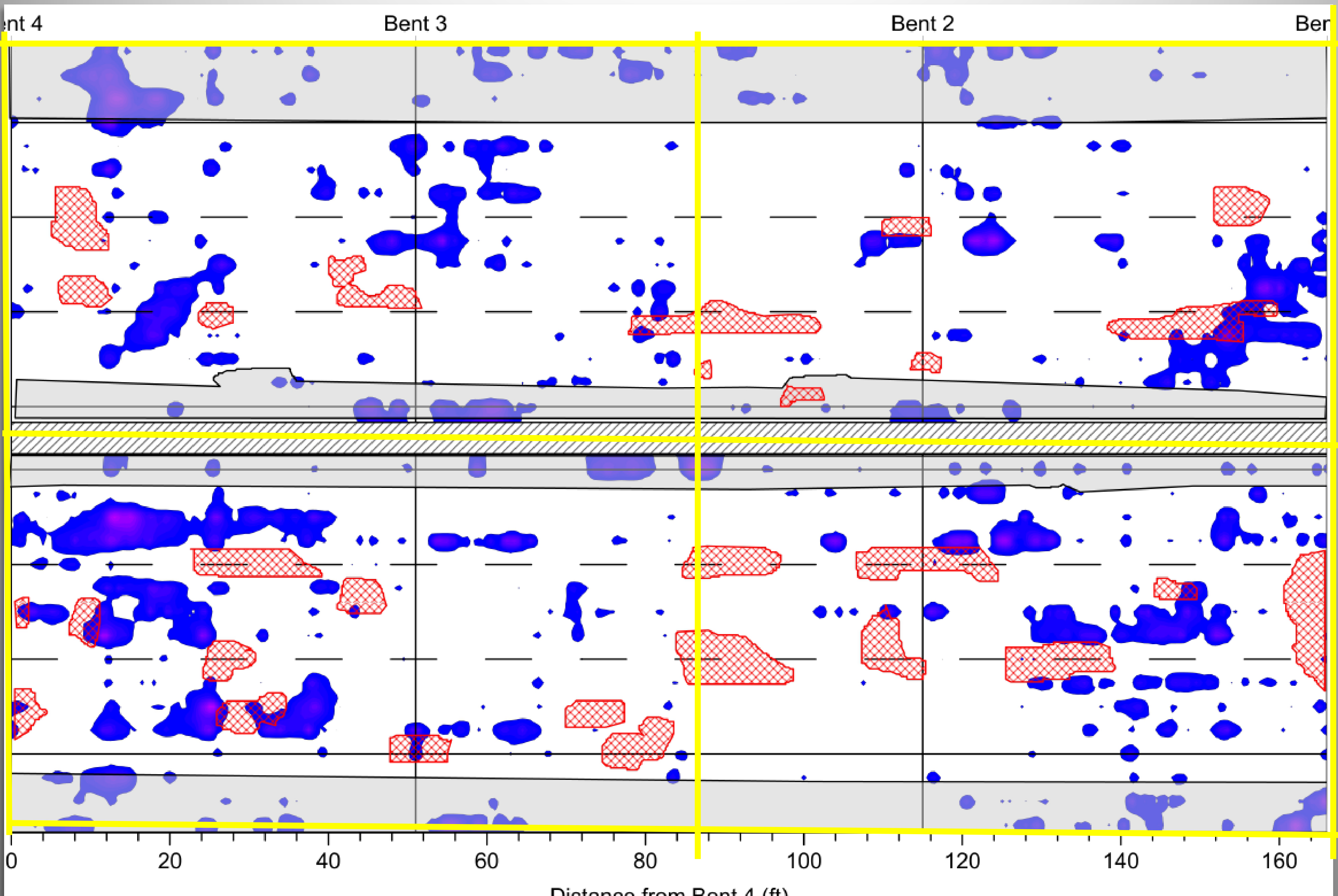

ent 4
Bent 3
Bent 2
Ber
0
20
40
60
80
100
120
140
160
Distance from Bent 4 (ft)

Figure 37

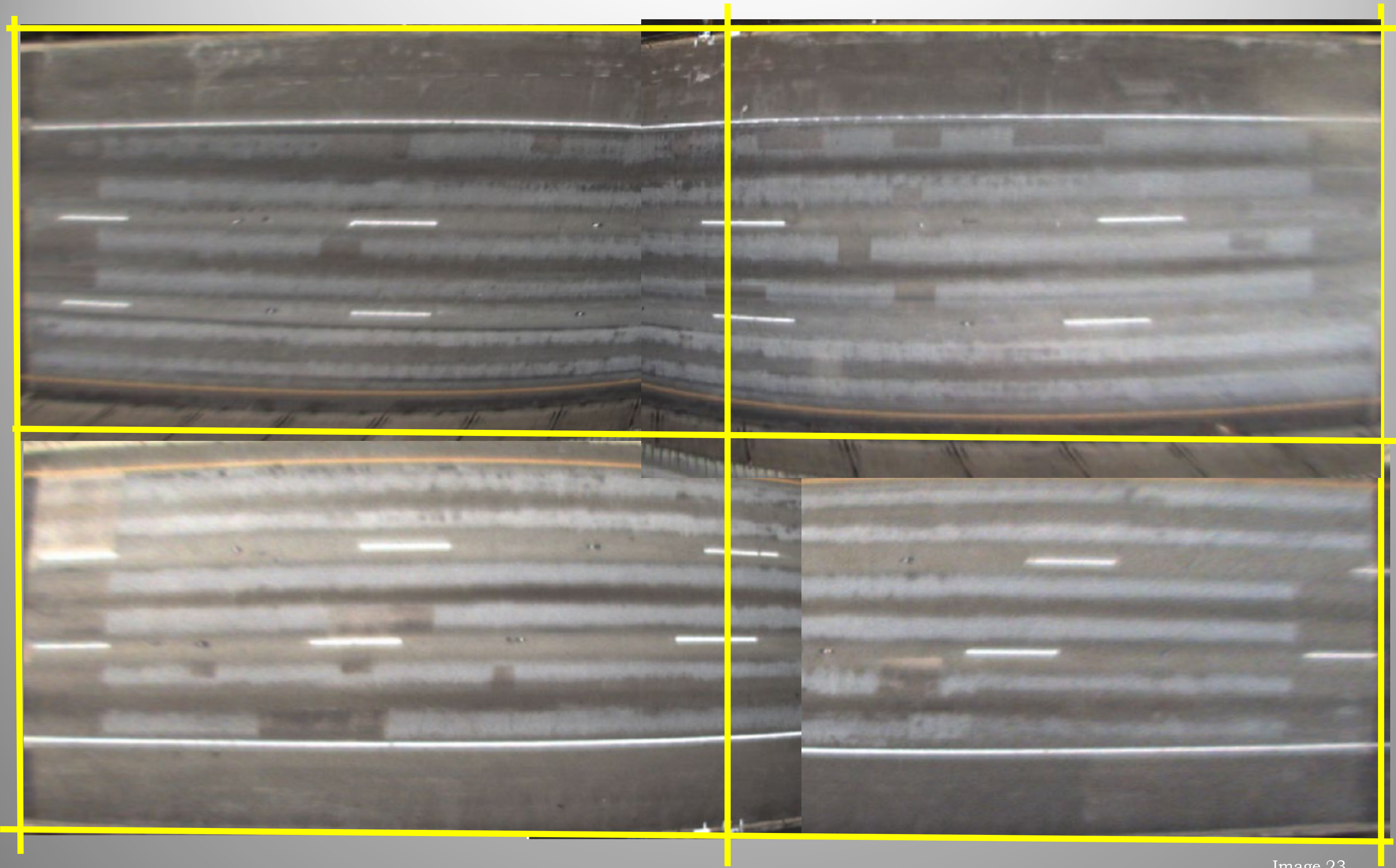


Image 23

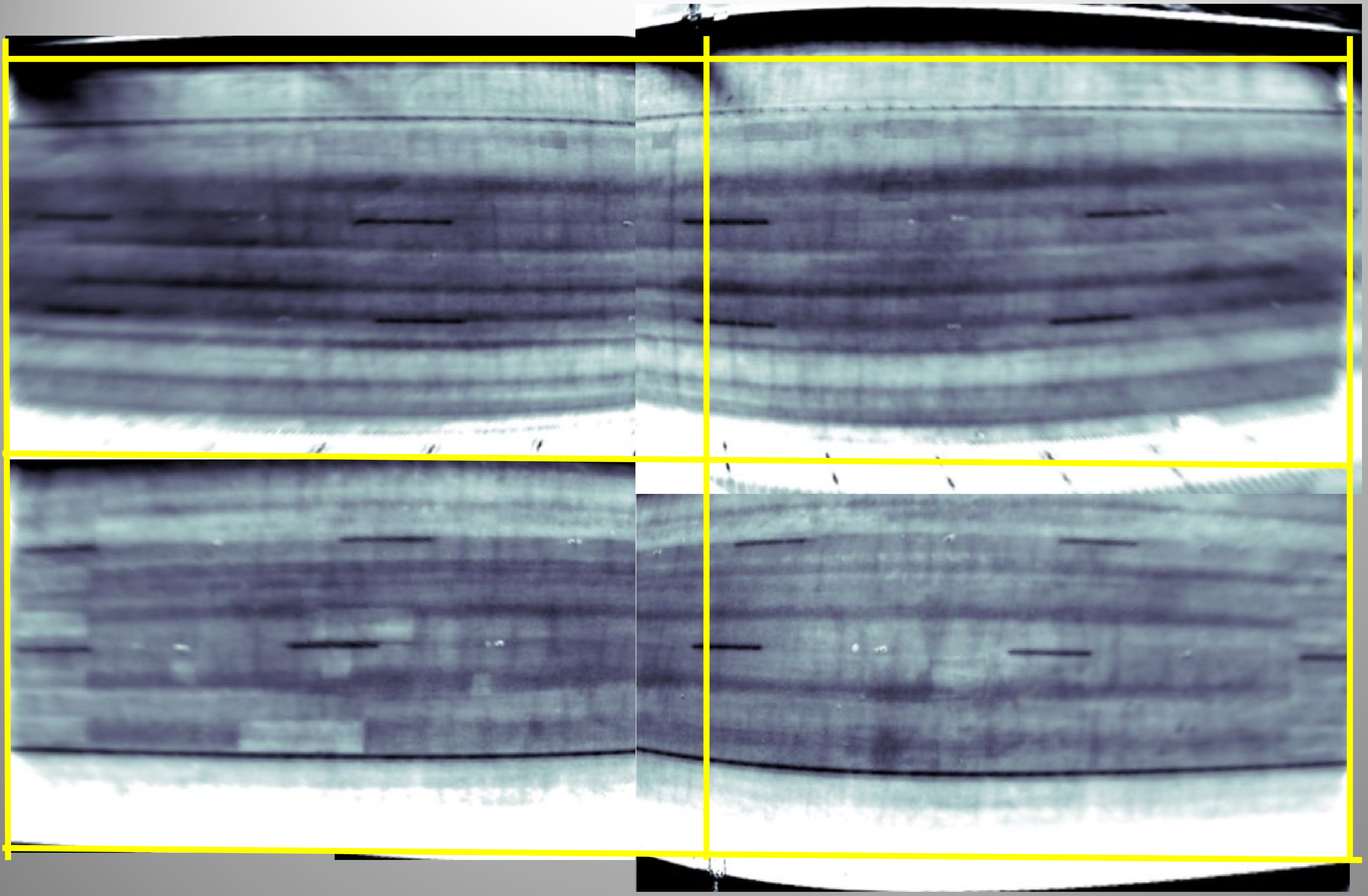


Image 25

Processed for surface defects

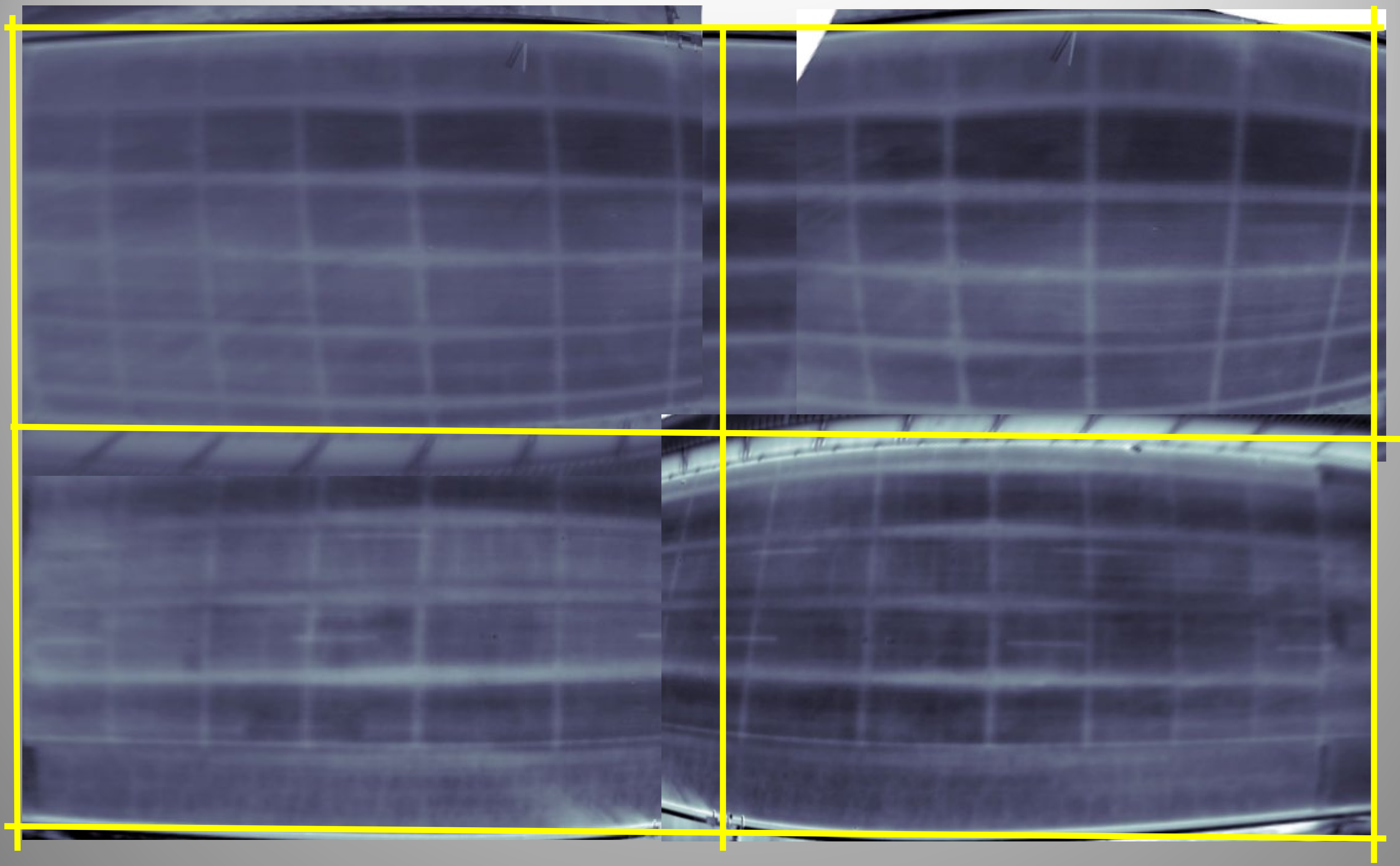


Image 24

Processed for subsurface structural details

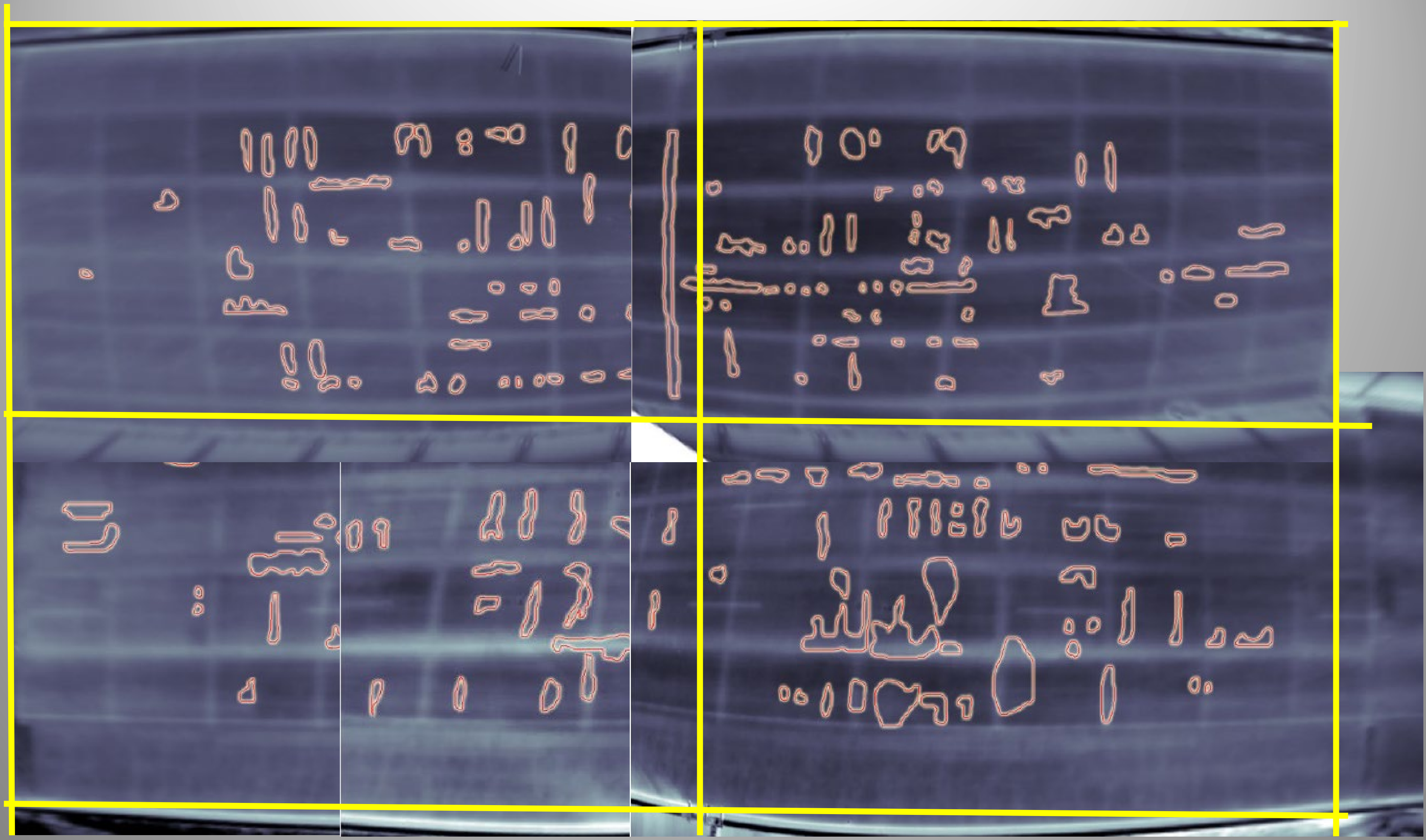


Image 26

Structural view with identified defects

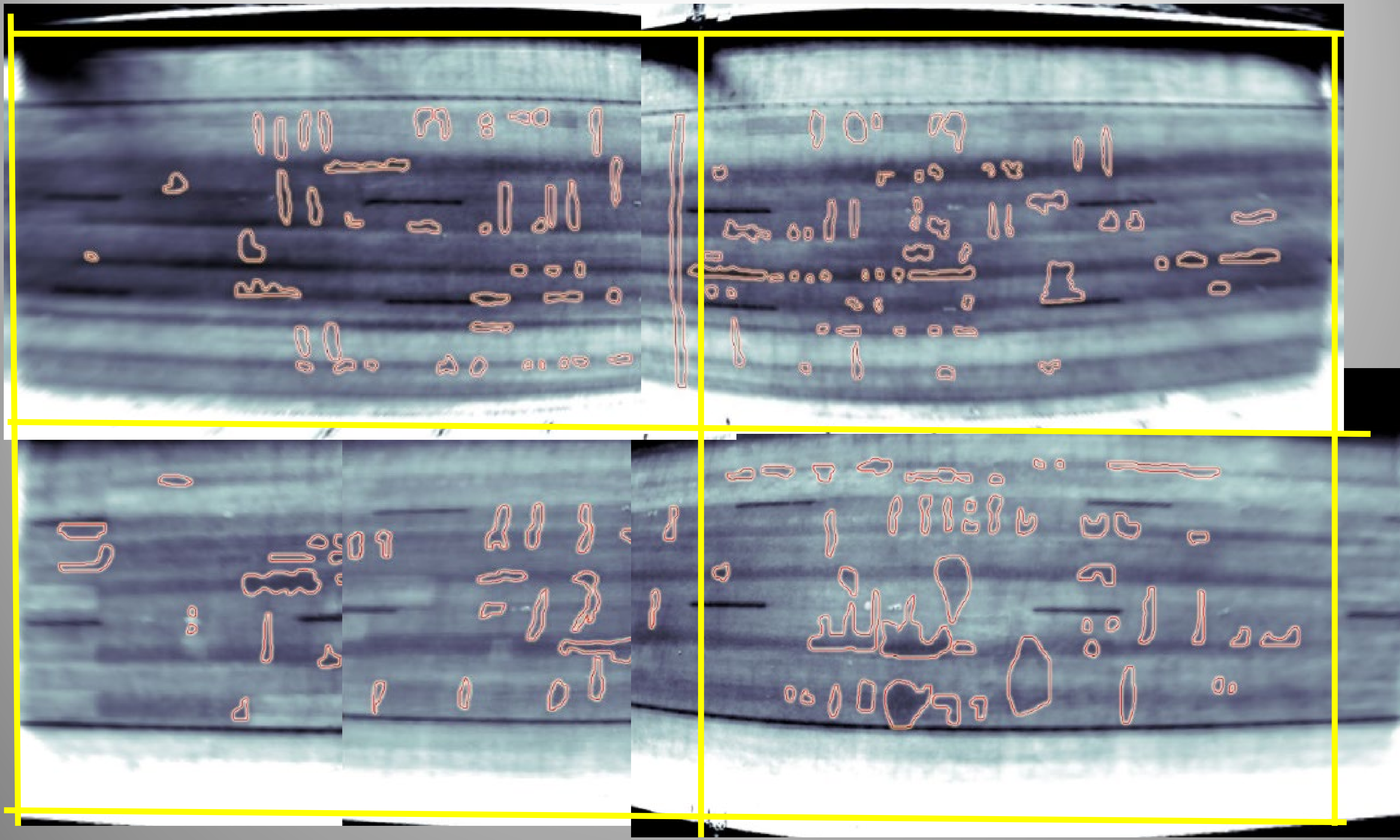


Image 27

Processed for surface defects

I-5 over SW 26th Avenue (08203B)

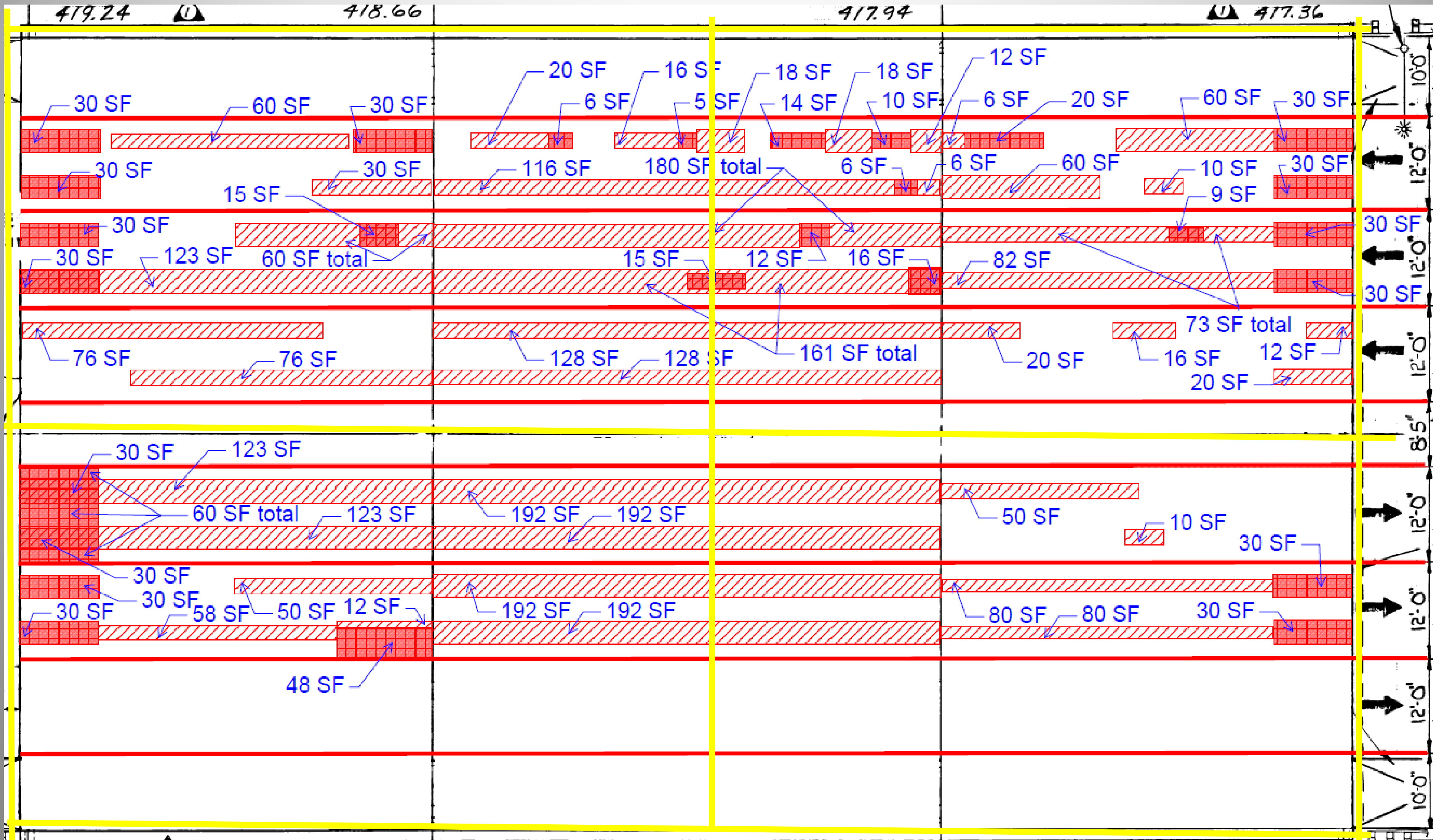


Figure 38

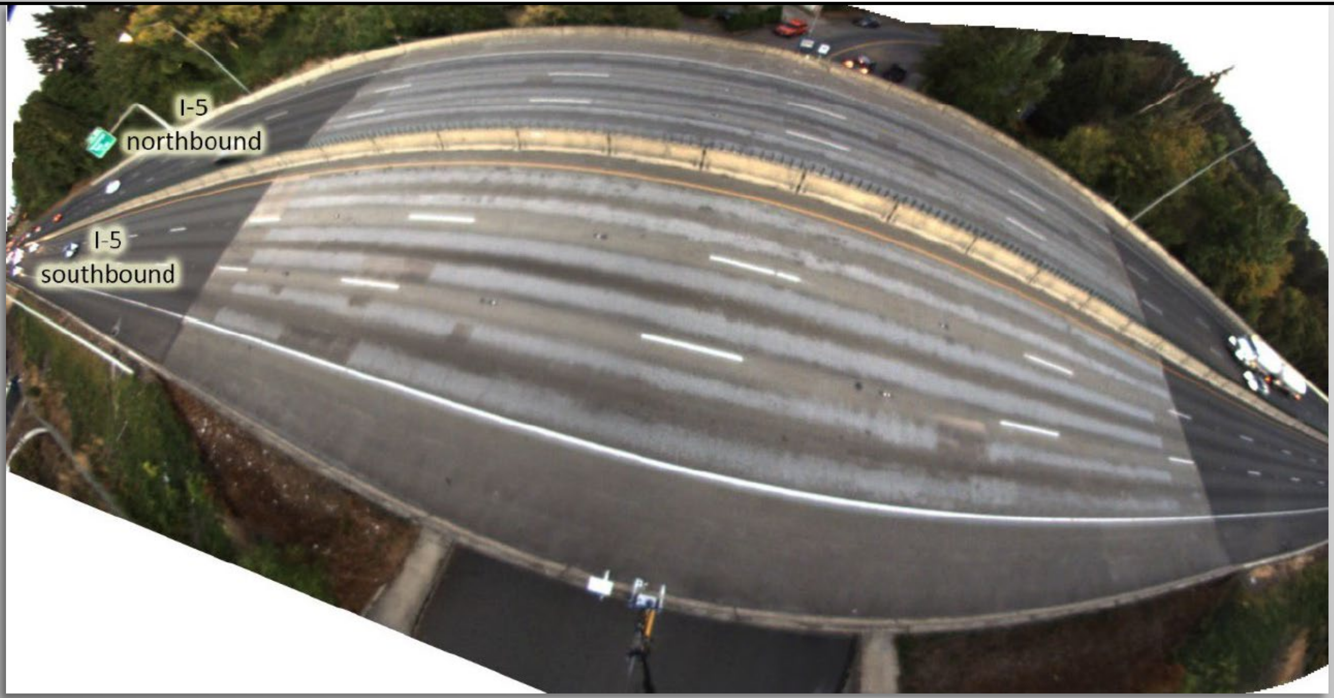


Image 28

- **3rd Party Inspection ~25% delaminated:**
  - NB: 1700 ft^2 of Delamination
  - SB: 1400 ft^2 of Delamination
  - 0.007% - 0.022% chlorides from core samples
  - (deemed not sufficiently close to the 0.04% threshold)
  - 4,000 – 8,600 psi
- **Long Term Infrared (~5.6% delaminated, more precisely drawn)**
  - NB: 500 ft^2
  - SB: 460 ft^2
  - Core sample sent to potentially calibrate depth of delamination
- **Recall High-speed infrared (~7% delaminated, 13% defect by GPR)**

Q: How long is the coast of Britain?

A: It depends on the size of your measuring stick.

(Why it would be helpful to have an agreed upon standard)

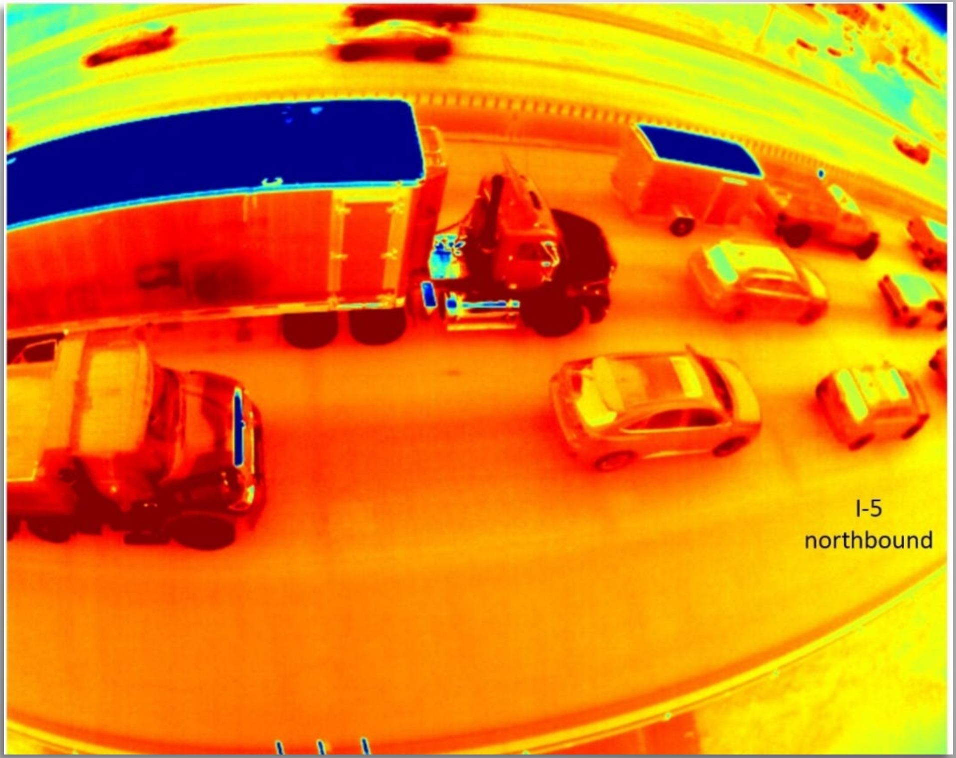


Image 29

Conclusions:

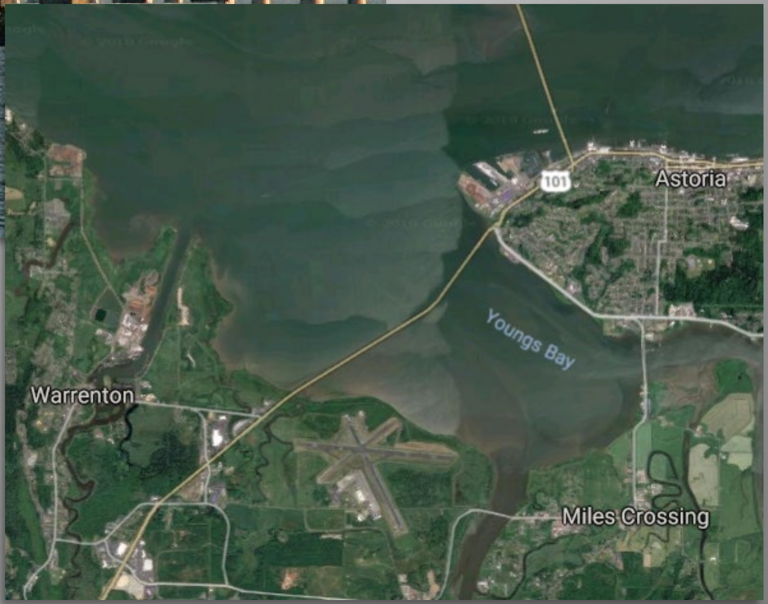
- **Chain drag/ coring and long-term IR make the Same recommendation: replace structural overlay**
- **But: because of life cycle costs/ roadway & traffic control**
  - **ADT: 121,000**
- **Decision was made to replace whole structure with thicker deck**
- **So we won't actually get a direct relation to quantities**
- **We will get a cost-effective bridge**

Image 30

Routine Inspection: RC Deck

- 30% CS2 (Delamination, cracking, rutting)
- 1% CS3 (Exposed rebar, cracking)

Image 31



Maintenance Recommendations:

- Rehab deck (2017)
- Patch spalls/exposed rebar (2007)

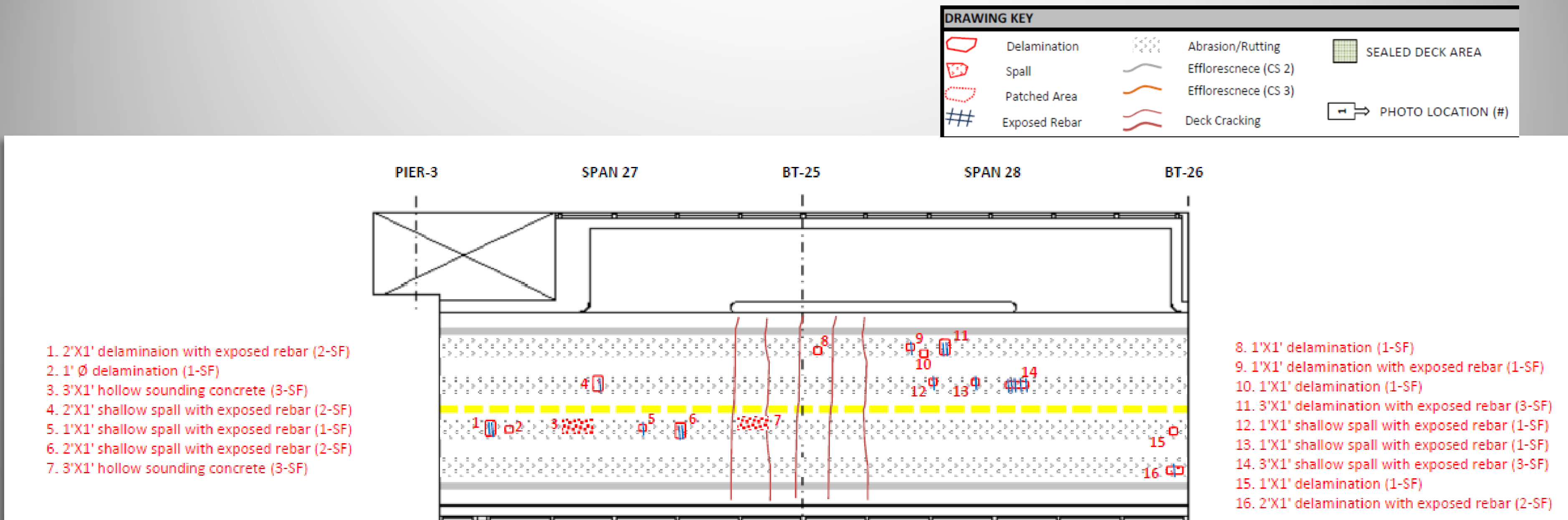


Figure 39

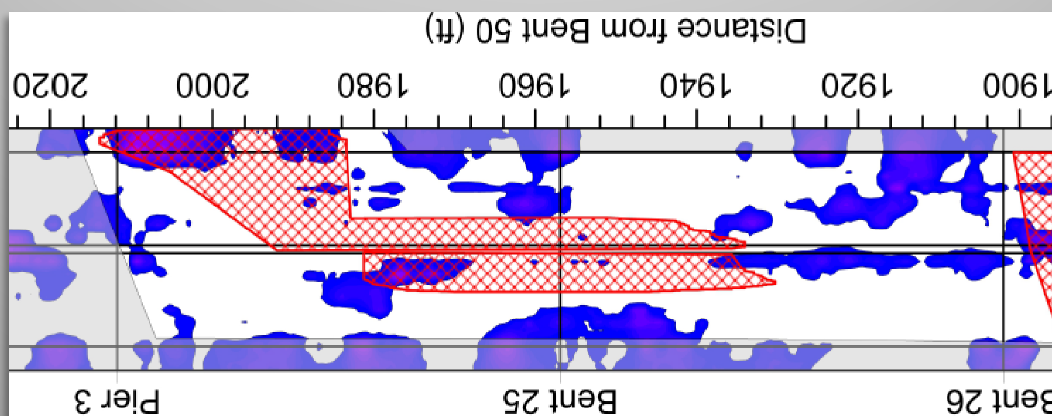
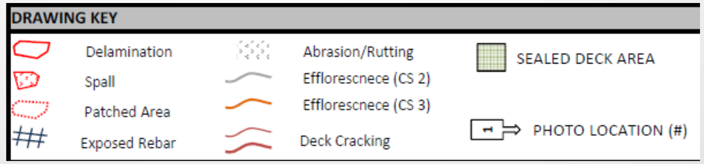


Figure 40

- **1% CS3 (Exposed rebar, cracking)**



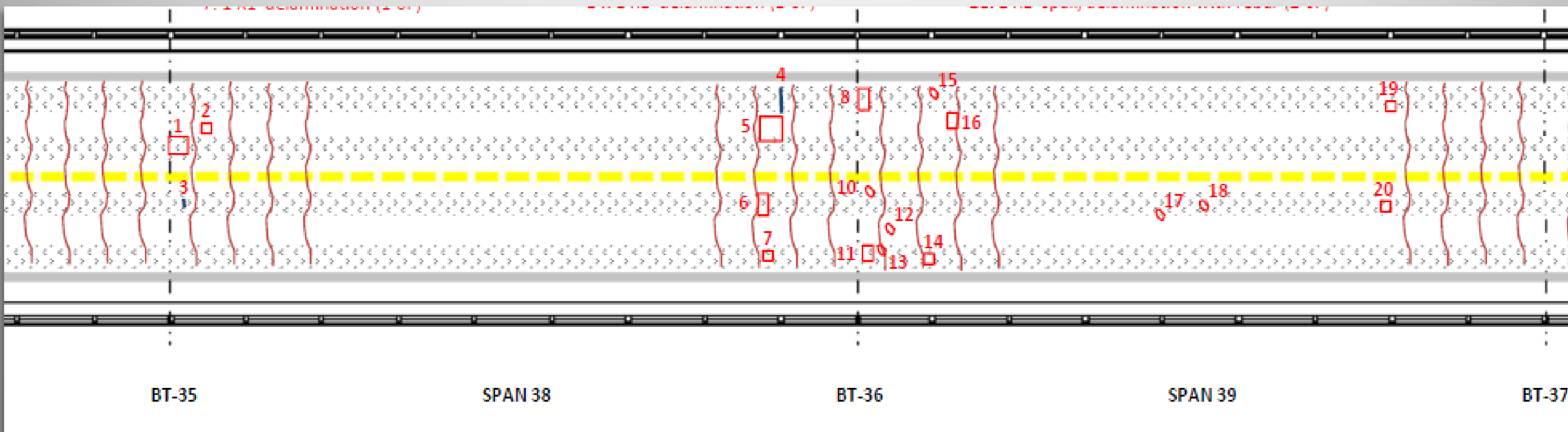


Figure 41

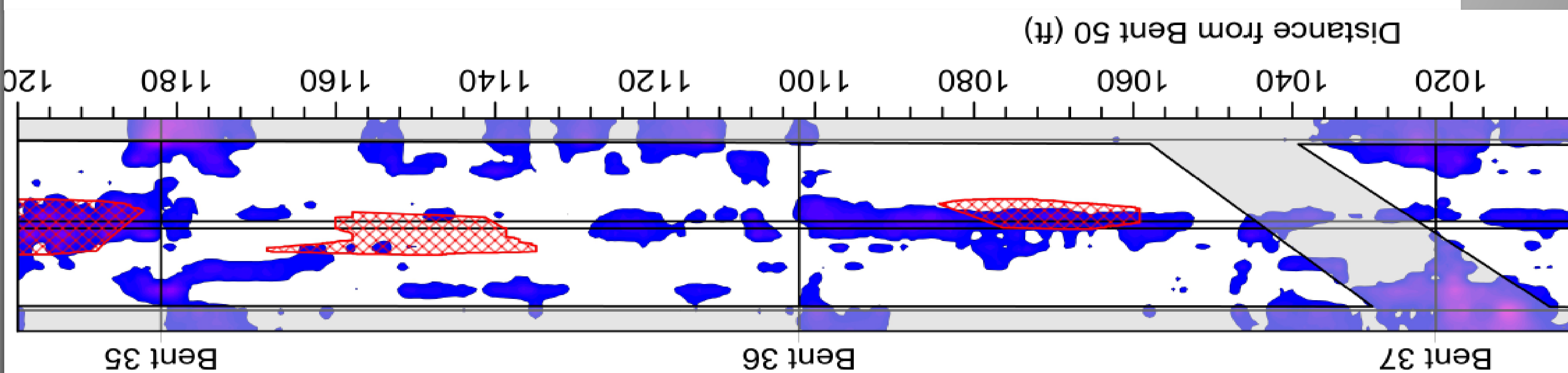


Figure 42

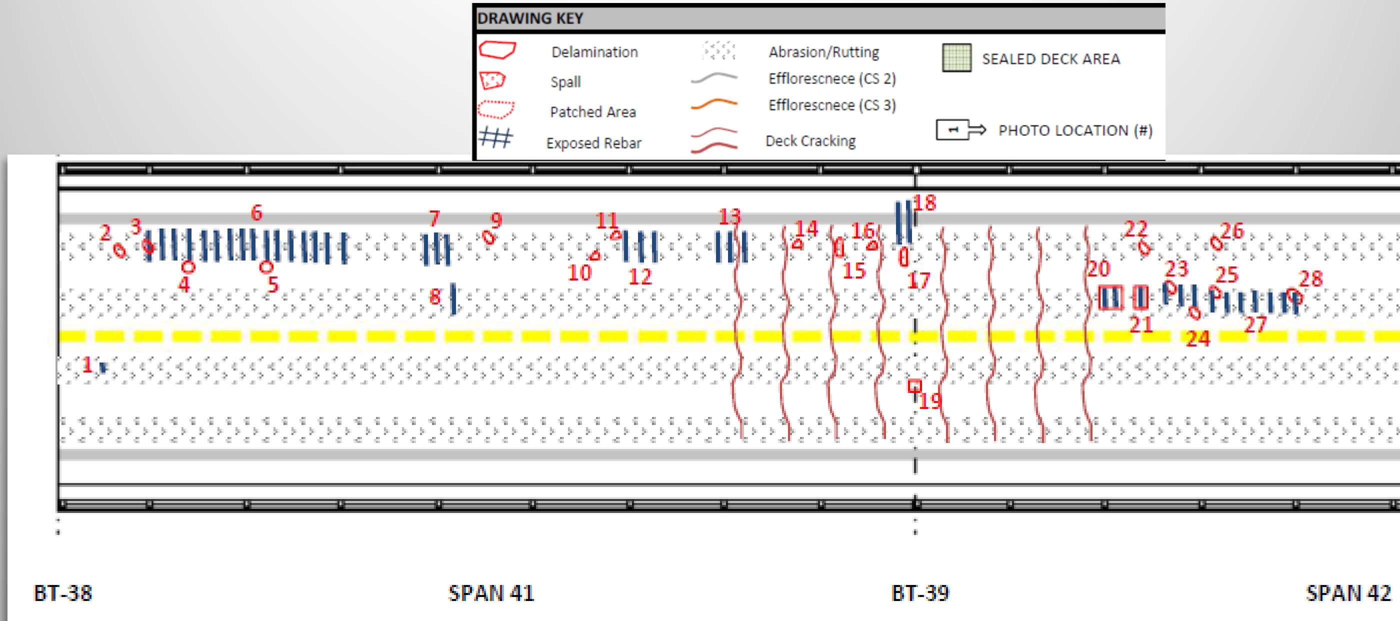


Figure 43

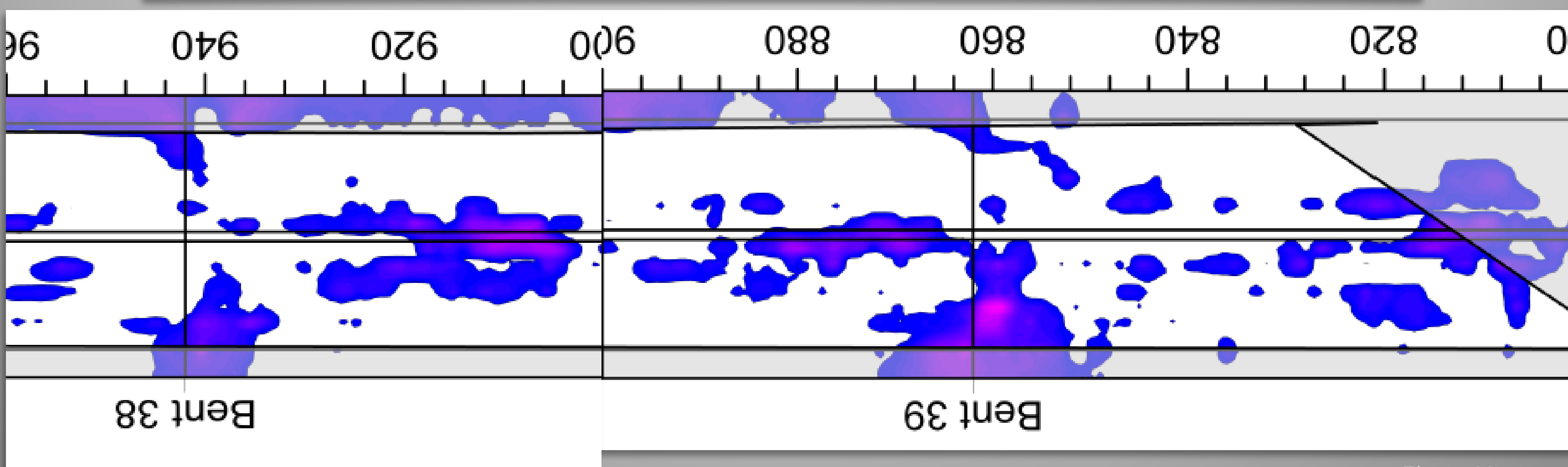


Figure 44

New Youngs Bay (08306) US101

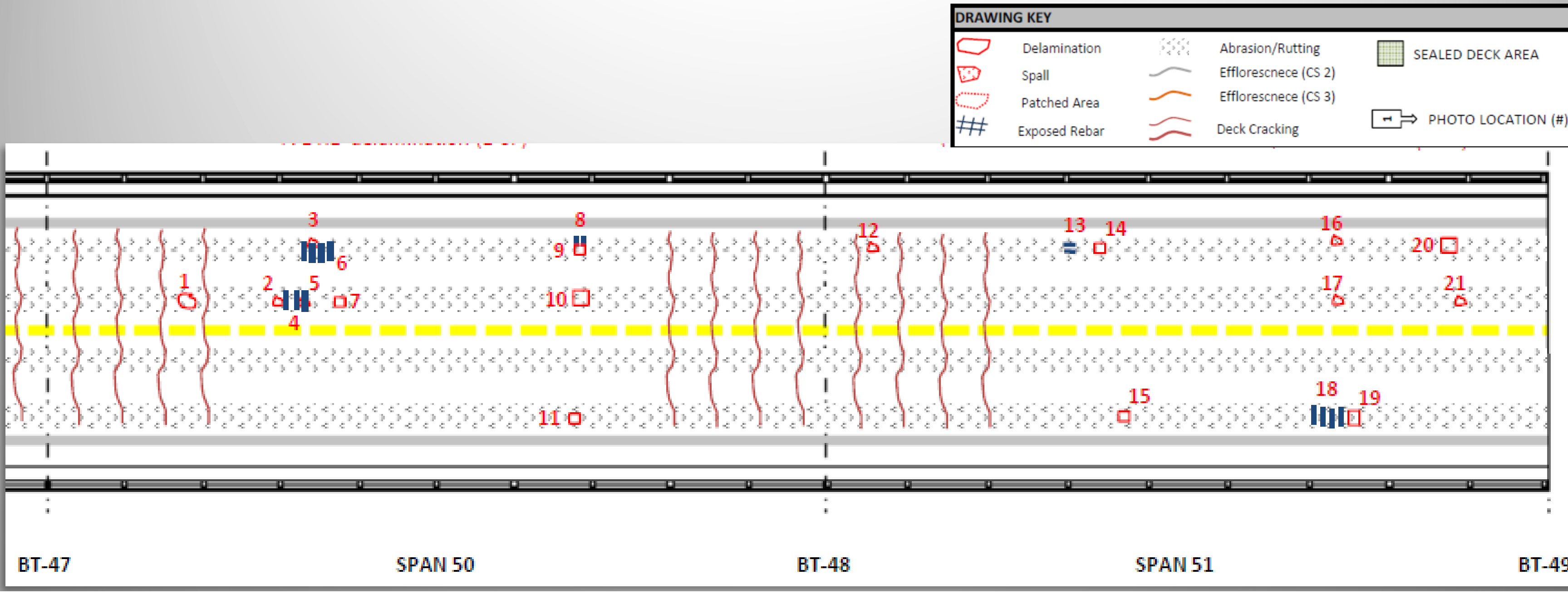


Figure 45

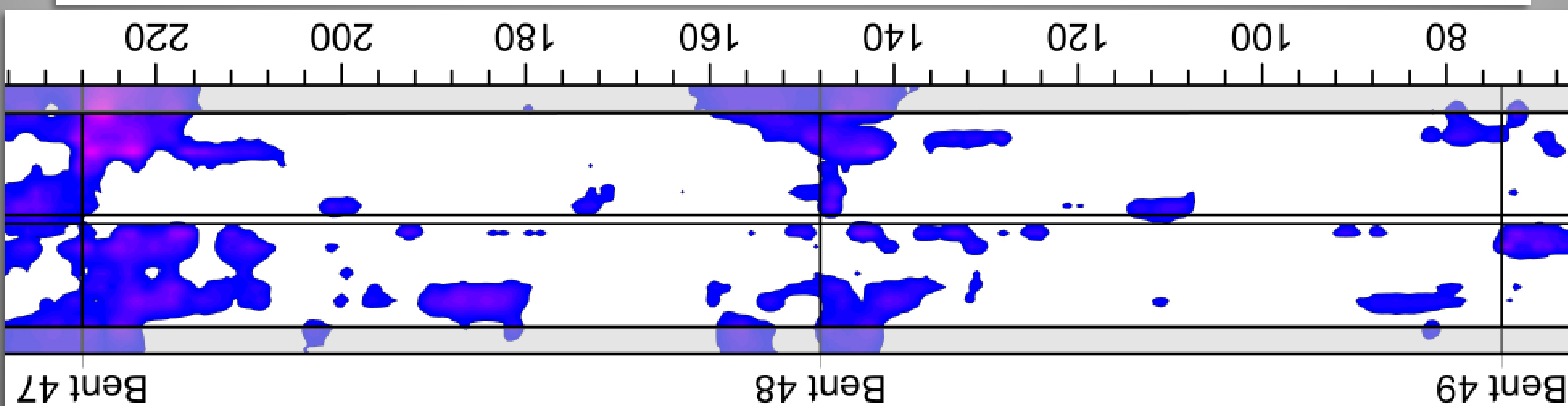


Figure 46

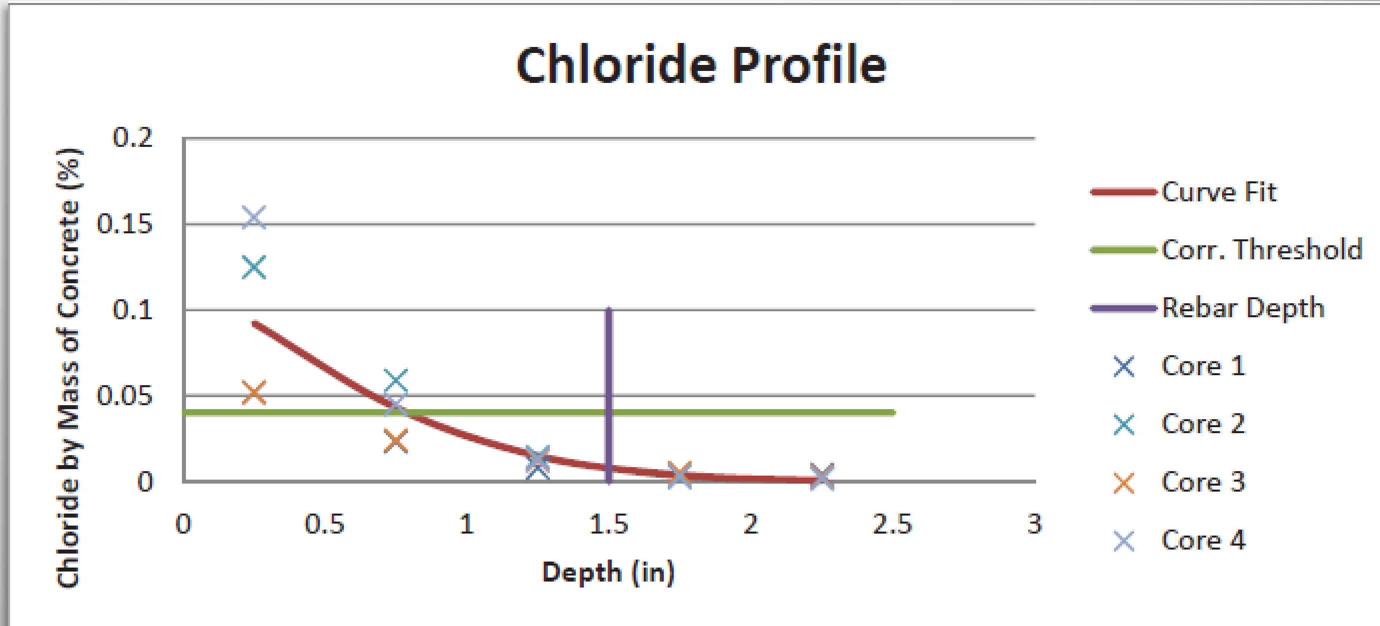


Chart 7 *Evaluation of in-service Bridge Decks using Chloride Analysis*[5]

Cores 3, 4

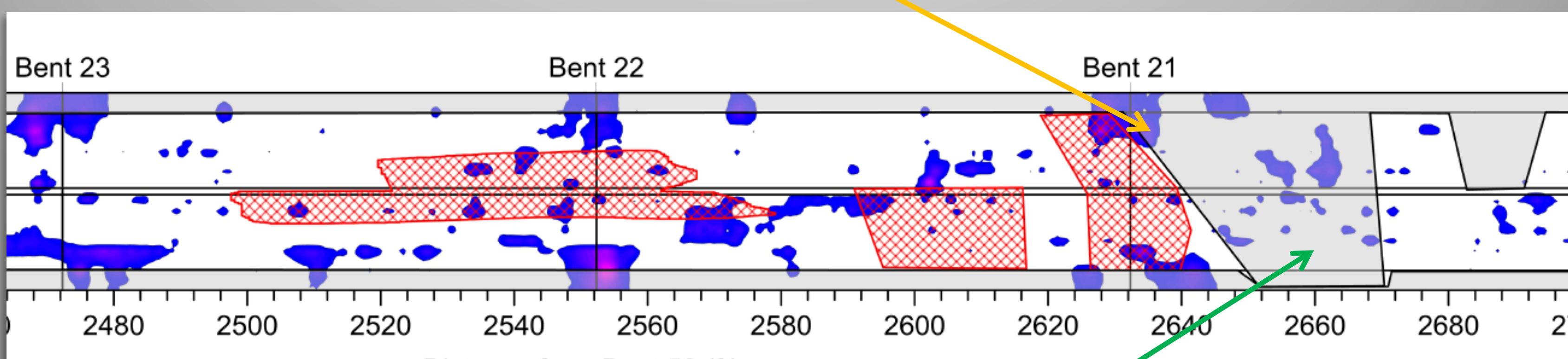


Figure 47

Lift span interference

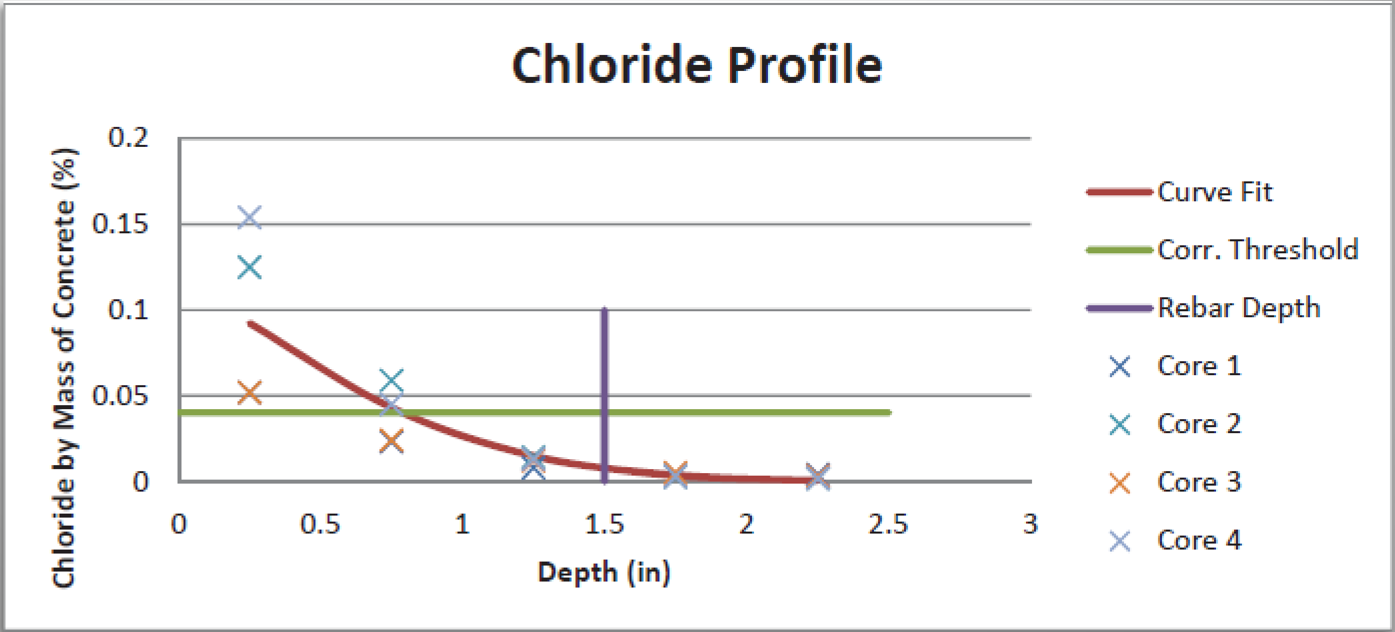


Chart 7 *Evaluation of in-service Bridge Decks using Chloride Analysis*[5]

Cores 1, 2

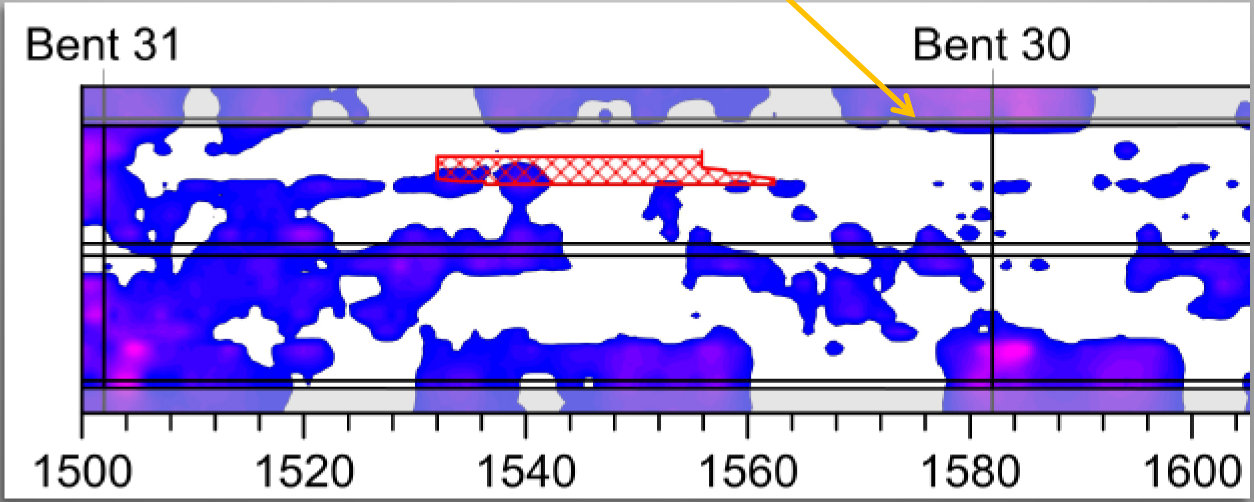


Figure 48

Conclusions:

Chain Drag Quantities:

219 ft^2 delams	(0.1%)
322 ft^2 Exposed Rebar	(0.1%)
1400 ft^2 CS3 Cracking	(0.5%)
34,800 ft^2 CS2 Cracking	(13%)

High-Speed:

1676 ft^2 Delam (IR)	(6%)
78,000 ft^2 Defective (GPR)	(29%)

Solution

Overlay (awaiting quantities)
& Cathodic Protection


Image 32


Image 33

Image 34

Traffic noise proved to limit effectiveness of the human ear as a sensor—with or without earplugs.

(NRR 29 are standard earplugs, which reduces noise level (29-7)/2 = 11 dB and performance is better at High-frequency sound (8000 Hz vs. 125 Hz.)

“Flexural oscillation of a delaminated area is typically in a 1 to 3 kHz Range.”[6]

Manual Sounding – Note earplugs

Image 35

Sounding

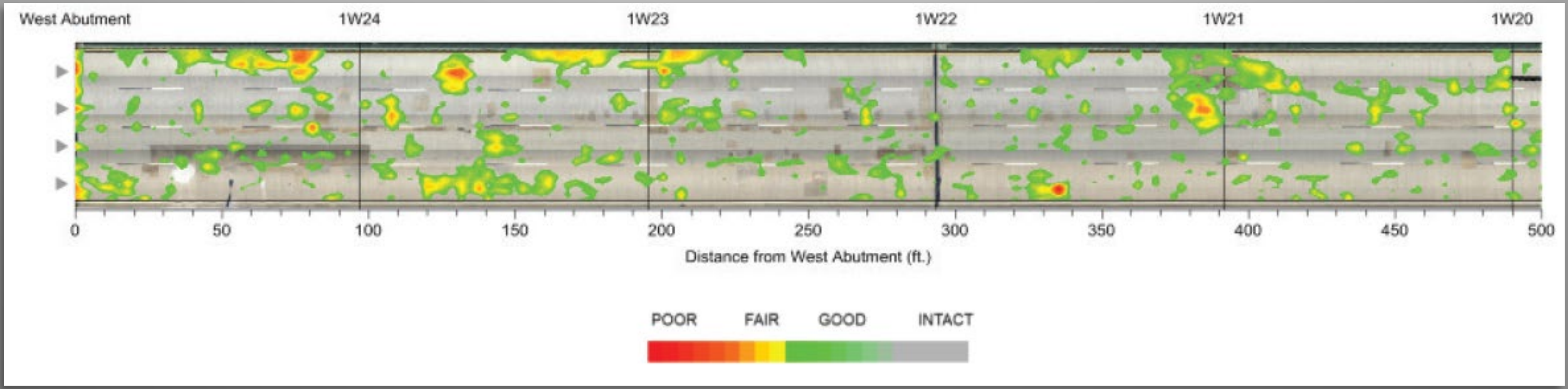


Figure 49

Figure 50

Robot-Assisted Bridge Inspection Tool

5 instruments for recording; 1 laser scanner for navigation

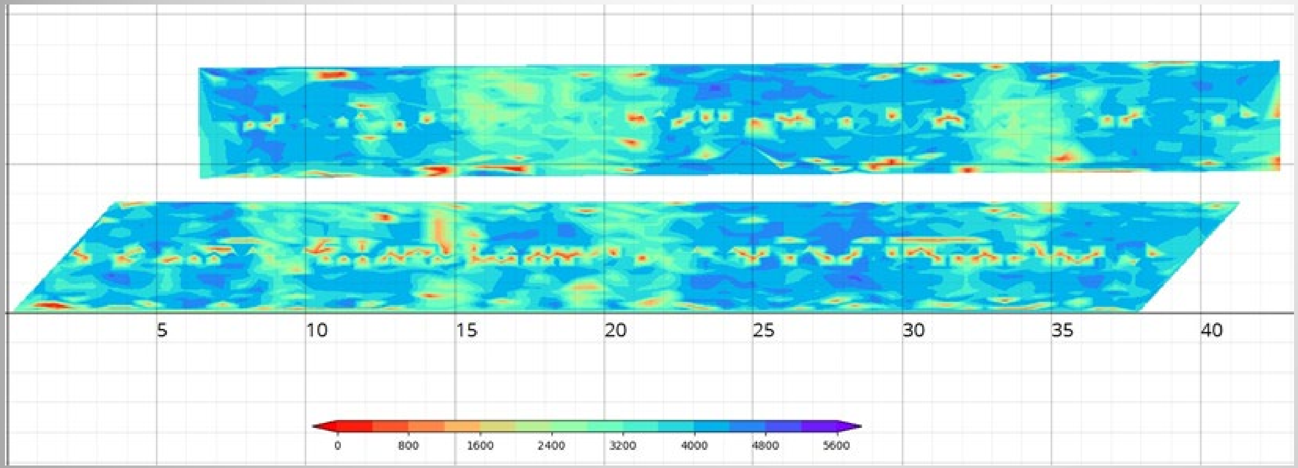


Figure 51

Ultrasonic Surface Wave
ksi (lower is worse)

Electric Resistivity
kOhm (High Resistivity is Worse)

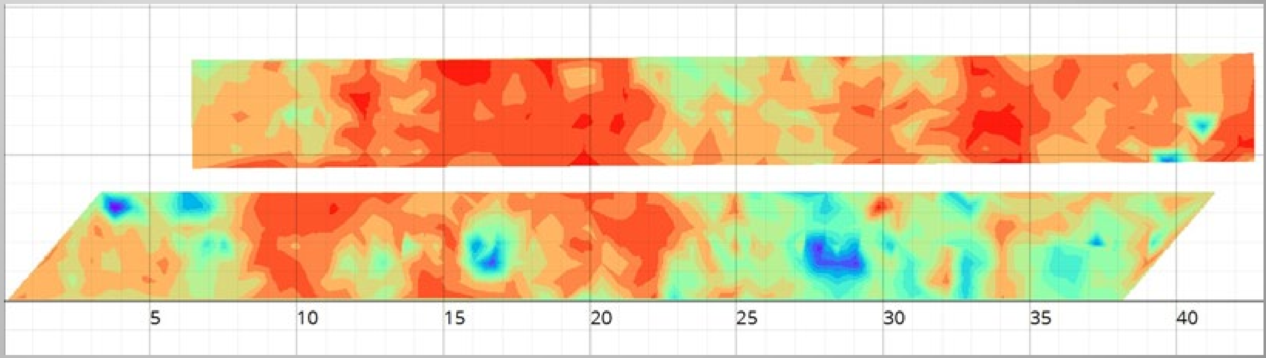


Figure 52

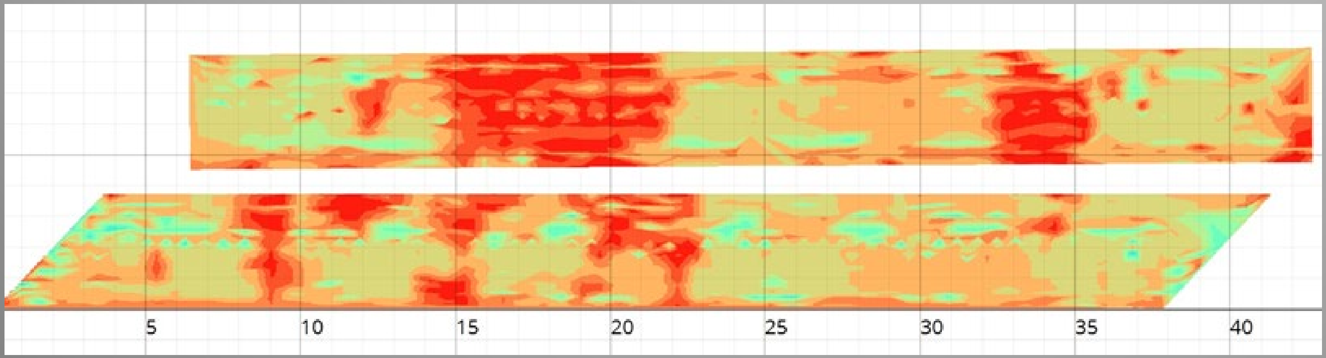


Figure 53

Impact Echo
Hz (lower is worse)

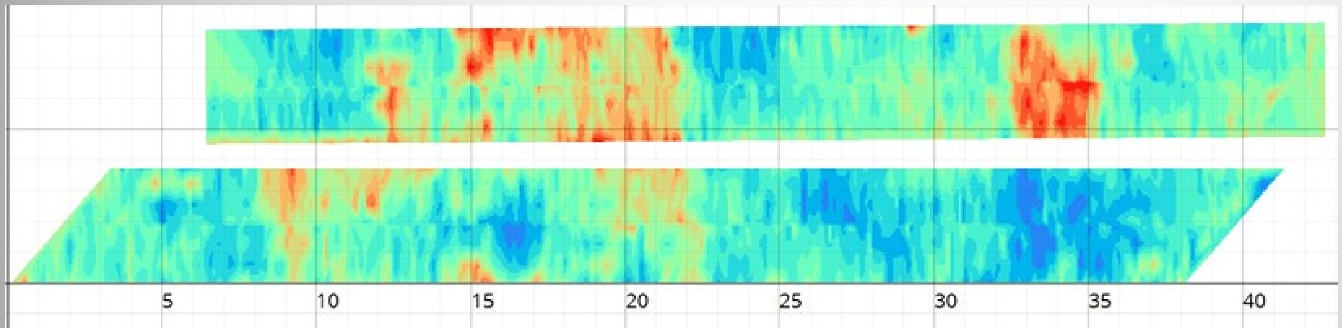


Figure 54

GPR
dB (lower = less cover)

Cover Depth
(In.) Can we get to ± 0.5 inches?

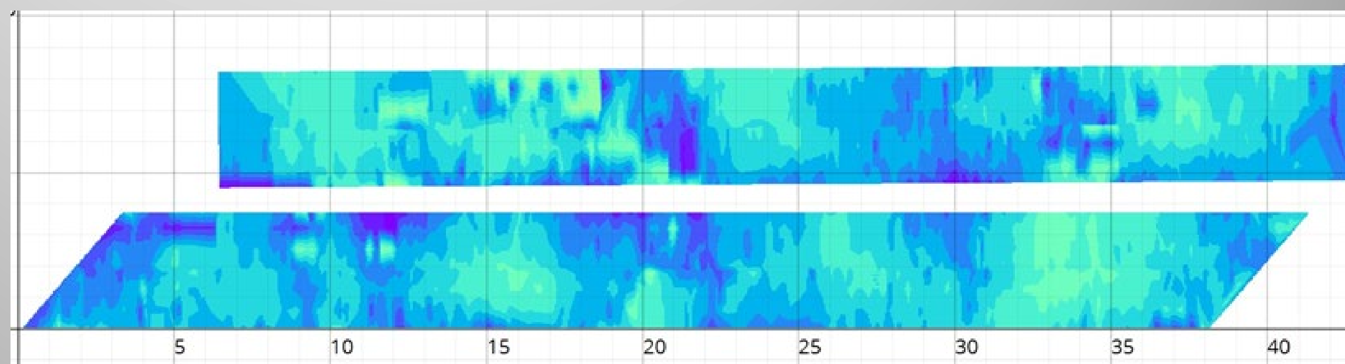


Figure 55

Figure 55

Repair Areas
Serious, Poor Fair, Good = CS1, 2, 3, 4, etc.? Or Class 1, 2, 3 removal?

The Future

- Our current platforms can fly for approx. 20 mins per battery set
- We do not own a thermal camera at this point, but the off the shelf option is a FLIR XT camera @ $10k
- Photos can be shot at a fixed interval and analyzed on free desktop software provided by FLIR
- We are just starting to research the idea of a tethered UAS option. This would allow for a constant power and data feed to keep the UAS in the air for extended periods of time. I am submitting a research proposal to study the effectiveness of this solution.

-Christopher Harris PE,
ODOT Engineering Automation

Wind and airspace restrictions remain limiting factors for drone inspection – not the cameras or the payload capacity

: Southern bent pin connection. Taken from senseFly albris main HD camera. Focal length: 8 mm, 35mm equivalent: 25 mm. (Full image)

Figure 56[6]

Conclusions

- Network-wide strategies and **high-speed methods are not in our near-future**, full-scale implementation plans
- That said, we are **still calibrating the raw data** for more **meaningful definitions** and precise, reliable defect quantities
  - Shared interest between agencies and contractors in fine-tuning data → defect translations.
- We have already seen how more intensive **NDE methods can inform specific decisions on bridges for which there is planned work** and avoid large quantity-related, change order costs (on the order of $100,000)
- **Thankful** for the opportunity to explore these options and learn from other states

Questions for the group

1. **Have you discovered reliable techniques for determining depth of delamination (below half thickness)?**

2. **Do you have well-defined contract or procedure language for you results?**
   1. What does “good”, “fair”, “poor”, “severe” mean?
   2. How do you otherwise interpret or quantify these terms?
3. **Your best methods for sharing these results with other parts of your agency?**

4. **Any recommendations on standardizing?**
   1. Units of measurement
   2. Environmental limitations

Questions

Suzhou, China

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