Alaska Department of Transportation & Public Facilities

2.5 Million Density Tests in 22 Nights on Glenn Hwy

Rich Giessel

November 2017

Continuous Full Coverage (CFC)

- Why use CFC testing technology?

Donald M. Burmister (1948)

- “The primary problem is not so much to determine the average conditions, as it is to make reasonably certain that possibly the most unfavorable conditions are known over a given area that may give rise to soft spots.”

Problems with Random Testing

- Not suitable for heterogeneous materials
- Not suitable for finding defects on paving projects as there is almost zero probability of locating pot hole size defects

Advantages of Systematic Testing

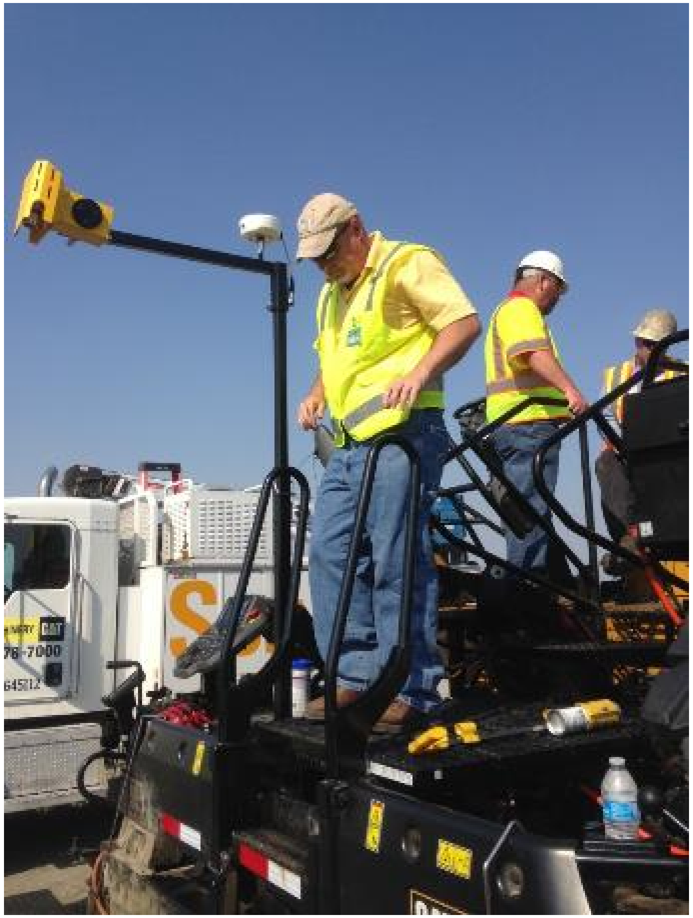
- Uses multiple inputs to “look for” failure zones
- High probability of detecting defects

IC, PaveIR, PaveScan-AK History

- Alaska DOT began using Intelligent Compaction (IC) at Sitka Airport 2013
- Following demonstration projects in 2011 with the PaveIR Bar and in 2015 with the PaveIR Scanner, PaveIR was specified on the Glenn Highway-Hiland to Eklutna Project in 2016
- First demonstration of PaveScan RDM was performed same project in September 2016

Pave IR Bar (2011)

PaveIR Scanner (2015)



Intelligent Compaction (IC)

- Intelligent Compaction provides:
  - Geo-located Data
  - Pass Coverage
  - Relative Stiffness
  - Temperature mapping at time of roller pass

Infrared Scanner

- PaveIR provides
  - Geo-located Data
  - Complete map of asphalt mat surface temperature
  - Viewable in real time
  - Calculates degree of thermal segregation / 150'
  - Provides a permanent temperature record

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  - 2640 Readings per minute walking at 3 mph gives 528 Densities/min. (each an average of 5 readings)

What is Dielectric?

- Related to Speed of RADAR through a Material

$$e = C^2 / V^2 \quad \text{or} \quad V = C / \sqrt{e}$$

Where: V = velocity of RADAR in material

C = Speed of light in a vacuum

e = Dielectric

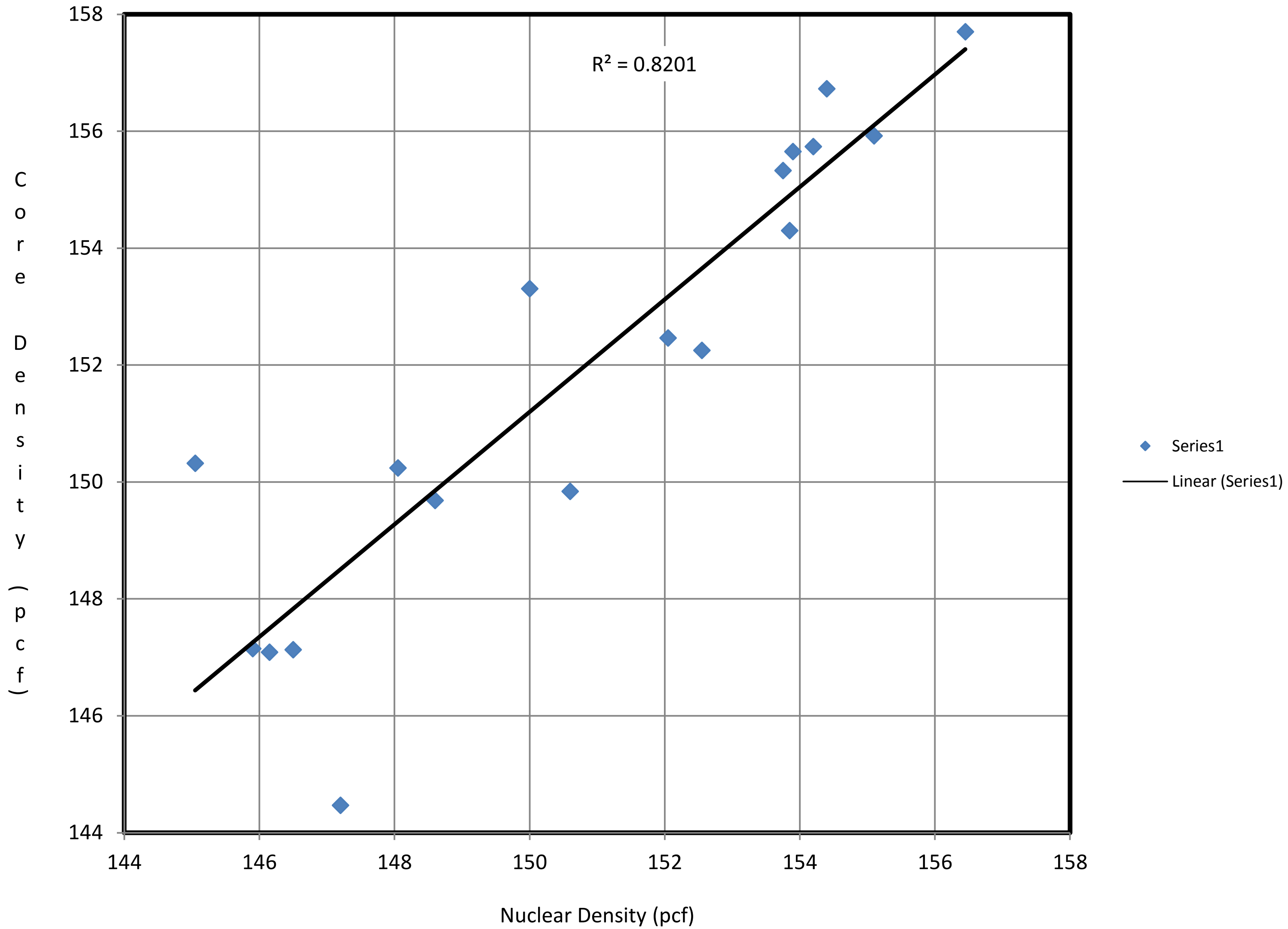
Relative Speeds of RADAR

RADAR is fastest in Air	e = 1
RADAR is slowest in Water	e = 81
Asphalt Concrete	e = 4 to 7

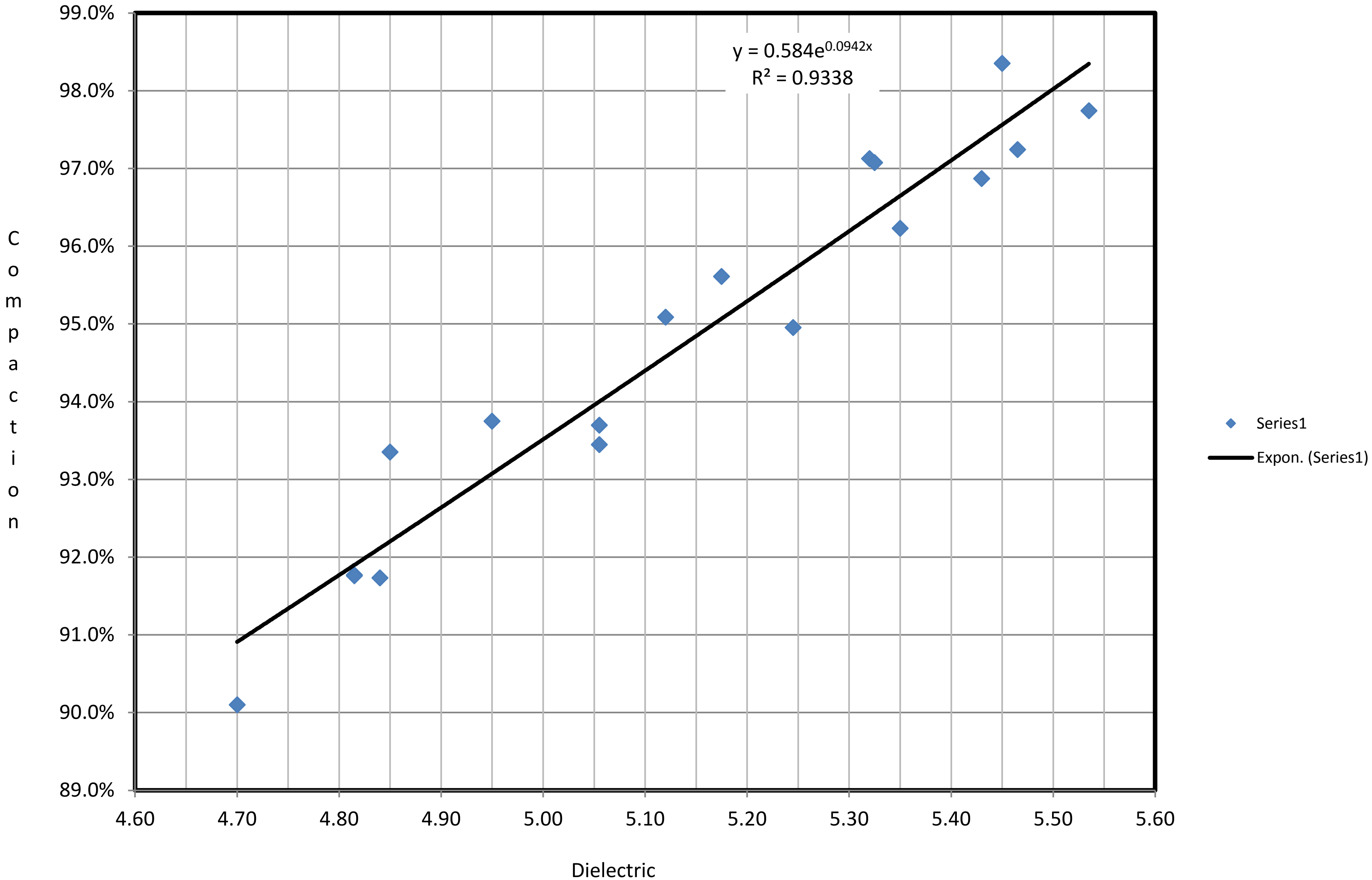
(note more air gives lower dielectric, i.e. RADAR passes through porous asphalt faster)

LOW DIELECTRIC = LOW DENSITY

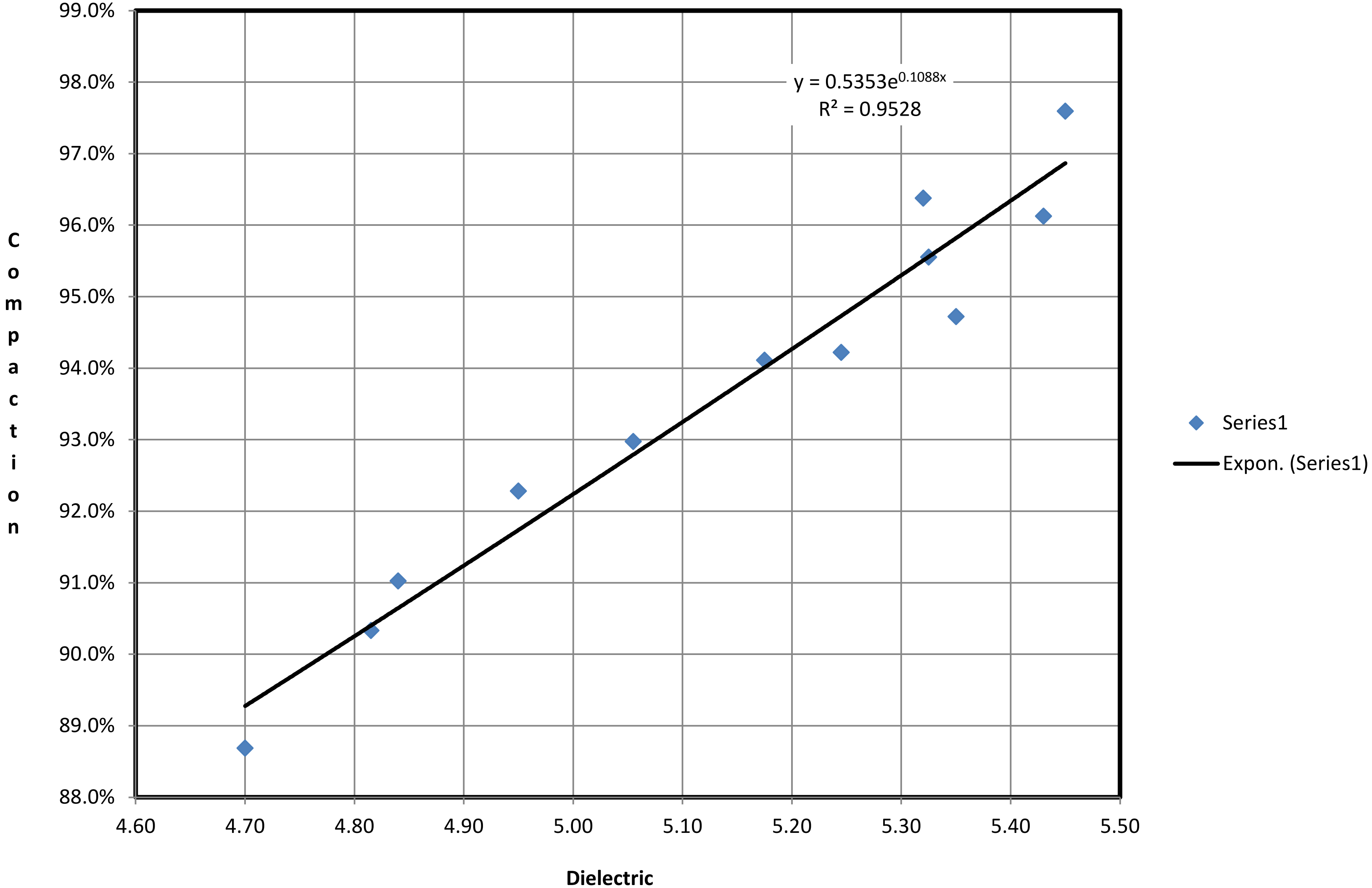
Calibration: Cores vs Nuke, $R^2 = 0.82$



Calibration: Cores vs RDM, R^2 = 0.93



Calibration w/Cores after 1 Day of Traffic
Cores vs RDM $R^2 = 0.95$



Pursuing Calibration w/ $R^2 = 1.0$

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- It is important keep track of one’s location by marking stations and core locations.
- Multiple 200’ lane sections w/6 Cores from each. Three 200’ sections 500’-1200’ apart.
- Day old pavement gives better calibration than hot mat.

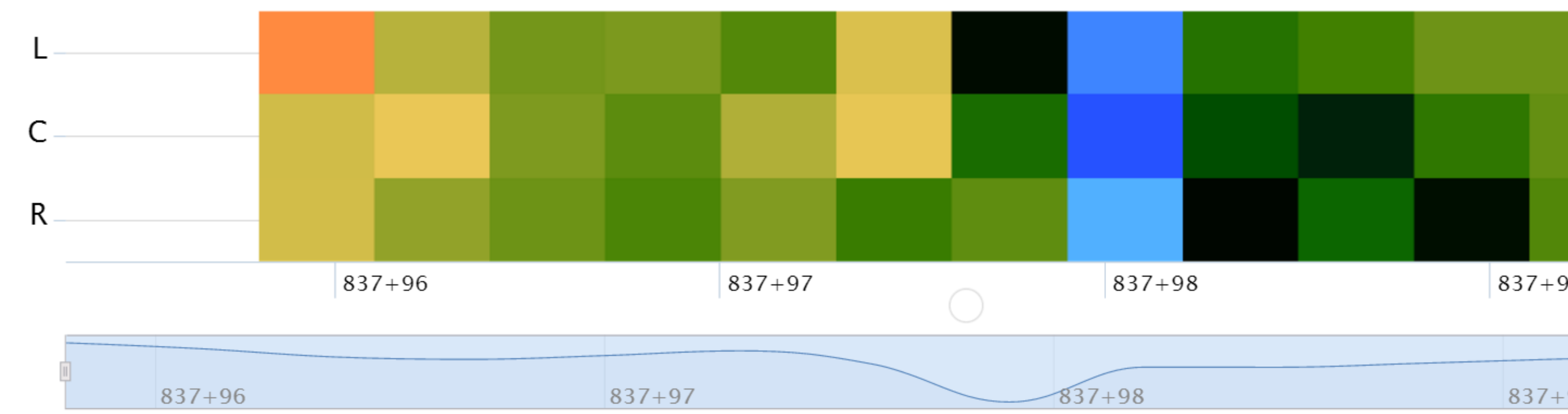
Pursuing Calibration w/ $R^2 = 1.0$

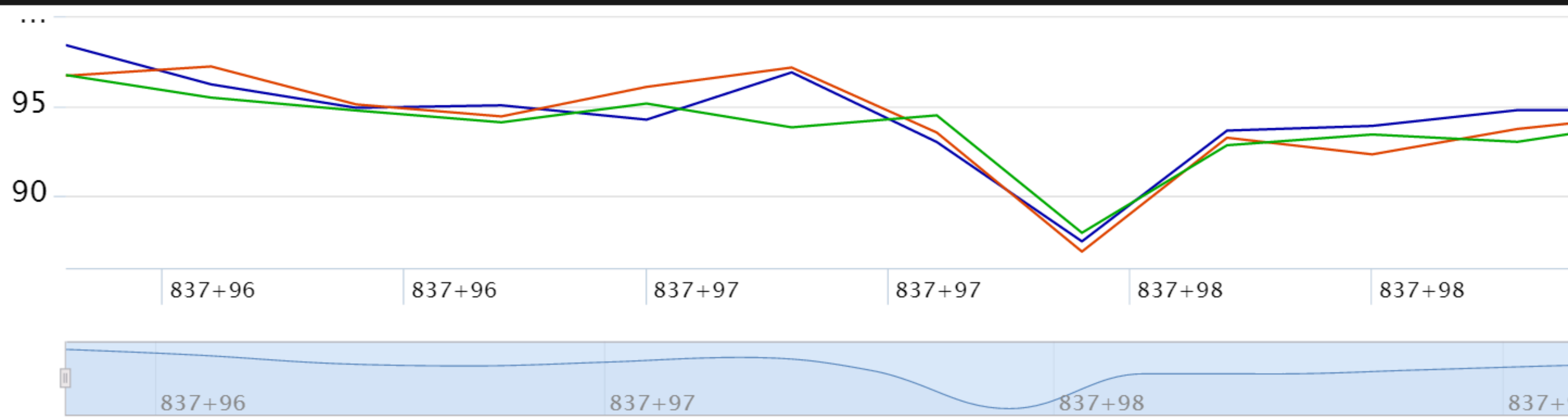
- Next step for Alaska DOT&PF will be performing a Maximum Specific Gravity test on each calibration core and using the core specific MSG to calculate each density.
- Our goal is to keep R^2 above 95% for each mix design placed on a project evaluated with the RDM.

What can we “SEE” with GPR?

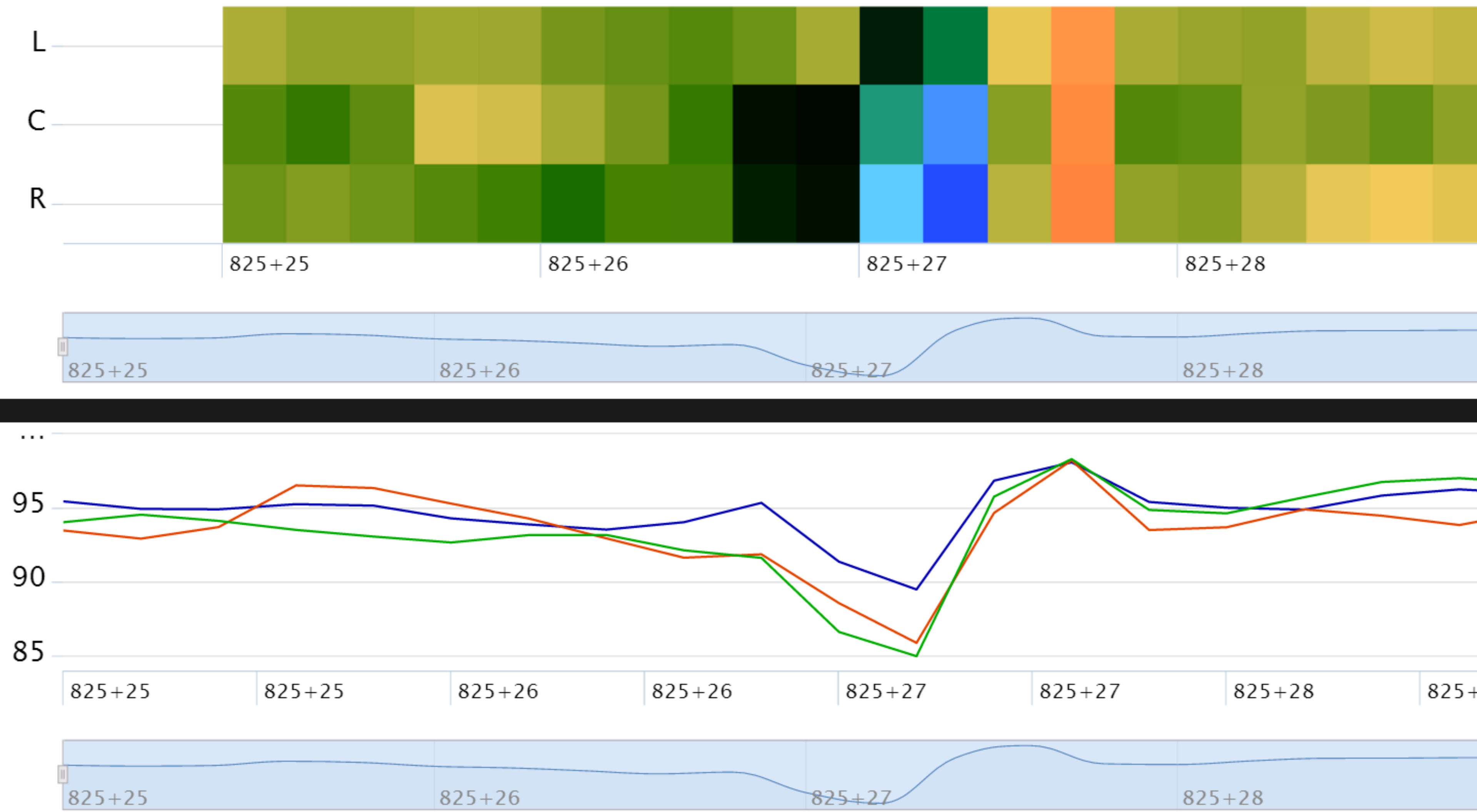
- Answer: Defects we have never “SEEN” before
- For example, density variation across a longitudinal joint

Core 69J (92.9%) – Resolution 0.25 ft

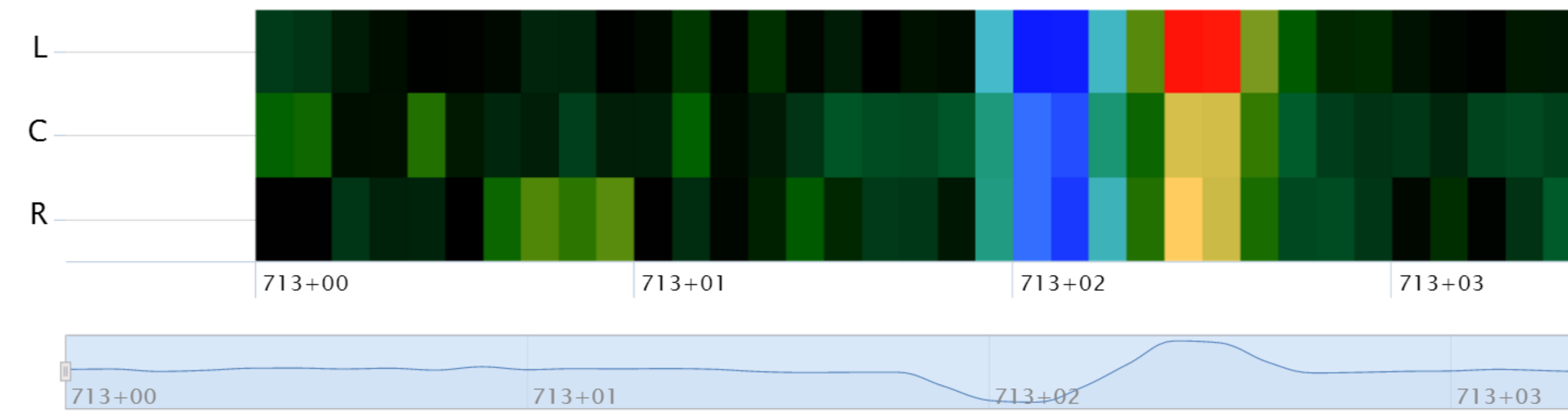


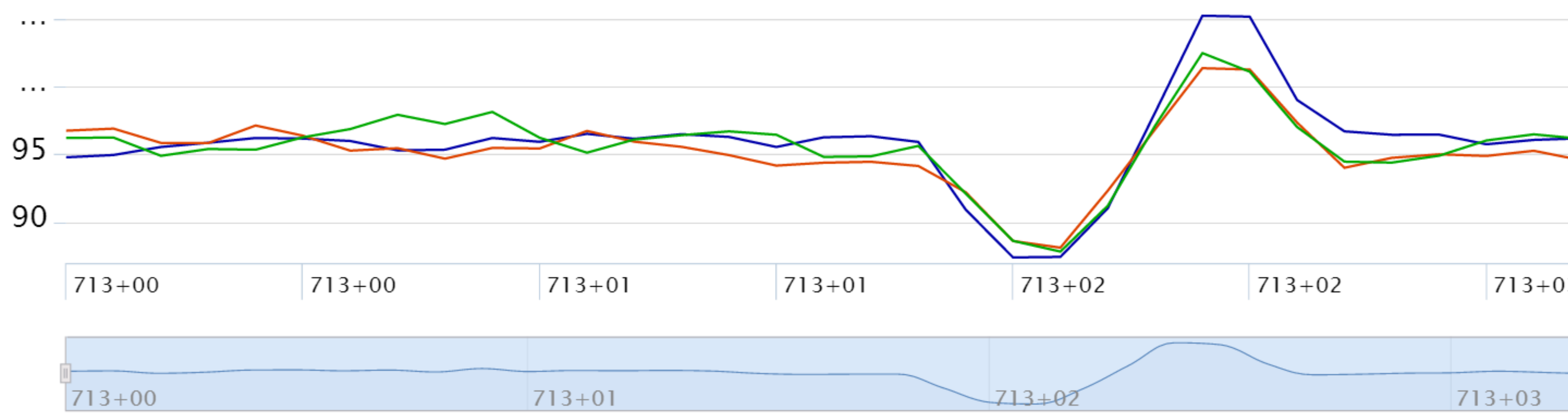


Core 70J (91.7%) – Resolution 0.25 ft



Core 87J (94.9%) – Resolution 0.10 ft





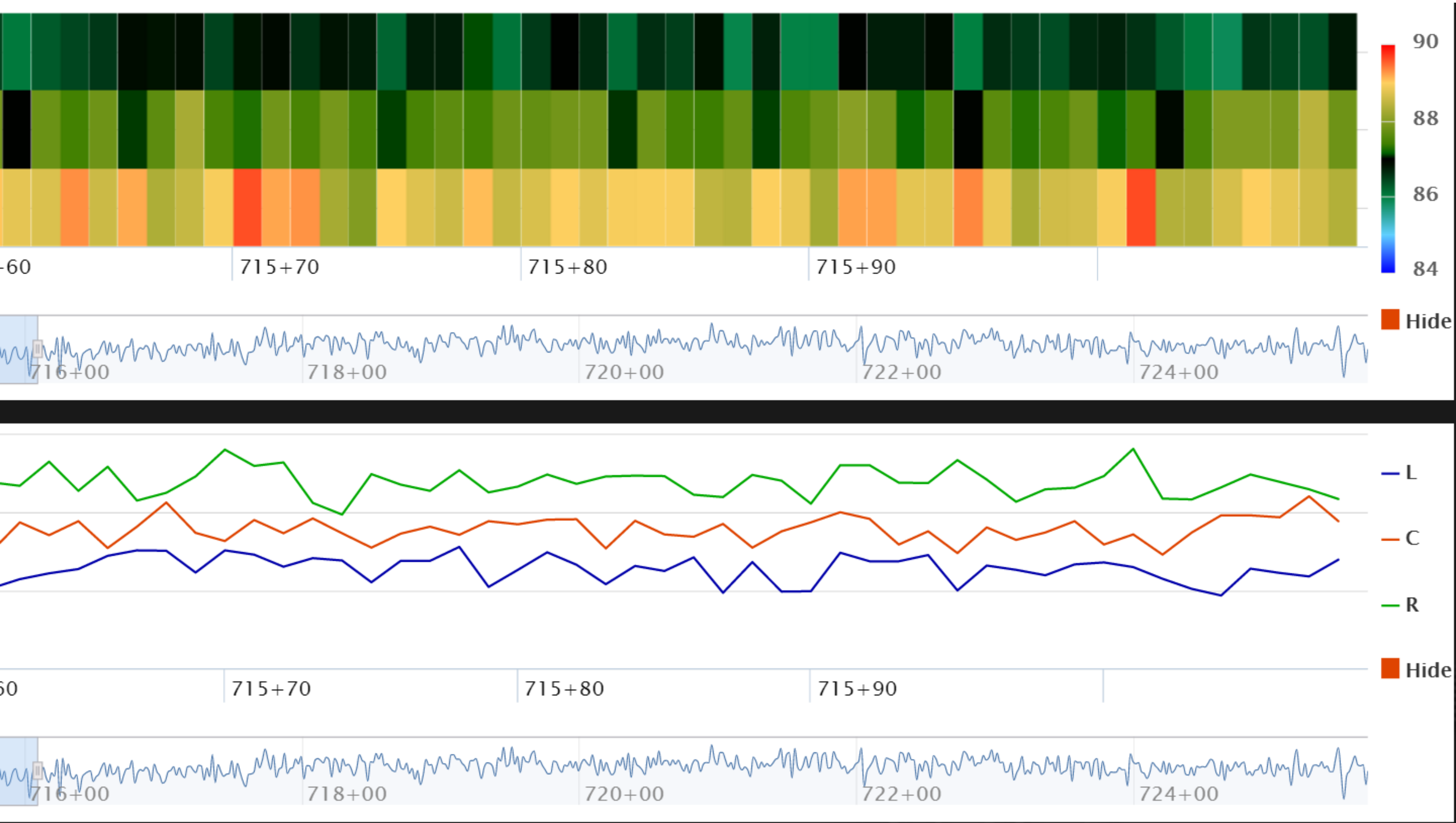
Core 87J – Distance Statistics

Sensor Position	Total Dist	Median	Average	Min	Max	Standard Dev
Center	4.2	95.2647	95.2054	88.1275	101.343	2.28774
Left	4.2	96.161	95.9437	87.4141	105.199	3.10059
Right	4.2	96.0255	95.6037	87.8418	102.452	2.49736

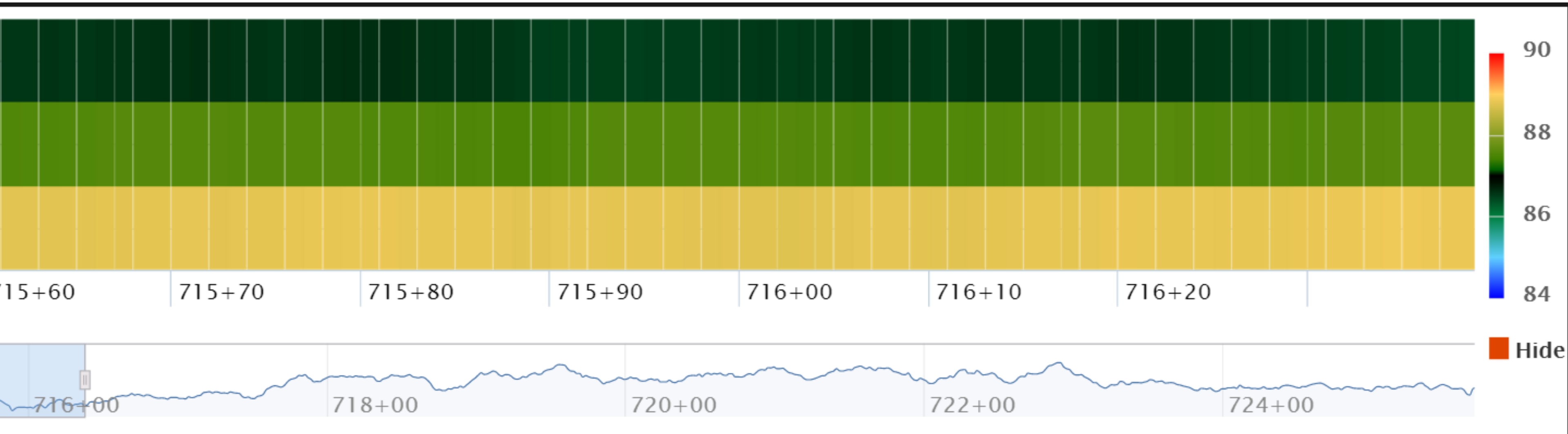
Core 87J – Time Statistics

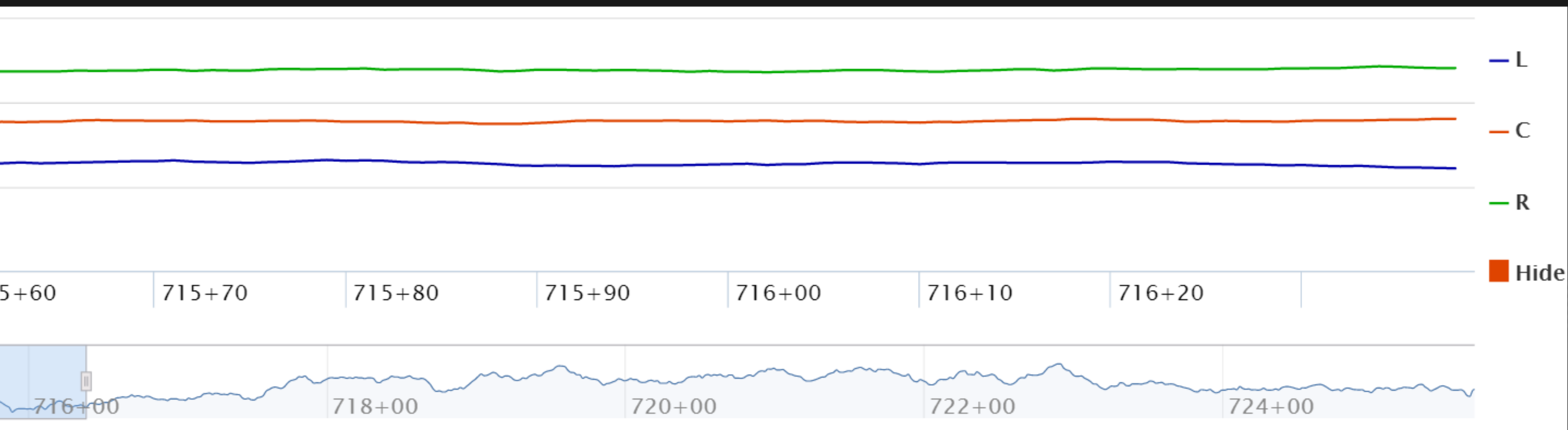
Sensor Position	Total Dist	Median	Average	Min	Max	Standard Dev
Center	1269	87.8607	87.8692	86.8951	88.8963	0.306642
Left	1269	86.557	86.5422	84.4503	87.6718	0.34858
Right	1269	88.985	88.9778	87.8945	90.2777	0.352063

Core 87J – Time Graphic, 0.1 ft

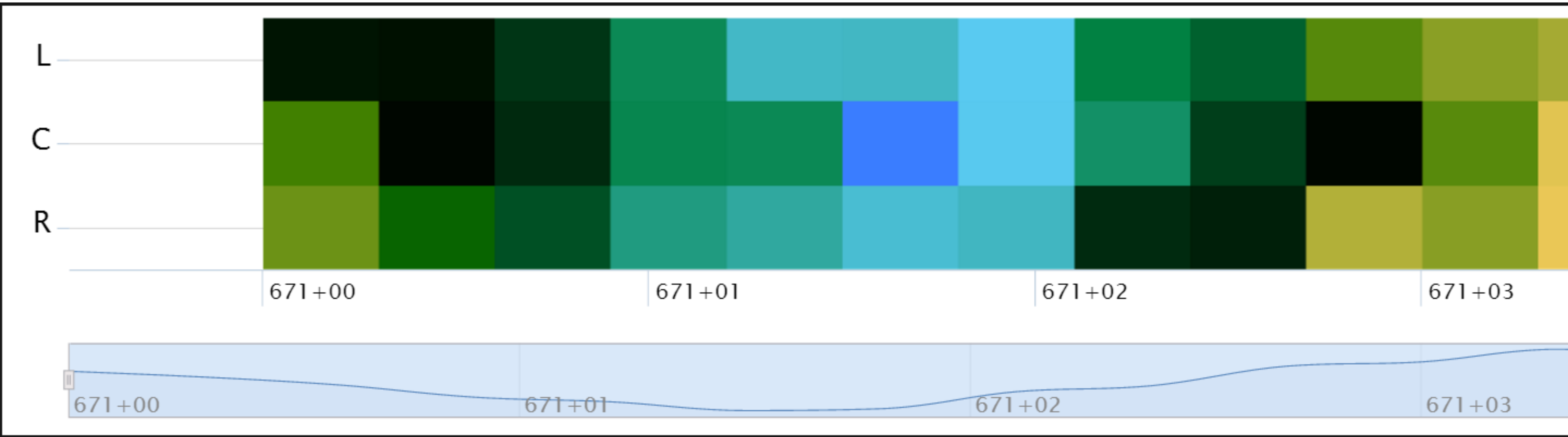


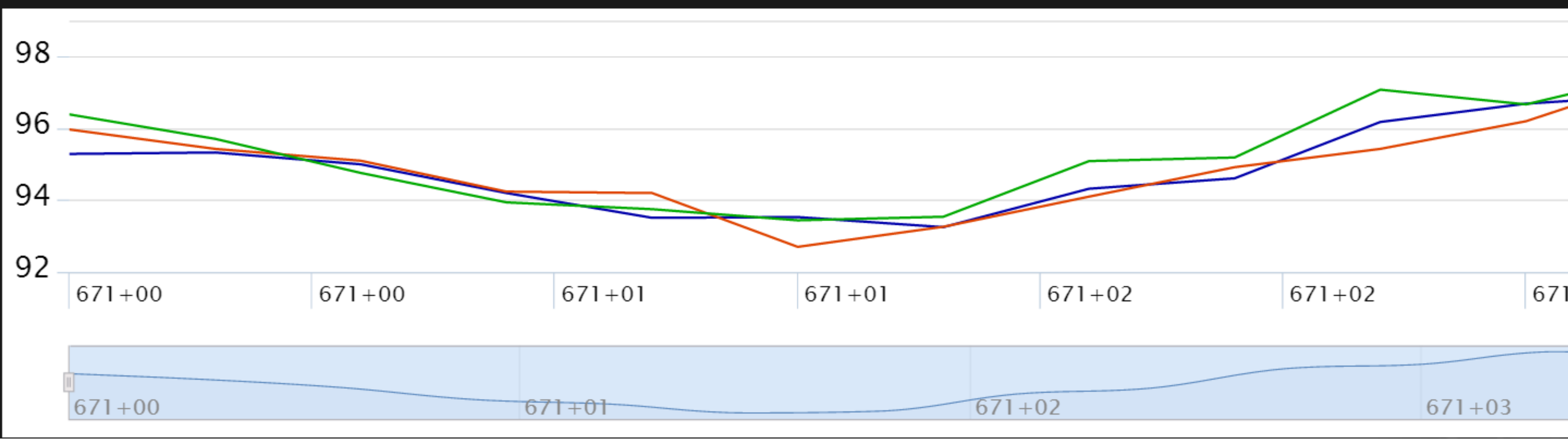
Core 87J (94.9%) – Time, 3 ft Ave





Core 85J (92.4%) – Resolution 0.25 ft





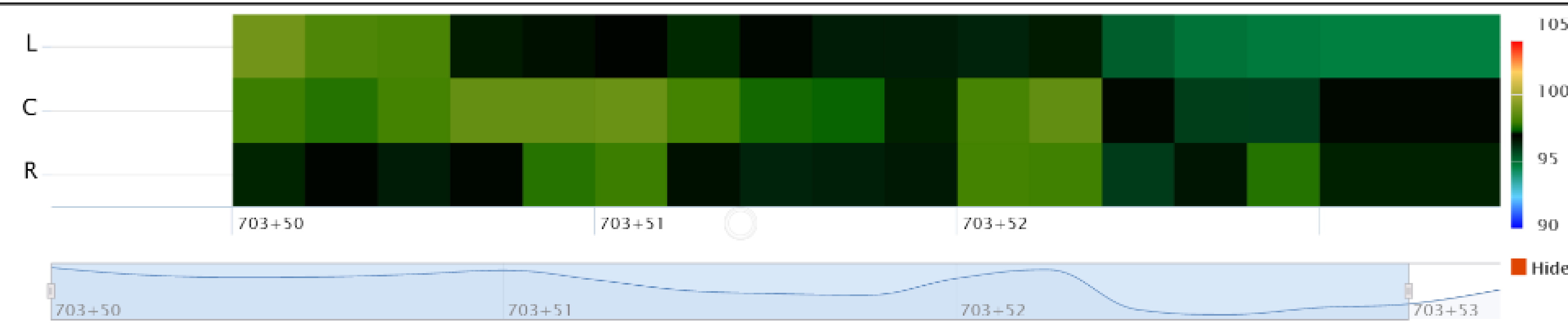
Core 85J – Distance Statistics

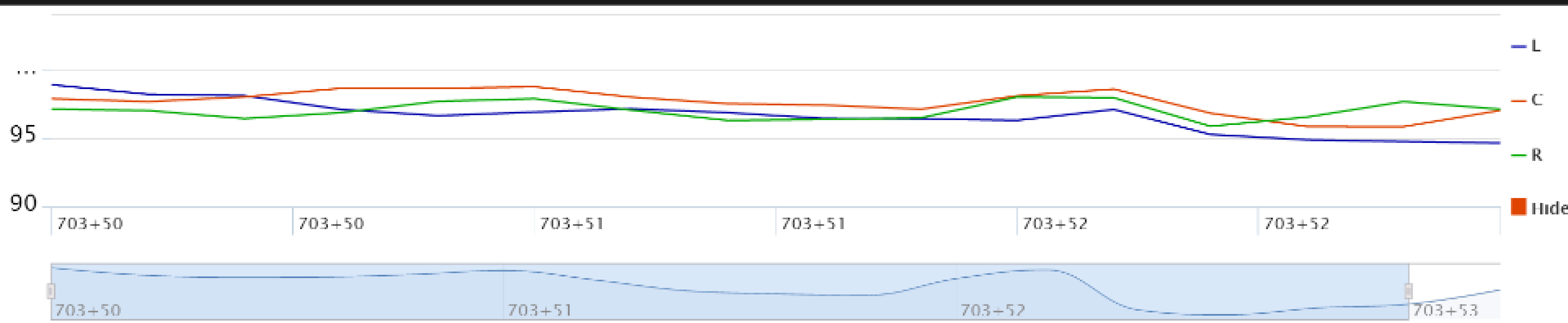
Sensor Position	Total Dist	Median	Average	Min	Max	Standard Dev
Center	4.3	95.2377	95.1644	92.0473	98.6728	1.44811
Left	4.3	95.1536	95.1277	92.6158	98.0502	1.31434
Right	4.3	95.7133	95.6349	93.0337	99.1354	1.63348

Core 85J – Time Statistics

Sensor Position	Total Dist	Median	Average	Min	Max	Standard Dev
Center	1406	94.93	95.0007	93.6112	98.9016	0.496972
Left	1406	94.3386	94.3408	92.922	97.3542	0.426824
Right	1406	94.8968	94.874	92.179	96.719	0.47235

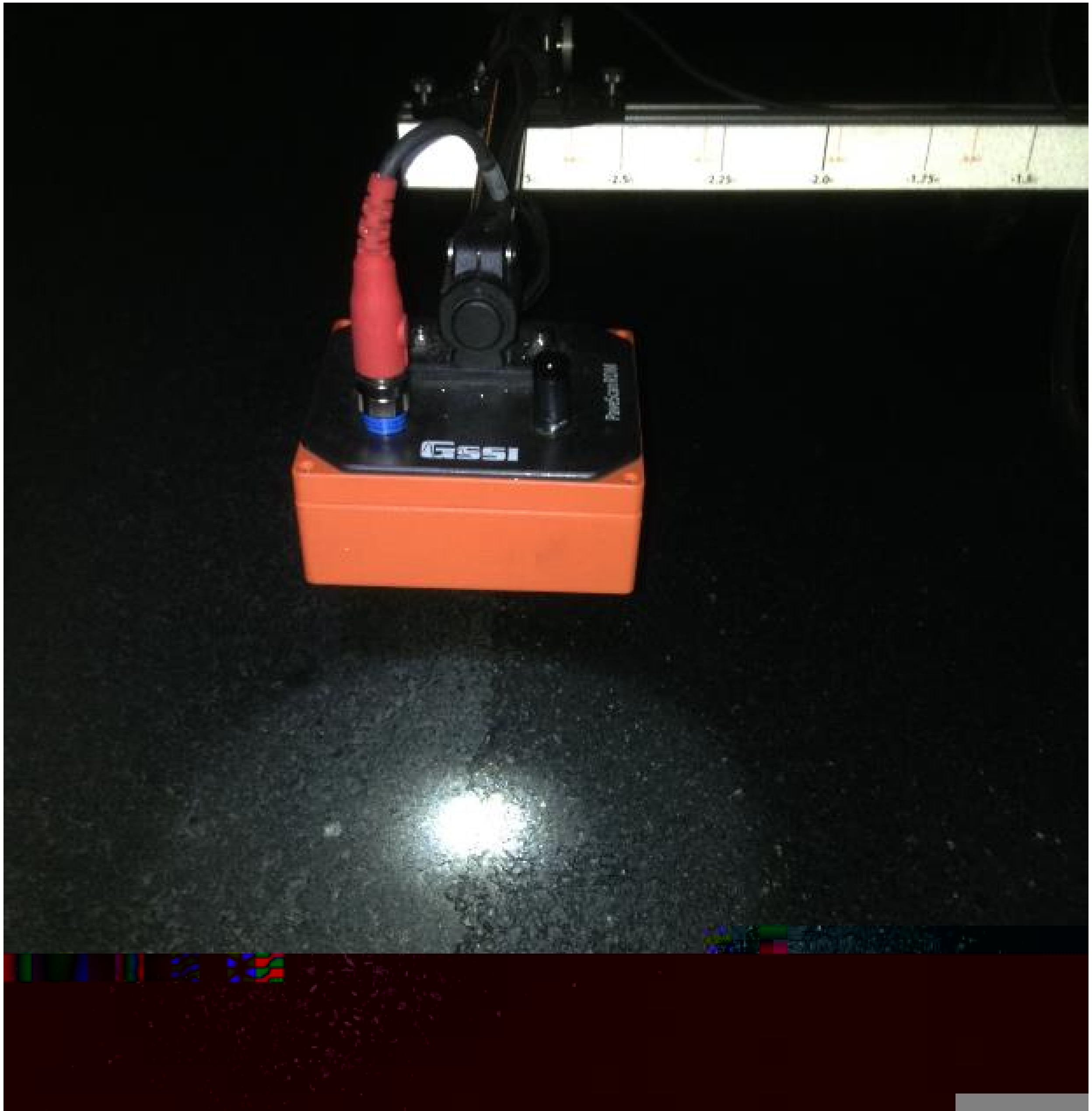
Calibration Core 19J (96.2%) 0.25 ft





Longitudinal Joint at Core 19J

Keeping Antenna Centered on Joint



PaveScan RDM on Night Paving

Same Operator Repeatability?

How Repeatable is PaveScan RDM on Joint Centerline?			
200' Run		Same 200' of 9000' Run	
Station	File 032-R	Station	File 029-R
(SB Lane 2)	Dielectric	(SB Lane 2)	Dielectric
952+0.00	5.18	951+87.50	5.21
to	-	to	-
953+99.00	5.60	953+86.50	5.38
Ave Dielectric:	5.2950		5.2679
Ave Comp:	**96.2%**		**96.0%**
Note:			
Filtered out > 99.5% Compaction Values			

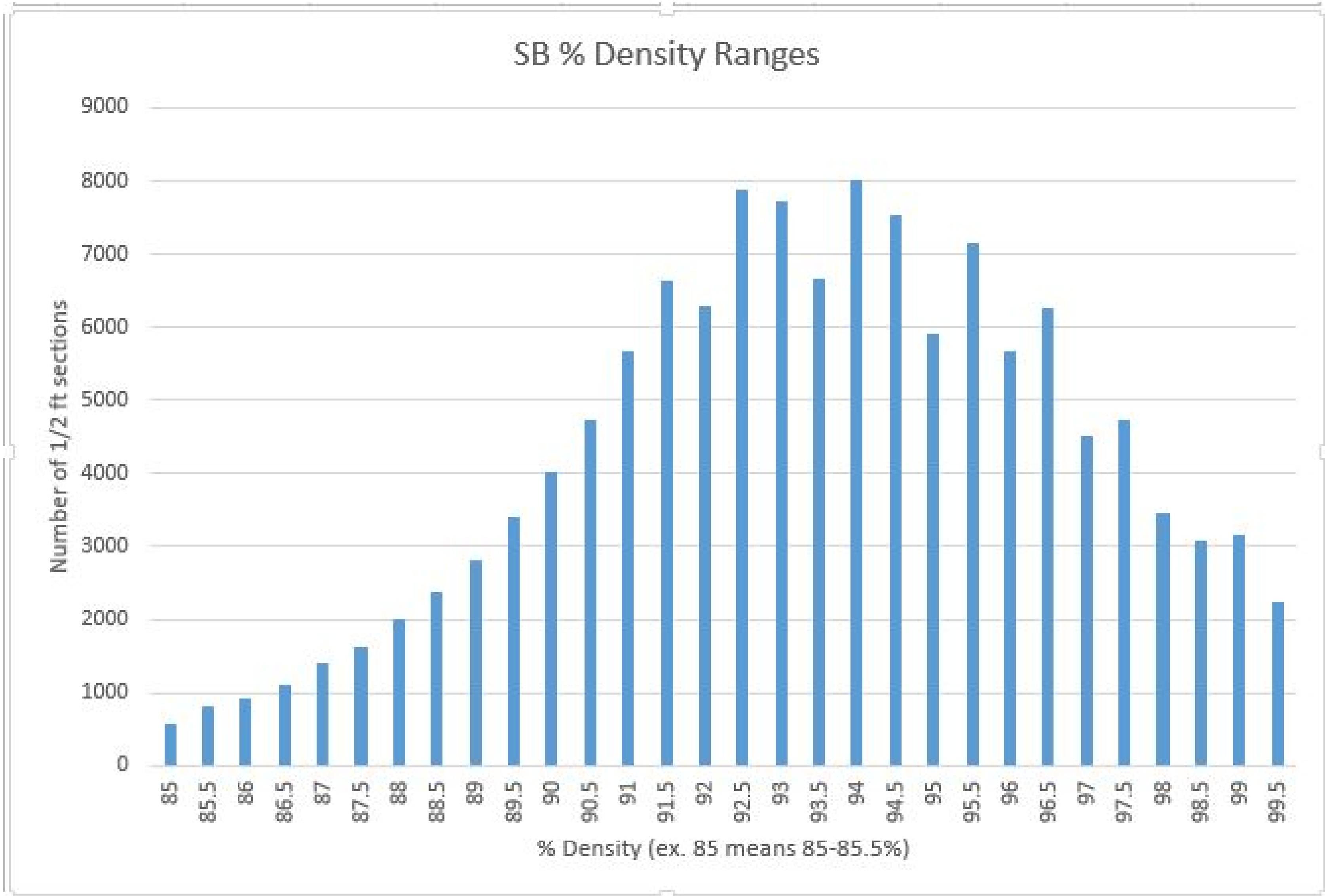
Core Densities

Compaction Summary - 2017 Data		
	% Compaction	
	Bulk/MSG	Bulk/MSG
	Panel	Joint
SB-L1 Average Panel Density (20 Cores)	94.8	
NB-L1 Average Panel Density (17 Cores)	95.4	
SB-L2 Average Panel and Joint Densities (33 Cores)	94.9	94.1
SB-L3 Average Panel and Joint Densities (3 Cores)	95.5	93.4
NB-L2 Average Panel and Joint Densities (28 Cores)	94.7	95.0
Project Averages	**94.9**	**94.5**
Max	97.6	97.8
Min	92.3	90.9
Note:		
50 of 101 (50%) of Panel Cores 95.0% or Higher		
26 of 64 (41%) of Joint Cores 95.0% or Higher		

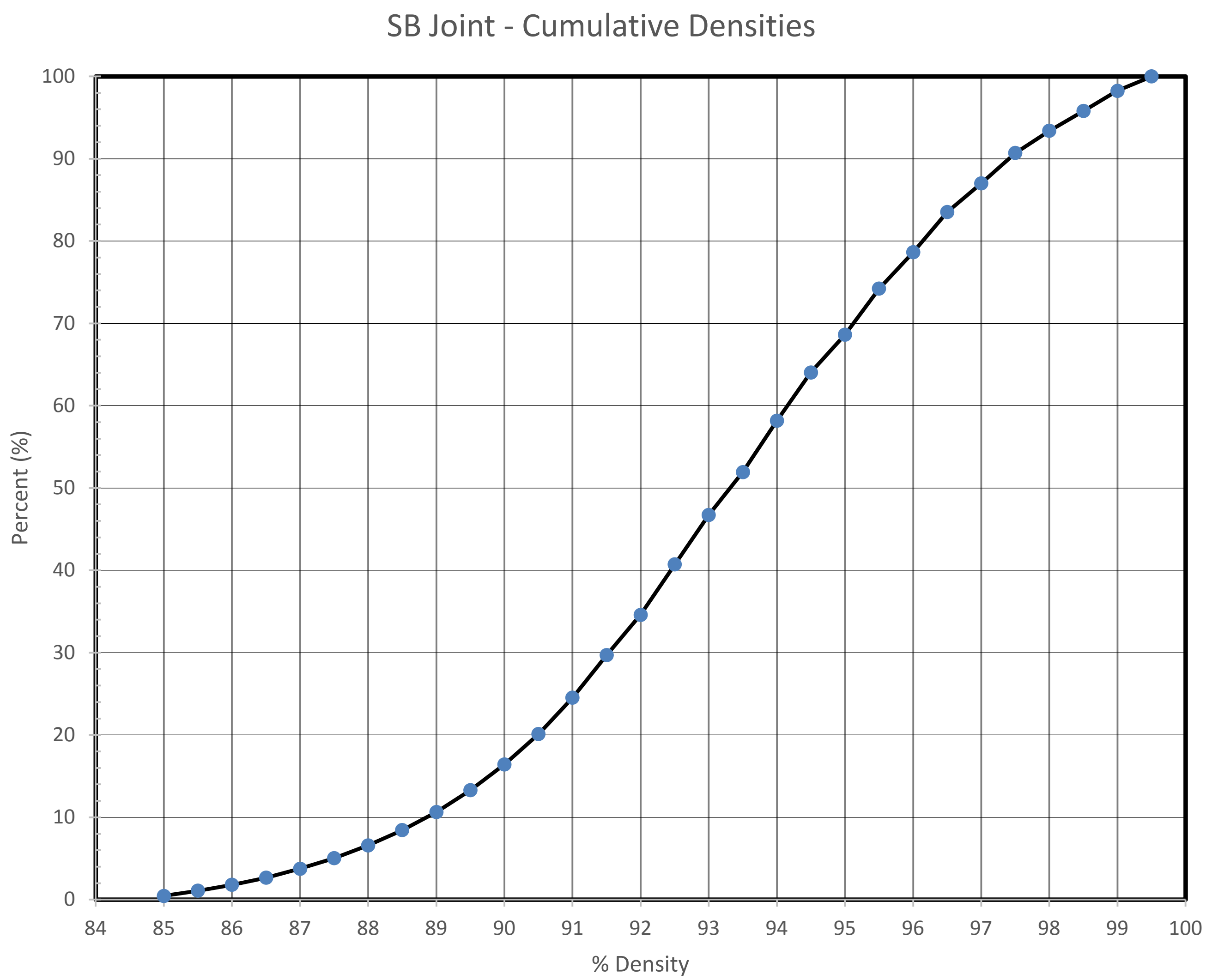
RDM vs Core - Joint Density Summary

South Bound Joint Density - Antenna on Joint Centerline			
Distance (ft)		% Compaction	
Station	DMI		Joint Ave
75,810 ft	75,686 ft	RDM Raw Data	94.0
14.36 miles			
RDM Filtered Data (85-100%)			**93.6**
36 SB Joint Cores =			**94.1**
North Bound Joint Density - Antenna on Hot Side of Joint			
53,860 ft	53,624 ft	RDM Raw Data	94.0
10.2 miles			
RDM Filtered Data (85-100%)			**94.2**
28 NB Joint Cores =			**95.0**

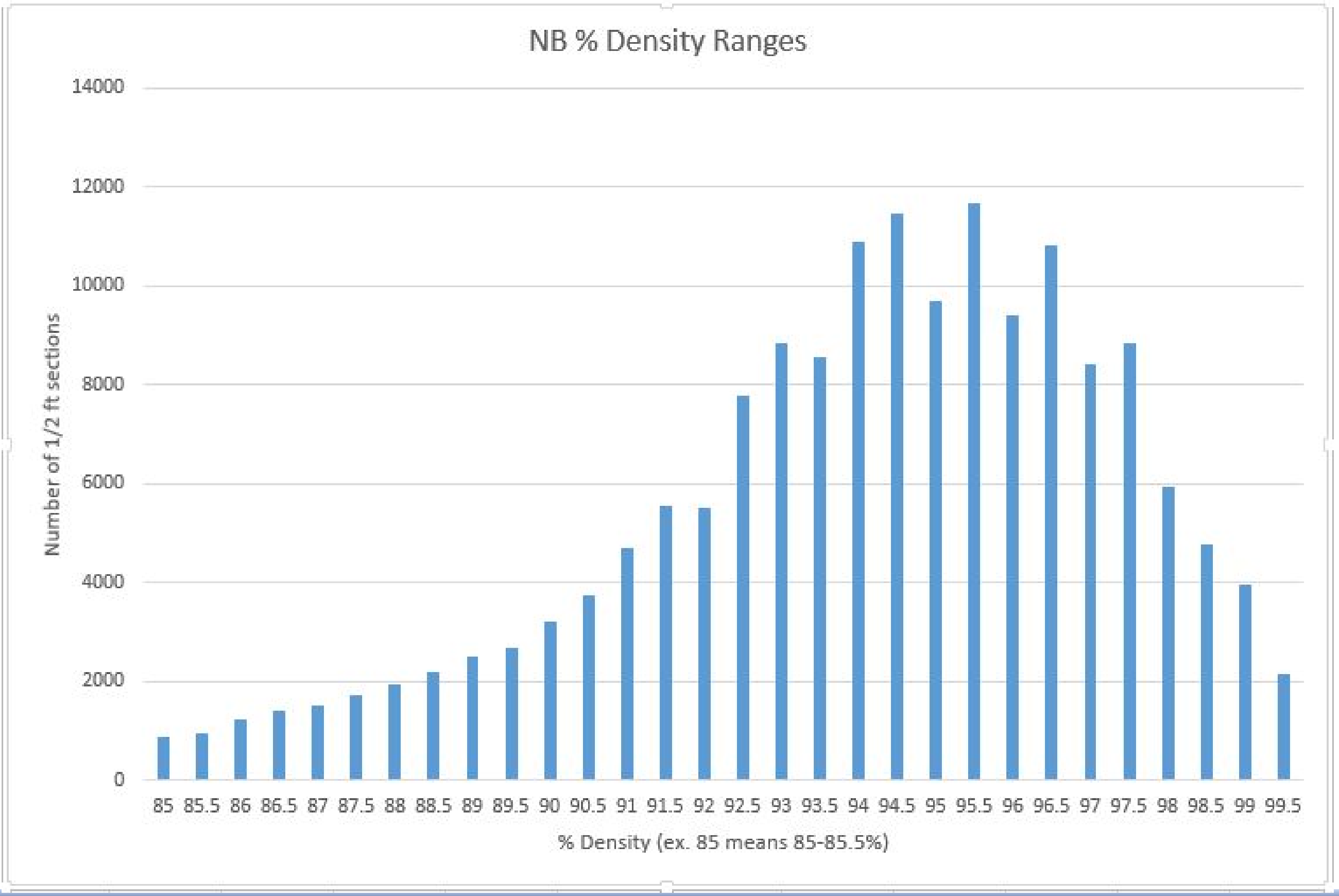
SB(Joint CL) Density Histogram



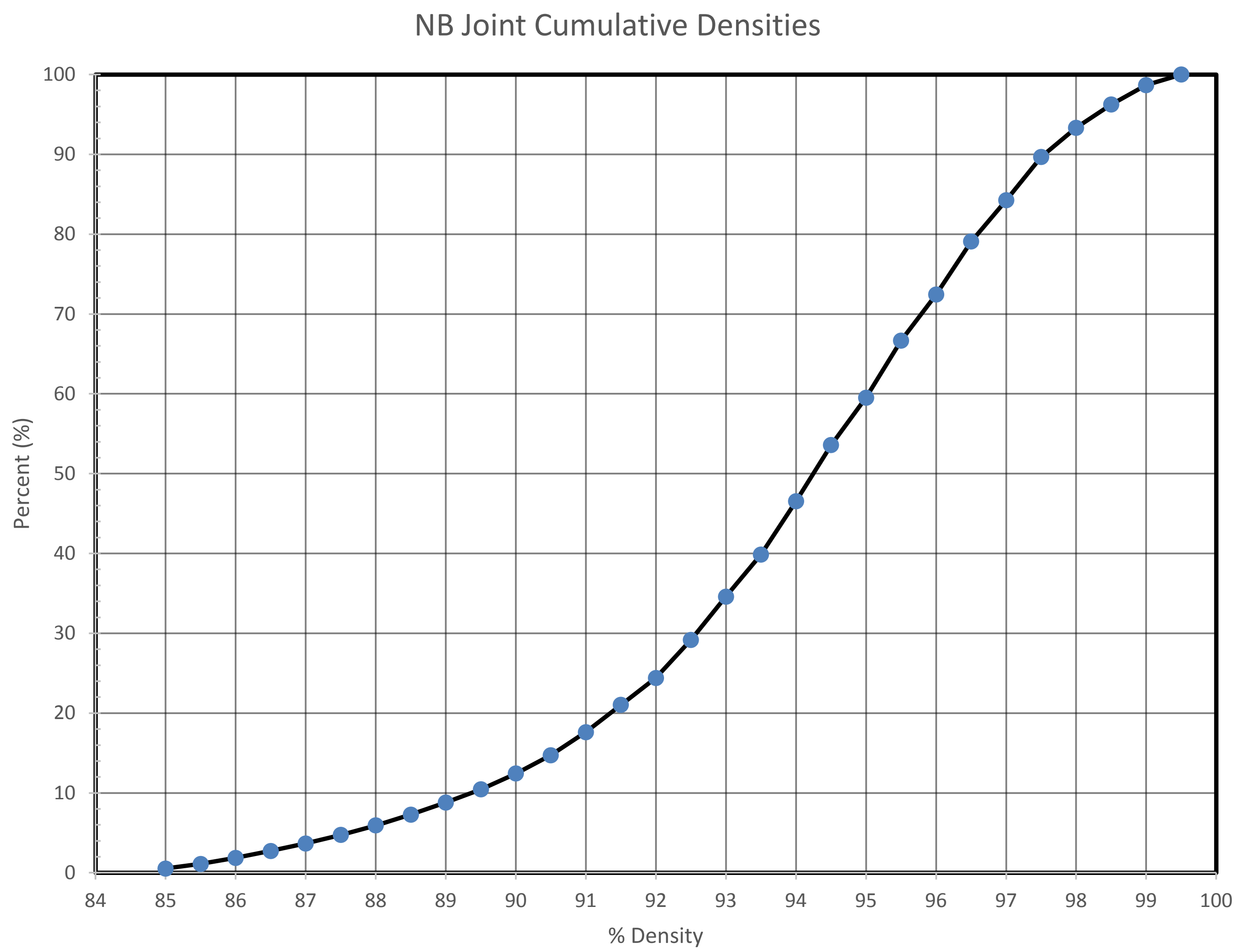
SB Joint 24.5% below 91% Density



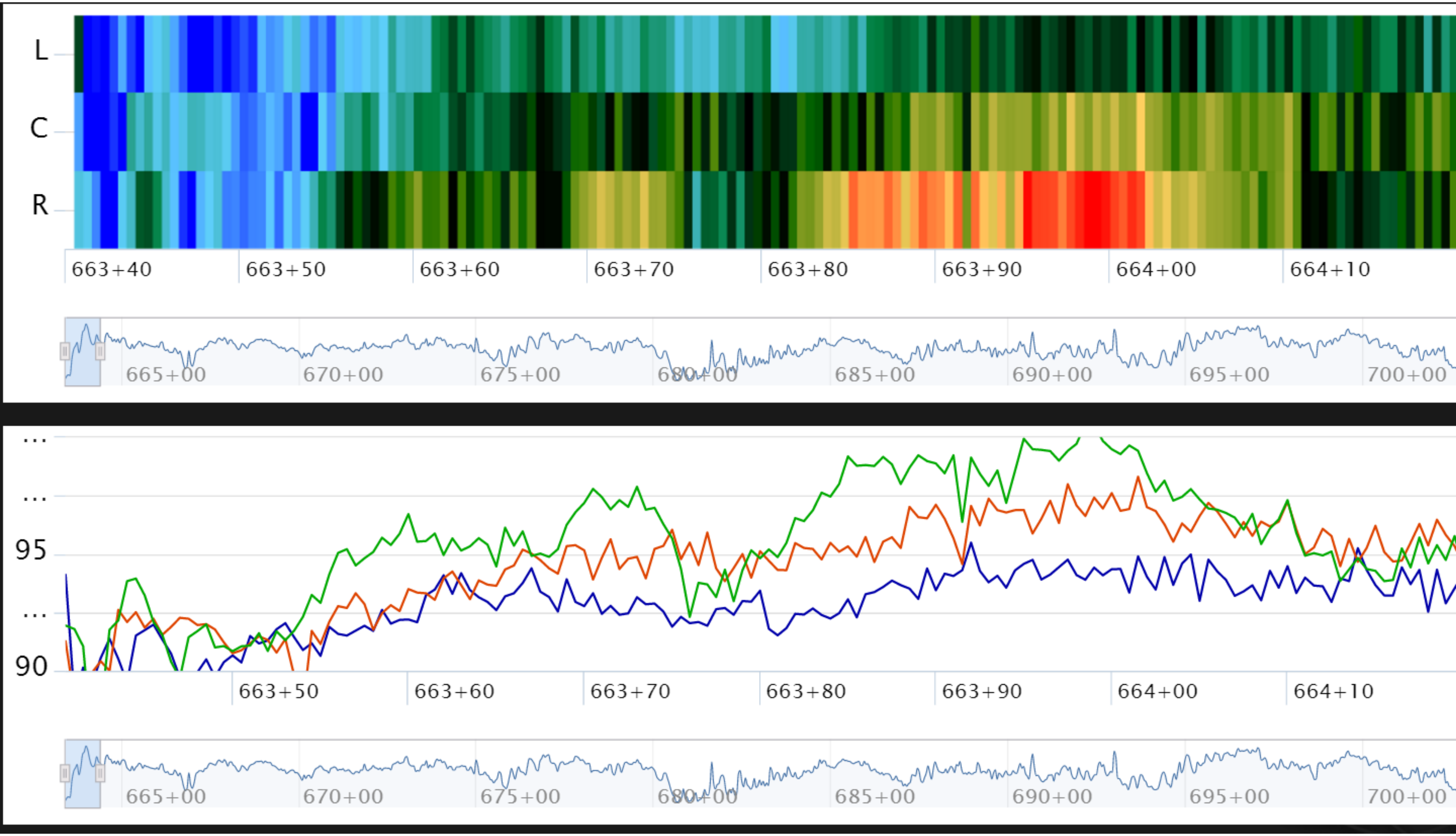
NB(Hot Side) Density Histogram



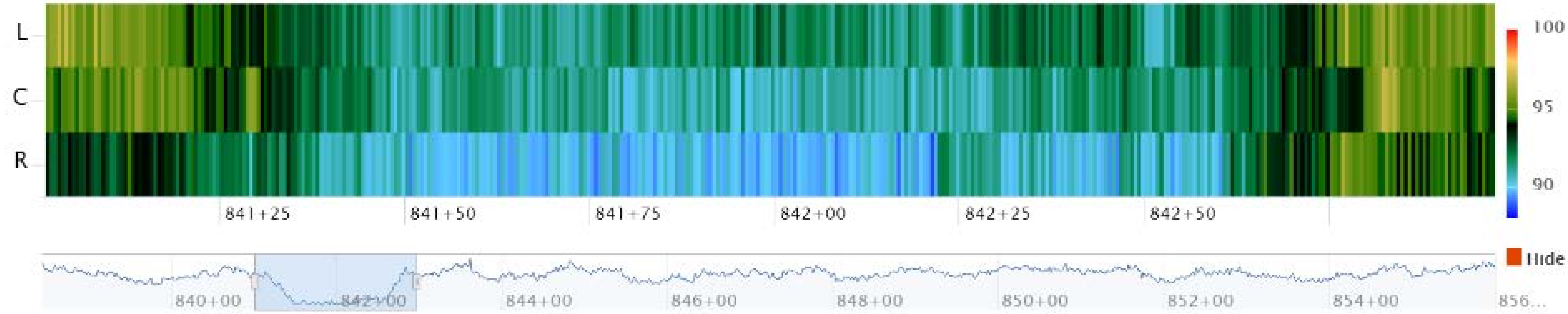
NB Joint 17.6% below 91% Density

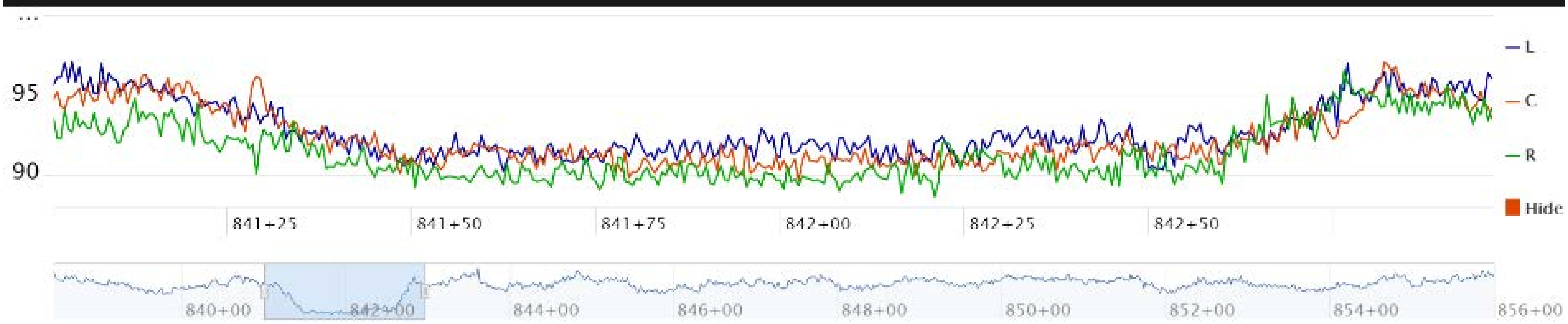


Start of Paving = Low Density

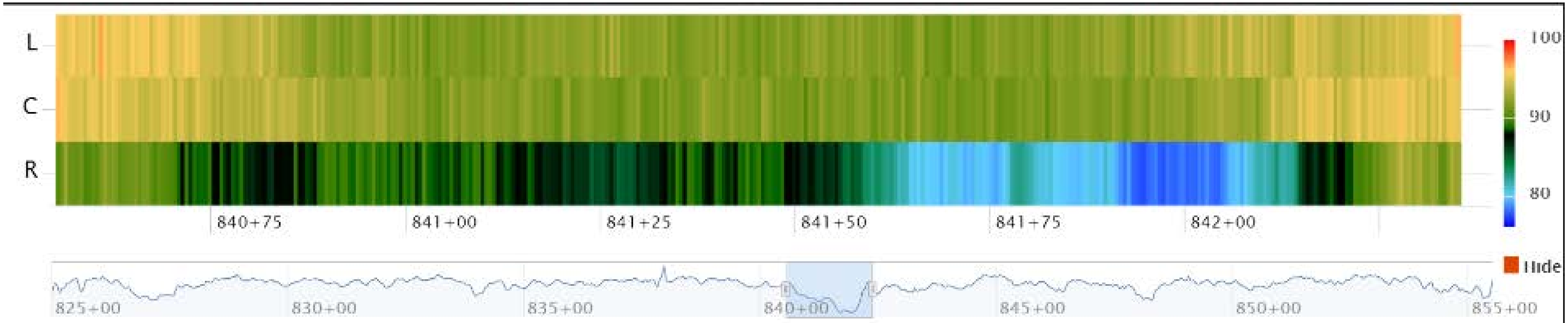


Low Density is Typical at Bridges
S. Birchwood Bridge,
SB Lane 2, 18-24’ LT





S. Birchwood Bridge, SB Lane 2, 12-18' LT



Next Steps

- Increase joint bonus to $2.00/ft but raise the bar to 96% compaction for the full bonus

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- Increase joint bonus to $2.00/ft but raise the bar to 96% compaction for the full bonus
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- Have joint bonus increase linearly from minimum acceptable value to 96.0% in 0.1% increments.

Next Steps – Density Bonus

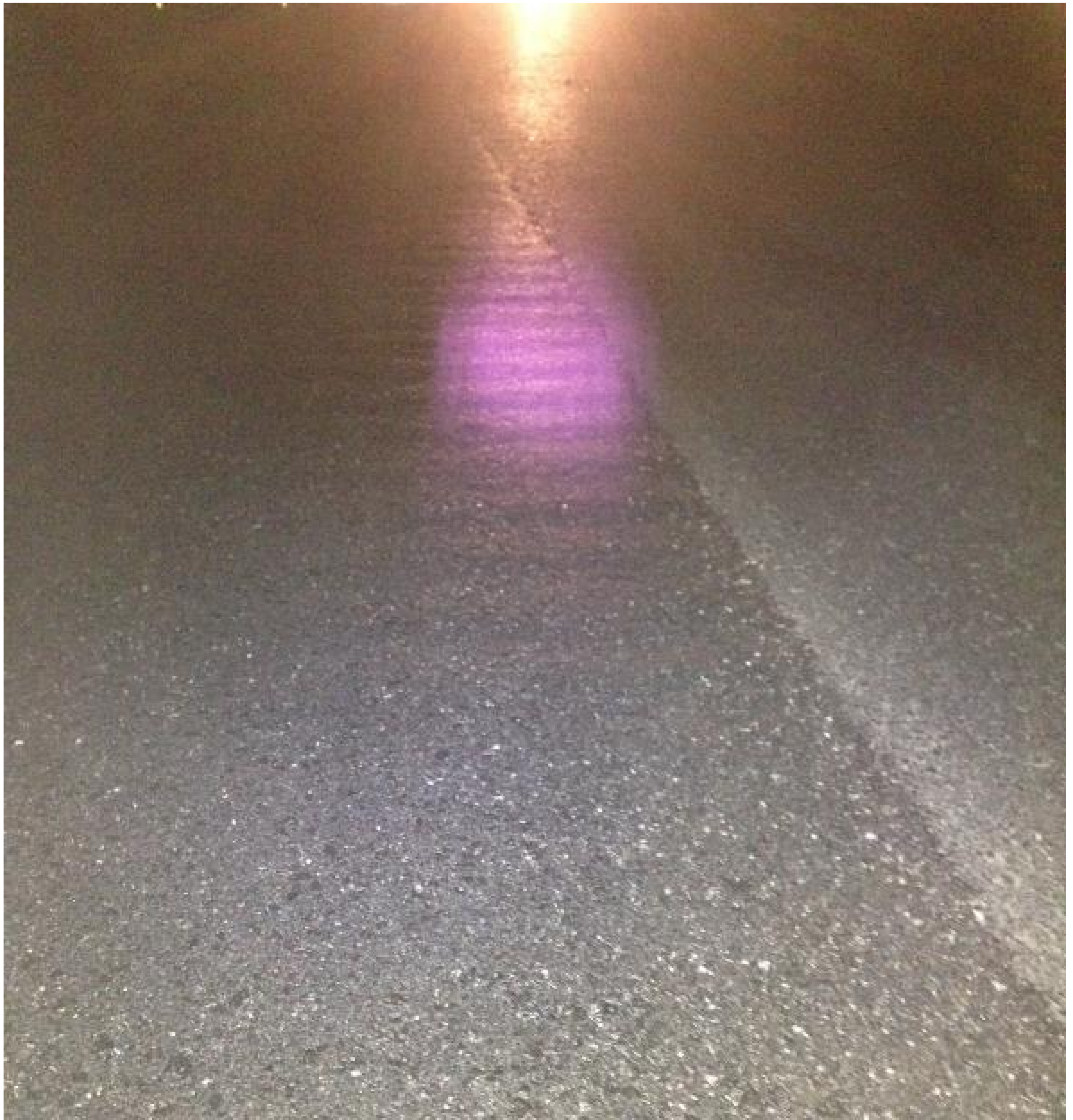
- Increase joint bonus to $2.00/ft but raise the bar to 96% compaction for the full bonus
- Raise the minimum joint density to 92.0%
- Have joint bonus increase linearly from 92.0% to 96.0% in 0.1% increments
- Have mat density bonus increase linearly from zero at 92% to 5% Bonus at 96%
- Require sealant application on all mat sections and joints below 92.0%, including Bridges

What equipment might one see when incentives are given for superior joint compaction?


16-8527
E650

Joint Heater Longitudinal Joints

What you don’t want to see



Questions?

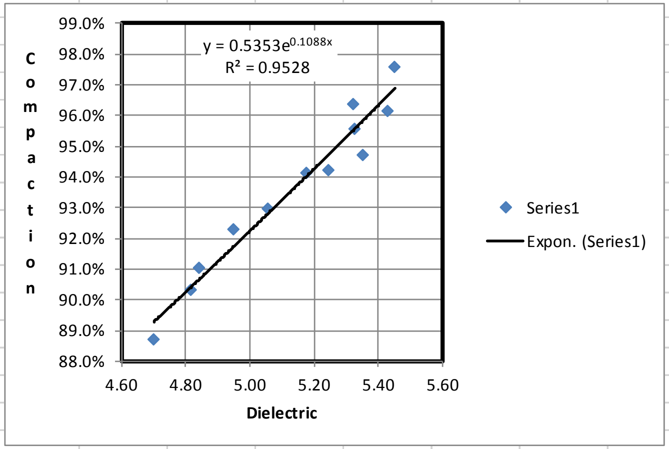
Appendix

- Core-GPR-Nuclear Calibration, xls worksheet
- Random Core-GPR Density Comparison, xls
- Two Photos of RDM orientation for collecting Distance data perpendicular to longitudinal joint

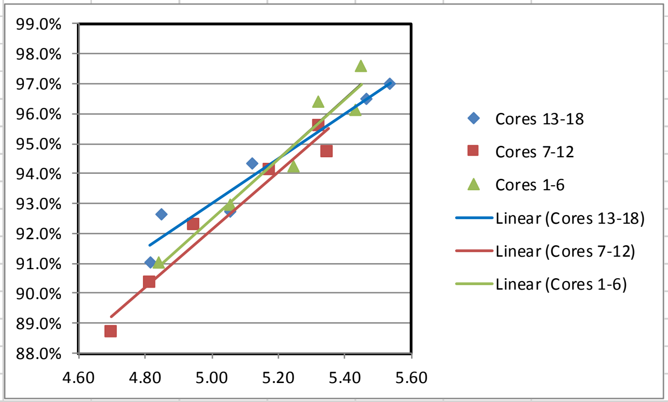
Density vs. Dielectric for May 31, 2017

	MSG	Rice Density			
2016 Mix design MSG =	2.568	159.8	pcf		
2017 Mix design MSG =	2.579	160.5	pcf		
6-1-17 Field mix MSG, Marshall setting on Gauge =	2.576	160.3	pcf		
Composite sample from cores 1-6, MSg, % Oil =	2.596	161.6	pcf	4.77	% Oil
Composite sample from cores 7-12, MSg, % Oil =	2.617	162.9	pcf	4.68	% Oil
Composite sample from cores 13-18, MSg, % Oil =	2.596	161.6	pcf	4.98	% Oil
MSG for Calibration Core 19J =	2.592	161.3	pcf		

GHHE	Nuclear Gauge Field Readings				Dielectric Values			Drilled Core	% MSG
Core #	WD1(pcf)	WD2(pcf)	WD Ave	% MSG	Time	Distance	Average	Density (pcf)	
1	155.7	157.2	156.5	97.6%	5.47	5.43	5.45	157.7	97.6%
2	146.3	146.0	146.2	91.1%	4.81	4.87	4.84	147.1	91.0%
3	152.8	152.3	152.6	95.1%	5.29	5.20	5.25	152.3	94.2%
4	153.2	154.3	153.8	95.9%	5.44	5.42	5.43	155.3	96.1%
5	148.8	147.3	148.1	92.3%	5.06	5.05	5.06	150.2	93.0%
6	155.0	153.4	154.2	96.2%	5.37	5.27	5.32	155.7	96.4%
7	149.9	144.5	147.2	91.8%	4.69	4.71	4.70	144.5	88.7%
8	154.6	153.1	153.9	96.0%	5.35	5.35	5.35	154.3	94.7%
9	145.3	146.5	145.9	91.0%	4.86	4.77	4.82	147.1	90.3%
10	143.7	146.4	145.1	90.5%	4.90	5.00	4.95	150.3	92.3%
11	154.8	153.0	153.9	96.0%	5.35	5.30	5.33	155.7	95.6%
12	149.0	151.0	150.0	93.5%	5.20	5.15	5.18	153.3	94.1%
13	146.4	146.6	146.5	91.4%	4.85	4.78	4.82	147.1	91.1%
14	152.8	151.3	152.1	94.8%	5.08	5.16	5.12	152.5	94.4%
15	148.4	148.8	148.6	92.7%	4.81	4.89	4.85	149.7	92.6%
16	155.2	155.0	155.1	96.7%	5.41	5.52	5.47	155.9	96.5%
17	152.0	149.2	150.6	93.9%	5.05	5.06	5.06	149.8	92.7%
18	154.1	154.7	154.4	96.3%	5.55	5.52	5.54	156.7	97.0%



Data from Cold mat placed 5-30-2017 and sampled 5-31-2017 from Cores 1-12



Data from Hot mat placed and sampled 5-31-2017 from Cores 13-18

2017 Glenn Highway Resurfacing - Hiland to Ekluntna — Longitudinal vs Transverse Mat Readings

Note: All readings are from the Center Antenna of the PaveScan RDM unless otherwise noted.

Acceptance and Assurance Drilled Core Density vs. PaveScan Readings:

Core No.	File No.	Date	Lab Density	Lot MSG	PaveScan Reading, % Maximum "Rice" Density (Calibration MSG = 2.576)							2.576	Average of Time or Distance	Difference (PaveScan - Lab)
					Time		Distance		3 readings across joint			3 Rdg Joint		
					Median	Average	Median	Average	Hot	Joint	Cold	Average		
64	22	6/9/17	**95.0**	2.582	94.0	94.1	No Data	No Data					**94.1**	-0.9
64		"		Nuke→	95.8	95.7		**95.7**					Nuke Δ →	0.7
64J	23	6/9/17	**94.6**		96.3	96.3	No Data	No Data					**96.3**	1.7
64J		"						Nuke→	96.1		93.2	**94.6**	Nuke Δ →	0.0
69	36	6/10/17	**96.1**	2.582	97.0	97.0						Time	**97.0**	0.9
"	40	"					96.3	96.3	←Transv.			Distance	**96.3**	0.2
69J	37	6/10/17	**92.9**		86.6	86.6						Time	**86.6**	-6.3
"	38	"					94.7	94.6				Distance	**94.7**	1.8
"	38	"							93.6	86.9	93.3	**91.3**	←3" Blocks	-1.6
"	38	"							95.0	89.4	92.9	**92.5**	←6" Blocks	-0.4
70	43	6/10/17	**93.7**	2.582	93.5	93.5						Time	**93.5**	-0.2
"	44	"					93.9	94.4	←Transv.			Distance	**94.2**	0.5
"	45	"					92.3	92.3	←Long.				**92.3**	-1.4
70J	46	"	**91.7**		84.1	84.1						Time	**84.1**	-7.6
"	47	"					94.4	93.8				Distance	**94.1**	2.4
"	47	"							88.6	85.9	94.7	**89.7**	←3" Blocks	-2.0
"	47	"							92.3	88.3	95.6	**92.0**	←6" Blocks	0.3
72	52	6/13/17	**95.4**	2.580	94.4	94.4						Time	**94.4**	-1.0
"	53	"					95.1	95.1	←Transv.			Distance	**95.1**	-0.3
"	56	"					94.7	94.6	←Long.			Distance	**94.5**	-0.9
72A	54	"	**94.9**	2.580	95.0	95.1						Time	**95.0**	0.1
"	55	"					94.5	94.6	←Transv.			Distance	**94.5**	-0.4
"	57	"					94.3	94.4	←Long.			Distance	**94.3**	-0.6
72J	58	"	**94.5**	2.580	92.5	92.5						Time	**92.5**	-2.0
"	59	"					95.9	95.5				Distance	**95.7**	1.2
"	59	"							95.3	89.8	93.8	**93.0**	←3" Blocks	-1.5
"	59	"							95.9	92.8	93.4	**94.0**	←6" Blocks	-0.5
"	60	"	Rt. Antenna 77,790+21.2' on Joint				91.2	91.1				Joint reads Low→	**91.2**	-3.3
"	61	"	Rt. Antenna 77,790+22.5' on Cold Side				98.4	98.3				Cold side reads High→	**98.3**	3.8
"	62	"	Rt. Antenna 77,790+22.6' on Hot Side				94.6	94.6				Hot side reads Very Close→	**94.6**	0.1
73	64	6/13/17	**94.8**	2.580	94.4	94.4						Time	**94.4**	-0.4
"	65	"					93.5	93.6	←Long.			Distance	**93.6**	-1.2
73J	66	"	**95.1**	2.580	91.0	91.1						Time	**91.0**	-4.1
"	67	"					95.8	96.2				Distance	**96.0**	0.9
"	67	"							98.8	90.9	94.6	**94.8**	←3" Blocks	-0.3
"	67	"							100.0	92.2	94.9	**95.7**	←6" Blocks	0.6
74	69	6/13/17	**94.0**	2.580	96.4	96.4						Time	**96.4**	2.4
"	70	"					95.9	95.9	←Long.			Distance	**95.9**	1.9
74J	71	"	**93.4**	2.580	93.3	93.3						Time	**93.3**	-0.1
"	72	"					96.2	95.4				Distance	**95.8**	2.4
"	72	"							93.0	91.1	92.6	**92.2**	←3" Blocks	-1.2
"	72	"							98.9	91.7	92.9	**94.5**	←6" Blocks	1.1
Calibration Core 19J - 26±' distance runs														
19J	76	6/14/17	Rt. Antenna 70,350+26.8' on Joint				97.9	97.6				Joint reads High→	**97.8**	1.6
"	77	"	Rt. Antenna 70,350+26.5' on Cold Side				96.3	96.4				Cold side reads Very Close→	**96.3**	0.1
"	78	"	Rt. Antenna 70,350+30.6' on Hot Side				98.6	98.6				Hot side reads High→	**98.6**	2.4
"	79	"	**96.2**	2.580	99.4	99.4						Time	**99.4**	3.2
"	80	"					97.8	97.6				Distance	**97.7**	1.5
"	80	"							96.8	95.9	95.9	**96.2**	←3" Blocks	0.0
"	80	"							97.4	98.0	96.4	**97.3**	←6" Blocks	1.1
76	83	6/14/17	**96.3**	2.580	96.2	96.2						Time	**96.2**	-0.1
"	84	"					95.9	96.1	←Transv.			Distance	**96.0**	-0.3
76J	85	"	**95.6**	2.580	95.8	95.8						Time	**95.8**	0.2
"	86	"					97.2	97.0				Distance	**97.1**	1.5
"	86	"							97.0	95.1	96.7	**96.3**	←3" Blocks	0.7