Project No. 03-100

EVALUATING THE PERFORMANCE OF CORRIDORS WITH ROUNDABOUTS

FINAL REPORT – Appendices L–O

Prepared for:
National Cooperative Highway Research Program
Transportation Research Board
National Research Council

By:
Kittelson & Associates, Inc.

In association with:
Institute for Transportation Research and Education
Texas Transportation Institute
Write Rhetoric

December 2013

NCHRP
Project 03-100

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L.1 CORRELATION TABLES

Exhibit 1: Correlation Analysis for Upstream Dataset - Unimpeded

	Influence Area Length	Geometric Delay	Free-Flow Speed	Segment Length	Spacing	Access Points	Curb Length	Median Length	Approach Width	Central Island Dia.	Inscribed Circle Dia.	Circulating Speed	Speed Limit	Circulating Lanes	Midblock Lanes	Acceleration Rate	Prop Curb
Influence Area	+1.00																
Geometric Delay	**+0.76**	+1.00															
Free-Flow Speed	+0.47	+0.46	+1.00														
Segment Length	+0.38	+0.28	**+0.82**	+1.00													
Spacing	+0.37	+0.28	**+0.75**	**+0.97**	+1.00												
Access Points	+0.04	+0.07	+0.42	**+0.68**	**+0.70**	+1.00											
Curb Length	+0.13	+0.17	+0.33	+0.26	+0.23	+0.06	+1.00										
Median Length	+0.08	+0.06	**+0.73**	**+0.91**	**+0.88**	**+0.69**	+0.26	+1.00									
Approach Width	+0.18	+0.19	**+0.50**	+0.29	+0.26	+0.13	+0.22	+0.30	+1.00								
Central Island Dia.	+0.32	+0.41	**+0.63**	+0.36	+0.32	+0.08	+0.38	+0.31	**+0.66**	+1.00							
Inscribed Circle Dia.	+0.27	+0.31	**+0.64**	+0.43	+0.40	+0.20	+0.36	+0.40	**+0.81**	**+0.94**	+1.00						
Circulating Speed	+0.03	-0.03	**+0.53**	+0.40	+0.39	+0.23	+0.12	+0.45	**+0.50**	+0.33	+0.41	+1.00					
Speed Limit	+0.30	+0.32	**+0.90**	**+0.70**	**+0.63**	+0.33	+0.15	**+0.66**	**+0.52**	**+0.62**	**+0.62**	**+0.60**	+1.00				
Circulating Lanes	+0.11	+0.11	+0.43	+0.30	+0.27	+0.10	+0.29	+0.34	**+0.75**	**+0.53**	**+0.67**	+0.38	+0.38	+1.00			
Midblock Lanes	+0.00	+0.09	+0.37	+0.26	+0.29	+0.18	+0.30	+0.39	**+0.68**	**+0.50**	**+0.63**	+0.37	+0.28	**+0.83**	+1.00		
Acceleration Rate	+0.13	+0.01	**-0.66**	**-0.60**	**-0.53**	-0.41	-0.17	**-0.63**	-0.16	-0.21	-0.23	-0.25	**-0.62**	-0.28	-0.25	+1.00	
Prop Curb	-0.49	-0.35	**-0.55**	**-0.56**	**-0.55**	-0.31	+0.43	-0.35	-0.22	-0.18	-0.23	-0.25	**-0.56**	-0.10	-0.01	+0.30	+1.00

Exhibit 2: Correlation Analysis for Downstream Dataset - Unimpeded

	Influence Area Length	Geometric Delay	Free-Flow Speed	Segment Length	Spacing	Access Points	Curb Length	Median Length	Approach Width	Central Island Dia.	Inscribed Circle Dia.	Circulating Speed	Speed Limit	Circulating Lanes	Midblock Lanes	Acceleration Rate	Prop Curb
Influence Area	+1.00																
Geometric Delay	**+0.80**	+1.00															
Free-Flow Speed	**+0.82**	**+0.73**	+1.00														
Segment Length	**+0.75**	**+0.62**	**+0.86**	+1.00													
Spacing	**+0.72**	**+0.58**	**+0.80**	**+0.97**	+1.00												
Access Points	+0.36	+0.24	+0.46	**+0.68**	**+0.71**	+1.00											
Curb Length	+0.47	+0.43	+0.41	+0.34	+0.31	+0.06	+1.00										
Median Length	**+0.57**	+0.43	**+0.77**	**+0.91**	**+0.89**	**+0.71**	+0.30	+1.00									
Approach Width	+0.35	+0.36	+0.42	+0.29	+0.26	+0.08	+0.21	+0.31	+1.00								
Central Island Dia.	**+0.53**	**+0.59**	**+0.61**	+0.41	+0.34	+0.07	+0.40	+0.40	**+0.69**	+1.00							
Inscribed Circle Dia.	**+0.54**	**+0.59**	**+0.63**	+0.48	+0.42	+0.18	+0.38	+0.49	**+0.83**	**+0.94**	+1.00						
Circulating Speed	+0.13	-0.08	+0.37	+0.31	+0.27	+0.22	+0.10	+0.44	+0.48	+0.29	+0.38	+1.00					
Speed Limit	**+0.63**	**+0.57**	**+0.92**	**+0.74**	**+0.67**	+0.34	+0.26	**+0.71**	+0.46	**+0.61**	**+0.62**	+0.48	+1.00				
Circulating Lanes	+0.30	+0.31	+0.37	+0.30	+0.26	+0.14	+0.23	+0.36	**+0.69**	**+0.51**	**+0.65**	+0.42	+0.35	+1.00			
Midblock Lanes	+0.14	+0.10	+0.15	+0.21	+0.21	+0.18	+0.13	+0.33	+0.48	+0.28	+0.45	+0.29	+0.08	**+0.74**	+1.00		
Acceleration Rate	-0.16	+0.15	+0.32	+0.18	+0.13	+0.10	+0.00	+0.25	+0.00	+0.24	+0.20	-0.01	+0.45	+0.05	-0.04	+1.00	
Prop Curb	-0.47	-0.46	**-0.55**	**-0.56**	**-0.55**	-0.33	+0.38	-0.42	-0.26	-0.21	-0.26	-0.07	-0.54	-0.15	-0.06	-0.12	+1.00

L.2 ROUNDABOUT INFLUENCE AREA DETAILS

RIA VARIABLE PLOTS

Exhibit 3: Variable Plot: Influence Area by Circulating Speed

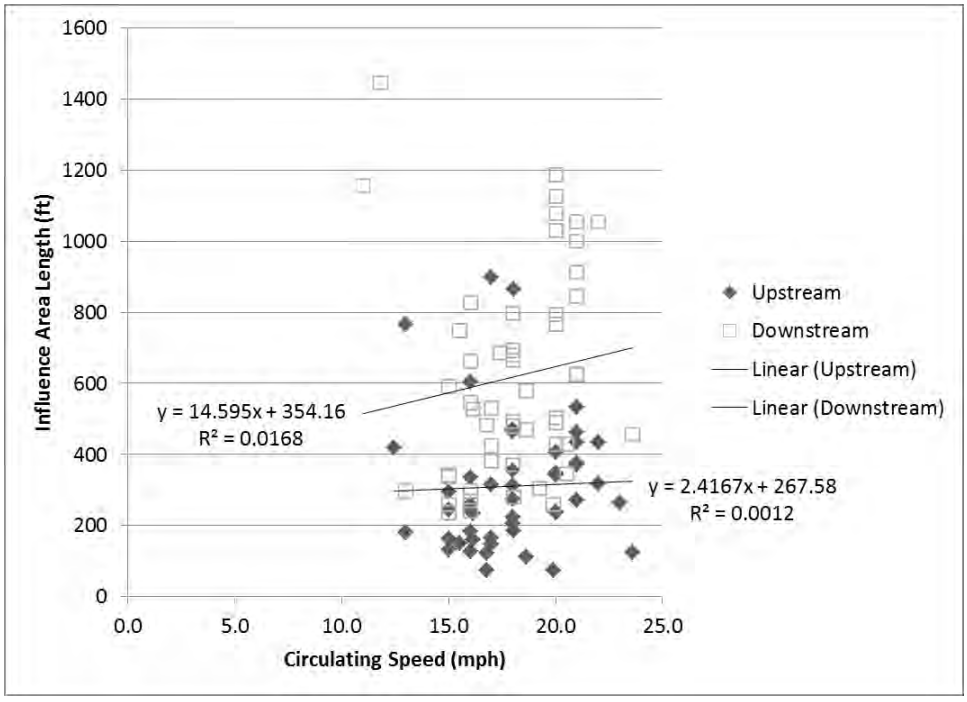
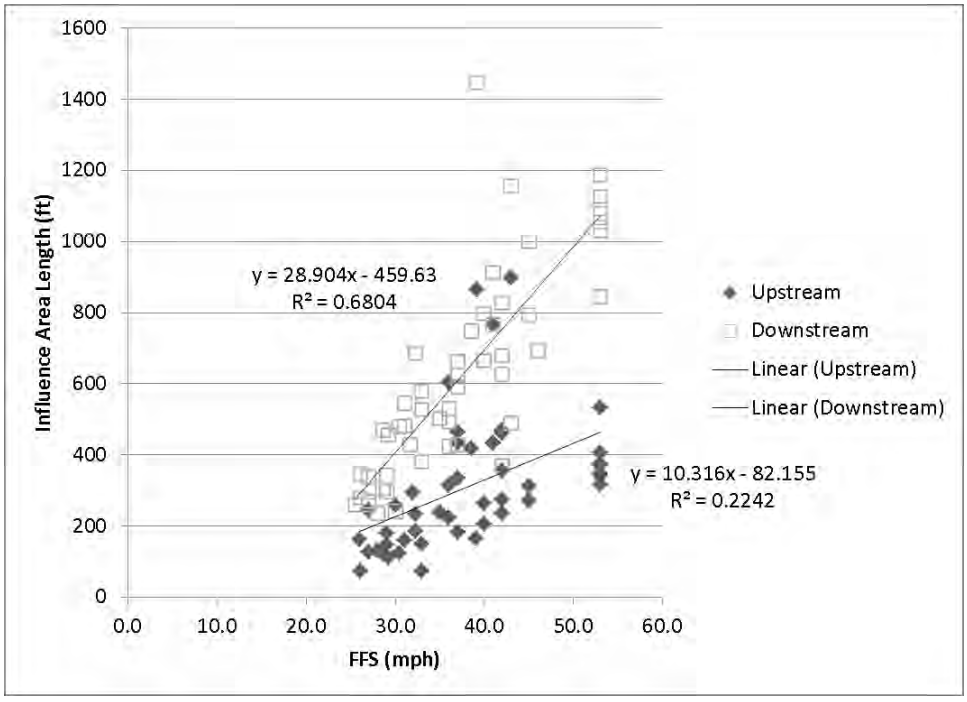


Exhibit 4: Variable Plot: Influence Area by FFS



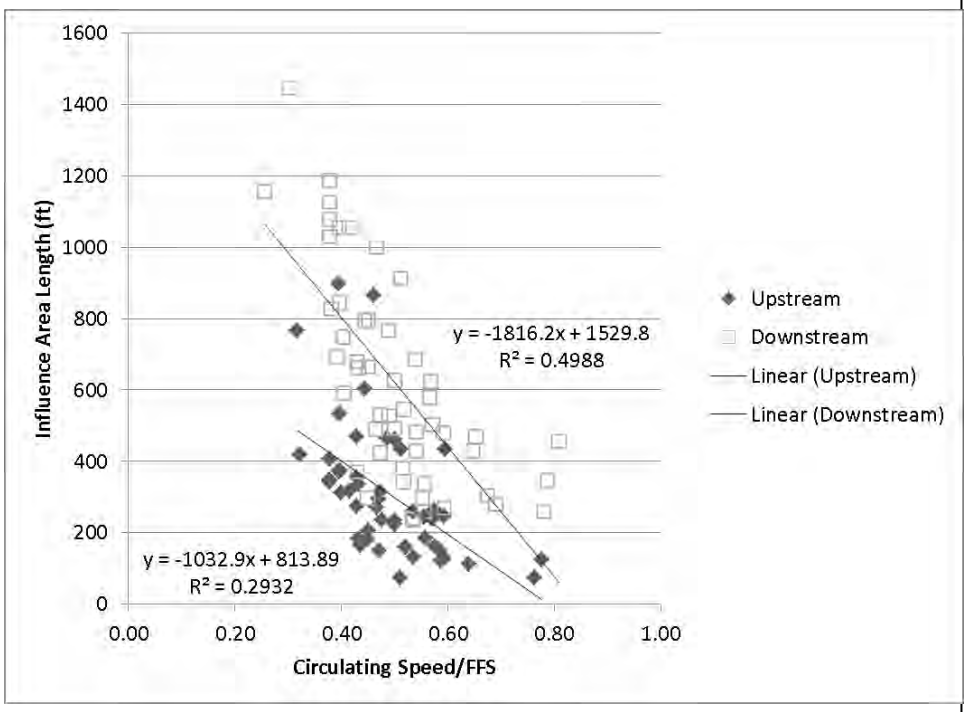


Exhibit 5: Variable Plot: Influence Area by Circulating Speed /FFS

RIA MODEL RESULTS

Exhibit 6: RIA Upstream Models

Model	Intercept value	Intercept p	Speed Limit value	Speed Limit p	FFS value	FFS p	Circulating Speed/FFS value	Circulating Speed/FFS p	Approach Width value	Approach Width p	Median Length value	Median Length p	Curb Length value	Curb Length p	Midblock Lanes value	Midblock Lanes p	Circulating Speed value	Circulating Speed p	ICD value	ICD p	CID value	CID p	R2
U1	217.9	0.264	10.6	0.009							0.0	0.234	0.1	0.368			-15.2	0.221					0.160
U2	-62.6	0.599			10.9	0.005			-2.7	0.692									0.1	0.914			0.228
U3	-51.1	0.673			10.3	0.008			-3.6	0.514											0.5	0.626	0.232
U4	-7.6	0.949			10.4	0.006									-90.8	0.108					0.8	0.442	0.268
U5	165.7	0.146	3.0	0.366											-76.0	0.210					1.7	0.108	0.148
U6	-367.5	0.008			21.5	<0.0001					-0.1	0.002	0.0	0.995							-0.6	0.474	0.383
U7	811.2	0.000	0.1	0.970			-1032.5	0.001															0.295
U8	**165.9**	**0.307**			**13.8**	**<0.0001**											**-21.1**	**0.046**					**0.289**
U9	-348.9	0.009			19.3	<0.0001					-0.1	0.002											0.376
U10	-81.9	0.457			10.3	0.001																	0.224

Exhibit 7: RIA Downstream Models

Model	Intercept		Speed Limit		FFS		Circulating Speed/FFS		Approach Width		Median Length		Curb Length		Midblock Lanes		Circulating Speed		ICD		CID		R2
	value	p	value	p	value	p	value	p	value	p	value	p	value	p	value	p	value	p	value	p	value	p	
D1	420.2	0.066	15.1	0.001							0.1	0.090	0.2	0.007			-27.6	0.035					0.557
D2	-455.9	0.001			27.8	<0.0001			-2.0	0.803									0.6	0.676			0.681
D3	-451.6	0.001			27.9	<0.0001			-0.8	0.890											0.5	0.676	0.681
D4	-468.9	0.000			28.0	<0.0001									6.7	0.887					0.4	0.708	0.681
D5	-110.4	0.454	14.8	0.001											21.1	0.740					2.0	0.125	0.432
D6	-553.9	0.000			31.1	<0.0001					0.0	0.219	0.1	0.080							-0.1	0.918	0.710
D7	943.7	0.000	9.9	0.007			-1320.9	<0.0001															0.566
D8	**-149.8**	**0.364**			**31.4**	**<0.0001**											**-22.5**	**0.019**					**0.714**
D9	-580.5	0.000			33.3	<0.0001					-0.1	0.203											0.690
D10	-459.2	<0.0001			28.9	<0.0001																	0.680

L.3 GEOMETRIC DELAY DETAILS

GEOMETRIC DELAY VARIABLE PLOTS

Exhibit 8: Variable Plot: Geometric Delay by Circulating Speed

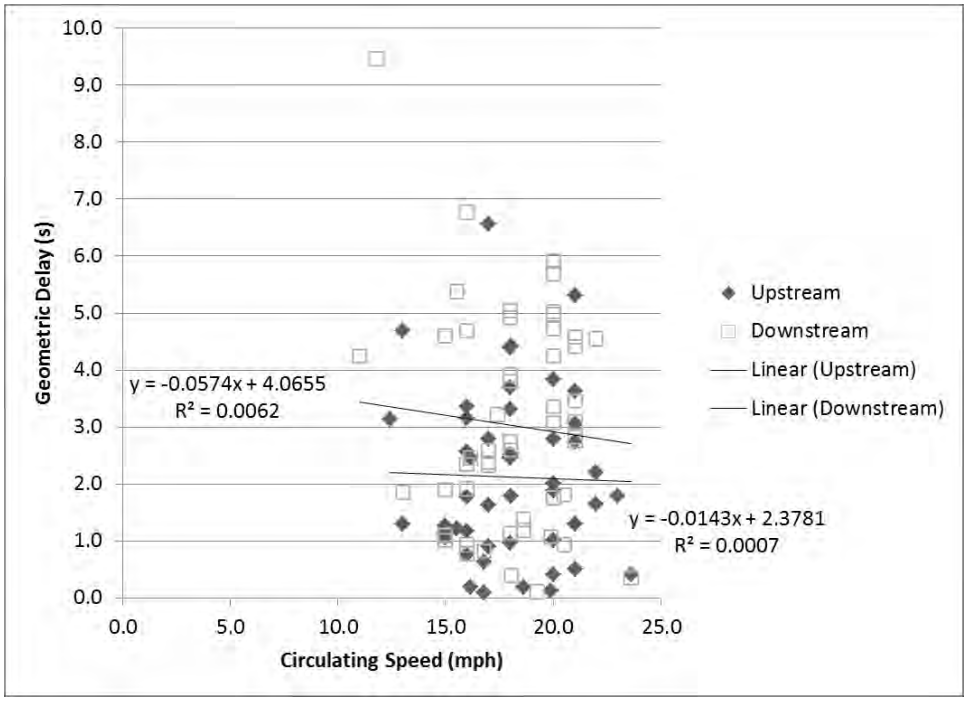
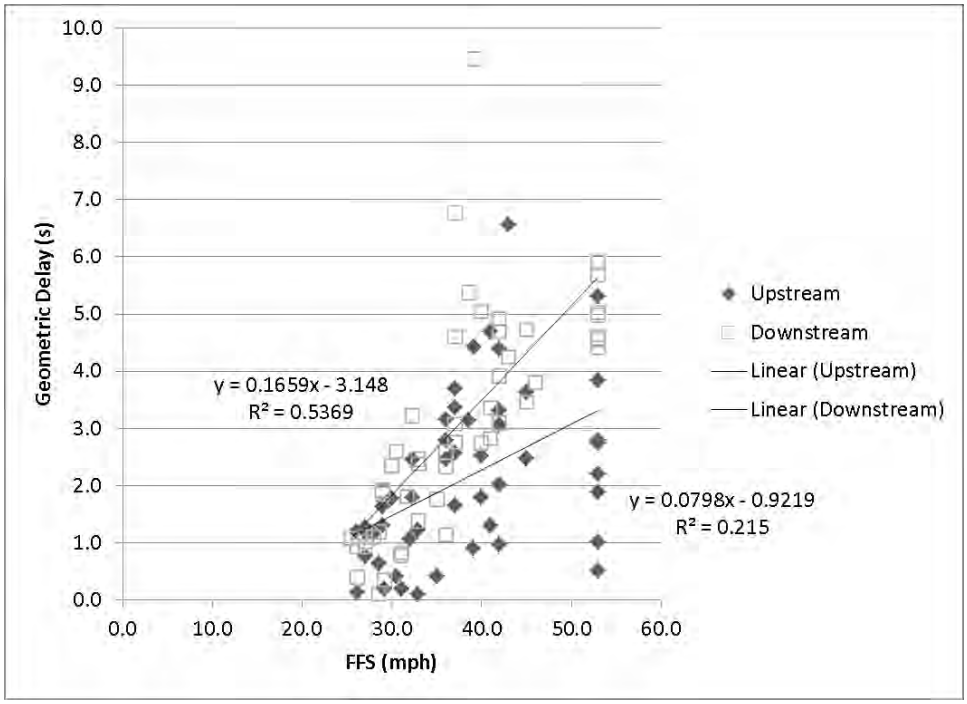


Exhibit 9: Variable Plot: Geometric Delay by FFS



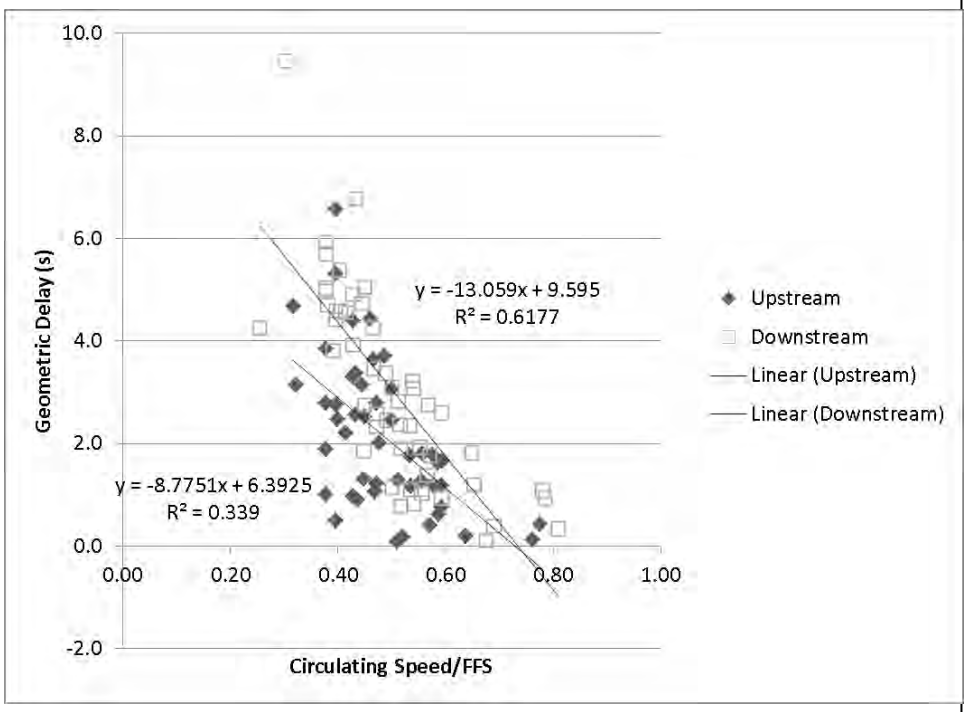


Exhibit 10: Variable Plot: Geometric Delay by Circulating Speed/FFS

GEOMETRIC DELAY MODEL RESULTS

Exhibit 11: Geometric Delay Upstream Models

Model	Intercept Val.	Intercept p	Influence Area Length Val.	Influence Area Length p	FFS Val.	FFS p	SL Val.	SL p	Circulating Speed/FFS Val.	Circulating Speed/FFS p	Number of Access Points Val.	Number of Access Points p	Median Length Val.	Median Length p	Circulating Speed/SL Val.	Circulating Speed/SL p	Circulating Speed Val.	Circulating Speed p	R2
U1	0.26	0.334	0.01	<0.0001															0.575
U2	-0.89	0.309			0.08	0.001													0.212
U3	0.49	0.514					0.05	0.027											0.099
U4	6.40	<0.0001							-8.77	<0.0001									0.337
U5	2.06	<0.0001									0.03	0.637							0.005
U6	2.06	<0.0001											0.00	0.687					0.003
U7	5.02	<0.0001													-5.29	0.001			0.210
U8	-1.16	0.207			0.09	0.001					-0.07	0.305							0.230
U9	0.46	0.550					0.05	0.032			-0.02	0.793							0.101
U10	**1.57**	**0.213**			**0.11**	**<0.0001**											**-0.21**	**0.012**	**0.315**
U11	1.30	0.310			0.12	<0.0001					-0.07	0.290					-0.21	0.012	0.332

Exhibit 12: Geometric Delay Downstream Models

Model	Intercept		Influence Area Length		FFS		SL		Circulating Speed/FFS		Number of Access Points		Median Length		Circulating Speed/SL		Circulating Speed		Circulating Delay		R2
	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p	
D1	-0.16	0.678	0.01	<0.0001																	0.634
D2	-3.16	0.000			0.17	<0.0001															0.534
D3	-0.80	0.332					0.11	<0.0001													0.323
D4	9.64	<0.0001							-13.13	<0.0001											0.618
D5	2.74	<0.0001									0.17	0.091									0.056
D6	2.31	<0.0001											0.00	0.002							0.181
D7	8.25	<0.0001													-9.33	<0.0001					0.482
D8	-3.48	0.000			0.18	<0.0001					-0.08	0.269									0.546
D9	-0.74	0.375					0.11	<0.0001			0.03	0.705									0.325
D10	0.85	0.456			0.20	<0.0001											-0.29	<0.0001			0.672
D11	0.55	0.644			0.21	<0.0001					-0.07	0.318					-0.29	<0.0001			0.679
D12	-0.33	0.363																	1.15	<.0001	0.681
D13	-2.03	0.079			0.10	0.001											-0.05	0.476	-0.02	0.704	0.779
D14	-1.97	0.082			0.10	0.001											-0.05	0.487	0.77	<.0001	0.778
D15	**-2.63**	**<.0001**			**0.09**	**<.0001**													**0.84**	**<.0001**	**0.776**
D16	-1.92	0.006	0.00	0.048	0.05	0.077													0.73	<.0001	0.794

L.4 APPENDIX D: FFS MODEL DETAILS

FFS PREDICTION VARIABLE PLOTS

Exhibit 13: Variable Plot: Free-Flow Speed by Circulating Speed

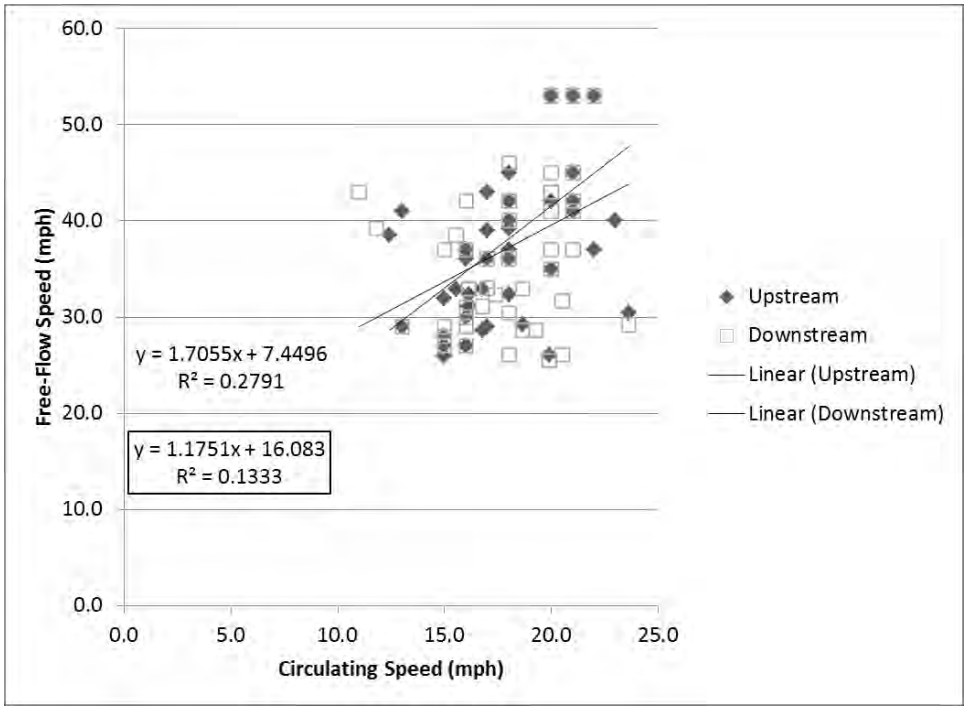
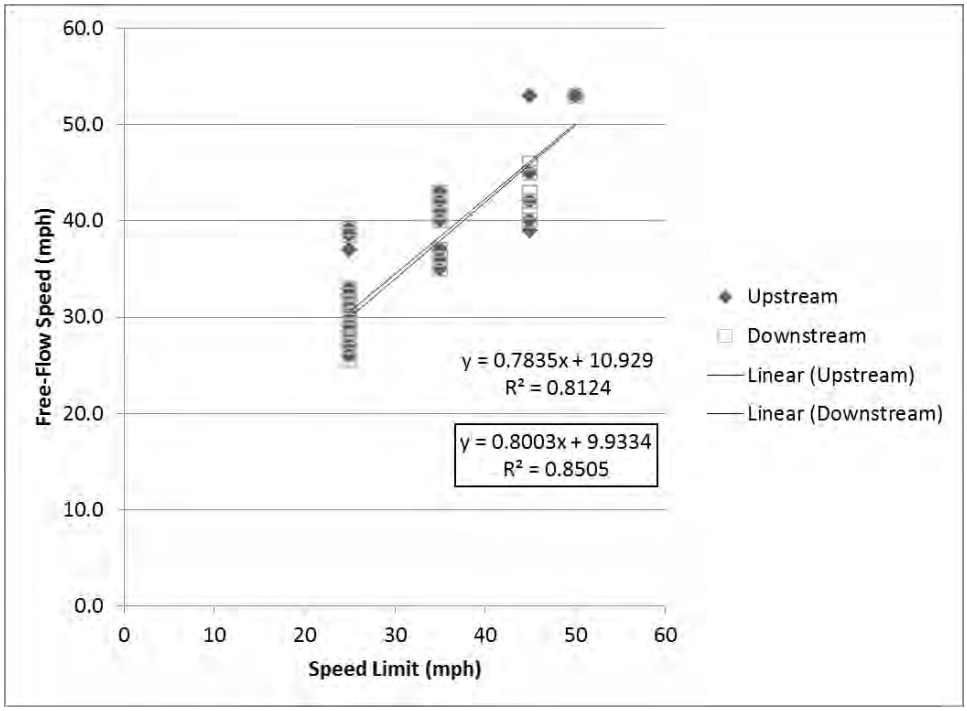


Exhibit 14: Variable Plot: Free-Flow Speed by Speed Limit



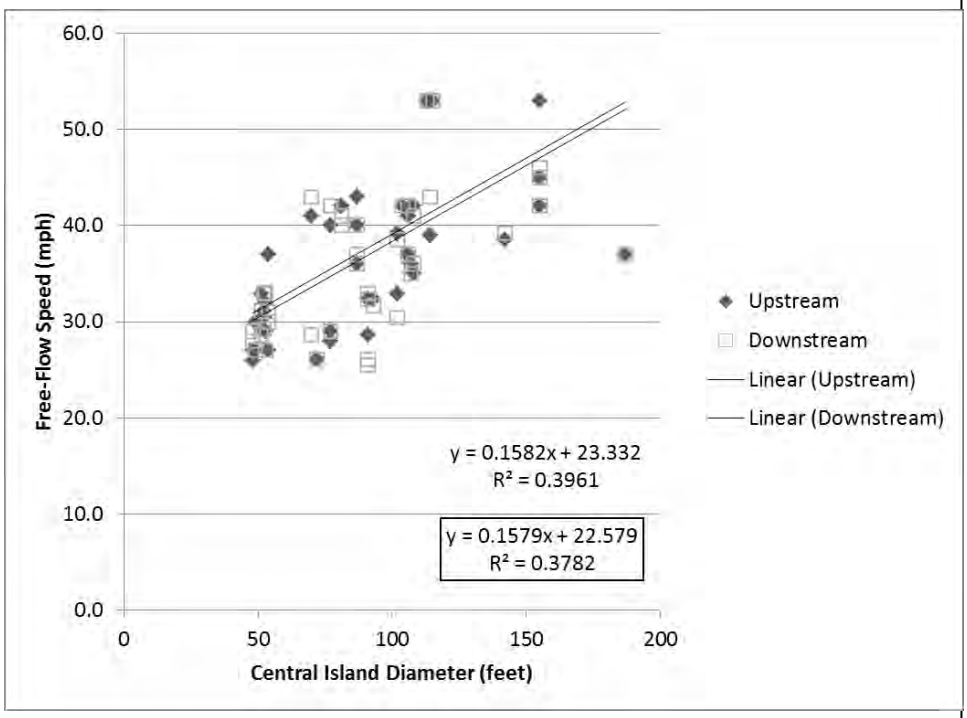


Exhibit 15: Variable Plot: Free-Flow Speed by Central Island Diameter

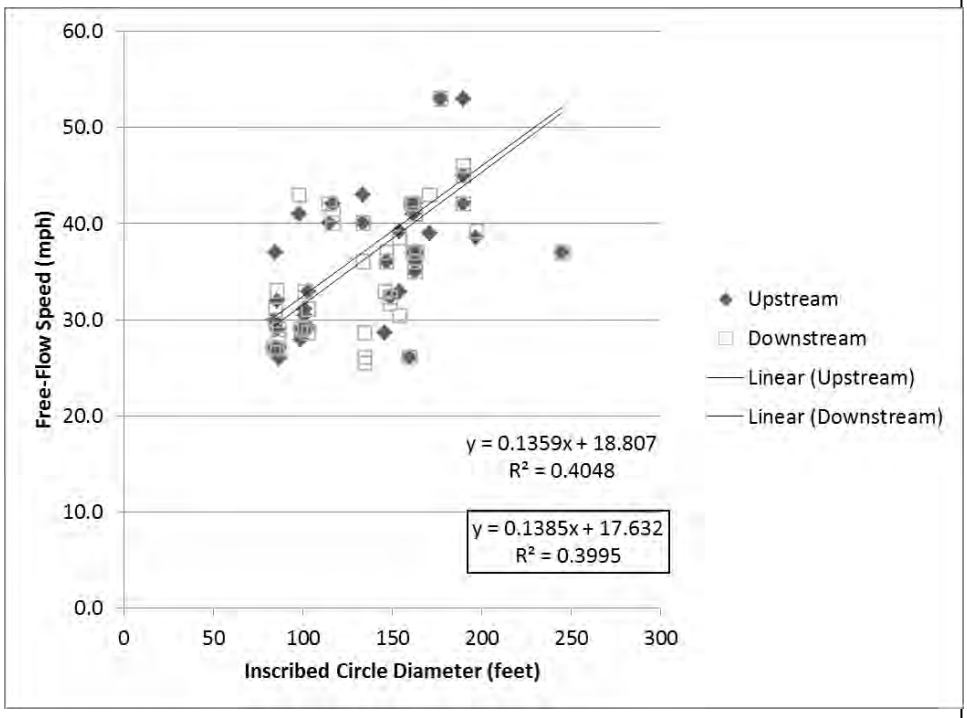


Exhibit 16: Variable Plot: Free-Flow Speed by Inscribed Circle Diameter

FFS PREDICTION MODEL RESULTS

Exhibit 17: FFS Upstream Models

	Intercept		Segment Length		Speed Limit		ICD		CID		Overlap 1=yes 0=no		R2
Model	**value**	**p**	**value**	**p**	**value**	**p**	**value**	**p**	**value**	**p**	**value**	**p**	
U1	30.5	<0.0001	0.0	<0.0001									0.679
U2	10.7	<0.0001			0.8	<0.0001							0.714
U3	22.6	<0.0001	0.0	<0.0001			0.1	0.000					0.746
U4	9.5	<0.0001			0.7	<0.0001	0.0	0.135					0.822
U5	23.0	<0.0001			0.0	<0.0001			0.1	<0.0001			0.788
U6	16.5	<0.0001	0.0	<0.0001	0.5	<0.0001							0.847
U7	15.9	<0.0001	0.0	<0.0001	0.4	<0.0001			0.0	0.013			0.863
U8	30.8	<0.0001	0.0	<0.0001							-1.2	0.500	0.681
U9	15.9	<0.0001	0.0	<0.0001	0.5	<0.0001					-4.2	0.001	0.877
U10	**15.1**	**<0.0001**	**0.0**	**<0.0001**	**0.4**	**<0.0001**			**0.0**	**0.001**	**-4.7**	**<0.0001**	**0.901**

Exhibit 18: FFS Downstream Models

Model	Intercept value	Intercept p	Segment Length value	Segment Length p	Speed Limit value	Speed Limit p	ICD value	ICD p	CID value	CID p	Overlap 1=yes 0=no value	Overlap 1=yes 0=no p	R2
D1	28.5	<0.0001	0.0	<0.0001									0.743
D2	9.9	<0.0001			0.8	<0.0001							0.751
D3	22.9	<0.0001	0.0	<0.0001			0.0	0.003					0.778
D4	8.6	<0.0001			0.7	<0.0001	0.0	0.139					0.858
D5	23.2	<0.0001			0.0	<0.0001			0.1	0.000			0.799
D6	15.8	<0.0001	0.0	<0.0001	0.5	<0.0001							0.891
D7	15.5	<0.0001	0.0	<0.0001	0.4	<0.0001			0.0	0.275			0.893
D8	28.8	<0.0001	0.0	<0.0001							-1.0	0.504	0.745
D9	15.1	<0.0001	0.0	<0.0001	0.5	<0.0001					-4.1	<0.0001	0.920
D10	**14.6**	**<0.0001**	**0.0**	**<0.0001**	**0.5**	**<0.0001**			**0.0**	**0.038**	**-4.4**	**<0.0001**	**0.926**

L.5 OPERATIONAL MODEL DETAILS

Exhibit 19: Downstream Descriptive Statistic – Operational Data

Variable	Units	Mean	Std Dev	Min	Max
Segment Speed	Mph	31.4	7.1	16.4	48.7
Total Delay	Sec	3.1	2.3	0.0	15.1
Entering Flow/Lane	Veh.	390.9	152.5	169.0	686.0
Conflicting Flow	Veh.	167.6	189.1	0.0	726.0
Speed Limit	Mph	35.4	9.6	25.0	50.0
Free-Flow Speed (FFS)	Mph	36.7	8.3	21.7	53.0
Unimpeded Speed	Mph	31.8	6.9	23.3	49.0
Circulating Speed	Mph	18.0	2.7	5.0	22.0
Approach Lanes	Count	1.7	0.5	1.0	2.0
Central Island Diam.	Ft	97.9	33.9	48.0	187.0
Inscribed Circle Diam.	Ft	146.7	38.9	84.0	245.0
Prop Median	fraction	0.8	0.3	0.1	1.1
Prop Curb	fraction	0.8	0.4	0.0	1.0
Midblock Turbulence	binary	0.5	0.5	0.0	1.0
Segment Length	Ft	961.2	880.5	250.0	3953.0
Spacing	Ft	1678.0	1814.0	361.0	8004.0
Median Length	Ft	792.0	907.9	153.0	3953.0
Curb Length	Ft	585.5	428.1	0.0	2031.0
Number Access Points	Count	1.2	2.2	0.0	16.0
Approach Capacity	veh/ln	971.0	160.1	546.7	1130.0
Vol/Cap Ratio	fraction	0.4	0.2	0.2	1.1
Overlap Segment	Binary	0.1	0.3	0.0	1.0

Exhibit 20: Upstream Descriptive Statistic – Operational Data

Variable	Units	Mean	Std Dev	Min	Max
Segment Speed	Mph	28.7	8.7	5.5	51.9
Total Delay	Sec	3.7	3.1	0.0	16.6
Entering Flow/Lane	Veh.	374.7	167.1	140.0	914.0
Conflicting Flow	Veh.	131.2	141.1	0.0	612.0
Speed Limit	Mph	35.3	9.4	25.0	50.0
Free-Flow Speed (FFS)	Mph	37.0	8.2	21.7	53.0
Unimpeded Speed	Mph	31.6	7.5	16.2	50.7
Circulating Speed	Mph	17.9	2.6	12.4	23.6
Approach Lanes	Count	1.6	0.5	1.0	2.0
Central Island Diam.	Ft	95.7	34.6	48.0	187.0
Inscribed Circle Diam.	Ft	142.7	39.8	84.0	245.0
Prop Median	fraction	0.8	0.4	0.0	1.0
Prop Curb	fraction	0.8	0.4	0.0	1.0
Midblock Turbulence	binary	0.6	0.5	0.0	1.0
Segment Length	Ft	776.5	777.7	95.0	3993.0
Spacing	Ft	1537.0	1568.0	238.0	8004.0
Median Length	Ft	567.9	798.2	39.0	3993.0
Curb Length	Ft	445.8	352.2	0.0	1627.0
Number Access Points	Count	1.2	2.4	0.0	17.0
Approach Capacity	veh/ln	1000.0	127.3	612.8	1130.0
Vol/Cap Ratio	fraction	0.4	0.2	0.1	0.8
Overlap Segment	Binary	0.1	0.4	0.0	1.0

Exhibit 21: Downstream Correlation Analysis – Operational Data

	Speed_Avg	delay_total	Flow_Entry_Lane	Flow_Confl	SL	Speed_FF	Speed_Unimp	CircleSpeed	Num_App_Lane	CID	ISD	Prop_Median	Prop_Curb	MB_Turb	Seg_Length	Spacing	Median_Length	Curb_Length	Num_AP	cap	vol_cap
Speed_Avg	+1.00																				
delay_total	+0.32	+1.00																			
Flow_Entry_Lane	-0.54	+0.01	+1.00																		
Flow_Confl	-0.07	+0.09	+0.10	+1.00																	
SL	**+0.76**	**+0.51**	-0.43	+0.05	+1.00																
Speed_FF	**+0.90**	**+0.64**	-0.41	+0.01	**+0.86**	+1.00															
Speed_Unimp	**+0.95**	**+0.53**	-0.48	-0.01	**+0.81**	**+0.94**	+1.00														
CircleSpeed	+0.46	+0.17	-0.37	-0.08	**+0.50**	+0.45	+0.49	+1.00													
Num_App_Lane	+0.38	+0.28	-0.42	+0.20	**+0.56**	+0.42	+0.41	+0.46	+1.00												
CID	**+0.50**	+0.40	-0.18	+0.11	**+0.69**	**+0.60**	**+0.54**	+0.43	**+0.64**	+1.00											
ISD	**+0.52**	+0.38	-0.29	+0.14	**+0.70**	**+0.59**	**+0.56**	**+0.50**	**+0.78**	**+0.93**	+1.00										
Prop_Median	+0.01	-0.20	+0.11	-0.21	+0.16	-0.02	+0.00	+0.26	+0.22	+0.21	+0.24	+1.00									
Prop_Curb	-0.48	-0.30	+0.07	-0.28	-0.36	-0.45	-0.48	+0.00	-0.20	-0.16	-0.22	+0.25	+1.00								
MB_Turb	-0.32	-0.25	-0.11	+0.29	-0.52	-0.40	-0.39	-0.27	-0.27	-0.46	-0.37	+0.05	+0.02	+1.00							
Seg_Length	**+0.86**	**+0.55**	-0.38	-0.08	**+0.62**	**+0.83**	**+0.90**	+0.34	+0.28	+0.32	+0.38	-0.03	-0.56	-0.31	+1.00						
Spacing	**+0.80**	+0.49	-0.36	-0.04	**+0.57**	**+0.76**	**+0.84**	+0.30	+0.26	+0.27	+0.34	+0.02	-0.55	-0.23	**+0.97**	+1.00					
Median_Length	**+0.81**	+0.39	-0.30	-0.13	**+0.63**	**+0.76**	**+0.84**	+0.42	+0.32	+0.35	+0.42	+0.34	-0.42	-0.27	**+0.92**	**+0.91**	+1.00				
Curb_Length	+0.43	+0.42	-0.22	-0.20	+0.37	**+0.51**	+0.47	+0.24	+0.20	+0.38	+0.34	+0.05	+0.35	-0.28	+0.37	+0.33	+0.37	+1.00			
Num_AP	+0.45	+0.18	-0.24	-0.19	+0.16	+0.36	+0.45	+0.15	-0.02	-0.09	+0.00	+0.06	-0.35	+0.31	**+0.62**	**+0.65**	**+0.62**	+0.01	+1.00		
cap	+0.05	-0.10	-0.08	-0.99	-0.07	-0.02	+0.00	+0.04	-0.24	-0.13	-0.16	+0.18	+0.25	-0.30	+0.08	+0.04	+0.12	+0.17	+0.20	+1.00	
vol_cap	-0.43	+0.05	**+0.84**	**+0.58**	-0.28	-0.30	-0.37	-0.37	-0.20	-0.08	-0.14	-0.05	-0.14	-0.02	-0.31	-0.27	-0.28	-0.29	-0.26	-0.55	+1.00
OL	-0.17	-0.23	-0.23	+0.14	+0.10	-0.24	-0.15	-0.10	+0.25	+0.13	+0.22	+0.11	+0.07	-0.22	-0.24	-0.19	-0.18	-0.22	-0.21	-0.13	-0.09

Exhibit 22: Upstream Correlation Analysis – Operational Data

	Speed_Avg	delay_total	Flow_Entry_Lane	Flow_Confl	SL	Speed_FF	Speed_Unimp	CircleSpeed	Num_App_Lane	CID	ISD	Prop_Median	Prop_Curb	MB_Turb	Seg_Length	Spacing	Median_Length	Curb_Length	Num_AP	cap	vol_cap
Speed_Avg	+1.00																				
delay_total	-0.24	+1.00																			
Flow_Entry_Lane	-0.53	+0.09	+1.00																		
Flow_Confl	-0.36	**+0.66**	-0.15	+1.00																	
SL	**+0.63**	+0.18	-0.49	+0.06	+1.00																
Speed_FF	**+0.80**	+0.30	-0.49	+0.01	**+0.81**	+1.00															
Speed_Unimp	**+0.90**	+0.09	-0.49	-0.10	**+0.71**	**+0.90**	+1.00														
CircleSpeed	+0.44	-0.07	-0.41	+0.16	**+0.57**	+0.46	+0.49	+1.00													
Num_App_Lane	+0.31	+0.01	-0.53	+0.32	**+0.53**	+0.43	+0.37	**+0.51**	+1.00												
CID	+0.35	+0.29	-0.37	+0.32	**+0.71**	**+0.66**	+0.50	+0.45	**+0.64**	+1.00											
ISD	+0.35	+0.26	-0.45	+0.40	**+0.71**	**+0.61**	**+0.51**	**+0.53**	**+0.79**	**+0.94**	+1.00										
Prop_Median	-0.11	-0.14	-0.02	+0.01	+0.07	-0.08	-0.12	+0.28	+0.23	+0.10	+0.12	+1.00									
Prop_Curb	-0.46	-0.13	+0.21	+0.03	-0.33	-0.44	-0.48	-0.07	+0.05	-0.04	-0.07	+0.47	+1.00								
MB_Turb	-0.46	+0.12	-0.27	+0.36	-0.49	-0.38	-0.26	-0.08	+0.01	-0.39	-0.22	+0.21	+0.03	+1.00							
Seg_Length	**+0.79**	+0.14	-0.43	-0.09	**+0.55**	**+0.77**	**+0.84**	+0.28	+0.21	+0.27	+0.31	-0.07	-0.56	-0.28	+1.00						
Spacing	**+0.67**	+0.17	-0.39	-0.04	+0.50	**+0.67**	**+0.73**	+0.26	+0.18	+0.22	+0.28	+0.00	-0.57	-0.03	**+0.95**	+1.00					
Median_Length	**+0.70**	+0.01	-0.36	-0.12	**+0.54**	**+0.67**	**+0.74**	+0.41	+0.31	+0.31	+0.36	+0.36	-0.30	-0.02	**+0.88**	**+0.85**	+1.00				
Curb_Length	+0.33	+0.20	-0.16	+0.01	+0.27	+0.46	+0.40	+0.22	+0.33	+0.45	+0.40	+0.12	+0.40	-0.20	+0.30	+0.18	+0.31	+1.00			
Num_AP	+0.40	+0.08	-0.20	-0.02	+0.17	+0.33	+0.46	+0.13	+0.03	-0.02	+0.08	+0.04	-0.33	**+0.50**	**+0.67**	**+0.68**	**+0.67**	+0.06	+1.00		
cap	+0.36	-0.66	+0.15	-1.00	-0.08	-0.02	+0.10	-0.17	-0.35	-0.35	-0.43	-0.03	-0.04	-0.38	+0.10	+0.04	+0.12	-0.03	+0.03	+1.00	
vol_cap	-0.64	+0.32	**+0.95**	+0.15	-0.45	-0.47	-0.50	-0.35	-0.41	-0.24	-0.29	+0.01	+0.22	-0.14	-0.45	-0.39	-0.38	-0.16	-0.20	-0.16	+1.00
OL	-0.22	-0.13	-0.07	+0.19	+0.10	-0.25	-0.24	+0.18	+0.23	+0.15	+0.26	+0.04	+0.05	-0.29	-0.25	-0.18	-0.18	-0.25	-0.21	-0.18	-0.02

L.6 AVERAGE TRAVEL SPEED DETAILS

AVERAGE TRAVEL SPEED VARIABLE PLOTS

Exhibit 23: Variable Plot Average Travel Speed by Circulating Speed

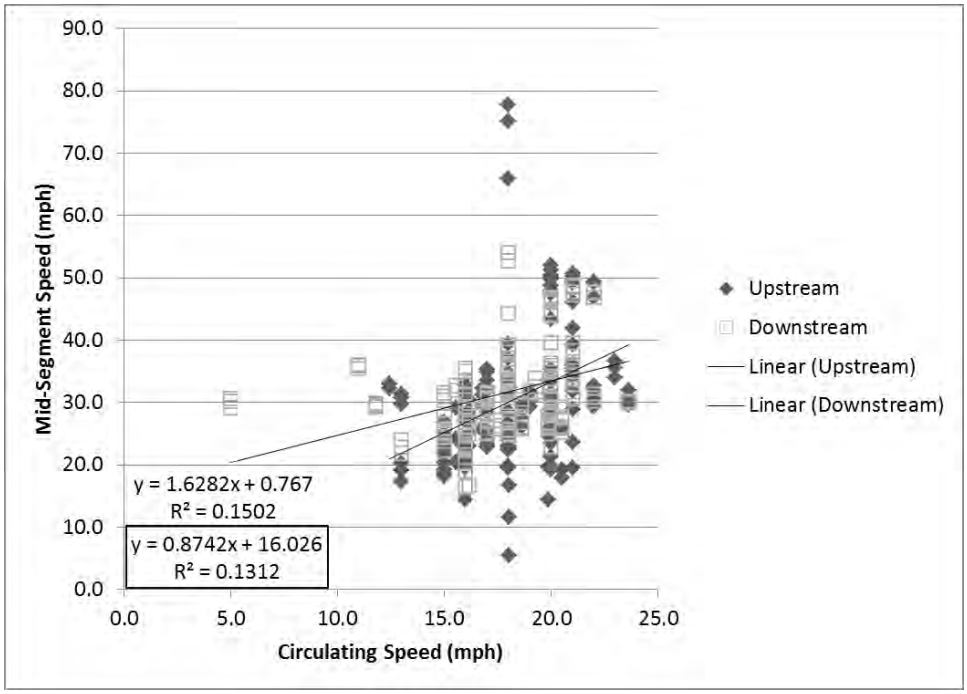
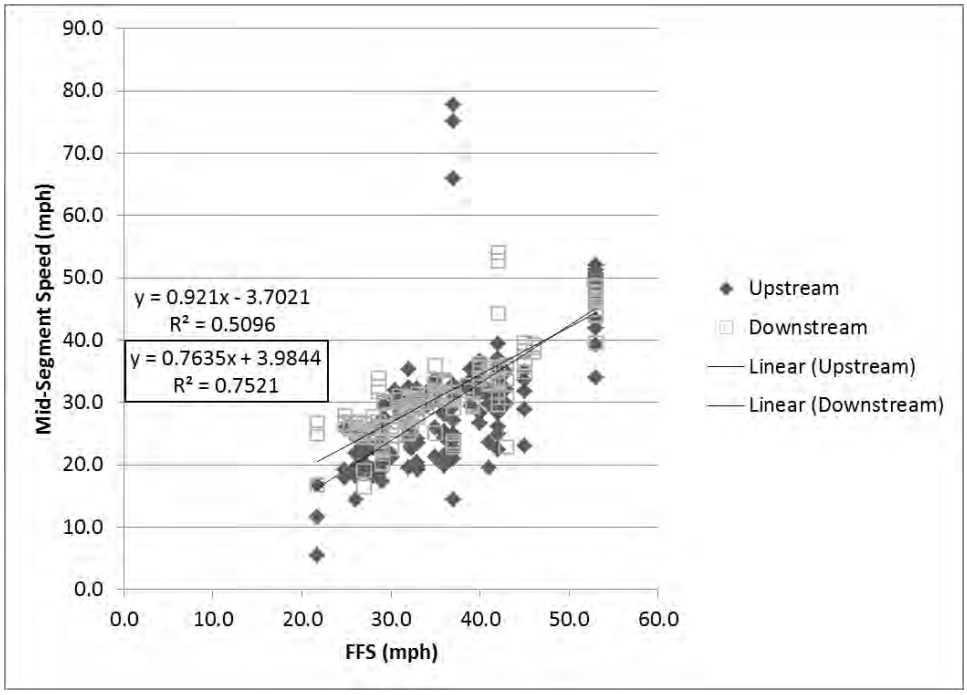


Exhibit 24: Variable Plot Average Travel Speed by FFS



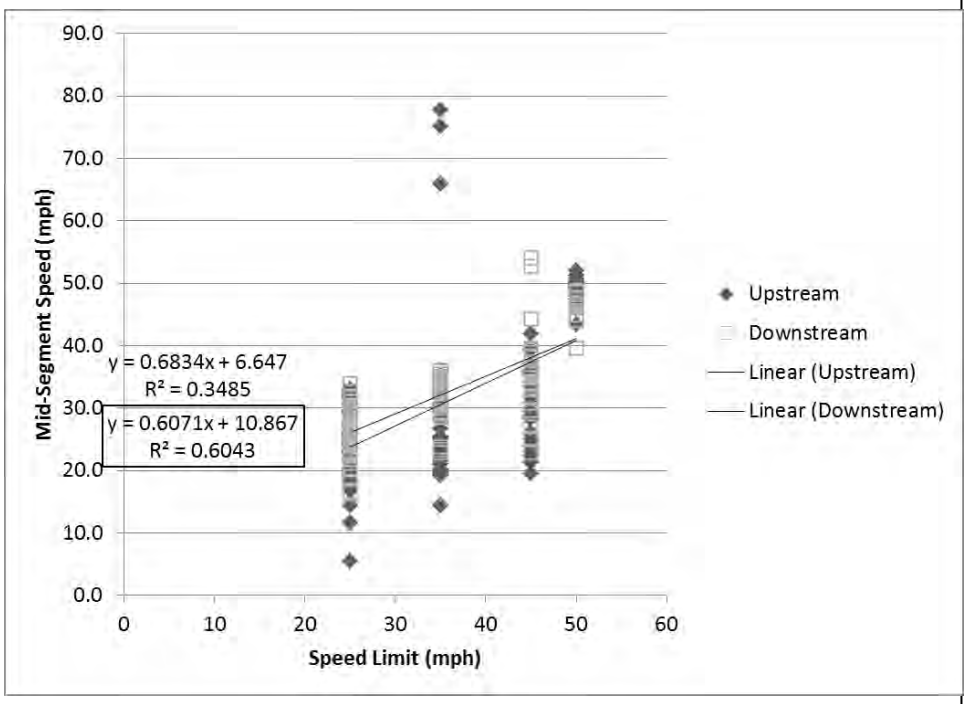


Exhibit 25: Variable Plot Average Travel Speed by Speed Limit

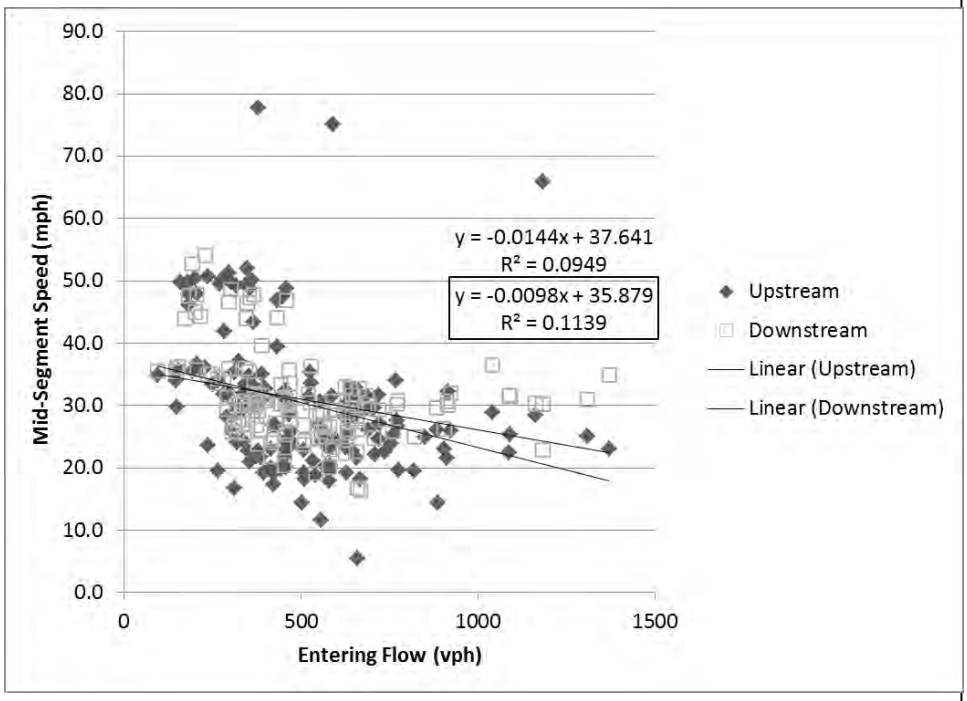


Exhibit 26: Variable Plot Average Travel Speed by Entering Flow

Exhibit 27: Variable Average Travel Speed by Volume-to-Capacity Ratio

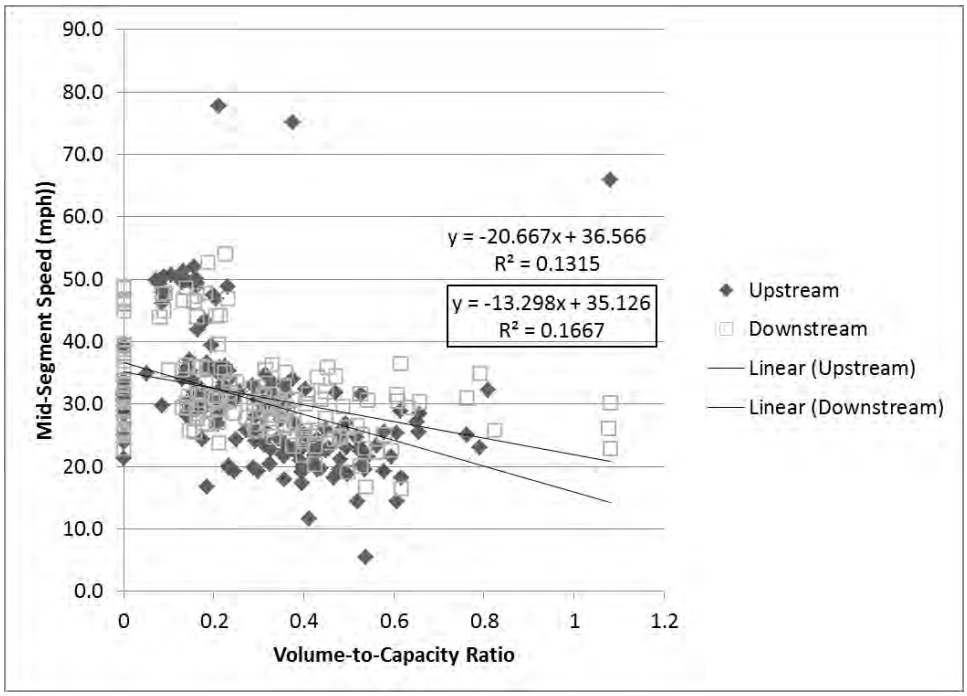
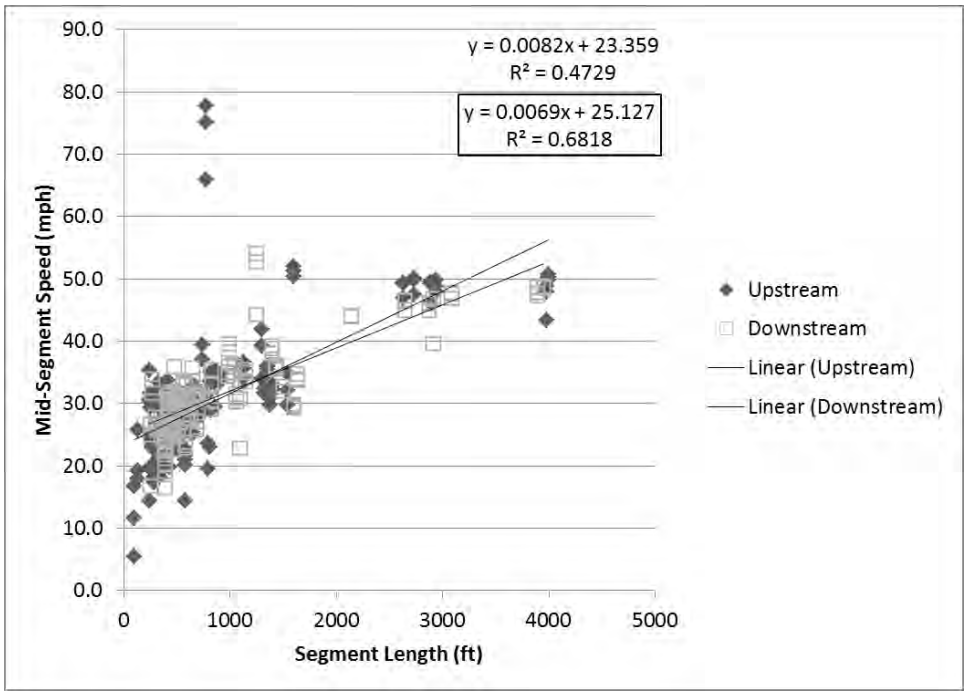


Exhibit 28: Variable Plot Average Travel Speed by Segment Length



AVERAGE TRAVEL SPEED MODEL RESULTS

Exhibit 29: Average Travel Speed Upstream Models

Model	Intercept		Entering Flow		Circulating Flow		Posted Speed Limit		Circulating Speed		Segment Length		Median Length		Approach Lanes		Proportion of Segment with Median		Volume / Capacity		FFS		R2
	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p	Value	p	
U1	13.28	0.001	-0.01	0.0008	-0.03	<0.0001	0.15	0.0272	0.68	0.0025	0.01	<0.0001	0.00	0.0281	-0.23	0.3526							0.87
U2	13.90	0.016	-0.01	0.1014			0.12	0.1973	0.39	0.2012	0.01	<0.0001	0.00	0.4441	-0.53	0.1287							0.73
U3	20.50	<0.0001					0.14	0.0908	0.39	0.1508	0.01	<0.0001					-3.18	0.0335	-16.20	<0.0001			0.79
U4	5.91	0.118	-0.01	0.0002	-0.03	<0.0001			0.59	0.0014	0.01	0.0003	0.00	0.0578	0.01	0.9757					0.44	<0.0001	0.90
U5	7.09	0.055	-0.01	<0.0001	-0.03	<0.0001			0.51	0.0045	0.00	<0.0001											0.90
U6	14.00	0.000	0.04	0.0932	-0.01	0.3247	0.19	0.0027	0.64	0.0025	0.01	<0.0001					-3.09	0.0072	-47.80	0.0263			0.88
U7	10.20	0.016	-0.01	0.0446							0.00	0.0001									0.48	<0.0001	0.76
U8	6.16	0.087	0.03	0.0544	-0.01	0.1816			0.58	0.0008	0.00	<0.0001					-1.97	0.0458	-45.70	0.0114	0.45	<0.0001	0.92
U9	13.80	0.006							0.29	0.2304	0.00	<0.0001					-2.22	0.1162	-15.64	<0.0001	0.38	0.0006	0.81
U10	17.20	<0.0001									0.00	<0.0001					-1.89	0.1734	-16.30	<0.0001	0.43	0.0006	0.81
U11	-0.82	0.014															-1.37	0.3698	-18.30	<0.0001	0.73	<0.0001	0.76
U12	**8.52**	**0.020**																	**-18.20**	**<0.0001**	**0.73**	**<0.0001**	**0.76**
U13	8.07	0.029	0.00	0.3009															-13.80	0.0172	0.76	<0.0001	0.76

Exhibit 30: Average Travel Speed Downstream Models

	Intercept		Entering Flow		Circulating Flow		Posted Speed Limit		Circulating Speed		Segment Length		Median Length		Approach Lanes		Proportion of Segment with Median		Volume / Capacity		FFS		
Model	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**R2**
D1	14.99	0.000	-0.01	0.0554	0.00	0.4440	0.29	<0.0001	0.24	0.1461	0.01	<0.0001	0.00	0.2764	-0.15	0.5859							0.59
D2	14.94	0.000	-0.01	0.0437			0.28	<0.0001	0.24	0.1379	0.01	<0.0001	0.00	0.3091	-0.13	0.6298							0.82
D3	16.59	<0.0001					0.32	<0.0001	0.28	0.0703	0.00	<0.0001					-4.23	0.0092	-3.98	0.0428			0.83
D4	9.92	0.008	-0.01	0.0034	0.00	0.5356			0.10	0.5026	0.00	0.4228	0.00	0.8586	0.01	0.9829					0.58	<0.0001	0.86
D5	9.74	0.003	-0.01	0.0025	0.00	0.5056			0.11	0.3768	0.00	0.0705									0.58	<0.0001	0.86
D6	17.95	<0.0001	-0.01	0.2045	-0.01	0.2490	0.30	<0.0001	0.31	0.0502	0.00	<0.0001					-3.99	0.0197	7.12	0.4258			0.84
D7	11.20	<0.0001	-0.01	0.0007							0.00	0.0702									0.60	<0.0001	0.85
D8	11.20	0.001	-0.02	0.0122	-0.01	0.0454			0.23	0.1082	0.00	0.0902					-1.61	0.2852	14.30	0.0718	0.56	<0.0001	0.87
D9	8.57	0.007							0.21	0.1536	0.00	0.0716					-2.15	0.1569	-4.49	0.0161	0.58	<0.0001	0.85
D10	10.20	0.0008									0.00	0.1099					-1.29	0.3584	-5.22	0.0042	0.63	<0.0001	0.84
D11	8.15	0.003															-1.51	0.2875	-5.58	0.0025	0.73	<0.0001	0.84
D12	**6.45**	**0.003**																	**-5.40**	**0.0032**	**0.74**	**<0.0001**	**0.83**
D13	6.40	0.003	0.00	0.2383															-3.25	0.2004	0.75	<0.0001	0.84

L.7 IMPEDED DELAY MODEL DETAILS

IMPEDED DELAY VARIABLE PLOTS

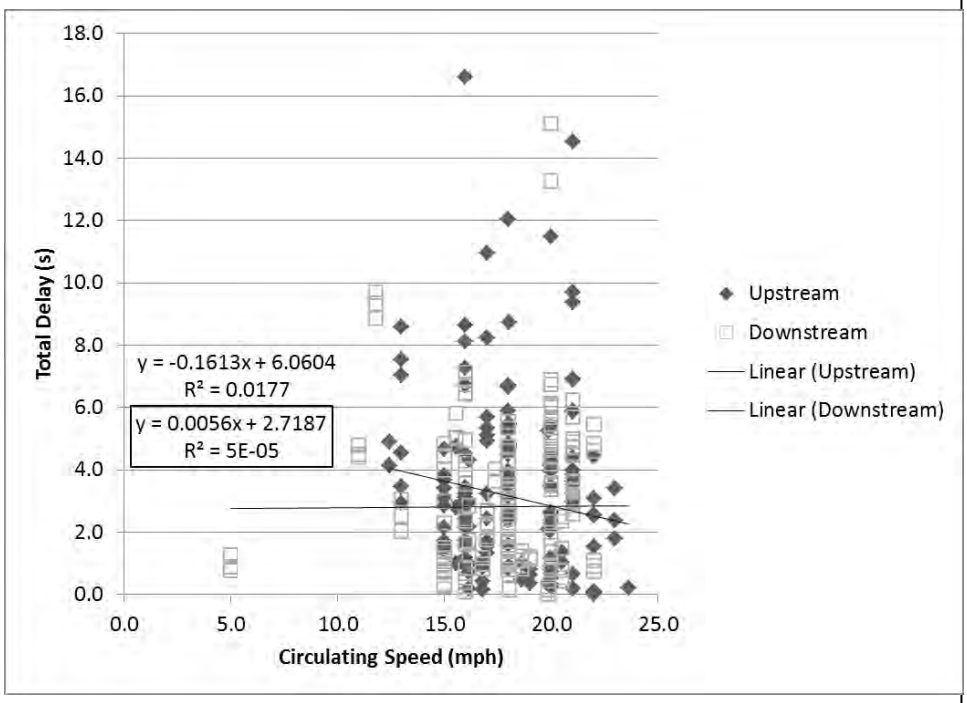


Exhibit 31: Variable Plot Impeded Delay by Circulating Speed

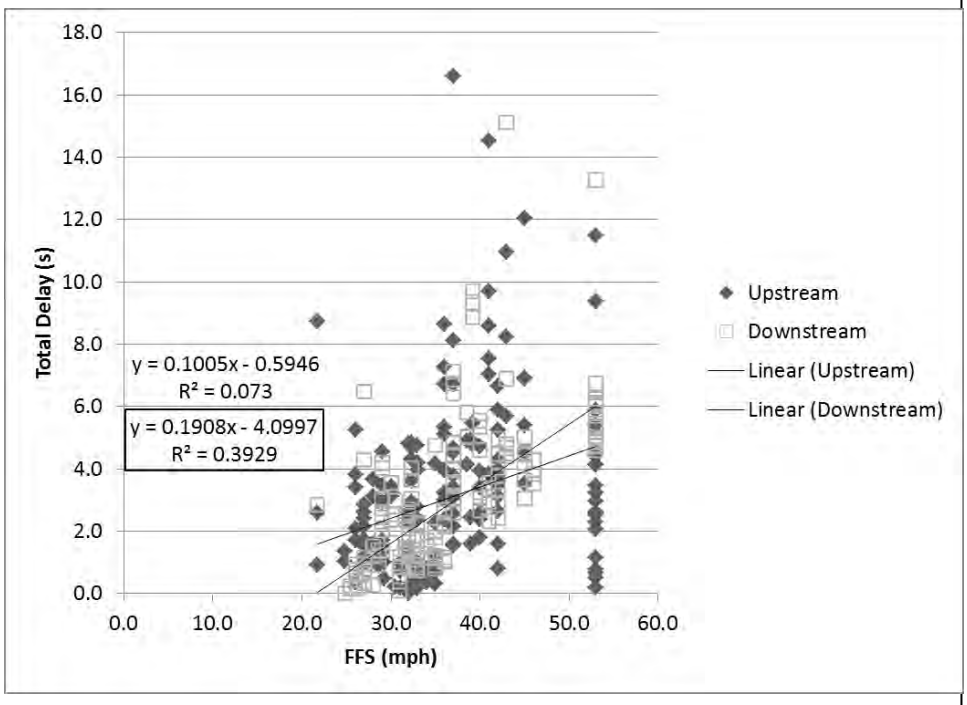


Exhibit 32: Variable Plot Impeded Delay by FFS

Exhibit 33: Variable Plot Impeded Delay by Speed Limit

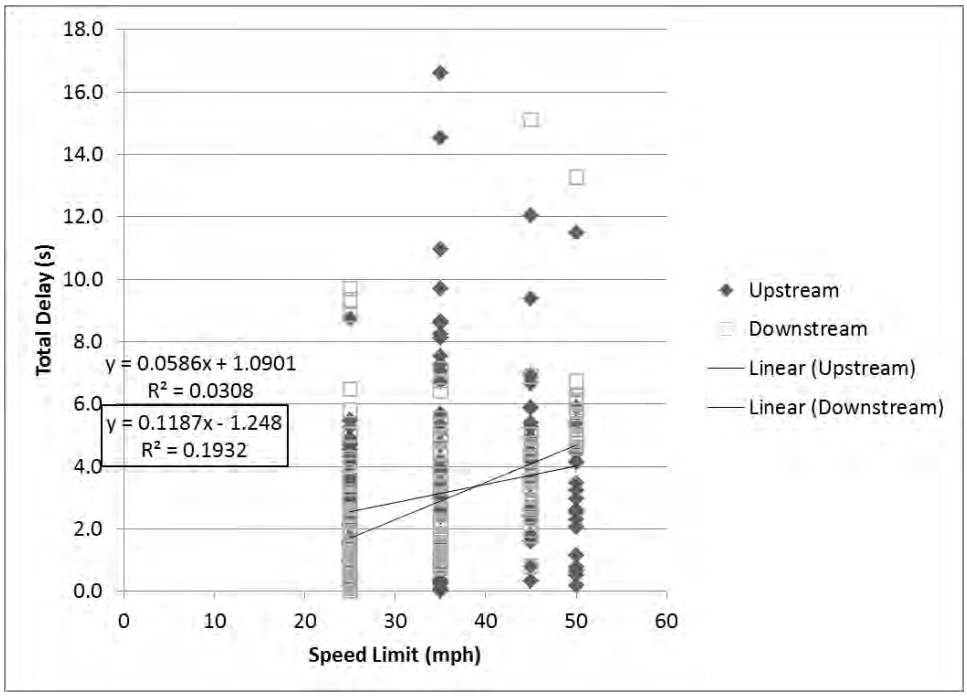
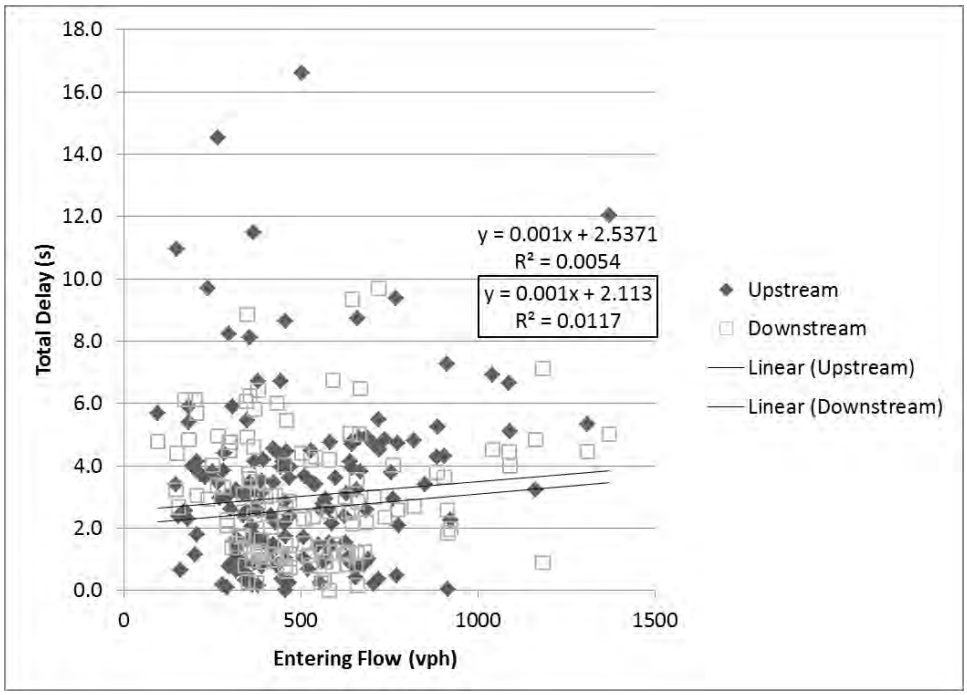


Exhibit 34: Variable Plot Impeded Delay by Entering Flow



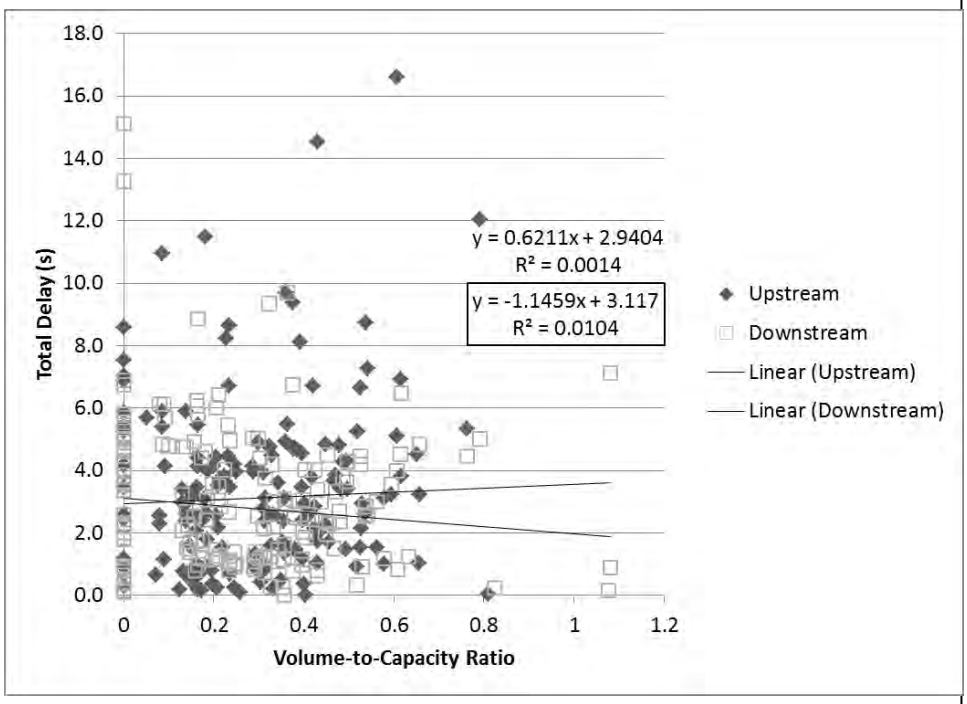


Exhibit 35: Variable Plot Impeded Delay by Volume-to-Capacity Ratio

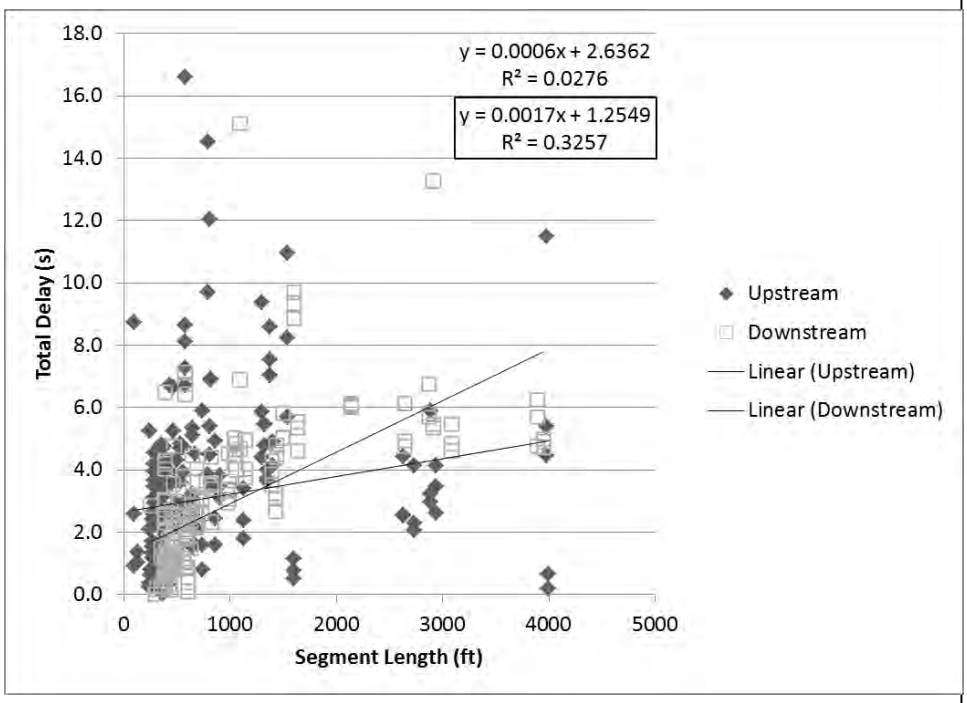


Exhibit 36: Variable Plot Impeded Delay by Segment Length

IMPEDED DELAY MODEL RESULTS

Exhibit 37: Impeded Delay Upstream Models

	Intercept		Entering Flow		FFS		Circulating Speed		Approach Lanes		Segment Length		Median Length		Curb Length		Volume / Capacity		
Model	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**R2**
D1	-2.62	0.0239	0.00	0.065					0.77	0.1021	0.0033	<0.0001	-0.0012	0.0867	0.0012	0.0492	0.24	0.888	0.60
D2	-1.01	0.1472	0.00	0.391							0.0027	<0.0001	-0.0011	0.0893	0.0016	0.0080	1.87	0.259	0.55
D3	-0.72	0.2340									0.0026	<0.0001	-0.0010	0.1120	0.0017	0.0051	3.04	0.0017	0.54
D4	-1.01	0.1487	0.00	0.0022							0.0029	<0.0001	-0.0012	0.0600	0.0015	0.0136			0.54
D5	-2.93	0.0636			0.20	<0.0001	-0.12	0.1225									2.01	0.052	0.45
D6	**-2.65**	**0.0424**			**0.07**	**0.0937**					**0.0020**	**0.004**	**-0.0010**	**0.0978**	**0.0014**	**0.0186**	**3.10**	**0.001**	**0.56**
D7	-5.54	0.0001	0.00	0.148	0.19	<0.0001											0.38	0.826	0.45

Exhibit 38: Impeded Delay Downstream Models

	Intercept		Entering Flow		FFS		Circulating Speed		Approach Lanes		Segment Length		Median Length		Curb Length		Volume / Capacity		
Model	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**Value**	**p**	**R2**
U1	1.48	0.2918	-0.04	<0.0001					-1.25	0.0410	0.0017	0.023	-0.0012	0.0800	0.0025	0.0005	46.68	<0.0001	0.69
U2	-1.03	0.1908	-0.04	<0.0001							0.0021	0.005	-0.0014	0.0341	0.0021	0.0027	43.41	<0.0001	0.67
U3	-1.63	0.1582									0.0023	0.034	-0.0016	0.1114	0.0023	0.0210	8.83	0.0002	0.26
U4	0.90	0.4655	0.00	0.1723							0.0016	0.180	-0.0013	0.2080	0.0023	0.0332			0.11
U5	-6.07	0.0369			0.20	<0.0001	-0.10	0.5007									10.42	<0.0001	0.32
U6	-8.22	0.0006			0.21	0.0016					0.0007	0.505	-0.0014	0.1231	0.0012	0.2227	10.33	<0.0001	0.37
U7	**-5.35**	**0.0004**	**-0.03**	**<0.0001**	**0.15**	**<0.0001**											**42.50**	**<0.0001**	**0.67**

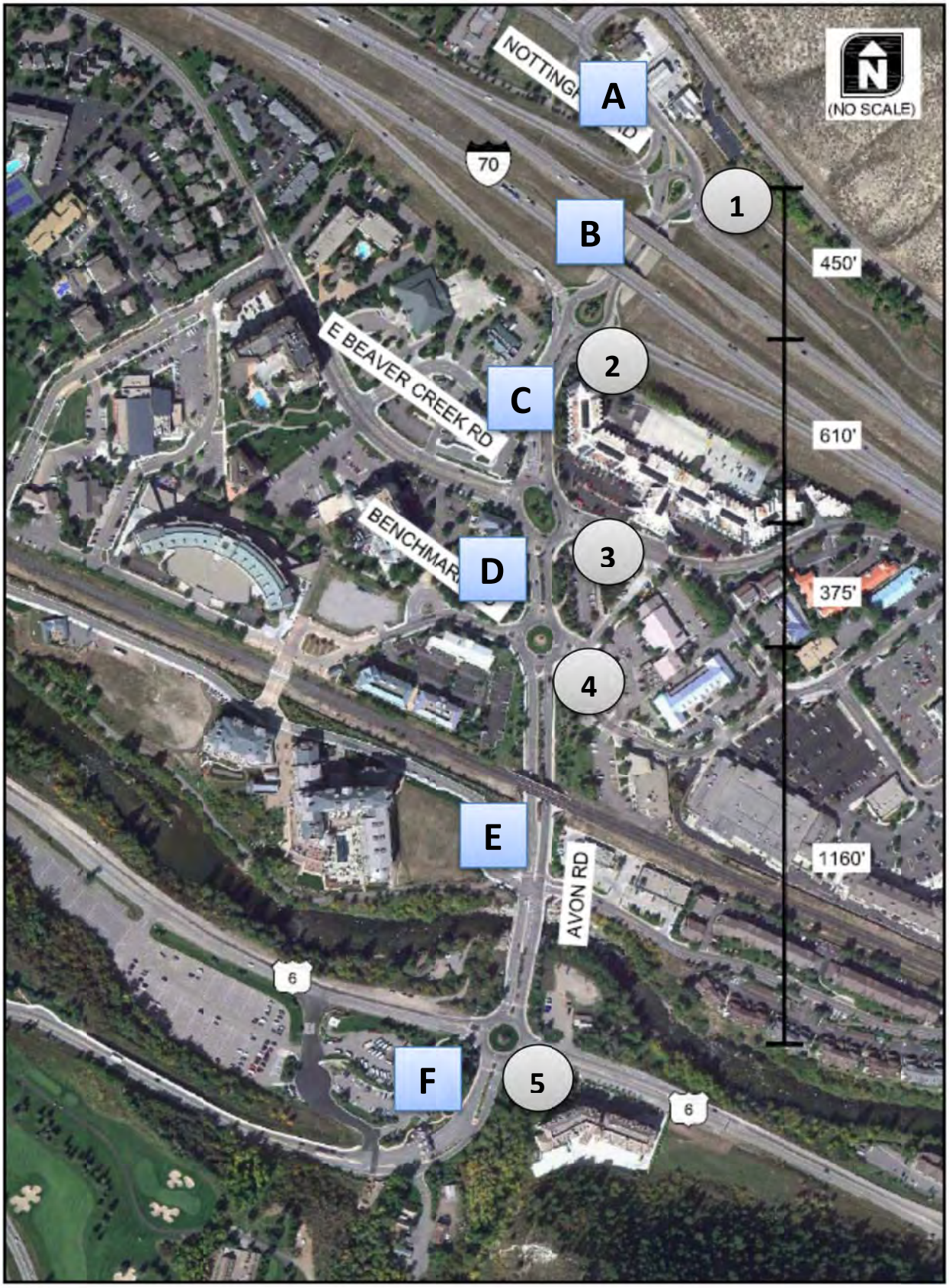
NCHRP 03-100

Appendix M

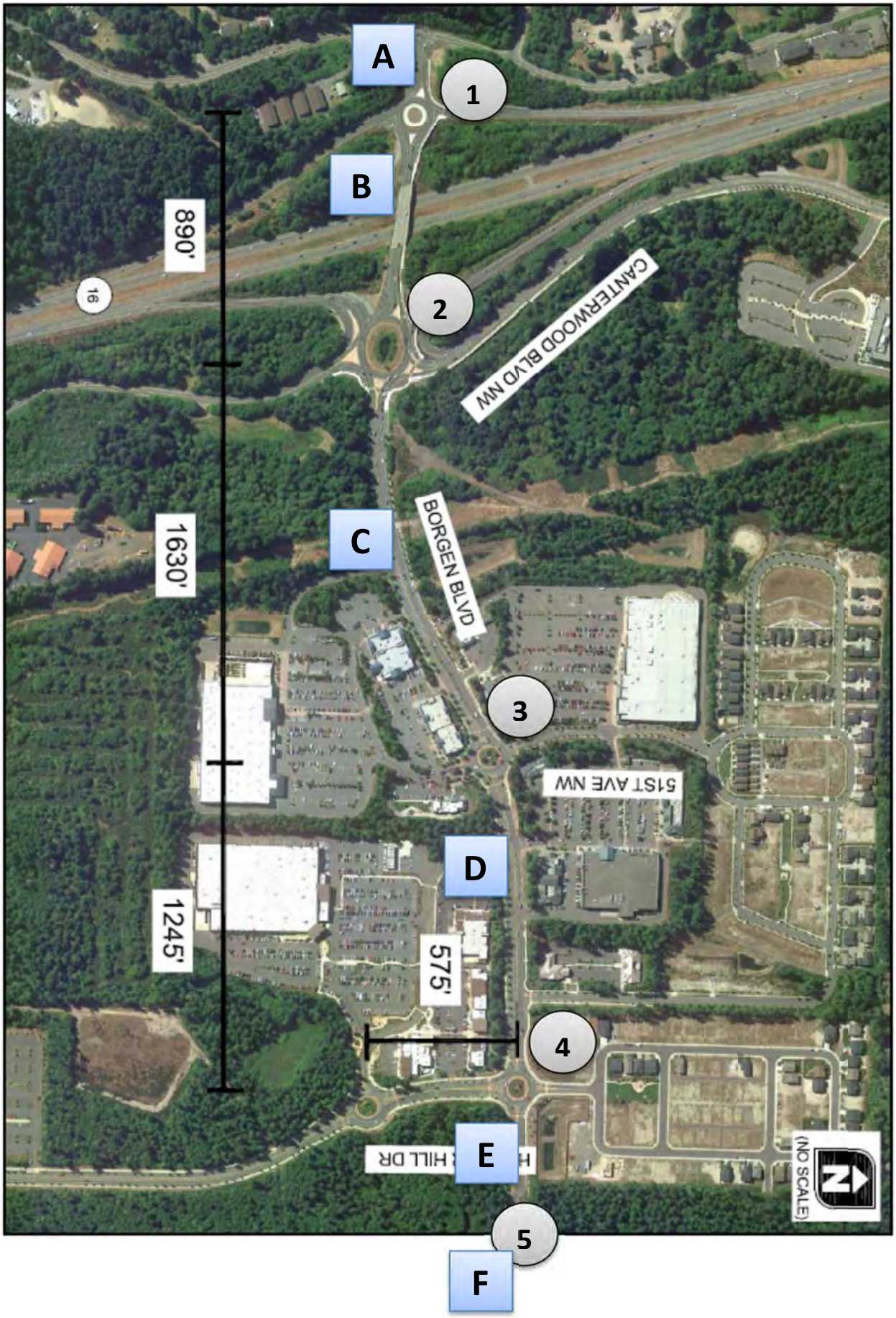
Corridor Numbering

May 2013

Avon Rd.


A
B
C
D
E
F
1
2
3
4
5
70
E BEAVER CREEK RD
AVON RD
6
6
450'
610'
375'
1160'
(NO SCALE)

Borgen Blvd.

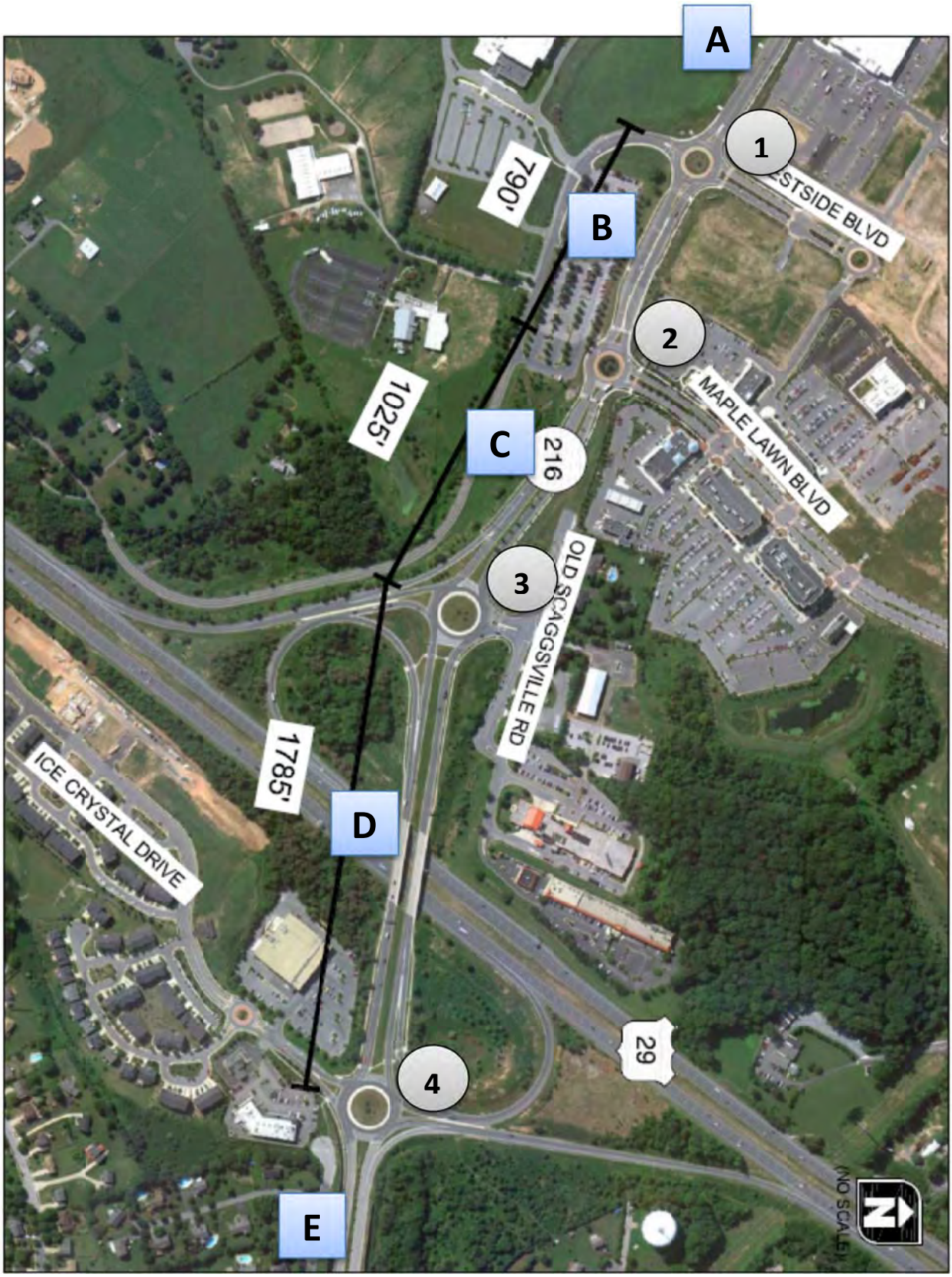

A
1
B
890'
16
2
CANTERWOOD BLVD NW
C
1630'
BORGEN BLVD
3
51ST AVE NW
D
1245'
575'
4
E
HILL DR
(NO SCALE)
5
F

Golden Rd.

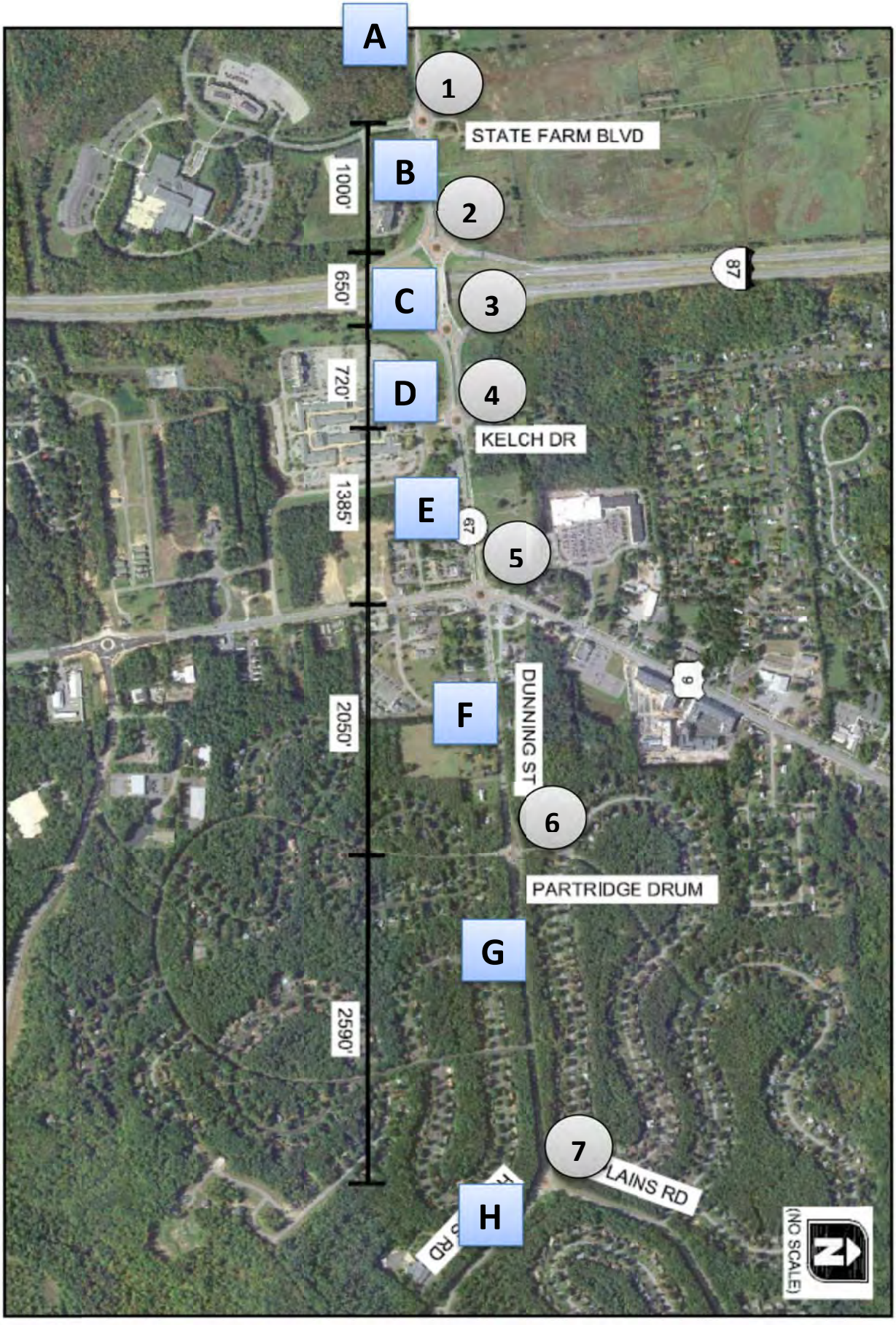

F
JACKSON ST
FORD ST
5
E
JOHNSON RD
2955'
D
4
16TH AVE
C
3
820'
B
2
810'
ULYSSES ST
1
850'
A
(NO SCALE)

La Jolla Blvd.

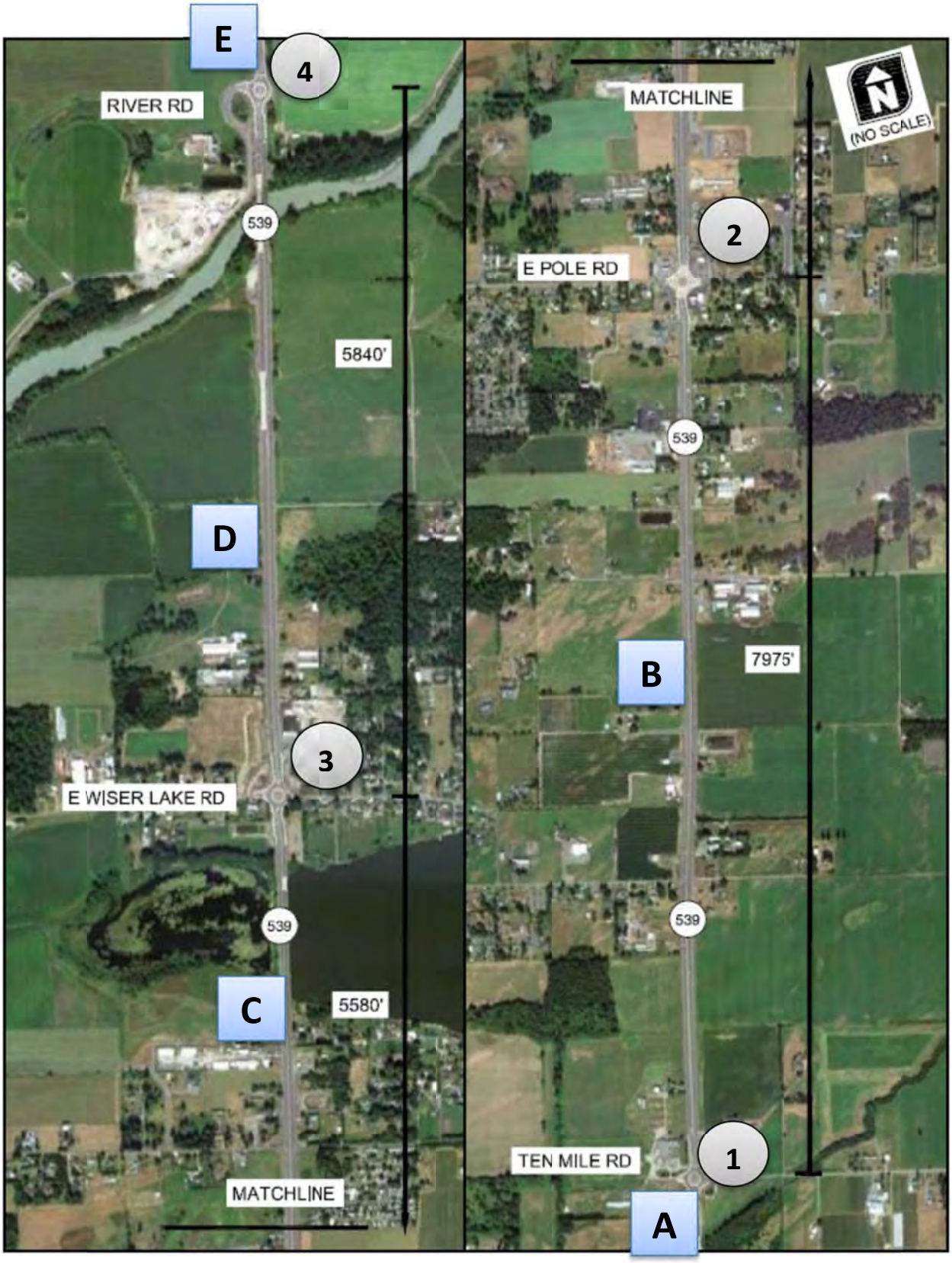
SR216


A
B
C
D
E
1
2
3
4
790'
1025'
1785'
216
29
WESTSIDE BLVD
MAPLE LAWN BLVD
OLD SCAGGSVILLE RD
ICE CRYSTAL DRIVE
(NO SCALE)

SR67


A
1
STATE FARM BLVD
B
1000'
2
87
650'
C
3
720'
D
4
KELCH DR
1385'
E
67
5
2050'
F
DUNNING ST
9
6
PARTRIDGE DRUM
G
2590'
7
LAINS RD
H
(NO SCALE)

SR539


E
4
RIVER RD
539
5840'
D
3
E WISER LAKE RD
539
C
5580'
MATCHLINE
MATCHLINE
(NO SCALE)
2
E POLE RD
539
B
7975'
539
1
TEN MILE RD
A

NCHRP 03-100

Appendix N

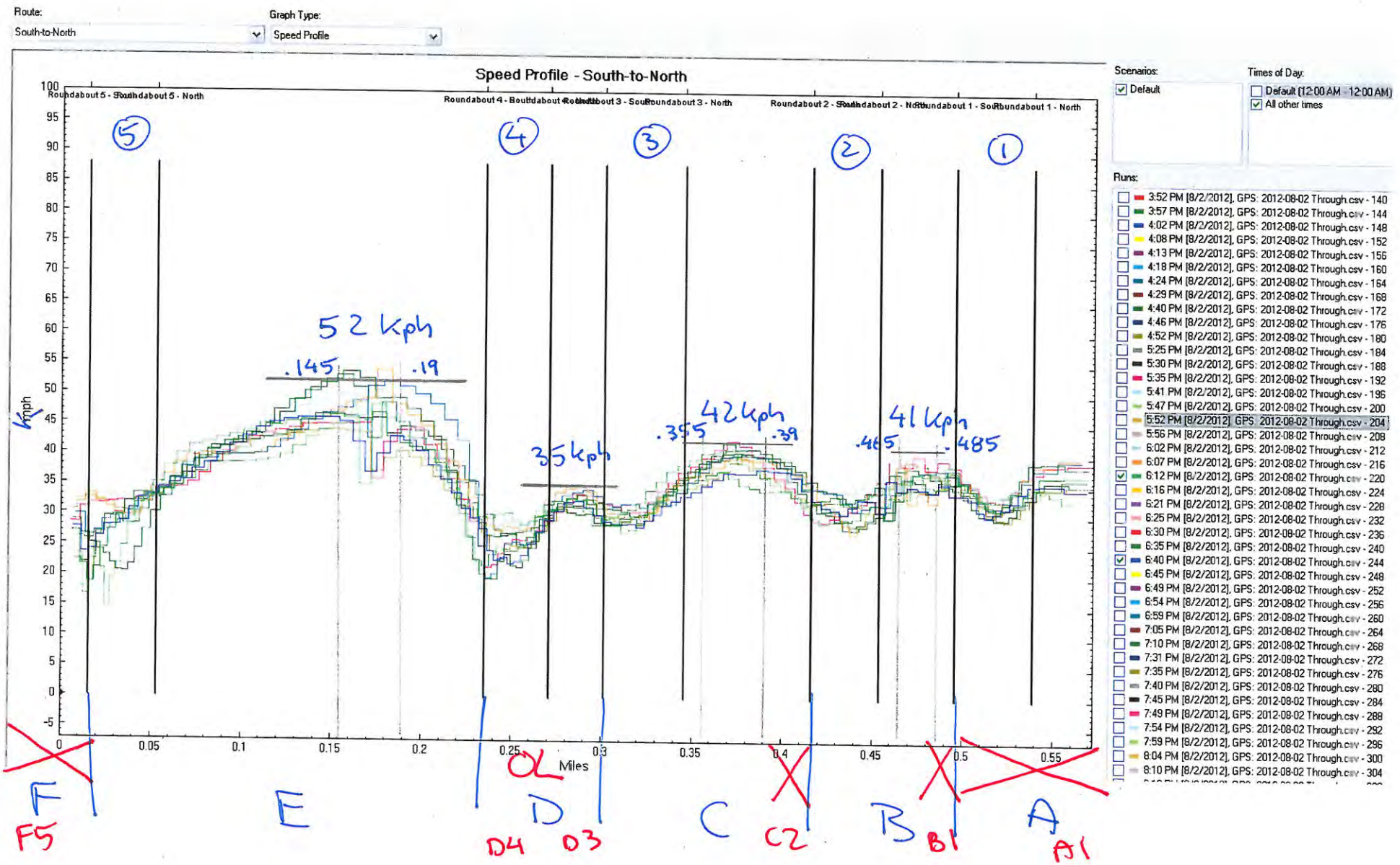
Speed Profiles

May 2013

3-100 UNIMPEDED ROUTES

12/5/2012
X - REMOVE
OL - OVERLAPPING RIA

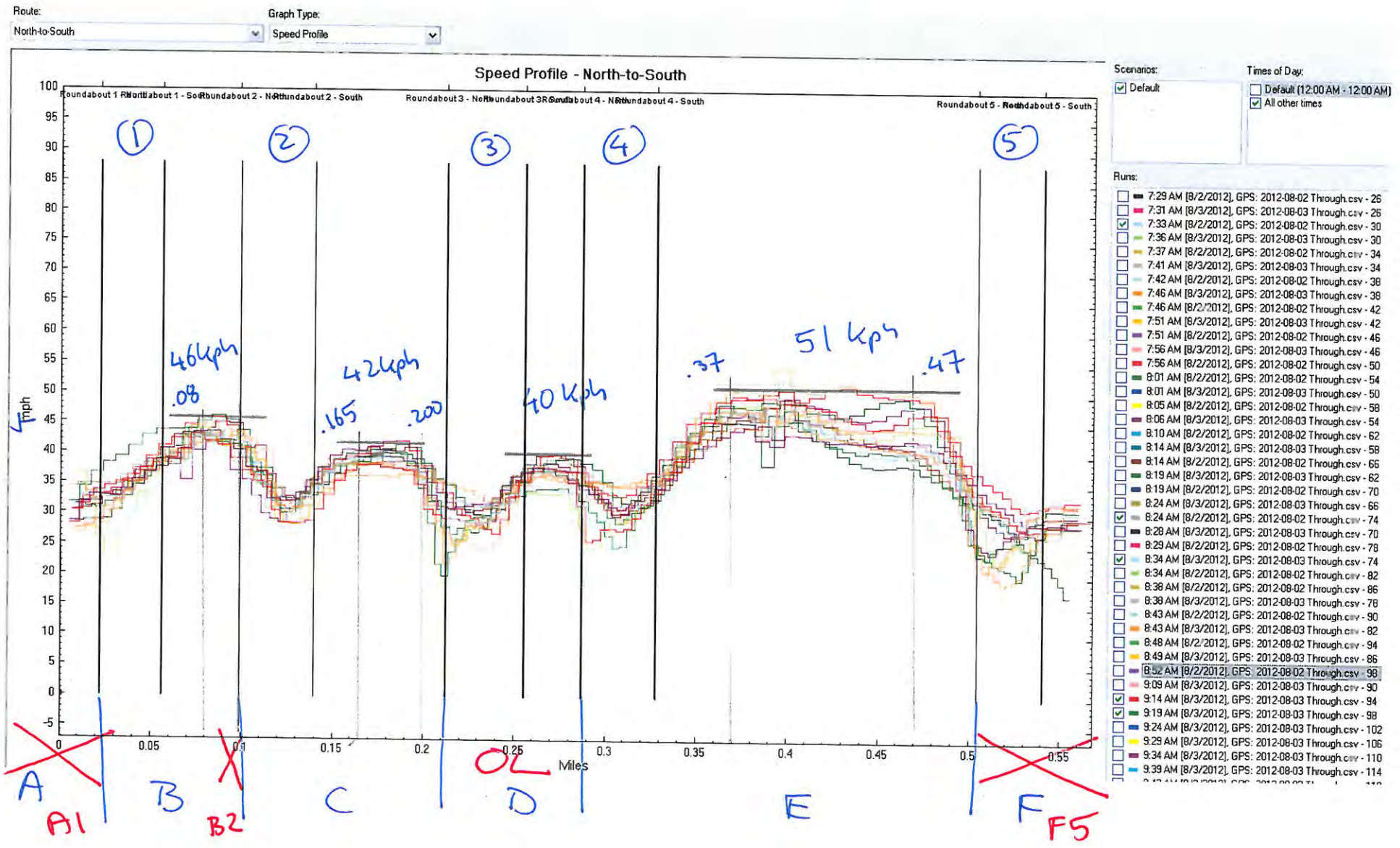
Avon - Northbound



3-100 UNIMPEDED ROUTES

12/5/2012
X - REMOVE
OL - OVERLAPPING RIA

Avon - Southbound



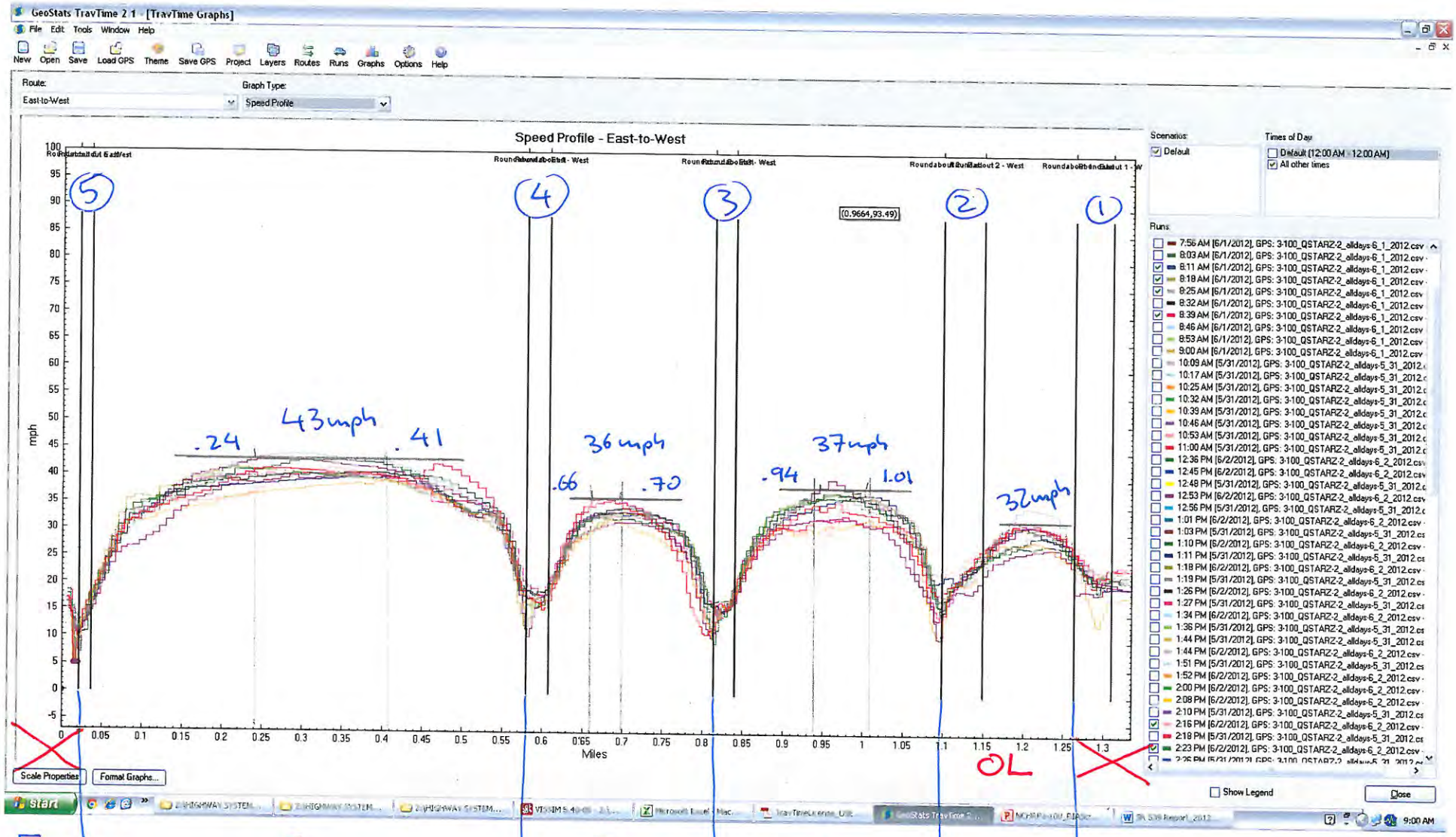
3-100 UNIMPEDED ROUTES

12/5/2012

Borgen - Westbound

X - REMOVE

OL - OVERLAPPING RIA



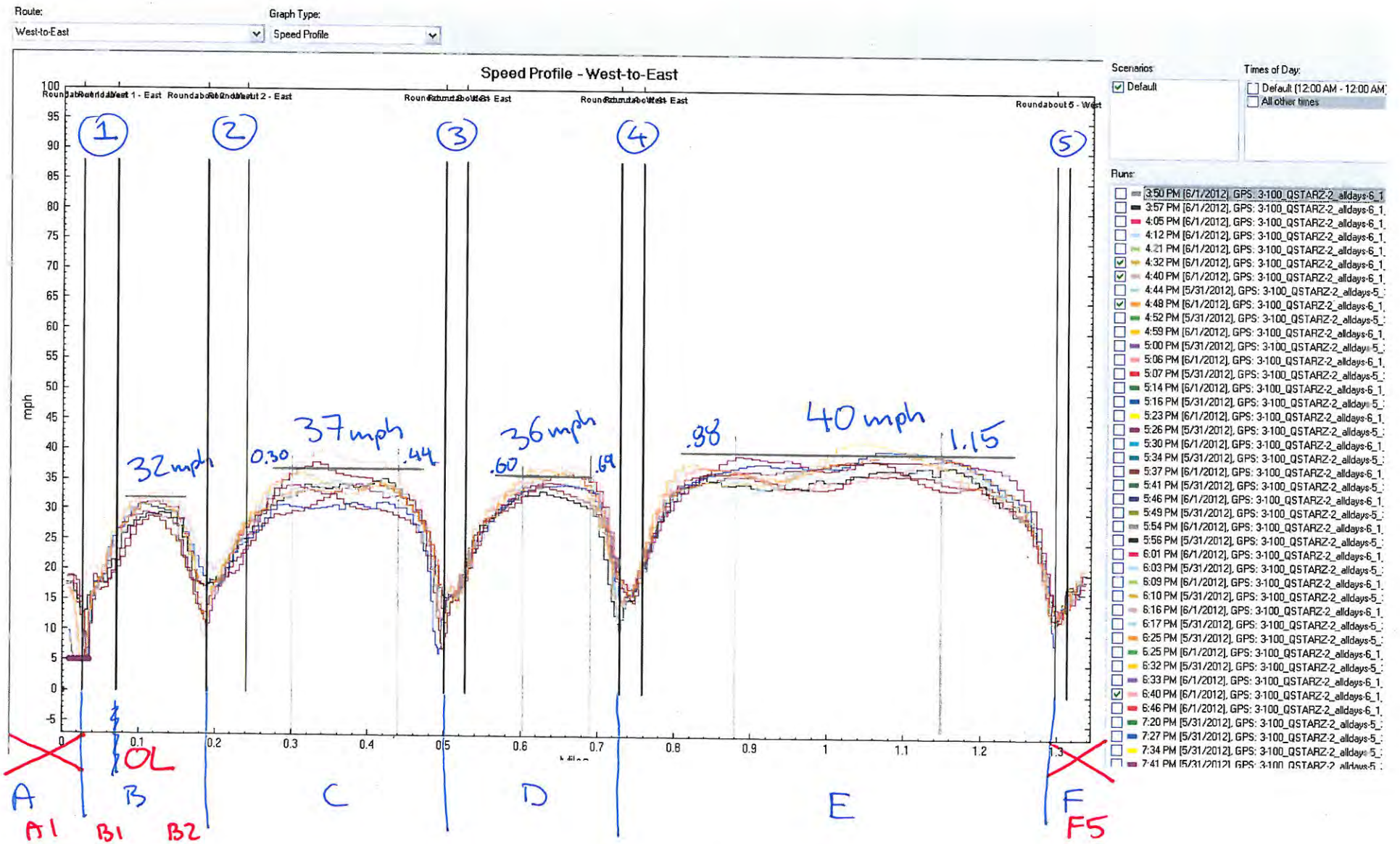
3-100 UNIMPEDED ROUTES

12/5/2012

X - REMOVE

OL - OVERLAPPING RIA

Borgen - Eastbound



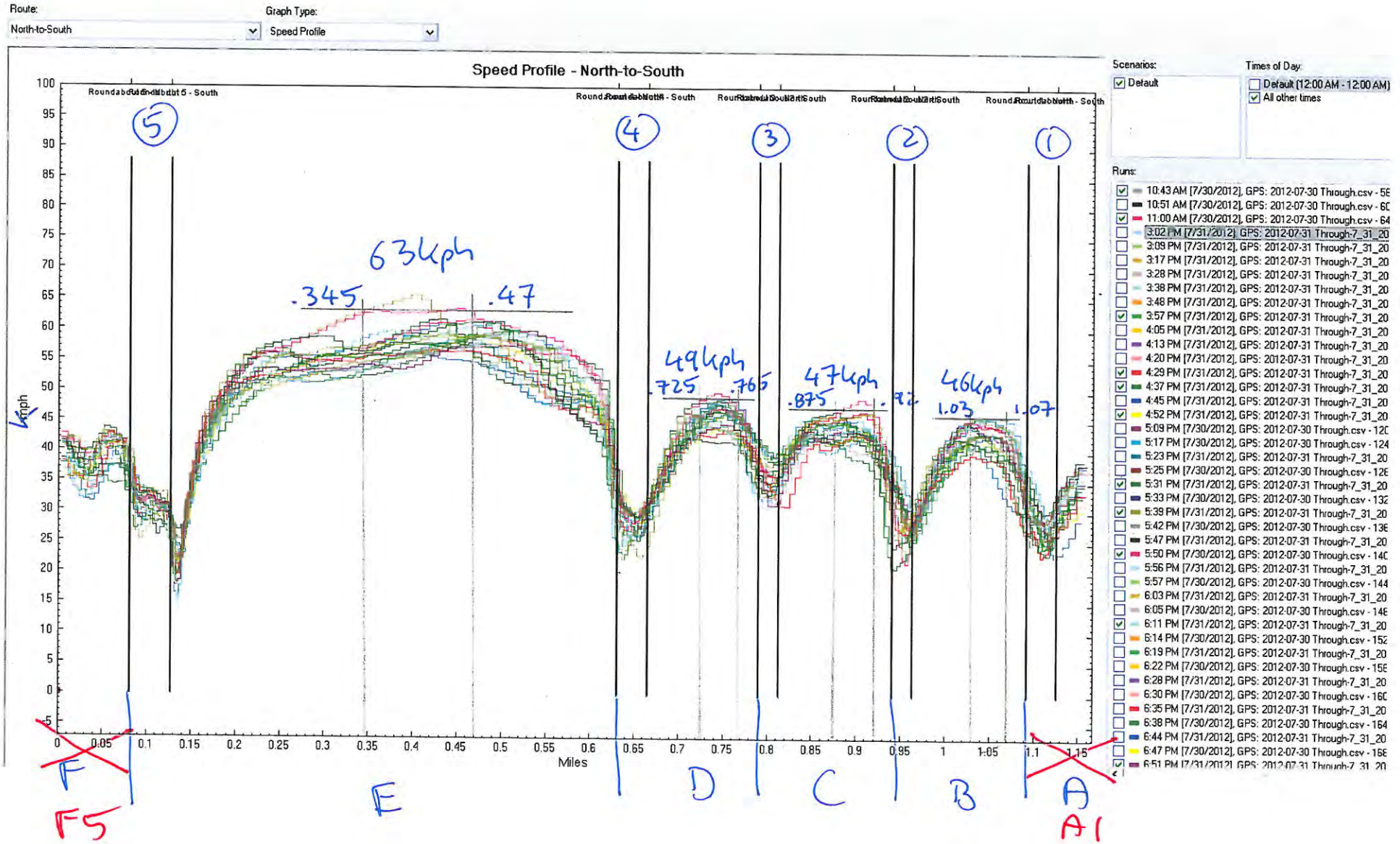
3-100 - UNIMPEDED ROUTES

12/5/2012

X - REMOVE

OL - OVERLAPPING RIA

Golden - Southbound



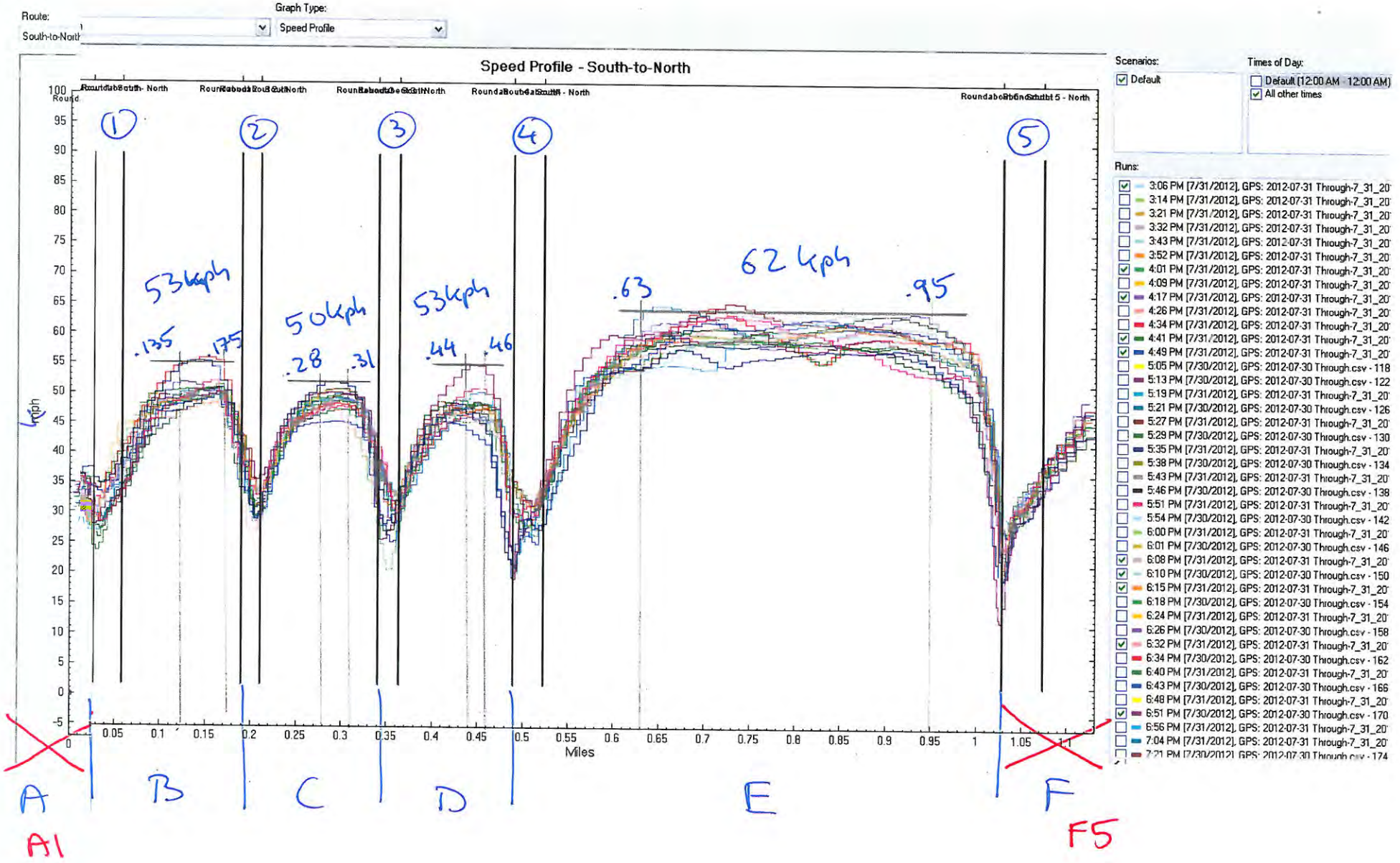
3-100 - UNIMPEDED ROUTES

12/5/2012

X- REMOVE

OL- OVERLAPPING RIA

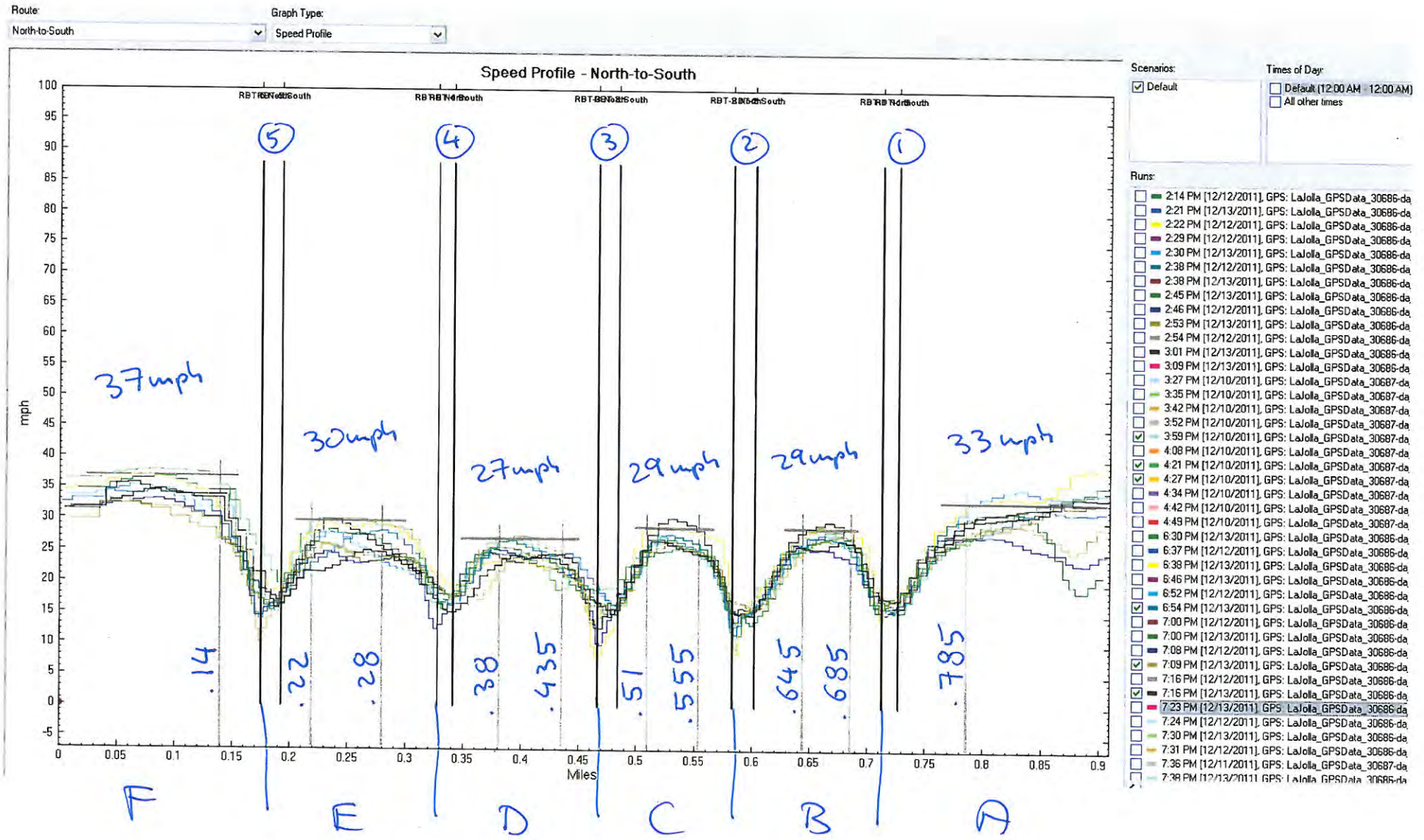
Golden - Northbound



3-100 UNIMPEDED ROUTES

12/5/2012
X- REMOVE
OL- OVERLAPPING
RIA

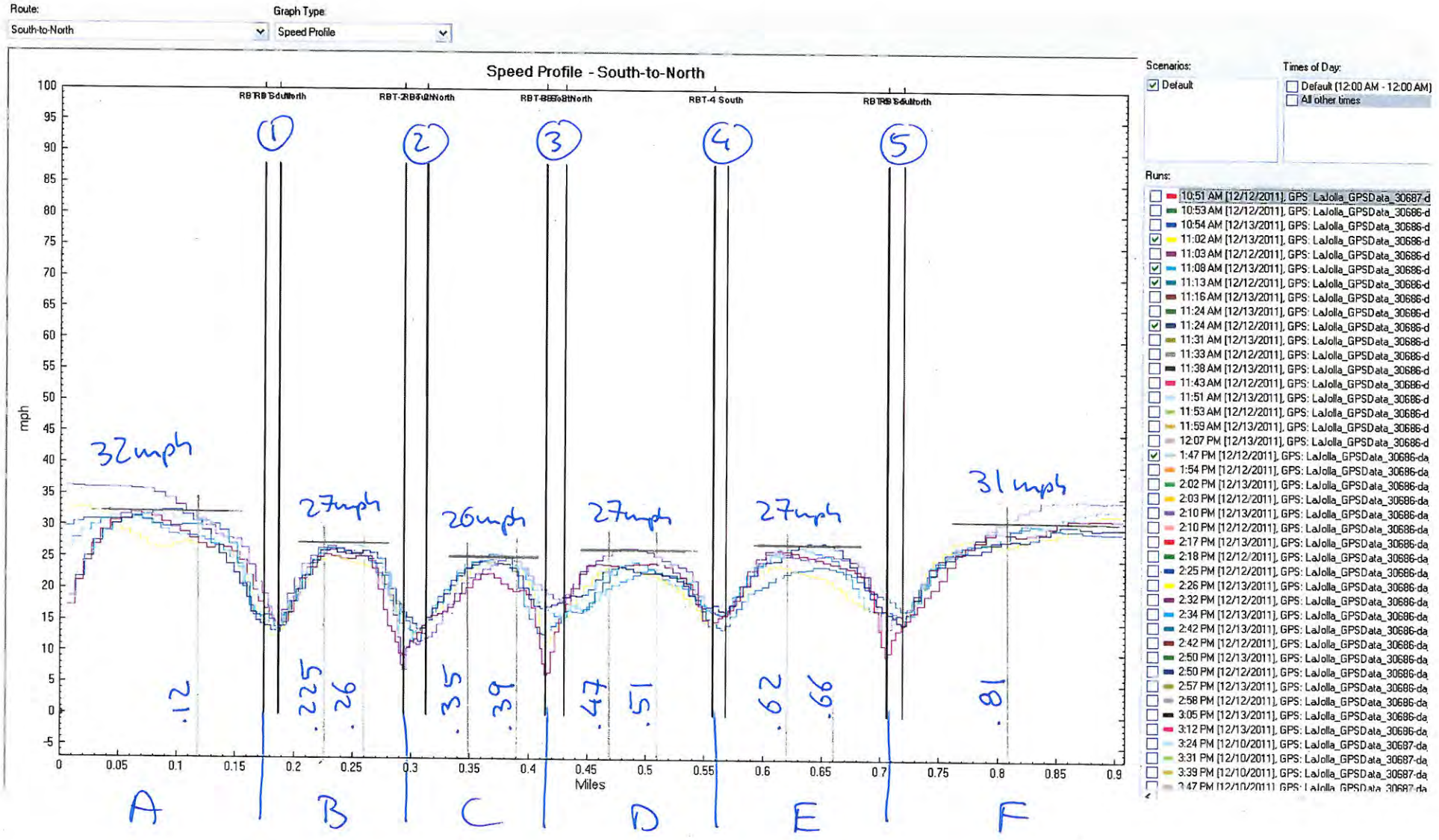
La Jolla - Southbound



3-100 UNIMPEDED ROUTES

12/5/2012
X - REMOVE
OL - OVERLAPPING
RIA

La Jolla - Northbound



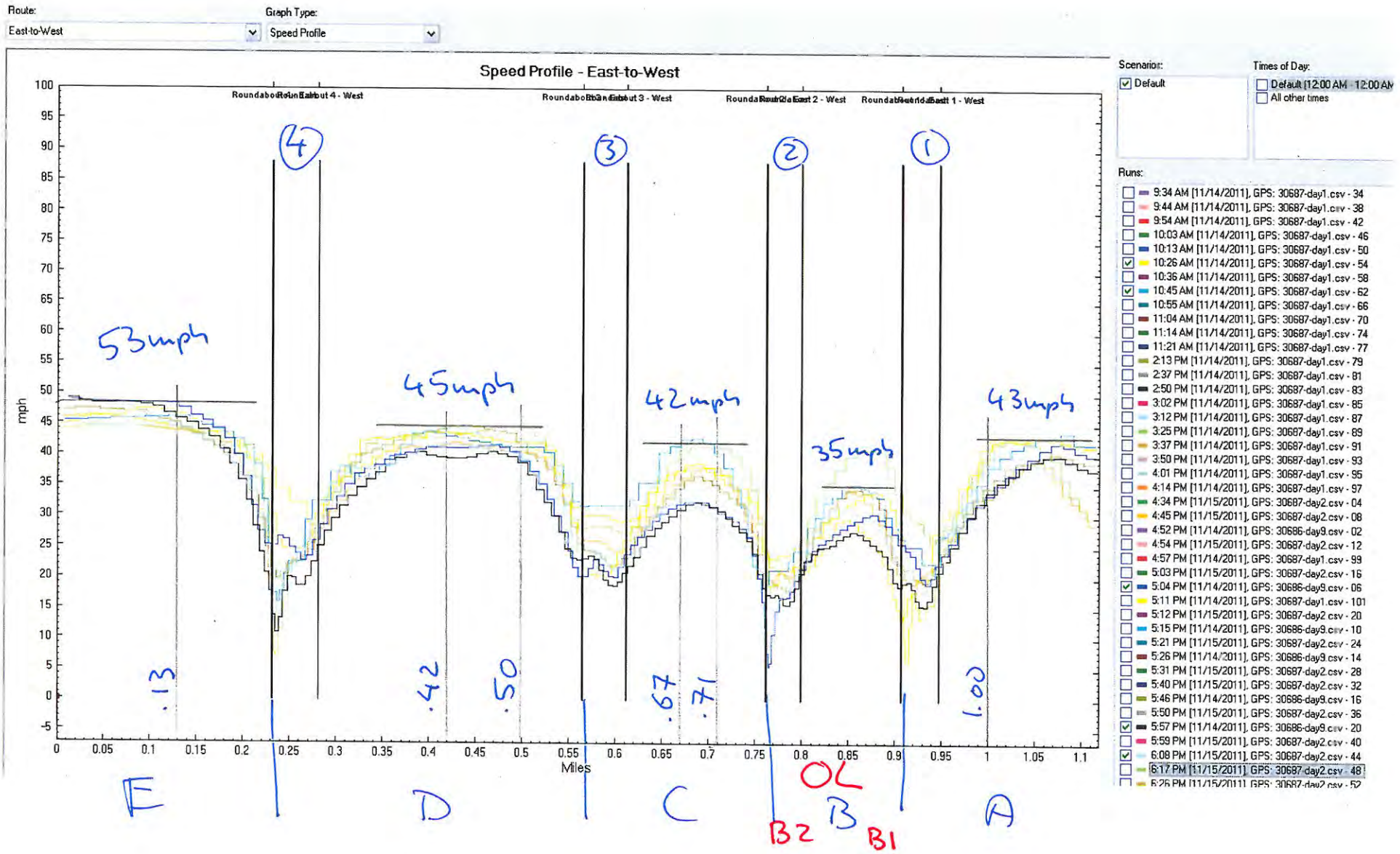
3-100 UNIMPEDED ROUTES

12/5/2012

X - REMOVE

OL - OVERLAPPING RIA

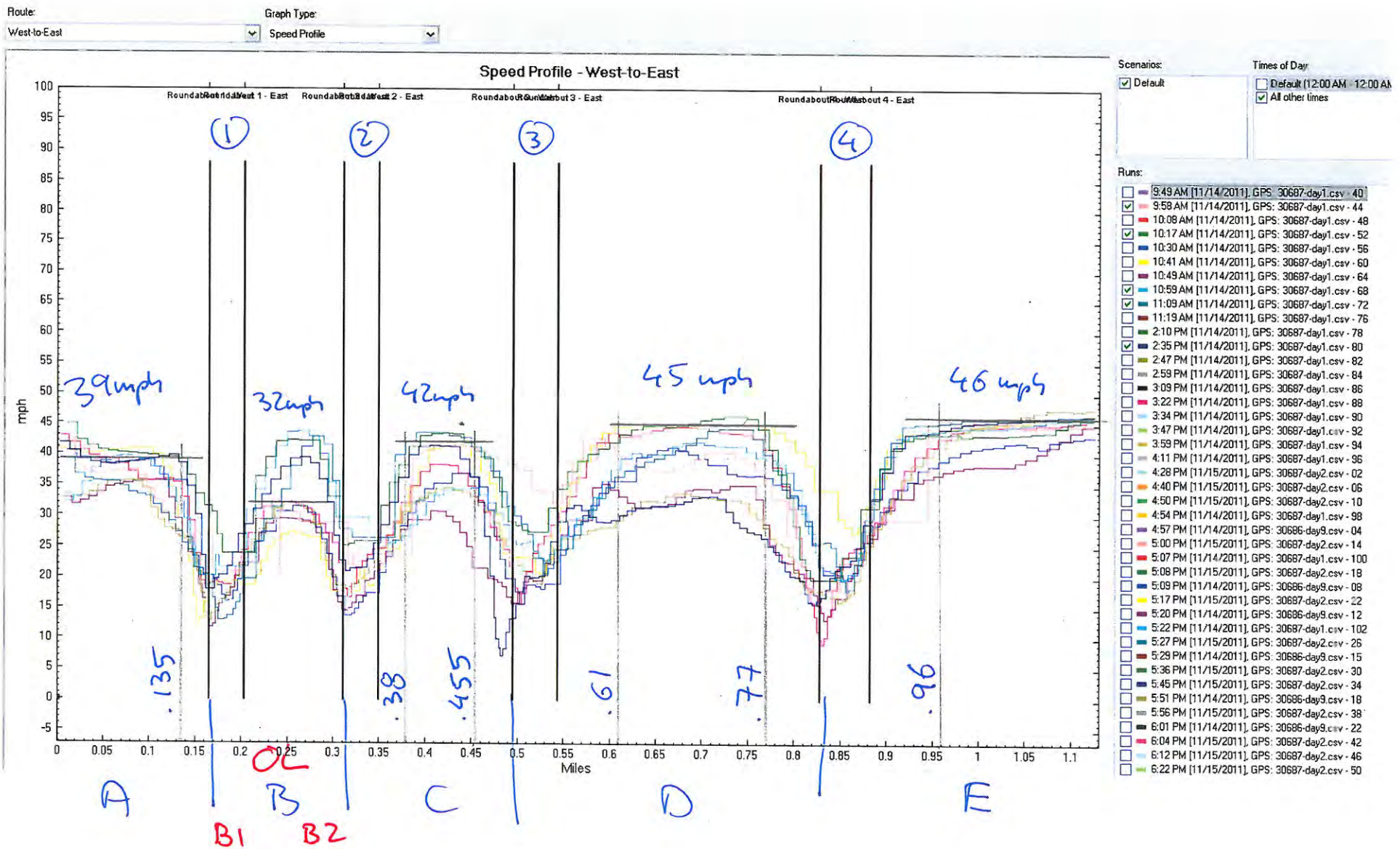
MD216 - Westbound



3-100 UNIMPEDED ROUTES

12/5/2012
X - REMOVE
OL - OVERLAPPING RIA

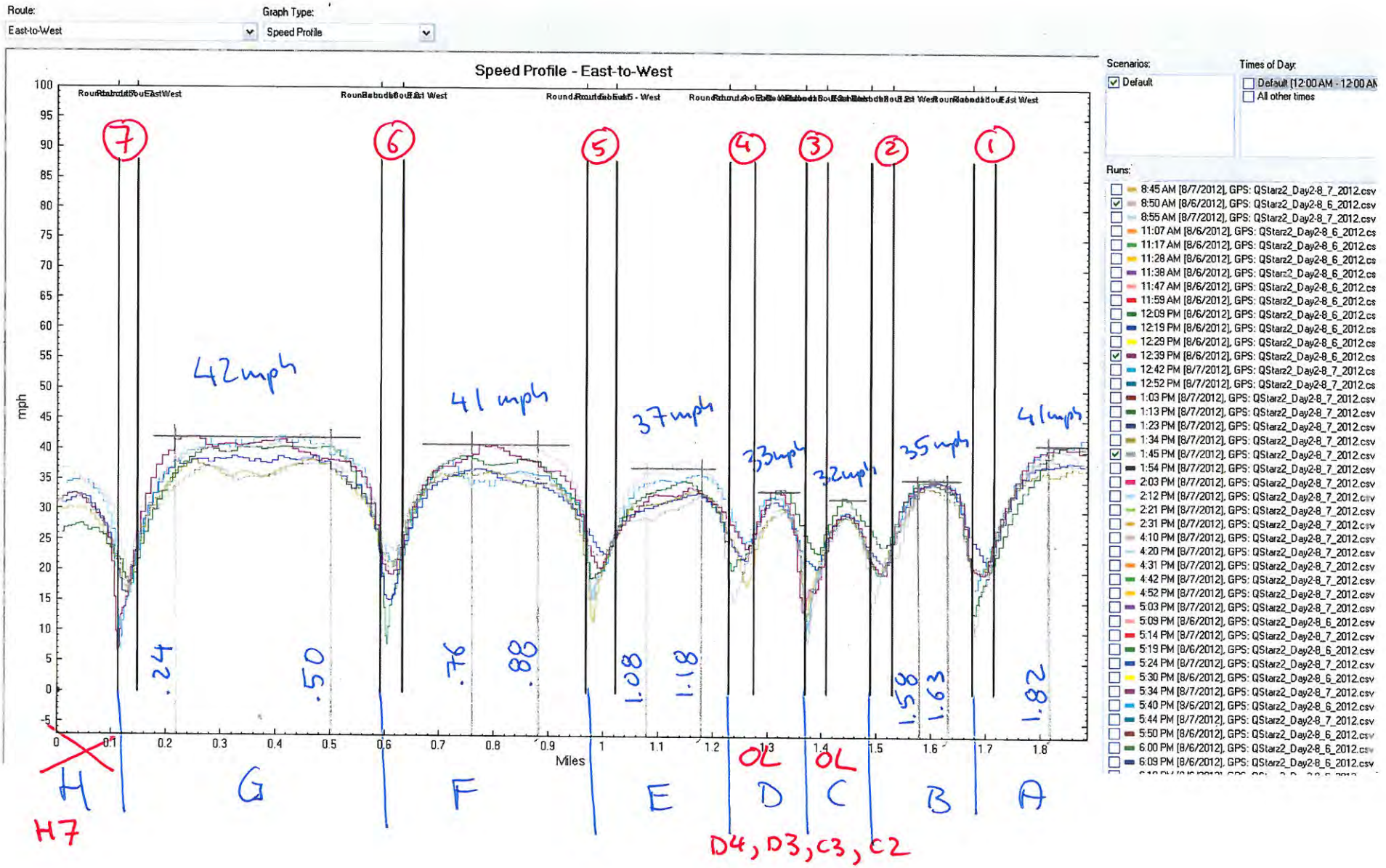
MD216 - Eastbound



3-100 UNIMPEDED ROUTES

12/5/2012
X - REMOVE
OL - OVERLAPPING
RIA

NY67 - Westbound



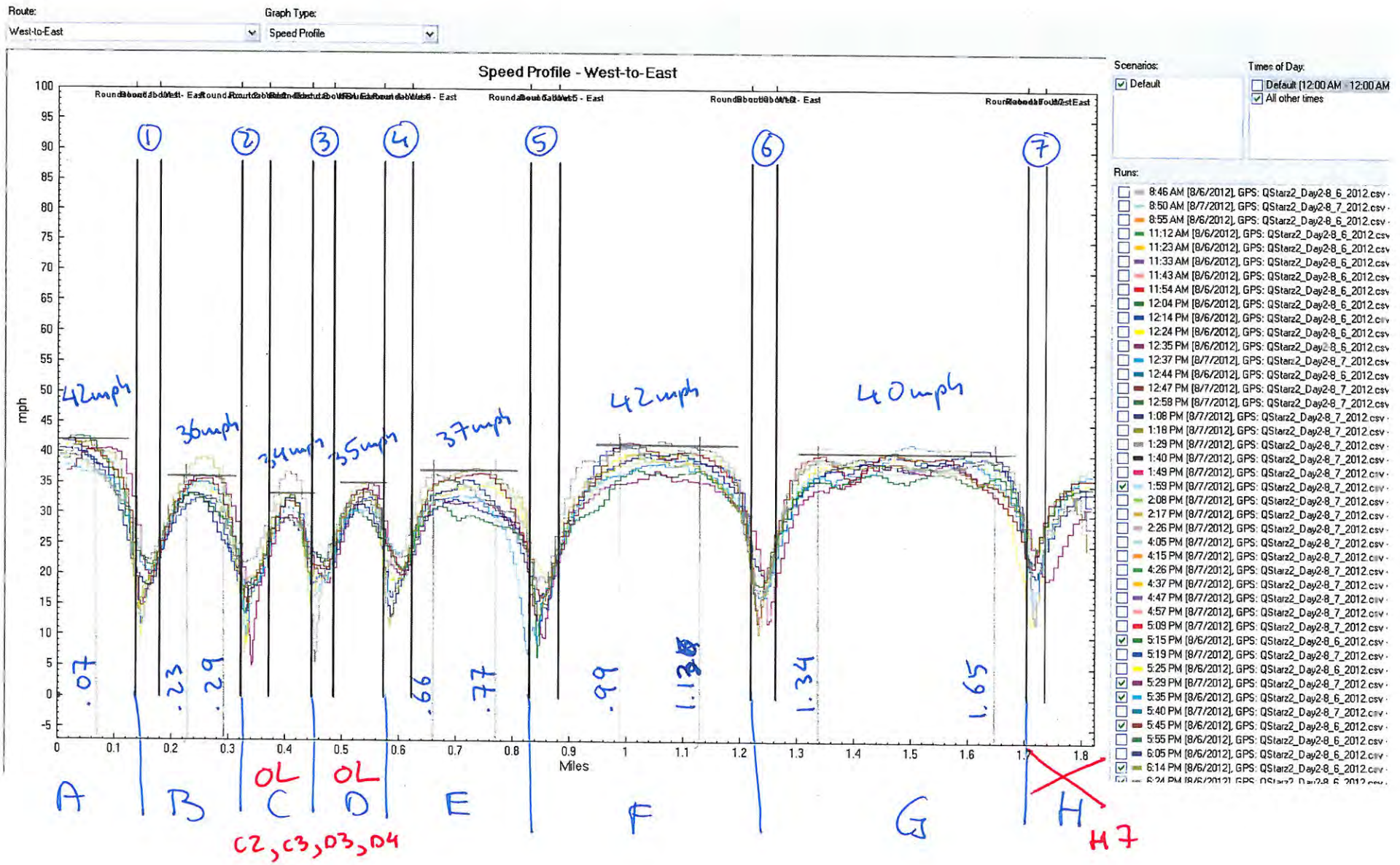
3-100 UNIMPEDED ROUTES

12/5/2012

X-REMOVE

OL-OVERLAPPING RIA

NY67 - Eastbound



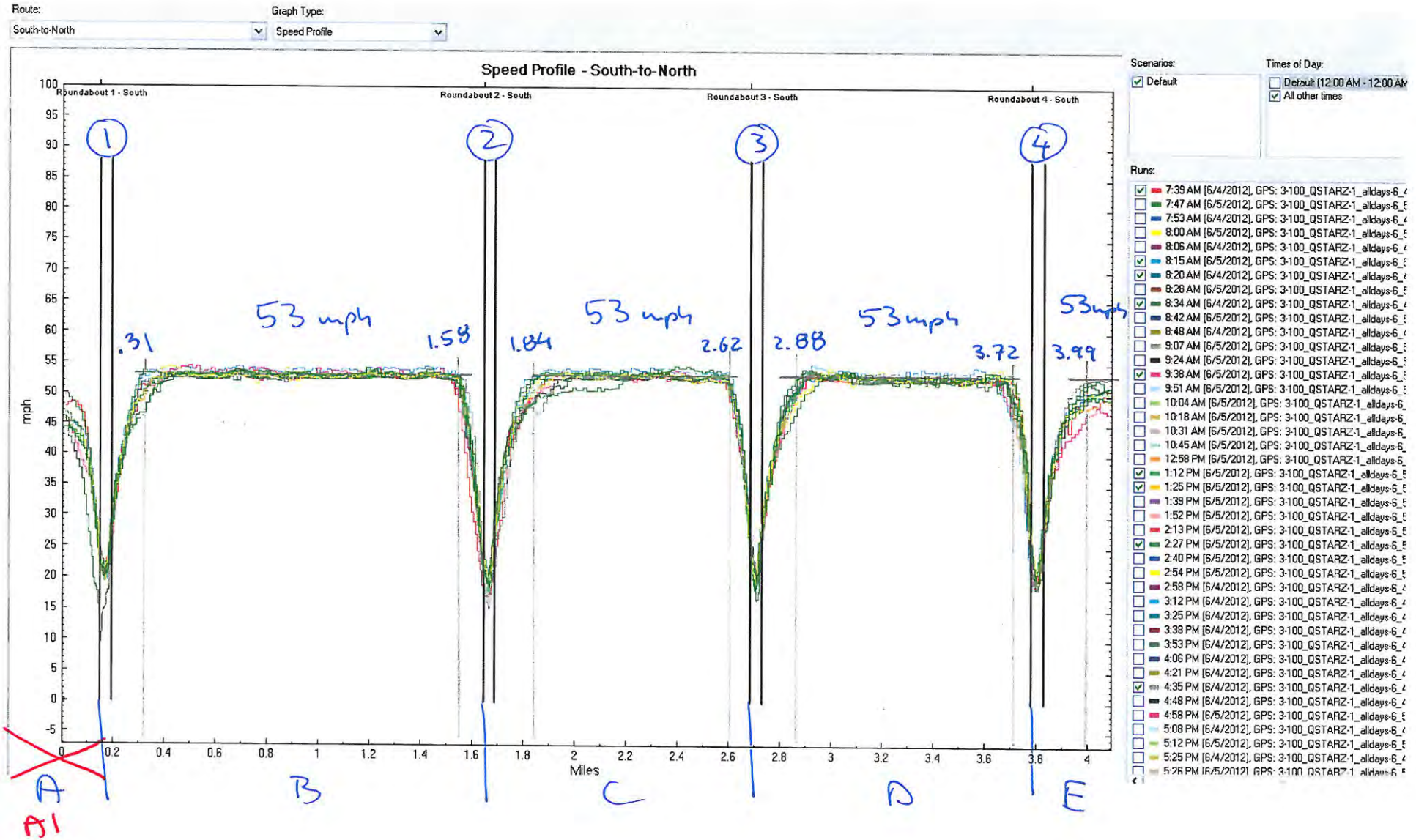
3-100 UNIMPEDED ROUTES

12/5/2012

X - REMOVE

OL - OVERLAP

WA539 - Northbound



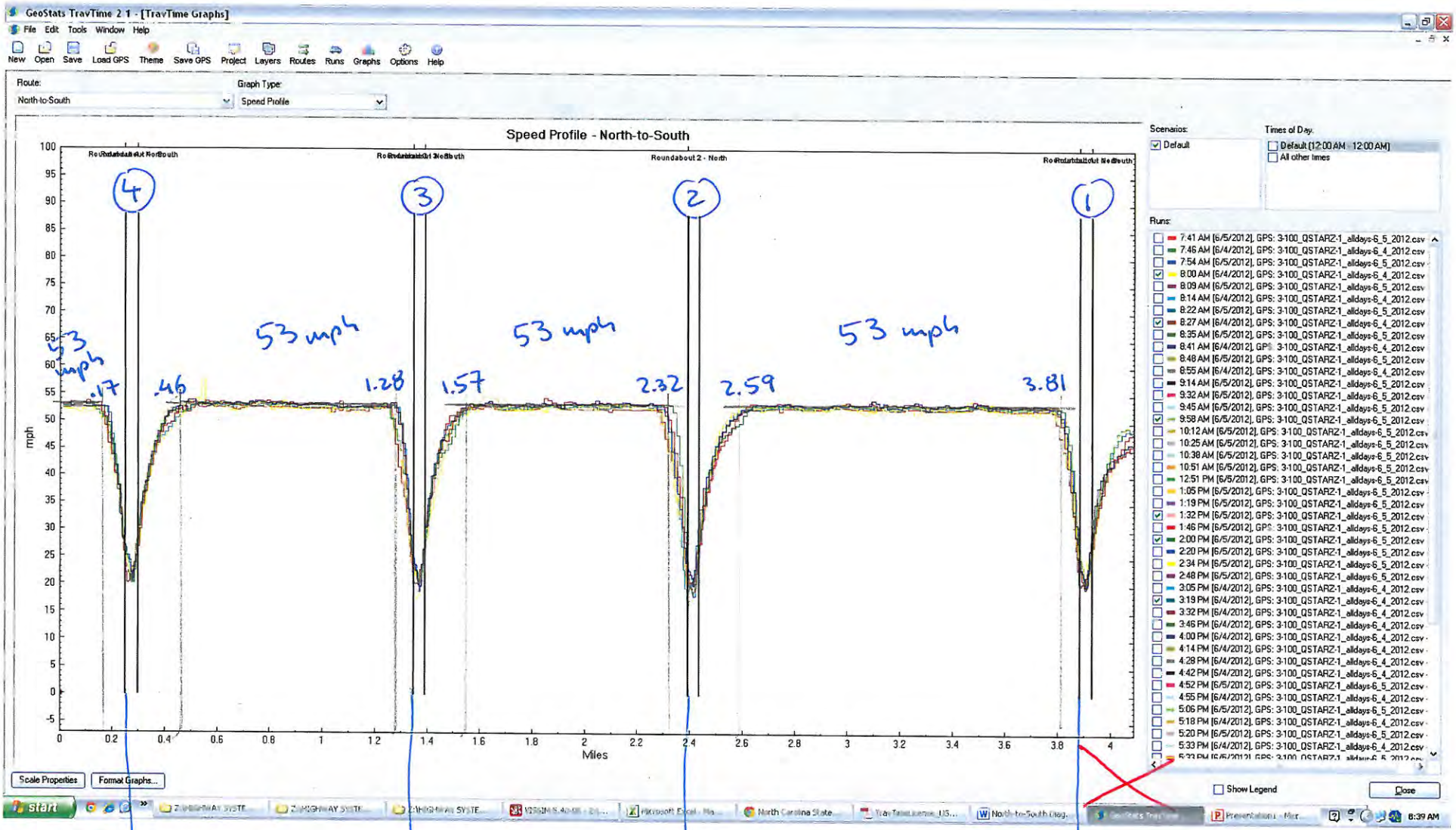
3-100 - UNIMPEDED ROUTES

12/5/2012

X - REMOVE

OL - OVERLAP

WA539 - Southbound



O. APPENDIX O - EQUIVALENT SIGNALIZED CORRIDOR COMPARISONS

O.1. CORRIDOR COMPARISONS

The following subsections provide intersection descriptions and results comparisons for each of the nine corridors. For maps of the corridors, refer to the site reports in Appendices B through J.

O.1.1. MD 216

O.1.1.1. *Description of Intersections*

The signalized MD 216 corridor developed by the research team is a four-lane, divided roadway with a speed limit of 40 mph. Signals are actuated-coordinated and operate at a 150-second cycle for all times of day. The research team selected this cycle length based upon their experience with studies and re-timings of actual signalized corridors in Maryland.

Intersection #1, at Old Columbia Road, has eastbound and westbound left-turn lanes on MD 216 that are controlled by protected-permissive phasing. The northbound and southbound approaches on Old Columbia Road each have a left-turn lane with permissive phasing and a shared through/right lane.

Intersection #2, a three-leg intersection at Maple Lawn Boulevard, has an eastbound left-turn lane on MD 216 that is served by protected-permissive phasing. The southbound approach on Maple Lawn Boulevard has a left turn-only lane and a shared left/right turn lane.

Intersection #3, at the US 29 southbound ramps and Old Scaggsville Road, has eastbound and westbound left-turn lanes on MD 216 that are served by protected-permissive phasing. There is a channelized right-turn lane from MD 216 eastbound to the US 29 southbound on-ramp. The side streets operate split phasing. The southbound leg (Old Scaggsville Road) has a left-turn lane and a through/right lane. The northbound leg (US 29 off-ramp) has a left turn–only lane, a shared left/through lane, and a channelized right-turn lane.

Intersection #4, at the US 29 northbound ramps and Ice Crystal Drive, has double eastbound left-turn lanes, a single westbound left-turn lane, and a channelized right-turn lane from MD 216 westbound to the US 29 northbound on-ramp. The left turns on MD 216 operate with protected-only phasing. The southbound leg (US 29 off-ramp) has a left turn–only lane, a through lane, and a channelized right-turn lane. The northbound leg (development access) has a left turn–only lane and a shared through/right lane. The side street left turns are served by protected-permitted phasing.

O.1.1.2. *Intersection Approach Delay*

As the Exhibit O-1 Synchro results reveal, the roundabouts present along the MD 216 corridor produce delay savings when compared with operations under

coordinated arterial signalized control. Along MD 216, the average approach delay savings from roundabout control per intersection is 10 to 13 seconds. The average approach delay savings percentage per intersection is 31 to 42.

Exhibit O-1 Approach Average Delay per Vehicle - PM Peak, MD216

Cross-Street and Approach Direction	Signalized Corridor		Roundabout Corridor	Comparison			
	Synchro (s/veh)	SimTraffic (s/veh)	Field Data (s/veh)	Roundabout vs. Synchro (s/veh)	Roundabout vs. Synchro (%)	Roundabout vs. SimTraffic (s/veh)	Roundabout vs. SimTraffic (%)
Old Columbia WB	4.5	6.8	8.3	3.8	84.4%	1.5	22.1%
Old Columbia EB	13.8	11.2	8.7	-5.1	-37.0%	-2.5	-22.3%
Maple Lawn WB	12.4	13.4	8.5	-3.9	-31.5%	-4.9	-36.6%
Maple Lawn EB	9.3	10.6	8.8	-0.5	-5.4%	-1.8	-17.0%
SB US-29 ramps WB	27.3	40.8	10.4	-16.9	-61.9%	-30.4	-74.5%
SB US-29 ramps EB	25.4	25.7	5.8	-19.6	-77.2%	-19.9	-77.4%
NBUS-29 ramps WB	30.3	29.8	10.9	-19.4	-64.0%	-18.9	-63.4%
NB US-29 ramps EB	32.9	44.2	13.6	-19.3	-58.7%	-30.6	-69.2%

O.1.1.3. *Corridor Travel Time*

Exhibit O-2's comparison values show improvements for MD 216 with roundabouts. Arterial roundabout through travel times improved by 16 and 24 percent in the eastbound and westbound directions, respectively, and arterial delays improved an average of 57 percent. Left-turn routes traveling off MD 216 towards cross streets demonstrated an average of 46 percent less travel time and 76 percent less delay than would be found with signalized control. Left-turn routes traveling onto MD 216 from cross streets demonstrated an average of 34 percent less travel time and 68 percent less delay than would be found with signalized arterial control.

Exhibit O-2 Route Travel Time and Delay - PM Peak, MD216

Route	Travel Time			Delay Time		
	Signalized (SimTraffic) (s)	Roundabout (Field) (s)	Comparison	Signalized (SimTraffic) (s)	Roundabout (Field) (s)	Comparison
1. West-to-East	186.5	156.0	-16%	81.8	42.0	-49%
2. East-to-West	189.8	144.0	-24%	86.1	30.0	-65%
3. East-South, left turn at #4 NB US-29	103.7	48.0	-54%	72.3	12.0	-83%
4. South-West, left turn from #4 NB US-29	191.4	114.0	-40%	101.2	24.0	-76%
5. West-North, left turn at #2 Maple Lawn	77.5	48.0	-38%	38.2	12.0	-69%
6. North-East, left turn from #2 Maple Lawn	188.2	138.0	-27%	103.8	42.0	-60%

O.1.2. LA JOLLA BOULEVARD

O.1.2.1. *Description of Intersections*

The signalized La Jolla Boulevard corridor developed by the research team is a two-lane, divided roadway. Every intersection has left-turn pockets on La Jolla Boulevard and no turn lanes on the side street. This design represents a signalized road diet, similar to the roundabout road diet that was implemented by the City of San Diego.

For the time periods in which turning movement counts were conducted, side-street volumes on La Jolla Boulevard do not meet the MUTCD's peak-hour signal warrant. However, it is possible that some intersections may meet other signal warrants. Therefore, the research team largely deferred to the intersection controls that existed prior to the installation of roundabouts. The intersections at Roundabout #1 (Colima Street), Roundabout #2 (Midway Street), and Roundabout #5 (Camino De La Costa) were previously TWSC and were modeled by the team as TWSC. Roundabout #4 (Bird Rock Avenue) was previously signalized and modeled by the team as a signal. Roundabout #3 (Forward Street) was previously AWSC, but with the road diet this intersection would operate at LOS F if it remained AWSC. The team chose to model Roundabout #3 as a signal.

The two signalized intersections have been assumed to operate with fixed-time control. This method of control provides pedestrians with a protected crossing of La Jolla Boulevard each cycle, even when vehicles are not present on the side street. This is consistent with the urban character of the corridor and the road diet. Each signal has two phases. The cycle length is 70 seconds in the weekday a.m. peak and midday time periods and 80 seconds in the weekday p.m. peak time period.

O.1.2.2. *Intersection Approach Delay*

As shown in Exhibit O-3, the roundabouts present along the La Jolla corridor generally produce an intersection approach delay savings when compared to the signalized intersection approaches at Forward Street and Bird Rock Avenue. When compared to the unsignalized intersection approaches, the roundabouts generally increase delay, as would be expected. When observing and comparing the approach delay results, note that some very high increases in approach delay are shown; however, the actual values for delay under non-roundabout and roundabout operations are low values (amplifying the comparison of percent difference). The approach delays for unsignalized intersections at Colima, Midway, and Forward are undefined in Synchro models, but were reported by SimTraffic.

Exhibit O-3 Approach Average Delay per Vehicle (seconds/vehicle) - PM Peak, La Jolla

Cross Street and Approach Direction	Signalized Corridor		Roundabout Corridor	Comparison			
	Synchro	SimTraffic	Field Data	Roundabout vs. Synchro	Roundabout vs. Synchro (%)	Roundabout vs. SimTraffic	Roundabout vs. SimTraffic (%)
Colima SB (unsignalized)	-	1.4	3.2	-	-	1.8	128.6%
Colima NB (unsignalized)	-	0.7	2.3	-	-	1.6	>200%
Midway SB (unsignalized)	-	2.2	4.8	-	-	2.6	118.2%
Midway NB (unsignalized)	-	1.3	5.2	-	-	3.9	>200%
Forward SB	4.0	6.8	4.6	0.6	15.0%	-2.2	-32.4%
Forward NB	8.4	8.5	1.5	-6.9	-82.1%	-7.0	-82.4%
Bird Rock SB	11.7	10.5	8.3	-3.4	-29.1%	-2.2	-21.0%
Bird Rock NB	8.0	10.9	2.1	-5.9	-73.8%	-8.8	-80.7%
Camino SB (unsignalized)	-	2.7	5.8	-	-	3.1	114.8%
Camino NB (unsignalized)	-	2.4	2.0	-	-	-0.4	-16.7%

O.1.2.3. *Corridor Travel Time*

Exhibit O-4's comparison values for La Jolla Boulevard show longer travel times and more delay with roundabouts on through routes. They also show longer travel times (in three of four cases) and less delay with roundabouts on left-turn routes. The results suggest that roundabouts may move traffic more efficiently (i.e. have less delay) but lower speeds (i.e. increase travel time) away from intersections. The roundabouts on La Jolla Boulevard are 600 to 800 feet apart, so drivers are accelerating or decelerating for much of the length of the mid-block segments. Specific lengths of acceleration and deceleration areas are described in Chapter 3 of this report. Speed profiles for this corridor are shown in the Appendix C. The results also indicate that roundabouts offered a greater delay benefit for left-turn routes than through routes.

Route	Travel Time			Delay Time		
	Signalized (SimTraffic)	Roundabout (Field)	Comparison	Signalized (SimTraffic)	Roundabout (Field)	Comparison
1. South-North	110.2	162.0	47%	21.4	24.0	12%
2. North-South	110.7	162.0	46%	21.8	24.0	10%
3. East-South, left turn from #1 Colima	41.4	54.0	30%	11.8	6.0	-49%
4. South-West, left turn at #4 Bird Rock	88.9	126.0	42%	32.8	6.0	-82%
5. West-North, left turn from #4 Bird Rock	75.0	70.0	-7%	29.5	6.0	-80%
6. North-East, left turn at #1 Colima	106.7	192.0	80%	24.7	36.0	46%

Exhibit O-4 Route Travel Time and Delay (seconds) - PM Peak, La Jolla

O.1.3. OLD MERIDAN

O.1.3.1. *Description of Intersections*

Old Meridian Street passes from the southwest to the northeast through a commercial, professional office area and through a high-density residential section of Carmel, Indiana, that is not yet fully developed. The signalized Old Meridian Street corridor developed by the research team has two lanes in each direction and has four roundabout intersections: Pennsylvania Street, Grand Boulevard, Main Street and Guilford Road. Signals are actuated-coordinated and operate at a 90-second cycle at all times of the day. The research team selected this cycle length based upon their experience with past retiming of actual signalized corridors.

Intersection #1, located at the junction of Old Meridian and Pennsylvania streets, has two northeast-bound and two southwest-bound primary travel lanes. In the northeast-bound direction, the left lane serves both through and left-turning traffic and the right lane serves only through traffic. A large-radius right-turn channel serves traffic traveling from the northeast to the south. In the southwest-bound direction, there is a 300-foot left-turn bay, a left-turn lane, a through lane, and another large-radius right-turn channel. Southbound traffic on Pennsylvania is accommodated by a shared left/through lane and a shared through/right lane, while northbound Pennsylvania has a shared left/through lane and a right-turn lane. All left turns at the intersection are permissive with the exception of the southwest-bound dual left, which is protected.

Intersection #2 is located at Grand Boulevard. This is a T-intersection with a single approach lane on Grand, a through and a shared through/right lane on northeast-bound Old Meridian, and a 200-foot left-turn lane with two through lanes on southwest-bound Old Meridian. Left turns from Old Meridian onto Grand are signalized in permitted mode.

The intersection of east-west running West Main Street is the third signalized junction along the Old Meridian corridor. Both the eastbound and westbound approaches on Main have a 200-foot left-turn bay and a shared/plus right lane. The geometry of the Old Meridian approaches is also the same, with a 200-foot left-turn lane, a through lane and share through/right lane in each direction. This signal provides protected/permissive left turns in all directions.

The fourth and final intersection in the Old Meridian corridor is located at Guilford Road. Northbound Guilford Road has a 125-foot right-turn bay and a shared through/right lane, while southbound Guilford (actually the exit from a parking lot) has a left-turn lane and a shared through/right lane. The approaches from Old Meridian have the same lane details on each approach, including a 200-foot left-turn bay, a through lane and a shared through/right lane in each direction. Left turns from Old Meridian are protected/permissive, while left turns from Guilford are permissive only.

In addition to the four roundabout intersections, there is a fifth major intersection at Carmel Drive, which is signalized. In the existing roundabout corridor data collection, some of the delay as well as variability in the observed travel times can be attributed to the signalized intersection at Carmel Drive (routes 1, 2, 3, and 6).

O.1.3.2. *Corridor Travel Time*

Exhibits O-5 and O-6 comparison values for the a.m. and p.m. peaks, respectively, demonstrate that arterial through travel performance along Old Meridian with roundabouts had both slightly higher travel time and delay when compared to signalized control. With roundabouts, arterial through travel times were 2.5 percent higher in the a.m. peak and 9 percent higher in the p.m. peak. For each peak period, the increased average travel time is due to increased travel time in the off-peak direction. Additionally, the delay times were 12 percent higher in the a.m. peak and 42 percent higher in the p.m. peak.

Route	Travel Time			Delay Time		
	Signalized (SimTraffic)	Roundabout (Field)	Comparison	Signalized (SimTraffic)	Roundabout (Field)	Comparison
1. South-North	170.7	180.6	6%	52.4	63.0	20%
2. North-South	164.4	162.6	-1%	37.3	38.4	3%
3. South-West, left turn at #3 Main	139.5	138.0	-1%	40.0	45.6	14%
4. West-North, left turn from #3 Main	92.6	64.8	-30%	52.6	17.4	-67%
5. North-East, left turn at #2 Grand	117.2	100.8	-14%	20.0	18.0	-10%
6. East-South, left turn from #2 Grand	119.5	94.8	-21%	56.0	37.2	-34%

Exhibit O-5 Route Travel Time and Delay (seconds) - AM Peak, Old Meridan

Route	Travel Time			Delay Time		
	Signalized (SimTraffic)	Roundabout (Field)	Comparison	Signalized (SimTraffic)	Roundabout (Field)	Comparison
1. South-North	202.5	192.0	-5%	75.3	74.4	-1%
2. North-South	142.7	175.8	23%	28.0	51.6	84%
3. South-West, left turn at #3 Main	153.7	156.0	1%	51.1	63.6	24%
4. West-North, left turn from #3 Main	104.0	68.4	-34%	52.6	21.0	-60%
5. North-East, left turn at #2 Grand	111.6	100.2	-10%	21.6	17.4	-19%
6. East-South, left turn from #2 Grand	97.8	105.0	7%	50.5	47.4	-6%

Exhibit O-6 Route Travel Time and Delay (seconds) - PM Peak, Old Meridan

With roundabouts, the left-turn routes off Old Meridian traveling toward cross streets demonstrated an average of 8 percent decrease in travel time and a slight 2 percent delay increase in the a.m. peak. In the p.m. peak hour, the roundabout corridor had an average of 5 percent lower travel time and 2.5 percent higher delay time than would be found with signalized arterial control. The left-turn routes onto Old Meridian from cross streets demonstrated reductions in travel time at an average of 26 percent and a 51 percent delay savings in the a.m. peak with roundabouts. In the p.m. peak hour, the roundabout corridor had an average of 14 percent reduction in travel time and 33 percent lower delay time than would be found with signalized arterial control on the routes with left turns onto Old Meridian.

O.1.4. SPRING MILL

O.1.4.1. *Description of Intersections*

Spring Mill Road is a mostly low-density residential corridor that parallels the more heavily–developed commercial and retail US 31 corridor to the east in Carmel, Indiana. The signalized Spring Mill corridor developed by the research team has a single lane in each direction and seven roundabout intersections: 96th Street, 106th Street, 116th Street, Dorset Boulevard, Main Street, 136th Street and 141st Street. The road was modeled as a two-lane facility based upon a conversation the research team had with the City of Carmel. City staff indicated that the road was planned as a two-lane, residential-oriented facility regardless of intersection control. Volumes are currently higher than forecast, but are expected to decrease when US 31 is upgraded to a freeway. Numerous driveways and minor street intersections (with TWSC on the minor street) are found along the corridor. Many of the signalized intersections are approximately one mile apart. The signalization plan for Spring Mill features actuated-uncoordinated operation for most intersections, with intersection cycle times ranging from 90 to 120 seconds. Main Street and Dorset Boulevard are 1400 feet apart, and operate in actuated-coordinated mode with a 100-second cycle length. The research team selected cycle lengths for all intersections based upon their experience with past retiming of actual signalized corridors.

Intersection #1, located at 96th Street, is the Spring Mill corridor's southernmost intersection. It is just south of Interstate 465, the Indianapolis beltway, and features a 150-foot left turn bay and a shared through plus right lane on each approach along Spring Mill. 96th Street is a four-lane facility, and at the intersection its approaches each have a 150-foot left-turn bay, a through lane and a shared through/right lane. All four left turns at the intersection operate in protected/permissive mode.

Intersection #2 is located north of I-465 at 106th Street, another two-lane facility. The cross street approaches both have a 150-foot left-turn bay and a through lane. The westbound approach also provides a 150-foot right-turn bay. Along Spring Mill Road, both approaches have a 150-foot left-turn bay, a through lane, and a 150-foot right-turn bay. All four left turns at the intersection operate in protected/permissive mode.

Intersection #3 is found at the junction of Spring Mill Road and 116th Street. The geometry and lane assignments at this intersection mirror that of the 96th Street intersection (i.e., Intersection #1). Three of the intersection's left turns are protected/permissive, but the eastbound approach allows only protected lefts.

Intersection #4 is found at Dorset Boulevard. Both Dorset and Spring Mill are two-lane facilities at this junction, and the roadway geometry on each approach includes a 150-foot left-turn and a shared through/right lane. Three of the intersection's left turns operate in permissive mode while the westbound approach is protected/permissive.

The signalized roundabout equivalent at Intersection #5, Main Street, has approach features that vary by direction. The cross street features a 150-foot left-

turn bay, two through lanes, and a 100-foot right-turn bay in the westbound direction, and a 150-foot left-turn bay, a through lane and a shared through/right lane in the eastbound direction. Northbound along Spring Mill there is a 150-foot left-turn bay and a shared through/right lane, and southbound has a 300-foot dual-left turn bay and a shared through/right lane. Spring Mill's left turns are protected only, while Main's left turns are permissive in the westbound direction and protected/permissive in the eastbound direction.

Intersection #6 is located where 136th Street crosses Spring Mill. Both roadways have a single travel lane in each direction. The Spring Mill approaches each have a 150-foot left-turn bay, a through lane, and a 150-foot right-turn bay. Eastbound 136th Street has a 150-foot left-turn bay and shared through/right lane, while westbound 136th has a 150-foot left-turn bay, a through lane, and 100-foot right-turn bay. Spring Mill's left turns have protected/permissive phasing, while 136th Street's left turns have permissivepermissive-only phasing.

Intersection #7, at 141st Street, is a T-intersection at the study corridor's northern limit. The northbound approach has a 150-foot left-turn bay and a through lane. The southbound approach has a shared through/right lane. The eastbound approach has a 200-foot left-turn bay and a right turn lane. The northbound left turn from Spring Mill operates in protected/permissive mode.

O.1.4.2. *Corridor Travel Time*

Exhibits O-7 and O-8's comparison values for the a.m. and p.m. peaks, respectively, demonstrate that with roundabouts the arterial's through travel performance along Spring Mill Road had lower travel time and less delay than with signalized control. With roundabouts, the average arterial through travel times were 12 percent lower in the a.m. peak and 10 percent lower in the p.m. peak. Delay times were 28 percent lower in the a.m. peak and 30 percent lower in the p.m. peak. Additionally, the left-turn routes traveling off Spring Mill towards cross streets demonstrated an average of 27 percent reduction in travel time and a 56 percent delay savings in the a.m. peak. In the p.m. peak the roundabout corridor had an average of 17 percent lower travel time and 38 percent lower delay time than with signalized arterial control. The left-turn routes turning onto Spring Mill from cross streets demonstrated an average of 27 percent reduction in travel time and a 58 percent delay savings in the a.m. peak with roundabouts. In the p.m. peak, roundabouts provided an average of 37 percent lower travel time and 71 percent lower delay time than would be provided with signalized arterial control.

Exhibit O-7 Route Travel Time and Delay - AM Peak, Spring Mill

Route	Travel Time (s)			Delay Time (s)		
	Signalized (SimTraffic)	Roundabout (Field)	Comparison	Signalized (SimTraffic)	Roundabout (Field)	Comparison
1. South-North	492.6	497.4	1%	108.5	106.8	-2%
2. North-South	707.9	538.2	-24%	304.9	139.8	-54%
3. South-West, left turn at #6 136th	484.6	435	-10%	139.6	78.6	-44%
4. West-North, left turn from #6 136th	135.5	90	-34%	77.4	32.4	-58%
5. North-East, left turn at #5 131st	295.1	166.8	-43%	189.1	61.2	-68%
6. East-South, left turn from #5 131st	490.8	394.2	-20%	174.8	73.2	-58%

Exhibit O-8 Route Travel Time and Delay (seconds) - PM Peak, Spring Mill

Route	Travel Time			Delay Time		
	Signalized (SimTraffic)	Roundabout (Field)	Comparison	Signalized (SimTraffic)	Roundabout (Field)	Comparison
1. South-North	602.4	556.8	-8%	203	166.2	-18%
2. North-South	558.4	490.2	-12%	154.8	91.8	-41%
3. South-West, left turn at #6 136th	558.6	508.8	-9%	191.7	152.4	-21%
4. West-North, left turn from #6 136th	139.1	81.0	-42%	76.9	23.4	-70%
5. North-East, left turn at #5 131st	193.5	145.2	-25%	88.7	39.6	-55%
6. East-South, left turn from #5 131st	577.6	390.0	-32%	248.4	69.0	-72%

O.1.5. BORGEN

O.1.5.1. *Description of Intersections*

Borgen Boulevard in Gig Harbor, Washington, is an east-west arterial corridor consisting of five roundabouts. The two roundabouts at the western end of the corridor serve ramps at an interchange with SR 16 as well as an arterial that parallels SR 16, and the other roundabouts service local roadways connecting with retail and residential development. The research team developed lane configurations and traffic-signal timings for a signalized equivalent to the Borgen roundabout corridor.

Intersection #1 in the signalized equivalent is the junction formed by the southbound SR 16 ramps and Borgen Boulevard. Both the exit and entrance ramps from/to SR 16 have two lanes, and along the southbound approach the lane assignment includes a left-turn lane and a shared lane serving left, through,

and right traffic. The eastbound Borgen approach includes two lanes, a through-only lane and a shared through/right lane. In the westbound direction, there are two through lanes and a protected-only, dual-lane left-turn bay that is 300 feet long.

Completing the interchange between SR 16 and Borgen, Intersection #2 is the junction of the northbound SR 16 ramps and Borgen Boulevard. As the roundabout for this junction also serves traffic for Canterwood Boulevard, it was decided by the research team to merge the SR 16 ramps and Canterwood into a combined roadway segment that would cross Borgen and form a single signalized intersection. The resulting intersection's approaches include a left-turn lane and a shared through/right lane in the southbound direction, a single through lane in the northbound direction that is augmented with a 200-foot left-turn bay and a 200-foot right-turn bay, two through lanes in the westbound direction supplemented by a 200-foot left-turn bay and a 300-foot right-turn bay, and a left-turn bay (200 feet), a through lane, and a shared through/right lane in the eastbound direction. All left turns at this intersection operate in protected/permissive mode.

Intersection #3, in the middle of the Borgen corridor, has the same lane assignment in both the eastbound and westbound directions—a 200-foot left-turn bay, a through lane, and a shared through/right lane. The approach geometry is also the same for the northbound and southbound 51st Avenue cross-street approaches: a left turn lane and a shared through/right lane. Signal operations are protected/permissive on Borgen and permissive left turns are provided on 51st Avenue.

Intersection #4 is the intersection of Harbor Hill and Borgen. East of Harbor Hill, Borgen changes from a four-lane to a two-lane roadway. The eastbound approach features a 200-foot left-turn bay, a through lane, and a right lane, and the westbound approach features a through lane, a left-turn bay and a right-turn bay—each of these bays is 200 feet long. For the cross street (Harbor), there is also a change of cross section. North of Borgen, Harbor is a two-lane facility, while south of Borgen, Harbor has four lanes. The southbound approach has a single lane serving all movements, while the northbound approach has a left turn lane and a shared through/right lane. Signal phasing includes protected/permissive lefts turns on Borgen, while the Harbor approaches are split phased.

The junction of Peacock Hill Avenue and Borgen is the fifth and final intersection in the signalized Borgen corridor. Westbound Borgen has a single lane serving all movements, while the eastbound Borgen approach has a shared through/right lane and a 200-foot left-turn bay. Northbound along Peacock Hill there is a 200-foot left-turn bay and a shared through/right lane. Southbound along Peacock Hill there is a shared through/left lane and a 200-foot right-turn bay.

O.1.5.2. *Intersection Approach Delay*

As shown in Exhibit O-9, the roundabouts present along the Borgen corridor produce a net approach delay savings when compared with operations under coordinated arterial signalized control. The average approach delay savings from

roundabout control per intersection along Borgen Boulevard is 5.4 to 5.8 seconds or 29 to 36 percent, depending on whether the comparison is to Synchro or SimTraffic.

Exhibit O-9 Approach Average Delay per Vehicle (seconds/vehicle) - PM Peak, Borgen

Cross Street and Approach Direction	Signalized Corridor		Roundabout Corridor	Comparison			
	Synchro	SimTraffic	Field Data	Roundabout vs. Synchro	Roundabout vs. Synchro (%)	Roundabout vs. SimTraffic	Roundabout vs. SimTraffic (%)
SB SR 16 ramps WB	18.2	16.7	2.4	-15.8	-86.8%	-14.3	-85.6%
SB SR 16 ramps EB	20.8	19.8	14.1	-6.7	-32.2%	-5.7	-28.8%
NB SR 16 ramps WB	16.0	24.5	19.9	3.9	24.4%	-4.6	-18.8%
NB SR 16 ramps EB	7.4	15.6	8.3	0.9	12.2%	-7.3	-46.8%
51st WB	11.6	12.8	8.9	-2.7	-23.3%	-3.9	-30.5%
51st EB	13.4	7.5	7.7	-5.7	-42.5%	0.2	2.7%
Harbor Hill WB	22.8	17.0	6.1	-16.7	-73.2%	-10.9	-64.1%
Harbor Hill EB	15.8	11.7	9.8	-6.0	-38.0%	-1.9	-16.2%
Peacock WB	13.5	14.5	7.2	-6.3	-46.7%	-7.3	-50.3%
Peacock EB	9.3	12.7	10.5	1.2	12.9%	-2.2	-17.3%

O.1.5.3. *Corridor Travel Time*

Exhibit O-10's comparison values contradict the intersection approach delay findings in that travel time increases, rather than decreases, are observed for Borgen Boulevard with roundabouts. This indicates that roundabouts reduce speed on the corridor. With roundabouts, the arterial's through travel times increased by 17 percent, and delay times increased by an average of two percent when compared to signal control. The left-turn routes turning off Borgen toward cross streets demonstrated an average of 1 percent increase in travel time and delay time, which is an average of 7 percent lower than would be found with signalized arterial control. The left-turn routes turning onto Borgen from cross streets demonstrated an average of 29 percent increase in travel time and 15 percent increase in delay times than would be found with signalized arterial control.

Route	Travel Time			Delay Time		
	Signalized (SimTraffic)	Roundabout (Field)	Comparison	Signalized (SimTraffic)	Roundabout (Field)	Comparison
1. East-West	177.4	198.6	12%	69.7	69.0	-1%
2. West-East	158.7	194.4	22%	63.6	66.6	5%
3. East-South, left turn at #3 51st	134.1	127.2	-5%	45.3	41.4	-9%
4. South-West, left turn from #3 51st	92.1	121.2	32%	55.3	67.8	23%
5. West-North, left turn at #3 51st	95.4	101.4	6%	49.3	47.4	-4%
6. North-East, left turn from #3 51st	109.1	136.2	25%	48.9	51.6	6%

Exhibit O-10 Route Travel Time and Delay (seconds) - PM Peak, Borgen

O.1.6. SR 539

O.1.6.1. *Intersections Description*

The signalized SR 539 corridor developed by the research team has four intersections, and those intersections are widely spaced through the mostly rural corridor. The central two intersections are modeled as signalized junctions operating in an actuated, uncoordinated/free mode, with background phasing resulting in a 120-second cycle length, while the outer two intersections in the corridor are modeled as unsignalized intersections. The research team selected this cycle length based upon their experience with past retiming of actual signalized corridors.

Intersection #1, River Road, is located at the northern end of the study corridor. It has a 200-foot left-turn bay on its SR 539 northbound approach, along with two through lanes. The southbound approach features a through lane and a shared through/right lane. River Road approaching from the west has a single lane serving both left and right movements. A stop sign on River Road controls the intersection. The research team chose not to signalize the intersection because it does not meet MUTCD signal warrants.

Intersection #2 is the junction of SR 539 with Wiser Lake Road. Both the northbound and southbound SR 539 approaches have a 200-foot left-turn bay, a through lane and a shared through/right lane. The east- and westbound approaches on Wiser Lake each have a single lane serving all movements. All left-turn movements at this intersection operate in permissive mode, with left-turning traffic yielding to opposing through traffic.

Intersection #3, at SR 539 and Pole Road, has geometry along both the main street and cross street that mirrors Intersection #2. However, at Pole Road the left turns from SR 539 are operated in protected/permissive mode rather than permissive-only mode. The left turns from Pole Road have permissive phasing.

Intersection #4, the southernmost intersection, is found at Ten Mile Road. SR 539's northbound and southbound approaches each feature a 200-foot left-turn

bay, a through lane, and a shared through/right lane in each direction. Like the other cross streets in this corridor, Ten Mile Road (actually a parking lot entrance/exit on the west side of the intersection) has a single lane serving all movements in each direction. This intersection operates with TWSC, with stop signs on Ten Mile Road (east side of intersection) and at the parking lot exit (west side of intersection). Volumes at the intersection do not meet MUTCD signal warrants.

O.1.6.2. *Intersection Approach Delay*

As shown in Exhibit O-11, the roundabouts present along the SR 539 corridor generally produce the overall higher average intersection approach delay. The roundabout control causes an average increase of 7.5 to 8.5 seconds when compared to SimTraffic or Synchro, respectively. As a percentage, intersection approach delay for the existing roundabout arterial movements on average is several times higher than the signalized arterial through movements. The extremity of the increases in arterial through approach delay are largely due to the very low values of delay reported under signalized operation, and the average approach delays under roundabout and signal control are rather low. Furthermore, two of the four intersections were modeled as TWSC in the equivalent signalized corridor because they did not meet MUTCD volume warrants.

Exhibit O-11 Approach Average Delay per Vehicle (seconds/vehicle) - PM Peak, SR 539

Cross Street and Approach Direction	Signalized Corridor		Roundabout Corridor	Comparison			
	Synchro	SimTraffic	Field Data	Roundabout vs. Synchro	Roundabout vs. Synchro (%)	Roundabout vs. SimTraffic	Roundabout vs. SimTraffic (%)
Ten Mile SB (unsignalized)	-	5.7	12.6	-	-	6.9	121.1%
Ten Mile NB (unsignalized)	-	0.6	14.9	-	-	14.3	>200.0%
Pole SB	8.2	13.0	9.9	1.7	20.7%	-3.1	-23.8%
Pole NB	11.2	15.6	22.1	10.9	97.3%	6.5	41.7%
Wiser Lake SB	2.1	5.4	12.6	10.5	>200.0%	7.2	133.3%
Wiser Lake NB	2.3	8.4	13.3	11.0	>200.0%	4.9	58.3%
River Rd SB (unsignalized)	-	0.5	7.6	-	-	7.1	>200.0%
River Rd NB (unsignalized)	-	4.8	20.6	-	-	15.8	>200.0%

O.1.6.3. *Corridor Travel Time*

Exhibit O-12 indicates that travel time on four of the six routes remained about the same under roundabout and signalized control. On the two routes involving a left turn onto the corridor, travel time increased by 16 to 17 percent. This was due to the delay experienced on the side street while waiting for the signal at SR 539 to turn green. On four of the six routes, delay more than doubled with roundabouts in comparison to signals. Much of the increased delay with roundabouts can be attributed to the rural, high-speed nature of this corridor. The speed differential between mid-block operating speeds and geometrically-controlled speeds at the roundabouts is greater on this corridor than on others

included in this project, resulting in increased geometric delay compared to a lower-speed corridor.

Exhibit O-12 Route Travel Time and Delay (seconds) - PM Peak, SR 539

Route	Travel Time			Delay Time		
	Signalized (SimTraffic)	Roundabout (Field)	Comparison	Signalized (SimTraffic)	Roundabout (Field)	Comparison
1. South-North	327.9	327.0	0%	30.2	74.4	146%
2. North-South	321.8	322.8	0%	23.4	63.6	172%
3. South-West, left turn at #2 Pole	153.6	142.8	-7%	12.7	32.4	155%
4. West-North, left turn from #2 Pole	245.8	207.0	-16%	54.6	52.2	-4%
5. North-East, left turn at #3 Wiser Lake	122.5	121.2	-1%	11.1	25.8	132%
6. East-South, left turn from #3 Wiser Laker	273.7	228.0	-17%	66.7	46.8	-30%

O.1.7. GOLDEN

O.1.7.1. *Description of Intersection*

The signalized Golden Road corridor developed by the research team has two types of geometric configurations. For most of the corridor, it is a four-lane, divided roadway with a speed limit of 30 miles per hour. However, south of Roundabout #1 (Ulysses Street), Golden Road features a two-lane configuration.

Side-street volumes on Golden Road for the time periods in which turning-movement counts were conducted do not meet the MUTCD's peak-hour signal warrant. However, it is possible that some intersections may meet other signal warrants. Therefore, the research team largely deferred to intersection controls that existed prior to the installation of roundabouts. The intersections at Roundabout #2 (Utah Street) and Roundabout #3 (Lunnonhaus Drive) were previously TWSC; accordingly, they were modeled by the team as TWSC. Roundabout #5 (Jackson Street/Ford Street) was modeled as a through roadway segment with right-in, right-out driveway access to local land use. Roundabout #1 (Ulysses Street) and Roundabout #3 (Johnson Road) were previously signalized and were therefore modeled by the team as signalized junctions. The two signalized intersections operate with actuated control, but without coordination due to the distance between them.

Intersection #1, at Ulysses Street, has a cycle length of 70 seconds in the p.m. peak time period. The intersection has a left-turn lane with permissive phasing on the Golden Road approaches. The eastbound approach has a through-only lane and a shared through/right-turn lane. The westbound approach has a shared lane serving through/right movements. The northbound approach on Ulysses Street has one shared through/right lane and one left-turn lane (which is controlled with permissive phasing). The southbound approach is a driveway access point serving a parking lot, and it also has one shared through/right lane and one left-turn lane with permissive phasing.

Intersection #2, at Utah Street, and Intersection #3, at Lunnonhaus Drive, were modeled by the team as TWSC. Each intersection has left-turn pockets on Golden Road and no turn lanes on the side street.

Intersection #4, at Johnson Road, has a 90-second cycle length in the p.m. peak time period. The intersection has a left-turn lane with protected-permissive phasing on the northbound and southbound approaches on Golden Road. The two approaches also have a shared lane for through/right movements. The eastbound leg on Johnson Road has a shared through/right lane, and a left-only lane with permissive phasing. The westbound leg on 16th Avenue has a single shared lane for all movements.

Intersection #5 (Jackson Street/Ford Street) was modeled as a roadway segment with a local access driveway serving land uses to the south. West of this location, Golden Road becomes a one-way roadway couplet, with Ford Street continuing westbound and Jackson Street approaching this location (in the eastbound direction). The only control feature is stop control added for northbound approach traffic leaving the parking lot to the south. Access to the driveway is restricted to right-in and right-out traffic only.

O.1.7.2. *Intersection Approach Delay*

As shown in Exhibit O-13, the roundabouts present along the Golden Road corridor produce an intersection approach delay savings on three of the four signalized approaches, with the overall average approach delay benefit being a reduction of 3.9 seconds or 41 percent as compared to the signalized control operations. On five of the six unsignalized approaches, roundabouts resulted in an increase in delay, as would be expected. The roundabout at Jackson Street had a greater increase in delay than the roundabouts at Utah Street and Lunnonhous Street, possibly because it has a larger inscribed circle diameter and increased geometric delay compared to the other roundabouts modeled as unsignalized intersections. When observing and comparing the approach delay results, note that some very high increases in approach delay are shown, but that the actual values for delay under signalized and roundabout operations are low values (amplifying the comparison of percent difference).

Approach	Signalized Corridor		Roundabout Corridor	Comparison			
	Synchro	SimTraffic	Field Data	Roundabout vs. Synchro	Roundabout vs. Synchro (%)	Roundabout vs. SimTraffic	Roundabout vs. SimTraffic (%)
Ulysses SB	8.3	12.7	2.0	-6.3	-75.9%	-10.7	-84.3%
Ulysses NB	9.1	13.8	5.0	-4.1	-45.1%	-8.8	-63.8%
Utah SB (unsignalized)	-	1.3	2.7	-	-	1.4	107.7%
Utah NB (unsignalized)	-	1.6	2.7	-	-	1.1	68.8%
Lunnonhaus SB (unsignalized)	-	1.7	1.5	-	-	-0.2	-11.8%
Lunnonhaus NB (unsignalized)	-	1.0	2.1	-	-	1.1	110.0%
Johnson SB	11.3	9.6	5.4	-5.9	-52.2%	-4.2	-43.8%
Johnson NB	7.2	6.3	7.9	0.7	9.7%	1.6	25.4%
Jackson SB (unsignalized)	-	0.4	11.6	-	-	11.2	>200.0%
Jackson NB (unsignalized)	-	3.3	8.0	-	-	4.7	142.4%

Exhibit O-13 Approach Average Delay per Vehicle (seconds/vehicle) - PM Peak, Golden

O.1.7.3. *Corridor Travel Time*

Travel time increased with roundabouts on the two through routes and the two routes with left turns off the corridor. Travel time decreased with roundabouts on the two routes with left turns onto the corridor, potentially because roundabouts eliminated delay experienced on the side street while waiting for the signal at Golden Road to turn green. Travel time and delay differences are approximately 10 seconds, or less, for five of the six routes.

Route	Travel Time			Delay Time		
	Signalized (SimTraffic)	Roundabout (Field)	Comparison	Signalized (SimTraffic)	Roundabout (Field)	Comparison
1. South-North	161.7	163.2	1%	19.9	28.2	42%
2. North-South	161.1	167.4	4%	22.5	30.0	33%
3. South-West, left turn at #4 Johnson	91.9	98.4	7%	24.2	27.6	14%
4. West-North, left turn from #4 Johnson	122.4	91.2	-25%	30.1	9.6	-68%
5. North-East, left turn at #4 Johnson	107.1	100.8	-6%	9.2	12.6	37%
6. East-South, left turn from #4 Johnson	110.2	99.0	-10%	33.2	31.2	-6%

Exhibit O-14 Route Travel Time and Delay (seconds) - PM Peak, Golden

O.1.8. AVON

O.1.8.1. *Intersections Description*

The signalized Avon Road corridor developed by the research team is a four-lane, divided roadway south of I-70, with a speed limit of 30 miles per hour. Within the interchange, there are three lanes (including a left-turn lane) and the

roadway transitions to the two-lane section north of the interchange. Signals are actuated-coordinated and operate at a 90-second cycle at all times of the day. The research team selected this cycle length based upon their experience with past retiming of actual signalized corridors.

Intersection #1, at the I-70 westbound off-ramp and Nottingham Road, has a 100-foot left-turn storage lane and an optional lane for left/through/right-turn movements on the westbound approach. The westbound side street operates with split-phase signal timing. The southbound leg (Nottingham Road) has two through lanes, and a channelized right-turn lane. The northbound leg (Avon Road) has one through lane and one 200-foot left-turn storage lane on Avon Road, with protected-permissive phasing.

Intersection #2, at the I-70 eastbound off-ramp and Avon Road, has an optional left/through lane with permissive phasing and a channelized right-turn lane on the eastbound approach. The southbound approach has one left-turn lane on Avon Road with protected-permissive phasing. The northbound approach has a through-only lane and a channelized right-turn lane.

Intersection #3, at Beaver Creek Road, has eastbound and westbound left-turn lanes with protected-permissive phasing, and it also provides a right-turn lane for both directions. Northbound and southbound approaches on Avon Road have a left-turn lane with protected-permissive phasing, a through-only lane, and a shared through/right lane.

Intersection #4, at Benchmark Road, has a left turn lane with protected-permissive phasing on both the northbound and southbound approaches. The two approaches on Avon Road also have a through-only lane and a shared through/right lane. The side streets operate in split-phase signal timing mode. The eastbound and westbound approaches have a left turn lane and a shared through/right lane.

Intersection #5, at US 6 at the south end of the corridor, has a left-turn lane with protected-permissive phasing on both the northbound and southbound approaches. The two approaches on Avon Road also have a through-only lane and a shared through/right lane. The eastbound approach has a through/right lane and a left-turn lane, with protected-permissive phasing. The westbound approach has a dedicated lane for each movement (i.e., left, through, and right turn). The westbound left turn operates with protected-permissive phasing.

O.1.8.2. *Intersection Approach Delay*

As shown in Exhibit O-15, the roundabouts present along the Avon corridor produce travel savings when compared with operations under coordinated arterial signalized control. The average approach delay savings from roundabout control per intersection along Avon Road is 6 to 7 seconds when compared to Synchro or SimTraffic, respectively. The average approach delay savings percentage per intersection along Avon Road is 53 to 61 percent when compared to Synchro or SimTraffic, respectively.

Approach	Signalized Corridor		Roundabout Corridor	Comparison			
	Synchro	SimTraffic	Field Data	Roundabout vs. Synchro	Roundabout vs. Synchro (%)	Roundabout vs. SimTraffic	Roundabout vs. SimTraffic (%)
I-70 WB Ramp SB	15.4	14.2	2.5	-12.9	-83.8%	-11.7	-82.4%
I-70 WB Ramp NB	6.6	11.0	1.8	-4.8	-72.7%	-9.2	-83.6%
I-70 EB Ramp SB	3.4	4.6	1.1	-2.3	-67.6%	-3.5	-76.1%
I-70 EB Ramp NB	5.6	4.9	2.6	-3.0	-53.6%	-2.3	-46.9%
Beaver Creek SB	8.8	13.5	5.8	-3.0	-34.1%	-7.7	-57.0%
Beaver Creek NB	11.1	14.4	9.4	-1.7	-15.3%	-5.0	-34.7%
Benchmark SB	10.4	11.0	4.2	-6.2	-59.6%	-6.8	-61.8%
Benchmark NB	12.8	13.4	7.7	-5.1	-39.8%	-5.7	-42.5%
US 6 SB	9.1	13.4	6.4	-2.7	-29.7%	-7.0	-52.2%
US 6 NB	24.0	18.7	5.9	-18.1	-75.4%	-12.8	-68.4%

Exhibit O-15 Approach Average Delay per Vehicle (seconds/vehicle) - PM Peak, Avon

O.1.8.3. *Corridor Travel Time*

Exhibit O-16's comparison values affirm the trends observed in the intersection-based findings from Exhibit O-15; namely, arterial performance is improved for Avon Road with roundabouts. Arterial through travel times improved by 10 to 15 percent, depending on direction, and arterial delays improved an average of 21 percent. The left-turn routes turning off Avon onto cross streets demonstrated an average of 28 percent less travel time and delay times that are, on average, 48 percent less than would be found with signalized arterial control. The left-turn routes turning onto Avon from cross streets demonstrated an average of 29 percent less travel time and delay times that are, on average, 48 percent less than would be found with signalized arterial control.

Exhibit O-16 Route Travel Time and Delay (seconds) - PM Peak, Avon

Route	Travel Time			Delay Time		
	Signalized (SimTraffic)	Roundabout (Field)	Comparison	Signalized (SimTraffic)	Roundabout (Field)	Comparison
1. South-North	133.8	120.6	-10%	64.1	55.2	-14%
2. North-South	125.9	107.4	-15%	56.3	40.8	-28%
3. South-West, left turn at #3 Beaver Creek	104.0	68.4	-34%	55.5	20.4	-63%
4. West-North, left turn from #3 Beaver Creek	99.4	72.0	-28%	63.9	32.4	-49%
5. North-East, left turn at #4 Benchmark	100.5	79.2	-21%	53.2	35.4	-33%
6. East-South, left turn from #4 Benchmark	88.3	62.4	-29%	48.9	25.8	-47%

O.1.9. SR 67

O.1.9.1. *Description of Intersections*

SR 67 (Dunning Street) in Malta, New York, is an arterial roundabout corridor connecting Interstate 87 with surrounding corporate, retail, and residential land uses. The signalized version of the SR 67 corridor developed by the research team has seven intersections, the westernmost six of which are coordinated. The six actuated-coordinated signals operate at a 90-second cycle during the p.m. peak conditions analyzed, while the remaining (and easternmost) signal operates in a "free," fully-actuated mode. The research team selected the cycle length for the coordinated intersections based upon their experience with past retiming of actual signalized corridors.

Intersection #1 is the westernmost intersection, found at SR 67's junction with State Farm Boulevard. This is a T-intersection, with two primary travel lanes in each direction along SR 67. The eastbound approach has a through lane and a shared through/right lane, while the westbound approach has a 150-foot left-turn bay and two through lanes. The northbound approach on State Farm has two lanes: one for left turns and one for right turns. The left turn from SR 67 operates in protected/permissive mode.

Intersections #2 and #3 represent the southbound and northbound ramp junctions of Interstate 87 with SR 67, respectively. Both the southbound (#2) and northbound (#3) ramps have three lanes, including a left-turn lane, a share left/through lane, and a right-turn lane. On the west side of the interchange, SR 67 has a 150-foot left-turn bay and two through lanes in the westbound direction, and two through lanes and a 150-foot right-turn bay in the eastbound direction. On the east side of the interchange, SR 67 has a 100-foot right-turn bay and two through lanes in the westbound direction and a 150-foot left-turn bay and two through lanes in the eastbound direction.

Intersection #4 is the junction of Blacksmith Drive/Kelch Drive with SR 67, just east of Interstate 87. Both approaches along SR 67 have a left-turn bay, a through lane, and a shared through/right lane. Northbound Blacksmith has a left-turn lane and a shared through/right lane, while southbound Kelch has a signal lane serving all movements. All left turn movements at this intersection operate in permissive mode.

Intersection #5 is the junction of US 9, a four-lane facility, and SR 67. West of US 9, SR 67 has two lanes in each direction, but to the east SR 67 reduces to one lane in each direction. At the intersection, SR 67 has a 300-foot left-turn bay, a through lane and a shared through/right lane in the eastbound direction and a 150-foot left-turn bay, a through lane, and a 500-foot shared through/right-turn lane in the westbound direction. Both US 9 approaches have a 150-foot left-turn bay, a through lane, and a shared through/right lane. All left turn movements at this intersection operate in protected/permissive mode.

Transitioning into a more-rural residential area, Intersection #6 has a 150-foot left-turn bay on each SR 67 approach and a single through/right lane in each direction. The cross street, Partridge Drum, has a single lane in each direction serving all movements on each approach. All left turn movements at this intersection operate in permissive mode.

Intersection #7 is the easternmost intersection and has SR 67 terminating at a "Y" intersection into Plains Road and Hermes Road. SR 67 has a single approach lane in the eastbound direction. Plains Road has a 100-foot left-turn lane and a through lane on the southwest-bound approach. Hermes Road has a left-turn lane and a 150-foot right-turn bay along the northwest-bound approach. The two left turns at the intersection operate in permissive mode.

O.1.9.2. *Intersection Approach Delay*

Substantial savings in intersection approach delay are observed in Exhibit O-17 for most intersection approaches under roundabout operation compared with signalized operation for the SR 67 corridor. The average approach delay savings per intersection along SR 67 is 5 to 7 seconds, or 30 to 50 percent, compared to Synchro or SimTraffic, respectively.

Exhibit O-17 Approach Average Delay per Vehicle (seconds/vehicle) - PM Peak, SR 67

Approach	Signalized Corridor		Roundabout Corridor	Comparison			
	Synchro	SimTraffic	Field Data	Roundabout vs. Synchro	Roundabout vs. Synchro (%)	Roundabout vs. SimTraffic	Roundabout vs. SimTraffic (%)
State Farm WB	1.1	3.8	2.7	1.6	145.5%	-1.1	-28.9%
State Farm EB	7.6	4.5	1.4	-6.2	-81.6%	-3.1	-68.9%
I-87 SB WB	12.9	17.6	0.0	-12.9	-100.0%	-17.6	-100.0%
I-87 SB EB	10.5	13.7	2.5	-8.0	-76.2%	-11.2	-81.8%
I-87 NB WB	19.2	16.5	5.0	-14.2	-74.0%	-11.5	-69.7%
I-87 NB EB	7.3	13.5	0.8	-6.5	-89.0%	-12.7	-94.1%
Kelch Dr WB	7.5	7.9	2.2	-5.3	-70.7%	-5.7	-72.2%
Kelch Dr EB	4.5	7.4	2.9	-1.6	-35.6%	-4.5	-60.8%
US 9 WB	17.8	25.9	15.2	-2.6	-14.6%	-10.7	-41.3%
US 9 EB	24.8	24.3	18.1	-6.7	-27.0%	-6.2	-25.5%
Partridge Drum / Fox Wander WB	6.6	9.1	5.6	-1.0	-15.2%	-3.5	-38.5%
Partridge Drum / Fox Wander EB	4.5	12.6	5.5	1.0	22.2%	-7.1	-56.3%
Plains / Hermes WB	6.7	5.5	11.3	4.6	68.7%	5.8	105.5%
Plains / Hermes EB	8.9	9.2	3.0	-5.9	-66.3%	-6.2	-67.4%

O.1.9.3. *Corridor Travel Time*

Exhibit O-18's values compare travel and delay times for arterial through travel and for routes that include left turns onto and off the arterial. Arterial through travel times for the roundabout control scenario were 2 percent higher than with signalized control, but delay times were reduced by 27 percent. For left-turning routes turning off SR 67 towards cross streets, travel times were roughly reduced 7 percent and delay times were reduced by 50 percent. For left-turning routes turning onto SR 67 from cross streets, travel times were 19 percent less than would be found with signalized arterial control; and delay times were reduced by 56 percent.

Exhibit O-18 Route Travel Time and Delay (seconds) - PM Peak, SR 67

Route	Travel Time			Delay Time		
	Signalized (SimTraffic)	Roundabout (Field)	Comparison	Signalized (SimTraffic)	Roundabout (Field)	Comparison
1. West-East	246.1	233.4	-5%	85.2	50.0	-41%
2. East-West	234.7	253.2	8%	79.4	69.6	-12%
3. East-South, left turn at #5 US 9	121.6	138.6	14%	40.7	22.8	-44%
4. South-West, left turn from #5 US 9	189.2	153.0	-19%	81.4	51.0	-37%
5. West-North, left turn at #5 US 9	175.9	127.8	-27%	75.1	33.6	-55%
6. North-East, left turn from #5 US 9	151.1	124.2	-18%	72.1	18.0	-75%

O.2. CONCLUSIONS

The nine corridors studied in this project have a wide variety of traffic volumes, functional classification, surrounding road networks, and surrounding land uses. From this diverse set of corridors, the research team observed the following:

- Approach delay on the arterial (major street) was compared on seven of the nine corridors. On six of these seven corridors, the average approach delay for all intersections in both directions was less with roundabouts than with signals. The degree of this savings varies greatly. The exception was the SR 539 corridor, where two of the four non-roundabout intersections were modeled as TWSC. This corridor also had the highest mid-block speed of all the corridors studied and thus a relatively high geometric delay with roundabouts.
- Through-route travel time and delay (average of both directions):
    - Increased on four corridors with roundabouts in comparison to signals—La Jolla, Old Meridian, Borgen, and Golden.
    - Decreased on four corridors with roundabouts in comparison to signals—MD 216, Spring Mill, Avon, and SR 67.
    - Travel time remained virtually unchanged on SR 539, and delay increased with roundabouts in comparison to signals.
    - All through-route comparisons previously listed in multiple tables are presented in Exhibit O-19. They are sorted by percent travel time difference.

Exhibit O-19 Through Route Travel Time and Delay, All Corridors

Corridor	Route	Travel Time			Delay Time		
		Equivalent Signalized Corridor (s)	Field-Measured Roundabout Corridor (s)	Difference	Equivalent Signalized Corridor (s)	Field-Measured Roundabout Corridor (s)	Difference
La Jolla Boulevard	1. South-North	110.2	162.0	+47%	21.4	24.0	+12%
La Jolla Boulevard	2. North-South	110.7	162.0	+46%	21.8	24.0	+10%
Old Meridian (AM)	1. South-North	170.7	180.6	+6%	52.4	63.0	+20%
Old Meridian (PM)	2. North-South	142.7	175.8	+23%	28.0	51.6	+84%
Spring Mill (AM)	1. South-North	492.6	497.4	+1%	108.5	106.8	−2%
Borgen Boulevard	1. East-West	177.4	198.6	+12%	69.7	69.0	−1%
Borgen Boulevard	2. West-East	158.7	194.4	+22%	63.6	66.6	+5%
Golden Road	1. South-North	161.7	163.2	+1%	19.9	28.2	+42%
Golden Road	2. North-South	161.1	167.4	+4%	22.5	30.0	+33%
SR 67	2. East-West	234.7	253.2	+8%	79.4	69.6	−12%
SR 539	1. South-North	327.9	327.0	0%	30.2	74.4	+146%
SR 539	2. North-South	321.8	322.8	0%	23.4	63.6	+172%
Old Meridian (AM)	2. North-South	164.4	162.6	−1%	37.3	38.4	+3%
Old Meridian (PM)	1. South-North	202.5	192.0	−5%	75.3	74.4	−1%
SR 67	1. West-East	246.1	233.4	−5%	85.2	50.0	−41%
Spring Mill (PM)	1. South-North	602.4	556.8	−8%	203	166.2	−18%
Avon Road	1. South-North	133.8	120.6	−10%	64.1	55.2	−14%
Spring Mill (PM)	2. North-South	558.4	490.2	−12%	154.8	91.8	−41%
Avon Road	2. North-South	125.9	107.4	−15%	56.3	40.8	−28%
MD 216	1. West-to-East	186.5	156.0	−16%	81.8	42.0	−49%
MD 216	2. East-to-West	189.8	144.0	−24%	86.1	30.0	−65%
Spring Mill (AM)	2. North-South	707.9	538.2	−24%	304.9	139.8	−54%

- Travel time and delay for routes with a left turn offthe arterial (average of both routes):
    - Travel time increased on La Jolla with roundabouts in comparison to signals, although delay decreased.

- Travel time decreased on six corridors with roundabouts in comparison to signals: MD 216, Old Meridian, Spring Mill, SR 539, Avon, and SR 67. Delay also decreased on all of these corridors except Old Meridian and SR 539.
- Travel time remained virtually unchanged on Borgen and Golden. Delay decreased with roundabouts on Borgen and increased with roundabouts on Golden.
- All comparisons for these routes previously listed in multiple tables are presented in Exhibit O-20. They are sorted by percent travel time difference.

Exhibit O-20 Left Turn Off Arterial Route Travel Time and Delay, All Corridors

Corridor	Route	Travel Time			Delay Time		
		Signalized (SimTraffic)	Roundabout (Field)	Comparison	Signalized (SimTraffic)	Roundabout (Field)	Compar-ison
La Jolla	3. East-South, left turn from #1 Colima	41.4	54	30%	11.8	6	-49%
SR 67	3. East-South, left turn at #5 US 9	121.6	138.6	14%	40.7	22.8	-44%
Golden	3. South-West, left turn at #4 Johnson	91.9	98.4	7%	24.2	27.6	14%
Borgen	5. West-North, left turn at #3 51st	95.4	101.4	6%	49.3	47.4	-4%
Old Meridian – PM	3. South-West, left turn at #3 Main	153.7	156	1%	51.1	63.6	24%
Old Meridian – AM	3. South-West, left turn at #3 Main	139.5	138	-1%	40	45.6	14%
SR 539	5. North-East, left turn at #3 Wiser Lake	122.5	121.2	-1%	11.1	25.8	132%
Borgen	3. East-South, left turn at #3 51st	134.1	127.2	-5%	45.3	41.4	-9%
Golden	5. North-East, left turn at #4 Johnson	107.1	100.8	-6%	9.2	12.6	37%
La Jolla	5. West-North, left turn from #4 Bird Rock	75	70	-7%	29.5	6	-80%
SR 539	3. South-West, left turn at #2 Pole	153.6	142.8	-7%	12.7	32.4	155%
Spring Mill – PM	3. South-West, left turn at #6 136th	558.6	508.8	-9%	191.7	152.4	-21%
Old Meridian – PM	5. North-East, left turn at #2 Grand	111.6	100.2	-10%	21.6	17.4	-19%
Spring Mill – AM	3. South-West, left turn at #6 136th	484.6	435	-10%	139.6	78.6	-44%
Old Meridian – AM	5. North-East, left turn at #2 Grand	117.2	100.8	-14%	20	18	-10%
Avon	5. North-East, left turn at #4 Benchmark	100.5	79.2	-21%	53.2	35.4	-33%
Spring Mill - PM	5. North-East, left turn at #5 131st	193.5	145.2	-25%	88.7	39.6	-55%
SR 67	5. West-North, left turn at #5 US 9	175.9	127.8	-27%	75.1	33.6	-55%
Avon	3. South-West, left turn at #3 Beaver Creek	104	68.4	-34%	55.5	20.4	-63%
MD 216	5. West-North, left turn at #2 Maple Lawn	77.5	48	-38%	38.2	12	-69%
Spring Mill - AM	5. North-East, left turn at #5 131st	295.1	166.8	-43%	189.1	61.2	-68%
MD 216	3. East-South, left turn at #4 NB US-29	103.7	48	-54%	72.3	12	-83%

- Travel time and delay for routes with a left turn onto the arterial (average of both routes):
    - Travel time increased on two corridors with roundabouts in comparison to signals: La Jolla and Borgen. Delay increased on Borgen and decreased on La Jolla.
    - Travel time and delay decreased on seven corridors with roundabouts in comparison to signals: MD 216, Old Meridian, Spring Mill, SR 539, Golden, Avon, and SR 67.
    - All comparisons for these routes previously listed in multiple tables are presented in Exhibit O-21. They are sorted by percent travel time difference.

Exhibit O-21 Left Turn Onto Arterial Route Travel Time and Delay, All Corridors

Corridor	Route	Travel Time			Delay Time		
		Signalized (SimTraffic)	Roundabout (Field)	Comparison	Signalized (SimTraffic)	Roundabout (Field)	Compar-ison
La Jolla	6. North-East, left turn at #1 Colima	106.7	192	80%	24.7	36	46%
La Jolla	4. South-West, left turn at #4 Bird Rock	88.9	126	42%	32.8	6	-82%
Borgen	4. South-West, left turn from #3 51st	92.1	121.2	32%	55.3	67.8	23%
Borgen	6. North-East, left turn from #3 51st	109.1	136.2	25%	48.9	51.6	6%
Old Meridian – PM	6. East-South, left turn from #2 Grand	97.8	105	7%	50.5	47.4	-6%
Golden	6. East-South, left turn from #4 Johnson	110.2	99	-10%	33.2	31.2	-6%
SR 539	4. West-North, left turn from #2 Pole	245.8	207	-16%	54.6	52.2	-4%
SR 539	6. East-South, left turn from #3 Wiser Laker	273.7	228	-17%	66.7	46.8	-30%
SR 67	6. North-East, left turn from #5 US 9	151.1	124.2	-18%	72.1	18	-75%
SR 67	4. South-West, left turn from #5 US 9	189.2	153	-19%	81.4	51	-37%
Spring Mill - AM	6. East-South, left turn from #5 131st	490.8	394.2	-20%	174.8	73.2	-58%
Old Meridian – AM	6. East-South, left turn from #2 Grand	119.5	94.8	-21%	56	37.2	-34%
Golden	4. West-North, left turn from #4 Johnson	122.4	91.2	-25%	30.1	9.6	-68%
MD 216	6. North-East, left turn from #2 Maple Lawn	188.2	138	-27%	103.8	42	-60%
Avon	4. West-North, left turn from #3 Beaver Creek	99.4	72	-28%	63.9	32.4	-49%
Avon	6. East-South, left turn from #4 Benchmark	88.3	62.4	-29%	48.9	25.8	-47%
Old Meridian – AM	4. West-North, left turn from #3 Main	92.6	64.8	-30%	52.6	17.4	-67%
Spring Mill - PM	6. East-South, left turn from #5 131st	577.6	390	-32%	248.4	69	-72%
Old Meridian – PM	4. West-North, left turn from #3 Main	104	68.4	-34%	52.6	21	-60%
Spring Mill – AM	4. West-North, left turn from #6 136th	135.5	90	-34%	77.4	32.4	-58%
MD 216	4. South-West, left turn from #4 NB US-29	191.4	114	-40%	101.2	24	-76%
Spring Mill – PM	4. West-North, left turn from #6 136th	139.1	81	-42%	76.9	23.4	-70%

In general, roundabout corridors appear to offer a greater reduction in travel time for routes involving a left turn than for through routes. Signals are often timed to favor major street through movements, so drivers experience delay while waiting to turn left onto an arterial or off an arterial if the turn has a protected phase or there are opposing through vehicles. Furthermore, for routes with a left turn onto the corridor, vehicles may be out of the green band once they are on the arterial and experience less than optimal progression.

La Jolla is the most urban of the nine corridors and has the second shortest average spacing between roundabouts (715'). SR 539 is the most rural of all the nine corridors and has the longest average spacing between roundabouts (6465'). On both of these corridors, the research team modeled some roundabouts as TWSC because site streets did not meet MUTCD signal warrants. In some ways, these two corridors represent the extremes nine corridors.

On La Jolla, travel time increased with roundabouts on five of the six routes and delay increased on three of six routes. On SR 539, travel time remained virtually the same on the two through routes and decreased on the four left turn routes. Delay decreased on the two routes with left turns onto the corridor and increased on the other four routes. On La Jolla, over half of the length of the through routes lies within the roundabout influence area, or the area upstream and downstream of the roundabout where speeds on an unimpeded run are lower than free-flow speed. On SR 539, a quarter of the length of the through routes lies within the roundabout influence area. On La Jolla, the differential between (mid-block) free-flow speed and speed through the roundabout is about 15 mph. On SR 539, this differential is about 40 mph.