DRAFT

I-95 Northbound at US 1 (Exit 126) Design and Study

Final Report

July 2018

Prepared by: Kimley»Horn

Prepared for: STARS VDOT

Table of Contents

1 INTRODUCTION

The region's only interstate, I-95, experiences heavy traffic flows during weekday mornings and afternoons. Currently, I-95 carries more than 115,000 vehicles per day (total in both directions) between Exit 130 (Route 3) and Exit 126 (US 1). The purpose of this study is to identify a proposed improvement at the US 1 and I-95 interchange that will mitigate existing congestion and safety issues on US 1 and I-95. The alternatives evaluation will consider improvements to both northbound US 1 and northbound I-95 at Exit 126.

The goals of the STARS (Strategically Targeted and Affordable Roadway Solutions) Program are to develop comprehensive, innovative transportation improvements to relieve congestion bottlenecks and create projects that improve critical traffic and safety challenges to be programmed in the VDOT Six-Year Improvement Program. The purpose of this project is to relieve existing and future traffic congestion in the study area, and improve safety. This report documents the existing and future conditions, the alternatives analyzed, and the preferred alternative, the planning level cost estimate, and preliminary conceptual design.

This project was conducted in two phases: 1) design concept development to specifically determine if a second northbound US 1 left-turn lane could be constructed under the I-95 bridge at the northbound I-95 signalized intersection, and 2) traffic analysis to document the future year no-build and build results within the study area, primarily focusing on the US 1 at I-95 ramp signalized intersection.

1.1 Study Area Limits

The study area for this project is shown in **Figure 1**. The study area consists of the following corridors and intersections.

Corridors

- Northbound I-95 between northbound US 1 ramp and Route 208 bridge consisting of two off-ramps and one on-ramp at Exit 126
- Northbound US 1 between Southpoint Parkway and the northbound I-95 intersections, which includes the following intersections

Intersections on US 1

Analyzed for improvements

- Southbound I-95 Ramps (Signalized)
- Northbound I-95 Ramps (Signalized)
- Market Street (Signalized)

Not analyzed for improvements

- Southpoint Parkway (Signalized)
- US 1 at commercial entrance [KFD/Exxon] (Signalized)

1.2 Purpose and Need of the Study

The purpose of this study is to identify proposed improvements at the US 1 and I-95 interchange (Exit 126) that will help to mitigate existing congestion and safety issues on both northbound US 1 and northbound I-95, especially during the morning peak hour. Improvement alternatives must be able to reduce the northbound queue length on northbound US 1 and improve the merging operations on northbound I-95. Ultimately, the purpose is to positively impact these two Corridors of Statewide Significance (CoSS).

Figure 1: Corridor Study Area

1.3 Safety Analysis

Kimley-Horn reviewed and analyzed crash data, from the VDOT crash database, to evaluate traffic safety within the study area and identify crash patterns. VDOT Roadway Network System (RNS) crash data was obtained for the latest available five years of crash data (January 1, 2012 to December 31, 2016). The following sections provide a summary of the crashes that occurred within the project study area during the five-year crash analysis period.

1.3.1 Summary of I-95 Northbound Crashes

Crashes on northbound I-95 from 1 mile south of the beginning of the off-ramp taper to northbound US 1 to 1-mile north of the end of on-ramp taper from US 1 were analyzed as part of this study. Over the 5-year crash analysis period, 231 crashes occurred in this area. Of the reported crashes there was one fatal crash, 70 injury crashes, and 160 property damage only (PDO) crashes. The one fatal crash occurred near the off-ramp to southbound US 1. The crash occurred in 2016 and was classified sideswipe – same direction crash. The crash was a result of an unsafe lane change from the center lane into the right lane causing the vehicle and two others to lose control. The fatal injury occurred to one of the drivers of the other vehicles. The driver at fault was determined to no be distracted, under the influence of alcohol, or exceeding the speed limit at the time of the crash. In total, it was found that the number of crashes year over year is also growing, with crashes showing a steady increase from 33 total crashes in 2012 to 57 crashes in 2016. A yearly summary of crashes by crash severity is shown in **Table 1**. Crash severity is coded using the KABCO scale, which is defined using the following classifications:

- K – Fatal Injury
- A – Suspected Serious Injury
- B – Suspected Minor Injury
- C – Possible Injury
- PDO – Property Damage Only

Table 1: Northbound I-95 Study Area Crashes

	Number of Crashes					
Year	K	A	B	C	PDO	Total
2012	0	2	5	0	26	33
2013	0	3	7	3	31	44
2014	0	5	9	0	34	48
2015	0	2	8	5	34	49
2016	1	6	11	4	35	57
Total	**1**	**18**	**40**	**12**	**160**	**231**

A summary of northbound I-95 crashes by collision type is included in **Figure 2**. The predominant crash type was rear end, which accounted for 58.9% of crashes. Rear-ends are typical crash types on congested facilities like I-95 within the study area. A crash density analysis was also performed and a summary is included in **Figure 3**. The high-density locations south of the Exit 126 interchange, near mile marker 125, were caused by clusters of congestion related rear end crashes. The other high-density crash area was the area near the on-ramp from US 1. A map of crashes classified by collision type for the merge area is included in **Figure 4**. This figure shows rear-end crashes occurring throughout the area. Specifically, 54% of crashes from the US 1 on-ramp to Route 208 overpass are rear ends and 65% of those rear ends occurred during heavy congestion. There were also angle and sideswipe – same direction crashes clustered in the area between the gore point and taper for the US 1 on-ramp.

1.3.2 Summary of US 1 Crashes

Crashes on US 1 in the study area, which includes the intersections of US 1 at the southbound I-95 ramps, at the northbound I-95 ramp, and at Market Street are summarized in **Table 2** by year and severity. The coding for crash severity is detailed in **Section 1.3.1**. Over the study period from 2012 to 2016, one fatal crash, 155 injury crashes, and 289 PDO crashes occurred. Altogether, 445 total crashes occurred and there was a steady frequency of close to 90 crashes per year. The one fatal crash was a pedestrian related incident. A pedestrian, under the influence of alcohol, attempted to cross northbound US 1 just south of the intersection at the northbound I-95 ramps and was struck by a vehicle. It was determined that the driver was not distracted or under the influence of alcohol. The crash occurred under clear weather conditions at 7:35 PM, the roadway was dark and not lighted.

Figure 2: Northbound I-95 Crashes (2012-2016) by Collision Type

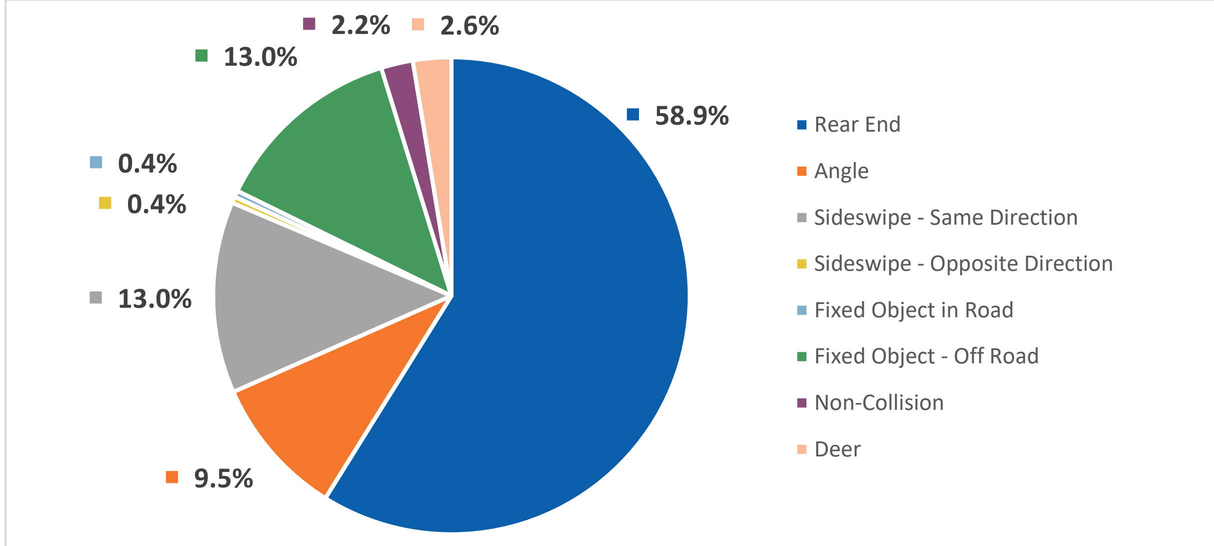


Table 2: US 1 Study Area Crashes

	Number of Crashes					
Year	K	A	B	C	PDO	Total
2012	0	7	9	13	50	79
2013	0	3	27	10	61	101
2014	0	7	21	4	59	91
2015	0	3	17	7	60	87
2016	1	1	19	7	59	87
Total	**1**	**21**	**93**	**41**	**289**	**445**

Figure 3: Northbound I-95 Crash Density Map (2012-2016)

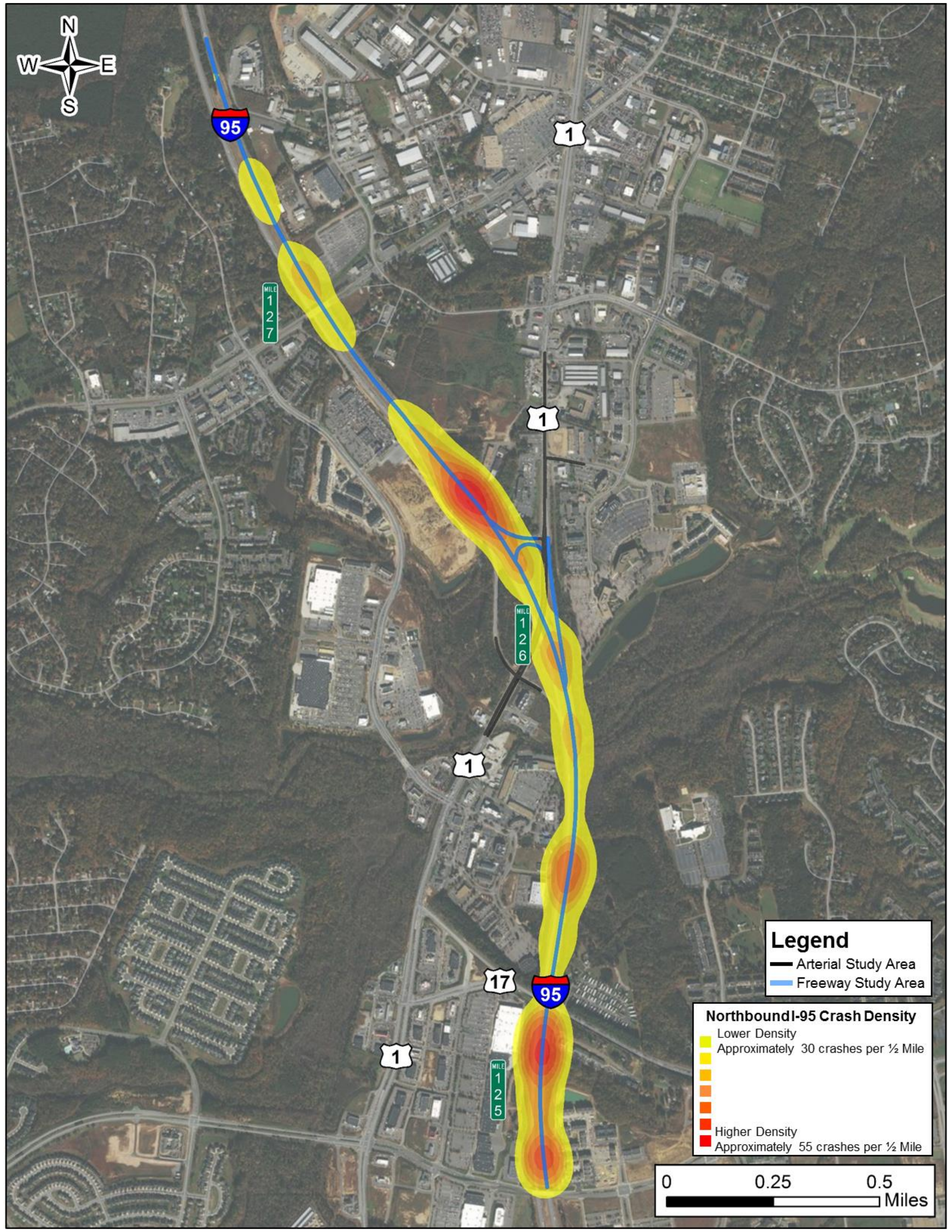


Figure 4: Northbound I-95 Exit 126 Merge Area Crash Map

Crash activity on US 1 was analyzed by intersection and a summary of crashes for the three study intersections by collision type is included in **Figure 5**. Crashes were assigned to intersections using intersection influence areas. Intersection influence areas typically comprise the functional area of the intersection, including turn lanes and tapers. Intersection influence areas were individually reviewed and extended as needed to include crashes related to the intersection that occurred outside of the functional area. The predominant collision type at all three intersections is rear end crashes at 56%, 47 %, and 55% for the southbound I-95 ramps, northbound I-95 ramps, and Market Street intersections, respectively, which can likely by attributed to the heavy congestion in the corridor. The intersection with the highest crash frequency was at the northbound I-95 ramps with 172 crashes in the 5-year study period. This intersection also had a higher proportion of angle crashes than the other two intersections at 44%.

A map of crashes at this intersection classified by collision type is included as **Figure 6**. This graphic shows a cluster of angle crashes where the northbound left turns, onto the northbound I-95 on-ramp, and southbound through movements conflict. The intersection operates with protected/permissive left-turn phasing. During the permissive portion of the traffic signal cycle vehicles are expected to look for gaps in traffic to make the northbound left turn and are not protected by a red light for southbound US 1 traffic. This permissive portion of the traffic signal cycle likely contributes to the high number of crashes between these two movements. There is also a cluster of crashes where the northbound I-95 off-ramp meets southbound US 1. This movement was changed from a merge to yield control somewhere in late 2015 or early 2016. After this change in traffic control and geometry, there was an increase in crashes in 2016 relating to this turning movement, from three or fewer before 2016 to six during 2016 as shown in **Table 3**. However, only two crashes relating to this movement occurred in 2017. To determine the safety impact of this change, more “after” data is required.

Table 3: Yearly Summary of Northbound I-95 to Southbound US 1 Crashes

Northbound I-95 to Southbound US 1 Crashes	
2012	3
2013	2
2014	1
2015	3
2016	6
2017	2
TOTAL	**17**

Figure 5: US 1 Intersection Crash Pie Charts by Collision Type

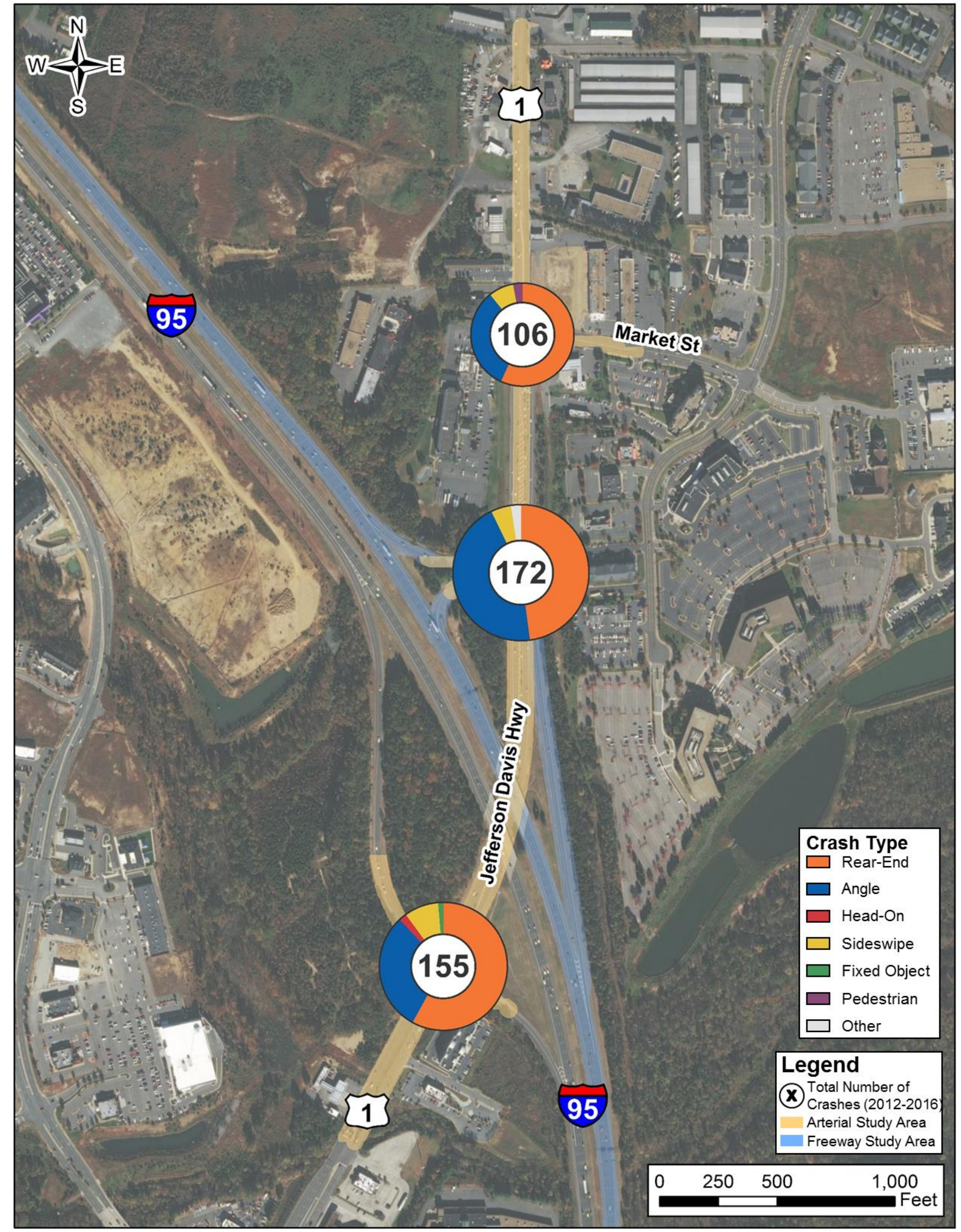
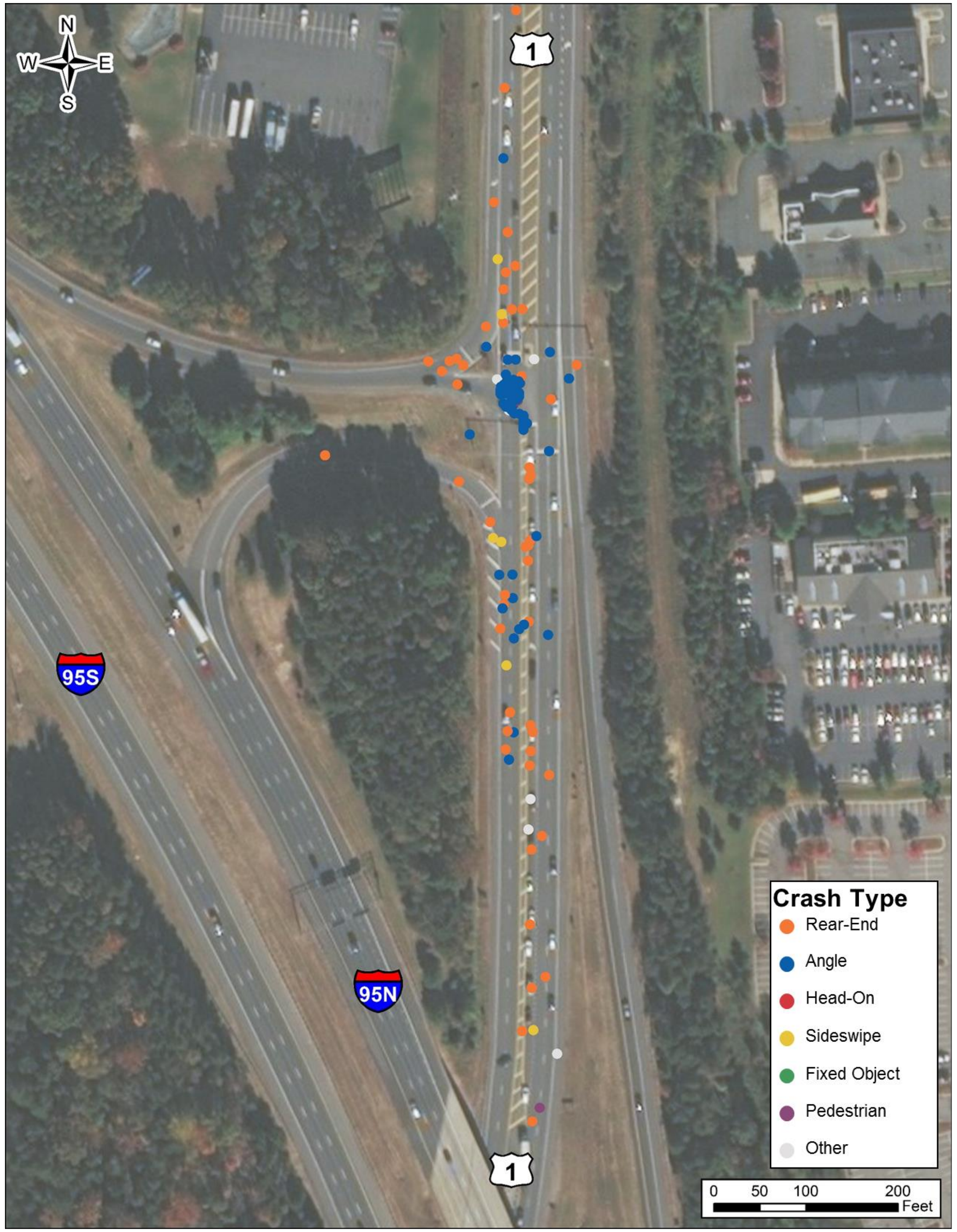


Figure 6: US 1 at Northbound I-95 Ramps Intersection Crash Map



2 Future Conditions

2.1 2040 No-Build Traffic Analyses

Once the study team determined that the proposed roadway improvements on US 1 were feasible, the no-build traffic analysis on US 1 and I-95 commenced.

Traffic operational analyses were conducted to evaluate the overall performance of the study corridor under AM and PM peak hour conditions in 2040. No weekend analysis was conducted for this project, especially since no weekend traffic counts were collected on US 1. However, traffic data on I-95 at Exit 126 were obtained from either the ongoing Fredericksburg Area MPO (FAMPO) I-95 Corridor Evaluation – Phase 2, conducted by Baker and ATCS in 2018 (heretofore referred to as the FAMPO Study) or the STARS I-95 Exit 126 Area Study, conducted by Kimley-Horn in 2015 (heretofore referred to as the Area Study). Traffic operations analysis were conducted on US 1 and I-95 using the calibrated CORSIM model developed for the Area Study. Inputs and analysis methodologies are consistent with the VDOT *Traffic Operations and Safety Analysis Manual (TOSAM).*

As the traffic analysis progressed, the scope of the traffic analysis was narrowed to focus on the key issues at the intersection of US 1 at I-95. The study team separated the traffic analysis into a screening analysis using HCS and Synchro and a more detailed analysis using CORSIM and Synchro. The Synchro and CORSIM files from the Area Study were used as the basis for this analysis.

- The interaction between traffic flow from the traffic signal onto the northbound I-95 entrance ramp was measured using methodologies from the *Highway Capacity Manual*, Version 6. The table showing the calculation of estimated maximum AM peak period traffic volumes that could be serviced by the traffic signal is provided in the Appendix.
- The Highway Capacity Software (HCS7) was used to evaluate the effectiveness of the entrance ramp merging operations and its corresponding density and speed. Since this ramp is projected to be over capacity in future conditions, the Highway Capacity Manual methodologies were not applicable to this condition. As a result, the study team used CORSIM to compare the no-build and build conditions on I-95.
- No existing conditions traffic analysis was conducted for this project. Instead, the future no-build conditions were compared to the build conditions to determine the effectiveness of the build alternatives.

2.1.1 Measures of Effectiveness

Due to the proximity of the signalized intersection to the interstate ramp at this location, the study team used a few measures of effectiveness to determine how the pieces of the network were operating.

Two measures of effectiveness were selected to document the quantitative performance of the US 1:

- Average vehicle delay by movement, approach, and intersection: measured in seconds per vehicle
- 95th percentile queue length: measured in feet

Three measures of effectiveness were selected to document the quantitative performance of the northbound I-95:

- Throughput: measured in vehicles per hour
- Speed: measured in miles per hour
- Density: measured in vehicles per mile per lane

The traffic operations at this interchange are complex, especially in the northbound US 1 to northbound I-95 movement in the morning peak hour. Improvements that reduce the queue length on northbound US 1 may not include adequate capacity to improve the northbound I-95 operations. In addition, it is important to find a balance of benefits to improve safety in the study area.

Because of these challenges, the study team used multiple traffic analysis tools to evaluate the effectiveness of the recommended improvements:

- Traffic signal analysis – Synchro and CORSIM
- Entrance ramp analysis – HCS and CORSIM

2.1.2 No-Build Geometry and Traffic Volumes

Since traffic analyses near this project were conducted using 2040 or 2045 as the future analysis years, it was determined that this study would be conducted using 2040 traffic volume to determine if the design concepts could accommodate anticipated growth. The future no-build turning movement traffic volumes and geometry on US 1 were obtained from the Area Study as shown in **Figure 7**; whereas traffic counts on I-95 were derived from the I-95 Corridor Study – Phase 2 as shown in **Figure 8** and **Figure 9**. The no-build condition on I-95 includes all funded SMART SCALE projects from Rounds 1 and 2, the Express Lanes Fredericksburg Extension to Exit 133 (US 17) project, and the Rappahannock River Crossing project.

Figure 7: No-Build Geometry and Traffic Volumes

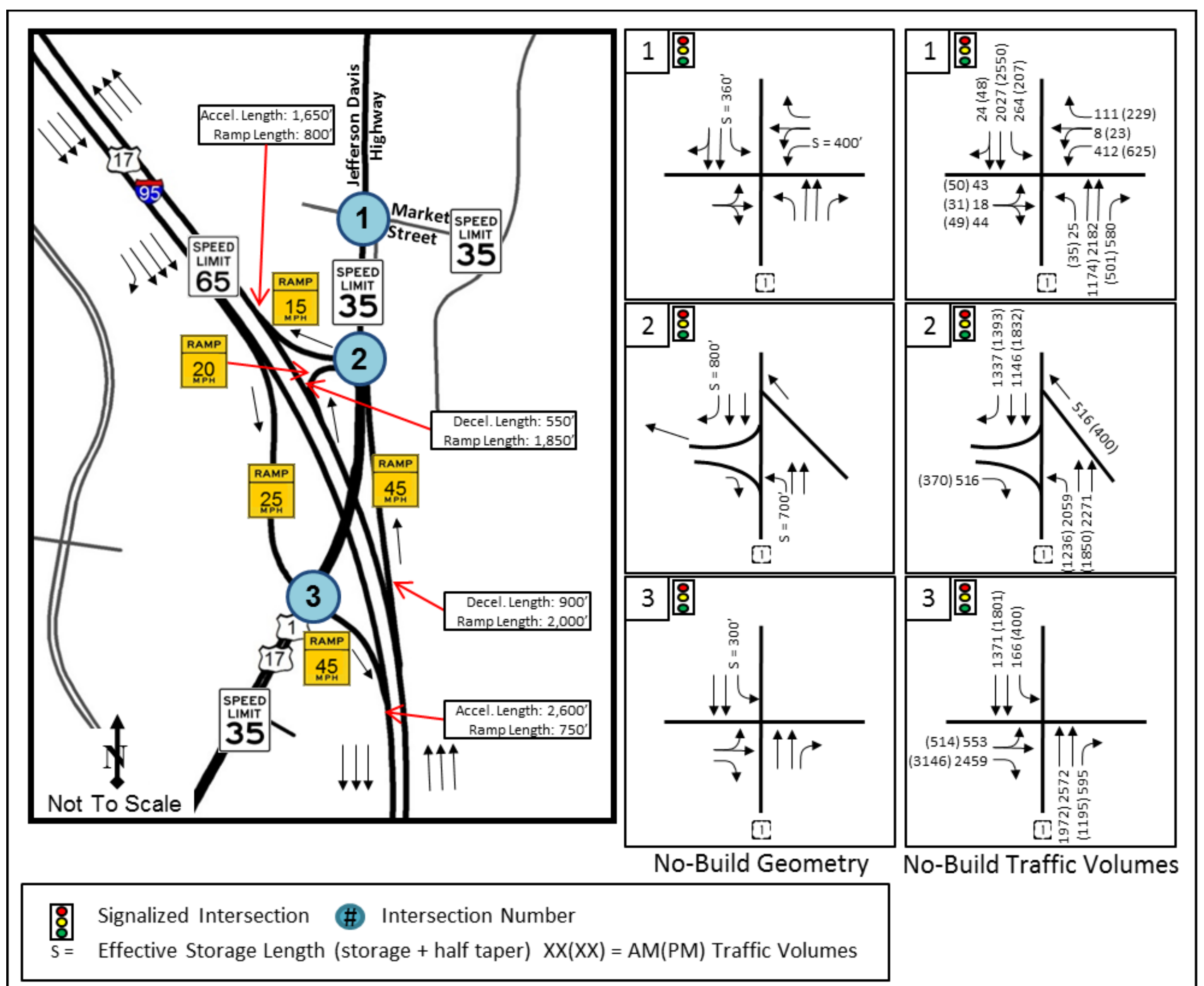
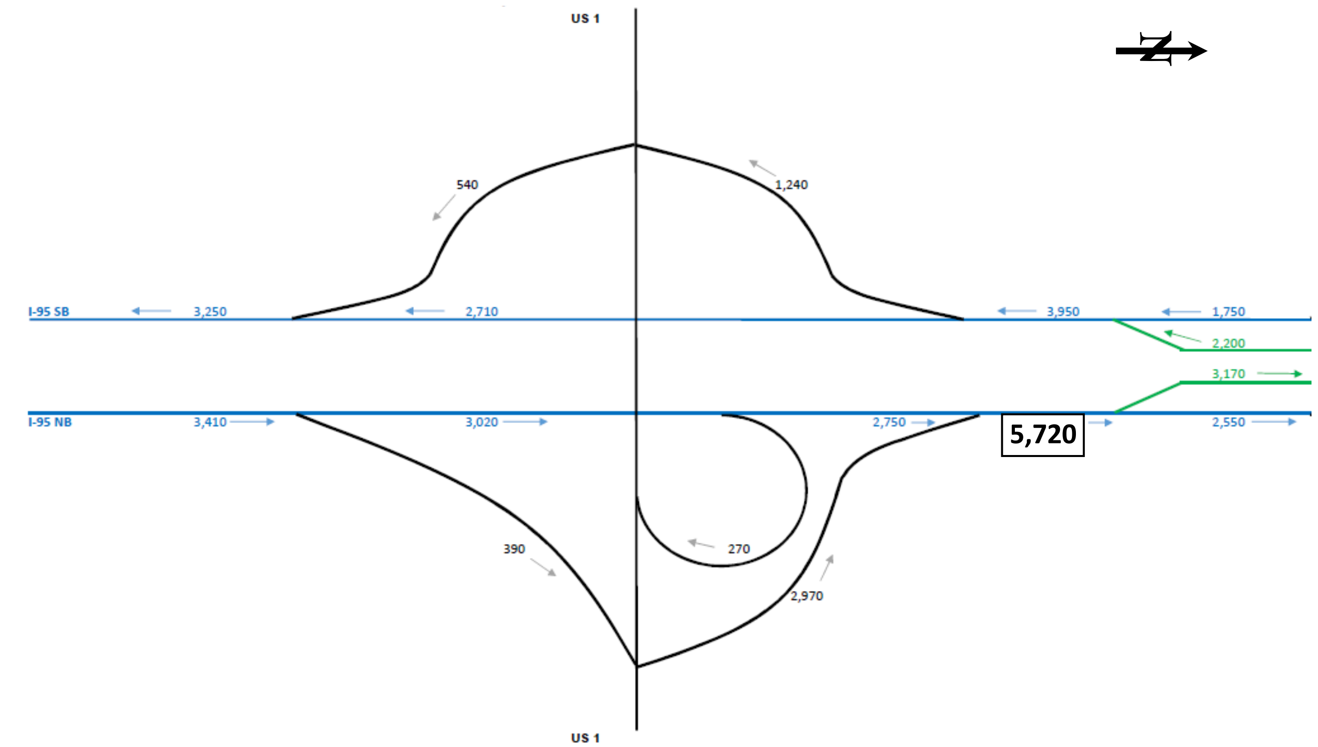
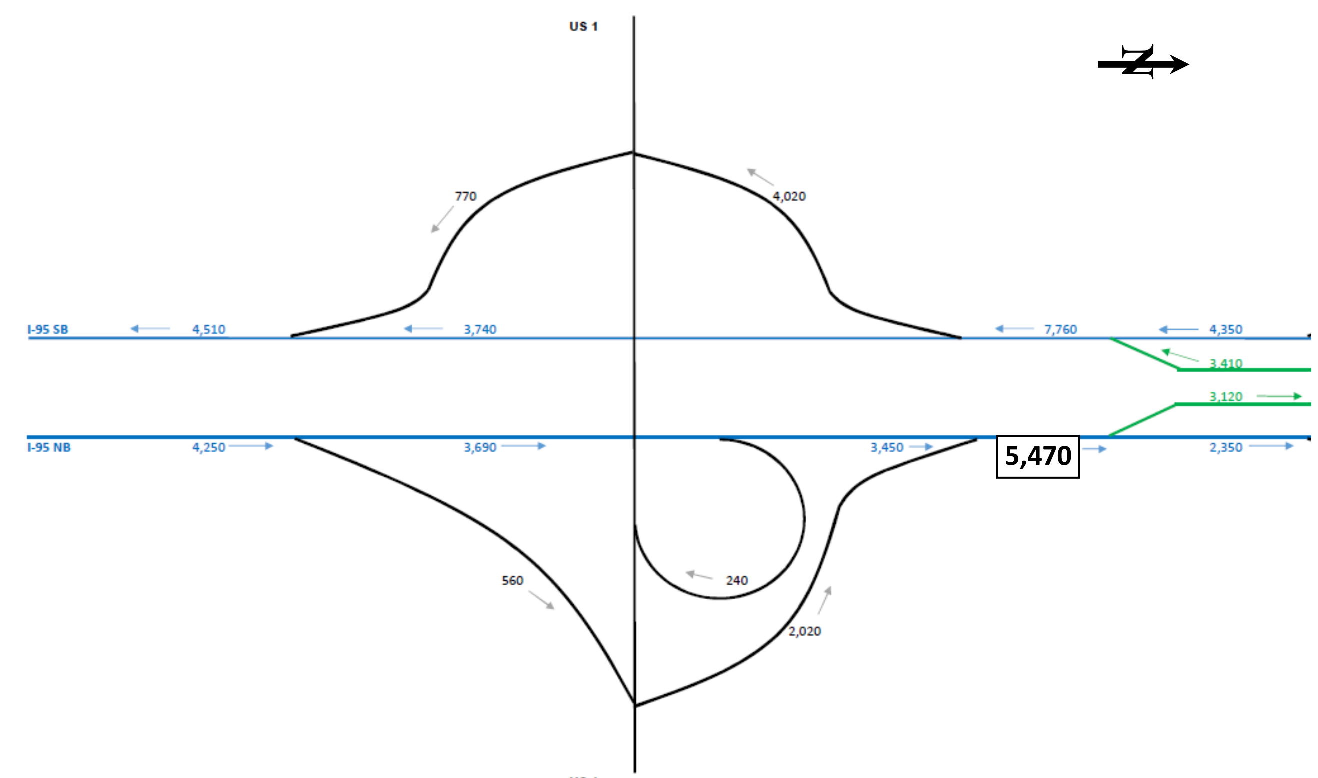


Figure 8. 2045 No-Build I-95 Traffic Forecast – AM Peak Hour



Source: From FAMPO_Model_3.1_20170623

Figure 9. 2045 No-Build I-95 Traffic Forecast – PM Peak Hour



2.1.3 Synchro Analysis

The study team used Synchro to evaluate the No-Build conditions at the signalized intersections in the corridor. Synchro was used to evaluate the delay and queue lengths for the study intersections.

2.1.3.1 Delay and Level of Service

The Transportation Research Board's (TRB) *Highway Capacity Manual* (HCM) methodologies govern the methodology for evaluating capacity and the quality of service provided to road users traveling through a roadway network. There are six letter grades of Level of Service (LOS), ranging from A to F. LOS A indicates a condition of little or no congestion whereas LOS F indicates a condition of severe congestion, unstable traffic flow, and stop-and-go conditions. Intersection LOS is defined in terms of control delay. **Table 4** summarizes the delay associated with each LOS category for signalized and unsignalized intersections, respectively. If intersection traffic volume exceeds capacity, a LOS F is automatically reported.

Table 5 summarizes the 2040 No-Build delay associated for the three signalized intersections and **Table 6** summarizes the 2040 No-Build queue lengths at each intersection.

Table 4: Signalized and Unsignalized Intersection Level of Service Criteria

LOS	Volume-to-Capacity Ratio	Control Delay (sec/veh)	
		Signalized Intersection	Unsignalized Intersection
A	≤ 1.0	≤10	≤10
B	≤ 1.0	>10 – 20	>10 – 15
C	≤ 1.0	>20 – 35	>15 – 25
D	≤ 1.0	>35 – 55	>25 – 35
E	≤ 1.0	>55 – 80	>35 – 50
F	> 1.0	>80	>50

Source: Transportation Research Board, Highway Capacity Manual 2010

Table 5: 2040 No-Build Signalized Intersection Delay and Level of Service

Intersection Number and Description		Type of Control	Lane Group	Northbound				Southbound				Eastbound				Westbound				Overall	
				AM		PM		AM		PM		AM		PM		AM		PM			
				Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	AM	PM
1	Market Street			US 1				US 1				Market Street				Market Street					
		Signal	Left	29.6	C	39.6	D	236.3	F	164.8	F	--	--	--	--	108.7	F	171.8	F	Delay	Delay
			Through	149.3	F	65.3	E	54.0	D	212.3	F	418.4	F	344.3	F	108.6	F	166.2	F	104.9	145.0
			Right	19.1	B	23.1	C	--	--	--	--	--	--	--	--	40.8	D	42.6	D	LOS	LOS
			Approach	120.4	F	55.2	E	74.8	D	208.8	F	418.4	F	344.3	F	94.4	F	136.3	F	F	F
2	I-95 Northbound Ramps			US 1				US 1				I-95 NB to NB US 1 Ramp				I-95 NB to SB US 1 Ramp					
		Signal	Left	83.8	F	404.9	F	--	--	--	--	--	--	--	--	--	--	--	--	Delay	Delay
			Through	0.7	A	0.4	A	83.5	F	49.8	D	--	--	--	--	--	--	--	--	303.9	168.6
			Right	--	--	--	--	852.9	F	377.3	F	16.4	B	30.4	C	†	--	†	--	LOS	LOS
			Approach	40.2	D	166.5	F	497.7	F	191.3	F	16.4	B	30.4	C	†	--	†	--	F	F
3	I-95 Southbound Ramps			US 1				US 1				From I-95 Southbound				To I-95 Southbound					
		Signal	Left	--	--	--	--	407.0	F	365.9	F	368.6	F	320.8	F	--	--	--	--	Delay	Delay
			Through	446.3	F	238.8	F	4.0	A	3.8	A	--	--	--	--	--	--	--	--	323.7	310.0
			Right	6.3	A-	8.4	A	--	--	--	--	394.4	B	585.3	F	--	--	†	--	LOS	LOS
			Approach	373.6	F	195.5	F	47.4	D	70.8	E	389.7	F	548.3	F	--	--	†	--	F	F

HCM 2000 results reported.
† SYNCHRO does not provide level of service or delay for movements with no conflicting volumes.

Table 6: 2040 No-Build Signalized Intersection Queue Lengths

Intersection Number and Description		Type of Control	Lane Group	Northbound			Southbound			Eastbound			Westbound		
				Effective Storage (ft)	95th Percentile Queue (ft)		Effective Storage (ft)	95th Percentile Queue (ft)		Effective Storage (ft)	95th Percentile Queue (ft)		Effective Storage (ft)	95th Percentile Queue (ft)	
					AM	PM		AM	PM		AM	PM		AM	PM
1	Market Street			US 1			US 1			Market Street			Market Street		
		Signal	Left			m18	360		#384				400		#649
			Through			#1151			#2067			#319			#643
			Right			391		-							
2	I-95 Northbound Ramps			US 1			US 1			I-95 NB to NB US 1 Ramp			I-95 NB to SB US 1 Ramp		
		Signal	Left	728	m#1413	m#1032									
			Through												
			Right				800		m#1434					†	†
3	I-95 Southbound Ramps			US 1			US 1			From I-95 Southbound			To I-95 Southbound		
		Signal	Left				300		m#559						
			Through			#2075			m48						
			Right			m180									

Synchro 95th percentile queue length results reported.
† SYNCHRO does not provide queue length for movements with no conflicting volumes.
m Volume for Synchro 95th percentile queue is metered by upstream signal.
95th percentile volume exceeds capacity, queue may be longer

Based on the movement capacity analysis during the 2040 AM and PM peak hours, the dual northbound left-turn lanes will be able to process the demand in the AM and PM peak hours. The southbound right-turn lane will not be able to process the demand in neither of the AM nor PM peak hour. Thus, the throughput, which will access the I-95 northbound on-ramp released by the metering effects from the signalized intersection on US 1 will be less than the actual demand.

2.2 2040 Build Analysis

2.2.1 Build Geometry and Traffic Volumes

The traffic volumes used for the No-Build analysis were used for the Build analysis; however, the geometry was changed because of the recommended improvements on US 1 in both directions as shown in **Figure 10**.

2.2.2 Synchro Analysis

The study team used Synchro to evaluate the build conditions at the signalized intersections in the corridor. Synchro was used to evaluate the delay and queue lengths for the study intersections.

2.2.2.1 Delay and Level of Service

The same methodology used for the No-Build analysis was used for the Build analysis. **Table 8** summarizes the 2040 Build delay associated for the three signalized intersections and **Table 9** summarizes the 2040 Build queue lengths at each intersection.

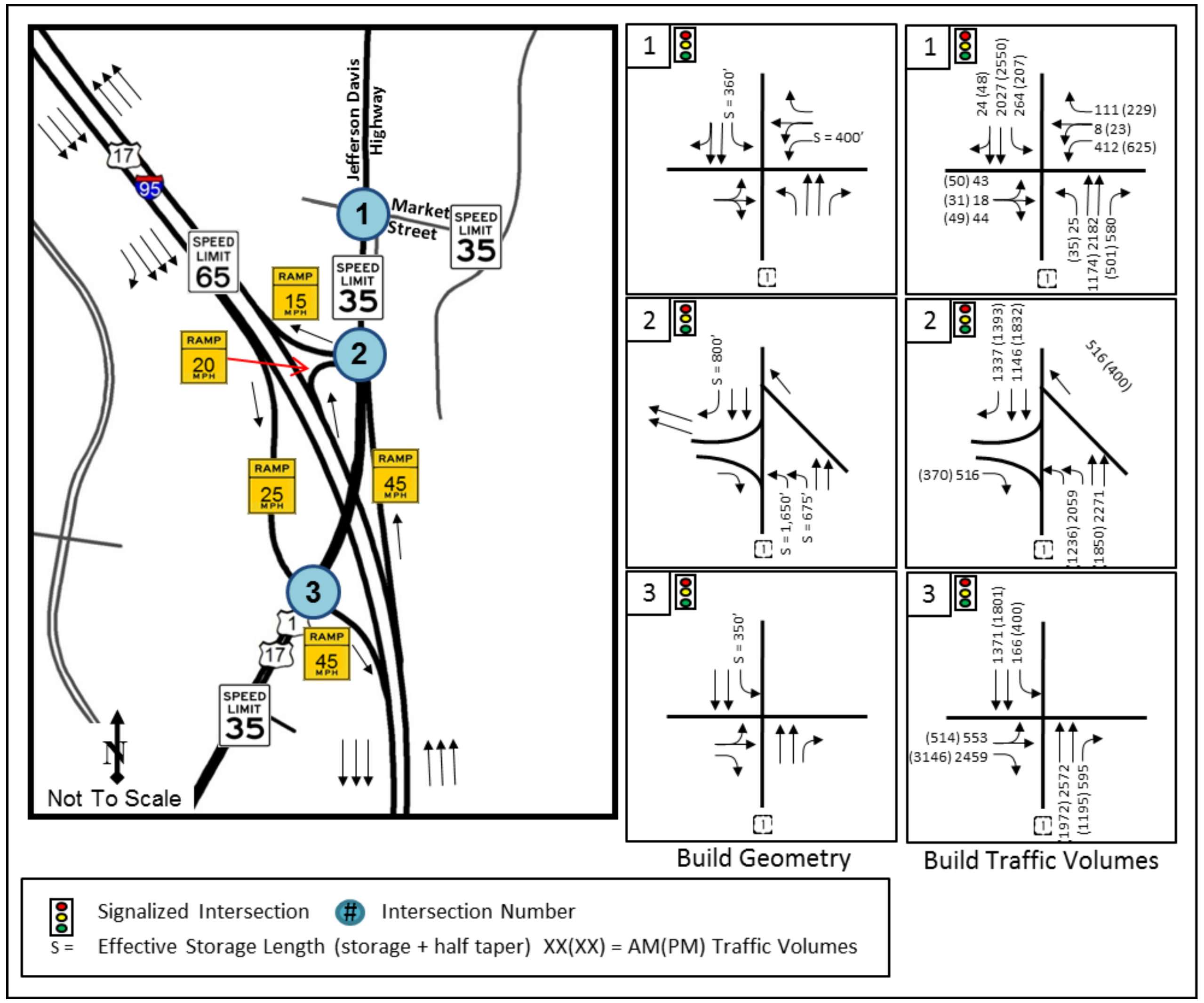
2.2.3 Freeway Analysis

2.2.3.1 Throughput Analysis

The US 1 at I-95 northbound ramps intersection meters traffic flow onto the I-95 northbound on-ramp. Using the *Highway Capacity Manual* (HCM), 6th Edition, Chapter 19 Signalized Intersections methodologies for signalized intersections and optimizing the signal timing phase splits, the adjusted saturation flow rates for the movement groups and the effective phase green times were used to calculate the capacity of the movements subject to the signal timing. The capacity was compared to the demand volumes to determine the throughput.

The movement capacity analysis was conducted in a three-step process. The first step was to optimize the signal phase timings using Synchro, Version 10, for the 2040 AM and PM peak hours. The 2040 Synchro models in AM and PM peak hours for the US 1 corridor were provided by VDOT. The models included the intersection of US 1 at I-95 northbound on-ramp and its adjacent intersections, however without the dual northbound left-turn lanes on US 1. The 2040 Synchro models were updated by adding the dual northbound left-turn lanes on US 1 at the intersection of I-95 northbound on-ramp. Then the signal phase timings at this intersection was optimized, while holding the network coordinated cycle length, offsets and phase timings of the remaining intersections constant.

Figure 10. Build Traffic Volumes and Geometry



The second step in the process was to calculate the adjusted saturation flow rates for the northbound left-turn movement and the southbound right-turn movement from US 1 onto the I-95 northbound on-ramp. HCM Equation 19-8, shown as below, was used to calculate the adjusted saturation flow rates for the left- and right-turn movements. The adjusted factors and assumptions used in the formula for the calculations are shown in the Appendix.

$s = s0 \times fw \times fhvg \times fp \times fbb \times fa \times fLU \times fLT \times fRT \times fLpb \times fRpb \times fwz \times fms \times fsp$ ***Equation 19-8 in HCM***

The adjusted saturation flow rates for the lane group were multiplied by the number of turn-lanes for each movement resulting in the adjusted saturation flow rate for the movement group.

The third step was to compute the capacity of each movement group subject to the signal by multiplying the adjusted saturation flow rate for the movement group with its proportion of the effective green time for the movement in the cycle.

Where the capacity of the movement group is greater than the demand volume for that movement, the throughput equals to the demand volume. Where the capacity is less than the demand volume, the throughput equals to the capacity of the movement. The total throughput on the ramp is the sum of the lower values of either capacity or demand. The results are shown in **Table 7**. Even though the computed throughput volumes are less than the demand volumes, the demand volumes were used in the CORSIM traffic analysis to determine the worst-case operations on the freeway.

Table 7: I-95 Northbound On-Ramp Throughput

Movement Group	AM		PM	
	Northbound Left	Southbound Right	Northbound Left	Southbound Right
Adjusted Saturation Flow Rate for Movement (vph)	3,618	1,611	3,618	1,612
Capacity of Movement Group Subject to Signal Timing (vph)	2,134	537	1,425	853
Demand Traffic Volume for Movement Group (vph)	2,059	1,337	1,236	1,393
Total Throughput Volume (vph)	2,596		2,089	

2.2.3.2 HCS Analysis

The Highway Capacity Software (HCS 7) was used to conduct a sensitivity analysis for varying lengths of the acceleration lanes using AM peak hour traffic volumes and density, expressed in passenger cars per mile per lane, as the primary measure of effectiveness. However, since the merging methodologies in the *Highway Capacity Manual* (HCM), 6th Edition do not differentiate results once the acceleration lane exceeds 1,500 feet, the study team determined that these capacity results should not be used for decision-making purposes, especially since the results were LOS F for all scenarios. The CORSIM analysis followed this analysis.

The study team analyzed the following scenarios:

- 2040 AM one-lane merge (1,500 feet acceleration lane)
- 2040 AM two-lane merge (acceleration lengths in design file as minimum length)
- 2040 AM two-lane merge (1,500 feet for each acceleration lane as maximum length allowable in HCS)
- 2045 FAMPO AM one-lane merge (1,500 feet acceleration lane)
- 2045 FAMPO AM two-lane merge (acceleration lengths in design file as minimum length)
- 2045 FAMPO AM two-lane merge (1,500 feet for each acceleration length as maximum length allowed in HCS)

The following assumptions were used for the merge area capacity analysis.

- Peak hour factors for the 2040 AM scenarios for the I-95 northbound mainline, I-95 northbound off-ramp at Exit 126B (considered as upstream adjacent ramp), and the I-95 northbound on-ramp from US 1 were calculated based on four 15-minute interval traffic volumes 2040 No-Build CORSIM files.
- Heavy vehicle percentages (HV%) for the 2040 AM scenarios for the I-95 northbound off-ramp at Exit 126B and the I-95 northbound on-ramp from US 1 were extracted from 2040 No-Build Synchro files.
- For the 2045 Hybrid AM scenarios, I-95 northbound mainline traffic volumes were derived from the 2045 FAMPO traffic forecast. Since the 2045 forecasts did not include PHFs, the PHF were assumed to be the same as the 2040 AM scenarios. All other inputs in the 2045 hybrid AM scenarios were the same as the 2040 AM scenarios.
- Rolling terrain was assumed for all scenarios, since both I-95 northbound mainline and the on-ramp are on an upgrade.

Table 8: 2040 Build Signalized Intersection Delay and Level of Service

Intersection Number and Description	Type of Control	Lane Group	Northbound				Southbound				Eastbound				Westbound				Overall	
			AM		PM		AM		PM		AM		PM		AM		PM			
			Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	AM	PM
1 Market Street			US 1				US 1				Market Street				Market Street					
	Signal	Left	29.6	C	39.0	D	236.3	F	164.8	F	--	--	--	--	108.7	F	171.8	F	Delay	Delay
		Through	149.3	F	66.0	F	54.0	D	212.3	F	418.4	F	344.3	F	108.6	F	166.2	F	104.9	145.3
		Right	19.1	B	24.4	C	--	--	--	--	--	--	--	--	40.8	D	42.6	D	LOS	LOS
		Approach	120.4	F	56.2	E	74.8	D	208.8	F	418.4	F	344.3	F	94.4	F	136.0	F	F	F
2 I-95 Northbound Ramps			US 1				US 1				I-95 NB to NB US 1 Ramp				I-95 NB to SB US 1 Ramp					
	Signal	Left	83.8	F	51.7	D	--	--	--	--	--	--	--	--	--	--	--	--	Delay	Delay
		Through	0.7	A	0.4	A	83.5	F	43.0	D	--	--	--	--	--	--	--	--	303.9	98.2
		Right	--	--	--	--	852.9	F	364.8	F	--	--	--	-	†	--	†	--	LOS	LOS
		Approach	40.2	D	21.5	C	497.7	F	182.0	F	--	--	--	-	†	--	†	--	F	F
3 I-95 Southbound Ramps			US 1				US 1				From I-95 Southbound				To I-95 Southbound					
	Signal	Left	--	--	--	--	407.0	F	365.6	F	368.6	F	320.8	F	--	--	--	--	Delay	Delay
		Through	446.3	F	238.8	F	4.0	A	3.7	A	--	--	--	--	--	--	--	--	323.7	310.0
		Right	6.3	A-	8.3	A	--	--	--	--	394.4	B	585.3	F	--	--	†	--	LOS	LOS
		Approach	373.6	F	195.5	F	47.4	D	70.7	E	389.7	F	548.3	F	--	--	†	--	F	F

HCM 2000 results reported.
† SYNCHRO does not provide level of service or delay for movements with no conflicting volumes.

Table 9. 2040 Build Signalized Intersection Queue Lengths

Intersection Number and Description	Type of Control	Lane Group	Northbound			Southbound			Eastbound			Westbound		
			Effective Storage (ft)	95th Percentile Queue (ft)		Effective Storage (ft)	95th Percentile Queue (ft)		Effective Storage (ft)	95th Percentile Queue (ft)		Effective Storage (ft)	95th Percentile Queue (ft)	
				AM	PM		AM	PM		AM	PM		AM	PM
1 Market Street			US 1			US 1			Market Street			Market Street		
	Signal	Left	280	m8	m18	360	#511	#384				400	#416	#649
		Through		#1621	#1156		#1371	#2067		#273	#319		#417	#643
		Right		326	406		-							223
2 I-95 Northbound Ramps			US 1			US 1			I-95 NB to NB US 1 Ramp			I-95 NB to SB US 1 Ramp		
	Signal	Left	728	m138	m#280									
		Through		m0			m#724							
		Right				800	m#2447	m#1443					†	†
3 I-95 Southbound Ramps			US 1			US 1			From I-95 Southbound			To I-95 Southbound		
	Signal	Left				300	m#219	m#546		#1091	#1003			
		Through		m#2400	#2075		m58	m47		#2459	#3866			
		Right		m70	m180									

Synchro 95th percentile queue length results reported.
† SYNCHRO does not provide queue length for movements with no conflicting volumes.
m Volume for Synchro 95th percentile queue is metered by upstream signal.
95th percentile volume exceeds capacity, queue may be longer

2.2.3.3 CORSIM Analysis

Operational impacts of modifying the existing single I-95 northbound acceleration lane to two lanes were assessed by comparing travel speed results obtained through a CORSIM point-processing analysis (PPA). The PPA was performed under future 2040 No-Build and Build conditions, along all three northbound I-95 mainline lanes and along each acceleration lane. Overall, one No-Build and four Build scenarios were evaluated in the PPA.

- No Build: One acceleration lane with approximately 1,350 feet of effective auxiliary length
- Build Scenario 1 (SC1): One acceleration lane with approximately 1,020 feet of effective auxiliary length and a second acceleration lane with approximately 2,220 feet of effective auxiliary length
- Build Scenario 2 (SC2): One acceleration lane with approximately 1,020 feet of effective auxiliary length and a second acceleration lane with approximately 3,220 feet of effective auxiliary length
- Build Scenario 3 (SC3): One acceleration lane with approximately 1,020 feet of effective auxiliary length and a second acceleration lane with approximately 4,220 feet of effective auxiliary length
- Build Scenario 4 (SC4): One acceleration lane with approximately 2,020 feet of effective auxiliary length and a second acceleration lane with approximately 4,220 feet of effective auxiliary length

Each of the five operational analysis scenarios were evaluated under 2040 AM and PM peak hour conditions. Travel speeds reported in the PPA outputs are time mean speeds (TMS), or the average speeds all vehicles are traveling at a specific point on a link. TMS results were obtained at 200-foot intervals along each lane, and the results were averaged from 10 individual microsimulations. By evaluating anticipated TMS, isolated instances of congestion can be better identified. **Figure 11** and **Figure 12** summarize AM peak hour PPA results, while **Figure 13** and **Figure 14** summarize PM peak hour PPA results.

The No-Build traffic analysis model consisted of the same network elements as the Build models, except at the US 1 and I-95 northbound on-ramp intersection. Initially, with the signalized intersection included in the No-Build model, approximately 50% of the anticipated 2040 peak hour traffic demand was not able to access the on-ramp, resulting in significant queuing on US 1. This unmet traffic demand resulted in low simulated merge traffic volumes (reduced demand by approximately 1,200 vehicles); thereby, resulting in an inaccurate representation of anticipated future merge operations on northbound I-95.

To obtain a more accurately represent the future merge operations on northbound I-95, the US 1 and I-95 northbound on-ramp signalized intersection was omitted from the 2040 No-Build AM and PM peak hour CORSIM models. With this approach, the on-ramp processed vehicles up to its approximate capacity and provided a more reasonable evaluation of merge operations on northbound I-95. After removing the signalized intersection, simulated ramp traffic volumes under AM peak hour conditions were approximately 2,165 vehicles. While this is still less than the forecasted 2040 AM peak hour demand of approximately 1,975 vehicles, the simulated traffic volume is comparable to the approximate capacity of a single-lane ramp. Under Build conditions, the proposed two-lane ramp had adequate capacity at both the intersection and along the ramp to accommodate future AM and PM peak hour traffic demands.

2.2.3.3.1 AM Peak Hour Results

Under 2040 No Build conditions, anticipated travel speeds in Lane 1 (i.e., outer mainline travel lane that is adjacent to the acceleration lane) are expected to range between approximately 25 and 50 MPH within the ramp merge area. These travel speeds are lower than those anticipated in Lane 2 or Lane 3, and are a result of vehicles merging from the acceleration lane. Upstream from the merge, travel speeds in Lane 1 are expected to be less than 45 MPH, indicating that merging operations are anticipated to reduce travel speeds upstream from the ramp as well.

Under all four AM Build scenarios, a second acceleration lane is expected to increase upstream travel speeds in Lane 1 by approximately 10 percent (i.e. an approximate 5 MPH increase in Lane 1 travel speeds upstream from the ramp merge). Under Build SC1 conditions, Lane 1 travel speeds within the ramp merge area are expected to range between approximately 43 and 49 MPH, and are similar to anticipated AM No Build conditions. Build SC2 includes a longer inside acceleration lane (A1) and is anticipated to increase Lane 1 travel speeds within the merge area by up to 4 MPH. In Build SC3, A1 is extended an additional 1,000 feet from Build SC2. This extension is expected to increase Lane 1 travel speeds within the merge area by up to 2 MPH as compared to Build SC2 conditions. Under SC4 conditions, the length of A1 is held constant from Build SC3; however, the outer acceleration lane (A2) is extended an additional 1,000 feet as compared to either of the three other Build scenarios. Overall within the merge area, it is not anticipated that Build SC4 will result in an increase in Lane 1 travel speeds as compared to Build SC3.

2.2.3.3.2 PM Peak Hour Results

Under 2040 No Build conditions, Lane 1 travel speeds within the merge area are expected to range between approximately 25 and 50 MPH. The mainline I-95 traffic volumes in the PM peak hour are approximately 700 vehicles per hour higher than in the AM peak hour. Because of this difference, merging speeds are much slower under 2040 No Build PM peak hour conditions than AM peak hour conditions. Like AM peak hour conditions, Lane 1 travel speeds upstream from the ramp merge are expected to be reduced due to ramp merge operations.

Under all four PM Build scenarios, a second acceleration lane is expected to increase upstream travel speeds in Lane 1 by approximately 10 percent (i.e. an approximate 5 MPH increase in Lane 1 travel speeds upstream from the ramp merge). Under Build SC1 conditions, Lane 1 travel speeds within the ramp merge area are anticipated to increase by up to 5 MPH from No-Build conditions. Under Build SC2, SC3, and SC4, Lane 1 travel speeds within the ramp merge area are anticipated to be like those expected under Build SC1 conditions.

2.2.3.3.3 Peak Hour Results

Under each AM scenario, the benefits of a second acceleration lane can be directly observed with the approximate 10 percent increase in Lane 1 travel speeds upstream from the ramp. Under each PM scenario, the benefits of a second acceleration lane can be directly observed with the approximate 45 percent increase in Lane 1 travel speeds upstream from the ramp. Within the ramp merge area, the length of the outermost acceleration lane has the largest impact on Lane 1 speeds. An increase in effective auxiliary lane length from approximately 2,220 feet (Build SC1) to approximately 3,220 feet (Build SC2) is anticipated to result in an approximate 4 to 5 MPH increase in AM and PM No-Build travel speeds in Lane 1. Further extension of the outermost acceleration lane is not anticipated to provide additional increases in Lane 1 travel speeds.

Figure 11: 2040 AM Traffic Volume Point Processing Results

Figure 12: 2040 PM Traffic Volume Point Processing Results

Figure 13: 2040 AM Speed Point Processing Results

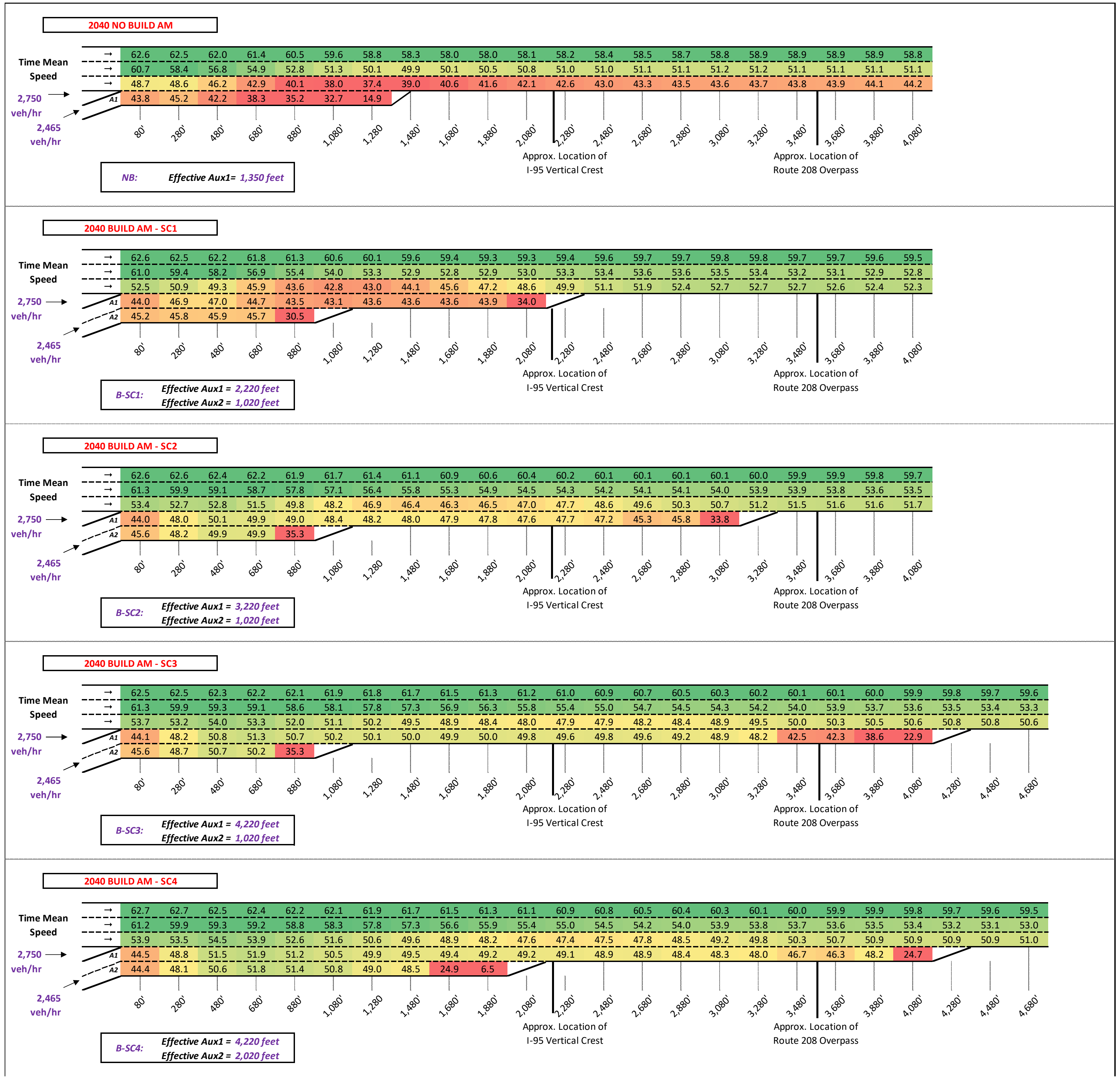


Figure 14: 2040 PM Speed Point Processing Results

3 Concept Development

3.1 Initial Concept Screening

Kimley-Horn divided the design analysis into two phases. Kimley-Horn starting by developing a design concept to specifically determine if a second northbound US 1 left-turn lane can be constructed under the I-95 bridge at the northbound I-95 signalized intersection. Once the feasibility for improvements on northbound US 1 was verified, Kimley-Horn then determined the feasibility of improvements to the northbound I-95 on-ramp and northbound I-95 to the Route 208 bridge over I-95.

3.1.1 US 1 Concept Design Process

Kimley-Horn began the design process by completing a field visit in which measurements were taken and compared to as-builts plans to determine the feasibility of a second northbound US 1 left-turn lane. The existing left-turn lane on northbound US 1 to the I-95 northbound on ramp has 700 feet of storage. After confirming the feasibility of a second northbound US 1 left-turn lane, Kimley-Horn developed two options of varying storage lengths for the inside and outside left-turn lanes. Kimley-Horn informed the SWG that bridge pier protection systems (BPPS) would be required to protect the I-95 bridge piers in both directions for both options. The typical section under the I-95 bridge for each concept in both directions would consist of a thirteen-foot left-turn lane, two eleven-foot through lanes, and a seven-foot outside paved shoulder.

Alternative 1 included 750 feet of storage for the inside left-turn lane and 1,350 feet for the outside left-turn lane. Alternative 1 would also consist of reconfiguring the I-95 northbound to southbound US 1 off-ramp to create a yield condition from the ramp onto southbound US 1.

Alternative 2 included 1,650 feet of storage for the inside left-turn lane and 675 feet for the outside left-turn lane. Alternative 2 would also consist of reconfiguring the I-95 northbound to northbound US 1 off ramp to create a yield condition from the ramp onto southbound US 1.

Kimley-Horn determined that both alternatives would require design exceptions for the lack of shoulder width on US 1, the stopping sight distance for US 1 due to the bridge piers for the I-95 overpass, and the vertical clearance under the I-95 overpass. The SWG provided additional input stating that both alternatives would also require operational impacts due to bridge maintenance inspections conducted every few months during the day.

Another design consideration that Kimley-Horn investigated was the length of the southbound US 1 left-turn lane at its signalized intersection with the southbound I-95 ramps. The accommodate southbound left turns, the effective storage length of the southbound left-turn lane is 350 feet.

3.1.2 I-95 Concept Design Process

Once it was determined that the dual left-turn lanes could be accommodated on US 1, Kimley-Horn needed to determine the length of the dual acceleration lanes on northbound I-95. Field measurements were compared to as-built plans to confirm that there is room for the two acceleration lanes.

Once the designs along I-95 were determined to be feasible, Kimley-Horn began analyzing the necessary lengths for the auxiliary lane on I-95 northbound. Alternative 3 was designed to meet the minimum distance needed to satisfy the AASHTO acceleration lane length. Alternative 3 included an 820-foot acceleration lane (for 45 mph to 70 mph), a 300-foot merging taper, a 540-foot auxiliary lane, and an 840-foot merging taper.

Alternative 4 was designed to maximize the safety and congestion improvements from US 1 to north of the Route 208 overpass. Alternative 4 included an 820-foot acceleration lane (for 45 mph to 70 mph), a 300-foot merging taper, a 2,440-foot auxiliary lane, and an 840-foot merging taper.

Alternative 5 was designed to balance the cost and benefits of the previous alternatives while meeting AASHTO standards. Alternative 5 included an 820-foot acceleration lane (for 45 mph to 70 mph), a 300-foot merging taper, a 1,440-foot auxiliary lane, and an 840-foot merging taper.

The design of the northbound acceleration lane was not only based on the results of the traffic analysis, but also on the results of the safety analysis even though safety is weighted at 5% compared to 45% for congestion for SMART SCALE scoring in the Fredericksburg area. As shown in **Table 10**, the crash modification factor for extending the acceleration lane by 1,000 feet provides a 55% reduction in related crashes; however, the cost of extending the acceleration by 1,000 was approximately $500,000. The study team used this information to determine the most appropriate acceleration lane length.

Table 10. Crash Modification Factors for Ramp Extensions

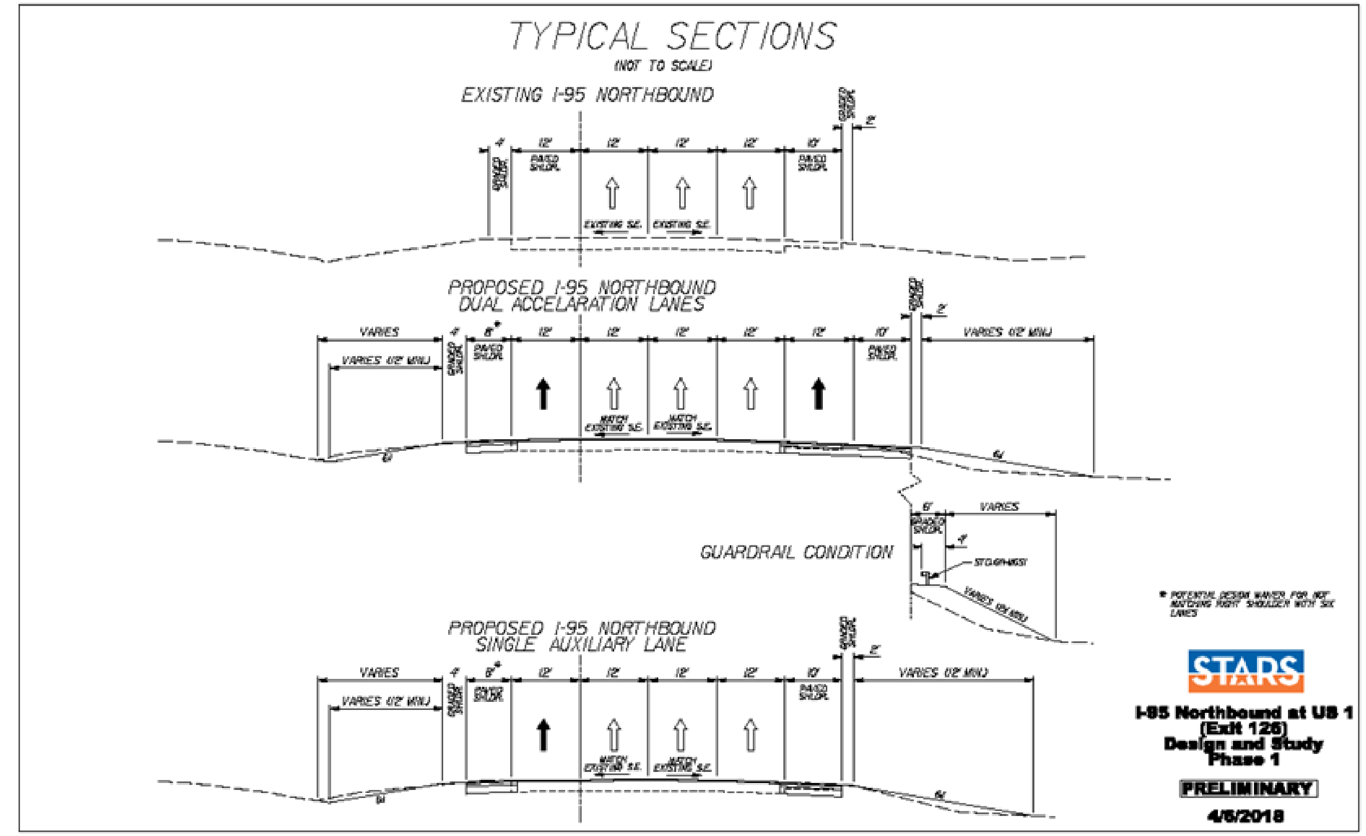
Extend Ramp Length	Planning Level CMF
Extend ramp acceleration length (250')	0.80
Extend ramp acceleration length (500')	0.65
Extend ramp acceleration length (1000')	0.45

4 Preferred Alternative

A combination of Alternative 2 and Alternative 5 was chosen as the preferred alternative for US 1 and I-95, respectively. The advantage of the Alternative 2 for US 1 is that it fully uses the second northbound left-turn lane at the intersection with the I-95 on-ramp. With alternative 1, the queue of the outside left-turn lane would have blocked the inside left-turn lane. The Alternative 2 design bypassed that problem by shifting all three northbound lanes 8 feet to the east, over 150 feet. But due to this shift, the gore point of the I-95 northbound off ramp to US 1 northbound (Ramp A) also needed to be adjusted. Alternative 2 also included a modification of the US 1 right-turn lane to the I-95 southbound on-ramp (Ramp B) to a thru-right lane and modifying the US 1 southbound left-turn lane to the I-95 southbound on-ramp (Ramp B) to include a 135-foot left-turn lane taper and 280-foot left-turn lane storage. The modifications to the right-turn lane will help the capacity on US 1 and help northbound drivers preposition to avoid any queues for the left turns to the I-95 northbound on-ramp. The modifications to the left-turn lane increase the effective storage to the existing deficient left-turn lane.

Ramp D also was widened from one to two lanes to accommodate the additional left-turn lane from US 1 at the I-95 northbound on-ramp intersection. To accommodate the additional lane from US 1, the preferred alternative includes a 420-foot long, 12-foot wide lane shift on I-95 northbound prior to the gore at Ramp D. This shift uses the existing full-depth inside shoulder on I-95 and will include an additional 8-foot inside, paved shoulder. Due to the lane shift, the proposed acceleration lane from US 1 will use the existing paved, right shoulder and widen the existing pavement. The lengthening of the auxiliary lane will also utilize the existing paved, right shoulder and widen the existing to meet VDOT standards. The typical sections for the preferred alternative is shown in **Figure 15**. The plan view graphics of the preferred alternative is shown in **Figure 16**, **Figure 17**, and **Figure 18**.

Figure 15: Preferred Alternative Typical Sections



4.1 Planning Level Cost Estimates

Planning level cost estimates, in 2018 dollars, were developed for the preferred alternative. Construction (CN) costs were estimated using a combination of PCES, the 2015 version of Transportation and Mobility Planning Division Statewide Planning Level Cost Estimate Spreadsheet, quantity take-offs, and recent bid costs. Preliminary engineering and construction engineering and inspection (CEI) costs were estimated as a percentage of construction costs including contingency. A 30% contingency was included on the construction items estimate (prior to adding CEI costs). A detailed cost estimate should be prepared during the design phase of this project. Cost estimates should be adjusted for appropriate inflation costs when used in funding applications or project allocations. The FY19 total cost for the project is approximately $20.4 million as is shown in **Figure 19**.

4.2 Project Summary

The previously described preferred alternatives are summarized in a one-page project summary sheet (**Figure 19**). The information pertaining to the project summary include project description, preferred alternative concept, traffic operational benefits, project cost, and project implementation schedule.

Figure 16: Preferred Alternative – Sheet 1

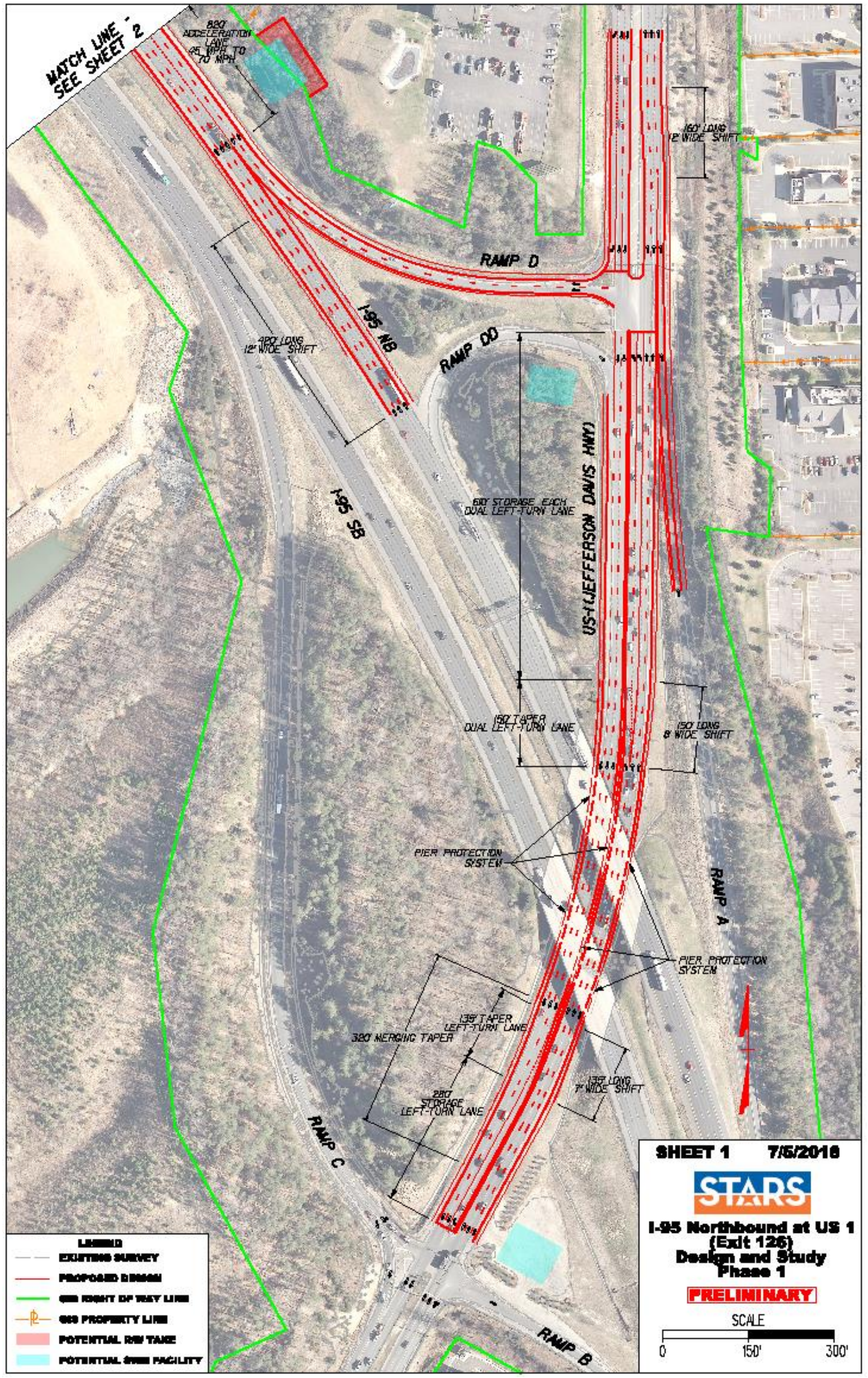


Figure 17: Preferred Alternative – Sheet 2

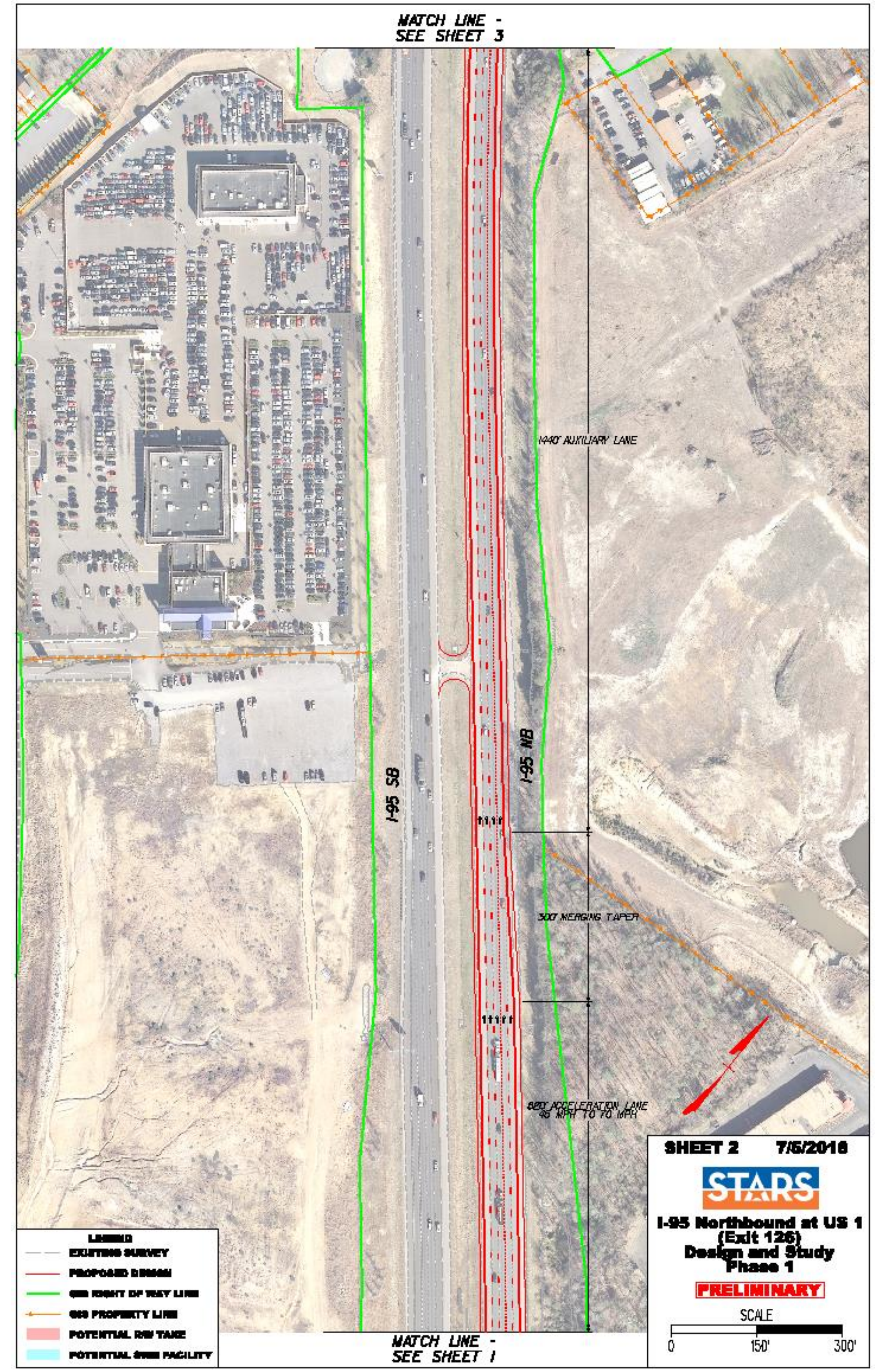
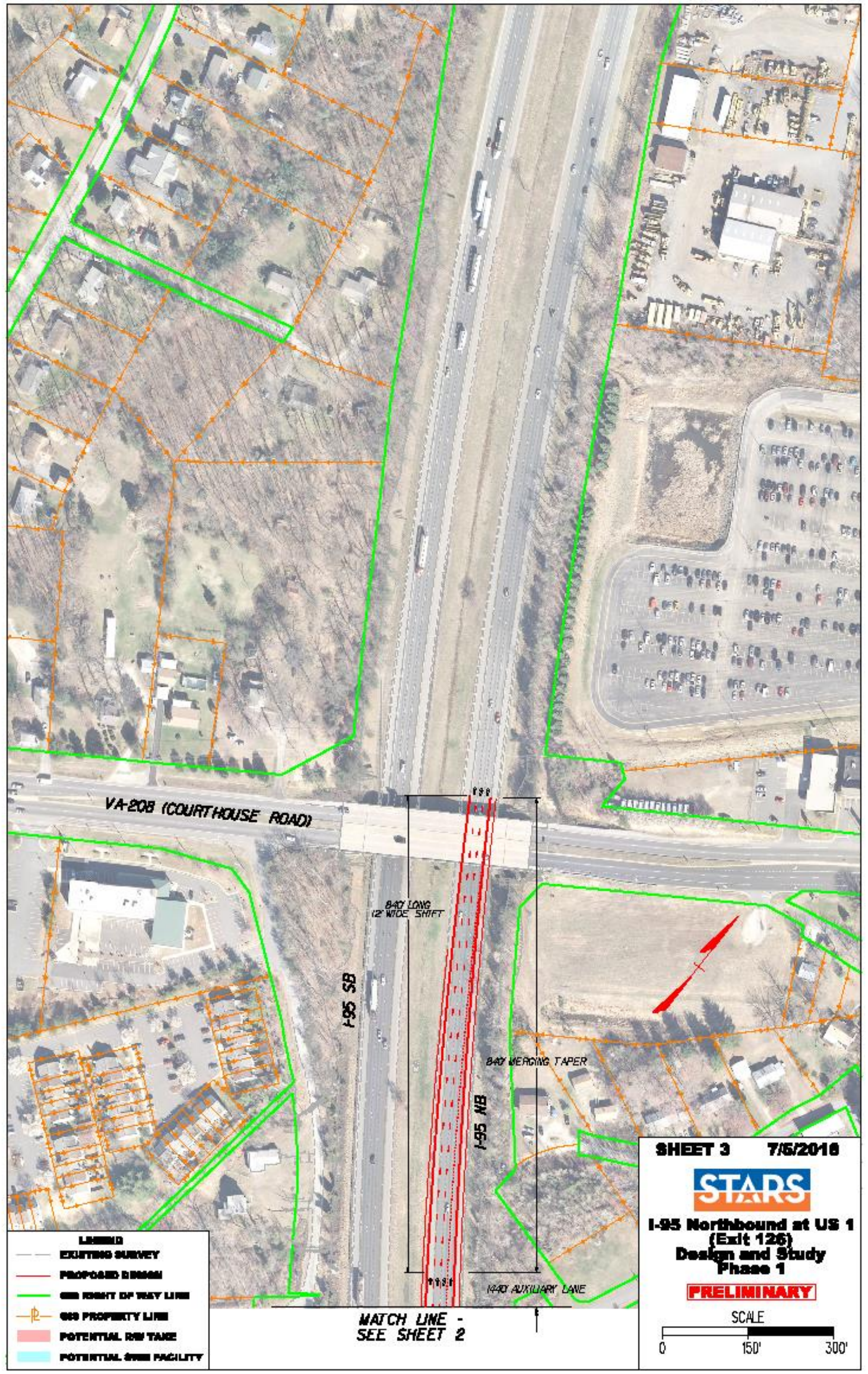


Figure 18: Preferred Alternative – Sheet 3



5 Next Steps

This study and design should be used as a planning tool to achieve the next steps of planning, programming, designing, and constructing the identified safety and operational improvements in the I-95 Northbound at US 1 (Exit 126) study corridor. To advance these projects beyond the planning stage, FAMPO should take the following steps.

5.1 Apply for Prioritized Funding Programs

The following funding sources should be considered for improvement projects identified in this study.

5.1.1 SMART SCALE

SMART SCALE allocates funding from the construction District Grants Program (DGP) and High-Priority Projects Program (HPPP) to transportation projects based on a scoring process. The scoring process evaluates, scores and ranks projects based on congestion mitigation, economic development, accessibility, safety, environmental quality, and land use factors. The location of the project determines the weight of each of these scoring factors in the calculation of the total score. For projects in Fredericksburg, the scoring factors with the highest weight are congestion (45%) and land use (20%). The preferred alternative is a candidate projects for SMART SCALE funding.

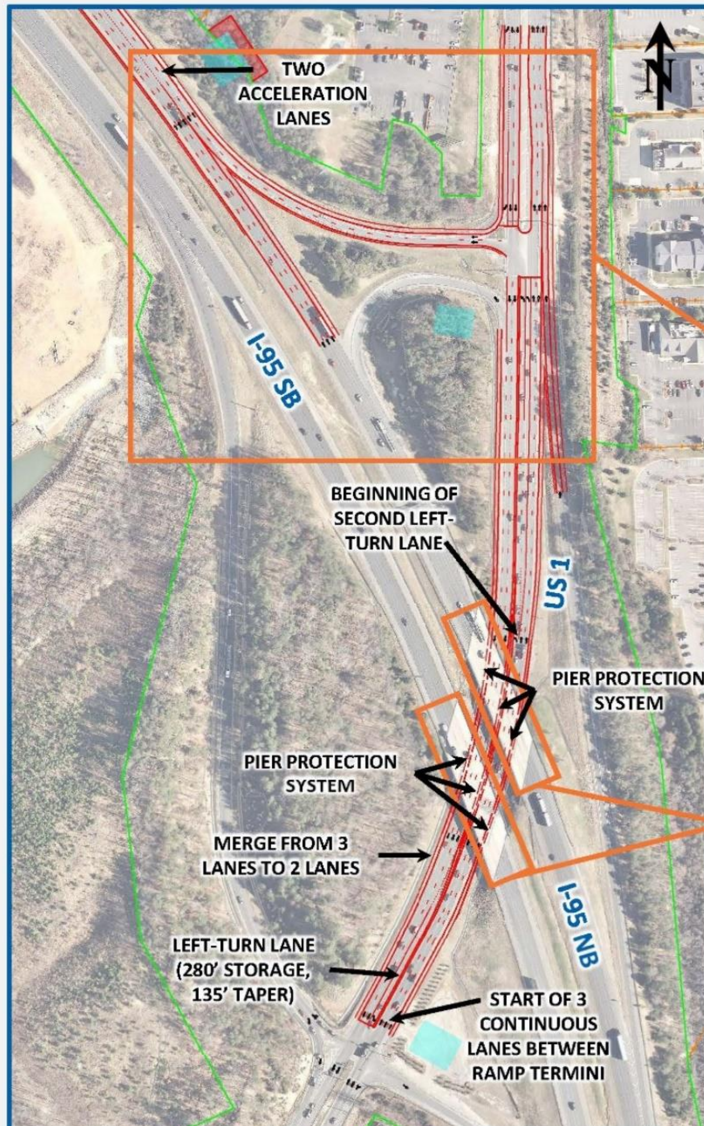
5.2 Advance Selected Projects to VDOT Six-Year Improvement Program (SYIP)

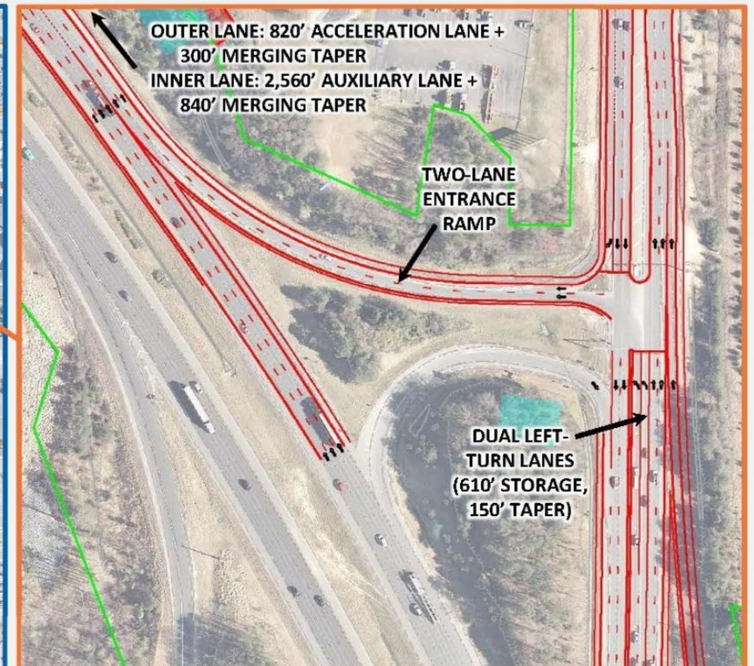
Once project applications are approved for funding through SMART SCALE, the project should be incorporated in the VDOT SYIP, so it can enter the project development process.

Figure 19: Project Summary Sheet

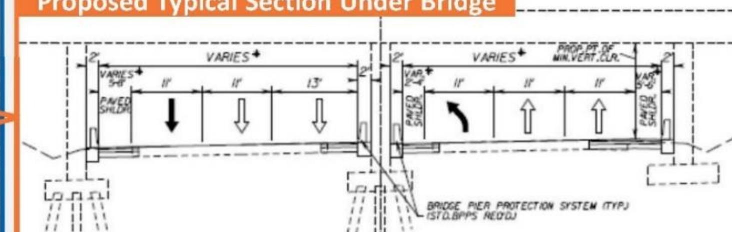
I-95 NORTHBOUND ENTRANCE RAMP AT US 1
DUAL LEFT-TURN LANES AND ACCELERATION LANE EXTENSION

Conceptual Design Layout





Proposed Typical Section Under Bridge



Legend

- - - -	Existing Survey	———	Proposed Design
———	GIS Right-of-Way Line	▭	Potential Right-of-Way Take
—⊥—	GIS Property Line	▭	Potential SWM Facility

Project Description

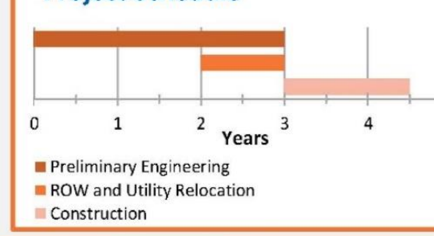
This project improves safety and operations on northbound US 1 and northbound I-95 at the I-95 Exit 126 interchange in Spotsylvania County by constructing a second northbound left-turn lane from US 1 onto the northbound I-95 entrance ramp. Capacity on US 1 is increased by the installation of a pier protection system for the I-95 bridges over US 1, which allows for three lanes in both directions on US 1 under I-95. In the northbound direction, the third through lane on US 1 becomes a second left-turn lane onto the northbound I-95 entrance ramp. In addition, the northbound I-95 entrance ramp from US 1 is reconfigured with two lanes and the acceleration lanes on I-95 are extended to provide motorists a greater distance to merge onto I-95. The dual left-turn lanes, two lane entrance ramp, and extended acceleration lanes provide additional entrance ramp capacity, which reduces congestion and improves safety by reducing congestion related crashes.

Planning Level Cost Estimate

Phase	Cost Estimate
Preliminary Engineering	$2,160,000
ROW and Utility Relocation	$846,000
Construction	$17,398,000
Total Cost =	$20,404,000

Note: Cost estimates reported in FY19 dollars

Project Schedule



Project Benefits

Traffic Operations Benefits

	AM Peak Hour 2040 No Build	AM Peak Hour 2040 Build	AM Peak Hour Δ	PM Peak Hour 2040 No Build	PM Peak Hour 2040 Build	PM Peak Hour Δ
US 1 at I-95 NB Ramps						
Overall Intersection Delay (sec/veh)	303.9	192.4	-111.5	168.6	98.2	-70.4
NBL 95th Percentile Queue Length (ft)	1,413	138	-1,275	1,032	280	-752
I-95 NB Entrance Ramp						
I-95 Spot Speed at Ramp Gore (mph)	48.7	53.4	+4.7	42.5	55.6	+13.1
Ramp Throughput (veh)	2,163	2,509	+346	1,978	2,001	+23

Safety Benefits

Improvement	Crash Modification Factor	Applicable Crashes (2012-2016)	Reduction in Crashes
US 1 at I-95 NB Ramps – Install 2nd NB left-turn lane			
Install left-turn lane	0.97	172	5
I-95 NB Entrance Ramp – Extend Acceleration Lane and Auxiliary Lane			
Extend acceleration lane (1,000')	0.45	35	20
Widening (3 lanes to 4 lanes)	0.80	20	4
TOTAL REDUCTION IN CRASHES			**29**

I-95 NORTHBOUND AT US 1 (EXIT 126) STUDY

APPENDIX

Results of Throughput Analysis – Northbound Left Turn on US 1

Movement - US Route 1 NBL at the Intersection of I-95 Northbound On-Rmp (Exit 126)					
Adjusted Saturation Flow Rate Calculation	Adjusted Factors	Units	AM	PM	Note
Base Saturation Flow Rate	S_0	pcphpl	1900	1900	
No. of Lanes	N		2	2	
Lane Width (ft)	Lw		12	12	
Adjustment Factor for Lane Width	f_w		1	1	1+(Lw - fw)/30
HV%	P_{HV}		5%	4%	
Grade%	P_g		1%	1%	Grade % assumed to be 1% based on the no-build Synchro model
Adjustment Factor for Heavy Vehicles and Grade	f_{HVg}		1.00	1.00	No adjustment made
Equivalent Truck	E_T		2	2	Terrain assumed to be level
Adjustment Factor for Parking	f_p		1	1	No on-street parking
Adjustment Factor for Bus Blocking Effect Within Intersection Area	f_{bb}		1	1	No bus blocking
Adjustment Factor for Area Type	f_a		1	1	Not a CBD
Adjustment Factor for Lane Usage	f_{LU}		1	1	When v/c approaches 1.0, the lane use factor is 1
Equivalent Number of Through Cars for a Protected Left-Turning Vehicle	E_L		1.05	1.05	
Adjustment Factor for Left Turn	f_{LT}		0.95	0.95	
Equivalent Number of Through Cars for a Protected Right-Turning Vehicle	E_R		1.18	1.18	Not applicable
Adjustment Factor for Right Turn	f_{RT}		0.85	0.85	Not applicable
Pedestrian Adjustment Factor for Left Turn	f_{Lpb}		1	1	No pedestrian conflicts
Pedestrian Adjustment Factor for Right Turn	f_{Rpb}		1	1	Not applicable
Adjustment Factor for Work Zone Presence at the Intersection	f_{wz}		1	1	No work zone present
Adjustment Factor for Downstream Lane Blockage	f_{ms}		1	1	Assumed no downstream lane blockage
Adjustment Factor for Sustained Spillback	f_{sp}		1	1	Assumed no sustained spillback from the I-95 NB on-ramp
Adjusted Saturation Flow Rate of Lane Group (NBL) (vph)	**s**	**vph**	**1809**	**1809**	
Adjusted Saturation Flow Rate of Movement Group (Dual NBL) (vph)	**s'**	**vph**	**3618**	**3618**	N x s
Signal Lane Group Capacity Calculation	Adjusted Factors	Units	AM	PM	Note
Cycle Length	C	sec	150	150	
Split	SP	sec	94	64.6	
Yellow	Y	sec	4	4	
All Red	AR	sec	2.5	2.5	
Extension of Green	e	sec	3.5	3.5	
Startup Lost Time	l1	sec	2.5	2.5	
Total Lost Time	t_L	sec	5.5	5.5	
Green	G	sec	87.5	58.1	
Effective Green	g	sec	88.5	59.1	Assume signal will max out every cycle
Effective Green/Cycle Length	g/C		0.59	0.39	
Capacity of Movement Group (Dual NBL) Subject to Signal (vph)		**vph**	**2134**	**1425**	Adjusted saturation flow rate of movement group x effective green/cycle length

Results of Throughput Analysis – Southbound Right-Turn on US 1

Movement - US Route 1 NBL at the Intersection of I-95 Northbound On-Rmp (Exit 126)					
Adjusted Saturation Flow Rate Calculation	Adjusted Factors	Units	AM	PM	Note
Base Saturation Flow Rate	S_0	pcphpl	1900	1900	
No. of Lanes	N		2	2	
Lane Width (ft)	Lw		12	12	
Adjustment Factor for Lane Width	f_w		1	1	1+(Lw - fw)/30
HV%	P_{HV}		5%	4%	
Grade%	P_g		1%	1%	Grade % assumed to be 1% based on the no-build Synchro model
Adjustment Factor for Heavy Vehicles and Grade	f_{HVg}		1.00	1.00	No adjustment made
Equivalent Truck	E_T		2	2	Terrain assumed to be level
Adjustment Factor for Parking	f_p		1	1	No on-street parking
Adjustment Factor for Bus Blocking Effect Within Intersection Area	f_{bb}		1	1	No bus blocking
Adjustment Factor for Area Type	f_a		1	1	Not a CBD
Adjustment Factor for Lane Usage	f_{LU}		1	1	When v/c approaches 1.0, the lane use factor is 1
Equivalent Number of Through Cars for a Protected Left-Turning Vehicle	E_L		1.05	1.05	
Adjustment Factor for Left Turn	f_{LT}		0.95	0.95	
Equivalent Number of Through Cars for a Protected Right-Turning Vehicle	E_R		1.18	1.18	Not applicable
Adjustment Factor for Right Turn	f_{RT}		0.85	0.85	Not applicable
Pedestrian Adjustment Factor for Left Turn	f_{Lpb}		1	1	No pedestrian conflicts
Pedestrian Adjustment Factor for Right Turn	f_{Rpb}		1	1	Not applicable
Adjustment Factor for Work Zone Presence at the Intersection	f_{wz}		1	1	No work zone present
Adjustment Factor for Downstream Lane Blockage	f_{ms}		1	1	Assumed no downstream lane blockage
Adjustment Factor for Sustained Spillback	f_{sp}		1	1	Assumed no sustained spillback from the I-95 NB on-ramp
Adjusted Saturation Flow Rate of Lane Group (NBL) (vph)	**s**	**vph**	**1809**	**1809**	
Adjusted Saturation Flow Rate of Movement Group (Dual NBL) (vph)	**s'**	**vph**	**3618**	**3618**	N x s
Signal Lane Group Capacity Calculation	Adjusted Factors	Units	AM	PM	Note
Cycle Length	C	sec	150	150	
Split	SP	sec	94	64.6	
Yellow	Y	sec	4	4	
All Red	AR	sec	2.5	2.5	
Extension of Green	e	sec	3.5	3.5	
Startup Lost Time	l1	sec	2.5	2.5	
Total Lost Time	t_L	sec	5.5	5.5	
Green	G	sec	87.5	58.1	
Effective Green	g	sec	88.5	59.1	Assume signal will max out every cycle
Effective Green/Cycle Length	g/C		0.59	0.39	
Capacity of Movement Group (Dual NBL) Subject to Signal (vph)		**vph**	**2134**	**1425**	Adjusted saturation flow rate of movement group x effective green/cycle length