Route 1 Corridor Study
Final Report

From North of Route 3 (William Street) to Princess Anne Street / Hanson Avenue

STARS VDOT

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Prepared for

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Table of Contents

Figures

Tables

1 INTRODUCTION

1.1 Background

The Virginia Department of Transportation Fredericksburg District Office (VDOT), VDOT Transportation Mobility and Planning Division (TMPD), the City of Fredericksburg and the Fredericksburg Area Metropolitan Planning Organization (FAMPO) identified the need to evaluate existing and future conditions along the Route 1 corridor. This STARS corridor study focuses on evaluating the Route 1 corridor north of the Route 3 (William Street) interchange to the Princess Anne Street / Hanson Avenue intersection, assessing measures to reduce congestion, and recommending possible spot improvements to address congestion and safety issues.

Route 1 is a critical north-south route in the City of Fredericksburg and is a component of the Corridor of Statewide Significance Corridor K. Originally constructed in the 1940's as a four-lane bypass to downtown Fredericksburg, this portion of Route 1 has experienced steady growth as the major non-interstate facility for N-S movement in the region and as the alternate to I-95 during ever-increasing periods of incidents and congestion on the Interstate. It functions as an important route for access to retail, commercial and residential uses along the corridor, as well as providing access to the University of Mary Washington. This corridor experiences heavy congestion during peak hours. The current (year 2017) Average Daily Traffic (ADT) volume along this corridor varies from 29,000 vehicles per day (vpd) at the Route 3 interchange to 33,000 vpd crossing the Rappahannock River into Stafford County, with traffic growing at an annual rate of nearly 5% in the northern part of the study area. In addition, eight of the top 100 crash locations within the Fredericksburg District are located on Route 1 within this corridor.

The City of Fredericksburg is currently in the process of updating their Comprehensive Plan for Neighborhood Area 6, which is located along the northern portion of this Route 1 corridor between the Rappahannock Canal and Rappahannock River. The draft plan update envisions improved traffic operations, safety and pedestrian equity along this portion of Route 1. Improvement measures that are being considered include vacation of unused roadways, re-alignment of Princess Anne Street and a range of pedestrian and access-related infrastructure improvements. The recommendations and outcomes of this planning effort will help inform the improvements that are evaluated as part of this STARS study.

1.2 Purpose of Study

The primary goal of this study is to determine and assess measures to reduce congestion, recommend possible adjustments to signal phasing and/or spot improvements to alleviate congestion and address safety as well as access management issues.

The ***operational*** issues intended to be addressed by this study include existing and future projected congestion within the corridor. This congestion is centered at the major intersections within the corridor primarily during the PM peak hour, which are currently heavily utilized by passenger cars and some truck traffic. Reduction in intersection delays would mitigate congestion, improve mobility and reduce travel time.

This study also intends to address existing and future ***safety*** concerns within the study corridor. During the recent five-year period, 571 crashes resulting in 100 visible injuries, were reported within this corridor. The types of crashes frequently reported include rear-end and angle crashes. These crash types are typically associated with recurring congestion and intersection conflict points along a corridor. Reduction in congestion along the corridor or reducing conflict points may have a corresponding safety benefit, in terms of reduction in number of crashes along the corridor.

Route 1 serves a mix of commercial, retail, residential and institutional uses. This study also intends to address ***access*** deficiencies within the limits of the study corridor by identifying and documenting driveway locations and their spacing, with the objective of recommending access management improvements in the context of *VDOT Access Management Standards for Entrances and Intersections.*

1.3 Study Work Group

The Study Work Group (SWG) includes local stakeholders, who provide local and institutional knowledge of the corridor, review study goals and methodologies, provide input on key assumptions, and review and approve proposed improvement concepts developed through the study process. The key members included in the SWG represent the following agencies:

- VDOT Fredericksburg Office and TMPD
- FAMPO
- City of Fredericksburg
- WSP Team

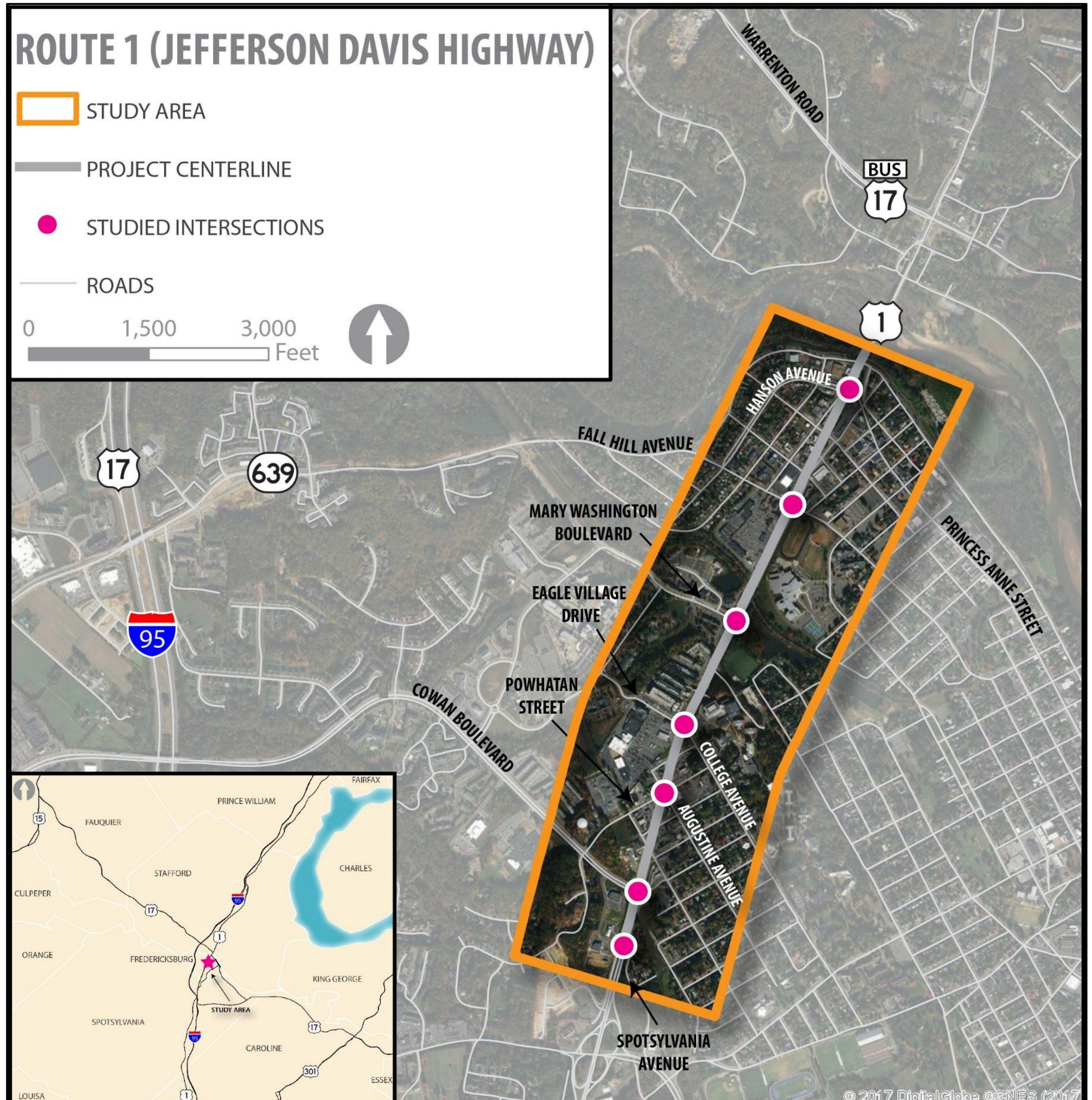
1.4 Study Area

This section of Route 1 is located within the City of Fredericksburg, Virginia. This north-south corridor is approximately 2.5 miles in length and includes eight (8) study intersections. These study intersections are listed below and shown in **Figure 1**.

Study Area Intersections

1. Route 1 and Princess Anne Street / Hanson Avenue
2. Route 1 and Fall Hill Avenue
3. Route 1 and Mary Washington Boulevard
4. Route 1 and College Avenue / Eagle Village Drive
5. Route 1 and Augustine Avenue / Powhatan Street
6. Route 1 and Cowan Boulevard
7. Route 1 and Cowan Crossing / Spotsylvania Avenue

Figure 1. Study Area Map



2 EXISTING CONDITIONS

2.1 Existing Land Use

Land use in the immediate vicinity of the study corridor between Route 3 (William Street) and Princess Anne Street / Hanson Avenue consists primarily of commercial properties, retail stores, light industrial uses, office/business/commerce centers, residential properties and the University of Mary Washington. This mix of both older and newer uses has evolved over time to create an environment of discontinuous pedestrian facilities and frequent asymmetrical access driveways and cross streets. The City's comprehensive plan seeks to encourage mixed-use redevelopment and some areas of additional density with a corresponding improvement in traffic mobility and general walkability.

2.2 Existing Roadway Network

An inventory of existing roadway conditions was prepared along Route 1 based on field reviews. Traffic, crash and Geographic Information System (GIS) data was used to document existing conditions. During the field review, the following data was collected and documented:

Digital photographs, videos, and observation to capture:

- Roadway geometry to include lane configuration, lane/shoulder widths
- Signs and pavement markings
- Posted speed limits
- Sight distance issues
- Safety concerns
- Existing driveway locations, their spacing and potential impact on crashes
- Observation of traffic operations (traffic mix, congestion, driver behavior)
- Inventory of existing roadway conditions to determine potential for safety improvements
- Inventory of intersection operations (signal phasing, queuing)

The study corridor includes eight (8) signalized and unsignalized intersections as discussed in **Sections 2.2.1** through **2.2.9** below:

2.2.1 Route 1 Corridor

Route 1 in the City of Fredericksburg from north of Route 3 (William Street) to Princess Anne Street / Hanson Avenue is classified as Urban Principal Arterial Highway per *VDOT Functional Classification*. Within the study area, Route 1 is a 4-lane divided and undivided roadway. The posted speed limit is 35 miles per hour along the corridor. Pedestrian facilities such as sidewalks, pedestrian crossing signals with ADA ramps are intermittent along each side of the corridor. No dedicated bike facilities are present within the study corridor.

2.2.2 Intersection 1: Route 1 at Princess Anne Street / Hanson Avenue

Princess Anne Street is classified as Minor Arterial per *VDOT Functional Classification.* The intersection of Route 1 at Princess Anne Street / Hanson Avenue is a 4-leg signalized intersection. The posted speed limit along Princess Anne Street / Hanson Avenue is 25 miles per hour. The northbound approach of Route 1 has one left-turn lane, one through lane, and one shared thru-right lane. The southbound approach has one left-turn lane, one through lane, and one shared thru-right lane. The eastbound approach of Hanson Avenue has one left-turn lane and one shared thru-right lane. The westbound approach of Princess Anne Street has one left-turn lane, one through lane, and one channelized right-turn lane. The signal operations include permitted/protected lefts for the northbound and southbound approaches and split phasing for the eastbound and westbound approaches. The northbound/southbound through movements are coordinated with adjacent signalized intersections. Pedestrian facilities (crosswalks, pedestrian signals) are currently not provided at this intersection. **Figure 2** shows an aerial of the intersection.

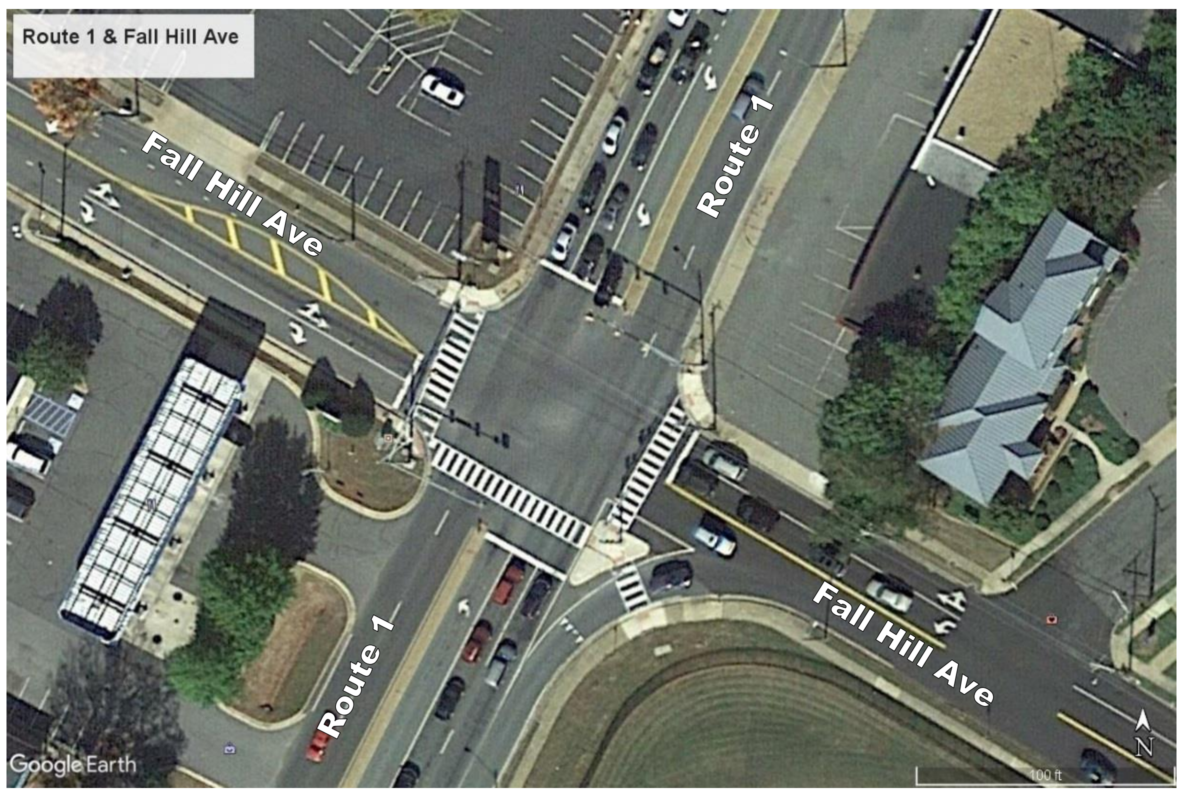
Figure 2: Route 1 at Princess Anne Street / Hanson Avenue

Source: Google Imagery

2.2.3 Intersection 2: Route 1 at Fall Hill Avenue

Fall Hill Avenue is classified as Major Collector per *VDOT Functional Classification.* The posted speed along Fall Hill Avenue is 25 miles per hour. The northbound approach of Route 1 has one left-turn lane, two through lanes, and one channelized right-turn lane. The southbound approach has one left-turn lane, one through lane, and one shared thru-right lane. The eastbound approach of Fall Hill Avenue has one shared left-thru lane and one right-turn lane. The westbound approach has one left-turn lane and one shared thru-right lane. The signal operations include permitted/protected lefts for the northbound and southbound approaches and split phasing for the eastbound and westbound approaches. The northbound/southbound through movements are coordinated with adjacent signalized intersections. Pedestrian facilities (crosswalks, pedestrian signals) are present across the northbound, eastbound and westbound approaches. **Figure 3** shows an aerial of the intersection.

Figure 3: Route 1 at Fall Hill Avenue

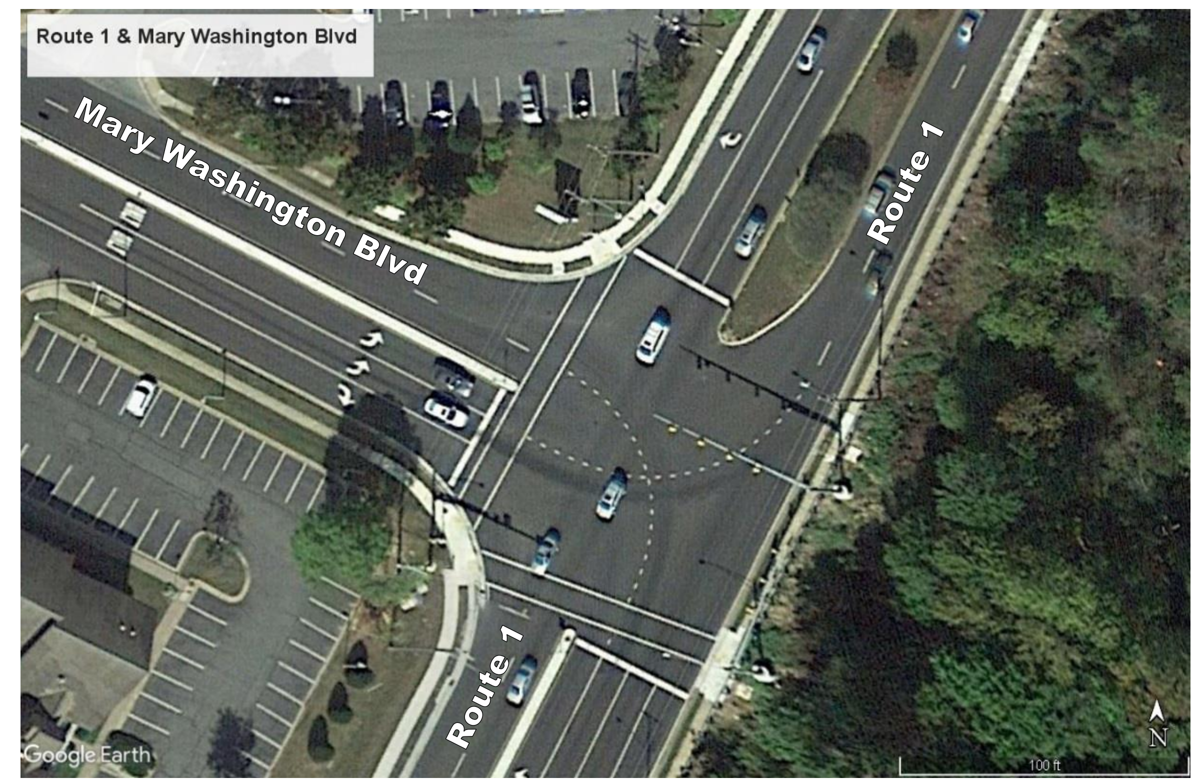


Source: Google Imagery

2.2.4 Intersection 3: Route 1 at Mary Washington Boulevard

Mary Washington Boulevard is classified as Minor Collector per *VDOT Functional Classification*. The intersection of Route 1 at Mary Washington Blvd is currently a 3-leg signalized T-intersection. The posted speed limit for Mary Washington Blvd is 35 miles per hour. The northbound approach of Route 1 has two left-turn lanes and two through lanes. The southbound approach has two through lanes and one right-turn lane. The eastbound approach of Mary Washington Blvd has two left-turn lanes and one right-turn lane. The signal operations include protected lefts for the northbound approach, with the eastbound rights overlapping with the northbound lefts and the southbound rights overlapping with the eastbound lefts. The northbound/southbound through movements are coordinated with adjacent signalized intersections. Pedestrian facilities (crosswalks, pedestrian signals) are provided for the northbound and eastbound approaches. **Figure 4** shows an aerial of the intersection.

Figure 4: Route 1 at Mary Washington Boulevard



Source: Google Imagery

2.2.5 Intersection 4: Route 1 at College Avenue / Eagle Village Drive

College Avenue is classified as Major Collector per *VDOT Functional Classification.* The intersection of Route 1 at College Avenue / Eagle Village Drive is currently a 4-leg signalized intersection. The posted speed limit for College Avenue and Eagle Village Drive is 25 miles per hour. The northbound approach of Route 1 has one left-turn lane, one through lane, and one shared thru-right lane. The southbound approach has one left-turn lane, two through lanes, and a right-turn lane. The eastbound approach of Eagle Village Drive has one left-turn lane and one shared thru-right lane. The westbound of College Avenue approach has one left-turn lane and one shared thru-right lane. The signal operations include permitted/protected lefts for the northbound approach, protected lefts for the southbound approach, and split phasing for the eastbound and westbound approaches. The northbound/southbound through movements are coordinated with adjacent signalized intersections. Pedestrian facilities (crosswalks, pedestrian signals) are provided for the southbound approach. **Figure 5** shows an aerial of the intersection.

Figure 5: Route 1 at Route 1 College Avenue / Eagle Village Drive

Source: Google Imagery

2.2.6 Intersection 5: Route 1 at Augustine Avenue / Powhatan Street

The intersection of Route 1 at Augustine Avenue / Powhatan Street is currently a 6-leg unsignalized intersection, with a service road running parallel to Route 1 to the west. Augustine Avenue, Eagle Village Driveway, and Powhatan Street are stop controlled while Route 1 is free-flow. Powhatan Street is classified as a Minor Collector per *VDOT Functional Classification.* There are no posted speed limits along these side roads. The northbound approach of Route 1 has one left-turn lane (hard left and soft left), one through lane, and one shared thru-right lane. The southbound approach has one hard left-turn lane, two through lanes, and one hard right-turn lane. The eastbound approach of the service road has one hard right-turn lane. The northwest approach of Augustine Avenue has one right-turn lane (hard right and soft right). The westbound approach of Powhatan Street has one hard right-turn lane. The southeast approach has of Augustine Avenue has one right-turn lane (hard right and soft right). Pedestrian facilities (crosswalks, pedestrian signals) are not currently provided at this intersection. **Figure 6** shows an aerial of the intersection.

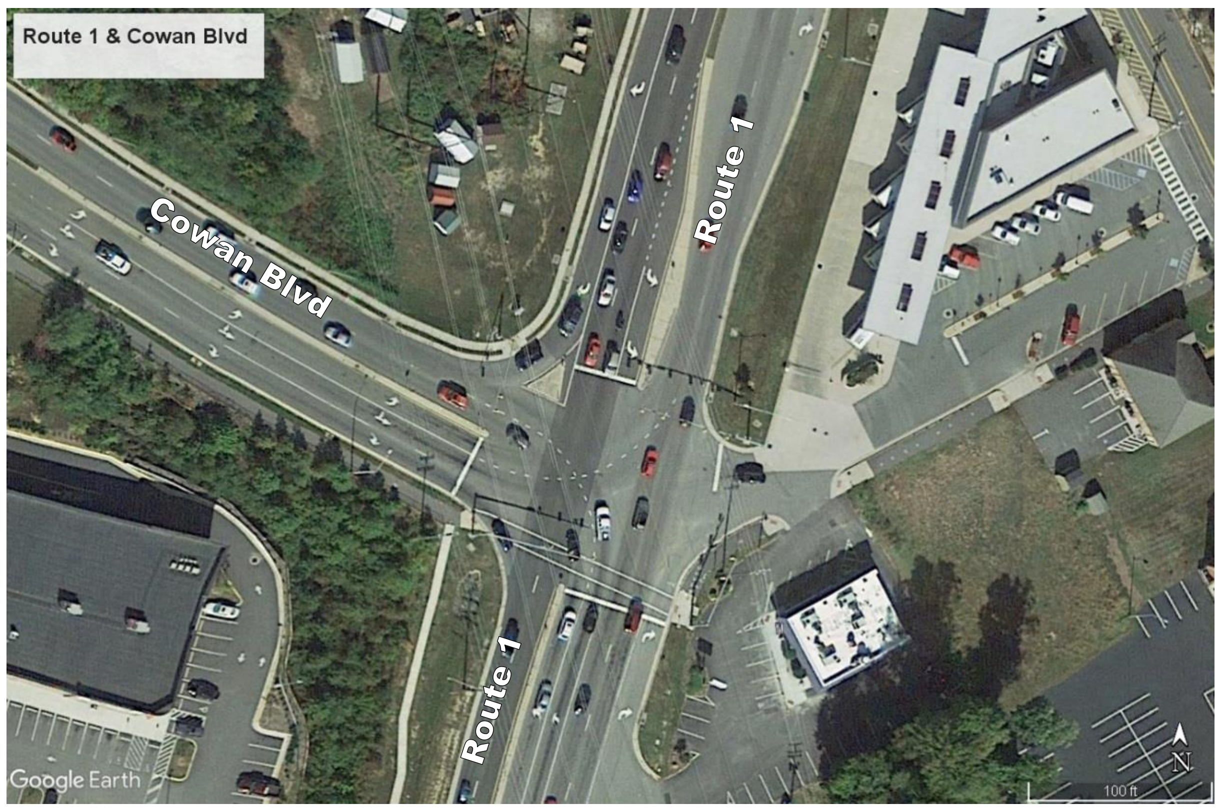
Figure 6: Route 1 at Augustine Avenue / Powhatan Street

Source: Google Imagery

2.2.7 Intersection 6: Route 1 at Cowan Boulevard

Cowan Blvd. is classified as Major Collector per *VDOT Functional Classification.* The intersection of Route 1 at Cowan Blvd is currently a 4-leg signalized intersection. The posted speed limit for Cowan Blvd is 35 miles per hour. The northbound approach of Route 1 has two left-turn lanes, two through lanes, and one right-turn lane. The southbound approach has one left-turn lane, two through lanes, and one channelized right-turn lane. The eastbound approach of Cowan Blvd has one left-turn lane, one shared left-thru lane, and one right-turn lane. The westbound approach has one shared left-thru-right lane. The signal operations include protected lefts for the northbound and southbound approaches and split phasing for the eastbound and westbound approaches, with the eastbound rights overlapping with the northbound lefts. The northbound/southbound through movements are coordinated with adjacent signalized intersections. Pedestrian facilities (crosswalks, pedestrian signals) are provided for the northbound approach. **Figure 7** shows an aerial of the intersection.

Figure 7: Route 1 at Cowan Boulevard



Source: Google Imagery

2.2.8 Intersection 7: Route 1 at Cowan Crossing / Spotsylvania Avenue

The intersection of Route 1 at Cowan Crossing / Spotsylvania Avenue is currently a 4-leg signalized intersection. The northbound approach of Route 1 has one left-turn lane, one through lane, and one shared thru-right lane. The southbound approach has one left-turn lane, two through lanes, and one right-turn lane. The eastbound approach of Cowan Crossing has one left-turn lane and one thru-right lane. The westbound approach of Spotsylvania Avenue has one left-turn lane and one thru-right turn lane. The signal operations include permitted/protected lefts for the northbound and southbound approaches and split phasing for the eastbound and westbound approaches, with the southbound rights overlapping with the eastbound approach. The northbound/southbound through movements are coordinated with adjacent signalized intersections. Pedestrian facilities (crosswalks, pedestrian signals) are currently not provided for this intersection. **Figure 8** shows an aerial of the intersection.

Figure 8: Route 1 at Cowan Crossing / Spotsylvania Avenue

Source: Google Imagery

2.3 Traffic Data

2.3.1 2017 Existing Traffic Volumes

Existing traffic volume data along the study corridor was collected in April 2017 while school was in session:

- 12-hour turning movement counts were collected in April 2017 from 6:00 am – 6:00 pm at the following intersections:
  - Route 1 / Hanson Ave / Princess Anne St
  - Route 1 / Fall Hill Ave
  - Route 1 / Mary Washington Blvd
  - Route 1 / Eagle Village Dr / College Ave
  - Route 1 / Augustine Avenue / Powhatan Street
  - Route 1 / Cowan Blvd
  - Route 1 / Cowan Crossing / Spotsylvania Ave

- Supplemental AM and PM peak period turning movement counts were collected in January 2018 while school was in session at the following locations:
  - Route 1 / Hanson Ave / Princess Anne St
  - Route 1 / Fall Hill Ave
  - Route 1 / Mary Washington Blvd
  - New traffic roundabout at Fall Hill Ave / Mary Washington Blvd

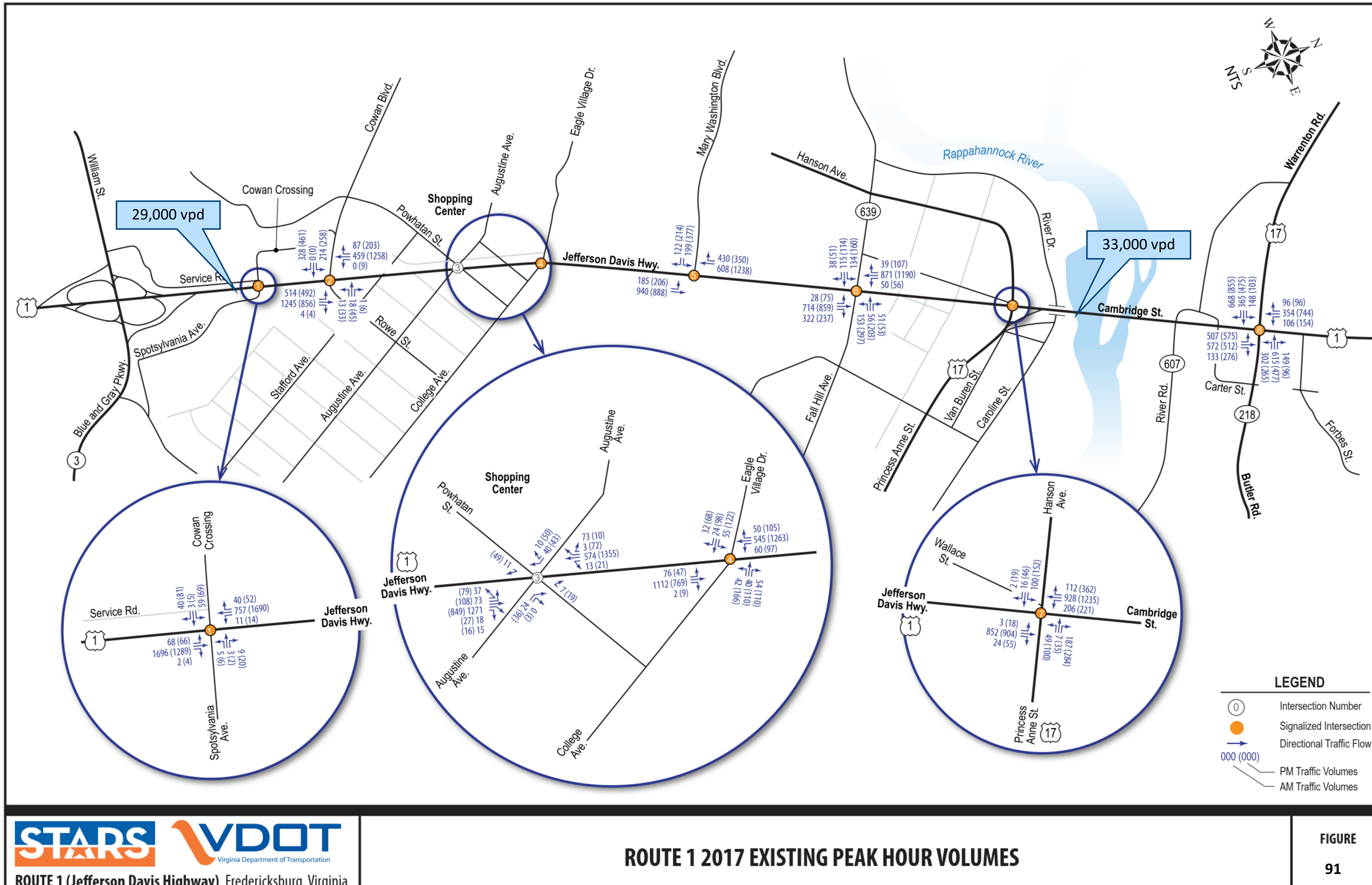
The field counts are enclosed with this report in the **Appendix**. The existing (2017) peak hour volumes and Average Daily Traffic (ADT) volumes are summarized in **Figure 9**.

2.3.2 Additional Data

In addition to traffic volumes, the following supplemental data was collected to support this study:

- Queue length measurements at selected signalized study area intersections to be used in the calibration of the existing Synchro/SimTraffic model.
- Peak period travel time runs for the entire corridor.
- Crash Data from the last five years to perform the crash analysis.
- Signal timing data from the City of Fredericksburg.

Figure 9. Existing (2017) Peak Hour and Average Daily Traffic Volumes



2.3.3 Existing Access Management

An evaluation of the existing driveways and access points along the study area corridor was completed to assess compliance with the current *VDOT Access Management Design Standards for Entrances and Intersections,* which is included as *Appendix F* of the *VDOT Roadway Design Manual*. The assessment involved an analysis of existing spacing of driveways and intersections and an evaluation of their compliance with VDOT minimum spacing standards for commercial entrances, intersections and median crossovers. **Table 1** provides a summary of the minimum spacing requirements for a Principal Arterial with a posted speed limit of 35 mph to 45 mph.

Table 1. Minimum Spacing Standards for Commercial Entrances, Intersections, and Median Crossovers

Highway Functional Classification	Minimum Centerline to Centerline Spacing (Feet)			
	Spacing between Signalized Intersections	Spacing between Unsignalized Intersections and Full/Directional Median Crossovers and Other Intersections or Median Crossovers	Spacing between Full Access Entrances and Other Full Access Entrances, Intersections, or Median Crossovers	Spacing between Partial Access Entrances (one or two-way) and Other Entrances, Intersections, or Median Crossovers
Principal Arterial	1,320	1,050	565	305

Source: VDOT Roadway Design Manual, Appendix F (Table 2-2)

A total of 50 access points are located within the study corridor of Route 1 north of the Route 3 (William Street) interchange to the Princess Anne Street / Hanson Avenue intersection. Most of these access points are closely spaced and serve commercial and retail parcels, with a small percentage serving residential parcels. Several strip malls have an entrance for every store front with less than 25 feet of sidewalk between entrances. These access points are shown graphically in the **Appendix** and identified as **AP1** through **AP50**. The spacing of these points was analyzed to assess their compliance with the VDOT minimum spacing standards shown in **Table 1**. **Table 2** below identifies the access points that do not meet the minimum spacing standard; as well as those that are compliant with the spacing standard.

Table 2. Access Points Analysis for the Corridor

Roadway	Number of Access Points	Per VDOT Spacing Guidelines	
		Compliant	Non-Compliant
Route 1	50	1 Total: AP4	49 Total: AP1 through AP3, AP5 through AP50

Note: Refer to the Appendix for graphical presentation of access points.

The spacing standards are not satisfied for 49 out of the 50 access point locations involving full/partial access driveways, entrances, median crossovers and intersections. The area serves urban/suburban land uses, with significant development along both sides of the roadway. Application of access management best practices would benefit corridor operations by reducing conflict points along the corridor.

3 Traffic Operational Analysis

3.1 Analysis Peak Periods

Weekday peak periods were identified from the count data for the arterial segments and for each study intersection. The common AM and PM peak hours for the overall network were determined based on the hourly variations in traffic volumes at each intersection, travel patterns along the study corridor and percentage of traffic during the highest hour. Based upon a review of the traffic count data, the following peak hours were identified for this study:

- AM Peak: 7:30 AM – 8:30 AM
- PM Peak: 4:30 PM – 5:30 PM

Peak Hour Factors (PHFs) were calculated for each overall intersection for the AM and PM peak hours using the turning movement count data. Similarly, heavy vehicle percentages were calculated for the AM and PM peak hours for each movement of the study intersections.

The supplemental counts performed at four locations in January, 2018 were incorporated into the model to account for any change in traffic patterns due to the new roundabout connection at Fall Hill Avenue and Mary Washington Blvd. The raw traffic counts were balanced throughout the network. Traffic volume balancing was required considering individual intersection peak hours and the resulting volume variations observed throughout the corridor. The peak hour traffic volumes were balanced using an iterative process of adjusting intersection approach and departure volumes until intersection volumes were within 10% for most movements. This 10% threshold could be exceeded for links with a significant number of access points (traffic generators or sinks) between the intersections.

3.2 Analysis Tools

Traffic operations analysis for the corridor was conducted using *Synchro 9.1* analysis software, as well as *SimTraffic,* which is a companion microsimulation tool for Synchro. The operational analysis was based on guidance provided in *VDOT Traffic Operations and Safety Analysis Manual (TOSAM), Version 1.0, November 2015 update.* Synchro is based on methodologies presented in *2010 Highway Capacity Manual*. SimTraffic was used to assess the traffic operations at the signalized and unsignalized intersections within the study area.

3.3 Measures of Effectiveness

The Measures of Effectiveness (MOEs) in traffic operations analysis quantify operational results and provides a basis for evaluating the performance of a transportation network. The MOEs reported for this study are consistent with TOSAM guidance for oversaturated conditions. A summary of the resulting Simtraffic MOEs evaluated for the study corridor is presented below:

- Maximum Queue Lengths (feet)
- Microsimulation Delay for each movement at intersections

Per the *TOSAM* guidance under *Section 8.6*, Highway Capacity Manual (HCM) Level of service (LOS) is not reported for intersections when utilizing simulation software such as *SimTraffic* as an analysis tool. Simulation software MOEs report microsimulation delay rather than the stochastic HCM delay. The microsimulation delay is reported for individual intersection movements as well as the overall delay for the intersection in **Table 3**. The overall intersection delay can be presented graphically by assigning color coding for ranges of microsimulation delay, which is a reference to *2010 Highway Capacity Manual* delay thresholds, but does not compare directly to Highway Capacity Software (HCS) deterministic results. The green, yellow and red color coding were assigned to delay thresholds for each study intersection.

Table 3: Intersection Color Coding based on Intersection Delay

Signalized Intersection Delay Thresholds (sec/veh)	Unsignalized Intersection Delay Thresholds (sec/veh)	Measure of Congestion	Color
< 10	< 10	Slight Delay	Green
> 10 – 20	> 10 – 15	Slight Delay	Green
>20 – 35	>15 – 25	Moderate Delay	Yellow
>35 – 55	>25 – 35	Moderate Delay	Yellow
>55 – 80	>35 – 50	Significant Delay	Red
>80	>50	Significant Delay	Red

Source of Delay Thresholds: Highway Capacity Manual 2010

3.4 Base Model Development and Calibration

AM and PM peak hour base *Synchro* models were developed using the data discussed under *Section 2.3.1* and following the guidance in *TOSAM*. The *SimTraffic* input parameters were in accordance with *Section 7.6.1* of *VDOT TOSAM* and included one 60-minute seed interval and four 15-minute recording intervals, with the PHF applied to the third interval. To account for simulation variance, 10 simulation runs were conducted and averaged together. The simulation settings remained at the default settings, with the exception of the headway factor for northbound movements in the PM peak in order to fine-tune model calibration.

To provide a more accurate representation of field conditions, the existing conditions *SimTraffic* models were calibrated to reasonably replicate balanced field observed traffic volumes and intersection queue lengths. This calibration process is an essential part of the model development as it ensures that the simulation reasonably replicates existing field conditions and can be used as the basis for the evaluation of future scenarios.

A summary of the volume, queue, and travel time calibration is provided in **Table 4**, with supporting documentation in the **Appendix**.

Table 4. Calibration Summary

Peak Period	Calibration Measure	Evaluation	Criteria	Total Number Evaluated	Total Number Met	Percent Met	Target Criteria	Target Met
AM	Volume (vph)	Turning Movements	Within ± 20% for < 100 vph Within ± 15% for ≥ 100 vph to < 300 vph Within ± 10% for ≥ 300 vph to < 1000 vph Within ± 5% for ≥ 1000 vph	90	85	94%	85%	Yes
	Queue Length	Turning Movements	Within ± 20% on oversaturated arterials	37	36	97%	85%	Yes
	Travel Time	Route	Within ± 30% on arterials	2	2	100%	85%	Yes
PM	Volume (vph)	Turning Movements	Within ± 20% for < 100 vph Within ± 15% for ≥ 100 vph to < 300 vph Within ± 10% for ≥ 300 vph to < 1000 vph Within ± 5% for ≥ 1000 vph	91	87	96%	85%	Yes
	Queue Length	Turning Movements	Within ± 20% on oversaturated arterials	37	33	89%	85%	Yes
	Travel Time	Route	Within ± 30% on arterials	2	2	100%	85%	Yes

3.4.1 Volume Calibration

The volume calibration results summary in **Table 4** shows that the calibration parameters are met for both AM and PM models. The full *SimTraffic* volume calibration results tables are shown in the **Appendix**. The volume calibration includes a comparison between simulated volumes (the average of 10 runs) and balanced field counts modeled in *Synchro* for the AM and PM Peak Hours. The tables show the difference and percentage difference between field counts and the average volumes from the simulation runs.

3.4.2 Queue Length Calibration

The queue calibration results summary in **Table 4** shows that the calibration parameters are met for both AM and PM models. The *SimTraffic* average queue calibration results tables are shown in the **Appendix.** The average queue length calibration includes a comparison between theoretical (simulated) average intersection queues obtained from an average of 10 simulation runs and the field measured average queues during the AM and PM peak hours.

3.4.3 Travel Time Calibration

The travel time calibration results summary in **Table 4** shows that the calibration parameters are met for both AM and PM models. The *SimTraffic* average travel time calibration results tables are shown in the **Appendix.** The average queue length calibration includes a comparison between theoretical (simulated) average corridor travel times obtained from an average of 10 simulation runs and the field measured average travel times during the AM and PM peak hours.

3.4.4 Microsimulation Sample Size

In addition to conducting proper model calibration, determining and applying an appropriate number of microsimulation runs is an important step in developing accurate microsimulation results. WSP followed the guidelines provided in *Section 5.4 of the VDOT TOSAM* and utilized the macro-enabled *VDOT Sample Size Determination Tool* to finalize the number of *SimTraffic* runs necessary for correctly reporting arterial and intersection MOEs. Ten *SimTraffic* microsimulation runs were initially recorded following the guidelines for *SimTraffic* Input Parameters found in *Section 7.6 of the VDOT TOSAM.* The Average Travel Speed obtained from each of these ten runs was then input into the VDOT Sample Size Determination Tool to verify that MOEs from these runs meet the required tolerance error and confidence interval. **Appendix** shows a screen capture of the *VDOT Sample Size Determination Tool*.

3.5 Intersection Operations: 2017 Existing Conditions

Traffic operations analyses were conducted using *SimTraffic* to evaluate overall performance of the study intersections and arterial segments within the corridor. *SimTraffic* run output reports provided a measure of movement delays and the maximum queues formed for each movement. Operational analyses were performed at each of the study intersections for the Existing 2017 Conditions scenario.

Microsimulation Delay in sec/veh was reported from *SimTraffic* for all the signalized and unsignalized intersections within the study area. The Microsimulation Delay includes the sum of the Total Delay per Vehicle (sec/vehicle) plus the Denied Delay per Vehicle (sec/vehicle) to account for any denied vehicles into the network.

Table 5 provides a summary of the AM and PM peak hour delay for each movement for the study intersections along the study corridor. **Figure 10** presents the overall intersection delay graphically with color coding to represent the average overall intersection delay. SimTraffic output sheets are provided in the **Appendix**.

The results from **Table 5** suggest that the following signalized intersections operate with an overall delay value that exceeds a moderate delay of 35 sec/veh:

Intersection 2 – US 1 and Cowan Boulevard/Rowe Street

- *Microsimulation delay of 41.1 sec/veh during the PM peak hour;*

Intersection 4 – US 1 and Eagle Village Drive/College Avenue

- Microsimulation delay of 42.7 sec/veh during the PM peak hour;

Intersection 6 – US 1 and Fall Hill Avenue

- Microsimulation delay of 55.6 sec/veh during the PM peak hour

Table 5. Existing (2017) SimTraffic AM and PM Peak Hour Delay (veh/sec)

Intersection Number and Description	Type of Control	Lane Group	Eastbound AM Delay	Eastbound PM Delay	Westbound AM Delay	Westbound PM Delay	Northbound AM Delay	Northbound PM Delay	Southbound AM Delay	Southbound PM Delay	Overall AM	Overall PM
1			Cowan Crossing		Spotsylvania Ave		US 1		US 1			
US 1 & Cowan Crossing / Spotsylvania Ave	Signal	Left	57.5	69.5	72.4	97.3	16.3	34.3	31.3	29.2	Delay	Delay
		Through	59.6	81.9	66.7	56.9	8.8	8.7	5.5	16.3		
		Right	8.9	28.1	14.4	18.9	7.4	4.5	3.3	9.6	9.3	15.4
		Approach	38.1	49.0	37.3	40.4	9.2	10.0	5.7	16.2		
2			Cowan Blvd		Rowe St		US 1		US 1			
US 1 & Cowan Blvd / Rowe St	Signal	Left	44.1	64.7	57.7	67.4	45.1	56.5	0.0	106.8	Delay	Delay
		Through	-	-	64.3	70.0	13.3	19.3	35.8	46.4		
		Right	18.1	44.7	23.9	37.2	1.8	2.8	4.3	13.1	25.8	41.1
		Approach	28.3	51.7	57.9	66.3	22.4	32.7	31.5	42.4		
3*			Powhatan St		Powhatan St		US 1		US 1			
US 1 & Powhatan St	Two-Way Stop	Left	-	-	-	-	12.9	53.7	14.6	14.3	Delay	Delay
		Through	-	-	-	-	3.7	1.1	2.7	6.8		
		Right	7.3	40.5	1.4	1.2	3.6	3.1	4.0	8.0	4.6	25.1
		Approach	7.3	40.5	1.4	1.2	4.6	13.6	3.2	6.9		
3*			Augustine Ave		Augustine Ave		US 1		US 1			
US 1 & Augustine Ave	Signal	Left	-	-	-	-	17.5	63.8	-	-	Delay	Delay
		Through	-	-	-	-	3.7	1.1	2.7	6.8		
		Right	13.5	711.7	31.0	25.1	3.6	3.7	3.2	7.0	4.6	25.1
		Approach	11.5	711.7	32.6	25.1	4.6	13.6	3.2	6.9		
4			Eagle Village Driveway		College Ave		US 1		US 1			
US 1 & College Ave / Eagle Village Drive	Signal	Left	55.7	64.0	52.9	70.8	17.4	56.8	62.4	98.4	Delay	Delay
		Through	50.1	74.8	53.0	67.1	13.5	28.6	12.0	38.2		
		Right	14.5	51.1	25.5	48.8	11.0	31.9	5.7	19.7	17.3	42.7
		Approach	41.7	64.4	42.0	63.7	13.7	30.1	15.5	40.8		
5			Mary Washington Blvd		-		US 1		US 1			
US 1 & Mary Washington Blvd	Signal	Left	40.0	58.1	-	-	55.9	47.7	-	-	Delay	Delay
		Through	-	-	-	-	12.7	9.7	23.1	34.5		
		Right	5.9	21.4	-	-	-	-	10.3	21.0	19.6	28.9
		Approach	27.2	44.7	-	-	19.1	16.5	17.9	31.7		
6			Fall Hill Ave		Fall Hill Ave		US 1		US 1			
US 1 & Fall Hill Ave	Signal	Left	47.5	59.5	49.6	91.6	30.8	66.8	24.8	78.1	Delay	Delay
		Through	47.6	60.1	43.6	84.1	14.4	30.7	19.4	65.2		
		Right	43.3	54.0	21.6	76.0	8.5	10.4	17.5	71.7	22.0	55.6
		Approach	46.8	58.8	42.5	87.5	13.2	29.1	19.6	66.3		

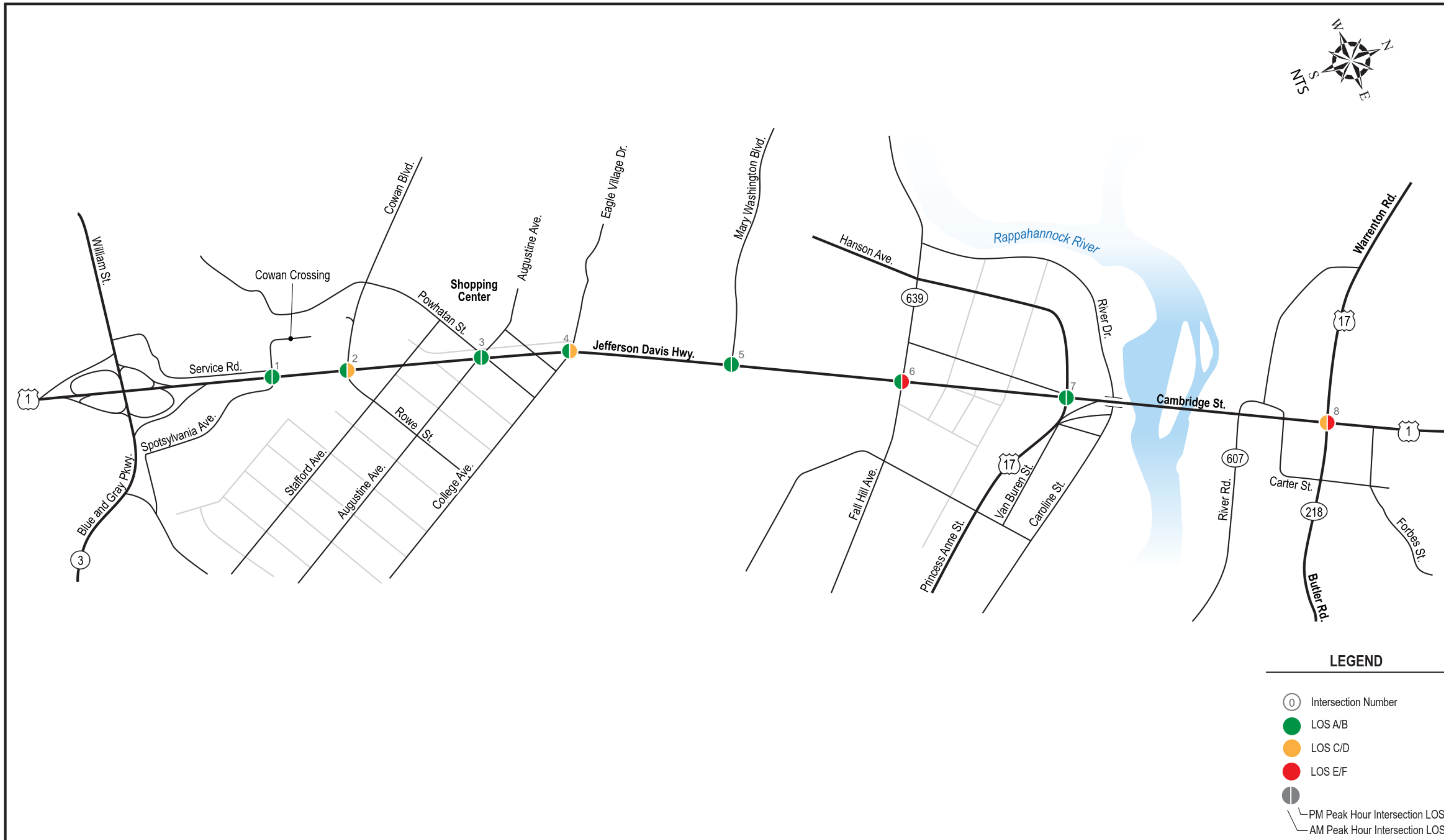
Intersection Number and Description	Type of Control	Lane Group	Eastbound		Westbound		Northbound		Southbound		Overall	
			AM	PM	AM	PM	AM	PM	AM	PM		
			Delay	Delay	Delay	Delay	Delay	Delay	Delay	Delay	AM	PM
7			Hanson Ave		Princess Anne St		US 1		US 1/Cambridge St			
US 1 & Hanson Ave / Princess Anne St	Signal	Left	55.9	70.1	60.9	69.1	31.5	44.3	22.3	50.1	Delay	Delay
		Through	49.7	64.3	52.0	64.8	22.0	26.6	12.4	31.0		
		Right	17.6	30.0	7.0	12.2	18.9	25.1	12.5	32.8	19.2	33.1
		Approach	54.6	66.1	19.8	30.3	22.0	26.8	14.0	33.6		

Note: Micro-simulation delay (sec/veh) results shown represent an average of 10 SimTraffic simulations runs and includes Total Delay plus Denied Delay in Seconds per vehicle

'-' Movements not applicable OR SimTraffic does not provide level of service or delay for movements with no conflicting volumes

**Intersection 3 is a 6-leg intersection and is listed twice to show Powhatan St & Augustine Ave MOEs separately*

Figure 10. Existing 2017 AM (PM) Peak Hour Intersection Operations Results



ROUTE 1 (Jefferson Davis Highway), Fredericksburg, Virginia

ROUTE 1 2017 EXISTING PEAK HOUR LEVEL OF SERVICE

FIGURE 10

Queue length, or the distance to which stopped vehicles accumulate in a lane at an intersection, is another performance measure of intersection operations. Lengthy queues may be indicative of intersection capacity or operational issues, such as absence of or insufficient dedicated turn lanes, inefficient signal timings or phasing. A queuing analysis was completed for the study intersections during the AM and PM peak hours. SimTraffic Maximum Queue Lengths in feet were reported for each lane. These queue lengths are based on an average of 10 simulation runs. **Table 6** provides a summary of the maximum queue lengths during the AM and PM peak hours as compared to the available storage bay lengths. The queue lengths in red text in **Table 6** are the movements in which the reported maximum queue lengths value exceeds the storage length available for that turning movement. The *SimTraffic* output sheets including the maximum queue lengths are included in the **Appendix**.

The movements in which the maximum queue exceeds the available storage bay length are summarized below:

Intersection 1 – US 1 and Cowan Crossing/Spotsylvania Avenue

- Eastbound left-turning movement (existing storage bay length of 100 ft.) indicates maximum queue lengths of 102 ft. and 120 ft. during the AM and PM peak hour, respectively. Storage length is limited by the Jefferson Davis Highway Service Road, which runs west of US 1 and intersects Cowan Crossing just west of the intersection.
- Southbound right-turning movement (existing storage bay length of 215 ft.) indicates a maximum queue length of 239 ft. in the PM peak.

Intersection 2 – US 1 and Cowan Boulevard / Rowe Street

- Northbound left-turning movement (existing storage bay length of 325 ft.) indicates a maximum queue length of 341 ft. Similar queues of 375 ft. were observed during PM peak hour field measurements.
- Southbound right-turning movement (existing storage 425 ft.) indicates a maximum queue length of 450 ft. during the PM peak.

Intersection 4 – US 1 and Eagle Village Drive/College Avenue

- Westbound left turning movement (existing storage 115 ft.) indicates a maximum queue length of 140 ft. during the PM peak hour. Similar queues of 140 ft. were observed during PM peak hour field measurements.
- Northbound left turning movement (existing storage 115 ft.) indicates a maximum queue length of 133 ft. during the AM peak hour and 140 ft. during the PM peak hour.
- Southbound right turning movement (existing storage 310 ft.) indicates a maximum queue length of 335 ft. during the PM peak hour.

Intersection 5 – US 1 and Mary Washington Boulevard

- Southbound right turning movement (existing storage 270 ft.) indicates a maximum queue length of 295 ft. during the PM peak hour

Intersection 6 – US 1 and Fall Hill Avenue

- Westbound left turning movement (existing storage 285 ft.) indicates a maximum queue length of 310 ft. during the PM peak hour. The SimTraffic data also indicates that upstream blockages occurred on the westbound approach. Similar queues of 275 ft. were observed during PM peak hour field measurements.
- Northbound right turning movement (existing storage 220 ft.) indicates a maximum queue length of 228 ft. during the AM peak hour and 245 ft. during the PM peak hour.
- Southbound left turning movement (existing storage 180 ft.) indicates a maximum queue length of 191 ft. during the AM peak hour and 205 ft. during the PM peak hour.

Intersection 7 – US 1 and Hanson Avenue/Princess Anne Street

- Westbound left turning movement (existing storage 100 ft.) indicates a maximum queue length of 116 ft. during the AM peak hour and 124 ft. during the PM peak hour. The SimTraffic data also indicates that upstream blockages occurred on the westbound approach. Similar queues of 150 ft. were observed during PM peak hour field measurements.
- Westbound right turning movement (existing storage 60 ft.) indicates a maximum queue length of 83 ft. during the AM peak hour and 85 ft. during the PM peak hour. This movement is essentially a long-channelized right-turn lane.
- Southbound left turning movement (existing storage 120 ft.) indicates a maximum queue length of 145 ft. during both the AM and PM peak hour.

Table 6. 2017 Existing Conditions: Summary of Maximum Queues (feet)

Intersection Number and Description	Type of Control	Lane Group	Eastbound			Westbound			Northbound			Southbound		
			Storage Bay Length	AM Queue (ft)	PM Queue (ft)	Storage Bay Length	AM Queue (ft)	PM Queue (ft)	Storage Bay Length	AM Queue (ft)	PM Queue (ft)	Storage Bay Length	AM Queue (ft)	PM Queue (ft)
1 US 1 at Cowan Crossing / Spotsylvania Ave			Cowan Crossing			Spotsylvania Ave			US 1			US 1		
	Signal	Left	100	102	120	50	28	32	175	171	168	175	48	73
		Through	--	67	161	--	43	60	--	441	367	--	182	556
		Right							--	357	312	215	62	239
2 US 1 at Cowan Blvd / Rowe St			Cowan Blvd			Rowe St			US 1			US 1		
	Signal	Left	375	182	301	--	101	176	325	319	341	125		82
		Through	--			--			--	324	488	--	305	621
		Right	--	257	474	--			360	23	34	425	87	450
3* US 1 at Powhatan St / Augustine Ave			Powhatan St			Powhatan St			US 1			US 1		
	Two-Way Stop	Left	-	-	--	-	-	--	275	110	267	50	25	21
		Through	-	-	--	-	-	--	-	6	288	-	49	76
		Right	-	37	96	-	21	21	-	5	92	-	35	28
3* US 1 at Powhatan St / Augustine Ave			Augustine Ave			Augustine Ave			US 1			US 1		
	Two-Way Stop	Left	-	-	--	-	-	--	275	110	267	-	25	21
		Through	-	-	--	-	-	--	-	6	288	-	49	76
		Right	-	42	496	-	35	49	-	5	92	-	35	28
4 US 1 at Eagle Village Drive / College Ave			Eagle Village Driveway			College Avenue			US 1			US 1		
	Signal	Left	-	107	210	115	111	140	115	133	140	500	107	413
		Through	-	83	270	-	142	442		388	449	-	282	795
		Right	-			-				402	446	310	90	335
5 US 1 at Mary Washington Blvd			Mary Washington Blvd			-			US 1			US 1		
	Signal	Left	650	172	299	-	-	--	415	175	147	-	-	--
		Through	-	-	--	-	-	--	-	364	222	-	289	751
		Right	-	75	190	-	-	--	-	-	--	270	257	295
6 US 1 at Fall Hill Ave			Fall Hill Ave			Fall Hill Ave			US 1			US 1		
	Signal	Left	-	334	401	285	201	310	300	73	275	180	191	205
		Through	-			-	155	619	-	298	449	-	310	773
		Right	285	163	274	-			220	228	245	-	340	797
7 US 1 at Hanson Ave / Princess Anne St			Hanson Ave			Princess Anne St			US 1			US 1 / Cambridge St		
	Signal	Left	-	149	242	100	116	124	120	46	116	120	145	145
		Through	-	69	151	-	131	314	-	381	467	-	270	563
		Right	-			60	83	85	-	370	474	-	285	597

NOTE: Shared lane groups are shown as merged cells

Micro-simulation maximum queues (ft) shown represent an average of 10 SimTraffic simulations runs

Red text indicates maximum queues that exceed storage capacity

"-" Cells indicate that a queue or turn bay did not exist

* Intersection 3 is a 6-leg intersection and is listed twice to show Powhatan St & Augustine Ave MOEs separately

3.6 Future Traffic Volumes

The existing traffic volumes were forecasted to the Future Year 2030, which was determined by the SWG as the design year for the improvements suggested by this study. Projecting the traffic volumes at the study intersections to the design year with an appropriate growth rate was the first step in developing future conditions analysis.

3.6.1 Traffic Forecasting Methodology

Along the study corridor, four segments of Route 1 are regularly measured, each yielding a different historic growth rate. Over the past 20 years, the range of historic growth rates is from less than 0.25% on the southern and northern ends of the corridor study to a maximum rate of about 1.25% between Fall Hill Avenue and Princess Anne Street. The overall Annual Growth Rate (AGR) for the corridor over the past two decades is approximately 0.5%.

From 2010-2011, positive growth has been observed on all segments, with the busiest segment (Fall Hill Avenue to Princess Anne Street) growing at over 3.50%. The remaining three segments showed more moderate AGRs of about 0.75% - 1.50%, over the past six years. The overall average of the four segments over the recent period is approximately 1.75%.

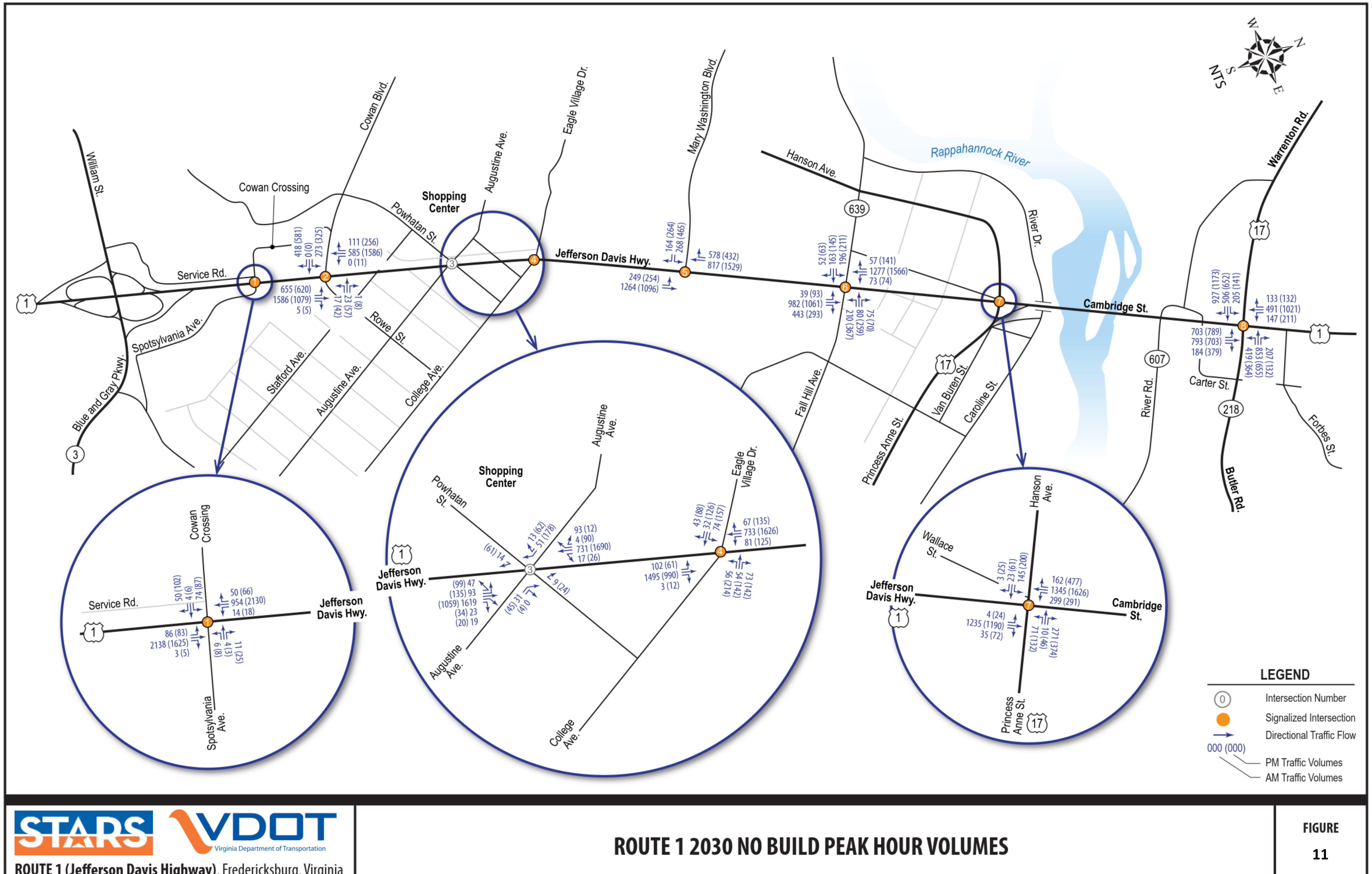
Although the growth rate throughout the corridor is expected to level-out in the future, the range along the corridor currently differs from segment to segment. The recommended growth rate for each segment is shown in **Table 7**.

Table 7. VDOT Recommended Growth Rate

City	Route	From	To	VDOT Recommended Growth Rate
Fredericksburg	1	Route 3	College Avenue	1.5%
Fredericksburg	1	College Avenue	Fall Hill Avenue	1.5%
Fredericksburg	1	Fall Hill Avenue	Princess Anne Street	2.0%
Fredericksburg	1	Princess Anne Street	Falmouth	2.0%

Based on the historic AADT data, review of VDOT recommended growth forecasts, and an understanding of the potential for development in the study area, the suggested growth rate of 1.5% from Route 3 to Fall Hill Avenue and 2.0% from Fall Hill Avenue to Falmouth were applied to the Existing 2017 traffic volumes to generate projected 2030 AM and PM peak hour traffic volumes. These growth rates put a weighted emphasis on the recent growth trend while applying a moderating factor and incorporating regionally funded projects in the area. The recent completion of Fall Hill Avenue construction and the resulting traffic increase expected to utilize that alternative also supports this projection. The 2030 peak hour volume projections are presented in **Figure 11**.

Figure 11. Future 2030 AM (PM) Peak Hour Traffic Volumes



3.7 Intersection Operations: 2030 Future No-Build Conditions

Operational analysis was performed at each of the study intersections for the 2030 Future No-Build Conditions scenario. **Table 8** provides a summary of the average AM and PM peak hour delay for each movement for the study intersections along the study corridor.

Queuing analysis was completed for the study intersections during the AM and PM peak hours for 2030 No-Build conditions. **Table 9** provides a summary of the maximum queue lengths reported by SimTraffic during the AM and PM peak hours for Route 1. The queue lengths are based on an average of 10 simulation runs.

Table 8. Future 2030 No Build SimTraffic AM and PM Peak Hour Delay (veh/sec)

Intersection Number and Description	Type of Control	Lane Group	Eastbound		Westbound		Northbound		Southbound		Overall	
			AM	PM	AM	PM	AM	PM	AM	PM		
			Delay	Delay	Delay	Delay	Delay	Delay	Delay	Delay	AM	PM
1			Cowan Crossing		Spotsylvania Ave		US 1		US 1			
US 1 & Cowan Crossing / Spotsylvania Ave	Signal	Left	58.5	76.6	71.0	80.1	22.1	86.0	53.3	43.5	Delay	Delay
		Through	50.6	71.8	61.7	67.9	16.5	40.5	5.5	11.0		
		Right	13.8	39.8	38.6	51.9	12.2	19.7	3.5	6.4	17.4	29.0
		Approach										
2			Cowan Blvd		Rowe St		US 1		US 1			
US 1 & Cowan Blvd / Rowe St	Signal	Left	52.1	99.6	58.9	74.8	57.0	157.3	0.0	187.7	Delay	Delay
		Through	--	--	58.3	73.9	12.7	36.5	21.8	80.3		
		Right	14.1	126.5	20.7	52.1	5.3	10.9	3.8	40.8	24.9	86.6
		Approach										
3*			Powhatan St		Powhatan St		US 1		US 1			
US 1 & Powhatan St	Two-Way Stop	Left	--	--	--	--	15.2	111.2	23.4	18.5	Delay	Delay
		Through	--	--	--	--	4.1	12.7	2.7	7.6		
		Right	7.7	46.4	0.9	1.5	3.8	8.1	4.3	10.7	5.6	149.2
		Approach										
3*			Augustine Ave		Augustine Ave		US 1		US 1			
US 1 & Augustine Ave	Signal	Left	--	--	--	--	19.6	131.2	--	--	Delay	Delay
		Through	--	--	--	--	4.1	12.7	2.7	7.6		
		Right	16.7	1871.8	63.3	28.9	4.4	7.6	3.2	7.4	5.6	149.2
		Approach										
4			Eagle Village Driveway		College Ave		US 1		US 1			
US 1 & College Ave / Eagle Village Drive	Signal	Left	74.9	71.9	55.6	322.9	23.4	92.0	58.6	100.1	Delay	Delay
		Through	72.9	89.6	53.8	334.7	15.7	46.3	15.1	32.5		
		Right	30.6	69.7	31.5	312.6	15.7	51.8	7.3	31.9	20.9	87.1
		Approach										
5			Mary Washington Blvd		-		US 1		US 1			
US 1 & Mary Washington Blvd	Signal	Left	45.1	74.2	--	--	28.7	73.7	--	--	Delay	Delay
		Through	--	--	--	--	8.4	14.4	24.6	20.5		
		Right	7.4	26.5	--	--	--	--	14.8	13.8	17.7	29.5
		Approach										
6			Fall Hill Ave		Fall Hill Ave		US 1		US 1			
US 1 & Fall Hill Ave	Signal	Left	63.4	294.6	53.8	14.4	37.0	95.2	40.2	45.5	Delay	Delay
		Through	63.5	303.0	48.1	20.5	23.2	29.3	37.5	36.4		
		Right	54.5	279.9	26.5	13.8	10.4	15.9	41.4	39.6	34.0	138.0
		Approach										

Intersection Number and Description	Type of Control	Lane Group	Eastbound		Westbound		Northbound		Southbound		Overall	
			AM	PM	AM	PM	AM	PM	AM	PM		
			Delay	Delay	Delay	Delay	Delay	Delay	Delay	Delay	AM	PM
7			Hanson Ave		Princess Anne St		US 1		US 1/Cambridge St			
US 1 & Hanson Ave / Princess Anne St	Signal	Left	63.3	115.5	64.1	509.1	48.7	71.8	48.7	274.3	Delay	Delay
		Through	51.0	68.9	65.6	502.1	19.7	41.0	18.5	217.0		
		Right	26.2	43.3	15.5	435.0	14.0	37.0	18.1	225.5	24.1	192.8
		Approach										

Note: Micro-simulation delay (sec/veh) results shown represent an average of 10 SimTraffic simulations runs and includes Total Delay plus Denied Delay in Seconds per vehicle

'-' Movements not applicable OR SimTraffic does not provide level of service or delay for movements with no conflicting volumes

**Intersection 3 is a 6-leg intersection and is listed twice to show Powhatan St & Augustine Ave MOEs separately*

Figure 12. Future 2030 No Build AM (PM) Peak Hour Intersection Operations Results

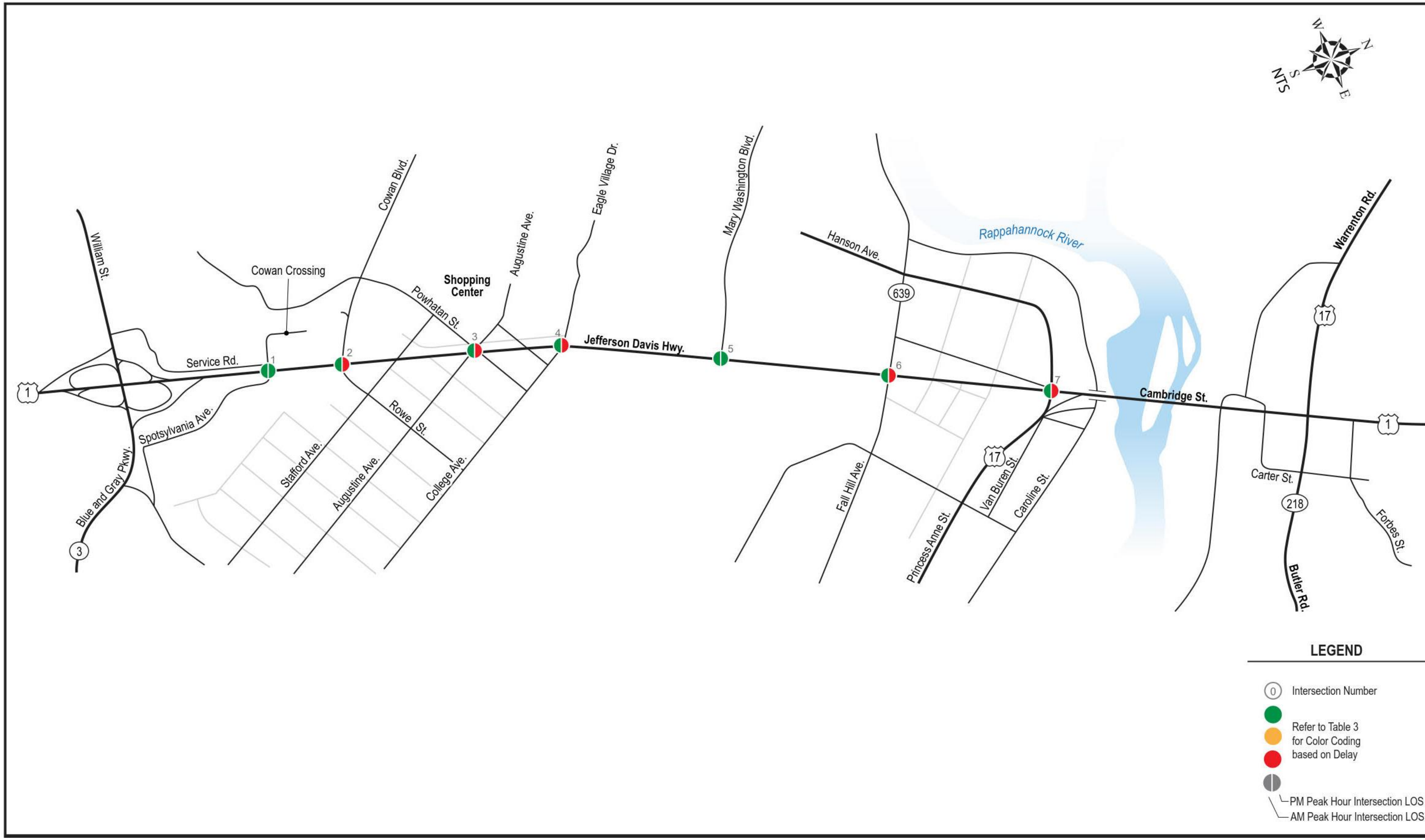


Table 9. Future 2030 No Build Conditions: Summary of Maximum Queues

ntersection Number and Description	Type of Control	Lane Group	Eastbound			Westbound			Northbound			Southbound		
			Storage Bay Length	AM Queue (ft)	PM Queue (ft)	Storage Bay Length	AM Queue (ft)	PM Queue (ft)	Storage Bay Length	AM Queue (ft)	PM Queue (ft)	Storage Bay Length	AM Queue (ft)	PM Queue (ft)
1 US 1 at Cowan Crossing / Spotsylvania Ave			Cowan Crossing			Spotsylvania Ave			US 1			US 1		
	Signal	Left	100	96	99	200	184	198	175	530	526	175	126	340
		Through	--	134	212	--	150	264	--	663	677	--	141	337
		Right							--	672	683	215	24	160
2 US 1 at Cowan Blvd / Rowe St			Cowan Blvd			Rowe St			US 1			US 1		
	Signal	Left	375	205	495	--	108	198	325	324	325	--	--	56
		Through	--	--	--	--	52	51	--	528	596	--	296	1,031
		Right	--	297	647	--			360	49	130	425	62	425
3* US 1 at Powhatan St / Augustine Ave			Powhatan St			Powhatan St			US 1			US 1		
	Two-Way Stop	Left	--	--	--	--	--	--	275	147	250	50	24	28
		Through	--	--	--	--	--	--	--	6	735	-	63	151
		Right	--	33	114	--	74	44	--	9	682	-	30	27
3* US 1 at Powhatan St / Augustine Ave			Augustine Ave			Augustine Ave			US 1			US 1		
	Two-Way Stop	Left	--	--	--	--	--	--	250	147	250	50	24	28
		Through	--	--	--	--	--	--	--	6	735	-	63	151
		Right	--	54	496	--	74	69	--	9	682	-	30	27
4 US 1 at Eagle Village Drive / College Ave			Eagle Village Driveway			College Avenue			US 1			US 1		
	Signal	Left	--	138	258	115	107	115	115	114	115	500	145	364
		Through	--	146	387	--	183	590	--	432	532	--	288	715
		Right	--			--			--	450	542	310	134	310
5 US 1 at Mary Washington Blvd			Mary Washington Blvd			-			US 1			US 1		
	Signal	Left	650	194	410	--	--	--	415	135	265	--	--	--
		Through	--	--	--	--	--	--	--	229	354	--	513	623
		Right	--	116	246	--	--	--	--	--	--	270	270	270
6 US 1 at Fall Hill Ave			Fall Hill Ave			Fall Hill Ave			US 1			US 1		
	Signal	Left	--	469	940	285	250	285	310	147	309	180	180	179
		Through	--			--	213	742	--	417	623	--	470	575
		Right	250	262	250	--			220	220	220	--	478	575
7 US 1 at Hanson Ave / Princess Anne St			Hanson Ave			Princess Anne St			US 1			US 1 / Cambridge St		
	Signal	Left	--	214	443	100	100	100	120	39	113	120	120	120
		Through	--	92	187	--	250	574	--	366	484	--	470	2,294
		Right	--			60	69	64	--	360	483	--	478	2,308
8 US 1 at US Bus. 17 (Warrenton Rd) / Route 218 (Butler Rd)			--			Route 218 (Butler Rd)			US 1			US 1		
	Signal	Left	240	240	240	230	230	1,862	250	250	250	425	319	425
		Through	--	1,824	2,450	--	1,865	2,054	--	1,724	1,873	--	412	2,460
		Right	--	1,867	2,448	--	1,864	2,048	180	180	180	250	250	250

NOTE: Shared lane groups are shown as merged cells
Micro-simulation maximum queues (ft) shown represent an average of 10 SimTraffic simulations runs
Red text indicates maximum queues that exceed storage capacity
"-" Cells indicate that a queue or turn bay did not exist
* Intersection 3 is a 6-leg intersection and is listed twice to show Powhatan St & Augustine Ave MOEs separately

4 Safety Analysis

In addition to the operational analysis, a safety analysis was performed along Route 1 from north of Route 3 (William Street) to Route 17 Bus/Route 218/Warrenton Road/Butler Road, in the City of Fredericksburg. The safety analysis, which included a review of crash data and existing field conditions, was conducted to identify and evaluate potential safety areas of improvement that occur along the roadway segment, determine the likely factors contributing to crashes, and propose potential mitigation activities.

4.1 Procedure

Crash data for the most recent five (5) years (August 30, 2012 through August 30, 2017) were obtained from VDOT's *Crashtools* Database. The crash data were evaluated to identify crash locations and patterns, severity of crashes, and likely causes for crashes. As part of the crash analysis, collision diagrams illustrating all crashes by year were developed and are included in the **Appendix**. The crash data and collision diagrams were examined to identify crash locations on which to focus during field reviews. Field reviews were conducted, with particular focus on the crash patterns, to evaluate conditions in the field that could be influencing the crash locations shown in the collision diagrams. The crash data were used to identify an AM Peak period (7:30AM–8:30AM) and a PM Peak period (4:30PM–5:30PM), during which the highest number of crashes occurred.

The crash data analysis will be used to identify factors that could potentially contribute to crashes. The crash data analysis findings describe trends in the data regarding the year, time of day, type of crash, and roadway condition.

4.2 Crash Data Analysis

4.2.1 Crashes by Year

A total of 561 crashes occurred from north of Route 3 (William Street) to Route 17 Bus/Route 218/Warrenton Road/Butler Road between August 30, 2012 and August 30, 2017, as shown in **Figure 13**. Note that the 2012 and 2017 bars are striped since the data does not include a full calendar year. The AADT values were used to associate the traffic volume with crashes per year, as shown in **Figure 13** (i.e. orange line). The AADT values steadily increased from 2013 to 2016, and the total number of crashes moderately fluctuated between 2013 and 2015 and then peaked in 2016.

Additionally, **Figure 14** shows that 145 non-visible injuries (26%) and 100 visible injuries (18%) occurred in the study area within the five-year period. The majority of crashes that occurred were property damage only, which accounted for 52% of all crashes. **Figure 15** provides a crash heat map of the overall corridor.

Figure 13. Number of crashes per year for the project study area.

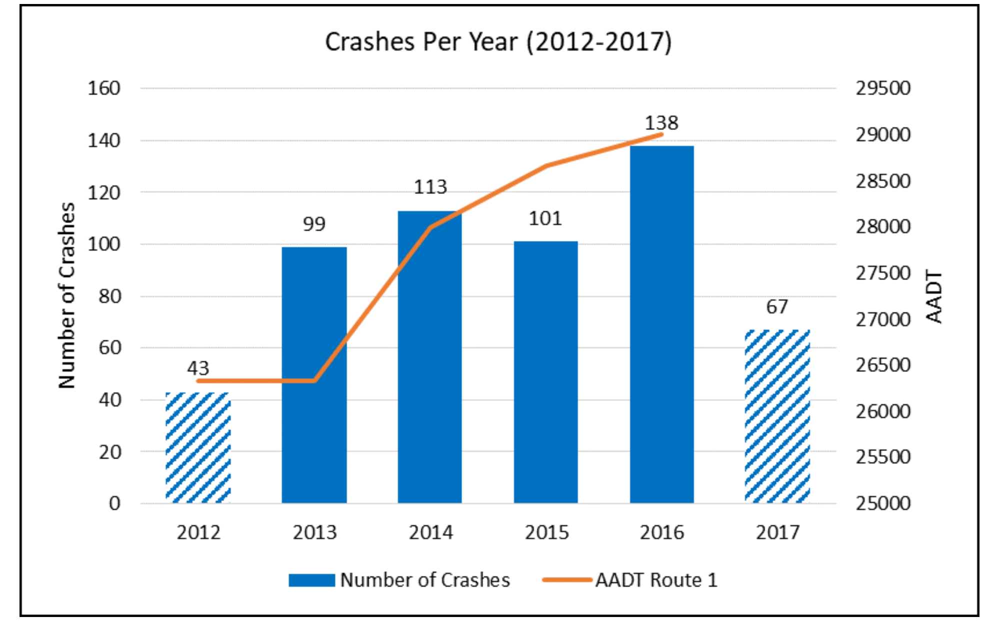


Figure 14. Severity of crashes for the project study area.

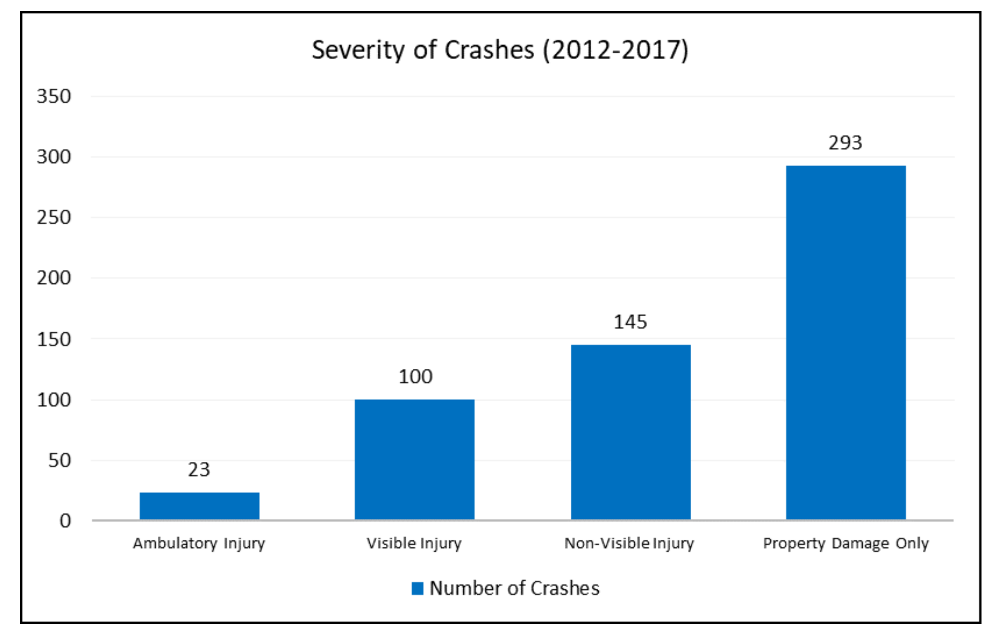
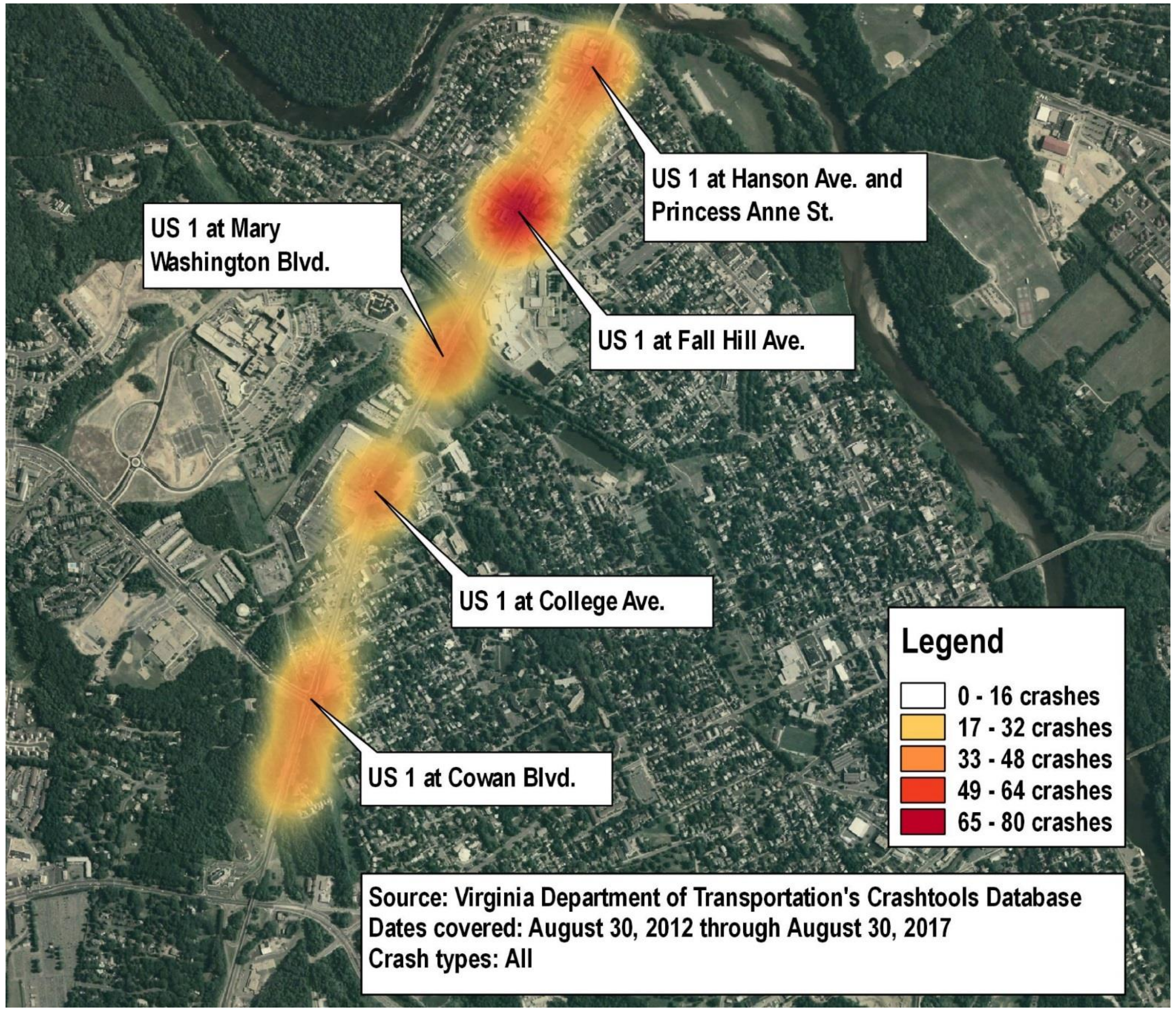


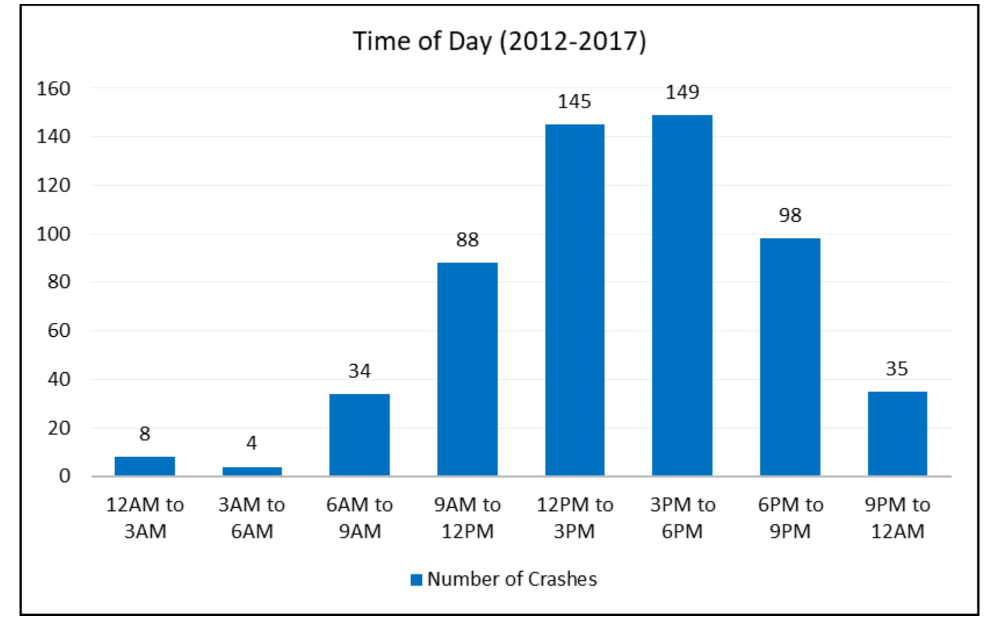
Figure 15. Crash Heat Map for Route 1 (2012-2017).



4.2.2 Crashes by Time of Day

Figure 16 displays the number of crashes that occurred by time of day, presented in 3-hour increments. The highest frequency of crashes occurred from 3PM–6PM (27%), from 12PM–3PM (26%), from 6PM–9PM (17%), and from 9AM–12PM (16%).

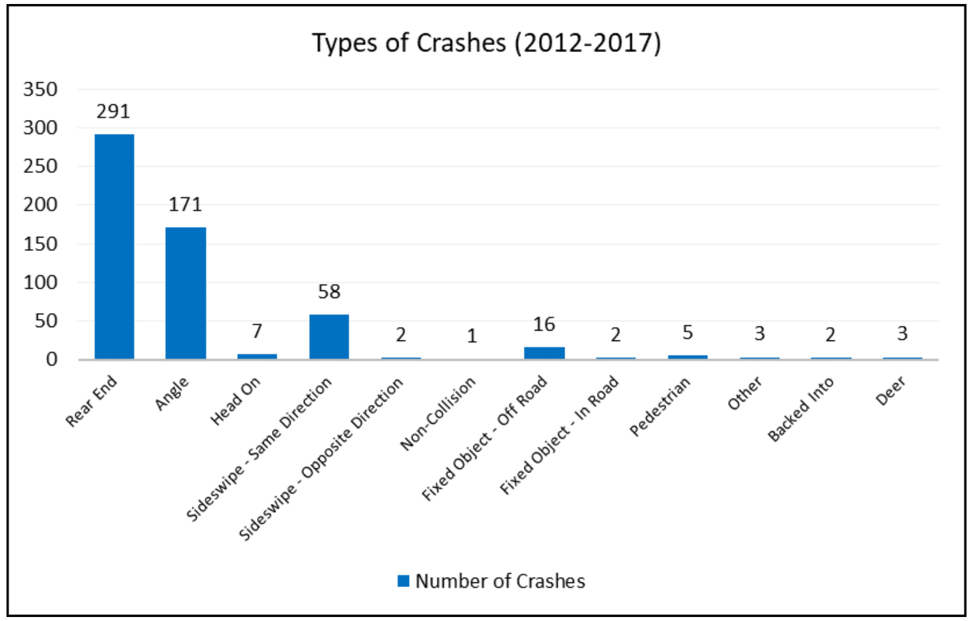
Figure 16. Number of crashes by time of day for the project study area.



4.2.3 Crashes by Type

As shown in **Figure 17**, the majority of crashes that occurred were rear-end crashes (52%), followed by angle crashes (30%), side-swipe – same direction crashes (10%), and fixed object – off road crashes (3%); the remaining crash types each accounted for approximately 1% of the overall crashes. It should be noted that 39 of the crashes (e.g., side-swipe and angle crashes) were incorrectly categorized within the *Crashtools* database. Crash classifications were corrected and updated based on the crash descriptions provided within the database to ensure an accurate crash type analysis.

Figure 17. Number of crashes by type of crash for the project study area.



Based on the collision diagrams that were reviewed, **Table 10** provides a summary of the most prominent crash locations along the route.

Table 10. Crash patterns along the project study area.

Location (Intersection, Segment)	Intersection Approach / Leg / Ramp	Most Prominent Crash Type(s)	Vulnerable Road User Crashes	Year(s)	Total Crashes (Highest Crash Type %)
Route 1 at Spotsylvania Avenue	NB approach / south leg	Rear-end, side-swipe	1 Pedestrian on south leg (2016)	2013-2016	27 total (63% rear-end)
Route 1 at Cowan Boulevard	NB approach	Rear-end	N/A	2016	5 total (60% rear-end)
Route 1 at College Avenue/Eagle Village Drive	SB approach	Rear-end	N/A	2013	6 total (100% rear-end)
	NB approach	Angle	N/A	2015	5 total (80% angle)
Route 1 at Mary Washington Boulevard	NB approach	Rear-end, angle	N/A	2014-2015	9 total (45% rear-end, 45% angle)
	SB approach	Rear-end	N/A	2015-2016	10 total (90% rear-end)
Route 1 at Fall Hill Avenue	NB approach	Rear-end, angle	1 Pedestrian (2015)	2013-2016	23 total (57% rear-end)
	SB approach	Rear-end	N/A	2013; 2016	10 total (60% rear-end)
Route 1 at Hanson Avenue	SB approach	Angle	N/A	2013-2016	18 total (78% angle)
Route 1 at Route 17 Bus/Route 218/Warrenton Road/Butler Road	NB approach	Rear-end	1 Pedestrian (2017)	2013; 2017	10 total (60% rear-end)
	SB approach	Rear-end	N/A	2013	4 total (75% rear-end)
	SB lanes	Rear-end, angle	N/A	2014	7 total (43% rear-end, 43% angle)
	EB approach	Rear-end	N/A	2015-2017	19 total (79% rear-end)

4.2.4 Crashes by Roadway and Weather Conditions

Figure 18 indicates the number of crashes by roadway surface condition. The majority (80%) of crashes occurred during dry roadway conditions. Wet conditions accounted for 19% of crashes. Additionally, **Figure 19** shows that most of the collisions occurred under clear/cloudy weather conditions (83%), followed by rainy weather conditions (14%).

Figure 18. Number of crashes by roadway surface condition for the project study area.

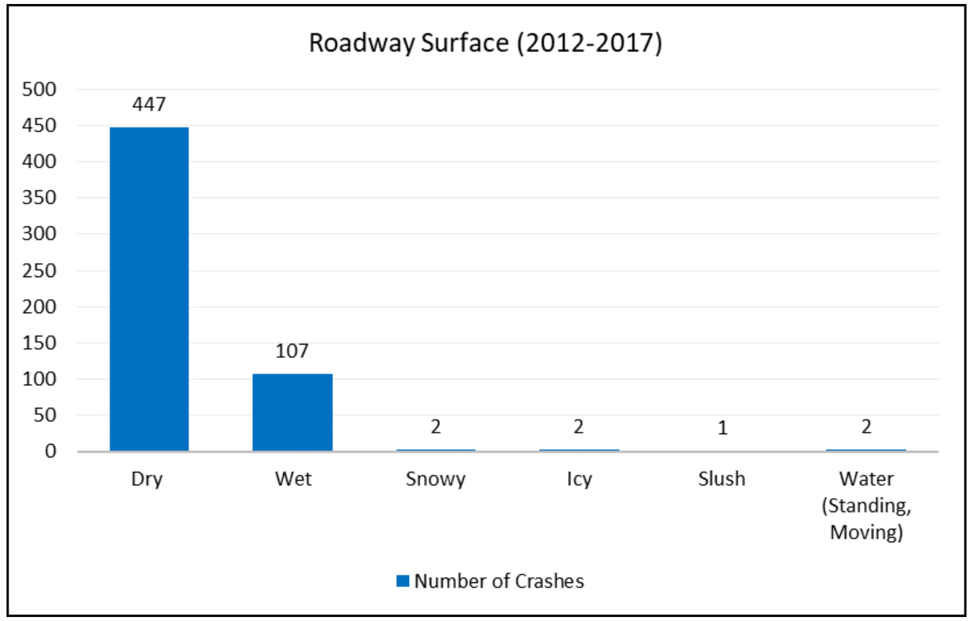
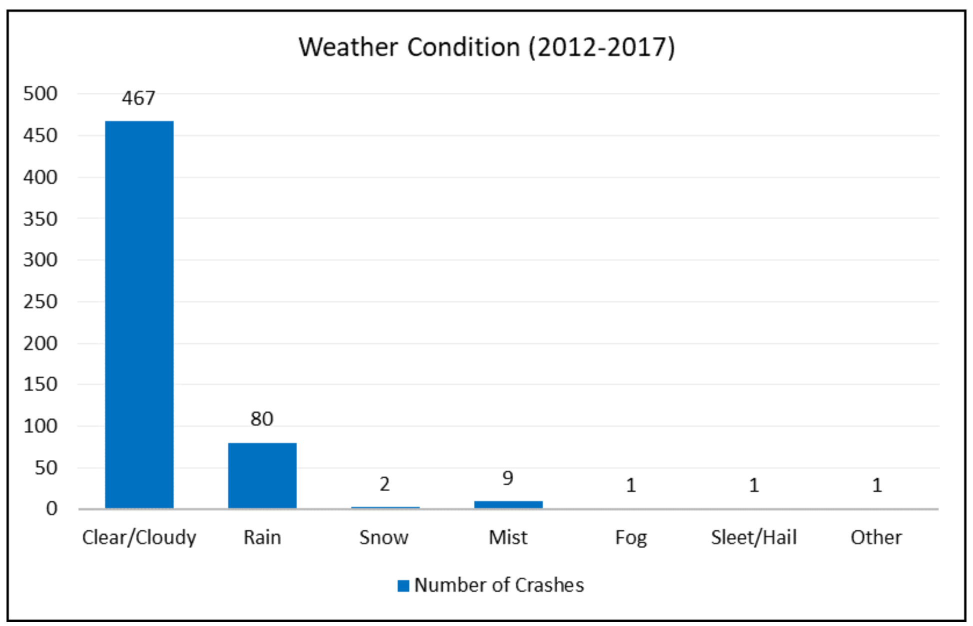


Figure 19. Number of crashes by weather condition for the project study area.



4.2.5 Crash Density by ¼-mile

Crash density histograms were developed in ¼-mile increments to provide a visual representation of crashes along the corridor based on crash type, crash severity, time-of-day, and roadway conditions. The Route 1 histograms were separated into northbound and southbound directions. Crash hot spots were identified along the corridor as locations with the highest crash density. As shown in **Figure 20**, three (3) crash hotspots were identified for Route 1 Northbound: 1) Spotsylvania Avenue intersection, 2) between Fall Hill Avenue and Charles Street, and 3) Warrenton Road intersection. As shown in **Figure 21,** three (3) crash hotspots were identified for Route 1 Southbound: 1) between Augustine Avenue and College Avenue, 2) between Fall Hill Avenue and Charles Street, and 3) Warrenton Road intersection. A discussion of the crash hotspots for the northbound and southbound directions is provided below.

4.2.5.1 Route 1 Northbound

HOTSPOT 1: SPOTSYLVANIA AVENUE INTERSECTION (MILEPOST 147.0-147.25)

A total of 33 crashes occurred at this hotspot. The majority of crashes were rear-end (70%) crashes, with most crashes resulting in property damage and visible injuries. In addition, the crashes predominately occurred from 12:00PM-3:00PM (27%) and 3:00PM-6:00PM (24%) and primarily under dry pavement conditions.

HOTSPOT 2: BETWEEN FALL HILL AVENUE AND CHARLES STREET (MILEPOST 148.25 – 148.50)

A total of 63 crashes occurred at this hotspot. The majority of crashes were angle (49%) and rear-end (41%) crashes, with most crashes resulting in property damage and non-visible injuries. In addition, the crashes predominately occurred from 12:00PM-3:00PM (32%) and 3:00PM-6:00PM (30%) and primarily under dry pavement conditions.

HOTSPOT 3: WARRENTON ROAD INTERSECTION (MILEPOST 149.0 – END)

A total of 46 crashes occurred at this hotspot. The majority of crashes were angle (39%) and rear-end (39%) crashes, with most crashes resulting in property damage and visible injuries. In addition, the crashes predominately occurred from 12:00PM-3:00PM (28%) and 9:00AM-12:00PM (24%) and primarily under dry pavement conditions.

4.2.5.2 Route 1 Southbound

HOTSPOT 1: BETWEEN AUGUSTINE AVENUE AND COLLEGE AVENUE (MILEPOST 147.5-147.75)

A total of 39 crashes occurred at this hotspot. The majority of crashes were rear-end (44%) and angle (44%) crashes, with most crashes resulting in property damage and non-visible injuries. In addition, the crashes predominately occurred from 12:00PM-3:00PM (28%) and 3:00PM-6:00PM (28%) and primarily under dry pavement conditions.

HOTSPOT 2: BETWEEN FALL HILL AVENUE AND CHARLES STREET (MILEPOST 148.25 – 148.50)

A total of 50 crashes occurred at this hotspot. The majority of crashes were angle (60%) and rear-end (34%) crashes, with most crashes resulting in property damage and non-visible injuries. In addition, the crashes predominately occurred from 12:00PM-3:00PM (28%) and 3:00PM-6:00PM (28%) and primarily under dry pavement conditions.

HOTSPOT 3: WARRENTON ROAD INTERSECTION (MILEPOST 149.0 – END)

A total of 50 crashes occurred at this hotspot. The majority of crashes were rear-end (66%) and angle (28%) crashes, with most crashes resulting in property damage. In addition, the crashes predominately occurred from 12:00PM-3:00PM (24%), 3:00PM-6:00PM (24%), and 6:00PM-9:00PM (24%) and primarily under dry pavement conditions.

Figure 20. Crash density histograms per ¼-Mile (Route 1 Northbound).

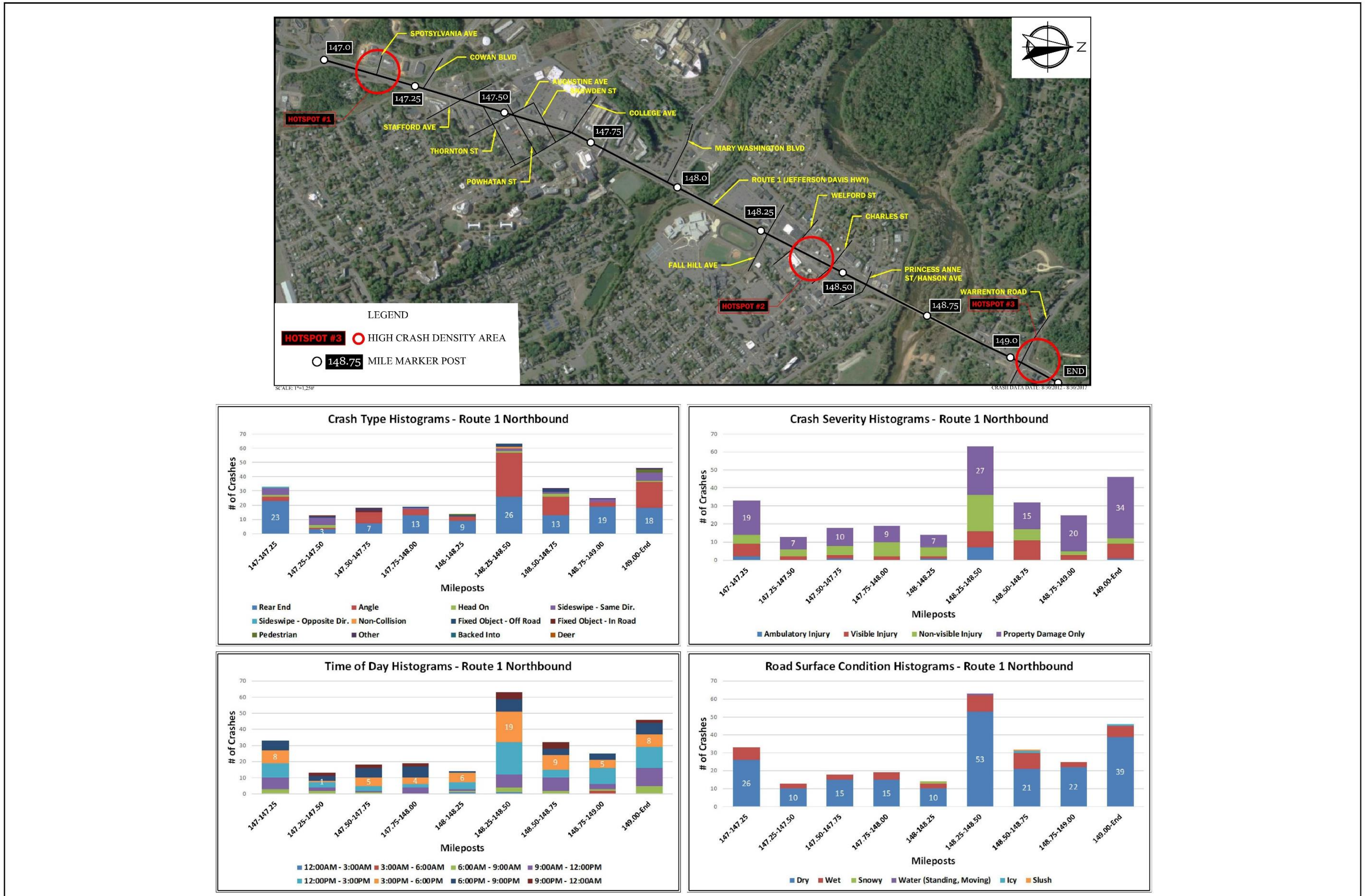
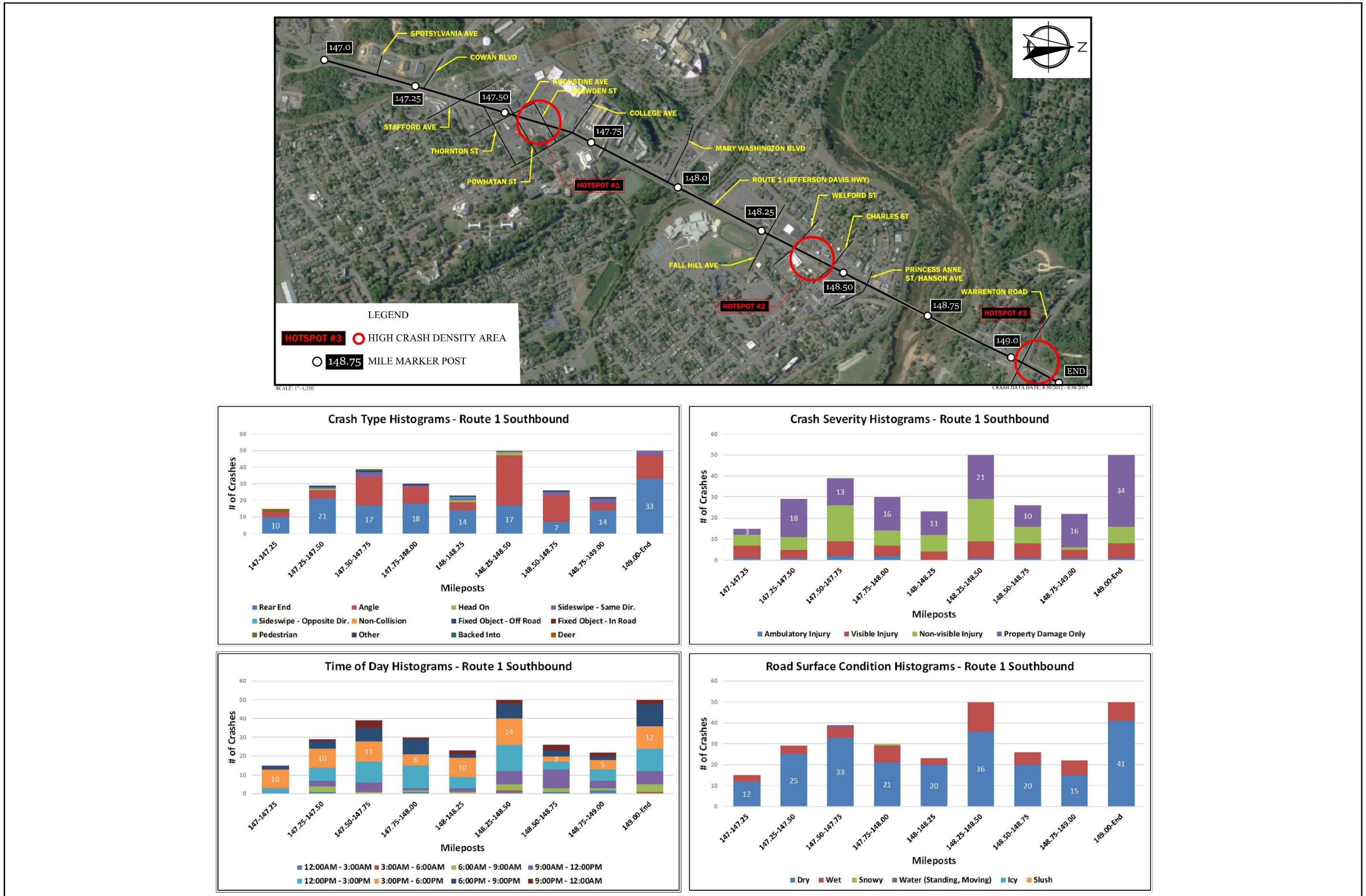


Figure 21. Crash density histograms per ¼-Mile (Route 1 Southbound).



4.2.6 Crash Rate (by intersection, segment, and ramps)

The crash rates were calculated utilizing the rate calculations described in the *Highway Safety Manual*. For the project area, crash rates were calculated by using the road segment equation and intersection equation, as shown in **Table 10** and **Table 11.** Road segments that exceed the statewide average for the same type of facility are shaded in red in **Table 11**. Four of the seven segments exceed the statewide average rate for total crashes as well as injury crashes.

Table 11. Crash rates (Intersections).

Intersection	Total Crash Rate (Per MEV)	Fatal Crash Rate (Per MEV)	Injury Crash Rate (Per MEV)	PDO Crash Rate (Per MEV)
Cowan Crossing/Spotsylvania Ave.	**0.35**	**0.00**	**0.24**	**0.11**
Cowan Blvd.	**0.45**	**0.00**	**0.23**	**0.22**
Eagle Village Dr.	**0.76**	**0.00**	**0.44**	**0.32**
Mary Washington Blvd.	**0.70**	**0.00**	**0.31**	**0.39**
Fall Hill Ave./SR 639	**0.80**	**0.00**	**0.43**	**0.37**
Princess Anne St./Hanson Ave.	**0.62**	**0.00**	**0.43**	**0.19**
Warrenton Rd./Butler Rd.	**0.84**	**0.00**	**0.20**	**0.65**

4.2.7 Crash Data Summary

The following observations were made for crashes that occurred during the five (5) year period from north of Route 3 (William Street) to Route 17 Bus/Route 218/Warrenton Road/Butler Road:

- No fatal crashes occurred.
- 48 percent (48%) of crashes resulted in non-fatal injuries (268 crashes) (i.e., ambulatory, visible, and non-visible injuries).
- 80 percent (80%) of crashes occurred under dry pavement conditions (447 crashes).
- 19 percent (19%) of crashes occurred under wet pavement conditions (107 crashes).
- 52 percent (52%) of crashes that occurred over the five (5) year period were rear-end crashes (291 crashes).
- 30 percent (30%) of crashes that occurred over the five (5) year period were angle crashes (171 crashes).
- 8 percent (8%) of crashes occurred during dark lighting conditions, which includes the following time periods: 9PM–12AM, 12AM–3AM, and 3AM–6AM (47 crashes).
- 6 percent (6%) of crashes (34 crashes) occurred during the AM peak period (6AM–9AM). 27 percent (27%) of crashes (149 crashes) occurred during the PM peak period (3PM–6PM).

Table 12. Crash rates (Road Segments).

Segment	Total CR (Per 100 MVM)		Statewide Average (2015)	Fatal CR (Per 100 MVM)		Statewide Average (2015)	Injury CR (Per 100 MVM)		Statewide Average (2015)	PDO CR (Per 100 MVM)		Statewide Average (2015)
SR 3 to Cowan Crossing/Spotsylvania Ave.	116.74	≤	151.62	0.00	≤	0.86	50.03	≤	51.77	66.71	≤	98.99
Cowan Crossing/Spotsylvania Ave. to Cowan Blvd.	179.91	≥	151.62	0.00	≤	0.86	64.25	≥	51.77	115.66	≥	98.99
Cowan Blvd. to Eagle Village Dr.	197.50	≥	151.62	0.00	≤	0.86	111.41	≥	51.77	86.09	≤	98.99
Eagle Village Dr. to Mary Washington Blvd.	77.26	≤	151.62	0.00	≤	0.86	46.35	≤	51.77	30.90	≤	98.99
Mary Washington Blvd. to Fall Hill Ave./SR 639	192.91	≥	151.62	0.00	≤	0.86	124.46	≥	51.77	68.45	≤	98.99
Fall Hill Ave./SR 639 to Princess Anne St./Hanson Ave.	362.09	≥	151.62	0.00	≤	0.86	208.90	≥	51.77	153.19	≥	98.99
Princess Anne St./Hanson Ave. to Warrenton Rd./Butler Rd.	144.45	≤	151.62	0.00	≤	0.86	37.14	≤	51.77	107.30	≥	98.99
	Exceeds the state average crash rate											

4.3 Field Review

Field observations were conducted at the project study area from Wednesday, January 3, 2018 through Thursday, January 4, 2018 during the AM and PM peak periods to assess traffic operations, roadway geometrics, safety, queuing, vehicle interaction conflicts, and existing signage. In order to evaluate these conditions within the field, various engineering manuals (e.g. Manual on Uniform Traffic Control Devices (MUTCD), Virginia Supplement to MUTCD, 2010 ADA Standards for Accessible Design (ADA)) were used. It should be noted, that while collision diagrams were utilized to determine crash patterns and areas of focus, other recommendations and/or observations were noted that may not be directly related to crash patterns but may reduce the risk of crashes.

Table 13 lists common observations/recommendations from the field and the respective standards. Note that existing standards will be cited within the Field Review and Recommendations sections for any unique observations/recommendations that are not listed within **Table 13**.

Table 13. Common field observations/recommendations and the associated standards.

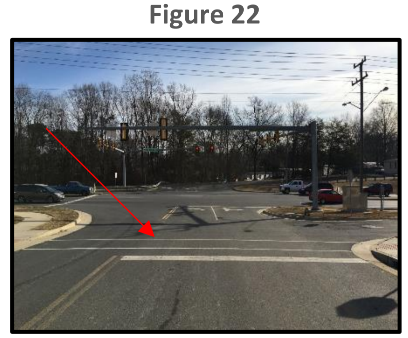
Observation/Recommendation	Associated Standard
Tactile domes do not comply with standards and should be updated	VDOT RBS; ADA Section 705.1
Pedestrian crossing pavement markings are faded and should be refurbished	MUTCD Section 3B.18
Stop bar/yield lines are faded and should be refurbished	MUTCD Section 3B.16
Stop sign is not present and should be installed	MUTCD Section 2B.10
Pedestrian facilities are not provided and should be installed	MUTCD Section 3B.18 and MUTCD Chapter 4E
Distance buffer between the stop bar and crosswalk at an intersection approach	MUTCD Section 3B.16
Street name sign letter height appears smaller than recommended	MUTCD Section 2D.43

A field review reference figure has been provided in the Appendix to provide specified locations of each of the numbered field review observations listed in the following sections.

4.3.1 Route 1 (Jefferson Davis Highway) at Spotsylvania Avenue

- The signal heads at the Route 1 and Spotsylvania Avenue intersection have backplates, but do not have yellow retroreflective borders installed. Based on the collision diagrams, rear-end collisions were prominent between 2013 and 2016, and poor visibility could have contributed to these statistics. *(See Recommendation A1)*

Figure 22



- Pedestrian facilities (e.g., ramps, tactile domes, and crosswalk) are set back approximately 50 feet west of the intersection along the west leg. No pedestrian facilities or crosswalks are provided across the north or south legs of the intersection **(Figure 22)**. It should be noted there was one pedestrian crash that occurred across the south leg in 2016. *(See Recommendation A2)*
- The northbound and southbound approaches do not provide overhead mast arm sign panels indicating "Spotsylvania Avenue" to approaching vehicles **(Figure 23)**. *(See Recommendation A3)*

Figure 23

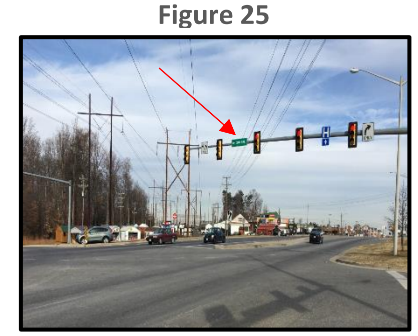
- Pavement markings for the northbound approach and the westbound approach alongside the south leg pavement striping are faded. *(See Recommendation A4)*
- Route signage along the southbound lanes currently exists approximately 100 feet north of the intersection. The sign indicates that drivers attempting to proceed to Route 3 or I-95 should make a right turn at the intersection of Route 1 at Spotsylvania, however vehicles should continue through the intersection in order to proceed to the Route 3 interchange. During the PM peak hour, vehicles were observed attempting to make last minute lane changes in anticipation of the turn. *(See Recommendation A5)*
- Westbound State Route 3 to northbound Route 1 provides no merging or yield pavement markings **(Figure 24)**. Additionally, no merging sign panel (W4-2) is provided to indicate that the State Route 3 westbound receiving lane along northbound Route 1 is ending. This merging sign panel is not a requirement; however, it could be beneficial to northbound vehicles at the merge point of westbound Route 3 and northbound Route 1. According to the collision diagrams, rear-ends and side-swipe crashes were prominent from 2013 through 2016. *(See Recommendation A6)*

Figure 24

4.3.2 Route 1 (Jefferson Davis Highway) at Cowan Boulevard

- Pavement markings for all the approaches are faded. *(See Recommendation A7)*
- The signal heads at the Route 1 at Cowan Boulevard intersection have backplates, but do not have yellow retroreflective borders installed. Based on the collision diagrams, rear-end collisions were prominent 2015. *(See Recommendation A8)*

Figure 25



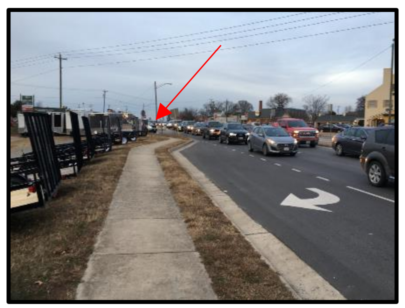
- No pedestrian facilities or crosswalks are provided across the north, east, or west legs of the intersection. *(See Recommendation A9)*
- The northbound and southbound approaches provide a "Cowan Boulevard" street sign on the mast arm, however the lettering height on this street sign may not meet MUTCD guidance as listed in Table 13 (**Figure 25**). In 2015, according to the collision diagrams, rear-end crashes were prominent, and the legibility of these overhead street name plates could have contributed to these statistics. *(See Recommendation A10)*

- The eastbound right-turn lane left sight distance is obstructed due to the location of the eastbound left-turning and through lane stop bars (**Figure 26**). Additionally, the horizontal layout in combination with the mast arm pole and traffic signal box (on the northwest corner) provides an obstructed view for eastbound right-turning vehicles. During the PM peak hour, vehicles were observed making unsafe right-turn movements to southbound Route 1 due to the current stop bar location. Based on collision diagrams, rear-end crashes (along the south leg of the intersection) and angle crashes occurred in 2012, 2013, and 2015, which could be attributed to this current layout for eastbound right-turning vehicles. *(See Recommendation A11)*

Figure 26

- Currently, the northwest corner provides a pedestrian ramp for pedestrians to travel southbound, but provides no pedestrian facilities to cross the west leg of the intersection. Additionally, the pedestrian tactile dome does not comply with standards outlined in **Table 13**. *(See Recommendation A12)*

Figure 27



- During the PM peak hour, southbound vehicle queues were observed extending back through subsequent intersections. This blocked the Route 1 at Stafford Avenue and Route 1 at Leonard Building & Truck unsignalized intersections along with the unsignalized intersections of Route 1 at Augustine Avenue and Route 1 and Powhatan Street. These vehicle queues caused vehicle blockages for eastbound vehicles from each of these unsignalized intersections, but also from northbound vehicles attempting to turn left onto these streets (**Figure 27**).

4.3.3 Route 1 (Jefferson Davis Highway) from Cowan Boulevard to College Avenue

Figure 28

- Sidewalk discontinuity appears to be an issue on both the west and east sides of Route 1, forcing pedestrians to walk on either grass paths and/or frontage road. Additionally, no pedestrian facilities (e.g., crosswalks and ramps) are provided along this stretch for pedestrians to cross Route 1. During the PM peak hour, several pedestrians were observed crossing Route 1 mid-block (**Figure 28**). *(See recommendation A13)*
- Pavement striping along the northbound lanes is faded. *(See recommendation A14)*
- The eastbound pavement markings at the Route 1 at Stafford Avenue unsignalized intersection are faded. *(See recommendation A15*)
- Currently, sporadic pedestrian facilities are provided at the eastbound approach at the Route 1 at Stafford Avenue unsignalized intersection. A pedestrian ramp, with an ADA standard compliant tactile dome, is provided on the southwest corner of the intersection, however no crosswalk is provided. Additionally, given the offset location of the southwest corner ramp, a crosswalk would be leading pedestrians into eastbound and westbound traffic along this road. A porkchop raised median is provided for southbound right-turning vehicles and provides ramps (without ADA compliant tactile domes) and a crosswalk through the channelized turn, from the northwest corner to the porkchop median. An additional ramp (without ADA compliant tactile domes) is provided, in the porkchop, for pedestrians attempting to cross Route 1, however no crosswalk is provided and a raised median dividing northbound and southbound traffic prevents pedestrians from crossing the road safely (**Figure 29**). *(See recommendation A13)*
- Currently, a pedestrian ramp (without ADA compliant tactile domes) exists at the northeast corner of the Route 1 at Stafford Avenue unsignalized intersection, however it does not provide a crosswalk for pedestrians walking southbound. Additionally, a ramp is not provided nor is a sidewalk provided for pedestrians to continue walking southbound on the east side of the road. *(See recommendation A13)*

Figure 29

- The westbound pavement markings at the unsignalized intersection of Route 1 at Thornton Street are faded. *(See recommendation A16)*
- Currently, a pedestrian ramp (without ADA compliant tactile domes) exists at the southeast corner of the Route 1 at Thornton Street unsignalized intersection, however a crosswalk is not provided for pedestrians walking northbound. Additionally, a ramp is not provided nor is a sidewalk provided for pedestrians to continue walking northbound on the east side of the road. *(See recommendation A13)*
- Pavement markings for all eastbound and westbound approaches at the unsignalized intersection of Route 1 at Augustine Avenue/Powhatan Street are faded. Additionally, lane assignment pavement striping is not provided on the eastbound roads for Augustine Avenue and Powhatan Street. *(See recommendation A17*)
- The Route 1 at Augustine Avenue sign post currently is placed approximately 10 feet east of the intersection, adjacent to the southeast corner. This location makes visibility difficult for vehicles traveling northbound. *(See recommendation A18*)
- The Route 1 at Powhatan Street sign post currently is placed approximately 10 feet east of the intersection, adjacent to the northeast corner. This location makes visibility difficult for vehicles traveling northbound. *(See recommendation A19*)
- Currently, sporadic pedestrian facilities are provided at the unsignalized intersection of Route 1 at Augustine Avenue/Powhatan Street. On the east side of the road, sidewalk discontinuity is prevalent. Beginning from the northeast corner of Powhatan Street, a sidewalk and ramp (ADA compliant) are present, however pedestrians proceeding southbound are not provided with ramps, crosswalks, or sidewalk (**Figure 30**). Based on the collision diagrams, there was a pedestrian related crash that could be attributed to the lack of pedestrian facilities. On the west side, no sidewalk is provided, and forces pedestrians to utilize the frontage road. This presents a hazard for pedestrians attempting to walk safely where vehicles are constantly flowing from the frontage road and eastbound/westbound movements onto Route 1. *(See recommendation A13)*

Figure 30

Figure 31

- The frontage road adjacent to the unsignalized intersection of Route 1 at Augustine Avenue/Powhatan Street, on the west side of the road, is disorganized. Multiple points of entry create multiple conflict points for northbound left-turning vehicles, southbound right-turning vehicles, eastbound right turning vehicles, and northbound/southbound vehicles traveling along the frontage road. This scenario, in combination with southbound vehicle queues from the intersection of Route 1 at Cowan Boulevard created several near-miss incidents (**Figure 31**). *(See recommendation A20)*
- Pavement markings for the eastbound and westbound approaches at the unsignalized intersection of Route 1 at Snowden Street are faded. *(See recommendation A21)*
- On the west side of the road, no pedestrian facilities are provided and thus forces pedestrians to share the frontage road with vehicles in order to proceed northbound or southbound or access the shopping center just west of the unsignalized intersection of Route 1 at Snowden Street. *(See recommendation A13)*
- On the east side of the road at the intersection of Route 1 at Snowden Street, a pedestrian ramp (ADA compliant) is provided on the southeast corner of the intersection, however the crosswalk is faded and a ramp is not provided on the northeast corner of the intersection. *(See Recommendation A13 and A22)*
- The Route 1 at Snowden Street sign post is currently placed approximately 20 feet east of the intersection, adjacent to the northeast corner. This location makes visibility difficult for vehicles traveling northbound. Additionally, there is a "Stop" sign panel (R1-1) located on this same street sign post that is approximately 15 feet east of the westbound stop bar (**Figure 32**). *(See Recommendation A23)*

Figure 32

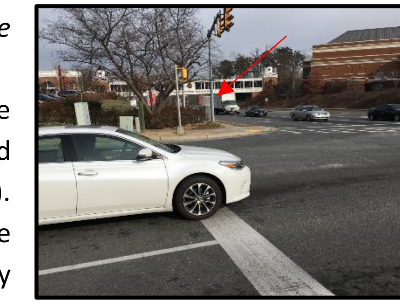
4.3.4 Route 1 (Jefferson Davis Highway) at College Avenue/East Village Drive

- The signal heads at the Route 1 and College Avenue/East Village Drive intersection have backplates, but do not have yellow retroreflective borders installed. Based on the collision diagrams, rear-end collisions were prominent along the northbound and southbound approaches in 2013, 2015, and 2016, and poor visibility of the signal heads could be contributing to these statistics. *(See Recommendation A24)*
- Pavement markings along the northbound and westbound approaches are faded. *(See Recommendation A25)*
- Currently, pedestrian ramps (with non-compliant ADA tactile domes) are provided across the east leg, but are placed approximately 10 feet east of the intersection along College Avenue (**Figure 33**). Additionally, neither a countdown timer nor pedestrian crosswalk is provided across the east leg of the intersection. Despite having some pedestrian features for crossing the east leg, the northbound approach does not provide "Turning Vehicles Yield to Pedestrians" sign panel (R10-15) on mast arm or along east side of the road along northbound approach. *(See Recommendation A26)*

Figure 33

- The westbound right-turn lane left sight distance is obstructed due to a hill located on the southeast corner. *(See Recommendation A27)*
- The eastbound right-turn lane left sight distance is obstructed due to shrubbery, mast arm pole, and traffic control box (**Figure 34**). *(See Recommendation A28)*

Figure 34



- The northbound approach to the intersection has vertical curvature associated with it. Vehicles traveling northbound begin to descend downhill approximately 500 feet prior to the intersection (**Figure 35**). According to the collision diagrams, rear-end collisions occurred more often in 2015 and 2016. Vertical and horizontal alignment of the road may be causing some of these collisions. *(See Recommendation A29)*
- Northbound left-turning vehicles onto East Village Drive have an obstructed view of southbound through traffic approaching the intersection. Currently, the left turn signal is a protected-permitted condition. According to the collision diagrams, angle crashes were prominent in 2015, and this obstructed view may be attributing to these crash statistics. *(See Recommendation A30)*

Figure 35

Figure 36

- During the PM peak hour, eastbound vehicle queues were observed extending back to the unsignalized intersection within the Eagle Village Shopping Center (**Figure 36**). These queues may be due to the shared roadway utilized by the East Village shopping center, business park, and Mary Washington Hospital users.

4.3.5 Route 1 (Jefferson Davis Highway) from College Avenue/East Village Drive to Mary Washington Boulevard

- Pavement markings are not provided for the eastbound and westbound approaches at the unsignalized intersection of Route 1 and Alvey Drive. *(See Recommendation A31)*
- The westbound approach does not provide a pedestrian crosswalk at the unsignalized intersection of Route 1 at Alvey Drive. *(See Recommendation A32)*
- A tactile dome is provided on the northeast corner, however is not compliant with ADA standards. Additionally, no tactile dome is provided for the ramp on the southeast corner at the unsignalized intersection of Route 1 and Alvey Drive. *(See Recommendation A33)*
- Currently, a ramp and tactile dome (ADA compliant) are provided for pedestrians at the northwest corner, however the sidewalk discontinues. Pedestrians proceeding south are not provided sidewalk or a ramp to continue and are forced to walk in the grass or cross the street without a crosswalk. Pedestrians were observed walking in the grass on the west side of the road. *(See Recommendation A13)*
- Currently, a street sign is provided on the southeast corner of the unsignalized intersection of Route 1 at Alvey Drive. The sign is intended for northbound vehicles; however this sign is difficult to see given the non-standard colors and fonts. *(See Recommendation A34)*

4.3.6 Route 1 (Jefferson Davis Highway) at Mary Washington Boulevard

Figure 37

- The signal heads at the Route 1 at Mary Washington Boulevard intersection have backplates, but do not have yellow retroreflective borders installed (**Figure 37**). *(See Recommendation A35)*

4.3.7 Route 1 (Jefferson Davis Highway) Mary Washington Boulevard to Fall Hill Avenue

- Currently, sidewalk exists along the west side of the road up to the southwest corner of the unsignalized intersection and Taco Bell entrance/exit driveway. The sidewalk continues and diverts pedestrians to walk west (approximately 40 feet) and provides a ramp with an ADA compliant tactile dome. Despite having these features, the sidewalk discontinues here, and neither sidewalk nor a ramp are provided on the northwest corner, and proceeding north. *(See Recommendation A13)*

4.3.8 Route 1 (Jefferson Davis Highway) at Fall Hill Avenue

- The signal heads at the Route 1 at Fall Hill Avenue intersection have backplates, but do not have yellow retroreflective borders installed. Based on the collision diagrams, rear-end crashes were prominent from 2013 through 2016 along the northbound and southbound approaches. Poor visibility of the signal heads could be contributing to these crash statistics. *(See Recommendation A36)*
- During the PM peak hour, northbound and southbound left turning vehicles were observed making turns with limited visibility due to obstructed views of oncoming vehicles making the left turn from the opposite direction. Each of these turning movements operate with protected-permitted phasing. Additionally, during the PM peak hour, the position of the sun provides additional obstruction and uncertainty for left turning vehicles and oncoming northbound through vehicles. Based on the collision diagrams, angle crashes were prominent in 2013, 2015, 2016, and 2017, and these conditions could be causing the increase in these types of crashes at the intersection. *(See Recommendation A37)*
- The northbound pavement markings are faded. *(See Recommendation A38)*
- The eastbound right turn movement left sight distance is obstructed due to commercial signage, traffic control box, and mast arm pole (**Figure 38**). Please note, relocating the existing commercial signage and traffic control related features is not a feasible low-cost improvement; however, it should be known that the limited left-sight distance due to these obstructions could be contributing to the angle crashes and rear-end crashes along the south leg.

Figure 38

- The southbound approach does not provide a "Turning Vehicles Yield to Pedestrians" sign panel (R10-15) on the mast arm. While these are not a requirement, this area is adjacent to a high school and university and is occupied by significant pedestrian traffic and these signs provide additional warning for vehicles making turns. *(See Recommendation A39)*

4.3.9 Route 1 (Jefferson Davis Highway) Fall Hill Avenue to Hanson Avenue

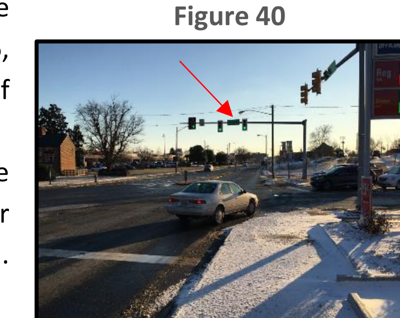
Figure 39

- Several commercial driveways exist along the east and west sides of the road, particularly between the unsignalized intersections of Route 1 at Welford Street and Route 1 at Charles Street (**Figure 39**). These unsignalized intersections create obscure vehicle movements based on their existing alignment relative to the Route 1 corridor mainline. Based on the collision diagrams, angular crashes and rear-end crashes were prominent from 2012 through 2014, as well as in 2015, and may be attributed to the layout currently in place. *(See Recommendation A40)*
- Currently, at the unsignalized intersection of Route 1 at Welford Street, the pavement markings for the eastbound and westbound movements are faded. *(See Recommendation A41)*
- Currently, pedestrian ramps exist at the unsignalized intersection of Route 1 at Welford Street in the northeast, northwest, and southwest corners; however, ADA compliant tactile comes are not provided. Additionally, no crosswalks are provided for pedestrians crossing the east and west legs of the intersection. *(See Recommendation A13 and A42)*
- The eastbound approach at the unsignalized intersection of Route 1 at Charles Street has faded pavement markings. *(See Recommendation A43)*
- Pedestrian ramps are provided at the unsignalized intersection of Route 1 at Charles Street on the northeast, northwest, and southwest corners, but do not provide the ADA compliant tactile domes. Crosswalks are not provided along the east and west legs of the intersections. *(See Recommendation A44)*
- The sidewalk at the unsignalized intersection of Route 1 at Charles Street on the northeast corner discontinues for pedestrians walking southbound, and thus forces pedestrians to walk in the grass (southbound) on the east side of the road. *(See Recommendation A13)*

4.3.10 Route 1 (Jefferson Davis Highway) at Hanson Avenue/Princess Anne Street

- The signal heads at the Route 1 at Hanson Avenue intersection have backplates, but do not have yellow retroreflective borders installed. *(See Recommendation A45)*
- During the PM peak hour, northbound and southbound left turning vehicles were observed making turns with limited visibility due to obstructed views of oncoming vehicles making the left turn from the opposite direction. Each of these turning movements operate with protected-permitted phasing. Additionally, during the PM peak hour, the position of the sun, provides additional obstruction and uncertainty for left turning vehicles and oncoming northbound through vehicles. Based on the collision diagrams, angle crashes were prominent in 2013, 2015, and 2016, and these conditions could be causing the increase in these types of crashes at the intersection. *(See Recommendation A46)*
- The northbound and southbound approaches provide a "Princess Anne Street/Hanson Avenue" street sign on the mast arm; however, the letter height appears to be smaller than what is recommended in **Table 13** (**0**). *(See Recommendation A47)*

Figure 40



- Pedestrian ramps (with ADA non-compliant tactile domes) are provided on the southeast and southwest corners of the intersection; however, no ramps are provided on the northwest and northeast corners. Additionally, no pedestrian facilities are provided for any legs of the intersection (**Figure 41**). *(See Recommendation A48)*

Figure 41

4.3.11 Route 1 (Jefferson Davis Highway) From Hanson Avenue/Princess Anne Street to Warrenton Road/Butler Road

- The westbound approach at the unsignalized intersection of Route 1 at Carter Street does not provide a stop bar or pedestrian crosswalk. *(See Recommendation A49)*
- The southbound right turn lane at the unsignalized intersection of Route 1 at West Cambridge Street does not provide a pedestrian crosswalk (**Figure 42**). *(See Recommendation A50)*

Figure 42

4.3.12 Overall Corridor

- Route 1 currently provides access to several private and commercial driveways along the corridor. Along most of these entrance/exit driveways, MUTCD signage, pavement markings, and pedestrian facilities are limited, not existent, or not up to standards (as outlined in **Table 13**). Please note, the City of Fredericksburg and VDOT are not responsible for the maintenance of these entrance/exit driveways; however, the lack of these could be contributing to unsafe vehicular movements and/or crashes along the corridor.
- Route 1, at various intersections and stretches of corridor, showed areas of vehicular queuing and backups. *(See Recommendation A51)*
- Generally, pedestrian facilities are discontinuous along the stretch of corridor on both the east and west sides of Route 1 corridor. *(See Recommendation A52)*

4.4 Recommendations

4.4.1 Route 1 (Jefferson Davis Highway) at Spotsylvania Avenue

A1. Consider installing backplates with retroreflective borders to all traffic signal heads for all approaches at the intersection. The installation of yellow retroreflective borders on the backplates can be used to improve visibility and could reduce the occurrence of rear-end collisions in the future for all approaches.

A2. Consider installing pedestrian facilities (e.g., pedestrian countdown signals, pedestrian crosswalk pavement markings, ADA ramps with tactile domes) to accommodate pedestrians crossing from the east and west sides of Route 1, per the standard outlined in **Table 13**.

A3. Consider installing overhead street name signs on the mast arms for northbound and southbound approaches, per the standard outlined in **Table 13**.

A4. Refurbish pavement markings along the northbound approach, per the standard outlined in **Table 13**.

A5. Consider relocating the route signage post to a location south of the intersection along the west side of the road.

A6. Consider installing merging sign panel (W4-2) along the east side of the road at the merge point of westbound Route 3 ramp and northbound Route 1 through lanes.

4.4.2 Route 1 (Jefferson Davis Highway) at Cowan Boulevard

A7. Refurbish pavement markings along all approaches of the intersection, per the standard outlined in **Table 13**.

A8. Consider installing backplates with retroreflective borders to all traffic signal heads for all approaches at the intersection. The installation of yellow retroreflective borders on the backplates can be used to improve visibility and could reduce the occurrence of rear-end collisions in the future for all approaches.

A9. Consider installing pedestrian facilities (e.g., pedestrian countdown signals, pedestrian crosswalk pavement markings, ADA ramps with tactile domes) to accommodate pedestrians crossing from the east and west sides of Route 1, per the standard outlined in **Table 13**.

A10. Consider replacing the existing “Cowan Boulevard” street signs on the mast arm for the northbound and southbound approaches with street signs that have a larger font, per the standard outlined in **Table 13**.

A11. Re-locate the eastbound right-turn lane stop bar closer to the intersection to provide adequate left sight distance. Should pedestrian facilities be implemented along the west leg of the intersection, the stop bar should comply with the buffer standard outlined in **Table 13**.

A12. Consider installing pedestrian facilities (e.g., pedestrian countdown signals, pedestrian crosswalk pavement markings, ADA ramps with tactile domes) to accommodate pedestrians crossing the west leg of Cowan Boulevard, per the standards outlined in **Table 13**. Additionally, install tactile domes that comply with standards outlined in **Table 13** at the northwest corner.

4.4.3 Route 1 (Jefferson Davis Highway) from Cowan Boulevard to College Avenue

A13. Evaluate the need for installation of bicycle and pedestrian facilities (i.e., pedestrian cross walk pavement markings, ADA ramps with tactile domes, etc.) that comply with standards outlined in **Table 13** along the east and west sides of Route 1.

A14. Refurbish pavement striping along the northbound lanes, per the standard outlined in **Table 13**.

A15. Refurbish the eastbound pavement markings at the unsignalized intersection of Route 1 at Stafford Avenue, per the standard outlined in **Table 13**.

A16. Refurbish the westbound pavement markings at the unsignalized intersection of Route 1 at Thornton Street, per the standard outlined in **Table 13**.

A17. Refurbish the eastbound and westbound pavement markings and striping at the unsignalized intersections of Route 1 at Augustine Avenue/Powhatan Street, per the standard outlined in **Table 13**.

A18. Relocate the existing Route 1 at Augustine Avenue sign post to be closer to the southeast corner of the intersection for better visibility for northbound vehicles.

A19. Relocate the existing Route 1 at Powhatan Street sign post closer to the northeast corner for better visibility for northbound vehicles.

A20. Reevaluate the driveway access openings within this stretch of corridor.

A21. Refurbish pavement markings along the eastbound and westbound approaches at the unsignalized intersection of Route 1 at Snowden Street, per the standard outlined in **Table 13**.

A22. Refurbish the pedestrian crossing pavement markings and install a ramp on the northeast corner that complies with standards outlined in **Table 13.**

A23. Relocate the existing Route 1 at Snowden Street sign post closer to the northeast corner for better visibility for northbound vehicles.

4.4.4 Route 1 (Jefferson Davis Highway) at College Avenue/East Village Drive

A24. Consider installing backplates with retroreflective borders to all traffic signal heads for all approaches at the intersection. The installation of yellow retroreflective borders on the backplates can be used to improve visibility and could reduce the occurrence of rear-end collisions in the future for all approaches.

A25. Refurbish pavement markings for the northbound and westbound approaches at the intersection, per the standard outlined in **Table 13**.

A26. Consider installing the pedestrian facilities (i.e., ADA ramps with tactile domes and pedestrian crosswalk pavement markings in compliance with **Table 13**) closer to the intersection. Additionally, consider installing pedestrian countdown signals per MUTCD Chapter 4E for the pedestrian crosswalk across the east leg of the intersection. Install a "Turning Vehicles Yield to Pedestrians" sign panel (R10-15) on the mast arm for the northbound right turning vehicles.

A27. Consider relocating the existing westbound right-turn stop bar closer to the intersection to provide right turning vehicles better left-sight distance.

A28. Consider relocating the existing eastbound right-turn stop bar closer to the intersection to provide right turning vehicles better left-sight distance. Additionally, trim vegetation that currently obstructs left-site distance on the northwest corner of the intersection.

A29. Consider installing an advanced warning sign panel (R3-3) approximately 500 feet south of the intersection along the east side of the road to face northbound traveling vehicles. Providing advanced warning signage for northbound approaching vehicles could increase awareness of the approaching signal and could mitigate future rear-end crashes along the northbound approach.

A30. Consider restricting the permitted phasing completely. This could prevent future angle crashes from occurring along the northbound movements. Please note that from an operational standpoint, changing the intersection phasing from protected-permissive to protected would likely increase delays at the intersection and would need to be further evaluated before implementation.

4.4.5 Route 1 (Jefferson Davis Highway) from College Avenue/East Village Drive to Mary Washington Boulevard

A31. Install pavement markings that comply with standards outlined in **Table 13** for the eastbound and westbound approaches at the unsignalized intersection of Route 1 at Alvey Drive.

A32. Install pedestrian pavement markings that comply with standards outlined in **Table 13** for the westbound approach at the unsignalized intersection of Route 1 at Alvey Drive.

A33. Install tactile domes that comply with standards outlined in **Table 13** at the northeast and southeast corners of the unsignalized intersection of Route 1 at Alvey Drive.

A34. Consider installing a more visible street sign panel for the intersection of Route 1 at Alvey Drive, per the standard outlined in **Table 13**.

4.4.6 Route 1 (Jefferson Davis Highway) at Mary Washington Boulevard

A35. Consider installing backplates with retroreflective borders to all traffic signal heads for all approaches at the intersection. The installation of yellow retroreflective borders on the backplates can be used to improve visibility and could reduce the occurrence of rear-end collisions in the future for all approaches.

4.4.7 Route 1 (Jefferson Davis Highway) at Fall Hill Avenue

A36. Consider installing backplates with retroreflective borders to all traffic signal heads for all approaches at the intersection. The installation of yellow retroreflective borders on the backplates can be used to improve visibility and could reduce the occurrence of rear-end collisions in the future for all approaches.

A37. Consider restricting the permitted phasing completely. This could prevent future angle crashes from occurring along the southbound movements. Please note that from an operational standpoint, changing the intersection phasing from protected-permissive to protected would likely increase delays at the intersection and would need to be further evaluated before implementation.

A38. Refurbish the northbound approach pavement markings, per the standard outlined in **Table 13**.

A39. Install "Turning Vehicles Yield to Pedestrians" sign panels (R10-15) on the mast arm for the southbound approach. This area is populated with high-density commercial retail and restaurants, which promotes active transportation; therefore, facilities should be provided to protect both pedestrians and bicyclists.

4.4.8 Route 1 (Jefferson Davis Highway) Fall Hill Avenue to Hanson Avenue

A40. Consider conducting an access management study to evaluate the existing side roads and driveways that converge at Route 1 on both the east and west sides of the road.

A41. Refurbish the pavement markings along the eastbound and westbound approaches that comply with standards outlined in **Table 13** at the unsignalized intersection of Route 1 at Welford Street.

A42. Update existing pedestrian ramps at the northeast, northwest and southwest corners and install pedestrian crossing pavement markings along the east and west legs of the unsignalized intersection of Route 1 at Welford Street that comply with standards outline in **Table 13**.

A43. Refurbish the eastbound approach pavement markings at the unsignalized intersection of Route 1 at Charles Street, per the standard outlined in **Table 13**.

A44. Update existing pedestrian ramps at the northeast, northwest and southwest corners and install pedestrian crossing pavement markings along the east and west legs of the unsignalized intersection of Route 1 at Charles Street that comply with standards outline in **Table 13**.

4.4.9 Route 1 (Jefferson Davis Highway) at Hanson Avenue/Princess Anne Street

A45. Consider installing backplates with retroreflective borders to all traffic signal heads for all approaches at the intersection. The installation of yellow retroreflective borders on the backplates can be used to improve visibility and could reduce the occurrence of rear-end collisions in the future for all approaches.

A46. Consider restricting the permitted phasing completely. This could prevent future angle crashes from occurring along the southbound movements. Please note that from an operational standpoint, changing the intersection phasing from protected-permissive to protected would likely increase delays at the intersection and would need to be further evaluated before implementation.

A47. Consider replacing the existing "Princess Anne Street/Hanson Avenue" street signs on the mast arm for the northbound and southbound approaches with street name signs using a larger font.

A48. Consider installing pedestrian facilities (e.g., pedestrian countdown signals, pedestrian crosswalk pavement markings, ADA ramps with tactile domes) to accommodate pedestrians crossing from the east and west sides and north and south sides of the intersection, per the standards outlined in **Table 13**. Additionally, install tactile domes at the southeast and southwest corners of the intersection that comply with the standard outlined in **Table 13**.

4.4.10 Route 1 (Jefferson Davis Highway) From Hanson Avenue/Princess Anne Street Warrenton Road/Butler Road

A49. Install pedestrian crosswalk and stop bar for the westbound approach per standards outlined in **Table 13** at the unsignalized intersection of Route 1 at Carter Street.

A50. Install pedestrian crossing pavement markings per standards outlined in **Table 13** across the southbound channelized right turn lane at the unsignalized intersection of Route 1 at West Cambridge Street.

4.4.11 Overall Corridor Recommendations

A51. It is recommended as part of the future conditions to evaluate and optimize signal timings in order to alleviate some of the congestion and queuing issues along the corridor.

A52. Consider evaluating the need for updating and/or installing pedestrian facilities along the corridor, per the standard outlined in **Table 13**.

Note: While these recommendations were provided based on the field review, it is up to the City of Fredericksburg and the Virginia Department of Transportation to provide both input and the final decision on what is to be modified, replaced, and/or updated.

5 Improvement Alternatives

This section summarizes the improvement alternatives considered for each intersection along the Route 1 corridor. The proposed improvements along Route 1 are primarily driven by a need to address existing and future safety and operational concerns. The alternatives were developed based upon the results of the Existing Conditions and No-Build Conditions analyses, field observation, review of prior studies/recommendations, as well as coordination with the Study Work Group which includes VDOT, City of Fredericksburg, and FAMPO.

5.1 Future Year 2030 Build Alternatives

The approximately 2.5-mile study corridor of Route 1 comprises of 8 signalized intersections. The following intersections are projected to experience LOS E/F conditions during the PM peak hour under the future conditions:

- Route 1 / Princess Anne St/Hanson Ave
- Route 1/ Fall Hill Ave
- Route 1 / Mary Washington Blvd
- Route 1 / College Ave
- Route 1 / Powhatan St/Augustine Ave
- Route 1 / Cowan Blvd
- Route 1 / Cowan Crossing/Spotsylvania Ave

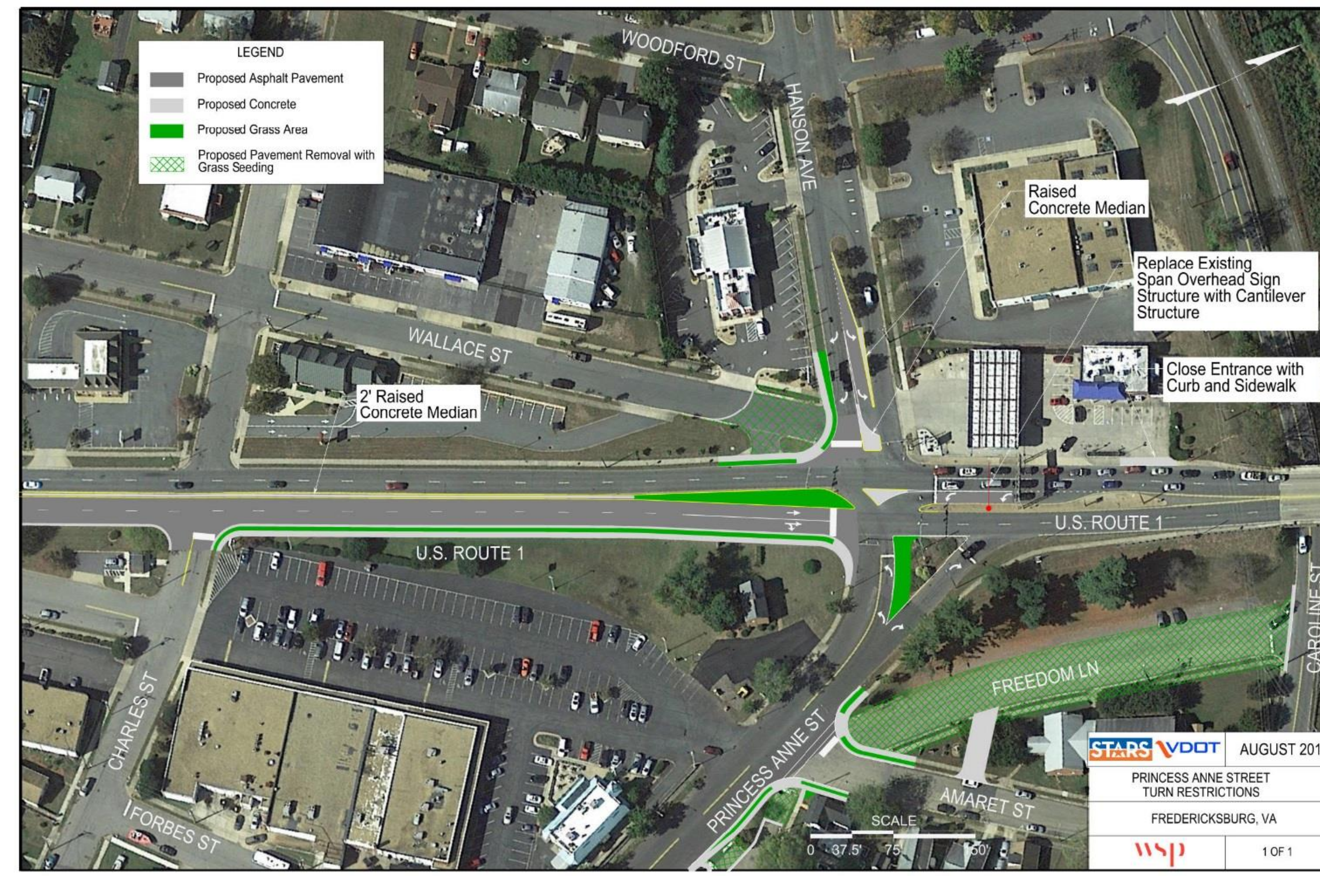
An Alternatives Development Workshop was held on February 20, 2018. The discussion during the Alternatives Development Workshop primarily focused on these intersection locations, since the congestion and safety issues within the study corridor are centered on these intersections. Several preliminary improvement alternatives were developed based on the operational analysis results for the Future 2030 No-Build scenarios as well as the Existing Conditions crash analysis. The improvement alternatives were vetted by the Study Work Group (SWG) and a list of Alternatives for evaluation were selected to move forward for the Future 2030 Build Analyses.

An Alternatives Evaluation Workshop webinar was held with the SWG on March 21, 2018 in order to discuss the preliminary evaluation of the alternatives. Information provided to the SWG in the Alternatives Evaluation Workshop is included below. Planning level conceptual layouts for each of these alternatives were developed and are described below. The layouts presented below cover only those locations where improvements are proposed. The locations where the improvements are planned by others or where there are no STARS proposed improvements have not been presented in this report.

5.2 Princess Anne Street/Hanson Avenue Intersection

The preferred alternative at this location proposes to modify Princess Anne Street westbound approach to restrict westbound throughs, convert the Hanson Avenue southbound approach to right-in/right-out, close Wallace Street access to Route 1 and Hanson Avenue, install median to prevent left turns to/from Charles Street, close Freedom Lane, and close access from Van Buren Street to Amaret Street. **Figure 43** shows the conceptual layout of the Preferred Alternative at this location.

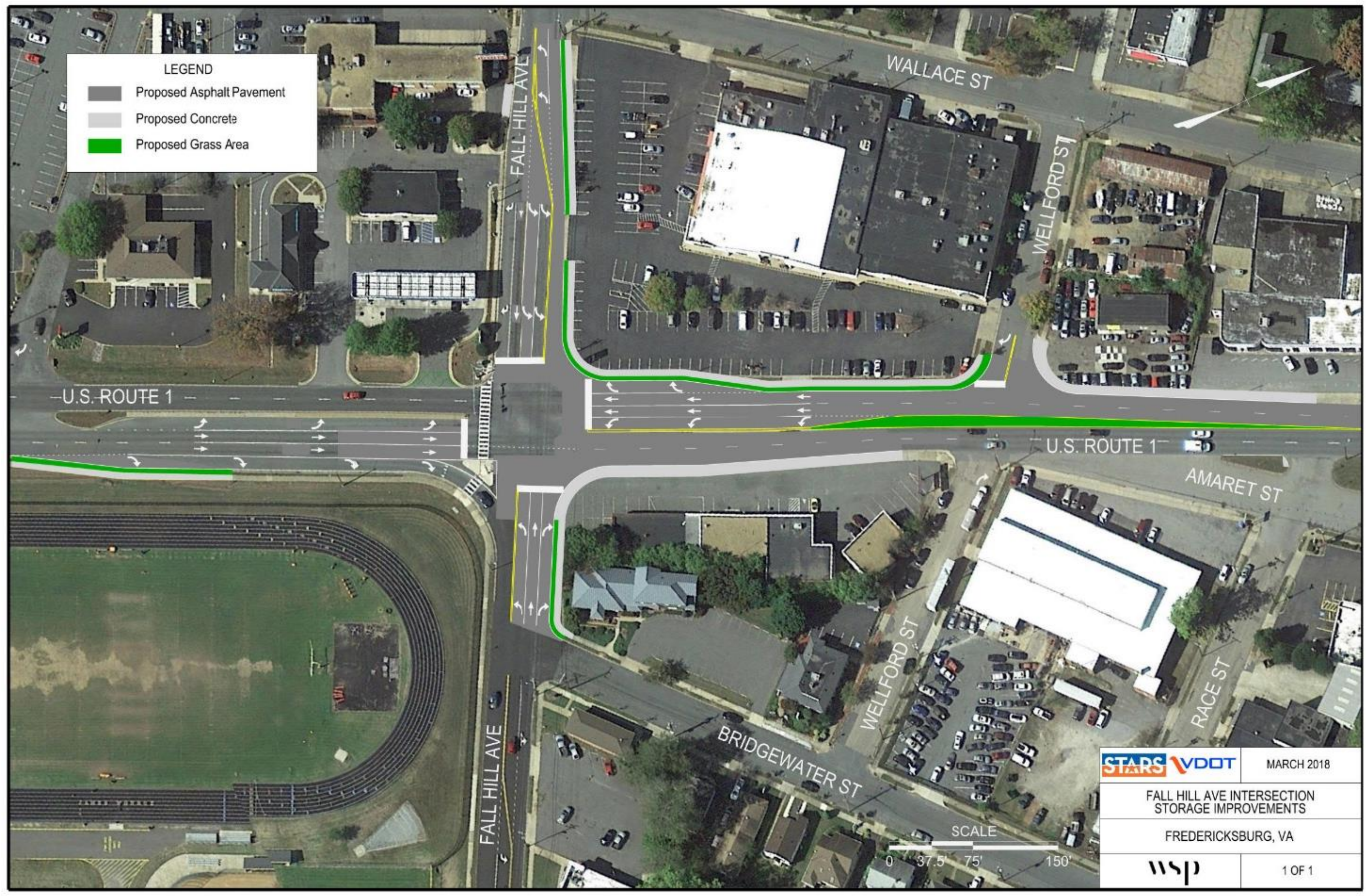
Figure 43. 2030 Preferred Alternative: Princess Anne St/Hanson Ave Intersection



5.3 Fall Hill Avenue Intersection

The preferred alternative at this location proposes to add eastbound dual left turn lanes, separate shared-thru lanes and add turn bays on all approaches in order to provide additional capacity and to remove split phasing on the eastbound and westbound approaches. **Figure 44** shows the conceptual layout of the Preferred Alternative at this location.

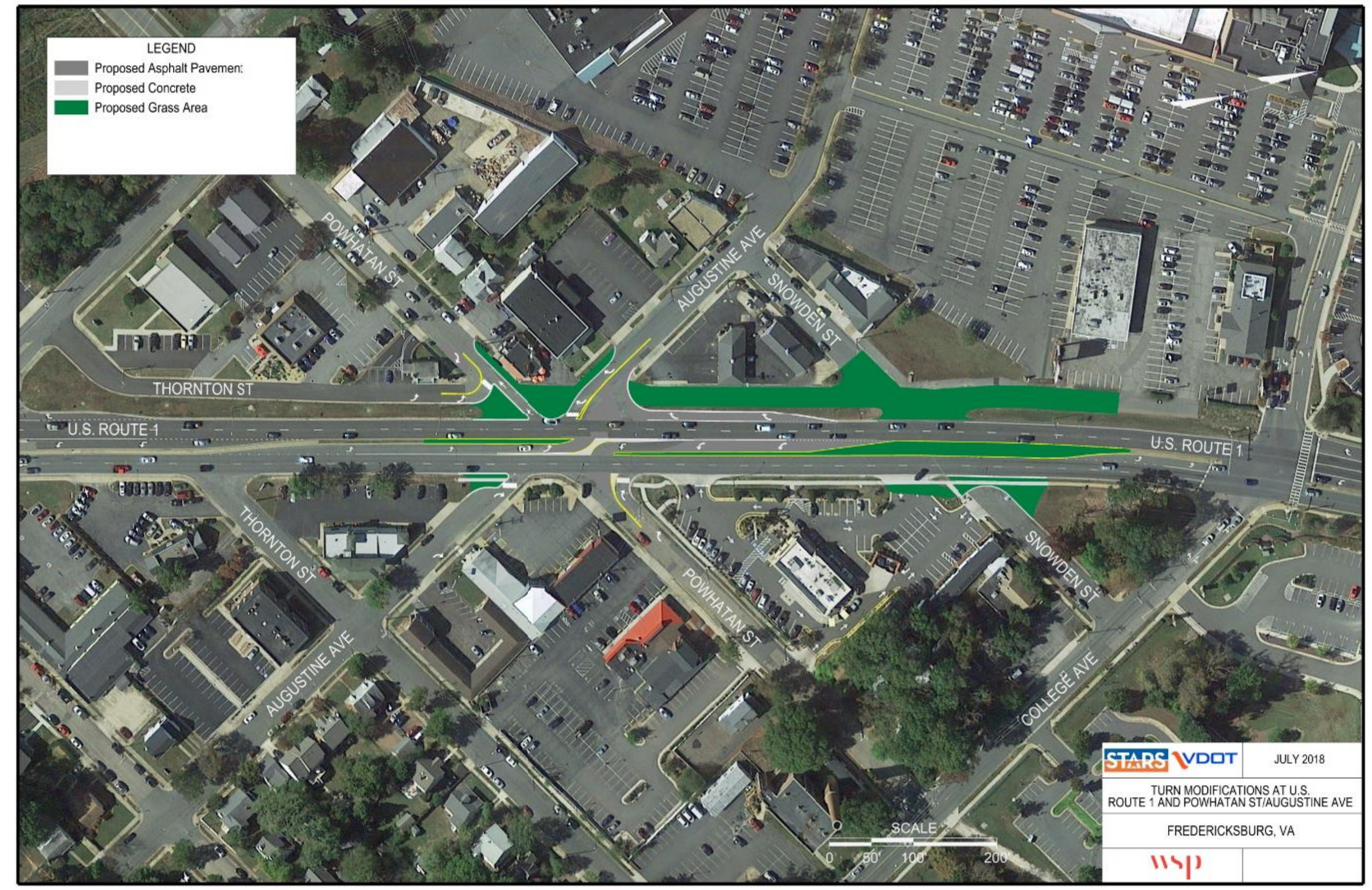
Figure 44. 2030 Preferred Alternative: Fall Hill Ave Intersection



5.4 Powhatan Street/Augustine Avenue Intersection

This alternative proposes to restrict certain turn movements to reduce conflict points and extraneous movements, as well as improve access management throughout the intersection. **Figure 45** shows the conceptual layout of the Preferred Alternative at this location.

Figure 45. 2030 Preferred Alternative: Powhatan St/Augustine Ave Intersection



5.5 Cowan Boulevard/Rowe Street Intersection

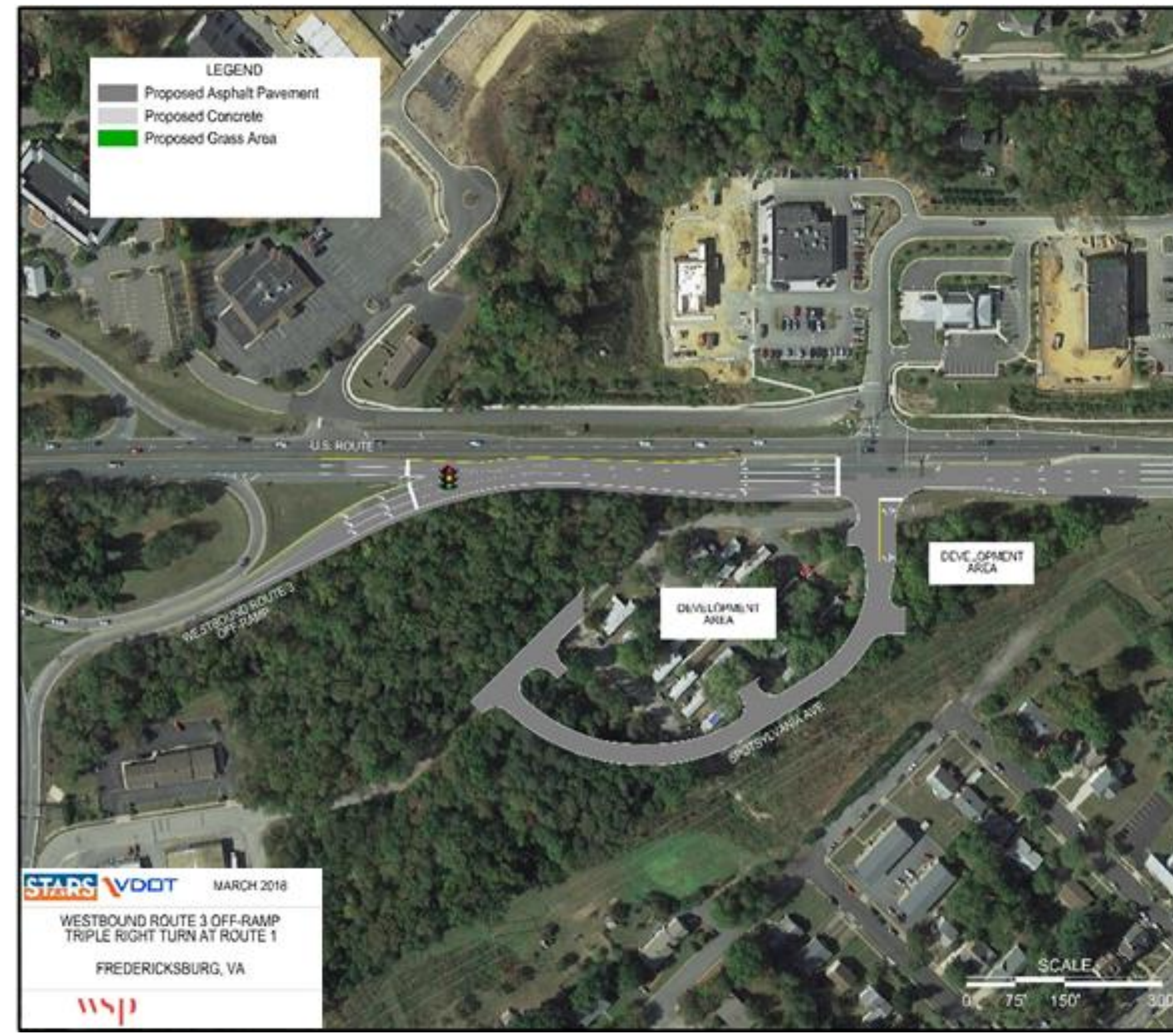
This alternative proposes to add a second eastbound right turn bay and to add a small westbound left turn bay, as well as the addition of a non-locking delayed response detector for the westbound approach of Rowe Street so that the approach call is delayed when a vehicle shows up on the approach. This allows westbound right turn vehicles time to make their right turn on red without calling the signal phase for the westbound approach, thereby limiting the amount of times the westbound approach is called. **Figure 46** shows the conceptual layout of the Preferred Alternative at this location.

Figure 46. 2030 Preferred Alternative: Cowan Blvd Intersection

5.6 Cowan Crossing/Spotsylvania Avenue Intersection

The preferred alternative at this location proposes to add triple right turns at westbound Route 3 off-ramp which terminate as a signalized T-intersection. In addition, it proposes to extend the northbound merge lane to be a third through lane that drops at Rowe Street while adding a northbound right turn lane at Spotsylvania Ave. Additionally, this alternative includes restriping the eastbound Cowan Blvd approach to a left, left/thru/right, right lane. **Figure 47** shows the conceptual layout of the Preferred Alternative at this location.

Figure 47. 2030 Preferred Alternative: Cowan Crossing/Spotsylvania Ave Intersection



6 Future 2030 Build Conditions Operational Analysis

The "Preferred Alternatives" from the alternatives development exercise were distributed among the members of SWG for feedback. Their feedback was further discussed, vetted and included in the final alternative conceptual layouts. These alternatives were modeled in Synchro and evaluated using SimTraffic for the Future 2030 Build condition traffic operations.

6.1 Intersection Operations: Future 2030 Build Condition

Operational analysis was performed at each of the study intersections for the 2030 Future Build Condition. The Synchro models were developed to test the combination of preferred alternatives for the entire corridor. **Table 14** summarizes the Preferred Alternative average AM and PM peak hour delay for each movement for the study intersections along the corridor. The SimTraffic outputs and screen capture of *VDOT Sample Size Determination Tool* can be found in **Appendix**. **Figure 48** shows the intersection delay for the Preferred Alternative graphically.

Queuing analysis was completed for the study intersections during the AM and PM peak hours for 2030 Build conditions. *SimTraffic* Maximum Queue Lengths in feet were reported for each lane. These queue lengths are based on an average of 10 simulation runs. **Table 15** summarizes the maximum queue lengths during the AM and PM peak hours for the Preferred Alternative.

Table 14. Future 2030 Build SimTraffic AM and PM Peak Hour Delay (veh/sec) (Preferred Alternatives Model)

Intersection Number and Description	Type of Control	Lane Group	Eastbound		Westbound		Northbound		Southbound		Overall	
			AM	PM	AM	PM	AM	PM	AM	PM		
			Delay	Delay	Delay	Delay	Delay	Delay	Delay	Delay	AM	PM
1			Cowan Crossing		Spotsylvania Ave		US 1		US 1			
US 1 & Cowan Crossing / Spotsylvania Ave	Signal	Left	57.1	78.1	57.6	90.1	16.6	66.7	38.6	48.1	Delay	Delay
		Through	53.7	75.3	49.6	78.6	10.9	18.1	8.3	19.1		
		Right	14.9	44.6	26.4	33.6	6.1	6.3	7.4	12.8	13.5	24.4
		Approach	41.2	61.7	46.9	69.9	10.8	19.1	10.3	20.2		
2			Cowan Blvd		Rowe St		US 1		US 1			
US 1 & Cowan Blvd / Rowe St	Signal	Left	41.8	67.6	54.5	196.5	45.2	102.8	0.0	157.5	Delay	Delay
		Through	41.8	67.6	62.0	227.3	16.3	19.5	28.4	54.2		
		Right	16.0	35.0	34.6	200.8	3.7	4.5	4.1	24.3	25.3	53.1
		Approach	25.7	46.4	59.5	209.7	24.6	49.0	25.2	51.0		
3*			Powhatan St		Powhatan St		US 1		US 1			
US 1 & Powhatan St	Two-Way Stop	Left	--	--	--	--	19.4	97.8	20.3	23.2	Delay	Delay
		Through	--	--	--	--	5.2	6.1	2.3	6.5		
		Right	--	--	1.0	1.7	5.3	5.3	2.9	6.6	5.5	74.0
		Approach	--	--								
3*			Augustine Ave		Augustine Ave		US 1		US 1			
US 1 & Augustine Ave	Signal	Left	--	--	--	--	19.4	97.8	20.3	23.2	Delay	Delay
		Through	--	--	--	--	5.2	6.1	2.3	6.5		
		Right	13.8	934.1	42.1	39.8	5.3	5.3	2.9	6.6	5.5	74.0
		Approach										
4			Eagle Village Driveway		College Ave		US 1		US 1			
US 1 & College Ave / Eagle Village Drive	Signal	Left	63.7	76.4	54.1	529.4	32.1	104.8	62.4	103.9	Delay	Delay
		Through	57.0	117.8	49.2	529.4	15.8	46.0	14.4	22.7		
		Right	18.3	91.9	29.6	514.2	18.8	48.1	7.4	21.5	20.2	109.1
		Approach	46.9	94.4	43.4	525.4	16.8	49.9	17.4	27.7		
5			Mary Washington Blvd		-		US 1		US 1			
US 1 & Mary Washington Blvd	Signal	Left	42.5	73.5	--	--	30.3	65.3	-	-	Delay	Delay
		Through	--	--	--	--	9.6	16.1	29.8	23.1		
		Right	7.2	27.3	--	--	-	-	14.5	15.1	19.3	29.9
		Approach	28.9	56.8	--	--	12.7	25.8	23.9	21.4		
6			Fall Hill Ave		Fall Hill Ave		US 1		US 1			
US 1 & Fall Hill Ave	Signal	Left	55.4	91.7	54.4	336.1	27.3	62.2	22.8	58.4	Delay	Delay
		Through	49.5	92.6	46.5	321.0	16.3	23.0	19.6	40.8		
		Right	47.4	86.8	14.8	285.6	7.5	9.2	13.5	38.2	23.3	85.5
		Approach	51.8	91.3	44.5	325.2	14.1	22.9	19.5	41.3		

Intersection Number and Description		Type of Control	Lane Group	Eastbound		Westbound		Northbound		Southbound		Overall	
				AM	PM	AM	PM	AM	PM	AM	PM		
				Delay	Delay	Delay	Delay	Delay	Delay	Delay	Delay	AM	PM
7	US 1 & Hanson Ave / Princess Anne St			Hanson Ave		Princess Anne St		US 1		US 1/Cambridge St			
		Signal	Left	--	--	60.0	274.8	--	--	29.7	41.6	Delay	Delay
			Through	--	--	--	--	60.0	274.8	8.6	19.9		
			Right	12.8	14.5	7.8	263.0	8.4	56.3	8.4	20.4	12.3	78.1
			Approach	12.8	14.5	16.2	265.8	11.5	65.3	11.9	22.5		
12	US 1 & Off-Ramp					Off-Ramp		US 1/Cambridge St		US 1/Cambridge St			
		Signal	Left	--	--	14.0	11.0	--	--	0.0	0.0	Delay	Delay
			Through	--	--	--	--	26.2	35.5	11.2	9.3		
			Right	--	--	1.3	2.7	0.0	0.0	--	--	11.2	9.3
			Approach	--	--	26.2	35.5	14.0	11.0	1.3	2.7		

Note: Micro-simulation delay (sec/veh) results shown represent an average of 10 SimTraffic simulations runs and includes Total Delay plus Denied Delay in Seconds per vehicle

'-' Movements not applicable OR SimTraffic does not provide level of service or delay for movements with no conflicting volumes

**Intersection 3 is a 6-leg intersection and is listed twice to show Powhatan St & Augustine Ave MOEs separately*

Figure 48. Future 2030 Build (Preferred Alternatives Model) AM (PM) Peak Hour Intersection Operations Results

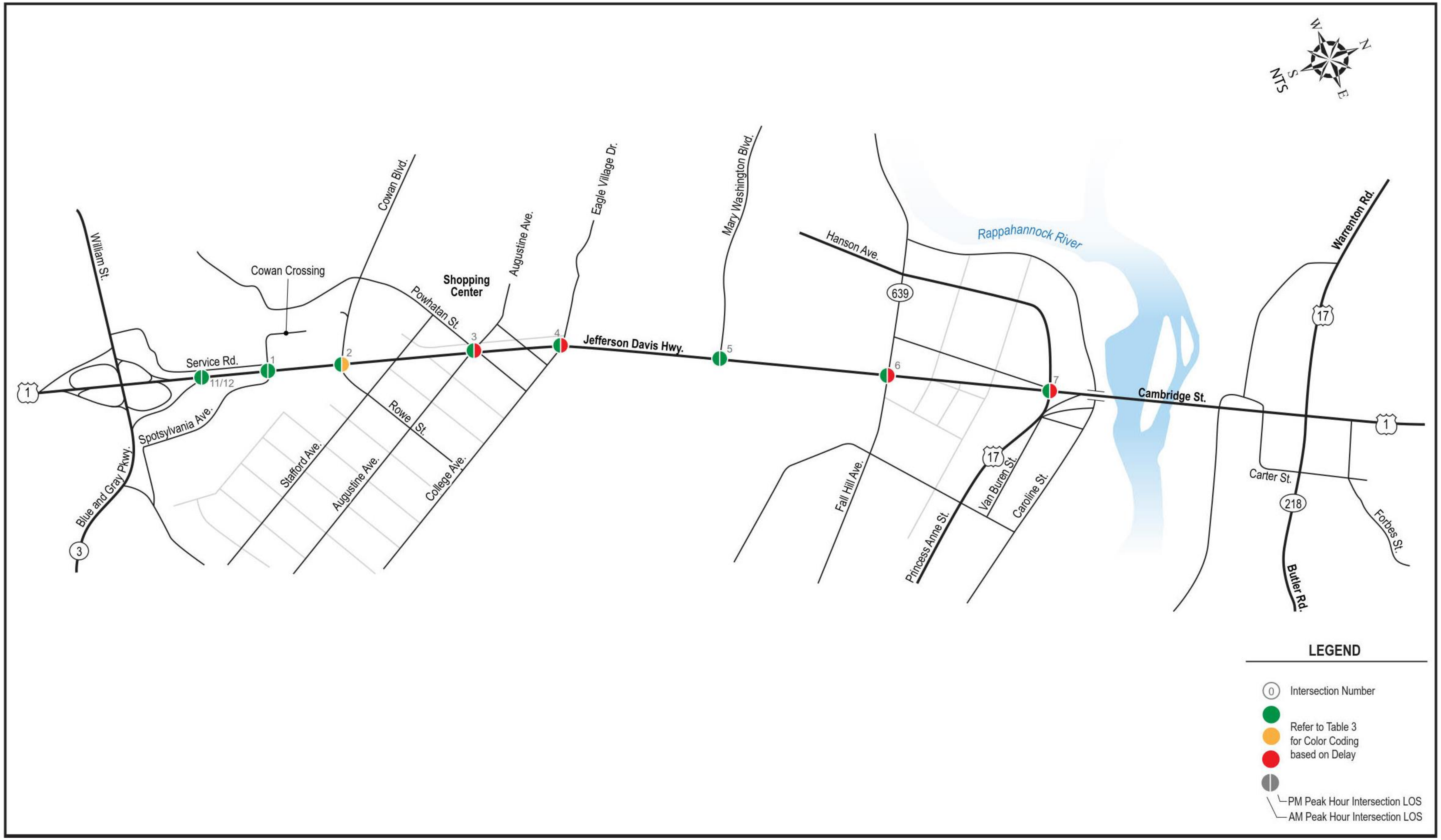


Table 15. Future 2030 Build Conditions (Preferred Alternatives Model): Summary of Maximum Queues

intersection Number and Description	Type of Control	Lane Group	Eastbound			Westbound			Northbound			Southbound		
			Storage Bay Length	AM Queue (ft)	PM Queue (ft)	Storage Bay Length	AM Queue (ft)	PM Queue (ft)	Storage Bay Length	AM Queue (ft)	PM Queue (ft)	Storage Bay Length	AM Queue (ft)	PM Queue (ft)
1 US 1 at Cowan Crossing / Spotsylvania Ave			Cowan Crossing			Spotsylvania Ave			US 1			US 1		
	Signal	Left	100	98	99	200	172	199	175	174	174	175	133	174
		Through	--	139	250	--	137	402	--	328	464	--	248	598
		Right							175	175	175	215	109	215
2 US 1 at Cowan Blvd / Rowe St			Cowan Blvd			Rowe St			US 1			US 1		
	Signal	Left	375	163	264	--	93	270	325	387	596	--	0	81
		Through	--	193	297	50	52	51	--	519	522	--	300	873
		Right	200	245	426					31	95	425	75	425
3* US 1 at Powhatan St / Augustine Ave			Powhatan St			Powhatan St			US 1			US 1		
	Two-Way Stop	Left	--	--	--	--	--	--	250	104	245	200	6	36
		Through	--	--	--	--	--	--	--	23	425	-	63	97
		Right	--	--	--	--	5	58	--	3	344	150	66	121
3* US 1 at Powhatan St / Augustine Ave			Augustine Ave			Augustine Ave			US 1			US 1		
	Two-Way Stop	Left	--	--	--	--	--	--	250	104	245	200	6	36
		Through	--	--	--	--	--	--	--	23	425	--	63	97
		Right	--	66	490	--	55	81	--	3	344	150	66	121
4 US 1 at Eagle Village Drive / College Ave			Eagle Village Driveway			College Avenue			US 1			US 1		
	Signal	Left	--	142	236	115	110	115	115	115	115	500	146	292
		Through	--	105	418	--	168	590	--	454	598	--	258	583
		Right	--			--			--	464	579	310	90	223
5 US 1 at Mary Washington Blvd			Mary Washington Blvd			-			US 1			US 1		
	Signal	Left	650	192	398	--	--	--	415	190	324	--	--	--
		Through	--	--	--	--	--	--	--	293	403	--	452	533
		Right	--	94	260	--	--	--	--	--	--	270	270	270
6 US 1 at Fall Hill Ave			Fall Hill Ave			Fall Hill Ave			US 1			US 1		
	Signal	Left	--	149	150	285	245	285	310	72	267	240	223	240
		Through	--	302	543	--	156	839	--	259	475	--	388	668
		Right	250	211	228	--	97	150	350	162	308	--	125	125
7 US 1 at Hanson Ave / Princess Anne St			Hanson Ave			Princess Anne St			US 1			US 1 / Cambridge St		
	Signal	Left	--	--	--	200	183	200	--	--	--	120	120	120
		Through	--	--	--	--	--	--	--	246	851	--	274	372
		Right	--	78	158	--	273	566	--	256	846	--	265	404
12 US 1 at Off-Ramp			--			Route 218 (Butler Rd)			US 1			US 1		
	Signal	Left	--	--	--	--	--	--	--	--	--	--	--	--
		Through	--	--	--	--	--	--	--	425	362	--	0	3
		Right	--	--	--	--	142	209	--	--	--	--	--	--

NOTE: Shared lane groups are shown as merged cells

Micro-simulation maximum queues (ft) shown represent an average of 10 SimTraffic simulations runs

Red text indicates maximum queues that exceed storage capacity

"-" Cells indicate that a queue or turn bay did not exist

* Intersection 3 is a 6-leg intersection and is listed twice to show Powhatan St & Augustine Ave MOEs separately

7 Crash Reduction Analysis

A crash reduction analysis was conducted for US Route 1 from north of Route 3 to Route 17 Bus/Route 218/Warrenton Road/Butler Road. As part of the crash reduction methodology, the *Crash Mitigation Factor Clearinghouse*[1] and *FHWA Desktop Reference for Crash Reduction Factors*[2] were utilized to calculate the Crash Reduction Factors (CRFs) associated with each proposed alternative along US Route 1 in Fredericksburg, Virginia, from the Virginia Department of Transportation (VDOT) and the City of Fredericksburg. The CRFs were applied to the crash history data from the *VDOT Crashtools Database*[3] to determine the expected number of crashes and the percent reduction in crashes per alternative. Expected crashes were projected to the year 2030 (base build year) and then calculated over a 20-year life cycle to 2050. The expected crashes were then utilized to compare the *No Build* and *Build* conditions based on the 20-year projection to evaluate the efficacy of the proposed alternative.

7.1 Analysis Methodology

The following sections describe the methodology that was used to determine the crash expectancy and cost savings associated with the proposed modifications.

7.1.1 Proposed Roadway Modifications and CRFs

The CRFs were selected based on the improvements designated for the *2030 and 2050 Build* conditions. **Appendix G, Tables 3** through **4** includes the following: 1) the countermeasures proposed, 2) categories of countermeasures obtained from the *CMF Clearinghouse* or *FHWA Desktop Reference* source, 3) applicable crash type and severity, 4) percent of applicable crashes, and 5) notes for selected CRFs. It should be noted that CRFs are not provided for all roadway modifications in *the Crash Mitigation Factor Clearinghouse or FHWA Desktop Reference for Crash Reduction Factors.* Roadway modifications without designated CRFs were not given a CRF for this analysis; therefore, those improvements did not have any impact on the expected crashes.

In some instances, CRF values were applicable to the intersection or segment as a whole and often involved multiple CRF values. To accurately calculate CRFs for some alternatives, a combined CRF was calculated using **Equation 1**. Some alternatives required combined CRFs and/or individual CRFs, depending on the specific improvements.

Equation 1. Combined CRF Calculation

$$Combined\ CRF = 1 - [(1 - CRF_1) * (1 - CRF_2) * \ldots * (1 - CRF_i)]$$

7.1.2 Applicable Crash Calculations

To properly determine how the improvements impact the 2030 and 2050 expected crashes, a detailed evaluation was conducted of historical crash data (2012-2017). Not every crash at a specific location would be eliminated due to an improvement. For example, when installing a median at the unsignalized intersection of US Route 1 at Charles Street, only crashes related to the northbound left-turn, southbound left-turn, eastbound through and left-turn movements, and westbound through and left-turn movements would be expected to be reduced. Therefore, the CRF should only be applied to the specific crashes that may have been affected by the improvement. So, for each improvement with a known CRF, the number of crashes impacted by the improvement was determined by analyzing each crash within the *VDOT Crashtools Database* from the five (5) most recent calendar years of crash data (2012-2017). Then, the percent of applicable crashes (i.e., number of applicable crashes across the five calendar years divided by the total number of crashes across the five calendar years) was determined for each improvement with a known CRF, as shown in **Equation 2**.

Equation 2. Percentage of Applicable Crashes Calculation

$$Percentage\ of\ Applicable\ Crashes = \frac{Number\ of\ Applicable\ Crashes}{Total\ Number\ of\ Crashes} * 100$$

7.1.3 Crash Reduction Evaluation

Based on the 2012-2017 crash data within the *VDOT Crashtools Database*, the average numbers of property damage only (PDO/O/O), non-incapacitating injury (B+C), and fatal/incapacitating injury/ambulatory injury (K+A) crashes over the most recent five years were calculated. The existing average crashes were then projected into 2030 (i.e., 13-year projection based on the 1.5% and 2.0% growth rates) to which a base build year was established. These estimates were then projected out to the year 2050 (i.e., 20-year projection) to estimate the expected number of PDO/O/O, B+C, and K+A crashes for the *Build* conditions over the 20-year life cycle, assuming a 1.5% growth rate (Route 3 to Fall Hill Avenue) and a 2.0% growth rate from Fall Hill Avenue to US Route 17.

To calculate the expected number of PDO/O, B+C, and K+A crashes for the *Build* conditions where 100% of the crashes were applicable, the appropriate combined CRFs were implemented where improvements were proposed, as shown in **Equation 3**.

Equation 3. Expected Crashes for the 2030 Build Conditions (100% Applicable Crashes)

$$2030\ Build\ Expected\ Crashes = 2030\ No\ Build\ Expected\ Crashes - (2030\ No\ Build\ Expected\ Crashes * CRF)$$

To calculate the expected number of (PDO/O), (B+C), and (K+A) crashes for the *Build* conditions where only a portion of the crashes were applicable, the appropriate combined CRFs were implemented where improvements were proposed, as shown in **Equation 4**.

Equation 4. Expected Crashes for the 2030 Build Conditions (<100% Applicable Crashes)

$$\begin{aligned} &2030\ Build\ Expected\ Crashes \\ &\quad = [2030\ No\ Build\ Expected\ Crashes - [2030\ No\ Build\ Expected\ Crashes * \%\ Applicable\ Crashes * (CRF)] \end{aligned}$$

The percent reduction in PDO/O, B+C, and K+A crashes between the *2050 No-Build* and *Build* conditions per alternative was calculated for each intersection and segment along the US Route 1 corridor over the 20-year cycle life.

Another factor that was devised in our analysis was accounting for certain movements being diverted from their existing location, based on the proposed alternative, back to the existing intersection under analysis. For example, the intersection of US 1 at Hanson Avenue/Princess Anne Street, a raised median is being proposed in the center of the existing intersection. As proposed in the alternative, the eastbound left turn movement is being removed, and thus is diverting vehicles ideally to divert along Woodford Street to Riverside Drive to Amaret Street to ultimately

1 Federal Highway Administration. (2017). Crash Modification Factors Clearinghouse. Washington, DC. Retrieved from http://www.cmfclearinghouse.org/.

2 Federal Highway Administration. (2014). *Desktop Reference for Crash Reduction Factors*. Washington, DC. Retrieved from https://safety.fhwa.dot.gov/tools/crf/resources/fhwasa08011/.

3 Virginia Department of Transportation. (2017). *Crash Analysis Tool*. Retrieved from https://public.tableau.com/profile/tien.simmons#!/vizhome/Crashtools8_2/Main.

end at the westbound Princess Anne approach right turn. Though eliminating these left-turn volumes and their respective crashes, the existing westbound approach will be impacted by these new volumes and are now subjected to potentially higher crash statistics. For the purposes of our analysis, projected increased percentages in vehicular volumes per the affected approach was calculated and applied to existing crash statics in order to project the overall increase or decrease in crash rates.

Projected crashes and crash reductions to the base build year (2030) is provided in **Appendix G, Table 5**. This base condition was then projected each year over the 20-year life cycle to determine the crash reductions through 2050.

7.2 Analysis Results

The total crash reduction values over the 20-year cycle life (i.e., from 2030 to 2050) and percentages for each alternative are provided in **Table 166**.

Table 16. Percent Crash Reduction per Alternative (20-Year Cycle Life)

Location	PDO/O Crashes (Reduction)	B+C Crashes (Reduction)	K+A Crashes (Reduction)
Princess Anne Street/Hanson Avenue	70.95	132.07	8.41
Fall Hill Avenue	70.09	74.42	12.04
Powhatan Street & Augustine Avenue	39.89	49.58	9.90
Cowan Blvd/Rowe Street	33.04	39.04	6.01
Cowan Crossing/Spotsylvania Avenue	19.17	30.83	7.29

[1] Crash Rate reduction percentages are assumed to remain the same over the 13-year and 20-year projections due to the assumed constant growth rate over the corridor.

8 Improvement Prioritization

The Improvement Prioritization process involved development of planning level cost estimates for the preferred alternatives, development of 20-year life-cycle operational and safety benefits for each improvement alternative and calculation of the Benefit-Cost ratios. These elements are described in the following sections.

8.1 Planning Level Cost Estimates

Planning level cost estimates were developed for all the preferred improvement alternatives using the *VDOT Project Cost Estimating System (PCES), Version 7.10* for VDOT Fredericksburg District. The 2018 costs obtained from the PCES tool were inflated to future year 2030 with a rate of total inflation of 39.83%. The cost estimates included Construction (CN), Right-of-Way and Utilities Relocation (ROW) and Preliminary Engineering (PE) costs. **Table 17** summarizes the cost estimates for each improvement alternative proposed and are expressed in year 2030 dollars. The PCES cost estimates are included in **Appendix**.

Table 17. Planning Level Cost Estimates (Year 2030 US Dollars)

Alternative/Location	Cost Estimate			
	Preliminary Engineering (PE)	Right-of-Way/Utilities (ROW)	Construction (CN)	Total
Princess Anne Street/Hanson Avenue	$243,746	$1,108,806	$1,321,083	$2,673,635
Fall Hill Avenue	$800,000	$2,900,000	$3,671,833	$7,371,833
Powhatan Street & Augustine Avenue	$154,356	$69,019	$805,074	$1,028,449
Cowan Blvd/Rowe Street	$253,991	$180,576	$1,383,121	$1,817,688
Cowan Crossing/Spotsylvania Avenue	$532,635	$330,548	$3,439,867	$4,303,050
			Sum	**$17,022,822**

The planning level cost estimates were developed to get a preliminary idea of the funding requirements for the proposed improvements along the corridor. The estimated costs include 10% contingency for CN and ROW.

8.2 Planning Level Schedule Estimates

Planning level schedules were developed for all improvement alternatives. Schedule estimates were based on familiarity with complexity of projects within the Fredericksburg District as well as discussions with the SWG. **Table 18** summarizes schedules by phases of project: Preliminary Engineering (PE), ROW and Utility Relocation (ROW) and Construction (CN).

Table 18. Planning Level Schedules (months)

Location	Schedule Estimate (months)			
	Preliminary Engineering (PE)[1]	Right-of-Way/Utilities (ROW)[3]	Construction (CN)[2]	Total
Princess Anne Street/Hanson Avenue	9.75	15	6	30.75
Fall Hill Avenue	9.75	24	8	41.75
Powhatan Street & Augustine Avenue	10.25	24	10	44.25
Cowan Blvd/Rowe Street	8.75	15	6	29.75
Cowan Crossing/Spotsylvania Avenue	9.75	18	8	35.75

Notes:

1. PE durations assume 3 design submittals with 3-week review period
2. Construction includes pre-submittals (1.5) and close out/punch list items (1)
3. ROW for access management includes permit modifications
4. Total duration does not include time for procurement and award

8.3 Benefit-Cost Analysis

A Benefit-Cost (B/C) analysis was conducted for the candidate projects to evaluate their cost effectiveness. An analysis period of 20-years was used to evaluate the life cycle benefits. A 20-year period is typically used for small to medium size transportation projects. The following factors were considered in the B/C calculations for each of the improvement alternatives evaluated:

8.3.1 Operational Benefit

The determination of operational benefit for each improvement alternative was based on the methodology of calculating reduction in travel delay because of the proposed improvements. This methodology converts the vehicle delay into person delays by accounting for the vehicle occupancy. Consistent with the *2009 National Household Travel Survey (NHTS)*[4], average vehicle occupancies of 1.13 and 1.74 were assumed for work trips and non-work trips, respectively, assuming 250 workdays per year and 60% of peak hour volumes are work trips.

Similarly, USDOT's *"Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis, 2016"*[5], *Table 4* was used to determine the hourly values for travel time savings for each occupant in a vehicle as $22.90/hour and $12.00/hour for work and non-work trips, respectively.

To determine annual peak hour delay savings, the calculated delay reduction per vehicle (*SimTraffic* analyses) in each respective peak hour was multiplied by the peak hour traffic volume at each intersection to obtain a compounded delay. Using the compounded delay savings and identified values for travel time savings, the annual cost benefits for each alternative were determined. The Present Value of Benefits (PVB_D) of the annual delay reduction benefits over a 20-year life-cycle was calculated using **Equation 5**:

Equation 5. Present Value of Benefits (PVB_D)

$$(P/A, i, n) = \frac{(1+i)^n - 1}{i(1+i)^n}$$

[4] FHWA Report No. FHWA-PL-11-022, Summary of Travel Trends: 2009 National Household Travel Survey

[5] USDOT Guidance: "The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations, Revision 2 (2016 Update)"

Where,

$(P/A, i, n)$ = Factor that converts a series of uniform annual amounts to its present value
i = Minimum attractive rate of return or discount rate = 3%
n = Years in the service life of the improvements = 20 years

Table 19 shows the delay reduction cost savings per alternative. The detailed calculations are summarized and included in the **Appendix.**

Table 19. Delay Savings Analysis

Alternative	Total Cost Savings
Princess Anne Street/Hanson Avenue	$25,509,115.00
Fall Hill Avenue	$9,655,648.00
Powhatan Street & Augustine Avenue	$14,290,082.00
Cowan Blvd/Rowe Street	$5,622,048.00
Cowan Crossing/Spotsylvania Avenue	$1,293,515.00

8.3.2 Safety Benefit

As part of the crash analysis, the differences in crashes between the *2050 No-Build* and *Build* conditions were calculated for PDO, injury, and fatal crashes over the 20-year life cycle. To further analyze the impact of the proposed alternatives, societal costs were applied to the crash reduction values, as provided by the *VDOT Highway Safety Improvement Program (HSIP)*[6]. Cost savings per crash type are provided below:

- K+A Crash = $923,829
- B+C Crash = $82,111
- PDO/0 = $10,549

Total cost savings per alternative are provided in Error! Reference source not found.**0.** Additionally, the breakdown of the crash reduction and cost savings (PVB_S) over the 20-year life cycle are provided in **Appendix**.

Table 20. Crash Cost Savings Analysis (PVB_S Over 20-Year Life Cycle)

Alternative	PDO	Injury	Fatal	Total Cost Savings
Princess Anne Street/Hanson Avenue	$553,918.00	$8,025,295.00	$5,751,835.00	$14,331,049.00
Fall Hill Avenue	$547,157.00	$4,522,214.00	$8,233,054.00	$13,302,426.00
Powhatan Street & Augustine Avenue	$312,595 .00	$3,028,707.00	$6,803,753.00	$10,145,056.00
Cowan Blvd/Rowe Street	$259,289.00	$306,433.00	$47,143.00	$612,867.00
Cowan Crossing/Spotsylvania Avenue	$253,312.00	$2,357,635.00	$4,176,896.00	$6,787,862.00

[1] Crash Rate reduction percentages are assumed to remain the same over the 13-year and 20-year projections due to the assumed constant growth rate over the corridor.

8.3.3 Cost of Construction

The 2030 cost estimate for each alternative as summarized in Table 22 was used in the calculation of B/C ratios. The following equation was used to develop the B/C ratios:

Equation 6. Benefit/Cost Ratio (BCR)

$$BCR = PVB/PVC$$

Where,

PVB = Present Value of Combined Benefits = $PVB_D + PVB_S$

PVC = Present Value of Costs = 2030 cost estimates

The present value of cost was projected to 2030 cost estimates with a rate of total inflation of 34.64% which is derived from the 2028 cost obtained from the Fredericksburg district. The manual estimates from Fredericksburg are included in **Appendix**.

Table 21 summarizes the calculated BCR for each of the improvement alternatives.

Table 21. BCR per Improvement Alternative

Alternative	Delay Reduction Benefit (PVB_D)	Safety Benefit (PVB_S)	Present Value of Costs (PVC)	Benefit-Cost Ratio (BCR)
Princess Anne Street/Hanson Avenue	$25,509,115.00	$14,331,049.00	$2,673,635.00	14.90
Fall Hill Avenue	$9,655,648.00	$13,302,426.00	$7,371,833.00	3.11
Powhatan Street & Augustine Avenue	$14,290,082.00	$10,145,056.00	$1,028,449.00	23.76
Cowan Blvd/Rowe Street	$5,622,048.00	$612,867.00	$1,817,688.00	3.43
Cowan Crossing/Spotsylvania Avenue	$1,293,515.00	$6,787,862.00	$4,303,050.00	1.88

8.3.4 Project Prioritization

Improvement projects should be prioritized at a regional level. The following factors should be considered while evaluating the proposed improvement alternatives to be advanced further for funding and construction:

- B/C Ratio: Typically, projects with B/C ratios greater than or equal to 1.00 indicate cost effectiveness of the improvements and are preferred by the Agencies;
- Safety Improvements and their Benefits;
- Geometric Improvements;
- No anticipated ROW Impacts: Projects that require additional right-of-way are typically costly and are not preferred.

Table 22 summarizes these factors for each improvement alternative proposed by this study.

[6] Virginia Department of Transportation (VDOT) Highway Safety Improvement Program (HSIP) http://www.virginiadot.org/business/ted_app_pro.asp

Table 22. Project Prioritization Criteria

Alternative	B/C Ratio	Safety Improvements	Geometric Improvements	No Anticipated ROW Impacts
Princess Anne Street/Hanson Avenue	14.90	✓	✓	
Fall Hill Avenue	3.11	✓	✓	
Powhatan Street & Augustine Avenue	23.76	✓	✓	
Cowan Blvd/Rowe Street	3.43	✓	✓	
Cowan Crossing/Spotsylvania Avenue	1.88	✓	✓	

✓ Indicates the criteria for the corresponding improvement alternative is fulfilled

Based on the review of the criteria and the calculated BCR, all the improvement alternatives proposed can potentially be submitted for SMART SCALE or seek other funding sources due to the operational improvements they offer. The VDOT Fredericksburg District in coordination with the localities may choose to advance some or all these projects at their discretion.

9 Conclusions And Recommendations

The STARS Route 1 (Jefferson Davis Highway) alternatives evaluation study from North of Route 3 (William Street) to Princess Anne Street / Hanson Avenue identifies operational, safety, access management and congestion issues along the corridor. This study also evaluates potential mitigation measures and improvement alternatives to address those issues. This study should be used as a planning level document to establish the next steps of planning, programming, designing and constructing the identified safety, operational and access management improvements within the corridor. Following are the specific steps that may be followed:

Gain Consensus and Prioritize Improvements

It is recommended to conduct outreach meetings with stakeholders who were not part of the SWG of this study to gain their consensus on the proposed candidate improvement alternatives. Prioritization of the improvements is suggested by considering the following factors:

- Benefit-Cost
- Local/District Preference
- Safety Benefits
- Geometric Improvements
- ROW Impacts

Prepare Projects for Advancement

Upon identifying and prioritizing the improvements at the regional level, the projects with the highest priority should be advanced to be included in the following plans:

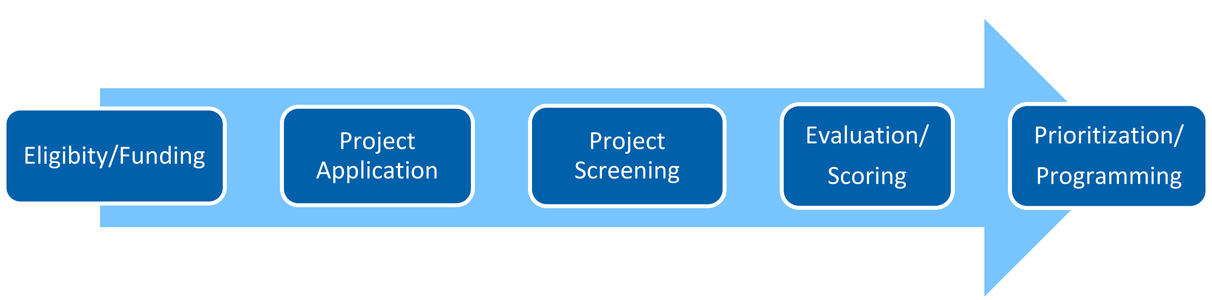
- Constrained Long Range Transportation Plan (CLRP)
- Transportation Improvement Plan (TIP)
- Statewide Transportation Improvement Plan (STIP)
- VDOT Six-Year Improvement Program (SYIP)

Secure Funding

There are several funding sources or revenue sharing programs that can be tapped into to fund the improvements identified in this study:

SMART SCALE

Virginia's SMART SCALE Process facilitates selecting the right transportation projects for funding and ensuring the best use of limited tax dollars. It includes five overreaching steps as depicted below:



Per the SMART SCALE Technical Guide, 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. For the projects in the Fredericksburg District, the scoring factors with the highest weight are:

- Accessibility (15%)
- Economic Development (5%)
- Safety (5%)
- Environmental Quality (10%)
- Congestion Mitigation (45%)
- Efficient Land Use (20%)

All the improvement alternatives identified in this study are candidate projects for SMART SCALE funding. Several of these projects can also be packaged together into one SMART SCALE application to achieve a better project score and to recognize cost savings associated with completing the projects concurrently.

The SMART SCALE funding may be accompanied by other sources of funding as listed below:

- Construction District Grants Program (DGP)
- High Priority Projects Program (HPPP)
- Congestion Mitigation and Air Quality Funding (CMAQ)
- Regional Surface Transportation Block Grant Program (RSTBG)
- Revenue Sharing
- Transportation Alternatives (TA) Set-Aside Funds
- Highway Safety Improvement Program (HSIP) and Other Safety Program Funds
- Tele-fees and Unpaved Road Related Funds
- State of Good Repair

SMART SCALE projects can be submitted by regional entities including counties, cities and towns that maintain their own infrastructure. Once the project has been screened, scored and selected for funding by the Commonwealth Transportation Board (CTB), it remains in the SYIP as a funding priority.

Project Completion

Once the funding is secured and improvements are ready for construction, the projects should be advanced and implemented with close coordination among the affected stakeholders in the region.