Road Safety Audit

Shenandoah National Park



Image Sources: US DOT Volpe, May 2025

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FINAL

U.S. Department of Transportation
Volpe Center

Executive Summary

Project Overview

The Shenandoah National Park (SHEN) Road Safety Audit (RSA) focuses on three intersections within the park where Skyline Drive intersects Virginia Department of Transportation (VDOT) roadways at or near Entrance Stations. The locations include the Front Royal Entrance Station, the Thornton Gap Entrance Station, and the Swift Run Gap Entrance Station. SHEN provides a unique auto-experience through driving Skyline Drive, a National Historic Landmark, a National Scenic Byway, and the primary roadway that traverses 105 miles through the entire length of the park. Access to Skyline Drive is only provided at four locations, all of which include Entrance Stations into SHEN. The park is open year-round; however, Skyline Drive is periodically closed due to inclement weather. Many facilities within the park are only open between March and November, with the exception of the Byrd Visitor Center, which is also open year-round.

One of the primary challenges throughout SHEN is accessing Skyline Drive, especially during peak visitation periods where congestion can be significant. The VDOT roads that provide access to SHEN are all four-lane divided principle arterial roadways typically with high traffic volumes, high speeds, and light levels of heavy vehicles. The three intersections within the study area are unsignalized. The combination of unsignalized control with high volume roadway, and peak congestion can cause a variety of safety challenges and dangerous visitor behavior. The three intersections are detailed below:

- Site 1: Skyline Drive at US-340
- Site 2: Thornton Gap Entrance Station
- Site 3: Swift Run Gap Entrance Station

Overall Recommendations

The RSA recommends a variety of safety countermeasures related to engineering, enforcement, and education. The key safety countermeasures include:

Site 1: Skyline Drive at US-340

- Improve signage and pavement markings along Skyline Drive at US-340.
- After more information related to the Front Royal Entrance Station Modernization project is further along in design, evaluate an intersection redesign of Skyline Drive at US-340.
- Direct emergency vehicles to use the access road between Criser Road/Parkview Drive and Skyline Drive during periods of peak congestion as it relates to emergency response.
- Provide information to improve awareness of bicycling usage throughout SHEN.

Site 2: Thornton Gap Entrance Station

- Improve left-turn movement capacity for people exiting SHEN to the east, mainly destined for the Washington, D.C. Metro.
- Reduce travel speeds along US-211.
- Improve signage and pavement markings along US-211 at the AT Crossing.
- Improve parking and access to the entrance sign for photos.

Site 3: Swift Run Gap Entrance Station

- Install dedicated walking lane for AT users along Skyline Drive to improve the crossing.
- Implement turning lanes along Skyline Drive to exit the park at Swift Run Gap.

- Reduce travel speeds along US-33 and remove second westbound travel lane (climbing lane) for downhill section.
- Improve parking and access to the entrance sign for photos.
- Perform maintenance to include regular sweeping at right-turn slip lane from US-33 westbound into Swift Run Gap.

These recommendations will be prioritized through stakeholder engagement with partner organizations and further evaluated for impacts to the natural, cultural, or historic landscape of the Park. The Park will develop a plan to strategically select and implement the preferred countermeasures with available funding and resources over the coming years.

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I. Introduction

Background and Purpose

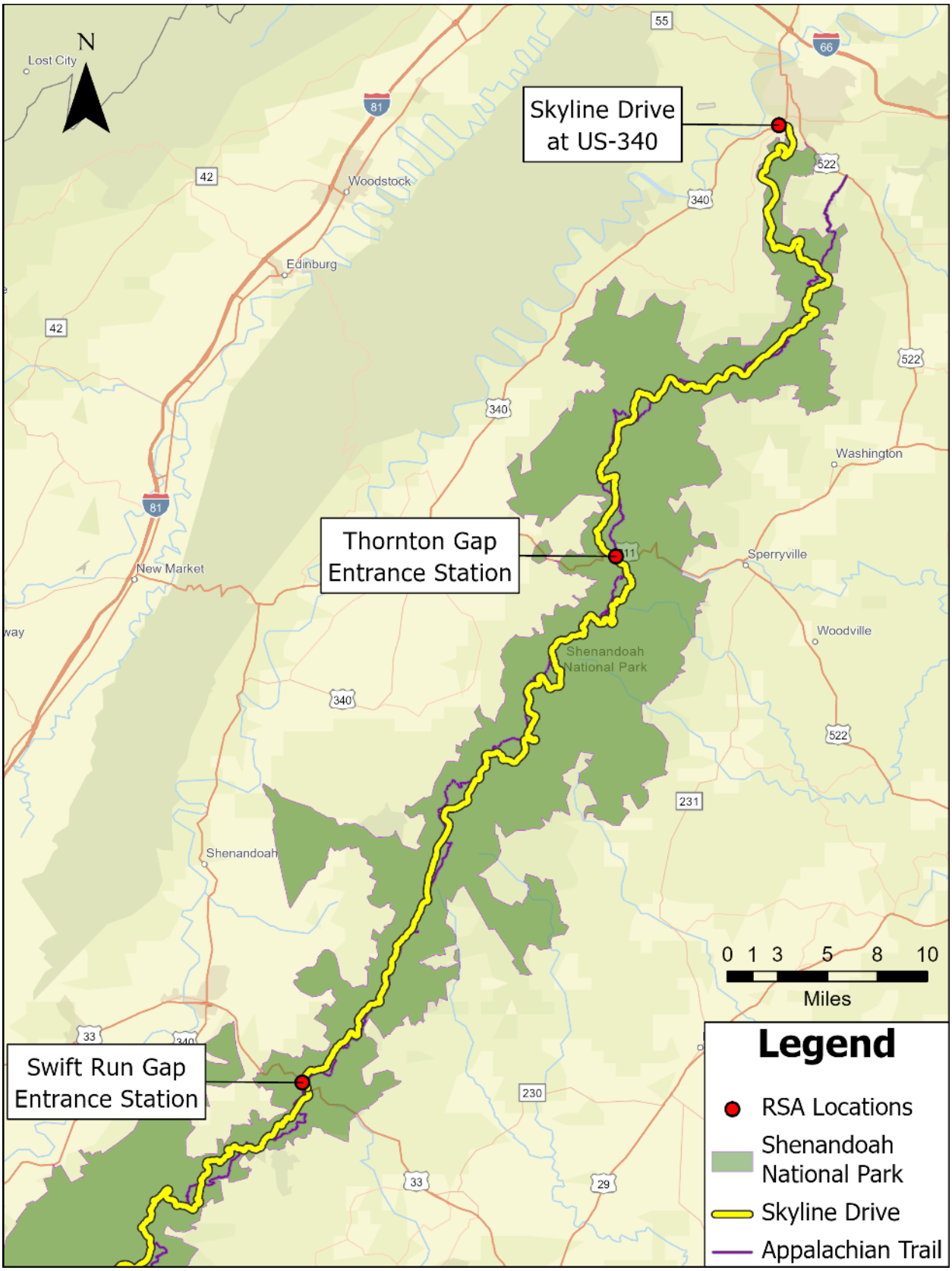
The Shenandoah National Park (SHEN) is located along the Blue Ridge Mountains in north central Virginia. SHEN is within the Northeast Region (NER) of the National Park Service (NPS) system. SHEN stretches for about 80 miles north to south and consists of more than 197,000 acres. Skyline Drive is the only roadway that traverses the entire length of the park for 105 miles. Access to Skyline Drive is only provided at four locations, all of which include Entrance Stations into SHEN. Skyline Drive is designated as both a National Historic Landmark and a National Scenic Byway. The Appalachian Trail (AT) travels through the park for 101 miles of trail. This Road Safety Audit (RSA) focuses on three sites at or near Entrance Stations, where NPS and SHEN transportation facilities meet Virginia Department of Transportation (VDOT) transportation facilities. The three sites, which are highlighted in Figure 1, include:

- **Site 1: Skyline Drive at US-340:** This site consists of the intersection of Skyline Drive at US-340, and the surrounding area. US-340 is also known as the Stonewall Jackson Memorial Highway. The intersection is the northernmost entrance point into SHEN and the beginning of Skyline Drive. The Front Royal Entrance Station is less than one mile south of this intersection.
- **Site 2: Thornton Gap Entrance Station:** This site consists of the Thornton Gap Entrance Station and the surrounding area. Primarily the RSA will focus on intersection where the road with the Thornton Gap Entrance Station intersects US-211. The short roadway between Skyline Drive and US-211 does not have a formal name and will be referred to as Thornton Gap Entrance Road. US-211 is also known as the Lee Highway. This site also includes the AT crossing across Skyline Drive and across US-211, the intersection of US-211 at Lower Panorama, Skyline Drive at Upper Panorama, the Skyline Drive bridge over US-211, and the interchange ramps between Skyline Drive and the Thornton Gap Entrance Station.
- **Site 3: Swift Run Gap Entrance Station:** This site consists of the Swift Run Gap Entrance Station and the surrounding area. Primarily the RSA will focus on intersection where the road with the Swift Run Gap Entrance Station intersects US-33. US-33 is also known as the Spotswood Trail. The short roadway between Skyline Drive and US-33 does not have a formal name and will be referred to as Swift Run Gap Entrance Road. This site also includes the intersection of Swift Run Gap Entrance Road at Skyline Drive, and the AT crossing across Skyline Drive, and the walking route along Skyline Drive over US-33.

The park is open year-round, but portions of Skyline Drive can be periodically closed during inclement weather. Visitors may still enter the Park on foot to hike even when Skyline Drive is closed. Most facilities within the park are open between March and late November (to include the Dickey Ridge Visitor Center and Park Store), except for the Byrd Visitor Center, which is open year-round. SHEN requires an entrance fee therefore almost all visitors are there to experience the park, by either driving Skyline Drive, hiking, camping, or participating in other recreational activities.

The NPS Northeast Regional Office (NERO) Federal Lands Transportation Program requested the USDOT Volpe Center (Volpe) to conduct an RSA within SHEN. The RSA will recommend safety countermeasures related to engineering, education, enforcement, and emergency services. The countermeasures identified are meant to document all potential safety enhancements. Some safety countermeasures may cause impacts to the natural, cultural, or historic landscape or may not align with other NPS priorities. All safety countermeasures should be evaluated further to understand the tradeoff between improving safety or impacts to valuable NPS resources.

Figure 1: Study Area Overview



Road Safety Audit Team

The audit team consists of staff members from the NPS, the state of Virginia, and the local jurisdictions. Agencies represented including SHEN, NERO, Virginia DOT, and the Potomac Appalachian Trail Club. The audit team members participated in various tasks including pre-meetings, the RSA site visit, and post meetings. Team members also provided valuable commentary and observations in addition to both quantitative and qualitative data. The full list of team members is provided in Table 1.

Table 1: Participating Road Safety Audit Team Members

Audit Team Member	Title	Agency/Affiliation
Eric Frey	Outdoor Recreation Planner	NPS, SHEN
Mindy Bogue	Fee Program Manager	NPS, SHEN
Russell Griswold	Project Manager	NPS, SHEN
Eric Yount	Park Ranger	NPS, SHEN
John Mahoney	Chief, Commercial Services	NPS, SHEN
Connor Smyth	Transportation Branch Manager	NPS, NERO
Alexandra McNally	Multimodal Transportation Program Manager	NPS, NERO
Tracy Stakely	Superintendent	NPS, SHEN
Stanley Cockrell	Deputy Chief, Facilities Management	NPS, SHEN
Evan Childress	Chief of Natural and Cultural Resources	NPS, SHEN
Jon Beck	Safety and Occupational Health Manager	NPS, SHEN
Sam Leckrone	Traffic Engineer	Virginia DOT Staunton District
Benjamin Fosu-Saah	Traffic Engineer	Virginia DOT Culpeper District
Darin Simpson	Traffic Engineer	Virginia DOT Staunton District
Steven Frooman	Traffic Engineer	Virginia DOT Culpeper District
Rush Williamson	Supervisor of Trails	Potomac Appalachian Trail Club
Michael Littman	Transportation Engineer	US DOT Volpe Center
Emily Maciejak	Community Planner	US DOT Volpe Center
Erwin Figueroa	Community Planner	US DOT Volpe Center

Audit Schedule

A detailed list of the key RSA activities and milestones are shown in Table 2 with the date and a short description of the activity or milestone.

Table 2: Road Safety Audit Schedule

Date	Activity or Milestone
February 5, 2025	RSA Kick-off meeting
May 24, 2024	Volpe delivered draft Existing Conditions Memo
April 30, 2025	RSA Site Visit Prep Meeting
May 31, 2024	Volpe delivered final Existing Conditions Memo
May 15, 2025 – May 16, 2025	Road Safety Audit Site Visit at Shenandoah National Park
August 14, 2025	First Draft of RSA (V1.0) delivered to NPS
September 3, 2025	Volpe leads a discussion of first draft report with NPS
September 12, 2025	Final Draft (V2.0) of RSA delivered to NPS and also sent to VDOT
September 30, 2025	Close out meeting with NPS and VDOT
October 3, 2025	Final 508 Compliant RSA delivered to NPS

II. Existing Conditions

Site 1: Skyline Drive at US-340

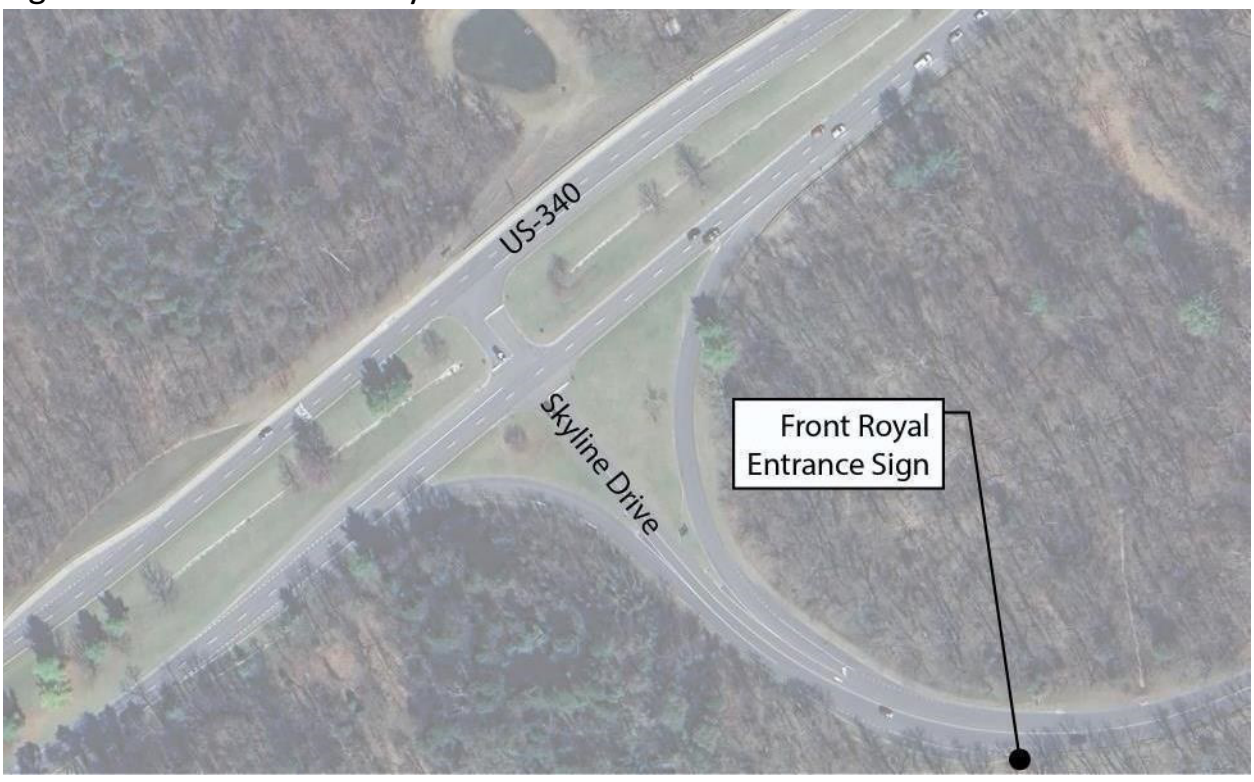
The intersection of Skyline Drive at US-340 serves as the entrance point to SHEN's Front Royal Entrance Station, shown in Figure 2. Skyline Drive is a two-way, two-lane roadway that terminates at the intersection with US-340 and is owned and maintained by NPS. The land to the northwest of the intersection is also owned by NPS. US-340 is a two-way, four-lane divided highway with large grass median, and is owned and maintained by VDOT. Virginia expanded US-340 into a divided highway in the 1950's. Since the grass median is wide, measuring approximately 90 feet, the intersection functions as two intersections, both of which are stop-controlled for Skyline Drive or vehicles making a left-turn or movement. The intersection is immediately adjacent to the city of Front Royal.

Northbound US-340 traffic access to Skyline Drive is provided through a channelized right-turn lane. Southbound US-340 traffic access to Skyline Drive is provided through a two stage unsignalized left-turn STOP sign-controlled movement, crossing both northbound US-340 travel lanes.

Skyline Drive traffic access to northbound US-340 is provided through a channelized right-turn lane. Access from Skyline Drive to southbound US-340 is provided through a two stage unsignalized left-turn STOP sign-controlled movement, crossing both northbound US-340 travel lanes.

During times of heavy congestion, usually during fall, Virginia and/or Front Royal police officers restrict visitor access to the Front Royal Entrance station, as well as restrict vehicles from making s at the next three intersections on the southbound approach of US-340. Visitors are redirected to use the Thornton Gap entrance. The Front Royal entrance is also the nearest entrance to I-66, which connects Washington, DC area residents to the park, contributing to the high traffic numbers.

Figure 2. Aerial View of Skyline Drive at US-340



Busy Season Congestion

The busiest season for the park occurs in the Fall, reaching peak numbers in October during fall foliage. The increase in visitors results in significant congestion at the Front Royal Entrance Station, particularly with vehicles using the station to enter the park. Traffic congestion extends well beyond the entrance station, frequently spilling over past the US-340 intersection. The queue extends through the City of Front Royal and up to I-66, both at Exit 6 to the north and Exit 13 to the east. Majority of congestion forms in the southbound approach to the intersection, with lower levels of congestion on the northbound approach.

During congestion, visitors grow inpatient and frustrated, which can lead to illegal maneuvers and risky behavior. One of the illegal maneuvers include vehicles bypassing the queue and trying to "sneak in" as they approach the intersection. Southbound US-340 vehicles will bypass the main entrance and make a U-turn at the Browntown Road/Skyline Vista Drive (State Route 649/9418) intersection to use the shorter queue in the northbound approach.

SHEN staff have provided specific guidelines and plans, as to how to handle traffic movement during traffic congestion to the local city and police jurisdictions. SHEN law enforcement has agreements with local law enforcement agencies, except for Front Royal Police and Warren County Police. Traffic congestion remains an issue, with SHEN staff helping to direct traffic when the Front Royal Entrance Station is backed up and at times, local enforcement blocked off the Skyline Drive access due to congestion and direct visitors to another entrance station, such as Thornton Gap.

Communication challenges exist that make it difficult for SHEN to inform visitors of traffic conditions at the Front Royal entrance station. Currently, no system exists that informs visitors of closed entrance stations and redirection of traffic to other entrance stations.

Sightline Challenges

The RSA team documented multiple sightline challenges. A crest curve is located south of the intersection along US-340, which limits sightlines for vehicles exiting left (towards the median) from Skyline Drive to US-340 southbound, as shown in Figure 3. According to field measurements, drivers waiting to turn left from Skyline Drive can see approximately 500 feet along US-340, which is adequate for vehicles traveling about 55 mph.

Figure 3. Crest Curve Limiting Visibility of Northbound US-340 Traffic



Mixed-Use Bicycle Traffic

From spring to fall, cyclists use the Front Royal entrance to enter the park, including a significant number of touring groups during spring. Entering the park can cause unsafe conditions due to lack of dedicated cycling infrastructure, including lack of road shoulders, differing travel speeds between cyclists and vehicles, and crossing of multiple lanes to enter Skyline Drive, as shown in Figure 4. This creates unsafe conditions for cyclists.

Figure 4. Cyclist Entering Skyline Drive from US-340



Emergency Vehicle Access

Traffic congestion impacts emergency vehicle access to the park. On Saturdays and Sundays, starting in the summer, emergency vehicles are forced to use the outbound lanes of Skyline Drive to avoid congestion delays. This situation intensifies in the fall with the increase of visitors to the park. The need for emergency vehicles to use outbound lanes increases the chances of collisions between outbound vehicles and emergency vehicles, as well as increase emergency response time due to need of coordination between SHEN and emergency vehicles to clear outbound lane for emergency use. The large distance between park entrances (the next station entrance, Thronton Gap, is more than 30 travel miles away), amplifies the dangerous safety conditions.

Rolling Stops

Vehicles roll through the stop sign as they exit Skyline Drive. With northbound US-340 traffic traveling higher than the posted speed limit of 40 mph, and limited visibility due to trees and road geometry, rolling stops create dangerous conditions and increase the potential for crashes.

Faded Pavement Markings

Some of the pavement markings at the intersection are fading, including the stop line on the US-340 median, as shown in Figure 5. Faded pavement markings can hinder the communication of the proper traffic rules to the driver.

Figure 5. Faded Stop Line on US-340 Median Lane

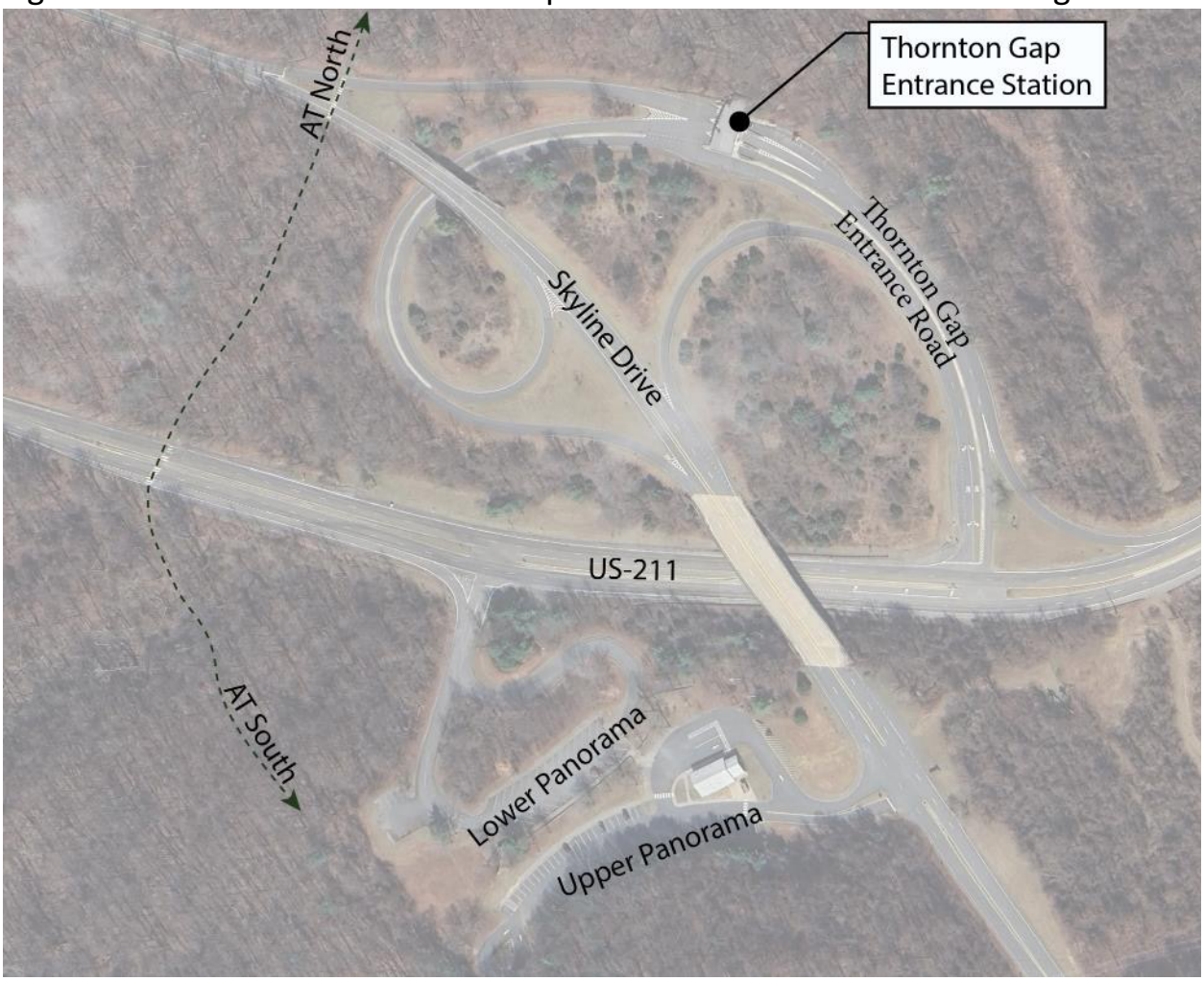


Site 2: Thornton Gap Entrance Station

US-211 intersects with the Thornton Gap Entrance Road at an unsignalized intersection. US-211 is owned and maintained by VDOT and shown in Figure 6. US-211 is a two-way, three-lane roadway, which includes a climbing lane, two lanes in the uphill direction and one lane in the downhill direction. US-211 widens to a two-way, four-lane roadway as it approaches Thornton Gap Entrance Road. When it becomes four lanes, the travel directions are separated by a concrete or grass median. The speed limit of US-211 is 45 mph and is reduced to 35 mph when leaving the Thronton Gap Entrance Station eastbound. Advisory speeds on US-211 are 30 mph in both directions near the entrance station due to horizontal curvature on steep grades.

US-211 at Thornton Gap Entrance Road is a three-legged intersection. The US-211 eastbound approach consists of a 300-foot left-turn lane, and two through lanes. The US-211 westbound approach consists of two through lanes and a channelized right-turn lane. The Thornton Gap Entrance Road southbound approach consists of one left-turn only lane and one right-turn only lane. Within proximity to the Entrance Station, Skyline Drive widens from a two-way, two-lane roadway into a two-way, four-lane roadway as it overpasses US-211, west of the entrance station.

Figure 6. Aerial View of Thornton Gap Entrance Station and Surrounding Area



The Appalachian Trail crosses US-211 west of the Thornton Gap Entrance Road and the Skyline Drive overpass. The trail crosses US-211 at an unsignalized crosswalk crossing five travel lanes, two in each direction, and a turn lane to the Lower Panorama parking area. The trail continues north, where it crosses both Skyline Drive, which consists of two travel lanes, and an on-ramp from Thornton Gap Entrance and Skyline Drive northbound.

Panorama is located to the south of the overpass over US-211. The Panorama has two parking lots, a comfort station, and serves as the trailhead to the nearby Mary's Rock. The two parking lots are physically separated, and each have their own vehicle access point. Access to Panorama upper lot is from Skyline Drive is at an unsignalized intersection. Access to the Panorama lower low is from US-211, also at an unsignalized intersection.

Busy Season Congestion

Busy season congestion during the fall contributes to safety challenges, similar to the Front Royal Entrance Station. Visitors grow impatient and frustrated, which can lead to illegal maneuvers and risky behavior. However, congestion at the Thornton Gap Entrance is primarily caused by traffic exiting the park, typically in the afternoon between 3:00 p.m. to 7:00 p.m. This creates long queues to exit the park, especially for visitors making a left-turn at US-211 to travel eastbound. SHEN staff noted that the congestion issue has worsened each year.

Long queues also develop for visitors accessing the park from the US-211 westbound approach. Visitors are supposed to queue using the right lane to access the channelized-right turn to Thornton Gap Entrance Road, as shown in Figure 7. Some visitors bypass the queue by utilizing the left lane and making a right turn to access the entrance road or slip into the right lane before the start of the channelized right-turn lane. This behavior is either due to lack of awareness of the advanced warning signs located along the US-211 westbound approach or done purposefully to skip the long queue. During the fall, SHEN employees convert the one-lane channelized-right turn lane into two lanes to accommodate the increase in traffic, as well as direct traffic at the intersection.

Figure 7. Westbound US-211 & Channelized-Right Turn Lane to SHEN



Limited Sightlines

Sightline issues occur at the intersection of US-211 and the Thornton Gap Entrance Road. The intersection is located at the crest of a hill, with westbound US-211 approaching from a horizontal curve, as shown in Figure 8. Eastbound US-211 approaches from a vertical curve, as shown in Figure 9. US-211 traffic may not see vehicles entering or exiting the park until they're close to reaching the intersection.

Figure 8. US-211 at Thornton Gap Entrance Road, Looking East



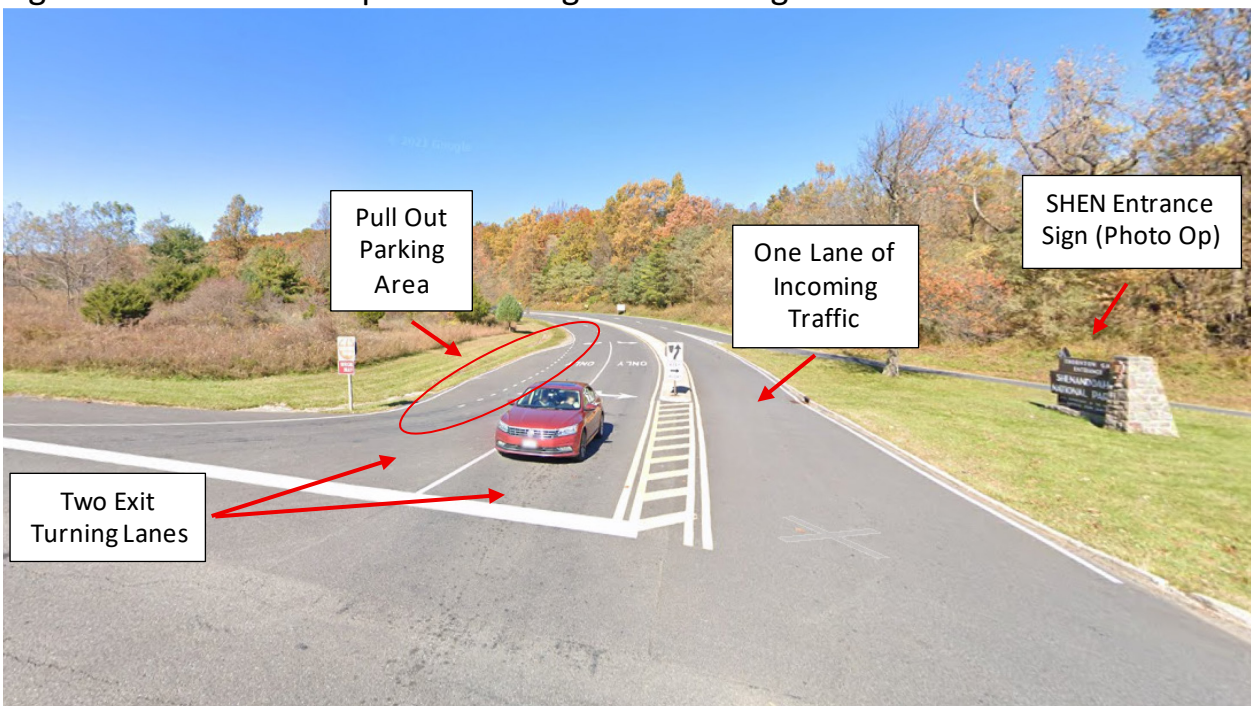
Figure 9. US-211 at Thornton Gap Entrance Road, Looking West



Pedestrian Access to the Entrance Sign

Thronton Gap Entrance Road has a pull-off parking spot next to the exit turn lanes out of the park, as shown on Figure 10. This spot is often used by visitors wanting to take a photo with the entrance sign located across the road. Pedestrians need to cross three traffic lanes to reach the sign. In addition, a crosswalk or pedestrian space is not provided, which increases the safety risk for people walking.

Figure 10. Thornton Gap Entrance Sign and Parking



Pull-Off Parking Use as Turn Lane

The pull-off parking spot is mistaken by drivers as part of the right-turn exit lane. The parking spot ends short of reaching the intersection, causing driver confusion. This situation can encourage dangerous driving behavior, with drivers using the grass shoulder to turn right onto westbound US-211.

Speeding along US-211

Vehicles are generally perceived to be traveling over the speed limit on this section of US-211, especially as the vehicles come over the hill and start to descend back down the other side. Specifically, westbound vehicles speed as they approach the Appalachian Trail crossing, and eastbound vehicles speed as they approach the intersection with Thornton Gap Entrance Road.

AT Crossing: Long Crossing and Unsafe Lane Configuration

The AT crosses US-211 at a five-lane cross section. As vehicles travel westbound on US-211, drivers cross the AT and then the lanes transition from two-lanes to one-lane just after the crossing and shown in Figure 11. This can lead to a safety challenge as faster vehicles race down the hill in the left lane to pass slower moving vehicles in the right lane. Additionally, in the eastbound direction, the right-turn lane into Lower Panorama begins right before the crossing, similarly adding one additional lane for hikers to cross and allowing for faster vehicles to pass slower vehicles turning right.

Figure 11. Westbound US-211 after AT Crossing Transition to One-Lane



Sign Clutter along US-211 Approaching AT Crossing

Sign cluttering along US-211 distracts drivers from warning signage for the AT crossing. For drivers traveling in the westbound direction, fourteen road signs are present between Thornton Gap Entrance Road and the AT crossing, many of which are unrelated to the AT crossing or the roadway. Sign clutter can lead to drivers ignoring important safety signs, such as the trail crossing sign. Portions of the signs can be seen in Figure 12.

The trail crossing signage color at Skyline Drive differs from the one used at the US-211 crossing. The US-211 trail crossing sign uses a fluorescent yellow-green background, as shown in Figure 12, while the trail crossing sign in Skyline Drive uses a standard yellow background, as seen in Figure 13. Virginia MUTCD states that Trail Crossing signs shall use a fluorescent yellow-green background (Section 9C.04, Virginia MUTCD 11th edition). Although the provisions in the Virginia MUTCD are not applicable to Skyline Drive, as the roadway is maintained by the NPS, considerations should be made to align the background colors of Trail Crossing signs along the road, with those on V-DOT maintained roadways.

Figure 12. Sign Clutter on Westbound US-211, Approaching AT Crossing



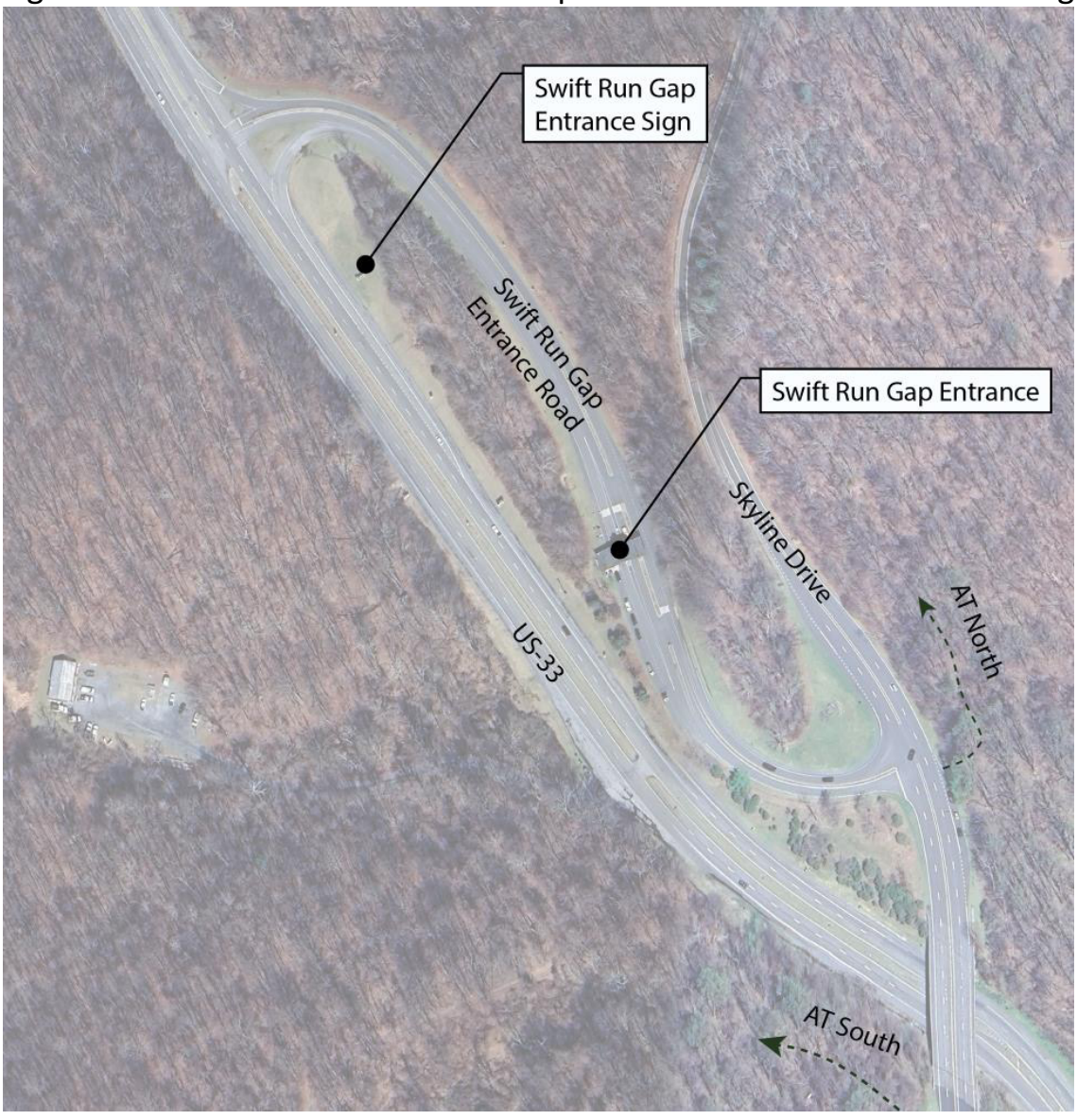
Figure 13. Trail Crossing Sign at AT and Skyline Drive



Site 3: Swift Run Gap Entrance Station

Skyline Drive is a two-way, two-lane roadway that widens to a two-way, four-lane roadway as it approaches US-33 and the Swift Run Gap Entrance. The road is owned and maintained by NPS. Swift Run Gap Entrance is one of the four entrance station locations to Shenandoah National Park that provides access to Skyline Drive. US-33 is a two-way, three-lane roadway that widens to a two-way, four-lane roadway divided by a concrete curb and grass median as it approaches US-33 and the Swift Run Gap Entrance. North of the Swift Run Gap Entrance, US-33 has one westbound lane, and two eastbound lanes. South of the Entrance, US-33 has two westbound lanes, and one eastbound lane. These are known as climbing lanes where slow-moving traffic up the steep roadway can be passed by faster vehicles. Advisory speeds on US-33 are 30 mph west of Skyline Drive, and 25 mph east of Skyline Drive. A two-way, multi-lane road, referred to herein as the Swift Run Gap Entrance Station Road, connects Skyline Drive to US-33. Figure 14 shows an aerial view of the Swift Run Gap Entrance Station and surrounding area.

Figure 14. Aerial View of Swift Run Gap Entrance Station and Surrounding Area



US-33 and Swift Run Gap Entrance intersect at an unsignalized intersection. Skyline Drive overpasses US-33. The southbound side of the overpass adds a shoulder lane. The AT intersects Skyline Drive just south of the overpass on the west side of Skyline Drive and the trail continues north of the overpass, on the east side of Skyline Drive. Westbound US-33 traffic access to the Swift Run Gap Entrance and Skyline Drive is provided through a right-turn slip lane. Eastbound US-33 traffic access to Swift Run Gap Entrance and Skyline Drive is provided through an unsignalized left-turn movement in a dedicated left-turn lane, crossing both westbound US-33 travel lanes. Skyline Drive access to US-33 is through an access road referred to herein as the Swift Run Gap Entrance Road. This access road also connects both roads to the Swift Run Gap Entrance Station. During peak visitation, vehicles entering from US-33 westbound cause congestion backing up traffic, which sometimes reaches the bridge carrying Skyline Drive (0.3 miles from the slip lane entrance). Some minor congestion occurs in the evenings as visitors exit the park. Trucks will sometimes pull off on the shoulder space of US-33 south of the intersection, as they overheat coming up the hill in each direction.

Unsignalized Turning and High-Speed Traffic Along Westbound US-33

Turning left from Swift Run Gap Entrance Road to US-33 eastbound requires vehicles to cross multiple lanes of high-speed traffic and find a sufficient gap in traffic along both directions of US-33 traffic. While the sight distance is adequate, vehicles traveling downhill along westbound US-33 may be travel at higher-than-expected speeds (although speed data was not collected), and for drivers waiting to turn left, it can be difficult to judge how much time is available to make the maneuver. A driver's view, looking to the east, is shown in Figure 15.

Figure 15. Swift Run Gap Exit at US-33, Looking East



Right-Turn Exiting Park Merges at Lane Drop

Visitors exiting the park at the Swift Run Gap Entrance making a right turn onto US-33 westbound must merge onto US-33 right where the two lanes of fast-moving, high-speed traffic converge into one lane of traffic, as shown in Figure 16. This creates a conflict point for traffic, whereas at any given point there could be three vehicles, all traveling at different speeds, merging into essentially one lane of traffic at the same time.

Figure 16. Swift Run Gap Exit at US-33, Looking West



Loose Gravel on US-33 Westbound Right-Turn Slip Lane

Drivers traveling westbound on US-33 entering the park need to take the slip ramp into the park. Vehicles often travel at high speeds downhill on westbound US-33 approaching the right-turn. Loose gravel accumulates at the slip ramp which causes some motorists to skid, especially motorcyclists. The loose gravel is assumed to originate from the shoulder of US-33 and gets carried down the road settling at the ramp. The loose gravel and some pooling water are shown in Figure 17.

Figure 17. Loose Gravel Accumulation at the Westbound US-33 Right-Turn Ramp



Difficult for Minor Approach to Enter Skyline Drive with Four-Lane Cross Section

Similar to the intersection at US-33, vehicles turning onto Skyline Drive from the Swift Run Gap Entrance Road also require crossing multiple lanes along Skyline Drive. At this section, Skyline Drive expands to a four-lane cross section and vehicle continuing on Skyline Drive may pick up speed to pass slower moving vehicles. Meanwhile, vehicles making a turn from Skyline Drive into the Swift Run Gap Entrance Road are slowing down. This can be especially dangerous for vehicles traveling northbound on Skyline Drive as a vehicle passing may move to the left lane at the same time as a vehicle turning left and slowing down. In an area with several turning vehicle movements, on-street parking, and a major trail crossing, vehicles should be slowing down. The cross section is shown in Figure 18.

Figure 18. Swift Run Gap Entrance at Skyline Drive, Looking North



Appalachian Trail Crossing Safety Challenges

The AT intersects Skyline Drive just south of the bridge over US-33 on the west side of Skyline Drive and continues north of the bridge, on the east side of Skyline Drive. However, hikers are provided little to no signage, crossing markings, or signals alerting drivers of pedestrians crossing. Further, hikers are not provided with a dedicated pedestrian path on Skyline Drive, forcing pedestrians to utilize the narrow shoulder space on either side of the overpass to avoid walking in traffic, as shown in Figure 19. Drivers turning right onto Skyline Drive also have poor visibility of pedestrians due to a curve in the road, the bridge, and vegetation. This lack of signage, crossing markings, and/or signals, as well as the lack of dedicated pedestrian facilities, all present safety challenges for pedestrians and drivers who may not be familiar with the area or are otherwise unaware that the AT crosses this section of Skyline Drive.

Figure 19. RSA Team at the AT Crossing near the Swift Run Gap Entrance Road



Parking Safety Challenges at the Swift Run Gap NPS Entrance Sign

The entrance sign is a popular place to park and take photos. A shoulder is provided along US-33 that people use as a small parking pull off. Additionally, people frequently walk around, sometimes in large groups, posing for photos at the sign. The sign and parking area is shown in Figure 20.

Figure 20. NPS Entrance Sign at Swift Run Gap



III. Evaluation

Crash Data

SHEN is a park with concurrent jurisdiction, meaning both NPS rangers and local police officers respond to incidents throughout the park. The local police consist of either Virginia State Police Department or the numerous counties that intersect SHEN. Staff from these agencies did not attend the RSA. The RSA team collected crash data using the NPS Crash Data Query tool and the VDOT Crash Portal to compile a holistic list of crash data. The crash data consists of the three RSA study sites from 2016 through January 2025, a period of almost nine years. Throughout the nine years, approximately 34 crash incidents were reported in proximity to the three project sites including 13 at Site 1: Skyline Drive at US-340 (Front Royal Entrance); 9 at Site 2: Thornton Gap Entrance Station; and 12 at Site 3: Swift Run Gap Entrance Station. The crashes reported through the VDOT Crash Portal have crash narratives to provide a better understanding of the crash. That information was applied where possible. A crash summary table is shown in Table 3 and a map of all 34 crash locations by site are shown in Figure 21, Figure 22, and Figure 23.

Figure 21: Skyline Drive at US-340 (Site 1) Crash Data



Figure 22: Thornton Gap Entrance Station (Site 2) Crash Data



Figure 23: Swift Run Gap Entrance Station (Site 3) Crash Data



The crash data shows an average of 3.4 crashes per year at the three sites. About 62% of crashes resulted in property damage only, 18% of crashes resulted in no injuries, 3% of crashes resulted in non-incapacitating injuries, 9% of crashes resulted in visible injuries, 6% of crashes resulted in severe injuries. The crash data recorded one fatal injury (3% of crashes), which occurred at Site 3: Swift Run Gap Entrance Station. A key takeaway from the crash data was the high number of incidents that involved guardrails, for a total of about 18% of reported incidents. Hit and run incidents are also high with about 9% of incidents recorded across the three sites. Only one pedestrian crash (pedestrian injury reported) and two bicycle crashes were reported. Most of the crashes occur along Route 340/Stonewall Jackson Highway, Route 211/Lee Highway, and Route 33/Spotswood Trail rather than on Skyline Drive itself.

Table 3: Crash Data Summary (2016 – January 2025)

Crash Category	Count	Percentage
Location		
Site 1: Skyline Drive at US-340	13	38%
Site 2: Thornton Gap Entrance Station	9	26%
Site 3: Swift Run Gap Entrance Station	12	35%
Time		
Morning (6:00 a.m. – 10:00 a.m.)	6	18%
Midday (10:00 a.m. – 3:00 p.m.)	13	38%
Afternoon (3:00 p.m. – 7:00 p.m.)	10	29%
Evening (7:00 p.m. – 10:00 p.m.)	2	6%
Night (10:00 p.m. – 6:00 a.m.)	3	9%
Severity		
Property Damage Only	27	79%
Non-Incapacitating or Visible Injury	4	12%
Serious Injury	2	6%
Fatal Injury	1	3%
First Harmful Event		
Collision with Motor Vehicle	16	46%
Collision with the Guard Rail	6	18%
Collision with a Fixed Object (Tree or Building)	4	12%
Run Off Road	3	9%
Collision with a Bicycle	2	6%
Collision with Animal	2	6%
Collision with a Parked Motor Vehicle	1	3%

Visitor Movement Study

In February 2025, SHEN completed the Shenandoah Transportation and Visitor Movement study. The park collected extensive data on traffic volumes and visitor flow throughout the park. Some of the data from that study is used to inform safety challenges and recommended countermeasures at the three Sites within this RSA.

Visitor Flow Data

To get an understanding of how visitors moved throughout the park, the project included Figure 24, which shows the traffic volumes along the various segments of Skyline Drive, as well as how vehicles are entering and exiting the park. Visitors most often enter from either the Front Royal Entrance Station (Site 1: Skyline Drive at US-340) or the Thornton Gap Entrance Station (Site 2). This is supported by park staff feedback about growing traffic volumes at Thornton Gap due to congestion at Front Royal over the past few years. The busiest segment of Skyline Drive is between Thornton Gap Entrance Station and the Byrd Visitor Center and Big Meadow. This section has some of the most visited sites including Panorama, Mary's Rock Tunnel, Pinnacles, Stony Man, Skyland, Whiteoak Canyon, Hawksbill, Dark Hollow Falls, the Byrd Visitor Center, and Big Meadow Campground. As previously mentioned, many visitors from the DC Metro region enter the park at the Front Royal Entrance Station, travel past Thornton Gap to Big Meadow or another point of interest or trailhead, where they turn around and exit at Thornton Gap to go home. This trend seems to be supported by the data as the highest exit volume occurs at Thornton Gap exiting to the east. This requires vehicles to exit via a left-turn movement onto US-211, one of the key safety challenges from the RSA.

Figure 24: Weekend Daily Traffic Volume Flows, October 2023

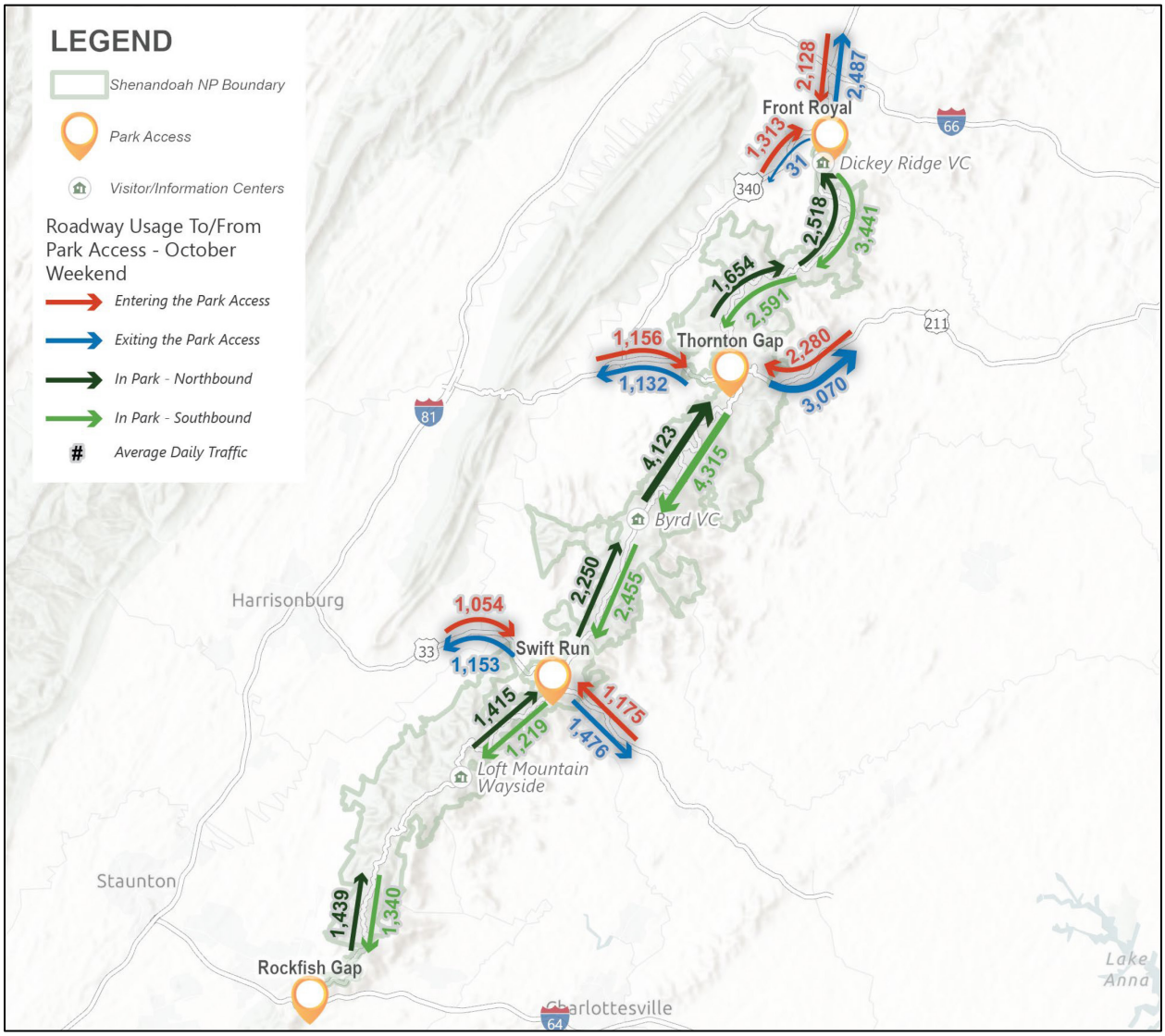
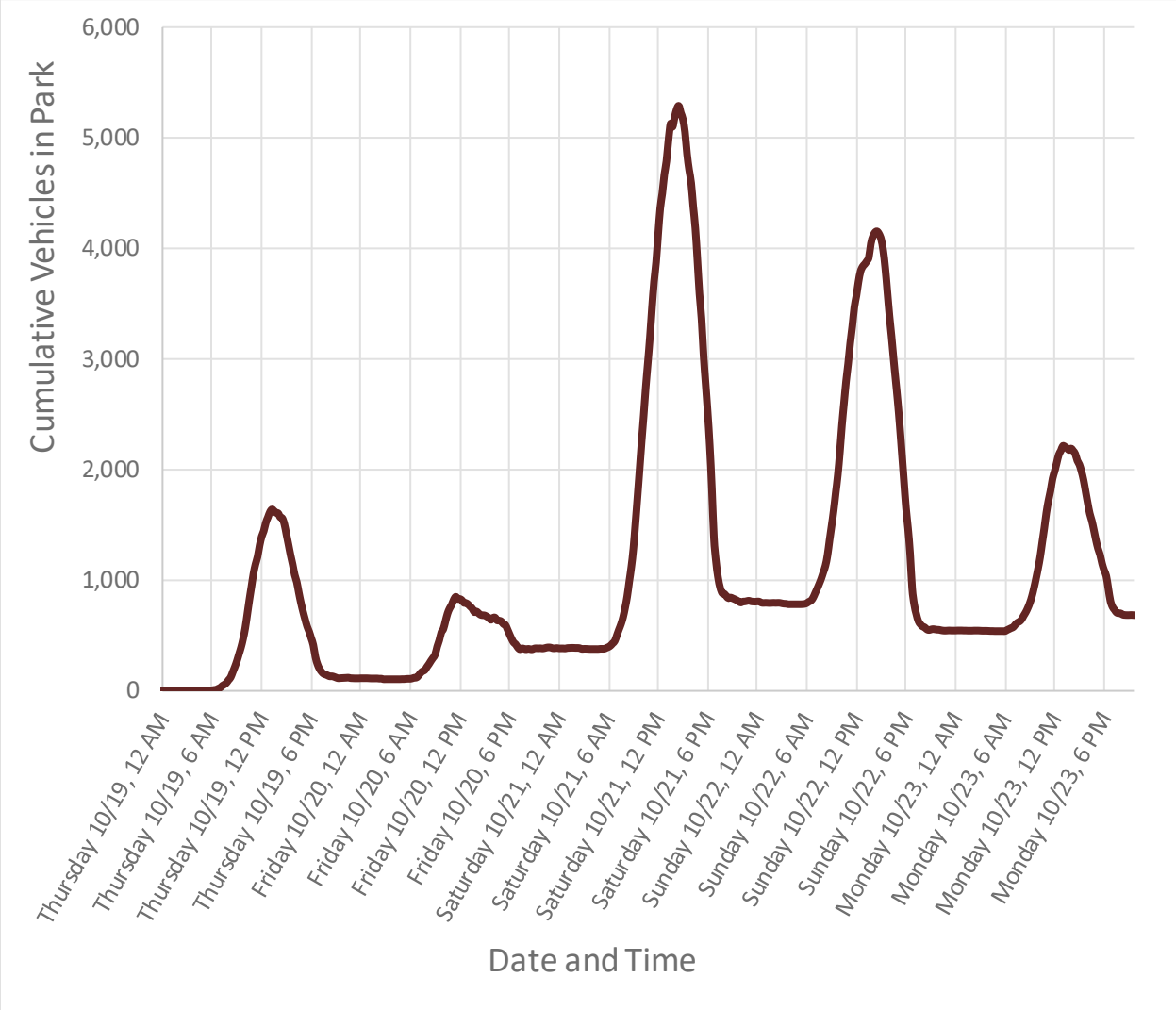


Figure 25 shows how the weekend visitation spikes, especially during the peak October weekends. Weekend visitation is more than double and can even triple the weekday visitation, which can cause significant congestion.

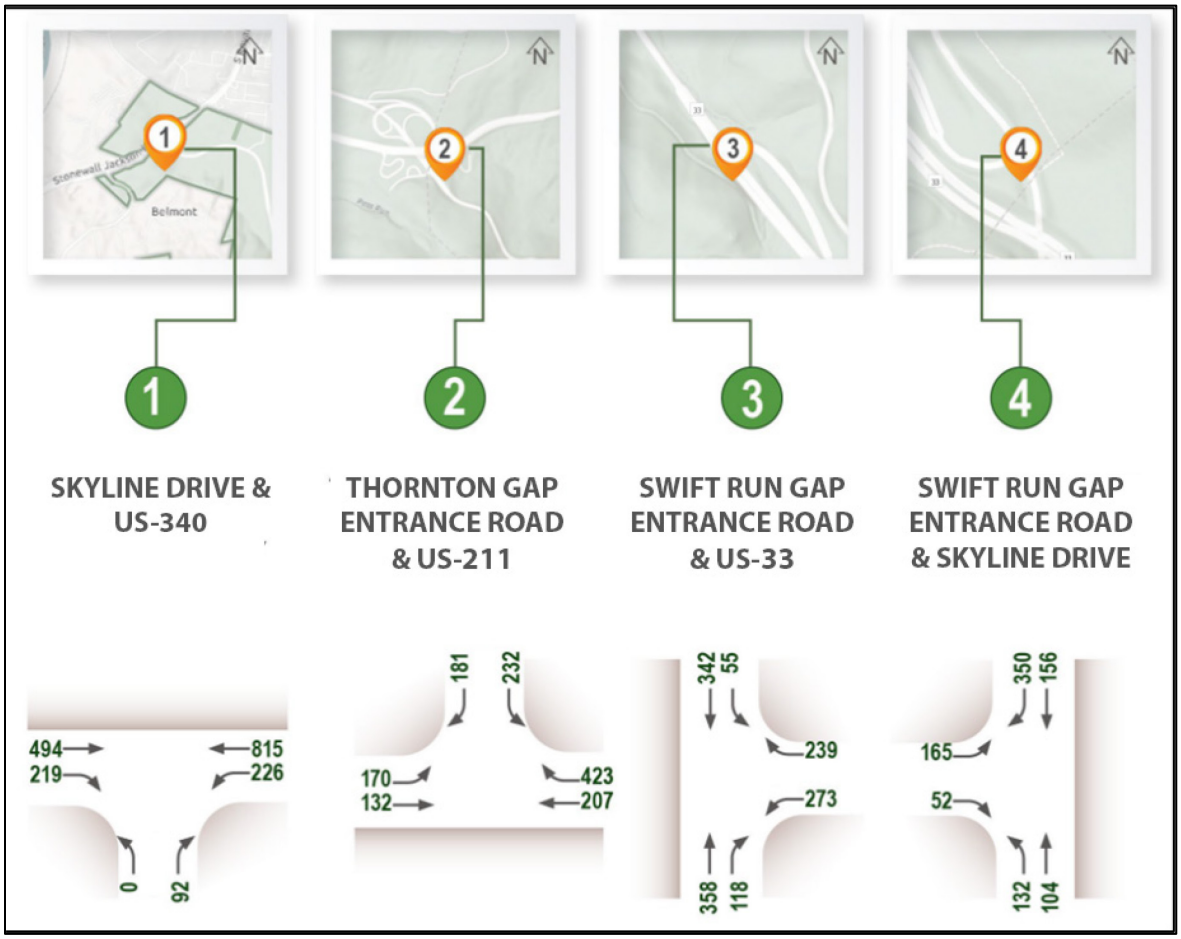
Figure 25: Cumulative Vehicles in Park
Thursday, October 19 through Monday October 23, 2023



Traffic Volume Data

Traffic volume data was collected at the three sites and four intersections. Figure 26 shows the Turning Movement Counts, which track individual vehicles at and around intersections to show how many vehicles are arriving at each approach and how many are turning. This information can be especially helpful when performing traffic modeling and evaluation of capacity at an intersection. This RSA will not perform a traffic analysis; however, any future intersection redesign must include a traffic model and analysis. The traffic volume data used in this study can be used for the traffic model.

Figure 26: Peak Hour Traffic Volume Data at Four Sites, October 2023 Weekend



NPS Visitor Use Statistics

According to the NPS Visitor Use Statistics, SHEN experiences more than one million recreational visitors per year with most visitation occurring between the months of April and November and the highest visitation occurring in the month of October. The monthly recreational visits are shown in Figure 27. In 2024, SHEN experienced an annual traffic count of 675,455 total vehicles across its four entrance stations, as shown in Figure 28. That same year, the park experienced about 1,720,211 recreation visits, of which, approximately 1,391,277 visits (81% of the total recreation visits) were reported to have traveled to one of the three entrance sites included in this RSA. Some additional visitors arrive via boundary sites, which mostly consist of trailheads outside the park that provide access to the SHEN trail network. Visitors arriving on those trails are expected to pay the entrance fee, but some inevitably do not, which can impact the accuracy of the visitation data.

Figure 27: SHEN Recreational Visits by Month, 2024

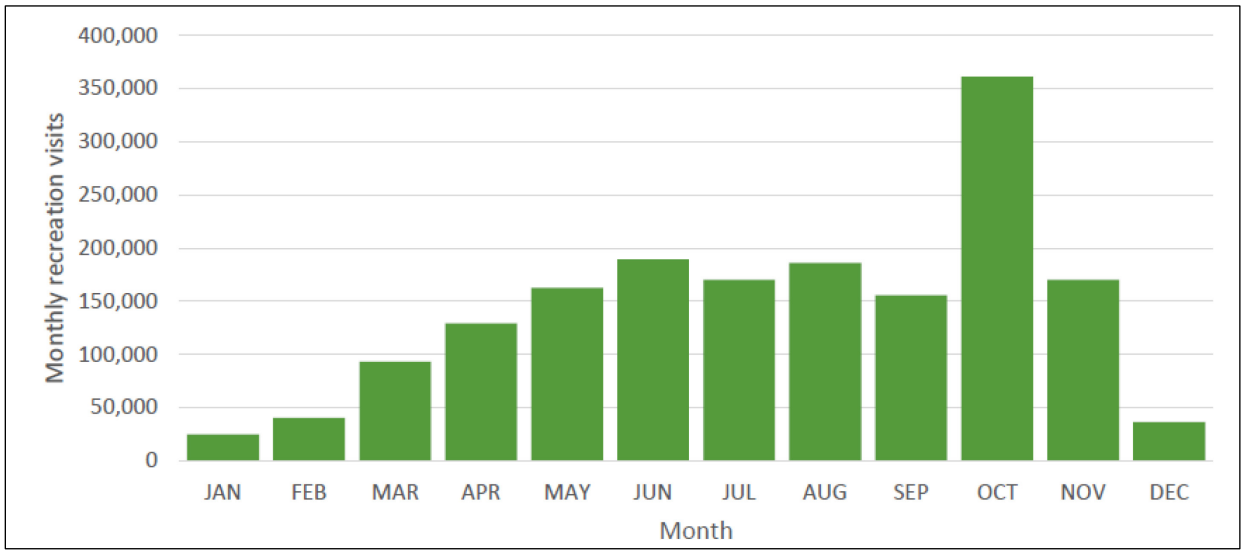
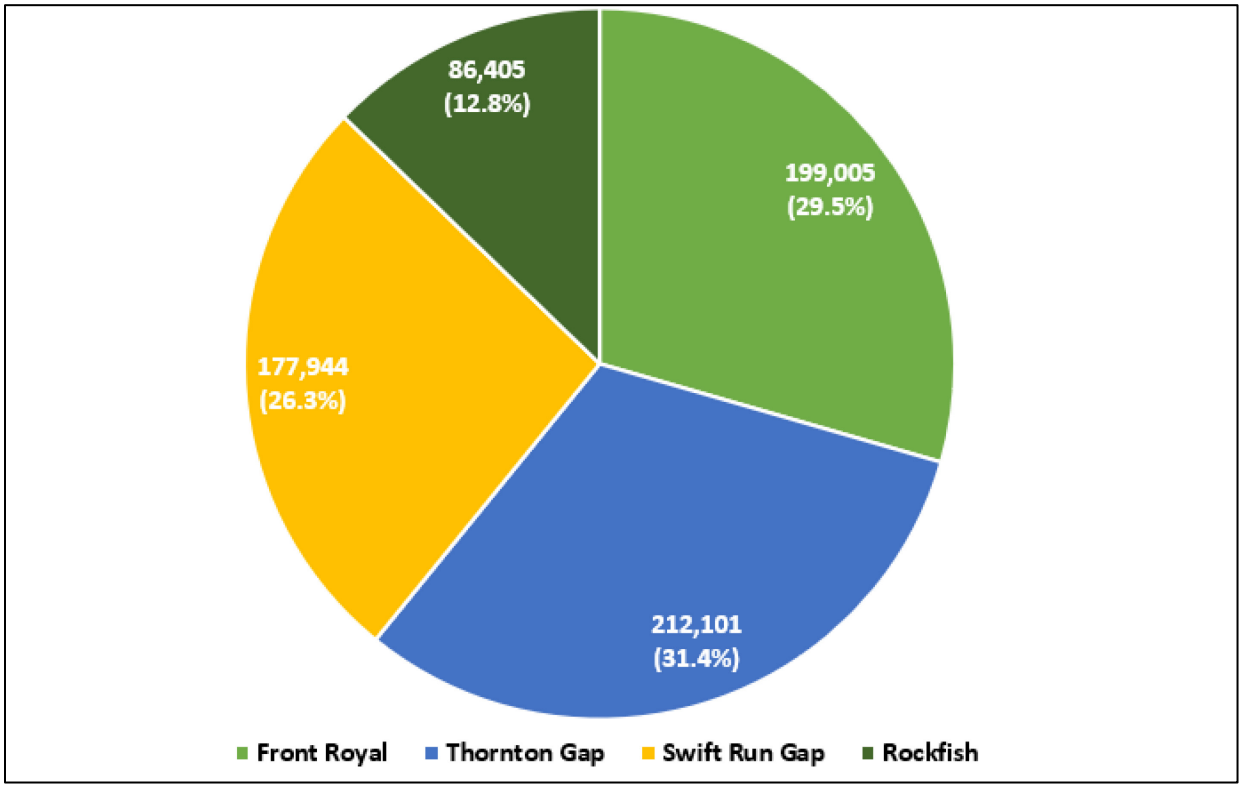


Figure 28: SHEN Annual Traffic Counts by Entrance Station, 2024



Vehicle Traffic Volumes

In partnership with Federal Highway Administration (FHWA), SHEN collects traffic data at the four entrance stations via inductive loop detectors. Figure 29 provides monthly averages of vehicle entries at each station in 2024. Similar to the visitation trends, the vehicle counter data shows a significant increase in October at all gates due to the influx of visitors viewing fall foliage. Thornton Gap has the highest vehicle entries for most of the peak season from May to September. However, in the peak month of October, Front Royal experiences the most vehicle entries in the park.

Figure 30 provides annual vehicle entrance counts since 2015 for each entrance station as well as the combined entries for a park-wide total shown on the secondary axis. Since 2015, annual park-wide vehicle entrances generally range between 525,000 and 620,000 with an outlier year of 2020, which reached almost 700,000 vehicles, and an outlier year of 2024, which reached almost 680,000 vehicles. Gate-specific trends generally mirror the combined entries trend showing entrance station volumes as relatively consistent since 2015. Thornton Gap consistently processes the most traffic volume with Front Royal as a close second. Swift Run Gap processes the third most traffic volume and Rockfish is consistently the lowest volume.

Figure 29: Monthly Vehicular Traffic Counts by Entrance Station, 2024

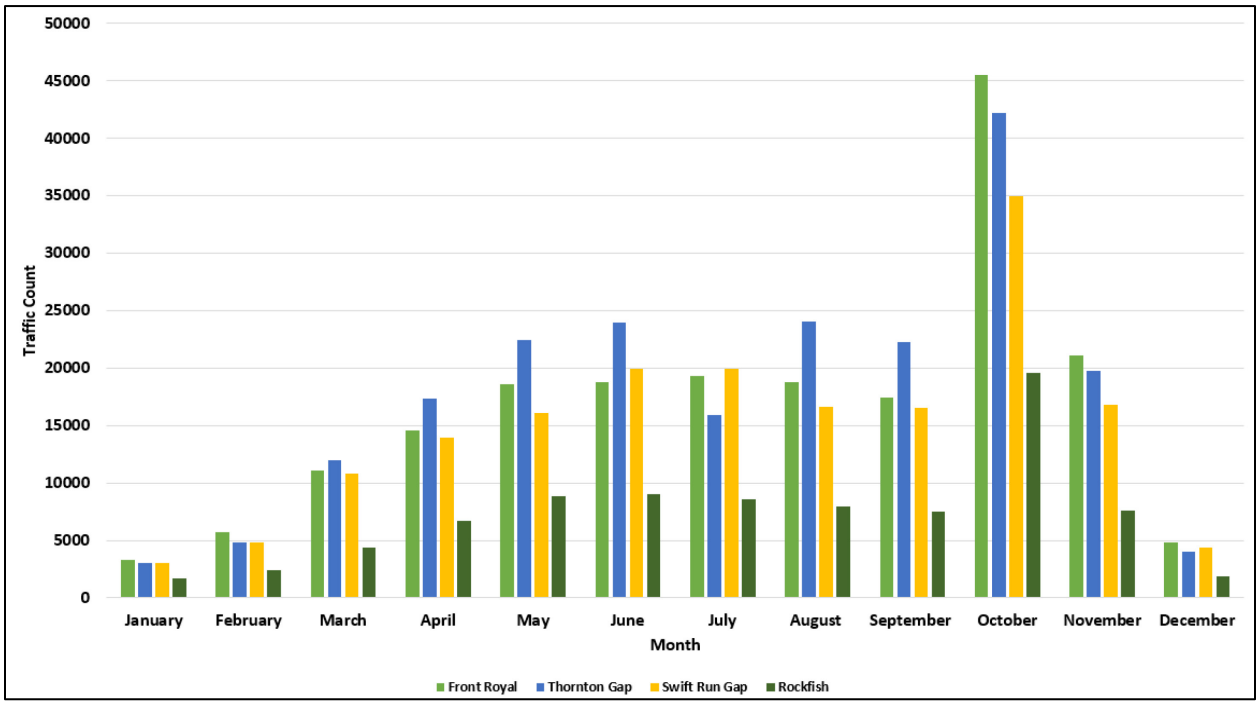
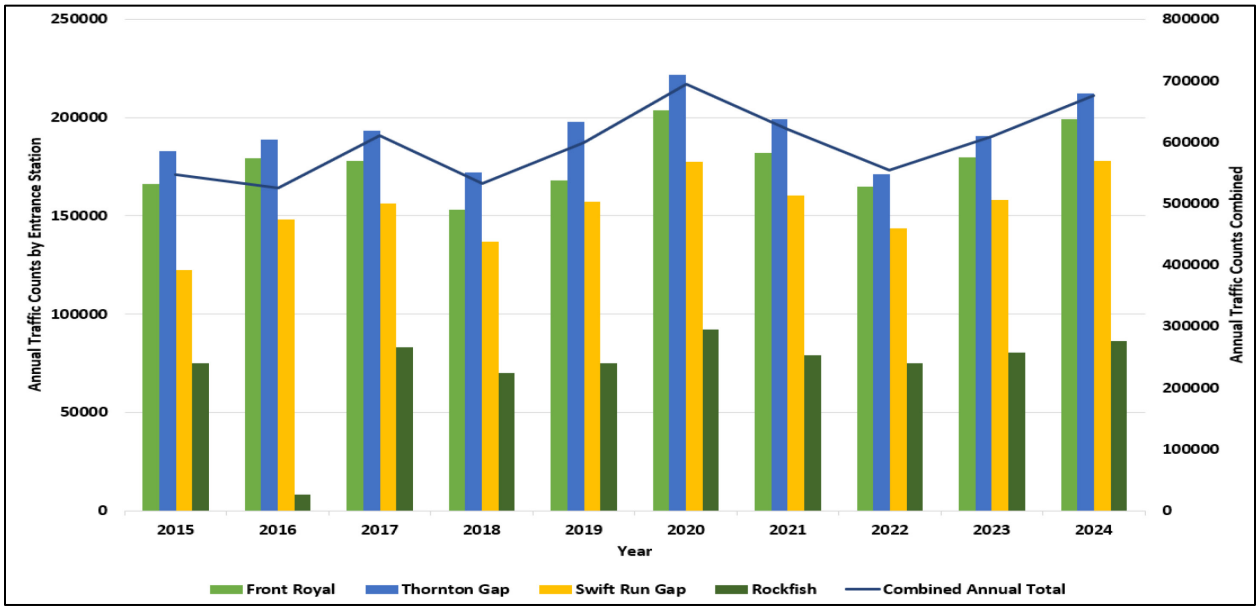


Figure 30: Annual Traffic Volumes at Entrance Stations, 2015 – 2024



Strava Metro Data

Strava is a user-based dataset where a smartphone application tracks the route using the GPS device. Strava aggregates the data, removes all personal information, and produces maps and downloadable data. Strava Metro is a platform created by Strava to offer data from users that consent to share information on their workout, generally running, walking, hiking, or biking. Given the hiking focused culture in SHEN, it is likely that many hikers in the park use Strava. However, long-distance hikers, such as hikers along the AT, may not use Strava given the potential drain on smartphone battery.

The Strava Metro data is shown in Figure 31, Figure 32, and Figure 33 for each of the three sites, respectively. The most pedestrian activity occurs around the Front Royal Entrance Station (Site 1: Skyline Drive at US-340). A large trail network and school are provided on the other side of US-340, and the Dicky Ridge Trail travels near the intersection and bypasses the entrance station. A significant amount of activity is also along Skyline Drive and crossing US-340, which can indicate a need for improved walking and hiking connections. Lastly, a small trail connection between the Browntown Road community to the south. At Thornton Gap, the AT is clearly the most used facility, and the road crossings are emphasized as part of the study area. Significant activity is also shown at Panorama, which has bathrooms and additional information. Skyline Drive also has some activity in addition to the Thornton Gap Entrance Road, which also has an entrance sign that people like to use to take photos. Lastly, the Swift Run Gap Entrance Station also has an AT section, which clearly has the most activity. Some people are also shown walking between the entrance station and Skyline Drive, as well as near the intersection with US-33. Another entrance sign is located along US-33, but the map does not appear to show Strava activity to the entrance sign. Some additional hiking activity is shown along Skyline Drive, but it is much less than the other sites. Most of the activity along Skyline Drive could be runners that like to use the pavement rather than trail network for running.

Figure 31: Strava Metro Heatmap, Walk, Run, Hike, Front Royal Entrance

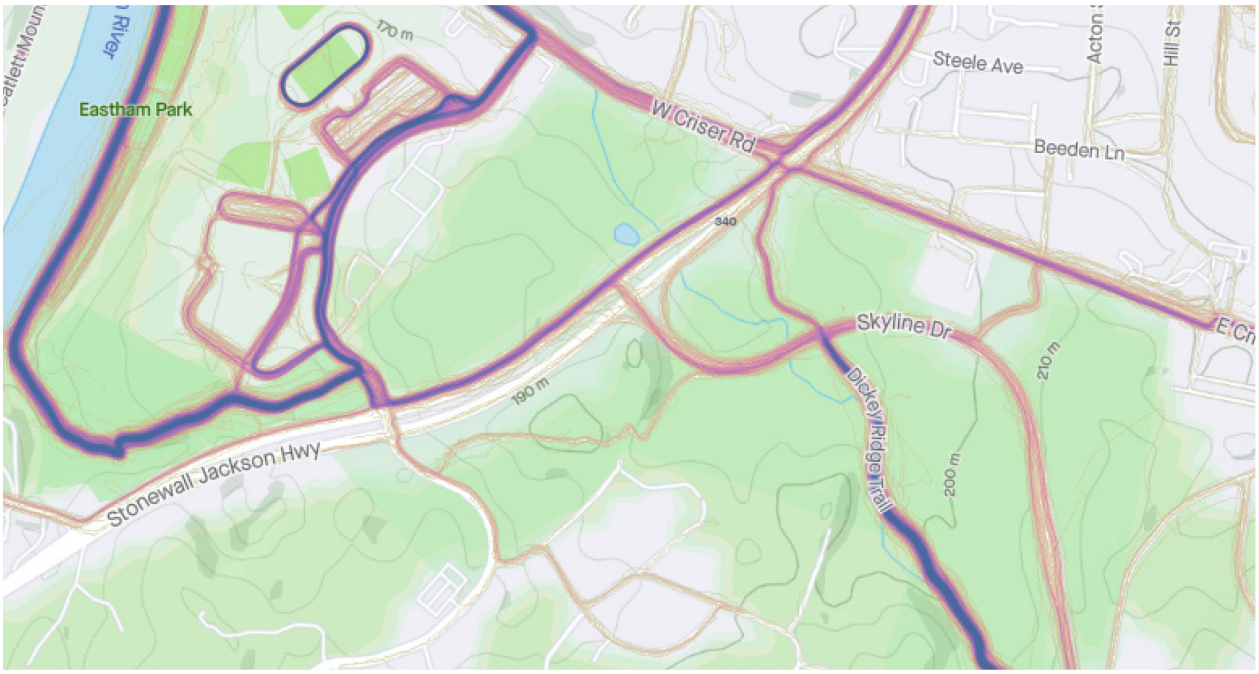


Figure 32: Strava Metro Heatmap, Walk, Run, Hike, Thornton Gap Entrance

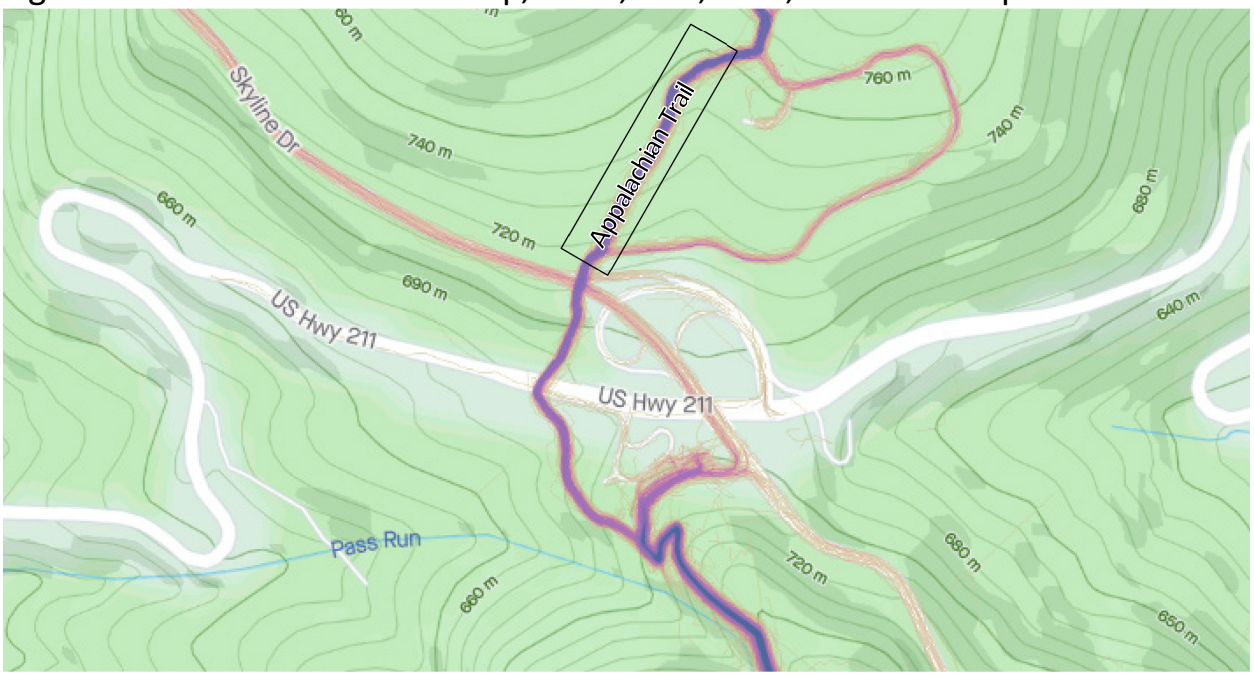


Figure 33: Strava Metro Heatmap, Walk, Run, Hike, Swift Run Gap Entrance



Stopping Sight Distance

Stopping Sight Distance (SSD) is a measurement used in roadway design for how far the driver can see an object in the road (in feet) and safely stop before hitting the object. It is typically applied to roadways with vertical or horizontal curves to make sure the driver of the vehicle can see far enough in front of the vehicle to safely proceed through the curve. However, it can also be applied at crosswalks. SSD is directly correlated with speed and grade, as the faster the driver travels, the more distance is required to observe an object in the road and the longer it takes to safely stop the vehicle. Downgrades increase the distance needed to safely stop and upgrades decrease the distance.

For this RSA, the four intersections and three roadway crossings were preliminarily evaluated for SSD. In general, SSD was adequate for the posted speed. As with many roadways, vehicle speeds can fluctuate significantly and high speeds can exacerbate many safety challenges, especially sight lines and SSD. The standard SSD tables from the AASHTO Green Book are provided in Table 4.

Figure 34, Figure 35, and Figure 36 illustrate the required SSD for turning vehicles based on the AASHTO Green Book and the actual sight lines (estimated using google earth) at each of the three sites. The SSD appear to be satisfied at the intersection of Skyline Drive at US-340 and at the intersection of the Swift Run Gap Entrance Road at US-33. However, based on initial calculations, the SSD is satisfied at the intersection of Thornton Gap Entrance Road at US-211.

Table 4: Stopping Sight Distance

Location	Posted Speed (mph)	Grade	Required SSD (ft)	Actual SSD (ft)
US-340, looking south	40	-3%	405	>500
US-340, looking north	40	+2%	375	500
US-211, looking east	45	+6%	415	380
US-211, looking west	45	-2%	470	380
US-33, looking east	55	-8%	710	750
US-33, looking west	55	+8%	530	>600

Note: The SSD calculation is from AASHO Green Book with grade adjustments. Break reaction distance predicated on a time of 2.5 seconds and deceleration rate of 11.2 ft/s^2.
Speed for calculation based on posted speed limit plus 7 mph

Figure 34: SSD – Skyline Drive at US-340

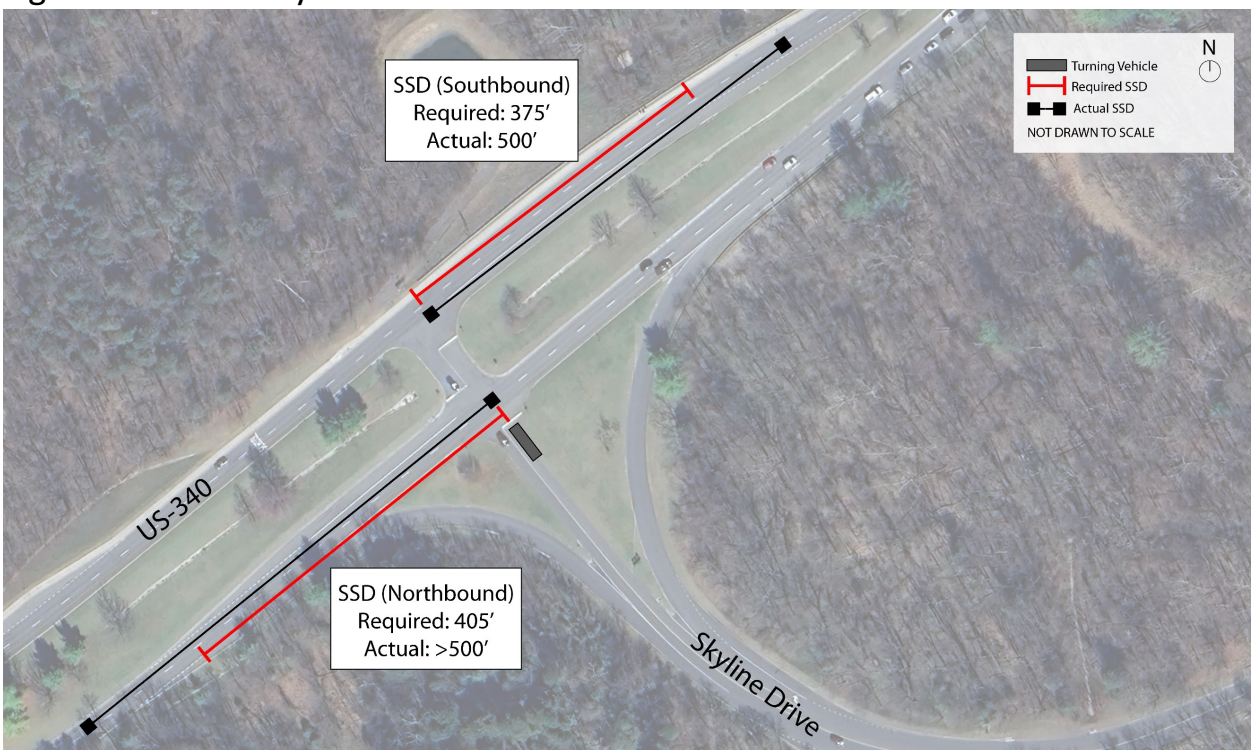


Figure 35: SSD –Thornton Gap Entrance Road at US-211

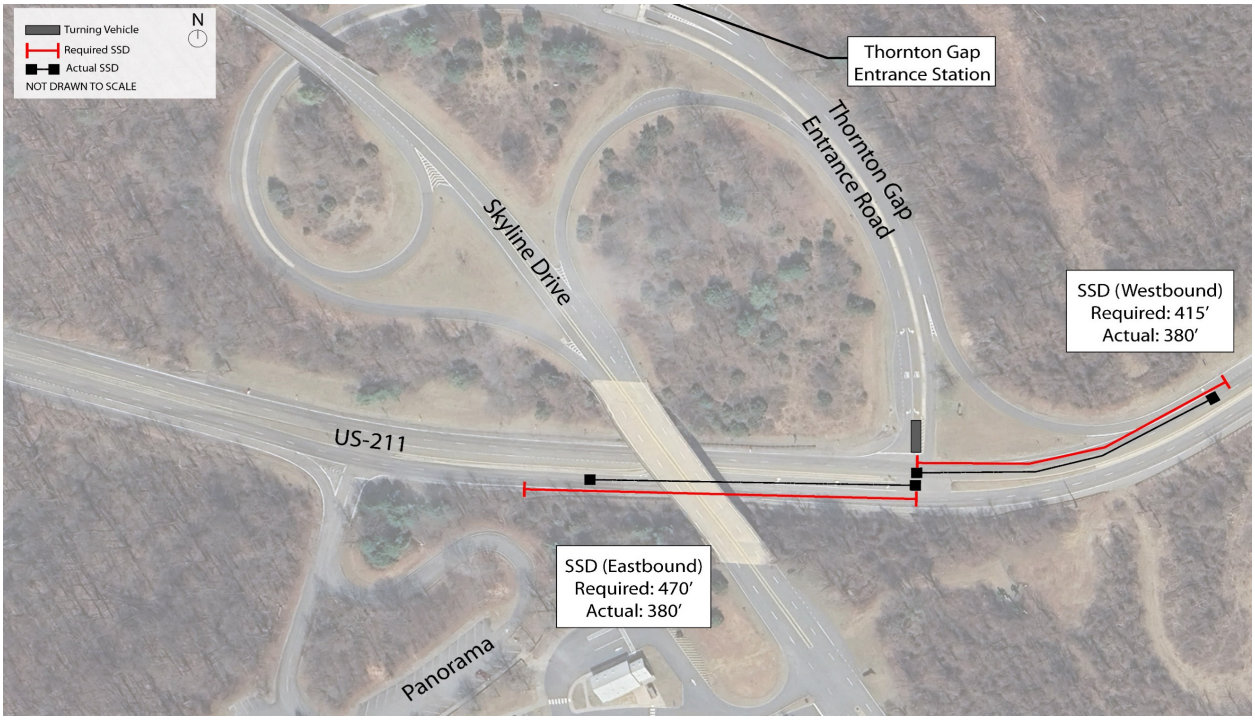
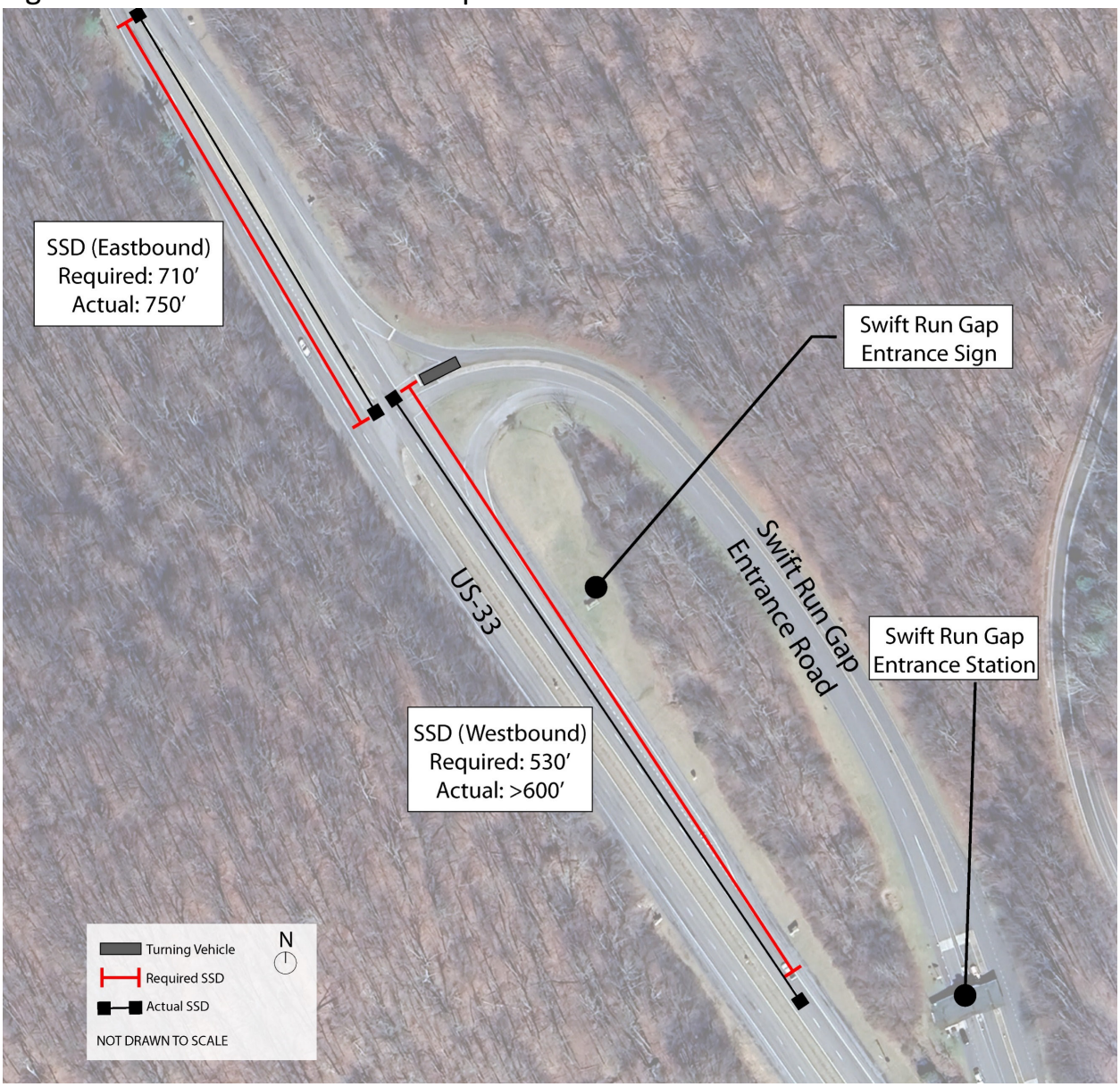


Figure 36: SSD – the Swift Run Gap Entrance Road at US-33



IV. Recommendations

Engineering Recommendations

Engineering recommendations typically refer to physical changes to the infrastructure. Some engineering recommendations can be higher cost that require a survey and formal design plans, and other engineering recommendations can be lower cost with temporary materials or pavement markings and signage that can be installed without survey or formal design plans. Many of these engineering recommendations will require close coordination with VDOT and may need to be further evaluated for their feasibility and effectiveness.

Site 1: Skyline Drive at US-340

The engineering recommendations at the Front Royal Entrance Station primarily include low-cost short-term improvements. The Park is in the process of designing a new entrance station that will increase capacity. However, that project is still at minimum, five years away from construction. Any long-term strategy should align with the entrance station capacity project.

Signage and Pavement Markings Modifications

Some additional signage and pavement markings will provide visitors with improved communications to travel through the intersection and access the Front Royal Entrance Station. The following signage and pavement markings are recommended, show in Figure 37:

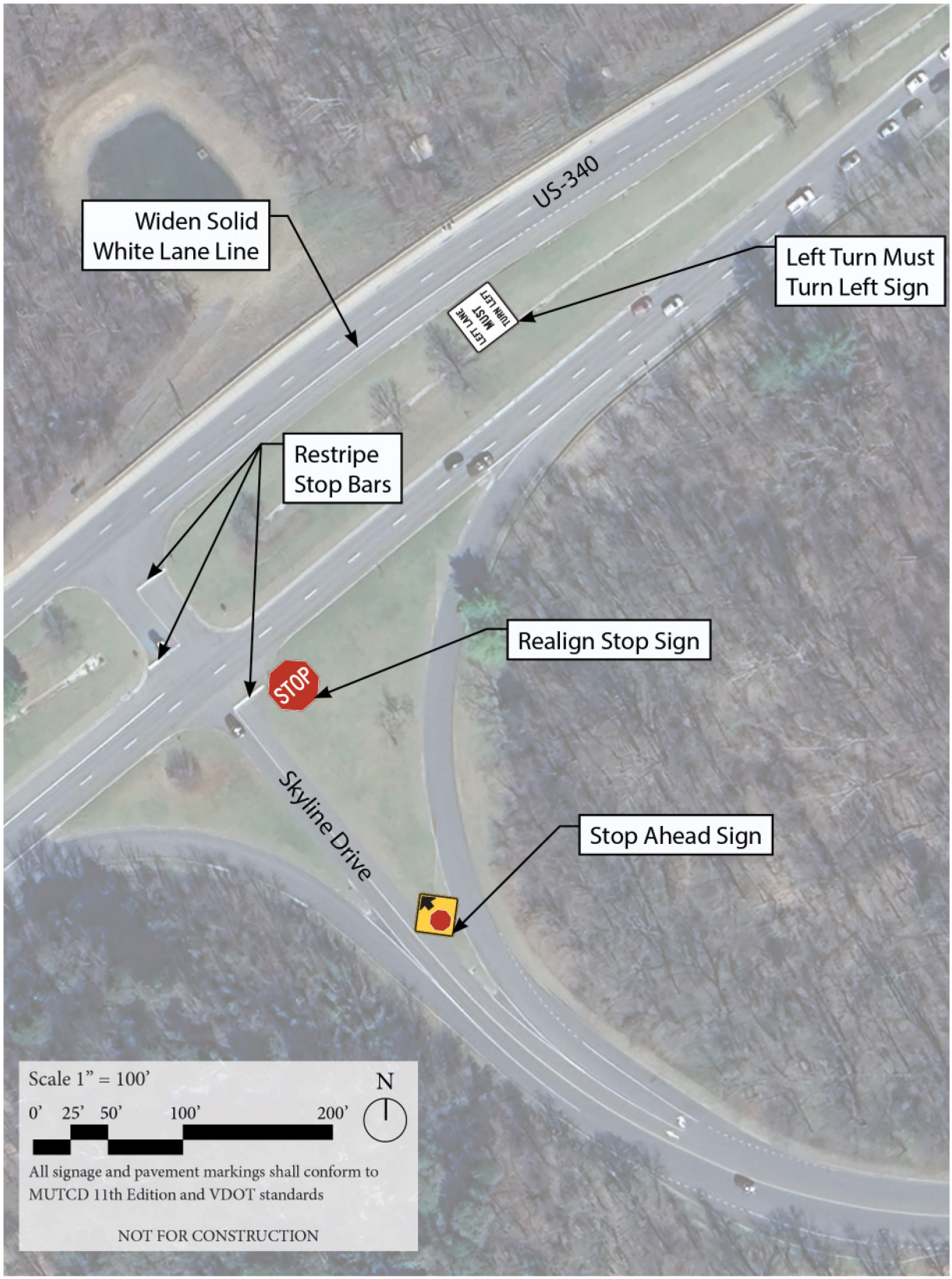
Signage:

- Install a “Stop Ahead” sign (W3-1) along Skyline Drive in advance of the US-340 intersection;
- Install a “Left Lane Must Turn Left” sign (R3-7L) on the median along US-340 southbound lane; and
- Realign the Stop Sign along Skyline Drive at the US-340 Intersection to face the travel lane and add red reflective tape along post.

Pavement Markings:

- Restripe all stop bars at the intersection
- Widen the Solid White Lane Line for the left-turn bay along US-340 southbound

Figure 37: Signage and Pavement Marking Modifications



Vegetation Clearing and Maintenance

Placement and overgrown vegetation causes sight distance challenges. Consider removing the tree located on the traffic island between northbound US-340 and channelized right turn lane into Skyline Drive will improve sightlines between US-340 traffic and vehicles exiting the park. The park should continue to maintain proper sight lines at all roadways and trim low-hanging branches that could impact sightlines. Maintenance should also extend to the existing culvert to prevent water back-up and maintain the flow of water to prevent additional safety challenges.

Front Royal Entrance Station Modernization Project

Shenandoah is currently in the process of developing design alternatives to modernize the Front Royal Entrance Station. Many of the safety challenges at this intersection are related to congestion at the entrance. The Park is in the conceptual design phase is hopeful to have the design completed in 2026. The project is not expected to have any significant expansion or operational modification and is primarily related to modernizing the facility and improving the comfort and aesthetics of the building.

Skyline Drive at US-340 Redesign

Concurrently with the entrance station expansion, a full intersection redesign could be considered to include a signalized intersection, a VDOT innovative intersection design, an interchange, or other operations modifications at the intersection of Skyline Drive at US-340. Given the high cost, impact to the local roadway network, and coordination with VDOT and other local agencies, a conceptual plan was not developed. A traffic study and more focused evaluation is a necessary next step.

Site 2: Thornton Gap Entrance Station

The engineering recommendations at the Thornton Gap Entrance Station include several alternatives for a major intersection redesign as well as an alternative access point through Panorama. Other engineering recommendations include minor pavement marking and signage improvements and localized modifications.

Improve Left-Turn Movements from Thornton Gap Entrance Road to US-211 Eastbound

The intersection of US-211 at Thornton Gap Entrance Road causes significant delays and congestion for visitors. As previously mentioned, the highest volume of exiting vehicles occurs at this location and a majority of visitors want to turn left to travel eastbound on US-211. Improving the ability for vehicles to exit SHEN at Thornton Gap is a priority for the park. High travel speeds along US-211 and limited sight lines can cause drivers to wait for long gaps in traffic. During high visitation periods the queue can extend back to over one mile along Skyline Drive causing impacts to visitors that are continuing along Skyline Drive. Three countermeasures have been recommended in this RSA:

- VDOT Innovative Intersection Continuous Green T (CGT):
  The CGT allows the left-turn vehicles from the minor approach use a channelized receiving lane onto the major street to merge onto the major street. This alternative is recommended to be signalized but can remain unsignalized, if deemed appropriate. VDOT developed a preliminary CGT model and deemed the improvement worth further evaluating as both an unsignalized intersection and possible signalized, if necessary. A CGT design will also require fairly significant realignment of US-211 to create space for a channelized receiving lane along US-211. VDOTs Innovative Intersection program recommends a variety of intersection designs that improve capacity and safety. An example of a CGT is shown in Figure 38.
- Redesign of Panorama to Accommodate Exiting Vehicles:
  An alternative to signalizing the primary intersection is to connect Skyline Drive to lower Panorama Parking Lot, which allows vehicles to make a right-turn onto US-211 eastbound, the

heavier movement. Given the large grade change between Skyline Drive and US-211 at Panorama, the driveway extension will likely need to be constructed to the west. SHEN staff noted that if this project was completed, it will likely only be utilized during the peak visitation periods. One example of a potential vehicular connection between Lower and Upper Panorama is shown in Figure 39. To pursue this alternative the park will have to provide additional compliance and evaluation as well as consider when it is operational and if a seasonal entrance station should be provided.

- Install a Signal:
  Given US-211 location within VDOT's Arterial Preservation Network, policy requires VDOT to explore unsignalized intersection treatments, with signalized intersections only implemented if unsignalized treatments are not deemed appropriate. Signalizing the intersection will allow for a protected vehicle movement out of the park, especially during higher visitation periods. This should increase capacity and allow people to exit more easily without waiting for a gap in traffic. Additionally, this will improve safety for vehicles exiting. Some drawbacks may include additional rear end crashes as vehicles traveling at higher speeds may not expect a traffic signal. A signal warrant analysis is needed to determine the need of signalization of the intersection.

Figure 38: Continuous Green T Infographic Developed by VDOT

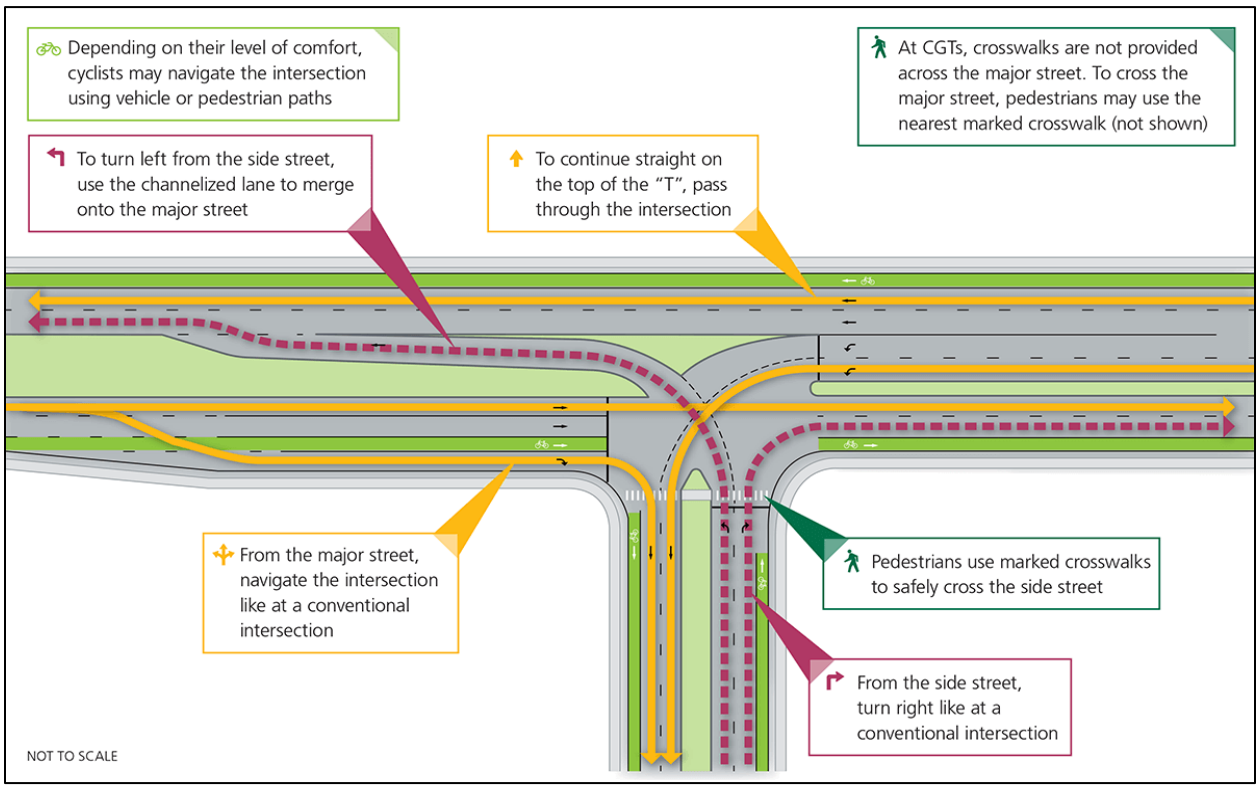
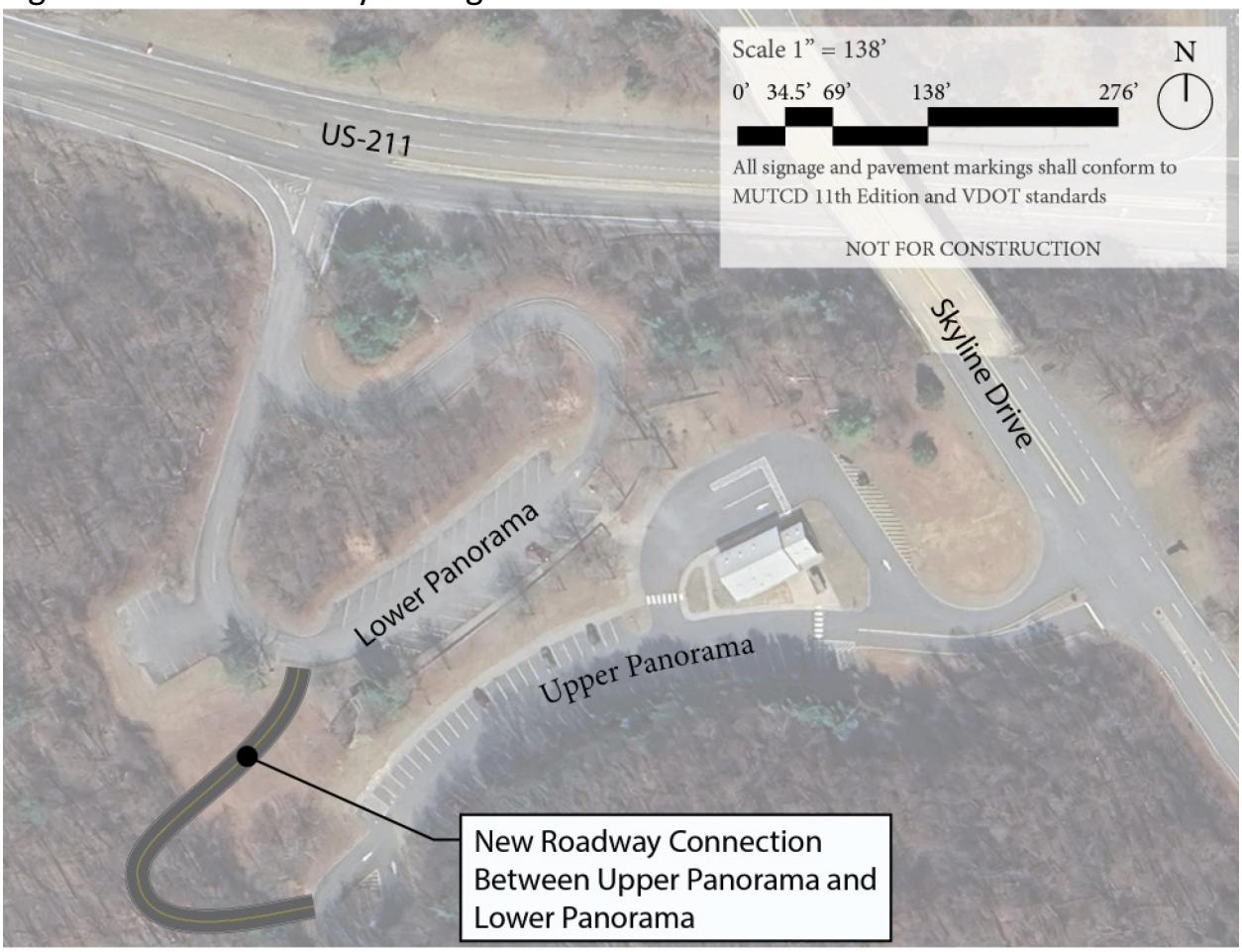


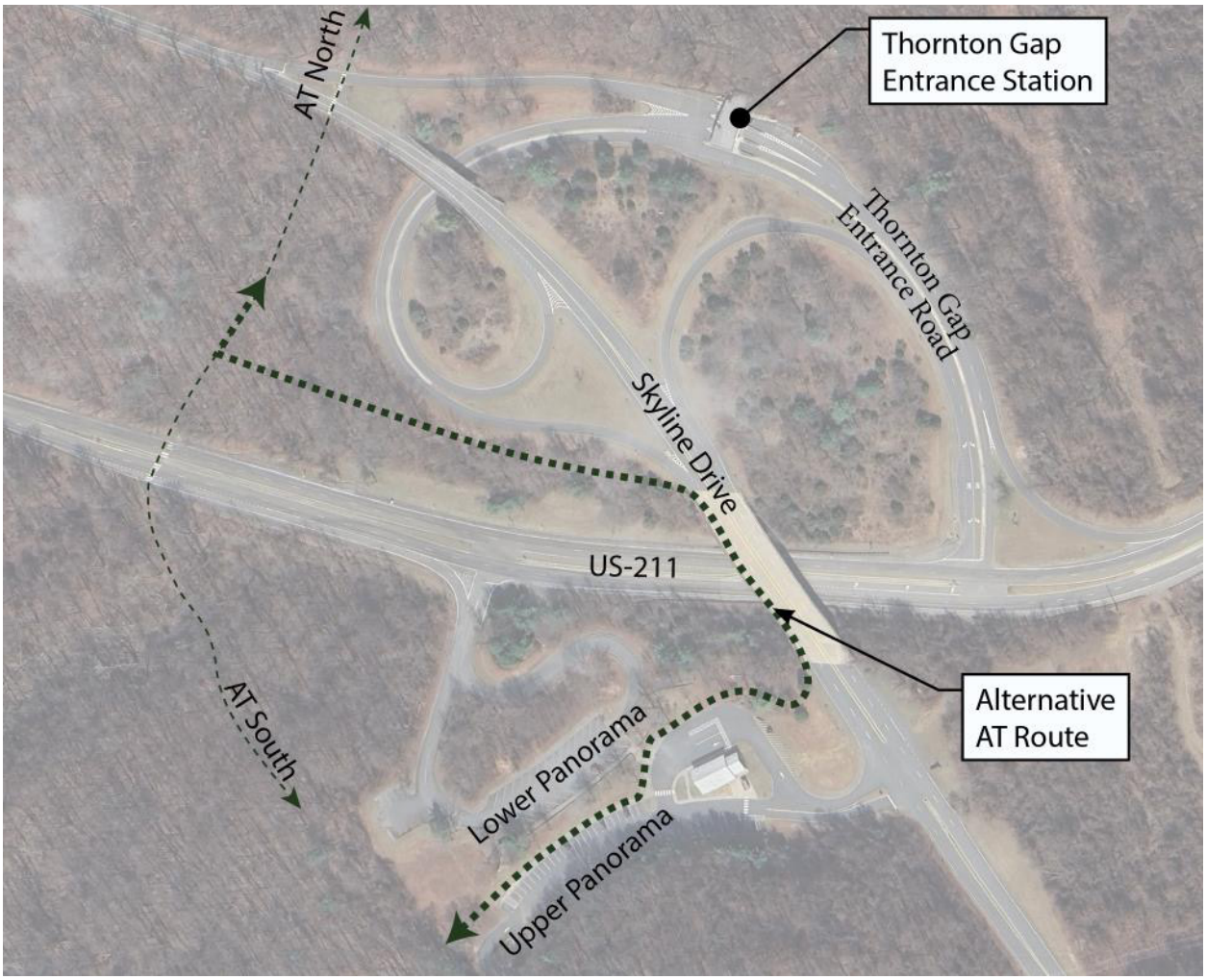
Figure 39: Exit Driveway through Panorama



Relocate the AT Crossing to Use the Skyline Drive Bridge

The AT crosses many high-speed, high-volume roadways at grade, which pose safety risks. Grade separation is usually a recommendation that should be considered. Rerouting the AT trail along Skyline Drive and along the bridge over US-211, as shown in Figure 40, will provide AT users with a grade separated alternative at a fraction of the cost of building a new pedestrian bridge. AT users could be rerouted through the Panorama site and along the west side of Skyline Drive back to the AT on the north side of US-211. If this alterative was pursued, pedestrian improvements to the Skyline Drive bridge over US-211 should be considered to include a designated pedestrian walking area, and a visual or physical barrier between moving traffic and AT users. The Skyline Drive cross section may need to be reconfigured to accommodate the pedestrian walking area.

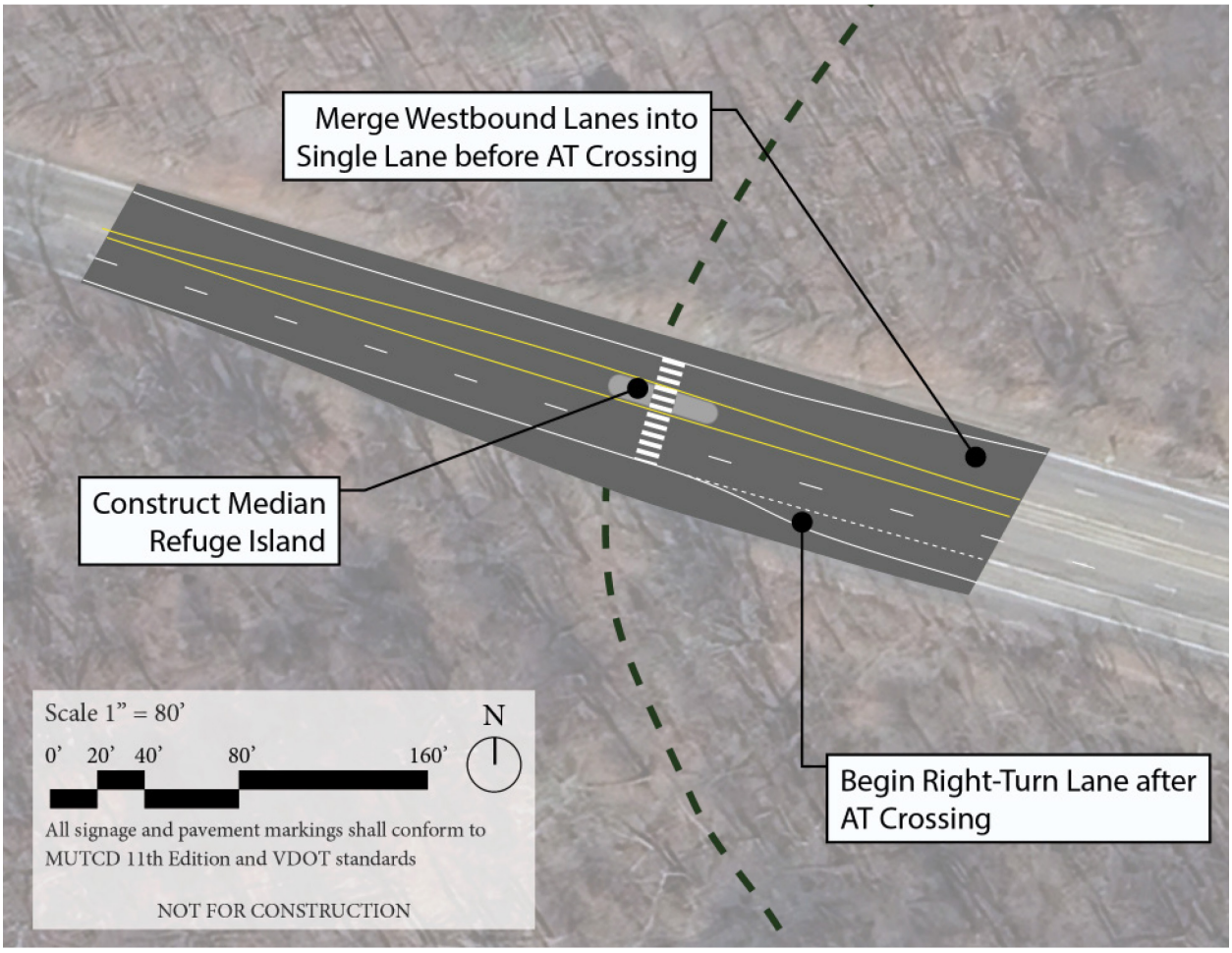
Figure 40: AT Crossing Relocation



AT Crossing, Modify the Vehicle Lane Configuration and Add Median Island

If the crossing is not relocated, safety at the existing AT Crossing can be improved by modifying the travel lane configuration. The US-211 westbound travel lanes merge area can be moved to just before the AT crossing, reducing the crossing to one travel lane in the westbound direction. The US-211 eastbound right-turn lane into Panorama can be shortened to reduce to two travel lanes in the eastbound direction. These modifications reduce the overall crossing length by approximately 22 feet and eliminate the need to cross two lanes, reducing potential conflicts. Additionally, these modifications provide additional roadway width for a formal pedestrian refuge island in the middle of the roadway allowing users to cross one travel direction at a time. A conceptual plan of the crossing is shown in Figure 41.

Figure 41: AT Crossing Lane Configuration Modification



Install Transverse Rumble Strips and Speed Feedback Signal along US-211

Vehicles are perceived to drive at high speeds along US-211, especially on the downhill grades. Transverse rumble strips and speed feedback signs are countermeasures that can reduce speeding by alerting travelers to their speed and the approaching point of interest. This countermeasure is especially effective in locations with high levels of tourism and non-local traffic.

Duplicate Entrance Sign at Panorama

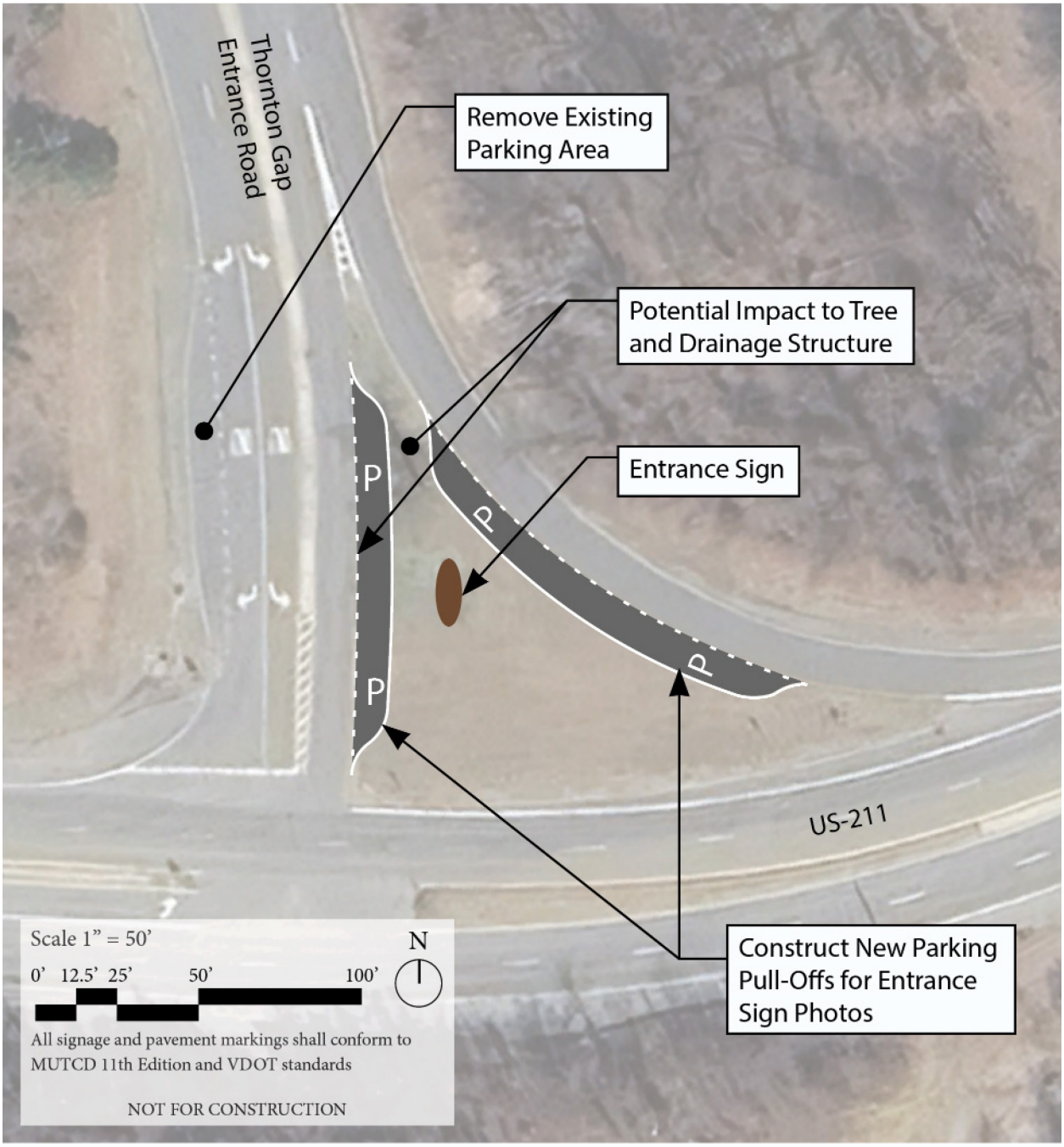
Visitors throughout NPS parks enjoy taking photos with the entrance sign. The entrance sign at Tornton Gap is difficult to access given the location and the lack of safe parking. To improve safety while still providing an opportunity for visitors to take photos with the sign, the park should consider installing a replica entrance sign at the nearby Panorama site. This could reduce the number of people walking to the existing sign and reduce the number of vehicles parking along the roadway. Additionally, it could improve congestion by reducing friction between people parking and driving. Further evaluation is recommended to determine a suitable location. An educational campaign is also recommended to notify visitors of the replica sign.

Relocate the Parking Area for Entrance Sign Photos

In addition, or instead of the replica entrance sign, the park should consider improving the parking to access the existing entrance station sign. The current location of the parking pull-out is problematic because it forces people to cross the street and is only accessible for people exiting the park. The

recommended locations for the parking pull-outs are within the island, allowing visitors to have direct access to the sign and access it upon entering the park. A conceptual plan for the relocated parking area is shown in Figure 42.

Figure 42: Relocated Parking Area for Entrance Sign Photos



Signage Improvements along US-211 and Approaching the AT Crossing

As noted in the existing challenges section, sign clutter along US-211 westbound can distract drivers from the approaching AT crossing. All signage unrelated to the crossing should be relocated to a different part of the roadway. Additionally, the signage related to the crossing, including advanced warning signage and signage at the crossing, should be converted to the MUTCD florescent yellow-green

color. Additionally, the pedestrian crossing sign (W11-2) should be converted to the hiker crossing sign with AT plaque from the Appalachian National Scenic Trail Sign Standards Manual, dated January 2021.

Pedestrian Fence on Skyline Drive Bridge over US-211

Due to the low railing height, a pedestrian fence may be helpful to prevent people from falling off. FHWA performed an assessment on all the bridges and tunnels, however a recommendation for the bridge was not made. If the AT is rerouted over the bridge, improvements to the walking experience are recommended. However, without rerouting the AT trail along the bridge, this safety countermeasure is unlikely to proceed given the low level of people walking over the bridge.

Site 3: Swift Run Gap Entrance Station

The engineering recommendations at the Swift Run Gap Entrance Station include infrastructure improvements at the intersection such as removing climbing lanes, creating additional parking at the entrance sign, converting through lanes to turn lanes at Swift Run Gap Entrance Road, creating a walking area for AT users, and a major intersection redesign of US-33 at Swift Run Gap Entrance Road.

US-33: Remove Westbound Climbing Lane at the Top of the Hill and Create Space for Parking at the Entrance Sign

US-33 has a peak elevation a little over 1,000 feet to the east of the intersection with Swift Run Gap Entrance Road. Currently, the westbound approach consists of two travel lanes that merge into one travel lane at the intersection and a 500-foot right-turn only lane. At the top of the hill, the second climbing lane is no longer necessary, and vehicles can merge into one lane to begin the downhill decent. By merging the westbound through travel lanes earlier, vehicles at the intersection will be able to exit Swift Run Gap Entrance Road easier and safer. This modification also provides additional roadway dimensions to add several parking spaces near the SHEN Entrance sign for photos. A conceptual plan is shown in Figure 43.

Skyline Drive: Convert Through Lanes to Turn Lanes at Swift Run Gap Entrance Road and Create a Walking Area for AT Users

Skyline Drive expands from a two-lane cross section to a four-lane cross section at the Swift Run Gap Entrance. The additional lanes are expected to be used for passing and/or turning. Turning vehicles are expected to use the west lane (left lane for northbound traffic, and right lane for southbound traffic) to complete turning movements. However, the additional lanes are unmarked which can lead to confusion for the driver when navigating through the intersection. This safety recommendation includes converting two of the general lanes into designated turning-only lanes. At the Skyline Drive northbound approach, the left-lane should be converted into a left-turn lane and at the Skyline Drive southbound approach, the right-lane should be converted into a right-turn lane.

The countermeasures also provide several secondary safety benefits. First, the overall cross section will be reduced, which allows additional roadway space to be converted into a walking area for AT users. Second, by eliminating the passing lanes, faster vehicles will not be able to overtake slower vehicles and will travel slower, leading to vehicles traveling at safer speeds. Figure 44 provides a design concept for the recommendation along Skyline Drive and at the AT crossing.

Figure 43: Modify Westbound US-33 Lane Configuration

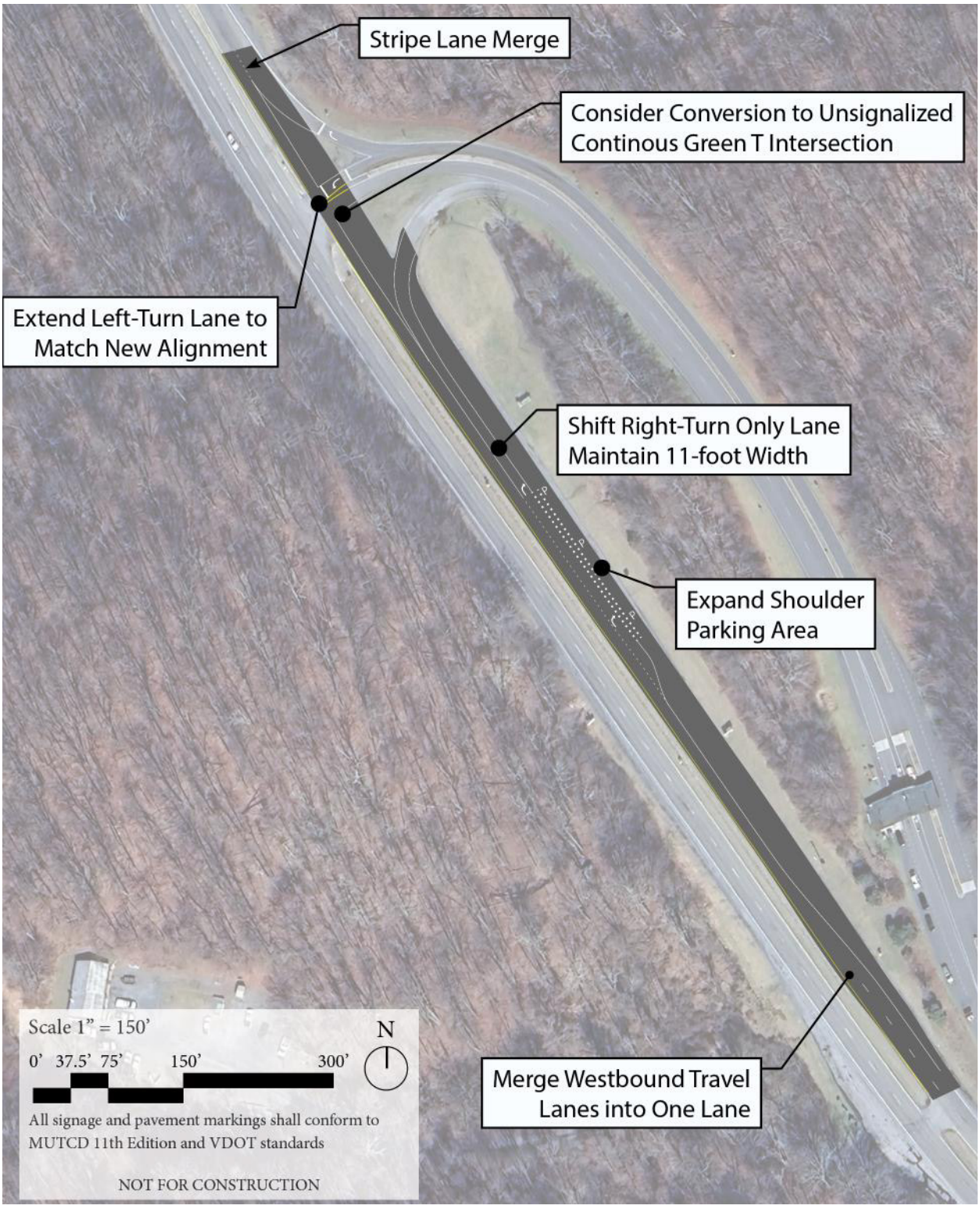
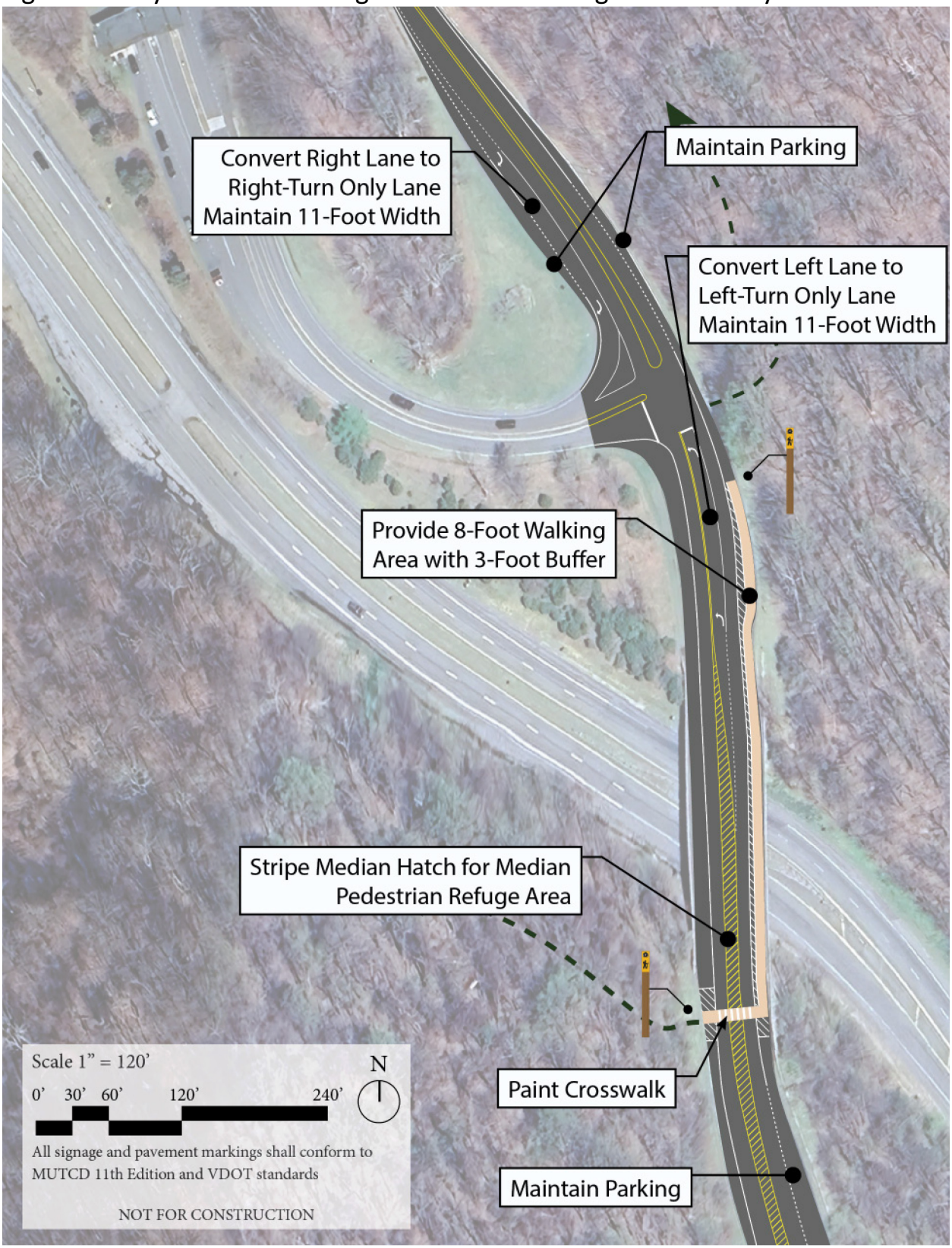


Figure 44: Skyline Drive Turning Lanes with Crossing and Walkway for AT



Regular Sweeping and Maintenance along US-33 and the Westbound Right-Turn Lane and VDOT Assessment

VDOT should perform regular street sweeping along US-33 to remove small debris and loose gravel from the roadway surface. Additionally, SHEN staff and specifically Swift Run Gap Entrance Station Staff, should regularly monitor the right-turn slip lane for loose gravel and clear the debris and loose gravel that accumulate. VDOT should also perform an assessment of US-33 to check for more permanent solutions such as re-grading the roadway, installing additional catch basins and/or drainage structures, or paving with a higher quality chip seal to improve the water runoff.

Education Recommendations

Education recommendations typically revolve around communication to the public or data to assist the park to make an informed decision. Education recommendations can be effective if implemented correctly. SHEN should continue to explore methods of communicating information to the public, especially revolving around peak season weekends.

Busy Season Traffic Management Planning and Local Partnership Improvements

SHEN should re-engage local agencies regarding the park's traffic management plan. New engagement with Front Royal leaders, VDOT, and Warran County can lead to opportunities for alignment of mutual goals on safety and congestion issues that affect both park visitors and residents, as well as understanding the considerations of each side. SHEN should continue to communicate information to the public related to congestion and delays at the entrance stations and suggest alternate routes or promote the use of alternate entrance stations.

Some tools for communicating with the public are listed below:

- **Variable Message Boards:** Consider the use of variable message boards, especially along the primary access roads such as I-66 and I-81, to signal real-time traffic conditions.
- **Well-Maintained Signage:** Appropriate signage that communicates information to the public.
- **Website Updates:** SHEN should use their website to provide real-time updates to existing roadway conditions. Potential programming that intersects with safety education campaigns are further opportunities to establish outreach.
- **Non-Web Based:** SHEN can use non-web-based platforms to communicate information to the public such as newspapers, local media, libraries, and PSAs, to share information about safety education campaigns and inform visitors of Park conditions.
- **Coordination with Local and State Transportation Agencies:** Partner with local and state transportation agencies should promote the same safety messages at the same time.
- **Coordination with Local Organizations and Clubs:** Strengthen the ties between local clubs, organizations, and the park to promote a cohesive and refined safety message that aligns interests with visitors and residents alike.

Bicycles on Road Informational Campaign

Skyline Drive has some markings and signage informing drivers to expect to share the road with cyclists. However, the signage and markings are easy to miss, especially in areas with other activity. While most of Skyline Drive is too narrow to formally accommodate bicyclists, shared lane markings and signage can be used to alert drivers of bicyclist presence. At each entrance station, SHEN should install a bicycle information message communicating to drivers that they may encounter bicyclists on the roadway. The safety massage should also be posted to the Driving Skyline Drive webpage. The message should include:

- Cyclists are allowed to travel in the travel lane and in groups. When you encounter a cyclist, slow down and be patient.
- Drivers should only pass bicyclists when it is safe and legal. Ensure adequate line of sight and the opposite travel lane is clear of oncoming traffic.
- Drivers should provide a minimum of 4-feet clearance when passing a cyclist and use a turn signal.

Speed Data Collection on VDOT Roadways

The RSA highlighted the three sites, which intersect with VDOT roadways. Some of the concerns were with the sight lines from minor approach, specifically vehicles exiting the park onto VDOT roadways. Speed data is critical for better understanding the line-of-sight challenges and if adequate sight lines exist for vehicles to safely maneuver through the intersection. VDOT should perform targeted speed data collection along US-340, US-211, and US-33 along both approaches approaching the intersection to evaluate if additional countermeasures should be recommended to either slow vehicles down or improve the sight lines.

Replica Entrance Sign

If the park decides to install a replica entrance sign, an educational campaign should supplement the decision to notify visitors of the additional photo opportunity. A variety of communication could be deployed such as information at visitor centers and entrance stations. It is recommended that signage in installed at the existing entrance sign indicating that photos at the sign are not recommended and instead a replica sign is provided at an alternative location.

Enforcement Recommendations

Enforcement recommendations can be necessary to improve behavioral safety challenges. Implementing selected countermeasures should reduce the frequency of undesirable behavior but may not eliminate the behavior completely. Parks should limit enforcement unless it is supplemented with other recommendations to further emphasize correct safety behavior in the absence of an officer.

Speeding Enforcement and Speed Management

At many parks, high vehicle speeds are one of the top safety concerns. Speed feedback signs should be placed along Skyline Drive, US-340, US-211, and US-33, or other areas near the entrance stations, to communicate to drivers that they should slow down if traveling at excessive speeds. Speed feedback signs are effective at reducing speeds along roadway with infrequent users, and a park like SHEN, which doesn't have regular commuters will typically reduce speeds when passing a speed feedback sign.

Additionally, the speed feedback signs can collect speed data, allowing SHEN and VDOT to further evaluate any potential speeding safety challenge(s) and conduct more targeted enforcement or implement other engineering or education safety countermeasures. Further, increased law enforcement along US-340, US-211, and US-33 through the park unit areas would help discourage speeding and other erratic driving behavior. The park will have to work closely with VDOT and its partners to work out the appropriate jurisdictional authority for any law enforcement activities.

Bicycle Permitting

Bicycle permits would allow the park to better prepare for cyclist use of Skyline Drive and could proactively address safety. Implementing a permitting system would improve safety by tracking expected dates of cycling routes and use and improve coordination between cycling touring groups and the park. In addition, the system would also allow for data collection to better understand cyclist use within SHEN. Bicycle permits should not be required and should be obtained free of change so as to not discourage bicycling usage.

Emergency Services

Emergency Services recommendations are related to responding to an emergency or a crash when they occur.

Special Emergency Access Roads

To improve emergency access to the park during periods of peak congestion, emergency vehicles should be directed to use the access road between Criser Road/Parkview Drive and Skyline Drive. Currently, this is a one-way road accessible only from Skyline Drive. To prevent non-emergency vehicles from using the road to enter the park, an automatic gate can be installed. Technologies such as radio frequency identification (RFID), and siren-activated sensors can be used to only allow authorized vehicles along the access road.

Recommendations Summary Table

The following section includes a summary table of the safety countermeasures and how they address the existing safety challenges. The summary table also shows the timeframe, cost, and safety payoff. The safety payoff, timeframe, and cost descriptions in Table 5 are used in Table 6, Table 7, Table 8, and Table 9. Costs and timeframes are estimated using engineering judgement. The safety payoff is a subjective measurement, and while it is also estimated using engineering judgement, it does not include a specific value. The number of crashes or incidents is a typical way to measure the impact of a safety countermeasure; therefore, a high safety payoff will likely lead to an observed reduction in crashes or incidents over a long period of time. Some safety countermeasures are documented in the Crash Modification Clearinghouse[1] and are associated with a crash modification factor (CMF), which is the multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure. Table 6 shows the summary of engineering recommendations for Site 1: Skyline Drive at US-340, Table 7 shows the summary of engineering recommendations for Site 2: Thornton Gap Entrance Station, Table 8 shows the summary of engineering recommendations for Site 3: Swift Run Gap Entrance Station, and Table 9 shows the summary of recommendations for education, enforcement, and emergency services.

Table 5: Estimated Timeframe and Cost

Rating	Safety Payoff	Timeframe	Cost
Low/ Short-Term	Difficult to measure safety benefit	<1 Year	<$50,000
Medium/ Medium-Term	Some safety benefits that may be measurable	1-3 Years	$50,000-$500,000
High/ Long-Term	Measurable safety benefit	> 3 Years	>$500,000

[1] https://www.cmfclearinghouse.org/

Table 6: RSA Recommendation Summary, Engineering at Site 1: Skyline Drive at US-340

Recommended Countermeasure	Existing Safety Challenge	Safety Payoff	Timeframe	Cost
Signage and Pavement Marking Modifications	Mixed-Use Bicycle Traffic Rolling Stops Faded Pavement Markings	Low	Short-Term	Low
Vegetation Clearing and Maintenance	Sightline Challenges	Low	Ongoing	Low
Front Royal Entrance Station Modernization	Busy Season Congestion Emergency Vehicle Access	High	Long-Term	High
Skyline Drive at US-340 Redesign	Busy Season Congestion Sightline Challenges	High	Long-Term	High

Table 7: RSA Recommendation Summary, Engineering at Site 2: Thornton Gap Entrance Station

Recommended Countermeasure	Existing Safety Challenge	Safety Payoff	Timeframe	Cost
Improve Left-Turn Movements from Thornton Gap Entrance Road to US-211 Eastbound	Busy Season Congestion Limited Sight Lines	High	Medium-Term/Long-Term	High
Relocate the AT Crossing to Use the Skyline Drive Bridge	AT Crossing: Long Crossing and Unsafe Lane Configuration	Medium	Medium-Term	High
AT Crossing, Modify the Vehicle Lane Configuration and Add Median Island	AT Crossing: Long Crossing and Unsafe Lane Configuration	Medium	Medium-Term	Medium
Install Transverse Rumble Strips and Speed Feedback Signal along US-211	Speeding along US-211	Medium	Short-Term	Medium
Duplicate Entrance Sign at Panorama	Pedestrian Access to the Entrance Sign Pull-off Parking Used as Turn Lane	Medium	Medium-Term	Low
Relocate the Parking Area for Entrance Sign Photos	Pedestrian Access to the Entrance Sign Pull-off Parking Used as Turn Lane	Medium	Medium-Term	High
Signage Improvements along US-211 and approaching the AT Crossing	Sign Clutter along US-211 Approaching AT Crossing	Low	Short-Term	Low
Pedestrian Fence on Skyline Drive Bridge over US-211	Low Railing on Skyline Drive Bridge Over US-211	Low	Medium-Term	Medium

Table 8: RSA Recommendation Summary, Engineering at Site 3: Swift Run Gap Entrance Station

Recommended Countermeasure	Existing Safety Challenge	Safety Payoff	Timeframe	Cost
US-33: Remove Westbound Climbing Lane at the Top of the Hill and Create Space for Parking at the Entrance Sign	Unsignalized Turning and High-Speed Traffic Along Westbound US-33 Right-Turn Exiting Park Merges at Lane Drop Parking Safety Challenges at the Swift Run Gap NPS Entrance Sign	Medium	Medium-Term/Long-Term	Medium/High
Skyline Drive: Convert Through Lanes to Turn Lanes at Swift Run Gap Entrance Road and Create a Walking Area for AT Users	Difficult for Minor Approach to Enter Skyline Drive with Four-Lane Cross Section Appalachian Trail Crossing Safety Challenges	High	Medium-Term/Long-Term	Medium/High
Regular Sweeping and Maintenance along US-33 and the Westbound Right-Turn Lane and VDOT Assessment	Loose Gravel on US-33 Westbound Right-Turn Slip Lane	Medium	Ongoing	Low

Table 9: RSA Recommendation Summary, Education, Enforcement, and Emergency Services

Recommended Countermeasure	Existing Safety Challenge	Safety Payoff	Timeframe	Cost
Busy Season Traffic Management Planning and Local Partnership Improvements	Busy Season Congestion	Medium	Medium-Term	Medium
Bicycles on Road Informational Campaign	Mixed-Use Bicycle Traffic	Medium	Short-Term	Low
Speed Data Collection on VDOT Roadways	Speeding along US-211	Medium	Short-Term	Medium
Replica Entrance Sign	Pedestrian Access to the Entrance Sign Pull-off Parking Used as Turn Lane	Medium	Medium-Term	Low
Speeding Enforcement and Speed Management	Speeding along US-211	Medium	Ongoing	Medium
Bicycle Permitting	Mixed-Use Bicycle Traffic	Medium	Medium-Term	Low
Special Emergency Access Road	Busy Season Congestion	Medium	Long-Term	Medium/High

V. Safe System Approach (SSA)

The USDOT National Roadway Safety Strategy outlines the importance of taking a Safe System Approach (SSA) to safety.



There is an opportunity to reduce the likelihood and severity of crashes and incidents throughout SHEN by applying the SSA. SSA elements apply to the strategies in this RSA through:

- Safer Roads through designating spaces for people walking along roadways within the park;
- Safer Speeds through speed reduction strategies at key intersections and entrance stations throughout the park, as well as along Skyline Drive, US-340, US-211, and US-33; and
- Safer People through communicating key educational safety messages to visitors.

Resources such as the NPS Active Transportation Guidebook, the FHWA Proven Safety Countermeasures, the FHWA PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System, and the Small Town and Rural Design Guide can help planners and designers at NPS, FHWA, VDOT, Potomac Appalachian Trail Club, Warren County, Page County, Rockingham County, and other local jurisdictions (i.e., the Towns of Front Royal, Elkton, and Luray) to determine design details for each safety strategy identified in the RSA.

VI. Implementation Strategy

The recommendations in this RSA should be considered to improve safety. Some recommendations may need to be further evaluated to determine the feasibility, cost, and effectiveness before implementing. NPS will also develop a Safety Implementation Plan that details the implementation strategy in more detail and identify the park or regional staff lead, the resources needed to implement the strategy, the timeline, and the most appropriate funding source, especially for higher cost recommendations.

The sites included in this RSA contain significant overlap with VDOT jurisdiction. As such, VDOT contributed to the development of this RSA and has agreed that the recommendations should be considered for further evaluation and implementation, as necessary. VDOT staff has the capability and availability to further evaluate the improvements, and will likely identify additional VDOT staff to engage with further.