KENTUCKY TRANSPORTATION CABINET

Cumberland Expressway Upgrade Study

Final Report • March 2022

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Executive Summary

The Kentucky Transportation Cabinet (KYTC) initiated this planning study to identify and evaluate potential improvements that would be necessary to upgrade the Louie B. Nunn Cumberland Expressway to meet Interstate design standards. The study area, shown in **Figure ES1**, encompasses the entire length of the Cumberland Expressway, including interchanges, from Interstate 65 (I-65) in Barren County (MP 0.0) through Metcalfe, Adair, and Russell counties to U.S. Highway (US) 27 in Pulaski County (MP 88.376).

The Cumberland Expressway was legislatively redesignated from a parkway to an expressway as part of Kentucky Senate Bill 215 in April 2021. The Federal 2021 Infrastructure Investment and Jobs Act (IIJA) also added it to the list of High Priority Corridors on the National Highway System to prioritize funding for the corridor. The IIJA also specifically stated that it will "be designated as a spur of Interstate Route 65". This study will identify and evaluate short-term and long-term improvement strategies to upgrade the Cumberland Expressway to current (2021) Interstate design standards. The goals of this study are to:

- Evaluate existing mainline, interchange, ramp, and bridge conditions to identify deficiencies with respect to Interstate design standards
- Evaluate existing traffic and safety conditions
- Develop a list of proposed improvements needed to meet Interstate design standards
- Evaluate proposed improvements with respect to traffic, safety, environment, and cost
- Develop a list of prioritized recommended improvements based on the technical evaluation and input from KYTC and the Federal Highway Administration (FHWA).

Interstate Design Standards

FHWA identifies ten controlling design criteria that define the operational and safety performance of an Interstate. A Design Exception (DE) can be requested when design features do not meet those standards if there is not an associated safety issue. The ten controlling criteria apply to high speed (≥50 mph) National Highway System routes and include:

1. Design Speed
2. Lane Width
3. Shoulder Width
4. Horizontal Curve Radius
5. Superelevation Rate
6. Stopping Sight Distance[1]
7. Maximum Grade
8. Cross Slope
9. Vertical Clearance
10. Design Loading Structural Capacity

This study evaluates the design features of the Cumberland Expressway for compliance with FHWA's ten controlling criteria as well as the American Association of State Highway and Transportation Officials (AASHTO) and KYTC design criteria for non-controlling criteria. **Table ES1** summarizes the guidelines used for the design standards for each mainline, structure, ramp, or loop feature. Items with an asterisk are part of the ten controlling criteria whereas those without an asterisk are KYTC standards. A Design Variance (DV) can be requested for standards that are not met if they are not one of the ten controlling criteria and if there are no safety issues present. The project team evaluated each design feature shown, compared against the listed official reference. A technical analysis was conducted by the project team to determine which deficient features would be recommended for improvement prior to Interstate conversion and which features would be recommended for DE or DV requests and only required for full compliance with Interstate standards.

1 Applies to the horizontal and vertical alignment except in the case of vertical sag curves.

Figure ES1: Study Area

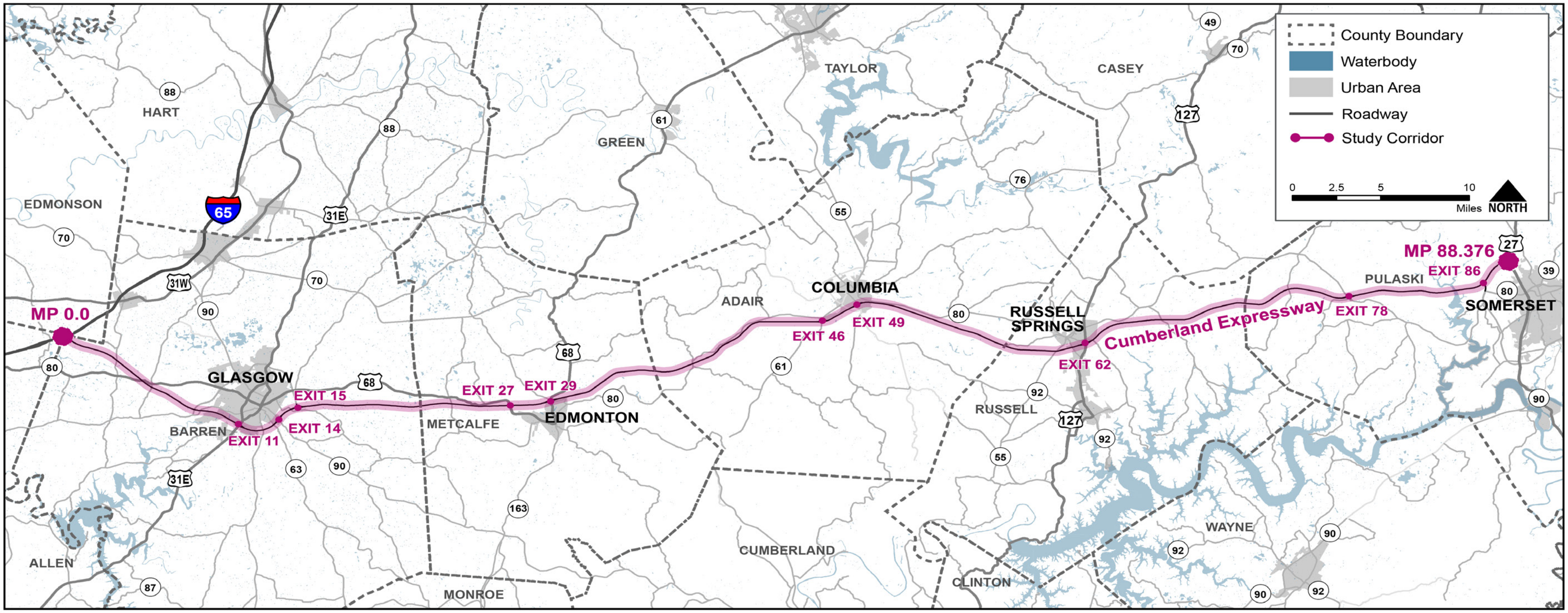

Table ES1: Interstate Design Criteria for Rural, 4-Lane Interstate Facilities

Design Element	Governing Agency	Reference	Mainline	Ramps	Loops
Design Speed*	AASHTO	A Policy on Geometric Design of Highways & Streets (Green Book), 2018	70 mph	35 mph	20 mph
Lane Width*	AASHTO	Green Book, 2018	12'	14'	15'
Inside Shoulder*	AASHTO	Green Book, 2018	4'	2'-4'	
Outside Shoulder*					
Truck DDHV ≤ 250	AASHTO	Green Book, 2018	10'	6'-10'	
Truck DDHV > 250	AASHTO	Green Book, 2018	12'		
Median Width	AASHTO	Roadside Design Guide, 2011 / A Policy on Design Standards - Interstate System (Interstate Design Guide), 2016	30' (Roadside Design Guide)/50' (Interstate Design Guide)	N/A	
Median Turnarounds	AASHTO	Green Book, 2018	May be spaced at 3 to 4-mile intervals or as needed		
Clear Zone	AASHTO	Roadside Design Guide, 2011	30'-46'	10'-18'	
Guardrail Height	KYTC	KYTC Standard Drawings	31"		
Horizontal Alignment					
Superelevation*	AASHTO	Green Book, 2018	8% Max		
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Maximum Vertical Grade*	AASHTO	2016 Interstate Design Guide/2018 Green Book	4%	4%-6%	6%-8%
Crest Vertical Curves – Minimum Stopping Sight Distance*	AASHTO	Green Book, 2018	730'	250'	115'
Sag Vertical Curves - Minimum Head Light Sight Distance	AASHTO	Green Book, 2018			
Bridges and Overpasses					
Bridge Width ≤ 200 feet	AASHTO	2016 Interstate Design Guide	37.5'	N/A	
Bridge Width > 200 feet	AASHTO	2016 Interstate Design Guide	31'	N/A	
Minimum Overpass Vertical Clearance*	AASHTO	2016 Interstate Design Guide/KYTC Highway Design Manual	16' (Interstate Design Guide)/16.5' (KYTC Highway Design Manual)	N/A	
Minimum Overhead Sign Vertical Clearance*	AASHTO	Manual on Uniform Traffic Control Devices (MUTCD), 2009	17'		
Divergence Angle	AASHTO	Green Book, 2018	2 to 5 degrees		
Speed Change Lanes	AASHTO	Green Book, 2018	Varies depending on the design speed of the entering or exiting curves		
Interchange Spacing	AASHTO	Green Book, 2018	1 mile (Urban); 2 miles (Rural)		
Interchange Control of Access	AASHTO	A Policy on Design Standards - Interstate System, 2016	300'		

*FHWA Design Controlling Criteria**

Committed Projects

There are five projects in the study area included in Kentucky's *Fiscal Year (FY) 2020 – FY 2026 Highway Plan*, and two projects in the KYTC Continuous Highway Analysis Framework (CHAF) database, listed below.

KENTUCKY FY 2020 – FY 2026 HIGHWAY PLAN PROJECTS

- 3-20004.00 – Address pavement condition from MP 20.1 to 22.357
- 3-20005.00 – Address pavement condition from MP 9.375 to 14.85
- 3-20013.00 – Address pavement condition from MP 22.357 to 36.16
- 3-80002.00- New Interchange on the Louie Nunn Cumberland Expressway at KY 249 in Glasgow
- 8-20007.00 – Address pavement conditions from Mile Post (MP) 62.544 to 72.087

CHAFS

- IP20020006- Modernize the Louie B. Nunn parkway for possible utilization as a portion of I 66
- IP20140050- Improve safety and address geometric deficiencies on the Louie B. Nunn Parkway at the Exit 27 interchange

Resurfacing, Restoration, and Rehabilitation (3R) projects like those listed above, as well as future projects, can possibly be used to construct some of the recommendations from this study.

Traffic Volumes and Operations

According to functional classification criteria, the Cumberland Expressway is currently identified as an Expressway. Current year (2020) Average Annual Daily Traffic (AADT) volumes range from 4,600 – 12,900 vehicles per day (vpd). Future year (2045) AADT volumes range from 6,700 – 18,700 vpd. Levels of service (LOS) were determined for the corridor, and found to be in the acceptable range, LOS A-C, for the entire corridor.

Safety

A historical crash analysis was performed to examine traffic safety trends and to identify potential safety issues. Five years of data (2015 to 2019) was used. 2020 crash data was not used due to changes in driver behavior and traffic volumes during the COVID-19 pandemic. Within the five-year period, 835 crashes were reported in the study area. Of the total crashes, 758 (91%) occurred on the mainline and 77 (9%) occurred on interchange ramps. There were 12 fatal crashes and 19 serious injury crashes (3.7% combined) over the five years. Most crashes (692, 82.9%) were property damage only crashes. The majority of crashes (621, 74.4%) were also single-vehicle crashes. This is consistent with the low volume rural nature of the roadway. Rear-end and sideswipe crashes were the other two major crash categories.

KYTC uses a performance metric called Excess Expected Crashes (EEC) to evaluate the need for safety improvements on state highways. EEC compares the number of observed crashes on a highway to the number of expected crashes using a crash prediction model for that highway type. A positive EEC indicates that more crashes are occurring than the model would have predicted, meaning that improvements may be warranted. A negative EEC indicates that fewer crashes are occurring than expected. Much of the Cumberland Expressway has a negative EEC. The overall EEC for the study area was -37.9 crashes per year and the EEC for fatal, serious & minor injury (KAB) crashes was -0.66 crashes per year. These results indicate that the Cumberland Expressway is operating better than predicted for a rural freeway/parkway facility with similar traffic volumes. While the highway operates well overall, there are some specific locations that could warrant safety related improvements. These locations were investigated further as part of the review of specific design standard topics.

Study Recommendations

Existing conditions along the Cumberland Expressway were evaluated with regards to three areas: mainline, structures, and interchanges and ramps. The conditions along the Cumberland Expressway were compared to Interstate standards and a list of potential improvement concepts was developed. An iterative process was used, in which the initial list of potential improvement concepts was shared with the project team to obtain feedback. Based on that feedback, the consultant team investigated certain locations further with respect to crashes, record plans, or other available data to determine which improvement concepts would need to be constructed before Interstate conversion (initial conversion), and which could possibly be granted a Design Exception (DE) or Design Variance (DV) but would be necessary for full interstate compliance. DEs and DVs can be granted when the element that does not meet Interstate standards does not contribute to a safety issue at that location. Planning level construction cost estimates were developed for the refined list of improvement concepts, which was presented and discussed in the final project team meeting. Based on feedback, a finalized list of recommended improvement concepts was developed. **Tables ES2** and **ES3** show the total costs (in 2021 dollars) for initial conversion and full compliance. An additional 15% was added to the construction cost to account for design and environmental related costs, and another 15% is added to the construction cost to account for any miscellaneous construction costs. **Table ES4** gives a summary of the improvement concepts recommended as part of this study. The table includes the construction cost in 2021 dollars, and whether the improvement would likely be needed prior to Interstate conversion, or for full compliance to Interstate standards.

Table ES2: Cost Estimates for Initial Conversion to Interstate Design Standards

Total Initial Conversion Cost (2021 $)	$26,351,243
Total Initial Conversion Construction Cost	$20,270,187
Design + Environmental (15%)	$3,040,528
Miscellaneous (15%)	$3,040,528

Table ES3: Cost Estimates for Full Compliance with Interstate Design Standards

Total Full Compliance Cost (2021 $)	$41,548,347
Total Full Compliance Construction Cost	$31,960,267
Design + Environmental (15%)	$4,794,040
Miscellaneous (15%)	$4,794,040

Table ES4: Summary of Recommended Improvements to Upgrade the Cumberland Expressway to Interstate Standards

Category	Subcategory	Miles	Cost (2021 $)	Initial Conver-sion	Full Compli-ance	Requires Design Exception	Requires Design Variance	Safety Concerns
Mainline								
Shoulders	Widen inside shoulder from 3' to 4'	15.086	$2,240,000		✓	✓		YES
Superelevation	Increase superelevation (locations with safety issues)	1.215	$623,000	✓				YES
	Increase superelevation (locations without safety issues)	0.104	$55,000		✓	✓		
Headlight Sight Distance	Increase curve length	0.112	$459,000		✓		✓	
Guardrail	Replace damaged guardrail	5	$807,000	✓				YES
	Add new guardrail to address safety issues	2.433	505,387	✓				
	Add new guardrail to address clear zone issues	2.5	$662,000	✓	✓		✓	
	Replace all guardrail less than 31"	29.2	$4,640,280		✓		✓	
Interchanges and Ramps								
Ramps - Accel/Decel	Exit 14 (KY 90) Increase EB accel length to 580'	N/A	$163,000	✓				
	Exit 78 (KY 80) Increase WB accel length to 580'	N/A	$138,000	✓				
Lane Width	Exit 88 (US 27) Increase cloverleaf lane width to 15'	N/A	$182,000	✓				
Interchange Rebuild	Exit 27 (US 68, Glasgow Road) Reconfigure to standard diamond	1.667	$15,000,000	✓				
Bridges								
Bridge Railing	Replace metal railing (locations with safety issues)	9	$1,179,800	✓				YES
	Replace metal railing (locations without safety issues)	11	$1,170,000		✓		✓	
Bridge Width	Widen bridge 7.5 ft	2	$1,042,800		✓		✓	
Bridge over Fishing Creek	100B00074L/100B00074R - Bridge over Fishing Creek - Replace bridge railing + widen 1 ft	1	$2,083,000		✓	✓		YES
	100B00074L/100B00074R - Bridge over Fishing Creek - Replace bridge railing + HFST	1	$1,010,000	✓				YES

Additional Safety and Operational Improvement Recommendations

A list of additional safety and operational improvements was developed to recommend improvements for locations that meet the design criteria but have a noted safety or operational deficiency that should be addressed.

Table ES5 shows the total cost (in 2021 dollars) of these improvements with an additional 15% added for design and environmental related costs, and another 15% for miscellaneous construction costs. **Table ES6** shows a summary of these recommendations.

Table ES5: Cost Estimates for Additional Safety and Operational Improvements

Total Operational and Safety Improvement Cost (2021 $)	$4,724,850
Total Operational and Safety Improvement Construction Cost	$3,634,500
Design + Environmental (15%)	$545,175
Miscellaneous (15%)	$545,175

Table ES6: Summary of Recommended Additional Safety and Operation Improvements

Category	Subcategory	Count	Cost (2021 $)	Safety Concern
Upgrade Ramp Terminal Design	Remove or modify channelization and modify right turn radius @ Exit 14 (KY 90) EB ramp	1	$30,000	YES
Add Traffic Signal at Interchange Ramps	Signalize the Exit 11 (US 31E) WB Ramp Terminal	1	$250,000	YES
Safety Improvements at KY 914	Continue High Friction Surface Treatment	1	$68,000	YES
Median Turnarounds	Remove median turnarounds	5	$60,000	NO
	Remove median turnarounds and install delineation bollards	5	$67,500	NO
	Pave gravel median turnarounds	7	$70,000	NO
	Install new median turnaround	1	$20,000	NO
Safety Improvements at WB On Ramp to I-65	Add signing, striping, and rumble strips	1	$10,000	YES
Cable Median Barrier	Add cable median barrier to prevent crossover crashes	16.1 (mi)	$3,059,000	YES

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Glossary of Terms

Full Name	Abbreviation
American Association of State Highway and Transportation Officials	AASHTO
A Policy on Design Standards – Interstate System, 2016	Interstate Design Guide
A Policy on Geometric Design of Highways & Streets, 2018	2018 Green Book
Area Development District	ADD
Average Annual Daily Traffic	AADT
Average Annual Daily Truck Traffic	AADTT
Census Bureau American Community Survey	ACS
Crash Data Analysis Tool	CDAT
Crash Modification Factor	CMF
Design Exception	DE
Design Hourly Volume	DHV
Design Variance	DV
Eastbound	EB
Environmental Justice	EJ
Environmental Overview	EO
Excess Expected Crashes	EEC
Federal Highway Administration	FHWA
Fiscal Year	FY
Geographic Information System	GIS
Headlight Sight Distance	HLSD
High Friction Surface Treatment	HFST
Highway Capacity Manual, 6th Edition	HCM 6
Highway Information System	HIS
Highway Safety Manual	HSM

Intermodal Surface Transportation and Efficiency Ace of 1991	ISTEA
Infrastructure Investment and Jobs Act (IIJA)	IIJA
Kentucky Transportation Cabinet	KYTC
Kentucky Transportation Center	KTC
Level of Service	LOS
Manual on Uniform Traffic Control Devices, 2009	MUTCD
Mile Post	MP
National Bridge Inspection Standard	NBIS
National Bridge Inventory	NBI
National Environmental Policy Act	NEPA
National Wetland Inventory	NWI
Outstanding State Resource Water	OSRW
Resurfacing, Restoration, and Rehabilitation	3R
Roadside Design Guide, 4th Edition (including 2012 and 2015 errata), 2011	Roadside Design Guide
Single Unit Truck	SU
United States Department of Transportation	USDOT
Vehicles per Day	VPD
Volume to Capacity Ratio	V/C
Westbound	WB

1 Introduction

The Kentucky Transportation Cabinet (KYTC) initiated this planning study to identify and evaluate potential improvements that would be necessary to upgrade the Louie B. Nunn Cumberland Expressway to meet Interstate design standards. The study includes both short- and long-term improvement strategies that KYTC could use to further project development and implementation. Members of the project team included the KYTC State Highway Engineer's Office, KYTC Districts 3 and 8, KYTC Central Office Divisions of Planning and Highway Design, the Federal Highway Administration (FHWA), the Barren River and Lake Cumberland Area Development Districts (ADDs), and the WSP Consultant Team, including HDR and TSW.

1.1 Study Background & Study Area

The Cumberland Expressway Upgrade Study will identify any roadway elements or characteristics that do not adhere to Interstate design standards and determine possible improvements to bring the roadway into compliance with those standards. The Cumberland Expressway was legislatively redesignated from a parkway to an expressway as part of Kentucky Senate Bill 215 in April 2021. There are state and local officials who have expressed interest in a further redesignation to a full Interstate. This study outlines what may be required to accomplish that redesignation.

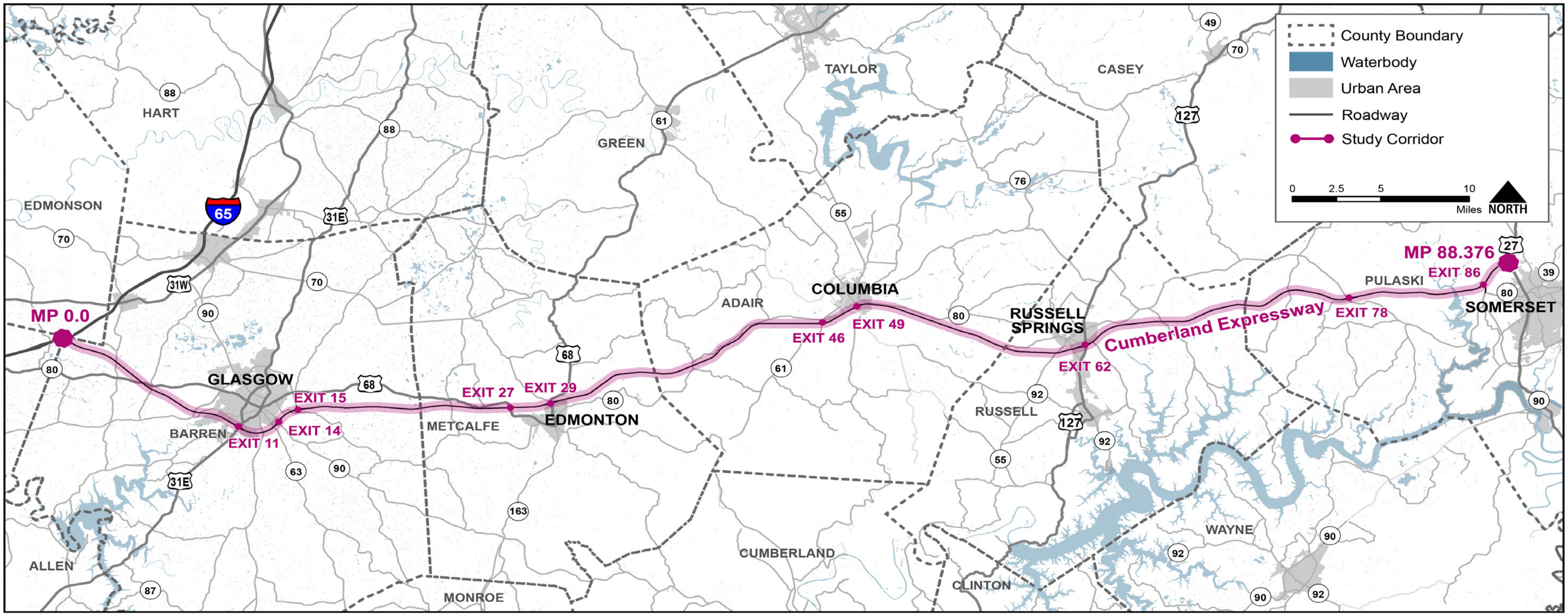
The study area, shown in **Figure 1**, encompasses the entire length of the Cumberland Expressway, including interchanges, from Interstate 65 (I-65) in Barren County (MP 0.0) through Metcalfe, Adair, and Russell counties to U.S. Highway (US) 27 in Pulaski County (MP 88.376). From west to east, the location of interchanges are: I-65, Kentucky Route (KY) 3600, US 31E, KY 90, KY 1519, US 68 (Glasgow Road), US 68 (Greensburg Street), KY 61, KY 55, US 127, KY 910, KY 80, KY 914, and US 27. The regionally significant cities within the study area include Glasgow, Edmonton, Columbia, Russell Springs, and Somerset.

1.2 2021 Infrastructure Investment and Jobs Act

The recently passed Infrastructure Investment and Jobs Act (IIJA)[1] specifically added the Cumberland Expressway to the list of High Priority Corridors on the National Highway System, which was first created by the Intermodal Surface Transportation and Efficiency Act of 1991 (ISTEA)[2]. This list was created to more rapidly advance and upgrade select corridors. ISTEA specifically stated that the purpose of the list was to "give priority to funding the construction of these corridors". The list was also created in the context of addressing the concern that, "many regions of the Nation are not now adequately served by the Interstate System or comparable highways and require further highway development in order to serve the travel and economic needs of the region".

1 https://www.congress.gov/117/bills/hr3684/BILLS-117hr3684enr.pdf
2 https://www.govinfo.gov/content/pkg/STATUTE-105/pdf/STATUTE-105-Pg1914.pdf

Figure 1: Cumberland Expressway Study Area



The recent IIJA also amends Section 127 of Title 23[3] of the United States Code addressing Interstate vehicle weight and use restrictions to allow that if the Cumberland Expressway is designated as an Interstate, a vehicle that could operate legally on it before the designation may continue to operate on it as long as it does not exceed 120,000 pounds gross vehicle weight. This would allow for farm vehicles to continue to use the highway. This amendment specifically calls out the I-65 designation stating, "The Louie B. Nunn Cumberland Expressway (to be designated as a spur of Interstate Route 65) from the interchange with Interstate Route 65 in Barren County, Kentucky, east to the interchange with United States Highway 27 in Somerset, Kentucky."

3 https://www.law.cornell.edu/uscode/text/23/127

1.3 Committed & Proposed Projects

KYTC provided a list of committed and proposed projects that could potentially address Interstate standard design deficiencies in the study area. There are five projects in the study area included in Kentucky's Fiscal Year (FY) 2020 – FY 2026 Highway Plan, and two projects in the KYTC Continuous Highway Analysis Framework (CHAF) database, listed below.

KENTUCKY FY 2020 – FY 2026 HIGHWAY PLAN PROJECTS

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CHAFS

- IP20020006- Modernize the Louie B. Nunn parkway for possible utilization as a portion of I 66.
- IP20140050- Improve safety and address geometric deficiencies on the Louie B. Nunn Parkway at the Exit 27 interchange

1.4 Study Objective

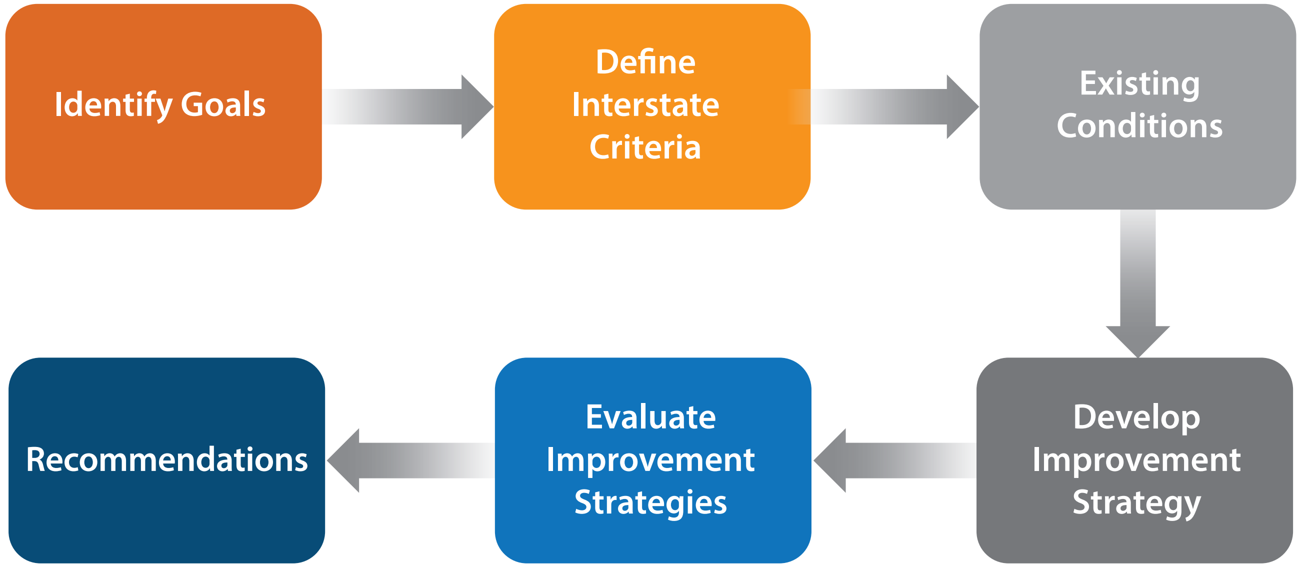
The objective of the Cumberland Expressway Upgrade Study is to identify and evaluate short-term and long-term improvement strategies to upgrade the Cumberland Expressway to current (2021) Interstate design standards. The study also identifies improvement strategies to address specific traffic operations and safety issues identified during the process.

1.5 Study Process

The study process consists of six major elements, summarized in **Figure 2**:

- Identify the goals of the study
- Define Interstate geometric design criteria
- Examine the existing conditions and identify locations that do not meet Interstate standards
- Develop potential improvement strategies
- Evaluate the improvement strategies based on the study goals
- Provide a prioritized list of short-term and long-term improvement recommendations

Figure 2: Study Process



The subsequent chapters of this report detail these steps, with additional information provided in the appendices.

1.6 Study Goals

The goals of the study are to:

- Evaluate existing mainline, interchange, ramp, and bridge conditions to identify deficiencies with respect to Interstate design standards
- Evaluate existing traffic and safety conditions
- Develop a list of proposed improvements needed to meet Interstate design standards
- Evaluate proposed improvements with respect to traffic, safety, environment, and cost
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1.7 Study Design Characteristics

FHWA identifies ten controlling design criteria that define the operational and safety performance of an interstate. The American Association of State Highway Transportation Officials (AASHTO) provides the standards for these criteria. A Design Exception (DE) can be requested when design features do not meet those standards if there is not an associated safety issue. The ten controlling criteria apply to high speed (≥50 mph) National Highway System routes and include:

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Interchange Control of Access	AASHTO	Interstate Design Guide, 2016	300’		

*FHWA Design Controlling Criteria**

2 Existing Geometric Conditions

To assess compliance with the Interstate design standards, a detailed inventory of the existing physical and geometric design characteristics was completed. The inventory assessed three main areas: mainline, structures, and interchanges and ramps using the following sources:

- KYTC Highway Information System (HIS) data
- KYTC record plans
- Google Earth aerial imagery and Street View
- Field review

A detailed account of the existing conditions is provided in **Appendix A**.

2.1 Mainline

Mainline roadway characteristics of the Cumberland Expressway are detailed below.

2.1.1 Terrain

Except from MP 57.791 to 72.087, which is defined as "Flat", the Cumberland Expressway terrain is "Rolling." The 2018 *Green Book* defines Rolling terrain as natural slopes that consistently rise above and fall below the road grade, and occasional steep slopes that offer some restriction to normal horizontal and vertical roadway alignment. Rolling terrain was selected to analyze roadway geometrics and design standards.

2.1.2 Design Speed

The mainline design speed of the Cumberland Expressway is 70 mph throughout the study area and is consistent with design speed for other interstates.

2.1.3 Lane Width

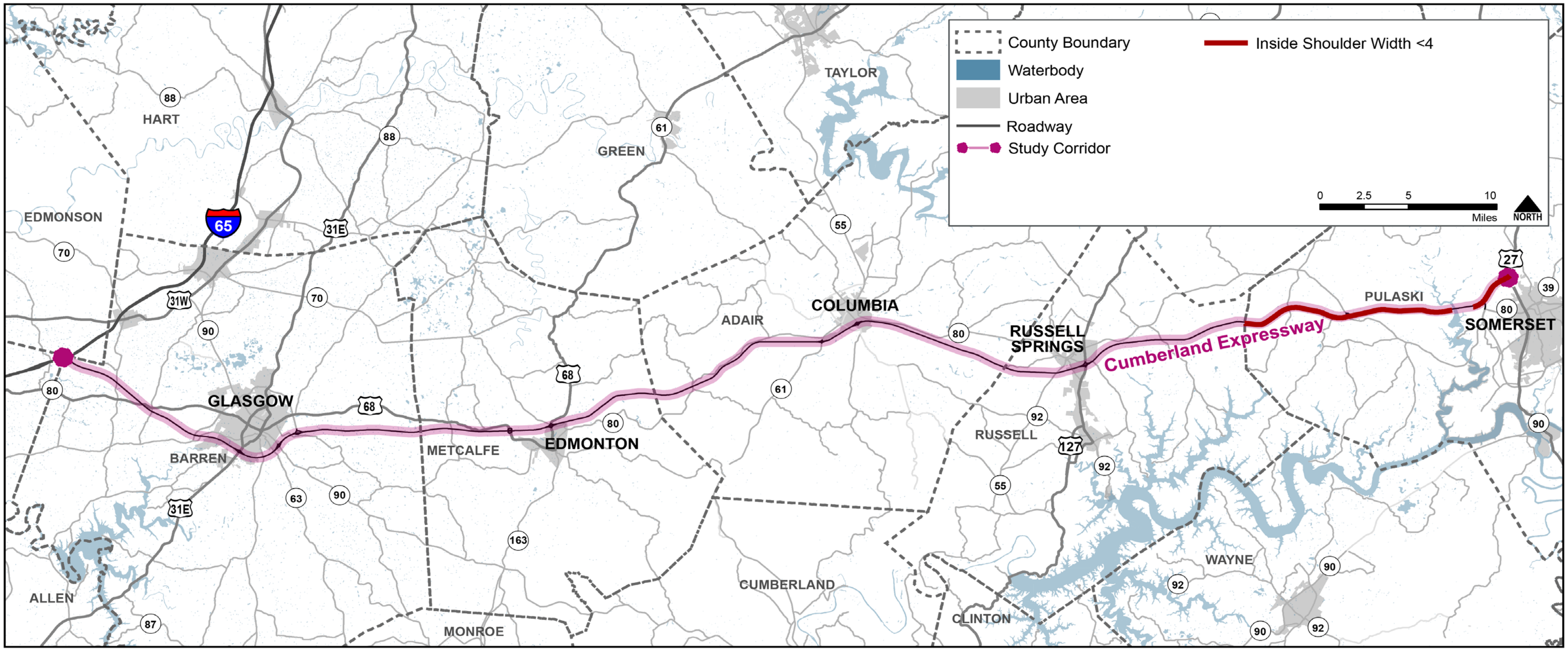
The mainline lane width design requirement for 70 mph is 12 feet minimum. According to HIS data, the minimum 12-foot lane width is maintained through the Cumberland Expressway mainline. A Section Engineer noted that there are locations in Adair County where the lane widths measure 11 feet. Therefore, it is recommended that the entire corridor be surveyed prior to conversion to determine if there are any locations where HIS or record plan data is incorrect so improvements can be made.

2.1.4 Shoulder Widths

Interstate standards for shoulder width are dependent on location and usage. For the inside shoulder, the design width should be paved and a minimum of 4 feet wide. Two segments (MP 72.09 to 84.29 and MP 85.49 to 88.38), making up approximately 15 miles have a three-foot paved inside shoulder and do not meet Interstate standards. There is one short segment (MP 84.757 to 85.346) that HIS noted as having an inside shoulder width less than 4 feet; however, a review of Google Earth imagery confirmed that shoulder width did meet the 4-foot minimum standard.

Where the truck Daily Design Hourly Volume (DDHV) is less than or equal to 250 vehicles per day (vpd), the minimum paved outside shoulder width should be 10 feet wide, while segments with truck DDHV greater than 250 are recommended to have a 12-foot paved shoulder width. Truck DDHV does not exceed 250 vpd throughout the study area, and the outside shoulder width meets the minimum required standard. This does not include shoulders on bridges, which are discussed in Section 2.2. **Figure 3** shows the limits of substandard inside shoulders in the study area.

Figure 3: Study Area Existing Shoulder Conditions



2.1.5 Median Width

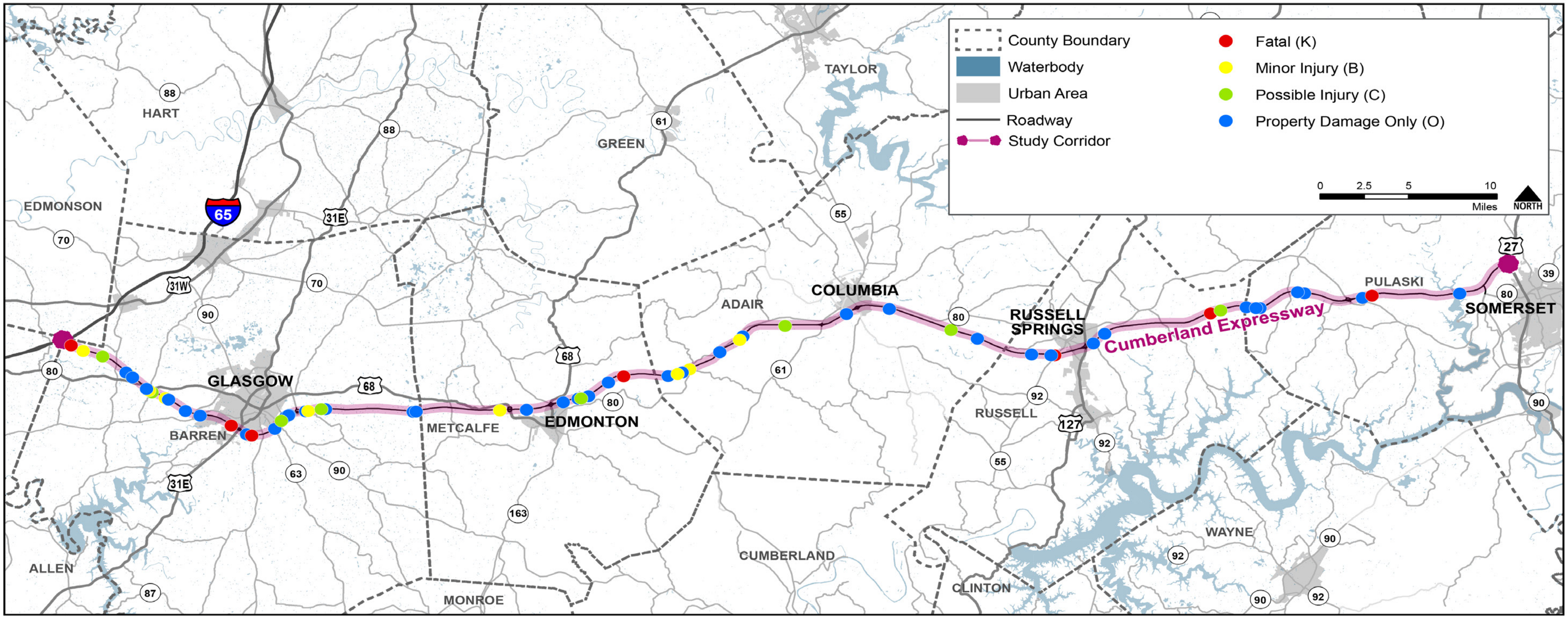
The *2011 Roadside Design Guide* requires a mainline highway with a design speed of 70 mph to maintain a median width of between 30 feet and 60 feet, where median barriers remain optional depending on traffic volume and safety concerns. Median widths of less than 30 feet require median barriers to be installed. The *2016 Interstate Design Guide,* states that median widths should be at least 50 feet wide, with 60 feet preferred in rural areas with level or rolling terrain. Two locations with a total combined length of 0.47 miles (compared to the 88.38-mile total corridor length) do not meet the 30-foot median requirement of the *Roadside Design Guide*. However, the 11-foot medians in those two locations have either guardrail or concrete barrier, meeting the requirement to install a barrier. The Cumberland Expressway has a depressed median width of 36 feet for 84.88 miles. This satisfies the *Roadside Design Guide* standard which indicates that median barriers are optional for this width when the traffic volume is below 20,000 vehicle per day (vpd). (No portion of the corridor is predicted to exceed 20,000 vpd even in 2045.) The remaining 3.03 miles of the Cumberland Expressway has a median width of 60 feet, satisfying the requirements of both the *Roadside Design Guide and the 2016 Interstate Design Guide.*

A review of the crash data revealed 62 crashes flagged as median cross-over crashes between 2015 and 2019. The crashes are shown in **Figure 4.** Seven (11%) of these crashes were fatal crashes, nine were minor injury crashes, eight were possible injury crashes, and the remaining 38 were property damage only crashes. Of the 62 crashes, 46 (74%) were single-vehicle crashes where a vehicle crossed the median. With regards to location, the crashes occurred throughout the corridor, but there was a slightly higher density of crashes from I-65 to east of Glasgow. Given the high severity of the median crossover crashes (11% fatal), the observed clustering of the crashes, and the fact that barrier is optional, it was decided that further investigation was warranted to determine if cable median barrier would be a beneficial safety improvement even though it is not required by standard. Section 6.4.3 describes the method used to evaluate the need for cable median barrier along the Cumberland Expressway.

2.1.6 Median Turnarounds

The *2018 Green Book* states that median turnarounds may be provided where interchange spacing exceeds five miles to avoid excessive adverse travel for emergency and law enforcement vehicles. *There* are 42 median turnarounds in the study area. These were evaluated for compliance/safety based on drainage, sight distance, the crash analysis, and AASHTO and KYTC guidelines. Of the 42 median turnarounds, 24 are not needed based on the *2018 Green Book* and KYTC guidelines, meaning the spacing is less than three miles from another median turnaround or interchange and is not located at a county line. It should also be noted that eight of the 42 median turnarounds identified are unpaved turnarounds located at crash cushions protecting bridge piers and are not practical to remove. Maintenance crews use these locations as turnarounds even though they are not considered official median turnarounds.

Figure 4: Median Crossover Crashes



2.1.7 Clear Zones

The 2011 *Roadside Design Guide* provides a range for the minimum clear zone requirement for an interstate, derived from the design speed, traffic volume, and roadside slope. For a 70 mph roadway, slopes of 6H:1V or flatter require a median width of 30 to 34 feet, with steeper slopes (4:1 to 5:1) requiring up to 38 to 46 feet. Without up-to-date study area typical sections, a foreslope of 4:1 was assumed in areas where it was not clear. Google Earth measurements were taken from the edge of the traveled way to the nearest visible obstruction (grade, rock cut, tree line, etc.) and approximately 17.2 miles along the Cumberland Expressway do not meet clear zone requirements.

2.1.8 Guardrail Placement and Condition

The 2011 *Roadside Design Guide* provides guidance on the application and situation of guardrail placement. According to the 2020 KYTC Standard Drawings and Active Sepias, any new guardrail shall be installed at a height of 31 inches from the edge of the paved shoulder. The adequate height of guardrail was 27 inches on previous Resurfacing, Restoration, and Rehabilitation (3R) projects.

Guardrail placement and condition inventory was gathered during field review by sampling heights for guardrail and noting end treatments and build condition. Guardrail height measurements were taken to assess whether the height was appropriate throughout the Cumberland Expressway. There is no existing guardrail installed at 31 inches. Approximately 66% of the guardrail measured were less than 27 inches and 34% were between 27 and 31 inches. Approximately 13% of the existing guardrail has damage and needs to be repaired/replaced.

2.1.9 Horizontal Alignment

DEGREE OF HORIZONTAL CURVATURE

According to the 2018 *Green Book*, the minimum horizontal curvature of a 70 mph design speed rural interstate is 1,810 feet with emax = 8.0%, as shown in the superelevation Table 3-7, equating to 3°10’ of curvature. All mainline horizontal curves throughout the Cumberland Expressway meet the minimum radius criteria, but not superelevation criteria.

SUPERELEVATION RATE

The superelevation rate has two standard requirements per the 2018 *Green Book*. The first Interstate standard requires the maximum superelevation rate for a rural interstate with 70 mph mainline to be 8.0% or less. The highest observed superelevation rate for the Cumberland Expressway mainline is 5.5%, which satisfies the superelevation requirement. The second Interstate standard requirement is dependent on the horizontal radius and the minimum superelevation for that radius. Based on HIS data, 33 curves along the Cumberland Expressway had either no superelevation or superelevation rates that do not meet the Interstate standard. The record plans were consulted for all 33 locations and indicated that only five locations were constructed without superelevation that meets the 70 mph design speed. Record plans were considered to be the most accurate for determining locations that do not meet Interstate standards. **Figure 5** shows these locations that do not meet the superelevation requirements. A detailed survey should be completed to collect the most accurate existing superelevation data.

NORMAL CROWN AND CROSS SLOPES

The minimum rate of cross slope applicable to the traveled way is determined by drainage needs. Cross slopes are added to help mitigate roadway conditions during rain, snow, or ice events. Typical cross slope (normal crown) values fall between a 1.58% and 2% slope. Any slope higher than 2% falls under the superelevation rate in the text above. The minimum horizontal radius for a normal crown for interstates is 14,500 feet. All normal crown and cross slopes meet Interstate standards.

2.1.10 Vertical Alignment

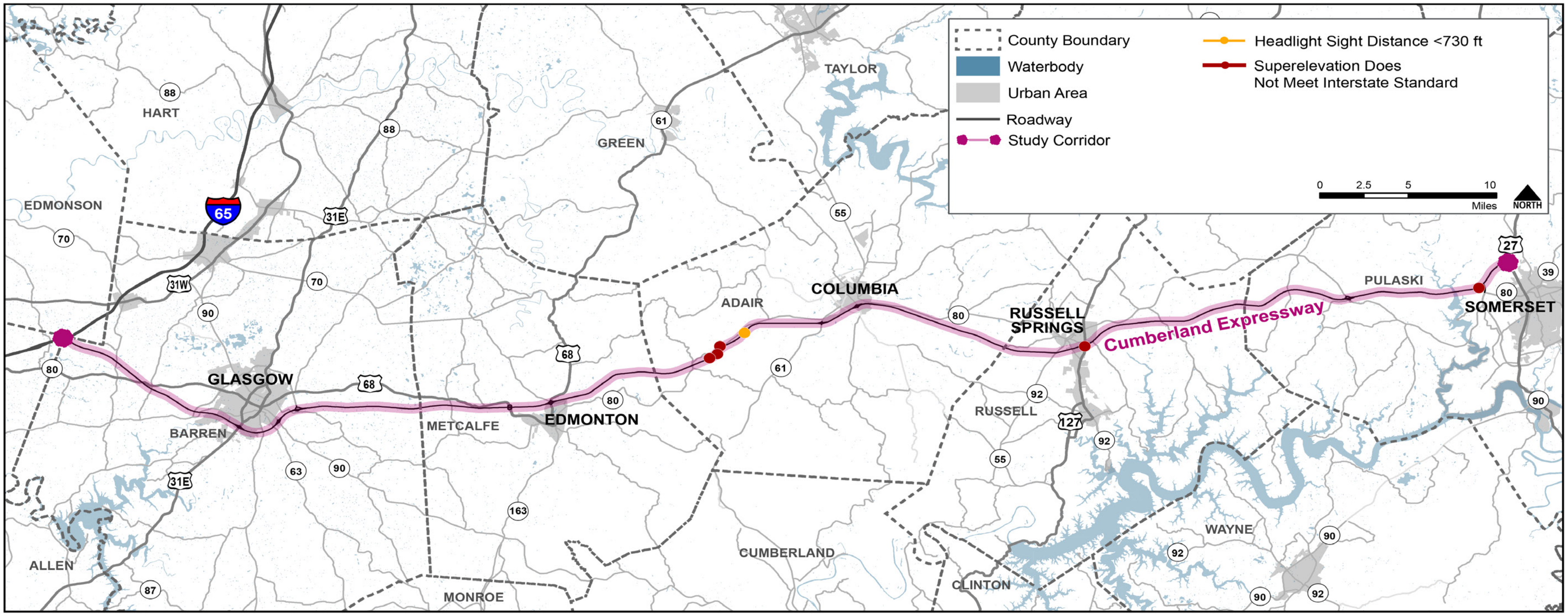
VERTICAL GRADE

The 2016 *Interstate Design Guide* states that the maximum vertical grade is 4.0% for a design speed of 70 mph for rolling terrain. HIS data indicated a vertical grade greater than 4.0% at 93 locations. However, a review of the record plans indicated that all of these locations were constructed with grades less than or equal to 4.0% and therefore meet Interstate requirements. Record plans were considered to be the most accurate for determining locations that do not meet Interstate standards. A detailed survey should be completed to collect the most accurate existing vertical grade data.

VERTICAL CURVES

According to the 2018 *Green Book*, to meet Interstate standards vertical curves must meet stopping sight distance for crest vertical curves and headlight sight distance for sag vertical curves. The required stopping sight distance is 730 feet for a 70 mph facility. All crest vertical curves along the Cumberland Expressway meet the stopping sight distance Interstate standard. One sag vertical curve at MP 41.929 has a headlight sight distance of 679 feet and does not meet the headlight sight distance requirement. **Figure 5** shows the existing horizontal and vertical curves that do not meet Interstate standards.

Figure 5: Study Area Existing Superelevation and Vertical Curve/Headlight Sight Distance Conditions

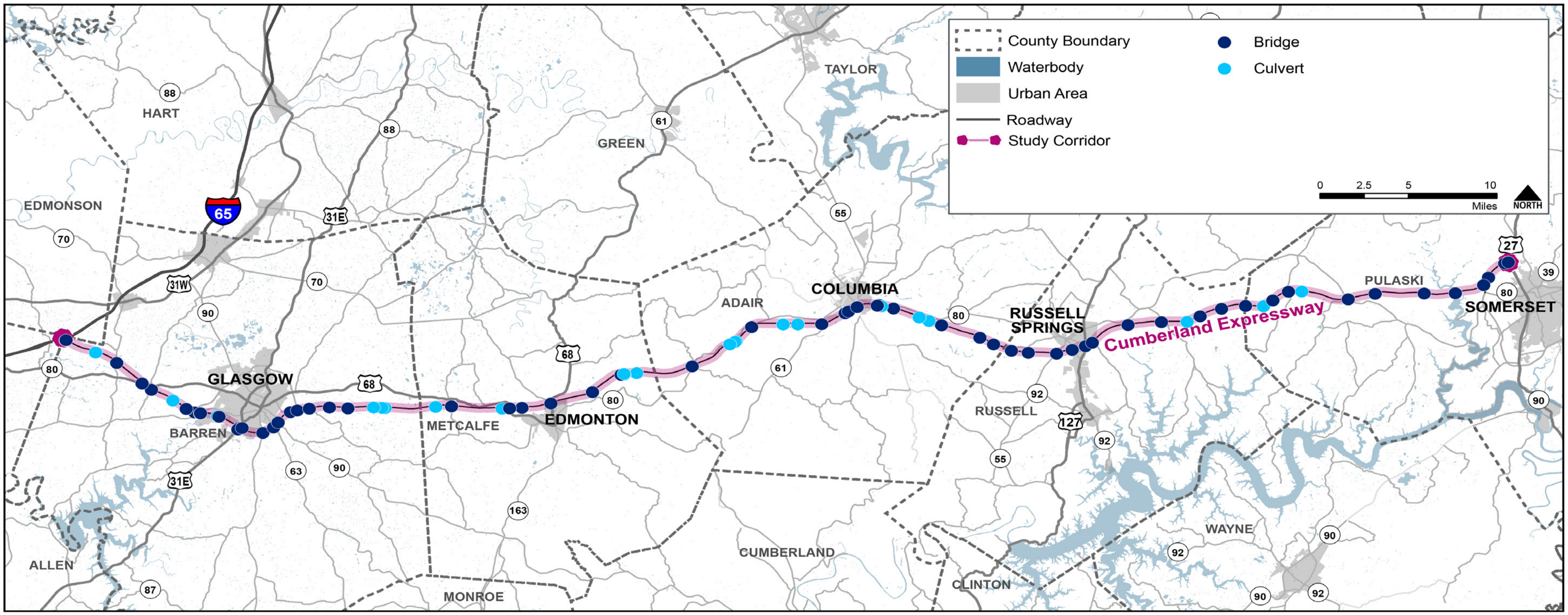


2.2 Structures

Within the study area, structures were reviewed for compliance with AASHTO Interstate design standards. The existing bridges and culverts are shown in **Figure 6**. The analysis included a review of 30 bridges over other roadways or waterways, 44 bridges for other roadways that crossed over the Cumberland Expressway, 21 box culverts (with spans greater than 20 feet as measured along the roadway centerline), and four overhead sign structures. There were no bridges that either carried the Cumberland Expressway over a railroad or a railroad over the Cumberland Expressway.

The structures data was sourced from a combination of KYTC bridge inspection report records, KYTC bridge inventories, and field verification measurements. Data for bridge width, vertical clearance, bridge condition rating, and bridge railing were taken from the KYTC bridge inspection report records. Bridges with a reported vertical clearance of less than 16.5 feet were verified with field measurements.

Figure 6: Study Area Existing Cumberland Expressway Structures



2.2.1 Bridge Width

The 2016 *Interstate Design Guide* defines the minimum bridge width on routes within the Interstate System and on routes to be incorporated into this system. For rural 4-lane Interstate facilities the mainline minimum clear bridge width for bridges in excess of 200 feet in length is 31 feet, and the minimum clear bridge width for mainline bridges less than or equal to 200 feet in length is 37.5 feet. This evaluation does not include bridges that pass over the Cumberland Expressway or box culvert structures on the Cumberland Expressway. A summary of the existing Cumberland Expressway bridges which do not meet the AASHTO requirements for interstate bridge width is provided in **Table 2**.

Table 2: Existing Deficient Bridge Widths

Bridge ID	Milepoint	County	Bridge Length (ft)	Bridge Width (ft)
005B00067R	0.031	Barren	277.0	26.33*
005B00068R	8.188	Barren	282.0	30.30
005B00068L	8.199	Barren	282.0	30.30
005B00071R	11.467	Barren	203.0	30.00
005B00073N	11.497	Barren	161.0	31.00*
005B00071L	11.498	Barren	203.0	30.00
005B00072R	11.541	Barren	191.0	30.00
005B00072L	11.576	Barren	191.0	30.00
005B00074N	11.586	Barren	131.0	25.00*
005B00075R	18.259	Barren	213.0	30.00
005B00075L	18.260	Barren	213.0	30.00
085B00042L	28.114	Metcalfe	298.3	30.00
085B00042R	28.125	Metcalfe	298.3	30.00
085B00043R	34.226	Metcalfe	210.0	30.00
085B00043L	34.227	Metcalfe	210.0	30.00
001B00062R	48.131	Adair	208.7	30.00
001B00062L	48.136	Adair	208.7	30.00
001B00063R	50.069	Adair	291.3	30.00
001B00063L	50.103	Adair	291.3	30.00
001B00069R	56.243	Adair	265.4	30.00
001B00069L	56.249	Adair	265.4	30.00
100B00074L	84.466	Pulaski	1746.0	30.00
100B00074R	84.471	Pulaski	1746.0	30.00

**Single Lane Bridge, excluded from mainline bridge width requirements*

2.2.2 Vertical Clearance

The 2016 Interstate Design Guide defines the minimum vertical clearance to structures in rural areas at 16 feet. This vertical clearance applies to all travel lanes, auxiliary lanes, shoulders, and collector-distributor roads. KYTC bridge inspection reports were reviewed for existing structure vertical clearance. No structures over the Cumberland Expressway had a noted vertical clearance less than 16 feet. The KYTC bridge inspection reports include a measurement of vertical clearance over the travel lanes only. Vertical clearance is only considered for bridge structures over the Cumberland Expressway. Vertical clearance from Cumberland Expressway bridges over other roadways was not considered as part of this study.

Field verification measurements were taken at locations with clearances less than or equal to 16.5 feet as recorded in the KYTC bridge inspection reports (**Table 3**) as well as for existing bridges with reinforced concrete haunched beams. These haunched beam bridges have a beam cross-section that thickens closer to the supports creating a situation where vertical clearance is less over the shoulder than over the driving lanes. All field verification measurements are shown in **Table 4** with those locations having less than 16.5 feet in clearance shown in ***bold italicized*** text. No field verification measurements found vertical clearance being less than 16 feet. Locations with less than 16.5 feet of vertical clearance may require further investigations when constructing any future 3R projects to ensure the 16-foot minimum vertical clearance is maintained after any pavement overlays occur.

Table 3: Existing Bridge Vertical Clearance Less than 16.50 Feet – Bridge Inspection Report

Bridge ID	Milepoint	County	Vertical Clearance (ft)
001B00055N	38.378	Adair	16.42
100B00069N	72.146	Pulaski	16.50
100B00070N	73.803	Pulaski	16.25
100B00067R	78.334	Pulaski	16.20
100B00067L	78.338	Pulaski	16.08

Table 4: Existing Bridge Vertical Clearance Concerns – Field Confirmed Measurements

				Vertical Clearance at Edge of Shoulder (ft)			
Bridge ID	Milepoint	County	Vertical Clearance over Driving Lanes*	EB Outside	EB Inside	WB Outside	WB Inside
005B00078N	3.300	Barren	17.84	17.16	18.00	17.91	17.00
005B00077N	5.253	Barren	18.01	16.75	18.16	18.83	18.75
005B00062N	5.919	Barren	17.62	17.16	18.08	17.00	17.58
005B00081N	10.175	Barren	17.5	17.00	17.50	18.00	17.25
005B00065N	12.949	Barren	17.42	17.83	17.41	17.91	16.50
005B00064N	13.631	Barren	17.42	***16.42***	17.00	16.83	***16.42***
005B00063N	14.068	Barren	17.25	19.41	18.66	17.83	16.58
005B00086N	15.027	Barren	17.45	16.83	17.25	18.16	16.66
005B00083N	16.108	Barren	16.72	***16.41***	16.50	16.50	16.75
005B00082N	17.276	Barren	16.60	17.91	16.66	***16.41***	***16.25***
085B00047N	32.302	Metcalfe	16.67	***16.41***	17.00	17.16	17.50
001B00055N	38.423	Adair	16.42	16.50	17.41	18.16	19.08
001B00068N	53.972	Adair	17.00	16.83	17.66	17.66	17.50
001B00070N	57.162	Adair	17.00	16.83	18.08	17.91	17.50
104B00027N	58.248	Russell	17.50	17.00	18.16	17.50	16.50
104B00028N	59.211	Russell	17.33	16.50	18.25	18.91	19.50
104B00020N	61.709	Russell	17.58	16.75	17.91	18.08	17.83
104B00025N	62.926	Russell	17.58	16.58	18.66	18.83	18.58
104B00023N	65.331	Russell	17.17	17.25	17.58	17.41	***16.41***
104B00026N	67.223	Russell	17.00	16.66	17.75	17.50	17.00
104B00029N	69.486	Russell	17.42	16.91	17.75	17.58	16.58
104B00024N	70.806	Russell	17.00	18.08	18.33	17.75	16.58
100B00069N	72.189	Pulaski	16.50	***16.41***	***16.33***	16.75	***16.08***
100B00070N	73.846	Pulaski	***16.25***	***16.25***	16.50	16.83	16.75
100B00068N	74.891	Pulaski	16.83	17.08	17.08	17.41	***16.25***
100B00067R	78.386	Pulaski	***16.25***	***16.33***	17.75	18.25	17.83
100B00067L^	78.386	Pulaski					
100B00072N	79.935	Pulaski	16.75	***16.33***	17.00	17.25	16.75
100B00073N	82.725	Pulaski	17.17	17.91	18.00	18.16	16.58

**From bridge inspection reports*

^Both 67R and 67L bridges carry KY 80 over the Cumberland Expressway. 67R with haunched beams has less vertical clearance than 67L, therefore no measurements shown for 67L.

2.2.3 Bridge Railing

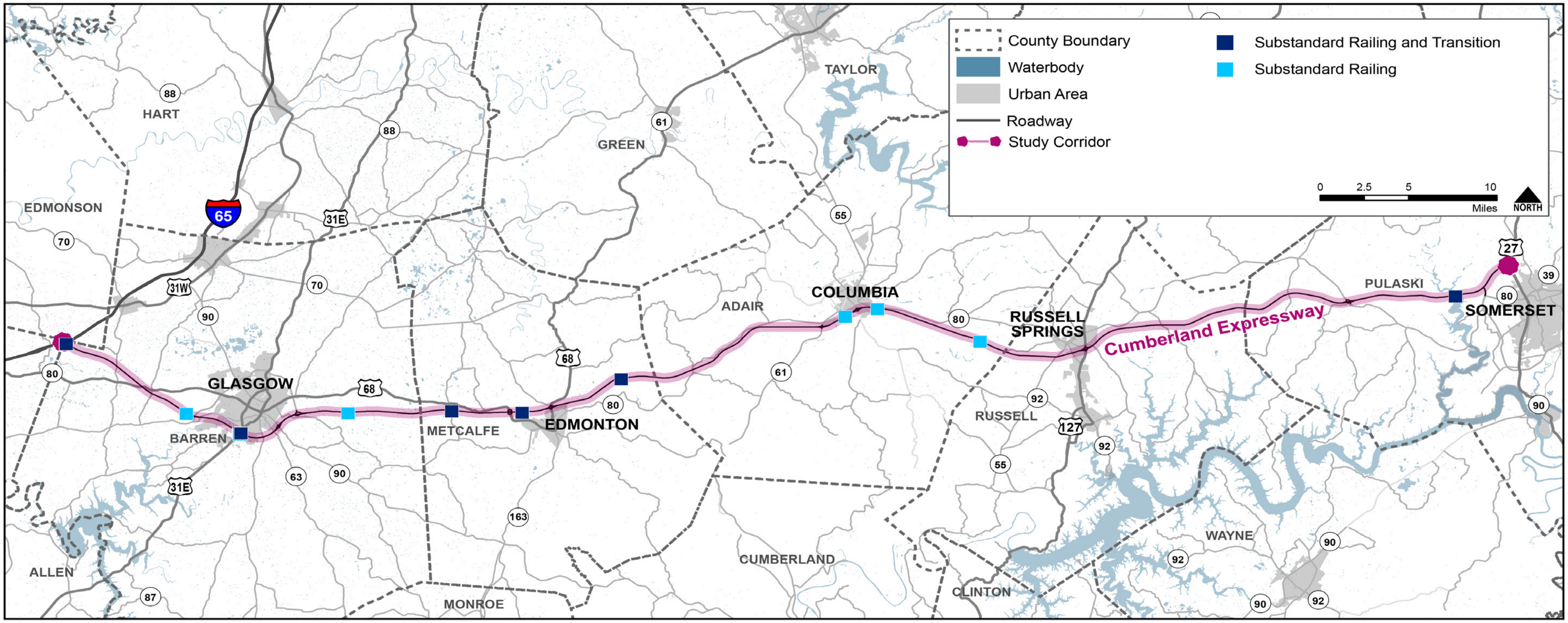
The KYTC bridge inspection reports note the bridge railing adequacy for all existing bridges. **Table 5** and **Figure 7** note existing bridges along the Cumberland Expressway which do not meet Interstate standards for bridge railing or railing transitions. The substandard bridge railing at these locations are typically due to the presence of non-crashworthy metal railing. The analysis did not include any bridges that pass over the Cumberland Expressway or box culverts on the Cumberland Expressway.

Table 5: Existing Bridges Railing

Bridge ID	Milepoint	County	Substandard Railing	Substandard Railing Transition
005B00067L	0.031	Barren	X	X
005B00067R	0.031	Barren	X	X
005B00068R	8.188	Barren	X	X
005B00068L	8.199	Barren	X	-
005B00071R	11.467	Barren	X	X
005B00073N*	11.497	Barren	X	-
005B00071L	11.498	Barren	X	X
005B00072R	11.541	Barren	X	-
005B00072L	11.576	Barren	X	-
005B00074N*	11.586	Barren	X	X
005B00075R	18.259	Barren	X	-
005B00075L	18.26	Barren	X	-
085B00040L	24.132	Metcalfe	X	X
085B00040R	24.135	Metcalfe	X	X
085B00042L	28.114	Metcalfe	X	X
085B00042R	28.125	Metcalfe	X	X
085B00043R	34.226	Metcalfe	X	X
085B00043L	34.227	Metcalfe	X	X
001B00062R	48.131	Adair	X	-
001B00062L	48.136	Adair	X	-
001B00063R	50.069	Adair	X	-
001B00063L	50.103	Adair	X	-
001B00069R	56.243	Adair	X	-
001B00069L	56.249	Adair	X	-
100B00074R	84.471	Pulaski	X	X
100B00074L	84.471	Pulaski	X	X

**These two bridges are located on ramps at the US 31E interchange.*

Figure 7: Study Area Existing Railing and Transition Conditions



2.2.4 Bridge condition rating

Bridge condition ratings, along with other factors, are used by KYTC to help determine if a bridge is to receive continued maintenance, be rehabilitated, or replaced. KYTC bridge inspection reports follow National Bridge Inspection Standard (NBIS) reporting requirements and note the bridge condition and health index for all existing structures. The bridge condition is determined by using the lowest rated of the National Bridge Inventory (NBI) condition ratings for the deck, superstructure, or substructure components. These ratings are based on a 0 to 10 scale and can be classified as follows.

- Good – Lowest component rating is greater than or equal to 7
- Fair – Lowest component is rated as 5 or 6
- Poor – Lowest component rating is less than or equal to 4

A review of the bridge condition ratings of all structures carrying mainline Cumberland Expressway and structures that cross over the Cumberland Expressway revealed no bridges or box culverts rated in “Poor” condition. 53 bridges and 20 box culverts are rated in “Fair” condition. 21 bridges and 1 box culvert are rated in “Good” condition. **Figure 8** provides the location of these structures along the Cumberland Expressway.

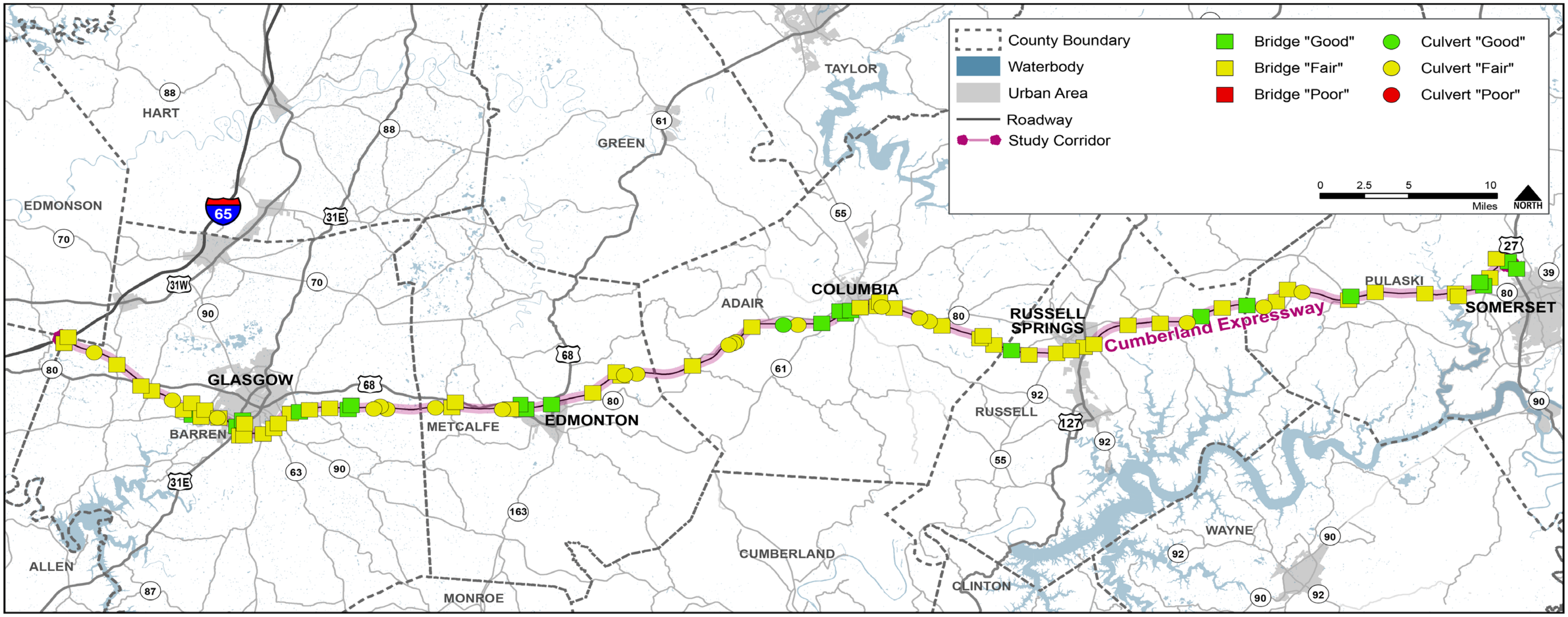
2.2.5 Overhead Sign Vertical Clearance

The *2016 Interstate Design Guide* defines the minimum vertical clearance for overhead signs at 17 feet. This vertical clearance applies to all travel lanes, auxiliary lanes, shoulders, and collector-distributor roads. Field measurements were obtained for the four overhead signs on the Cumberland Expressway. All overhead signs met the 17-foot minimum and in fact all exceeded 19-feet in clearance. **Table 6** shows the locations of each overhead sign.

Table 6: Existing Overhead Sign Locations

Milepoint	County	Description
0.30	Barren	Truss-mounted sign over WB
0.65	Barren	Truss-mounted sign over WB
1.16	Barren	Truss-mounted sign over WB
87.98	Pulaski	Truss-mounted sign over EB

Figure 8: Study Area Existing Structure Condition Ratings



2.3 Interchanges & Ramps

2.3.1 Design speed

The design speed for all ramps along the Cumberland Expressway meet the minimum Interstate standards set forth in the *2018 Green Book*.

2.3.2 Lane width

According to the *2018 Green Book*, the lane width standard for Interstate ramps is 14 feet for diamond interchange ramps and 15 feet for cloverleaf interchange loop ramps. One cloverleaf ramp, the Exit 88 (US 27) off-ramp is 14 feet wide. The Interstate standard would require the lane to be 15 feet wide. All other ramps along the Cumberland Expressway meet Interstate standards for lane width.

2.3.3 Shoulder width

Interstate standards from the *2018 Green Book* call for a 6- to 10-foot outside shoulder and a 2- to 4-foot inside shoulder for ramps with a design speed under 40 mph. For ramps with a design speed over 40 mph, the outside paved shoulder width must be 8 to 10 feet and the inside paved shoulder width must be 1 to 6 feet. Since the Cumberland Expressway falls under Traffic Condition A – predominantly passenger vehicles, but some consideration for SU trucks, the paved travel way should be at least 17 feet wide. All ramps along the Cumberland Expressway meet Interstate standards.

2.3.4 Horizontal Alignment

The horizontal alignment for all ramps along the Cumberland Expressway meet the minimum Interstate standards set forth in the 2018 Green Book for horizontal alignment. HIS data indicated that the two off-ramps at Exit 78 (KY 80) have a radius of 280 feet. The minimum radii for a design speed of 50 mph is 390 feet. A review of the record plans found that these ramps do meet the 390-foot minimum, thus all ramps along the Cumberland Expressway meet standards.

2.3.5 Vertical Grade

According to the *2016 Interstate Design Guide*, the vertical grade for Interstate ramps must be between 4% and 8% based on the design speed of the ramp. All ramps meet the vertical grade standard for Interstates along the Cumberland Expressway.

2.3.6 Vertical Curves

All vertical curves for ramps along the Cumberland Expressway meet the minimum standards for an interstate. **Appendix A** shows the stopping sight distance requirements and calculated stopping sight distance on each ramp.

2.3.7 Acceleration and deceleration lanes

The acceleration lanes and deceleration lanes require a certain length depending on the design speed of the entering and exiting curves on the ramp. **Table 7** shows the Interstate standard from the 2018 Green Book for lane length based on the design speed.

Six ramps do not meet the Interstate standard acceleration or deceleration lane length. The design speed for diamond interchange ramps with no posted speed limit were assumed to be 50 mph, while cloverleaf/loop ramps with no posted speed limit were assumed to be 25 mph, similar to ramps with advisory speeds posted in the study area. The ramps not meeting the Interstate standard are shown in **Table 8**.

Table 7: Minimum Acceleration/Deceleration Lane Length Requirements, AASHTO Green Book 2018

Auxiliary Speed (MPH)	Minimum Acceleration Lane Length (ft)	Minimum Deceleration Lane Length (ft)
25	1,420	550
30	1,350	520
35	1,230	490
40	1,000	440
45	820	390
50	580	340

Table 8: Locations That Do Not Meet Acceleration/Deceleration Lane Length Standards

Exit	Intersecting Route	Ramp	Existing Length (ft)	Required Length (ft)
14	KY 90	EB Entrance	500	580
27	US 68 (Glasgow Road)	EB Entrance	315	1420
27	US 68 (Glasgow Road)	WB Entrance	315	1420
78	KY 80	WB Entrance	450	580
27	US 68 (Glasgow Road)	EB Exit	315	580
27	US 68 (Glasgow Road)	WB Exit	315	580

2.3.8 Weaving Characteristics

The interchange at Exit 27 (US 68, Glasgow Road) in Metcalfe County is the only interchange with weaving characteristics not meeting Interstate standards. This type of interchange is known colloquially as a "Tollbooth Interchange" per its function prior to the removal of tolls on the Kentucky Parkway system. **Figure 9** shows the cloverleaf design that does not meet standards.

2.3.9 Interchange Spacing

The *2018 Green Book* requires interchange spacing to be at least 2 miles from crossing roadway to crossing roadway in rural areas, and 1 mile from crossing roadway to crossing roadway in urban areas. All interchanges meet interstate spacing standards along the Cumberland Expressway.

2.3.10 Control of Access

According to the *2016 Interstate Design Guide*, control of access for interchanges must be at least 300 feet as measured from the end of the ramp terminus radius/taper to the near side of the nearest access point for rural locations and 100 feet for urban locations to meet Interstate standards. All access points meet the Interstate requirements.

Figure 9: Exit 27 (US 68, Glasgow Road) Interchange

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3 Traffic Volumes and Operations

The traffic analysis addressed three major topics: traffic volumes, traffic operations, and traffic safety. The first two topics are covered in this chapter, while traffic safety is presented in the next chapter. The traffic volume work included examining historical and existing (2020) traffic volumes as well as forecasting future traffic to the design year of 2045. The traffic operations analysis included a capacity screening to determine if there are any potential operational issues in 2020 or 2045.

3.1 Existing (2020) Volumes

The existing traffic volume work included developing Average Annual Daily Traffic (AADT) volumes, design hour volumes (DHV), and truck percentages. While the project team selected 2020 as the baseline analysis year, it was agreed that the existing volumes would not be based on the 2020 traffic counts. This decision was made because of the reductions in traffic volumes and changes in travel patterns experienced during the COVID-19 pandemic. Instead, the existing (2020) volumes were developed using the moderate pre-pandemic growth trends and counts taken in 2017 through 2019. Details for the volume forecasting work are presented in the *Cumberland Expressway Traffic Forecast Report* in **Appendix B**.

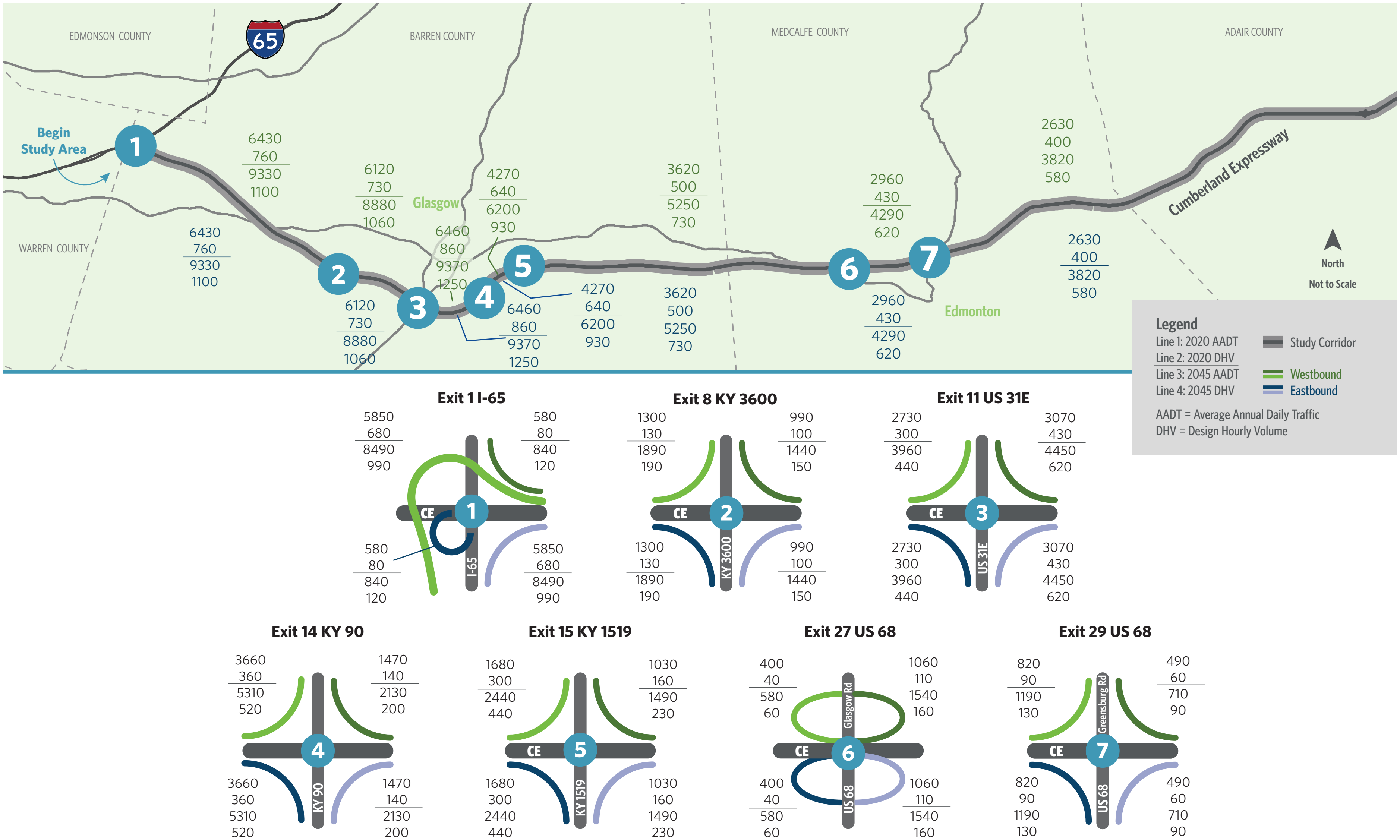
3.1.1 2020 AADT volumes

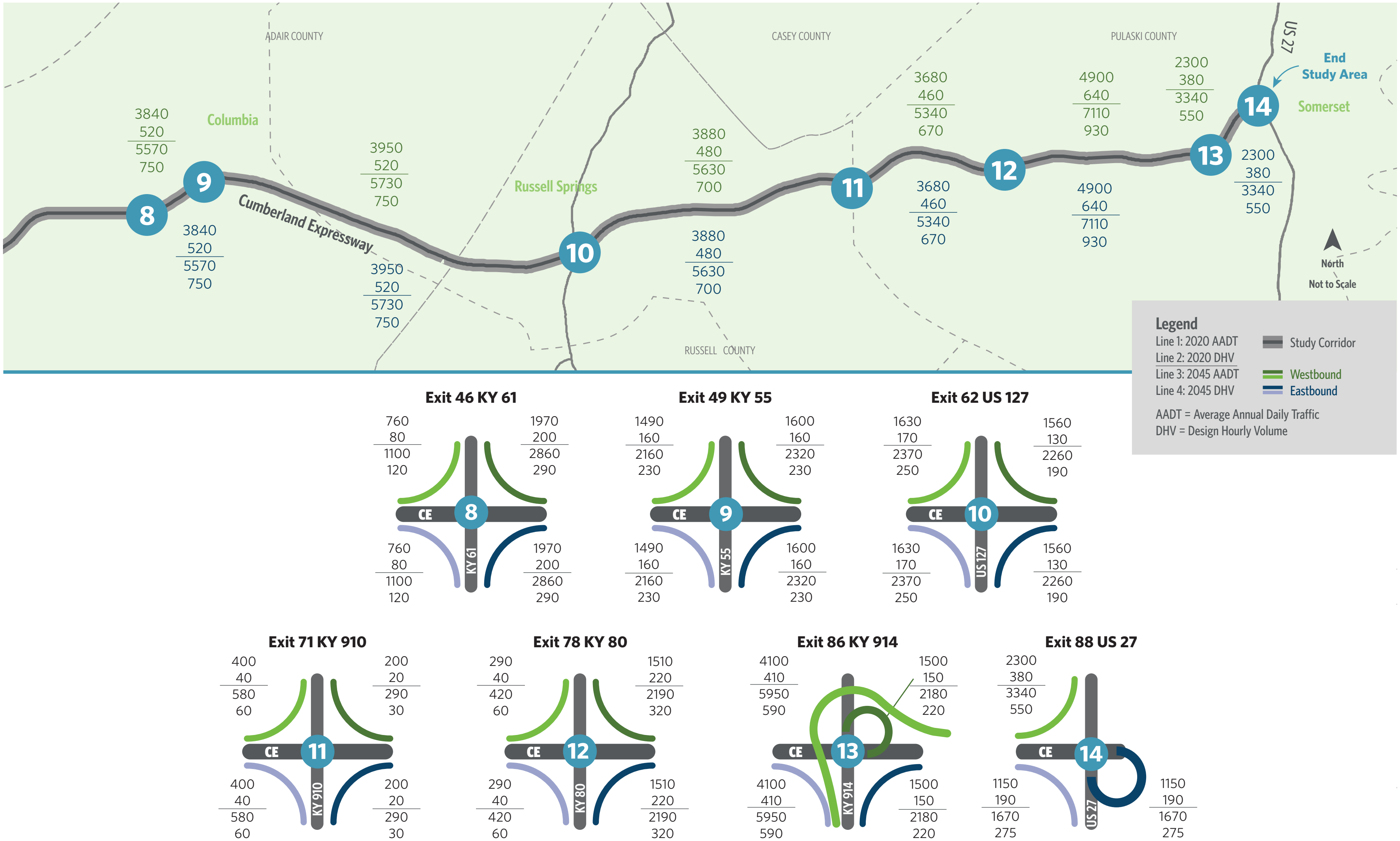
Current and historical average AADT information was obtained from KYTC for all mainline and ramp count stations. The period of 2009 to 2019 was selected to estimate historical growth trends because the data was complete, consistent, and represented the recent travel trends in the study area. The average traffic growth for this time period was 2.0%. This growth rate was applied to the most recent AADT values from before 2020 to generate the initial baseline (2020) AADT volumes. Subsequently, the mainline AADT values were divided in half based on an assumed 50/50 directional split. Finally, the AADT volumes were balanced through the system, with minor adjustments at ramps to generally match observed mainline counts. The resulting 2020 AADT mainline directional volumes (See **Figure 10**) range from a low of 2,300 (4,600 for both directions) in Pulaski County between Exit 86 (KY 914) and Exit 88 (US 27) to a high of 6,460 (12,920 for both directions) in Barren County between Exit 11 (US 31E) and Exit 14 (KY 90).

3.1.2 2020 DHV Volumes

Traffic volumes along much of the Cumberland Expressway tend to be relatively even throughout the day with limited peaking. In the more urban areas, such as near Glasgow, there is some moderate directional peaking. Considering the Cumberland Expressway and taking the limited peaking into account, it was determined that a single DHV for each freeway direction was the best approach for assessing traffic conditions. Therefore, a single directional DHV was calculated for each segment and ramp instead of separate AM and PM peak hour volumes. Hourly factors (K-factors) obtained from KYTC as well as hourly counts were used to generate DHV's for each mainline section and ramp. The volumes were balanced through the system, using minor adjustments at specific ramps to generally match observed counts. The final calculated DHVs for each segment were conservatively high, yet still reasonable, for this planning study. The directional DHVs (See **Figure 10**) ranged from a low of 380 (760 for both directions) in Pulaski County between Exit 86 (KY 914) and Exit 88 (US 27) to a high of 860 (1,720 for both directions) in Barren County between Exit 11 (US 31E) and Exit 14 (KY 90).

Figure 10: *2020 and 2045 AADT and DHV*





Cumberland Expressway | 2020 and 2045 AADT and DHV

Sheet 2 of 2

3.1.3 Truck Volumes

Truck data was obtained from KYTC to estimate Average Annual Daily Truck Traffic (AADTT) and truck DHVs for each segment of the Cumberland Expressway. The final balanced directional AADTTs ranged from a low of 310 (620 in both directions) at the far east end of the Cumberland Expressway to a high of 1,450 (2,900 in both directions) near Glasgow. The final directional truck DHVs ranged from a low of 40 (80 in both directions) at the far east end of the Cumberland Expressway to a high of 150 (300 in both directions) near Glasgow (**Figure 11**). Mainline truck percentages on the Cumberland Expressway range from 17% to 27% for daily volumes and from 13% to 21% for DHVs.

3.2 Future (2045) Volumes

Traffic volumes were projected to the 2045 design year to be consistent with AASHTO policy which calls for forecasts to be at least 20 years beyond the year in which the project plans, specifications, and estimates for construction are approved. The forecast includes projections for AADT, DHV, and truck volumes. Details for the volume forecasting work are presented in the *Cumberland Expressway Traffic Forecast Report* in **Appendix B**.

3.2.1 Traffic Growth Rate

The traffic growth rate was based on three factors: historical traffic growth, Kentucky Statewide Traffic Model (5971_KYSTMv19) forecasts, and projected population growth. The historical traffic growth on the Cumberland Expressway averaged 2.0% per year from 2009 to 2019. The Kentucky Statewide Traffic Model (5971_KYSTMv19) projected a much more modest 0.4% per year over the next 25 years. The projected population growth in the counties in the study area was also modest at approximately 0.4% annual population growth. Given the high historical growth and the more modest traffic and population projections, a 1.5% annual growth rate was selected for the study. This 1.5% growth was also applied to truck traffic in the study area to determine future truck volumes. This growth rate is high enough to test traffic operational performance in the study area over the next 25 years.

3.2.2 2045 Volumes

The projected 2045 AADT, DHVs, and truck volumes are presented in **Figure 10** and **Figure 11**. The highest volumes are again in the Glasgow area with a directional peak AADT and DHV of 9,370 and 1,250 respectively (18,740 and 2,500 in both directions). The AADTT and truck DHVs also peaked near Glasgow at 2,110 and 220 respectively (4,220 and 440 in both directions).

Figure 11: Truck AADT and DHV

3.3 Traffic Operational Analysis

The traffic operational analysis was conducted using the capacity screening methodology from the *Planning and Preliminary Engineering Applications Guide to the Highway Capacity Manual*[5] (NCHRP Report 825, 2016) to evaluate the potential for operational issues. Given that the volumes on the Cumberland Expressway appeared to be well below the capacity of the facility even in the highest volume areas, this screening approach was determined to be the most appropriate method for quickly and effectively determining if a detailed traffic operational analysis was needed for the study.

3.3.1 Capacity Screening

NCHRP Report 825 presents a service volume approach to examining capacity on freeways. The method uses information from the *Highway Capacity Manual 6th Edition (HCM 6)* to develop peak hour directional volume thresholds for Level of Service (LOS) A-C, LOS D, and LOS E. *NCHRP Report 825* provides service volumes thresholds for rural freeways in rolling terrain, but they are based on an estimate of 12% trucks. Therefore, new lower thresholds were derived for the Cumberland Expressway using the maximum segment percent trucks of 21%. The adjusted customized thresholds are presented in **Table 9**.

Table 9: Adjusted Peak Hour Service Volume Thresholds

LOS	Veh/Hr/Ln
A-C	1,140
D	1,400
E	1,590

For this analysis LOS D was selected as the "capacity" threshold to provide a conservative capacity test for further evaluation. The DHVs calculated previously were compared to the LOS D threshold to determine if any segments warranted further analysis. **Table 10** presents the results of the analysis for the eastbound direction and **Figure 12** graphs the demand volume and the LOS D threshold service volume for the eastbound direction. Even using the LOS D threshold, the highest volume to capacity (V/C) ratio is 0.45 and all portions of the freeway are expected to operate at LOS C or better in 2045. The westbound direction showed the same results with a maximum v/c ratio of 0.45. The analysis methodology and results for both directions are provided in **Appendix C**. In addition to the mainline analysis, a check was made for all ramp facilities in both directions comparing the ramp volumes to the capacity of a single lane ramp (approximately 2,000 vehicles per hour per the *HCM* 6). No issues were identified, with the highest ramp volume reaching 990 vehicles per hour in 2045. Based on the mainline and ramp screening analysis it was determined that a more detailed highway capacity analysis was not necessary.

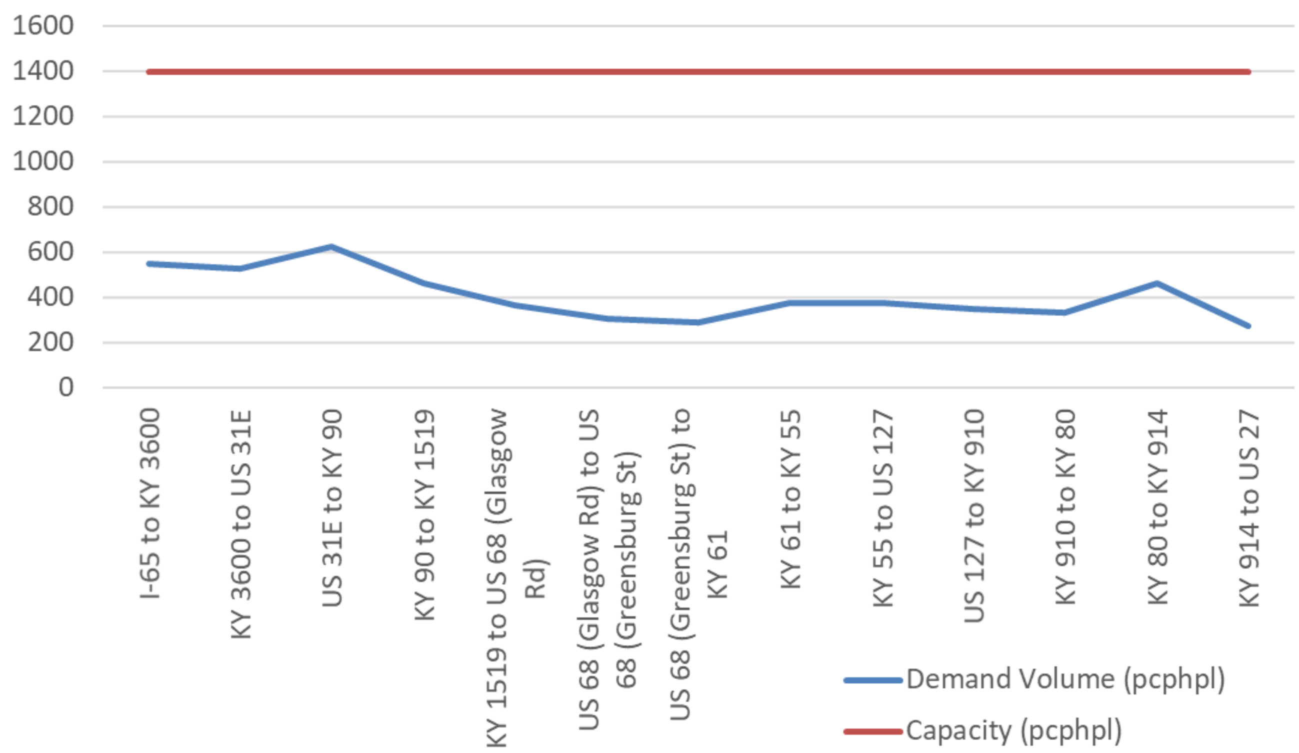
5 http://www.trb.org/NCHRP/Blurbs/174958.aspx

Table 10: Cumberland Expressway Eastbound Capacity Screening Analysis (2045 Volumes)

Segment Start	Segment End	Lanes	Speed Limit (mph)	2045 DHV (veh/hr, all lanes)	2045 DHV (pcphpl)	Max Capacity for LOS D (pcphpl)	V/C Ratio	LOS Estimate
I-65	KY 3600	2	70	1100	550	1400	0.39	LOS A-C
KY 3600	US 31E	2	70	1060	530	1400	0.38	LOS A-C
US 31E	KY 90	2	70	1250	625	1400	0.45	LOS A-C
KY 90	KY 1519	2	70	930	465	1400	0.33	LOS A-C
KY 1519	US 68 (Glasgow Road)	2	70	730	365	1400	0.26	LOS A-C
US 68 (Glasgow Road)	US 68 (Greensburg Street)	2	70	620	310	1400	0.22	LOS A-C
US 68 (Greensburg Street)	KY 61	2	70	580	290	1400	0.21	LOS A-C
KY 61	KY 55	2	70	750	375	1400	0.27	LOS A-C
KY 55	US 127	2	70	750	375	1400	0.27	LOS A-C
US 127	KY 910	2	70	700	350	1400	0.25	LOS A-C
KY 910	KY 80	2	70	670	335	1400	0.24	LOS A-C
KY 80	KY 914	2	70	930	465	1400	0.33	LOS A-C
KY 914	US 27	2	70	550	275	1400	0.20	LOS A-C

Note: veh/hr = vehicles per hour; pcphpl = passenger cars per hour per lane; LOS = Level of Service; V/C = volume to capacity

Figure 12: Eastbound 2045 Per Lane DHVs Compared to LOS D Service Volume Threshold



4 Safety

4.1 Historic Crash Analysis

A historical crash analysis was performed to examine traffic safety trends and to identify potential safety issues on the Cumberland Expressway. The crash data was derived using data from the Kentucky Transportation Center (KTC) Crash Data Analysis Tool (CDAT) database. Five years of data (2015 to 2019) was used in the analysis. 2020 crash data was not used due to changes in driver behavior and traffic volumes during the COVID-19 pandemic.

Within the five-year analysis period, 835 crashes were reported in the study area. Of the total crashes, 758 (91%) occurred on the mainline and 77 (9%) occurred on interchange ramps. A breakdown of the crashes by severity is presented in **Table 11**. As shown, there were 12 fatal crashes and 19 serious injury crashes (3.7% combined) over the five years. Most crashes (692, 82.9%) were property damage only crashes.

Table 11: Cumberland Expressway Crash Severity (2015-2019)

Severity of Crash	Mainline	Ramps	Total	Percent
Fatal Injury (K)	12	0	12	1.4%
Serious Injury (A)	16	3	19	2.3%
Minor Injury (B)	44	2	46	5.5%
Possible Injury (C)	59	7	66	7.9%
Property Damage Only (O)	627	65	692	82.9%
Total	758	77	835	100.0%

An examination of the crashes by manner of collision is presented in **Table 12**. Most crashes in the study area (621, 74.4%) were single-vehicle crashes. This is consistent with the low volume rural nature of the roadway. Rear-end crashes and sideswipe crashes were the other two major crash categories. The head-on crashes had the highest average severity of all the categories with four of the eight involving a fatality or injury (1 fatal, 2 severe injury, and one minor injury). It was also noted that commercial vehicles were involved in 8% of all reported crashes, which is a lower percent than their proportion of traffic volume on the Cumberland Expressway.

Table 12: Cumberland Expressway Crashes by Manner of Collision (2015-2019)

Manner of Collison	Mainline	Ramps	Total	Percent
Single Vehicle	598	23	621	74.4%
Rear End	66	43	109	13.1%
Sideswipe, Same Direction	59	4	63	7.5%
Backing	1	2	3	0.4%
Angle	22	2	24	2.9%
Sideswipe, Opposite Direction	6	0	6	0.7%
Head On	5	3	8	1.0%
Rear-to-Rear	1	0	1	0.1%
Total	758	77	835	100.0%

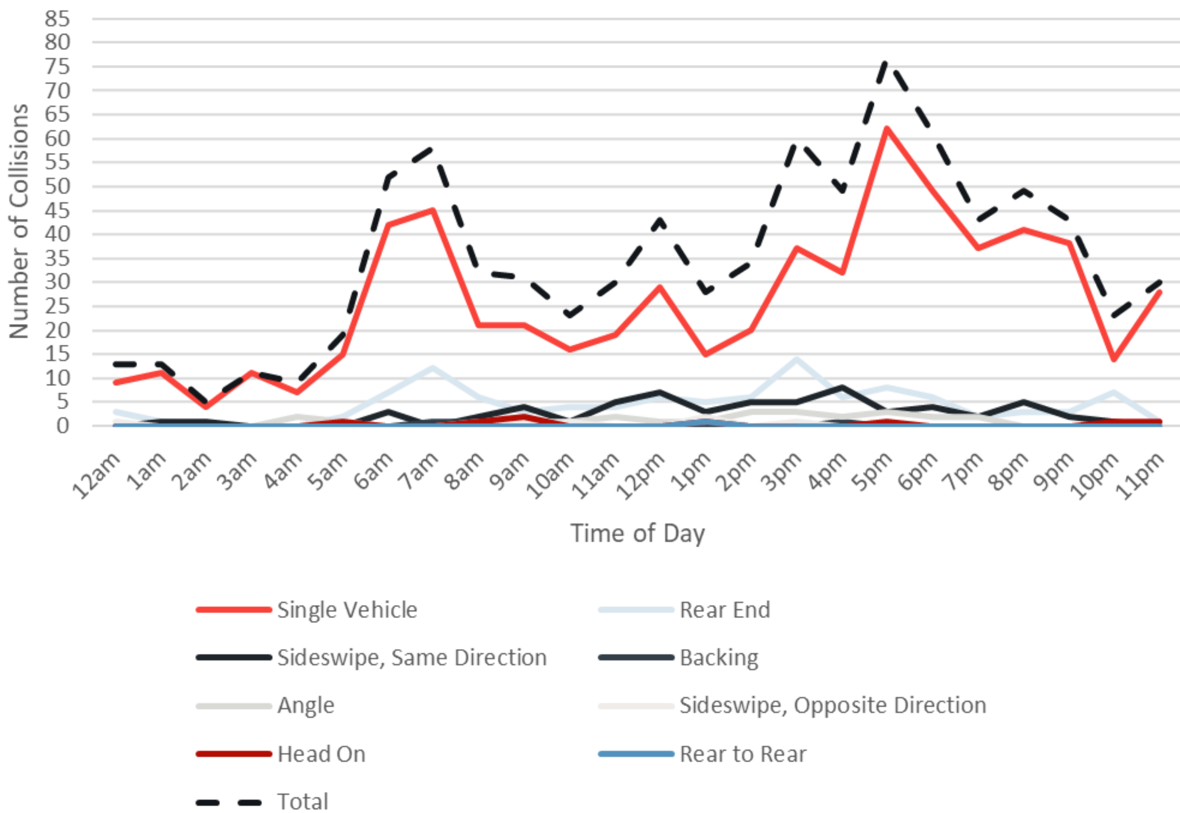
A further investigation of the single-vehicle crashes, **Table 13**, showed that the majority of the single-vehicle crashes involved either an animal (43%), guardrail/barrier (18%), or an embankment, rock cut, or ditch (17%). Of the single vehicle crashes the type that had the highest severity was the overturned category. Four of the overturned category crashes were fatal and four were serious injury.

Table 13: Single Vehicle Crashes by Type (2015-2019)

Category	Crashes	Percent
Animal, Deer	269	43.3%
Guardrail, Barrier, Rail	113	18.2%
Embankment, Rock Cut, Ditch	108	17.4%
Overturned	23	3.7%
Other Moveable Object	13	2.1%
Tree	10	1.6%
Other Object Not Fixed	9	1.4%
Unknown (Code Issue)	43	6.9%
Other	33	5.3%
Total	621	100.0%

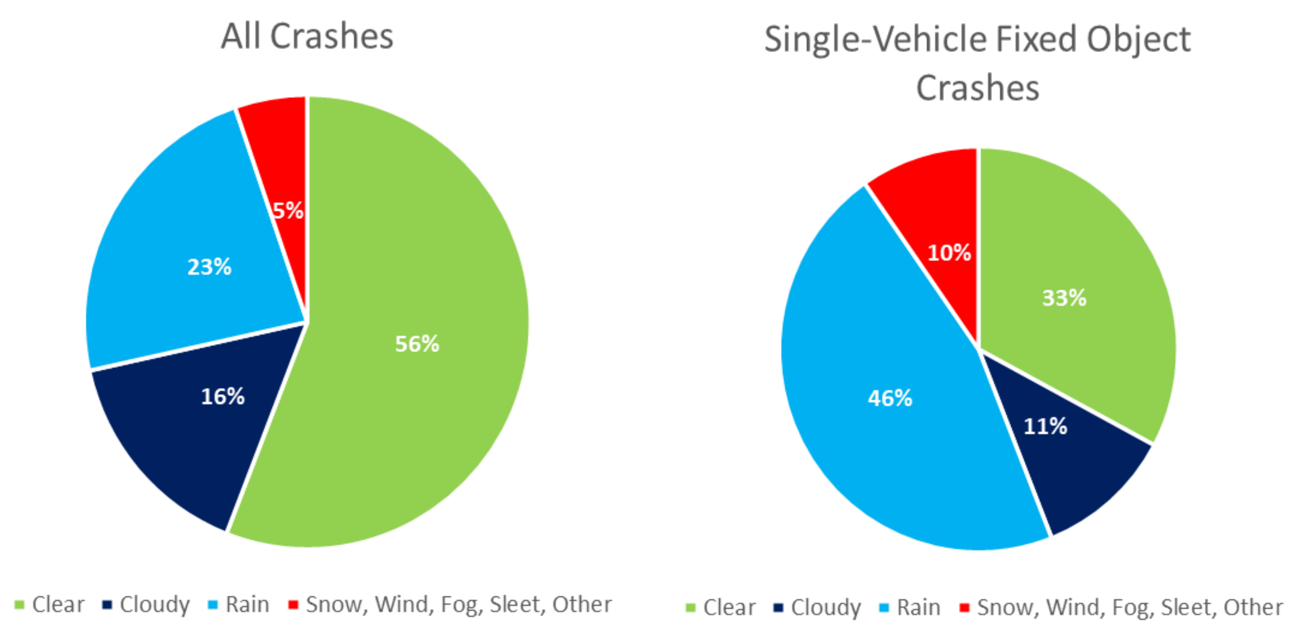
A review of crashes by time of day, **Figure 13**, shows that crashes tend to peak in the morning and afternoon, with the largest number of crashes occurring in the 5:00 to 6:00 pm period. This peaking pattern could be related in part to traffic volume patterns; though it is also likely related to environmental factors such as lighting, the presence of deer, and weather. For example, most animal crashes occur between 6:00 and 8:00 am and 5:00 and 10:00 pm.

Figure 13: *Manner of Collision by Time of Day (2015-2019)*



For single vehicle crashes that involved the driver striking a fixed object, weather played an important role. **Figure 14** provides crashes by weather conditions for all crashes and for single vehicle fixed-object crashes only. The percent of these crashes occurring during inclement weather (rain, snow, sleet, fog, etc.) is 56% compared with 28% for all crashes.

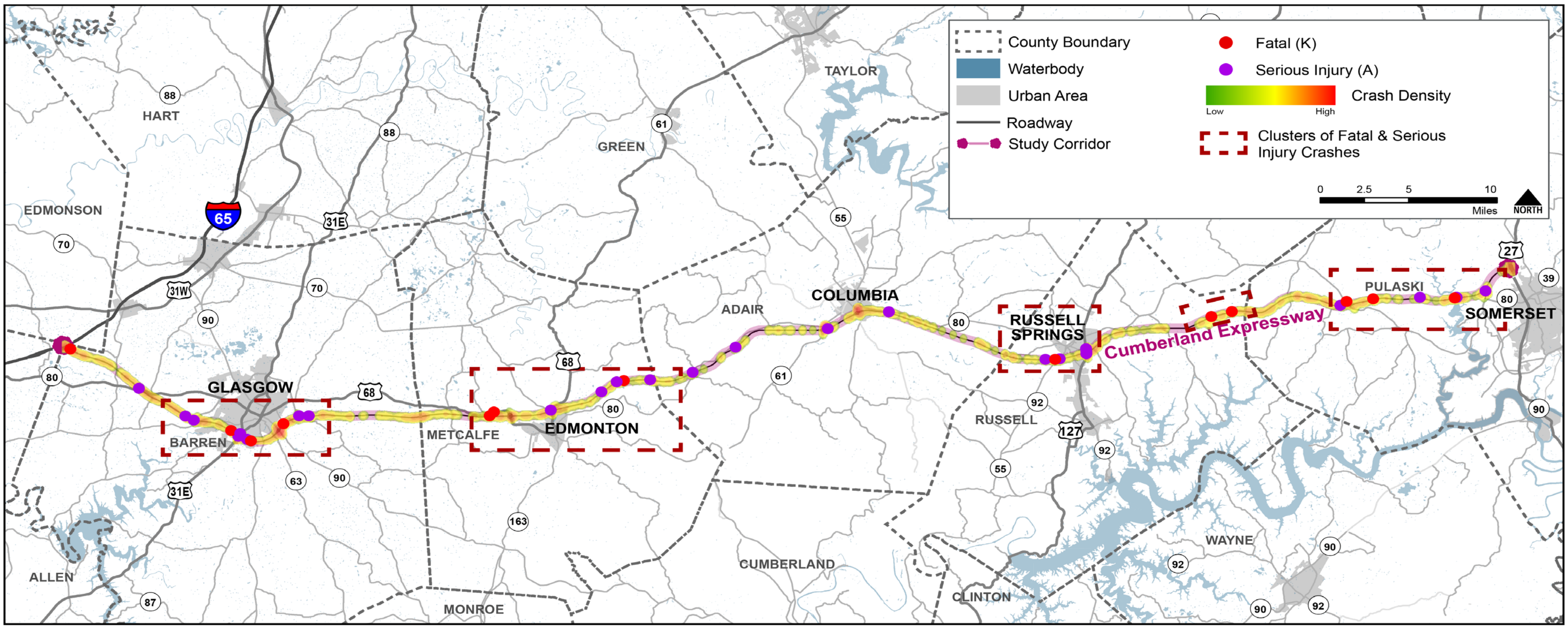
Figure 14: All Crashes and Single-Vehicle Fixed Object Crashes by Weather (2015-2019)



The location of crashes on the Cumberland Expressway was also examined as illustrated in **Figure 15**. Crashes were generally distributed throughout the study area, with higher numbers of crashes in the areas with the higher traffic volumes. The highest severity crashes (fatal and serious injury) were also present throughout the Cumberland Expressway, but there were clusters of these crashes near Glasgow in Barren County, in Metcalfe County from west of Edmonton to the Adair County line, near Russell Springs and in far western Russell County, and in central Pulaski County.

During the investigation of specific design issues, the detailed crash data was used in several ways to identify potential safety related issues. First, the crash data and volume data were used to calculate crash rates for specific segments or locations such as a curve or bridge location. Second, the detailed environmental and human factors data for crashes in an area were examined to determine possible causation. For example, if crashes were related to wet weather or standing water these items were noted. Finally, the crash type, severity and other factors were considered. For example, animal crashes were noted to make sure they did not impact unrelated design considerations.

Figure 15: Cumberland Expressway Crash Density Map (2015-2019)

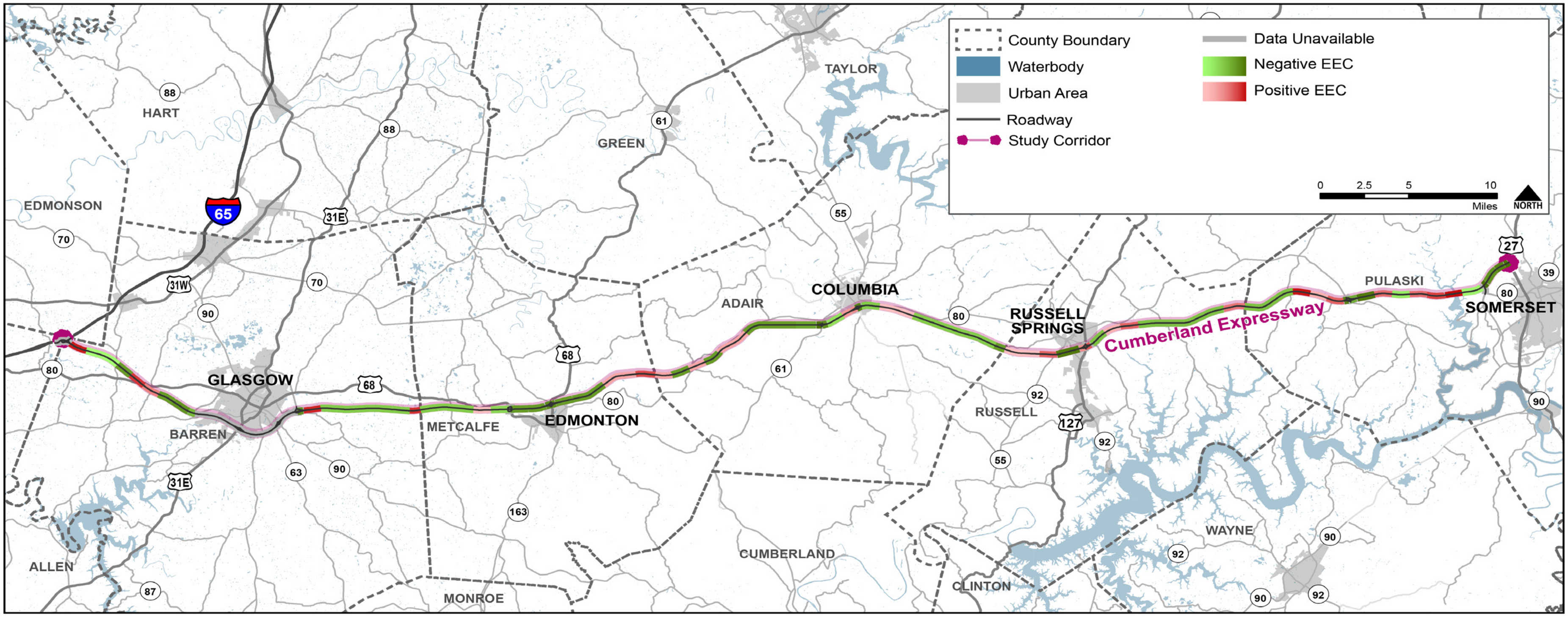


4.2 Excess Expected Crashes

KYTC and KTC have developed a more refined statistical methodology based on the *Highway Safety Manual (HSM)* to rank the safety needs of projects. Excess Expected Crashes (EEC) is based on a crash prediction model estimating the number of crashes expected on an average roadway segment of a given type and length. It represents the number of excess crashes a segment is experiencing compared to other roadways of its type, adjusting for traffic volumes and a statistical correction. EEC is positive when more crashes are occurring than expected and negative when fewer crashes are occurring than expected.

The EEC values for the Cumberland Expressway were obtained from KYTC and are color coded on **Figure 16**. As shown, much of the Cumberland Expressway is green indicating a negative EEC. The overall EEC for the study area was a negative value of -37.9 crashes per year, with the EEC for KAB (fatal, serious injury, minor injury) crashes summing to -0.66 crashes per year and the EEC for CO (possible injury, property damage only) crashes summing to -37.24 crashes per year. These results indicate that the Cumberland Expressway is operating better than would be predicted for a rural freeway/parkway with similar traffic volumes. One caveat to the EEC data is that there are some segments south of Glasgow that do not have calculated EEC values.

Figure 16: Areas with Positive (Poor) and Negative (Good) Excess Expected Crashes (EEC)



4.3 Summary of Safety Issues & Use of Safety Data

Overall, the Cumberland Expressway appears to be operating acceptably with regards to safety. This is most clearly demonstrated by the negative EEC using the rural freeway and parkway prediction equation. The current safety performance is in line with expectations for a rural interstate in Kentucky. One of the major safety issues flagged in the course of the review was the relationship between wet weather crashes and single-vehicle run-off-road crashes. In addition, there were several locations in the Cumberland Expressway that were identified as having clusters of severe (Fatal (K) or Serious Injury (A)) crashes.

The crash data, EEC information, and crash rates (calculated using the crash and volume data) were all used to evaluate the deficient locations and the possible improvements to address them. A safety scoring system was developed to help clarify which locations seemed to have the more substantial issues. Detailed investigation was also used to determine when there was or was not a relationship between a design issue and safety.

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5 Environmental Overview

Data was collected for an Environmental Overview (EO) based on a review of existing geographic information system (GIS) datasets, state and federal agency databases, literature research, and archival data. Desktop research was performed to identify and locate areas of importance or concern that lie within 250 feet of either side of the Cumberland Expressway. Once resources were identified, those resources were considered within the context of improvement concepts and the potential for those concepts to impact the identified resources. The detailed EO is attached as **Appendix D**.

The EO considered resources in the following categories: ecological resources; threatened and endangered species and important habitats; air quality and noise issues; Environmental Justice socioeconomic data; land use/farmland; hazardous materials; and historic and archaeological resources.

A key consideration for all improvement strategies identified in the study was whether they occur outside of existing right-of-way. Those occurring outside of existing right-of-way or creating ground disturbance have greater potential to impact natural and socioeconomic resources.

5.1 Natural Environment

The natural environment reviewed for the EO included threatened and endangered species and habitats, streams, wetlands, and floodplains. As anticipated for a corridor in excess of 88 miles, the potential to encounter natural environment resources are numerous. For example, the desktop review identified that threatened and endangered species habitats are found throughout the study area; similarly, over 125 stream crossings were readily identifiable within GIS datasets. Correspondingly, 27 floodplain crossings were also identified. Wetland areas were much less prevalent, with only four wetland areas being identified on National Wetland Inventory (NWI) mapping, although NWI mapping should be considered limited in its coverage.

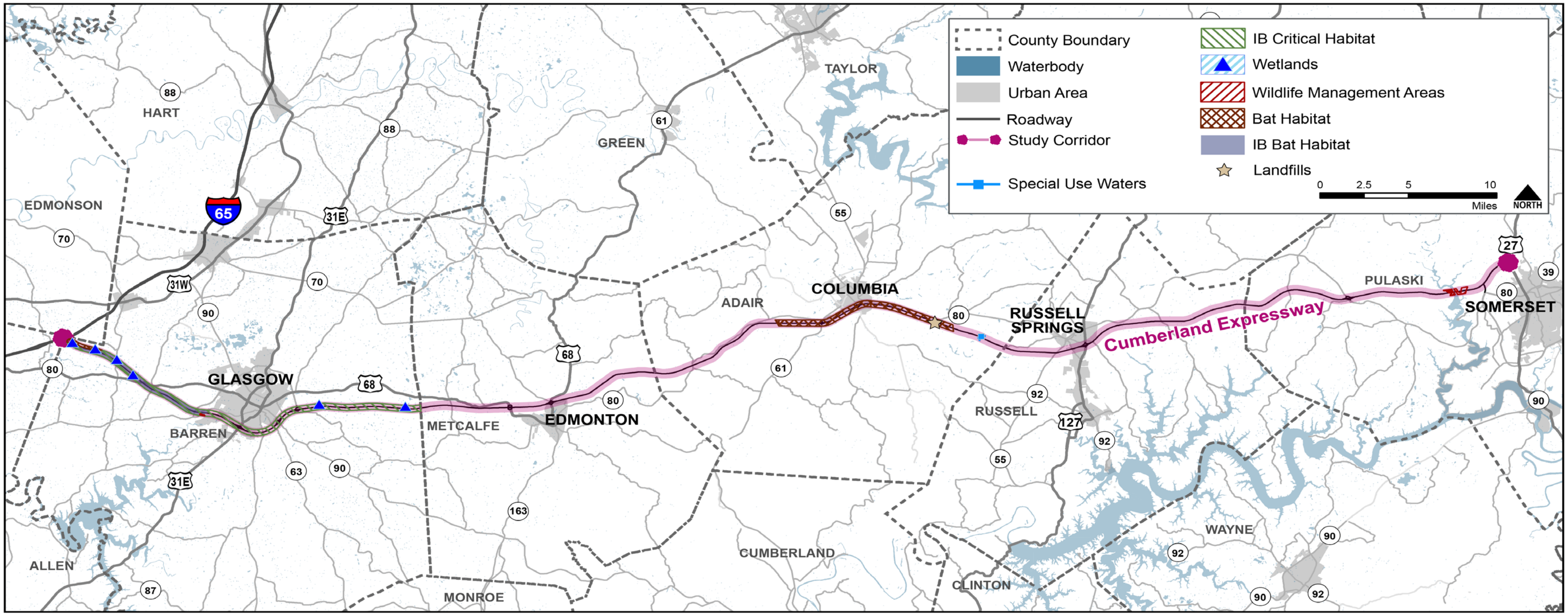
The nature of improvement concepts considered as a result of this study significantly limit the potential impacts to these resources, as most will occur within existing right-of-way and within previously disturbed areas. **Figure 17** and the bulleted items below provide a summary of the potential natural environment impacts to consider as a result of the conceptual improvements.

- **Mainline** – Potential mainline improvements may include improvements such as shoulder widening, superelevation adjustments, vertical grade decreases, headlight sight distance increases, and guardrail raising or replacement. These mainline improvements would not be anticipated to create impacts to the identified natural environment resources. These types of improvements occur within existing right-of-way and previously disturbed areas.
- **Interchanges** – Interchange improvements include increasing acceleration and deceleration lengths (Exit 14, KY 90 and Exit 78, KY 80), increasing lane widths, and rebuilding an interchange. Exit 27 (US 68, Glasgow Road) in particular does not meet current design standards and may require rebuilding to a standard diamond configuration. Such interchange improvements may occur outside of existing right-of-way and have the potential to create impacts to the natural environment. Impacts may include tree removal (potential bat habitat) and stream impacts.
- **Structures** – Bridge improvements may include replacement of bridge railing at locations throughout the study area and potential widening of the bridges over South Fork Beaver Creek. Natural environment impacts resulting from bridge railing replacement may include impacts to bat use of bridges. Bridge widening may include impacts to both bat use of the bridges and floodplain impacts. In addition,

bridges over Pettys Fork and Russell Creek are known northern long-eared bat summer 1 and/or swarming habitats. Russel Creek is an outstanding state resource water (OSRW), and the Fishing Creek Bridge is located in the Lake Cumberland Wildlife Management Area. Impacts to Both Russell Creek and Fishing Creek areas would require special consideration.

- **Additional Safety and Operational Improvements** – These improvements include removal of median turnarounds and the possible addition of traffic signals at Exit 11 (US 31E). Due to the nature of these improvements, i.e., within existing right-of-way or previously disturbed areas, no natural environment impacts would be anticipated.

Figure 17: *Study Area Existing Environmental Conditions*



5.2 Human Environment

The human environment reviewed for the EO included air quality and noise issues; Environmental Justice/socioeconomic data; land use/farmland; hazardous materials; and historic and archaeological resources. As with the natural environment, the potential for the improvement concepts to impact human made considerations is limited by the fact that most improvements are proposed to occur within existing right-of-way or within previously disturbed areas. However, for archaeological resources, impacts within existing right-of-way or other ground disturbance may be an environmental constraint; any future design will need to consider archaeological resources where ground disturbance occurs.

The bulleted items below provide a summary of the potential human impacts to consider relative to the conceptual improvements:

- **Mainline Improvements** – Mainline improvements occur within existing right-of-way and previously disturbed areas and would not be anticipated to create impacts to socioeconomic areas of consideration.
- **Interchanges** – Interchange improvements may occur outside of existing right-of-way and have the potential to create impacts to the human environment. Impacts may include changes in land use for the acquisition of right-of-way and impacts to archaeological resources would also be a consideration for interchange improvements, either as a result of right-of-way acquisition or other ground disturbance. The potential for impact is greatest for the conceptual improvement to rebuild Exit 27 (US 68, Glasgow Road) as a standard diamond interchange.
- **Bridges** – Bridge improvements including railing replacement at locations throughout the study area and potential bridge widening of the bridges over South Fork Beaver Creek create potential hazardous materials concerns. Bridge railings can contain asbestos which if removed require appropriate handling and disposal if above certain levels of asbestos.
- **Additional Safety and Operational Improvements** – These improvements (removal of median turnarounds, upgrading of ramp terminal design at Exit 14 (KY 90), and the possible addition of traffic signals at Exit 11 (US 31E)) would not be anticipated to create socioeconomic concerns as they would occur within existing right-of-way or previously disturbed areas.

The Lake Cumberland Area Development District (LCADD) completed a socioeconomic study of the area with an emphasis on Environmental Justice considerations. The Cumberland Expressway Interstate Upgrade Socioeconomic Study assessed the potential to encounter EJ populations within the study area. The report used 2019 U.S. Census Bureau American Community Survey (ACS) data, and numbers for Kentucky were used as the reference thresholds in determining EJ populations. As a result of the analysis, the report identified seven block groups with minority status and 27 block groups with poverty status. Minority populations were found primarily in areas closest to the more urbanized areas around Glasgow in Barren County, Columbia in Adair County, Russell Springs in Russell County, and Somerset in Pulaski County. Block groups with low-income populations were found throughout the study area. Any future design projects will need to consider the potential to disproportionately impact minority or low-income populations. The full Socioeconomic Study is included in **Appendix E**.

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6 Development of Potential Improvement Concepts

Based on the results of the existing conditions, traffic, and safety analysis, along with input from the project team, a list of potential improvement concepts was developed for mainline, interchanges and ramps, and bridge locations that do not meet current Interstate standards. An iterative process was used, in which the initial list of potential improvement concepts was shared with the project team to obtain feedback. Based on that feedback, the consultant team investigated certain locations further with respect to crashes, record plans, or other available data to determine which improvement concepts would need to be constructed before Interstate conversion (initial conversion), and which could possibly be granted a DE or DV but would be necessary for full compliance. Planning level construction cost estimates were developed for the refined list of potential improvement concepts, which was presented and discussed in the final project team Meeting. Based on feedback, a finalized list of recommendations was developed which is presented below. A list of additional safety and operational improvements was developed to recommend improvements for locations that meet the design criteria but have a noted safety or operational deficiency that could be addressed.

6.1 Mainline

6.1.1 Shoulder Width

There are two locations with inside shoulders that do not meet the four-foot requirement. The locations are listed in **Table 14** and shown in **Figure 18**.

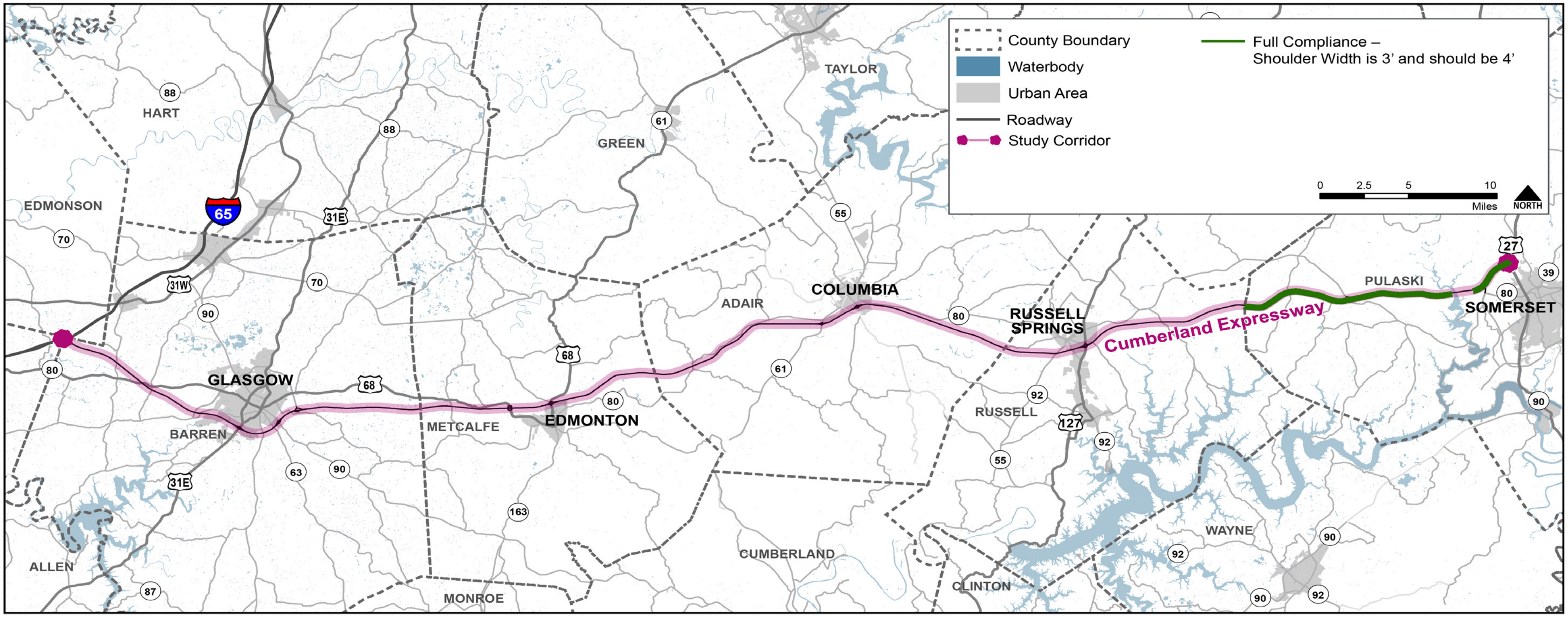
The 12-mile section from MP 72.09 to 84.29 has a crash rate that is approximately equal to the statewide average. According to the *HSM*, the 1-foot shoulder deficiency is predicted to increase crashes in the segment by approximately 2%. Given that this section of roadway has experienced approximately 22 crashes per year, it is expected that the narrow shoulder width could result in nine more crashes over a 20-year period. Using an average crash cost of $155,000/crash this is an undiscounted cost $1.395 million. Because of the minimal effect on crashes, this improvement can possibly be completed as part of future 3R projects, and a DE could be requested for this section. The cost of widening the inside shoulders at this location is approximately $1.811 million.

The three-mile section from MP 85.49 to 88.38 also has a 1-foot inside shoulder deficiency. This section does not have design related safety issues, therefore a DE could be requested and possibly upgraded as part of a future 3R project. During the historical crash period (2015-2019), 2 crashes per year occurred in this section, so a 2% increase in crashes over 20 years would be less than one crash. The cost to widen the inside shoulder along this section is approximately $429,000. All outside shoulders meet the ten-foot width requirement, with the exception of some bridges. Bridge width is discussed in Section 6.2.

Table 14: Mainline Shoulder Recommendations

Improvement	Direction	Length (mi)	Begin MP	End MP	Cost (2021 $)	Initial Conversion	Full Compliance	Requires Design Exception	Possible Design Related Safety Issue
Widen inside shoulder from 3' to 4'	Both	12.20	72.09	84.29	$1,811,000		✓	✓	Yes – Crash rate is greater than statewide average
Widen inside shoulder from 3' to 4'	Both	2.89	85.49	88.38	$429,000		✓	✓	No

Figure 18: Shoulder Width Improvement Locations



6.1.2 Horizontal curvature

There are five curves along the Cumberland Expressway that do not appear to meet superelevation requirements. Where superelevation requirements are not met, the maximum allowable side friction factor can be calculated, and a DE could be requested if this value is less than the maximum allowable. The side friction factor was calculated using the superelevation from the record plans for the five locations that do not meet interstate standards. All five were found to be less than 0.1 for each location, which meets the acceptable friction factor of a maximum of 0.1. The improvement recommendations for superelevation are listed in **Table 15** and shown in **Figure 19**.

The locations with superelevation that does not meet the 70 mph design speed were investigated to determine whether there are possible design related safety issues. Five of the locations do have possible design related safety issues. A higher density of wet or icy roadway condition crashes were observed at these locations. The locations that should be investigated further are included in the cost for improvements to be made prior to Interstate conversion. A DE could be requested for the remaining spots and they could possibly be upgraded as part of future 3R projects.

Planning level cost estimates were developed for each location where the superelevation does not meet the 70 mph design standard. The costs are based on the assumption that pavement wedging would be used to bring the superelevation up to standards, with locations that vary from the standard by more than 2.0% requiring earth work as well. The estimated cost to improve locations with possible design related safety issues is $623,000. The cost to bring superelevation to full compliance is $678,000, which includes the initial conversion locations. A detailed survey of the Cumberland Expressway is recommended to determine which locations do not currently meet the design standard before making any improvements.

6.1.3 Vertical Curves

There is one sag curve that does not meet the headlight sight distance (HLSD) requirement by 51 feet. This location is listed in **Table 16** and shown in **Figure 19**. The crash history does not indicate a possible design related safety issue, no crashes were observed in this area, therefore a DV for this location could be requested. The cost to improve the HLSD with pavement wedging and overlay is approximately $459,000.

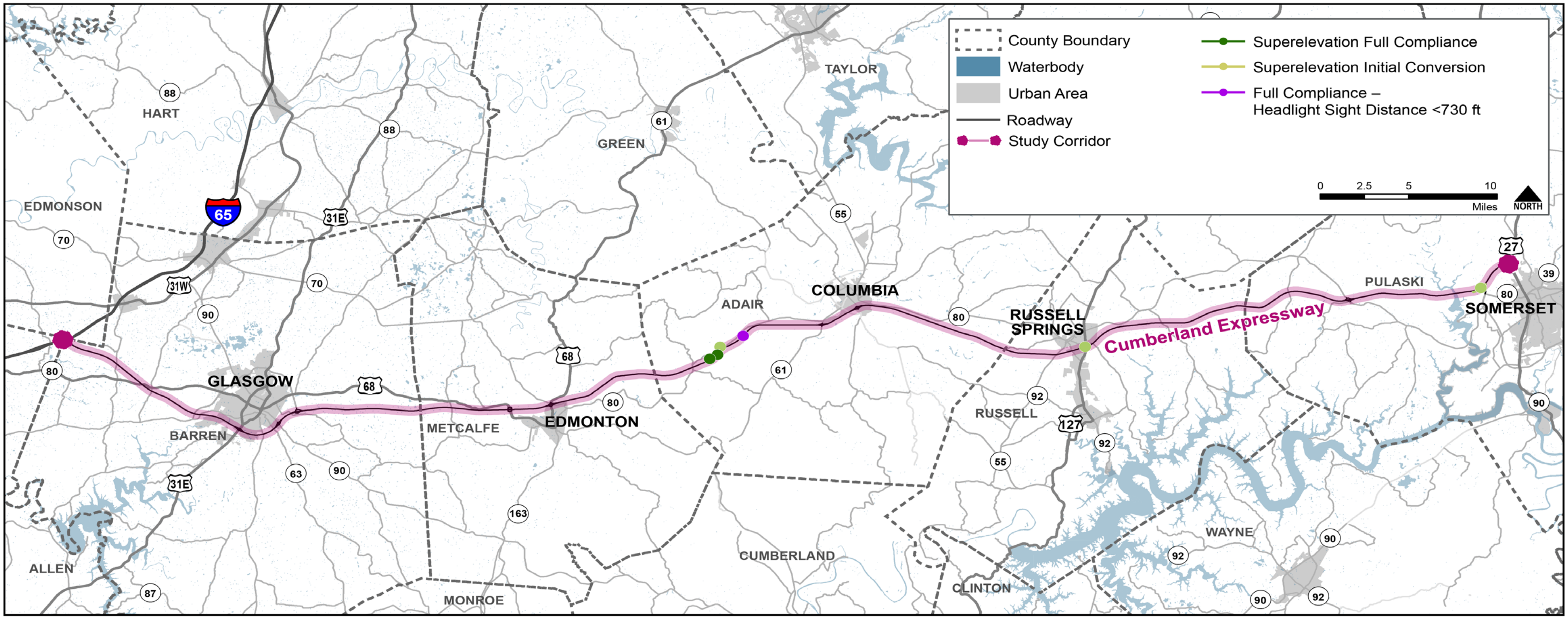
Table 15: Superelevation Improvements

Improvements	Measured Value (Record Plans)	Design Standard (%)	Deficiency (%)	Direction	Length (mi)	Begin MP	End MP	Cost (2021 $)	Initial Conversion	Full Compliance	Requires Design Exception	Possible Design Related Safety Issue
Adjust superelevation	3.9	4.2	0.6	Both	0.043	39.541	39.584	$23,000		✓	✓	No
Adjust superelevation	3.9	4.4	0.8	Both	0.061	39.913	39.974	$32,000		✓	✓	No
Adjust superelevation	3.9	4.2	0.6	Both	0.029	40.301	40.330	$15,000	✓			Yes – Wet road crashes
Adjust Superelevation	2.9	3.6	0.8	Both	0.210	62.332	62.542	$108,000	✓			Yes – Wet road crashes
Adjust Superelevation	3.4	3.6	0.2	Both	0.976	85.426	86.402	$500,000	✓			Yes – Wet road crashes

Table 16: Vertical Curve Improvements

Improvements	Measured Value (Record Plans)	Design Standard (ft)	Deficiency (ft)	Direction	Length (mi)	Begin MP	End MP	Cost (2021 $)	Initial Conversion	Full Compliance	Requires Design Variance	Possible Design Related Safety Issue
Increase HLSD of the curve by 51 feet	679	730	51	EB	0.112	41.929	42.041	$459,000		✓	✓	No

Figure 19: Horizontal and Vertical Curve Improvement Locations



6.1.4 Clear Zone

There are 85 locations along the Cumberland Expressway where the desired clear zone for an interstate is not met, caused mostly by rock cuts and steep slopes. It is not desirable to have guardrail in front of rock cuts, therefore adding new guardrail is only recommended for locations where steep slopes are within the clear zone. A DV will be required at locations where rock cuts are within the clear zone. Headwalls within the clear zone also require guardrail or replacement which is preferable to guardrail. It is difficult to identify headwall locations via Google Earth and field review, therefore an additional 2,000 feet of guardrail was added to the estimate to account for headwalls. A detailed survey should be completed to determine the exact amount and location of new guardrail to address clear zone requirements. Based on review in Google Earth, approximate 2.5 miles of new guardrail is needed to address clear zone issues in the study area. The estimated cost for this is $662,000, and it is recommended that this improvement be completed prior to initial conversion.

6.1.5 Guardrail

Guardrail that is damaged, is recommended to be replaced prior to initial conversion. Additionally, guardrail that is less than 31 inches in height, and is located in a high crash rate area, should also be replaced with guardrail that meets the standard prior to initial conversion. Based on field review and review of crash data, 7.4 miles of the Cumberland Expressway has a crash rate higher than the statewide average for similar roads. Within these 7.4 miles there are 2.433 miles of guardrail. The estimated cost of replacing this guardrail is approximately $505,387. All remaining guardrail that is less than 31 inches can possibly be replaced as part of future 3R projects. This is estimated to be 29.2 miles and cost $4,640,280. These locations will require a DV as part of the initial conversion. It was assumed that guardrail in locations with current pavement rehab projects would be replaced, and those locations were not included in the estimates. A detailed inventory of guardrail should be completed prior to replacement. Guardrail improvement locations and cost estimates are listed in **Table 17**.

Table 17: Guardrail Improvement Recommendations

Improvement	Direction	Length (mi)	Begin MP	End MP	Cost (2021 $)	Initial Conversion	Full Compliance	Requires Design Variance	Possible Design Related Safety Issue
Replace damaged guardrail	Both	5			$807,000	✓			N/A
Add new guardrail to address safety issues	EB	0.052	72.107	72.159	$23,237	✓			Yes – High crash rate segment
	EB	0.395	73.01	73.405	$77,568	✓			Yes – High crash rate segment
	EB	0.515	83.851	84.366	$96,576	✓			Yes – High crash rate segment
	WB	0.126	56.096	56.222	$34,958	✓			Yes – High crash rate segment
	WB	0.169	56.271	56.44	$41,770	✓			Yes – High crash rate segment
	WB	0.235	60.274	60.509	$52,224	✓			Yes – High crash rate segment
	WB	0.396	76.787	77.183	$77,726	✓			Yes – High crash rate segment
	WB	0.545	83.821	84.366	$101,328	✓			Yes – High crash rate segment
Add new guardrail to address clear zone issues	Both	2.5			$662,000	✓			Yes – Objects in clear zone
Replace all guardrail less than 31”	Both	29.2			$4,640,280		✓	✓	

6.2 Bridges/Culverts

Bridge improvements consist of upgrading railing to current crashworthy standards and widening to meet minimum clear width requirements. Several structures require both replacing railing and widening to meet clear width standards.

6.2.1 Bridge Railing

Twenty bridges on the mainline Cumberland Expressway were identified as needing the bridge railing upgraded to meet current crash standards. Cost estimates were developed to remove the existing metal railing and to replace it with a crash compliant bridge railing from the KYTC Standard Drawings list. The total cost to replace the railing for all of these bridges is estimated to be $2,349,800. These locations are listed in **Table 18** and shown in **Figure 20**.

A review of crash data at these bridges indicate that a possible design related safety issue could exist at nine locations. Replacing the bridge railing at these nine locations is recommended as part of an initial conversion with the other locations possibly being addressed with future 3R projects. See **Appendix F** for the locations of these bridges.

The twin bridge structure over Fishing Creek in Pulaski county does not meet current bridge railing standards and is discussed in more detail later in this section.

6.2.2 Bridge Width

Twenty-one bridges on the mainline Cumberland Expressway were identified as needing widened to meet the standard minimum clear width of 37.5 feet for structures less than or equal to 200 feet in length and 31.0 feet for structures longer than 200 feet in length. These locations are listed in **Table 19** and shown in **Figure 20**.

The existing clear width for bridges longer than 200 feet in length on the Cumberland Expressway was 30 feet. These same bridges also had deficient bridge railing that needed to be brought up to current standard. Replacing the metal railing with a concrete railing from the KYTC Standard Drawings list reduced the thickness of the barrier by approximately 6 inches per side, thus resulting in not only upgrading the railing to current standard, but also widening the bridge by 1-foot to meet the clear width standard. The cost of replacing this railing is shown in the above Bridge Railing section.

Two bridges in Barren County at milepoints 11.541 and 11.576 (005B00072L/005B00072R) that are less than 200 feet in length will need to be widened by 7.5 feet to meet the minimum clear width standard. The cost for widening these two structures to meet the minimum clear width, including additional beams, pier and abutment extension, and railing replacement, is estimated to be $1,042,800. A review of the crash data at this location did not show any safety concerns, therefore an improvement as part of initial conversion is not recommended.

The twin bridge structure over Fishing Creek in Pulaski county does not meet current bridge clear width standards and is discussed in more detail later in this section.

6.2.3 Vertical Clearance

No vertical clearance deficiencies were observed or measured between the Cumberland Expressway and an overpass structure. Eleven structures did have clearance elevations between 16.0 feet and 16.5 feet and would warrant additional measurements when future 3R projects are developed.

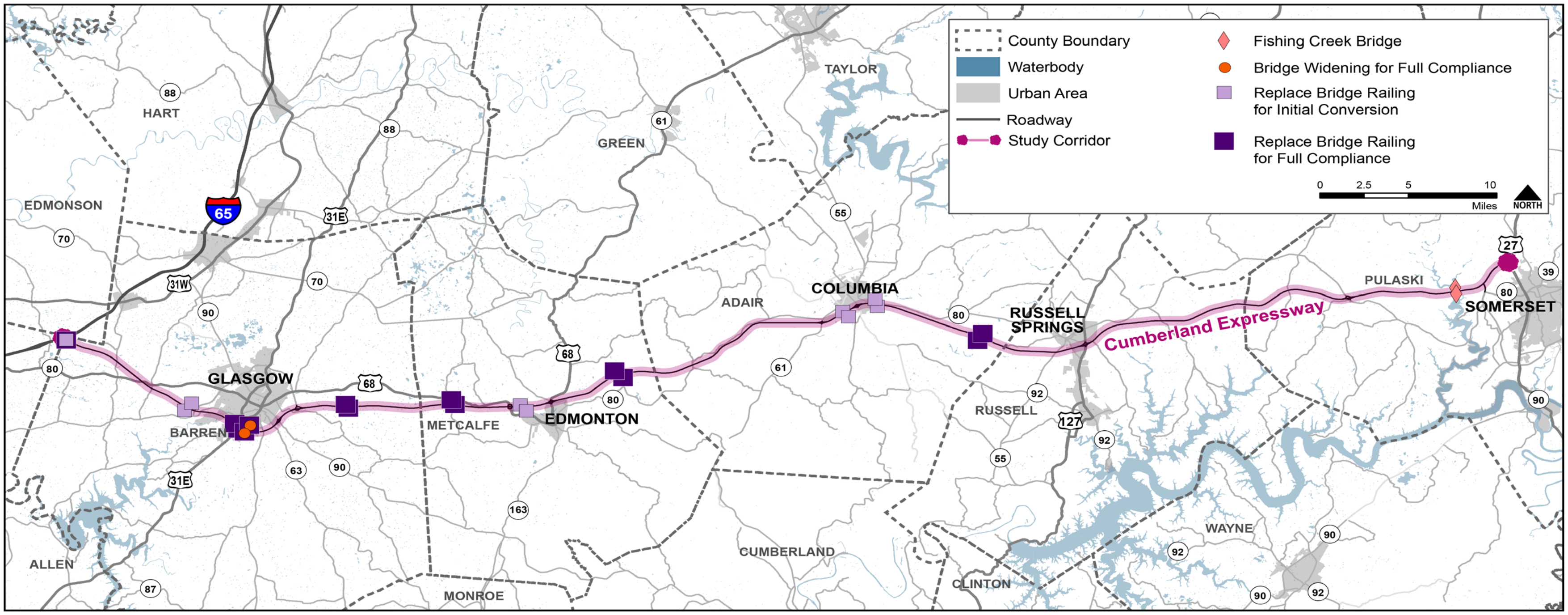
Table 18: Bridge Railing Improvements

Subcategory	Direction	Length (miles)	Begin MP (miles)	End MP (miles)	Cost (2021 $)	Initial Conver-sion	Full Compli-ance	Requires Design Variance	Possible Design Related Safety Issue
005B00067L - Bridge over I-65 - Replace bridge railing	EB and WB	0.052	0.031	0.083	$133,600	✓			Yes – High crash rate
005B00067R - Bridge over I-65 - Replace bridge railing	EB and WB	0.052	0.031	0.083	$133,600		✓	✓	No
005B00068L - Bridge over Beaver Creek - Replace bridge railing	EB and WB	0.053	8.199	8.252	$135,700	✓			Yes – High crash rate
005B00068R - Bridge over Beaver Creek - Replace bridge railing	EB and WB	0.053	8.188	8.241	$135,700	✓			Yes – High crash rate
005B00071L - Bridge over US 31E - Replace bridge railing	EB and WB	0.038	11.498	11.536	$103,300		✓	✓	No
005B00071R - Bridge over US 31E - Replace bridge railing	EB and WB	0.038	11.467	11.505	$103,300		✓	✓	No
005B00075L - Bridge over Mt. Pisgan Rd. - Replace bridge railing	EB and WB	0.040	18.260	18.300	$107,400		✓	✓	No
005B00075R - Bridge over Mt. Pishan Rd. - Replace bridge railing	EB and WB	0.040	18.259	18.299	$107,400		✓	✓	No
085B00040L - Bridge over KY 640 - Replace bridge railing	EB and WB	0.024	24.132	24.156	$72,500		✓	✓	No
085B00040R - Bridge over KY 640 - Replace bridge railing	EB and WB	0.024	24.135	24.159	$72,500		✓	✓	No
085B00042L - Bridge over S. Fork Little Barren River - Re-place bridge railing	EB and WB	0.056	28.114	28.170	$142,300	✓			Yes – High crash rate
085B00042R - Bridge over S. Fork Little Barren River - Replace bridge railing	EB and WB	0.056	28.125	28.181	$142,300	✓			Yes – High crash rate
085B00043L - Bridge over E. Fork Little Barren River - Re-place bridge railing	EB and WB	0.040	34.227	34.267	$106,100		✓	✓	No
085B00043R -Bridge over E. Fork Little Barren River - Re-place bridge railing	EB and WB	0.040	34.226	34.266	$106,100		✓	✓	No
001B00062L - Bridge over Pettys Fork - Replace bridge railing	EB and WB	0.040	48.136	48.176	$105,600	✓			Yes – High crash rate
001B00062R - Bridge over Pettys Fork - Replace bridge railing	EB and WB	0.040	48.131	48.171	$105,600	✓			Yes – High crash rate
001B00063L - Bridge over Russell Creek - Replace bridge railing	EB and WB	0.055	50.103	50.158	$139,500	✓			Yes – High crash rate
001B00063R - Bridge over Russell Creek - Replace bridge railing	EB and WB	0.055	50.069	50.124	$139,500	✓			Yes – High crash rate
001B00069L - Bridge over Russell Creek - Replace bridge railing	EB and WB	0.050	56.249	56.299	$128,900		✓	✓	No
001B00069R - Bridge over Russell Creek - Replace bridge railing	EB and WB	0.050	56.243	56.293	$128,900		✓	✓	No

Table 19: ***Bridge Width Improvements***

Subcategory	Direction	Length (miles)	Begin MP (miles)	End MP (miles)	Cost (2021 $)	Initial Conversion	Full Compliance	Requires Design Variance	Possible Design Related Safety Issue
005B00072L - Bridge over S. Fork Beaver Creek - Widen bridge 7.5 ft	EB and WB	0.036	11.576	11.612	$521,400		✓	✓	No
005B00072R - Bridge over S. Fork Beaver Creek - Widen bridge 7.5 ft	EB and WB	0.036	11.541	11.577	$521,400		✓	✓	No

Figure 20: ***Locations Requiring Bridge Railing and Widening Improvements***



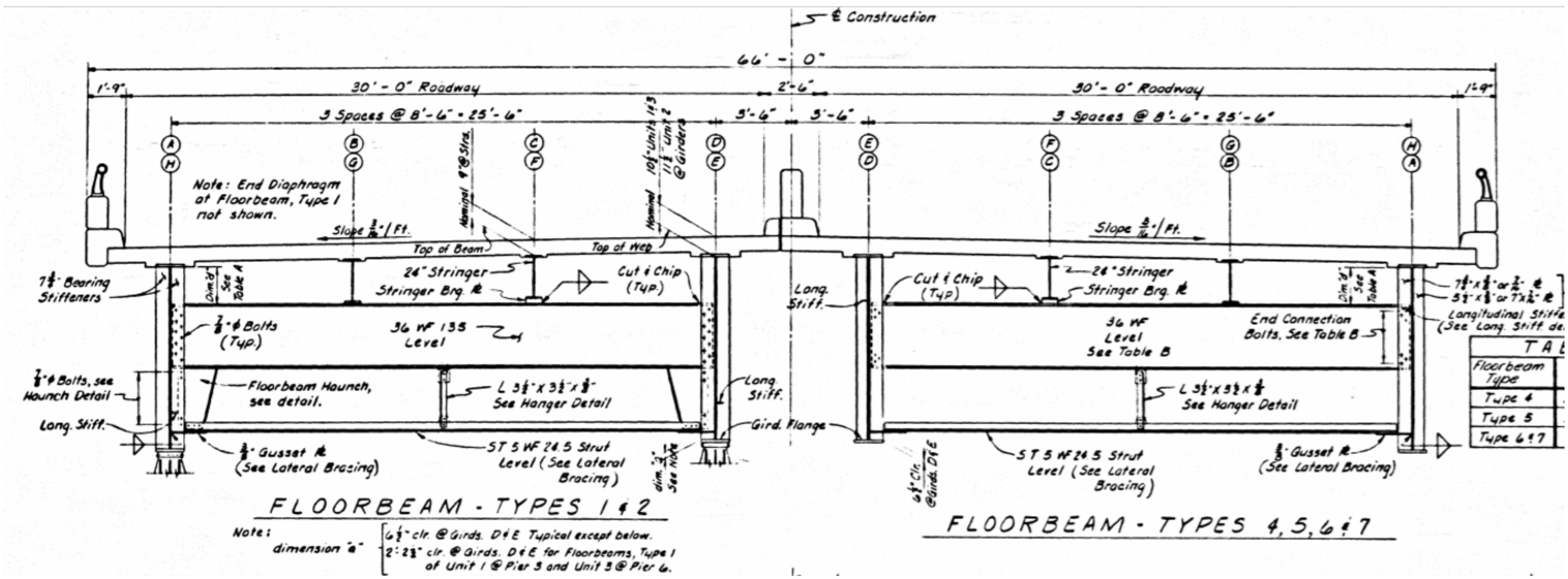
6.2.4 Fishing Creek Bridge

As noted previously, the twin bridge structure crossing Fishing Creek in Pulaski County (100B00074R and 100B00074L) does not meet the standards for bridge width or bridge railings. The bridges are 1,746 feet long and have a clear width of 30 feet, 1-foot shy of the standard. The railings also do not meet Interstate crash standards. See **Figure 21** for a typical section across the existing bridge.

To achieve full interstate compliance at this structure, the bridge would need to be widened 1-foot in each direction and both the inside and outside railing would need to be replaced with a crashworthy barrier. To achieve the full 31-foot clear width it would be necessary to widen the outside of both bridges by 1-foot. The outside railing would be replaced with a crashworthy barrier and the inside median barrier would need to also be replaced with a crashworthy barrier. The existing joint between these two parallel bridges would need to be modified to accommodate the new median barrier. The estimated cost of widening each structure by 1-foot, replacing the outside railing, and replacing the median barrier is $2,083,000. This would bring both structures up to current Interstate standards.

These bridges were identified as a high crash rate area. There were also several high severity crashes on the bridges (two fatal crashes and one severe injury crash) in the five-year analysis period (2015-2019). Many crashes on the bridge occurred during wet roadway conditions. Because of the identified safety concerns, several low-cost safety improvement options were explored, including adding raised shoulder rumble strips, providing a grooved pavement overlay on the bridge deck, and applying a high friction surface treatment (HFST). A predictive safety analysis was performed to compare potential crashes over a 20-year horizon.

Figure 21: *Bridge over Fishing Creek Typical Section*

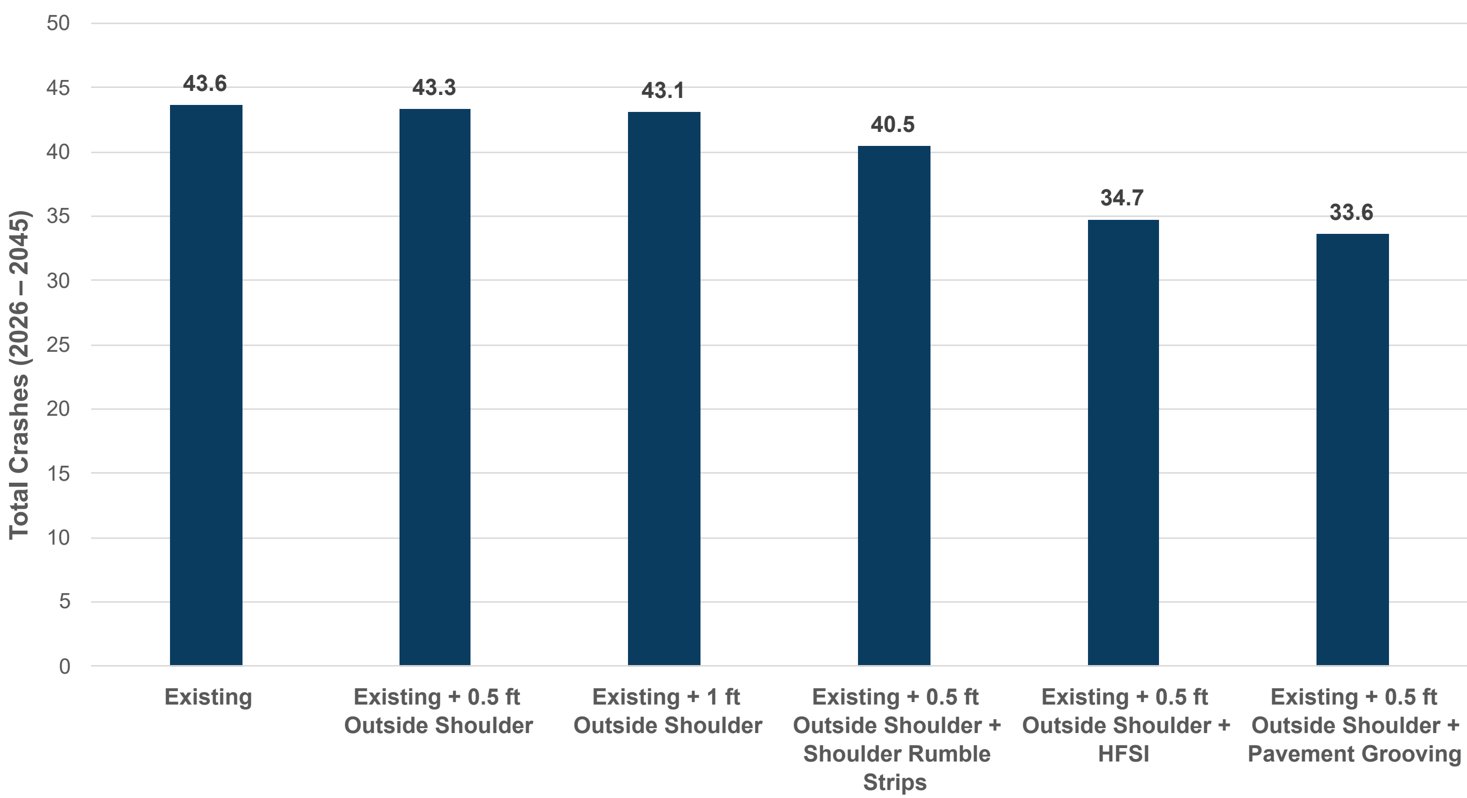


The results of the predictive safety analysis for a 20-year period (2026-2045) are illustrated in **Figure 22**. As shown, upgrading the bridge railings and adding 0.5 feet in clear width to each bridge will have a nominal impact on the predicted number of crashes (<1 crash prevented over 20 years), though upgrading the railings could prevent a more severe crash from occurring. Similarly, there was little marginal benefit from the full compliance option of widening the bridges by 1.0-foot.

The options that combined the upgraded railings with low-cost safety improvements all resulted in higher crash reductions (reductions of 3 to 10 crashes over the 20-year period). The currently recommended concept would be to replace the outside railing with a crashworthy concrete railing, which would increase the clear width by 0.5-foot on each bridge, and then apply a HFST to promote better vehicle traction and driver control. This concept would need to be examined in more detail to confirm its feasibility, but it is a safety treatment that has been used successfully in many locations around the state. The estimated cost of this option is $1,010,000. Although pavement grooving provided similar safety benefits as applying HFST to the existing bridge deck, it was not recommended for implementation due to the higher construction cost and impacts to traffic associated with needing to provide an overlay to the bridge deck.

This hybrid improvement approach could offer more safety benefits at a lower cost than the full compliance approach. For these reasons, it is recommended that a safety focused design approach be pursued along with a design exception as part of the initial conversion.

Figure 22: ***Predicted Crashes on Fishing Creek Bridges (2026 to 2045)***



6.3 Interchanges & Ramps

6.3.1 Acceleration/Deceleration Lane Lengths

Two locations have acceleration lane lengths that do not meet the 580 feet length requirement for 50 mph ramps. These include the eastbound acceleration lane from Exit 14 (KY 90) and the westbound acceleration lane from Exit 78 (KY 80). No safety concerns were identified at these locations. These lengths should be increased to meet the requirement prior to initial conversion. The cost is estimated to be $301,000. These locations are listed in **Table 20** and shown in **Figure 23**.

6.3.2 Lane Width

There is one ramp, the cloverleaf at Exit 88 (US 27) that does not meet the 15-foot lane width requirement. No safety concerns were identified at this location. This ramp should be widened prior to initial conversion. The cost is estimated to be $182,000. This location is listed in **Table 20** and shown in **Figure 23**.

6.3.3 Exit 27 Rebuild

Exit 27 (US 68, Glasgow Road) has an outdated loop ramp configuration that does not meet current design standards for acceleration and deceleration lane length. It is not possible to bring these up to Interstate design standards using the existing configuration. The interchange should be reconstructed. Safety concerns were identified in the weave section of the interchange. This location is shown in **Figure 23.** A standard diamond design is recommended, and a conceptual drawing is shown in **Figure 24**, which meets all Interstate design requirements. The estimated cost for rebuilding the interchange is $15,000,000.

Table 20: Acceleration and Deceleration Lane Length Improvements & Ramp Lane Width Improvements

Improvement	Measured Value (ft)	Design Standard (ft)	Deficiency (ft)	Direction	Cost (2021 $)	Initial Conversion	Full Compliance	Possible Design Related Safety Issue
Exit 14 - KY 90 - Increase EB accel length to 580’	500	580	80	EB	$163,000	✓		No
Exit 78 - KY 80 - Increase WB accel length to 580’	450	580	130	WB	$138,000	✓		No
Exit 88 - US 27 - Increase cloverleaf lane width to 15’	14	15	1	WB	$182,000	✓		No

Figure 23: *Interchange Improvement Locations*

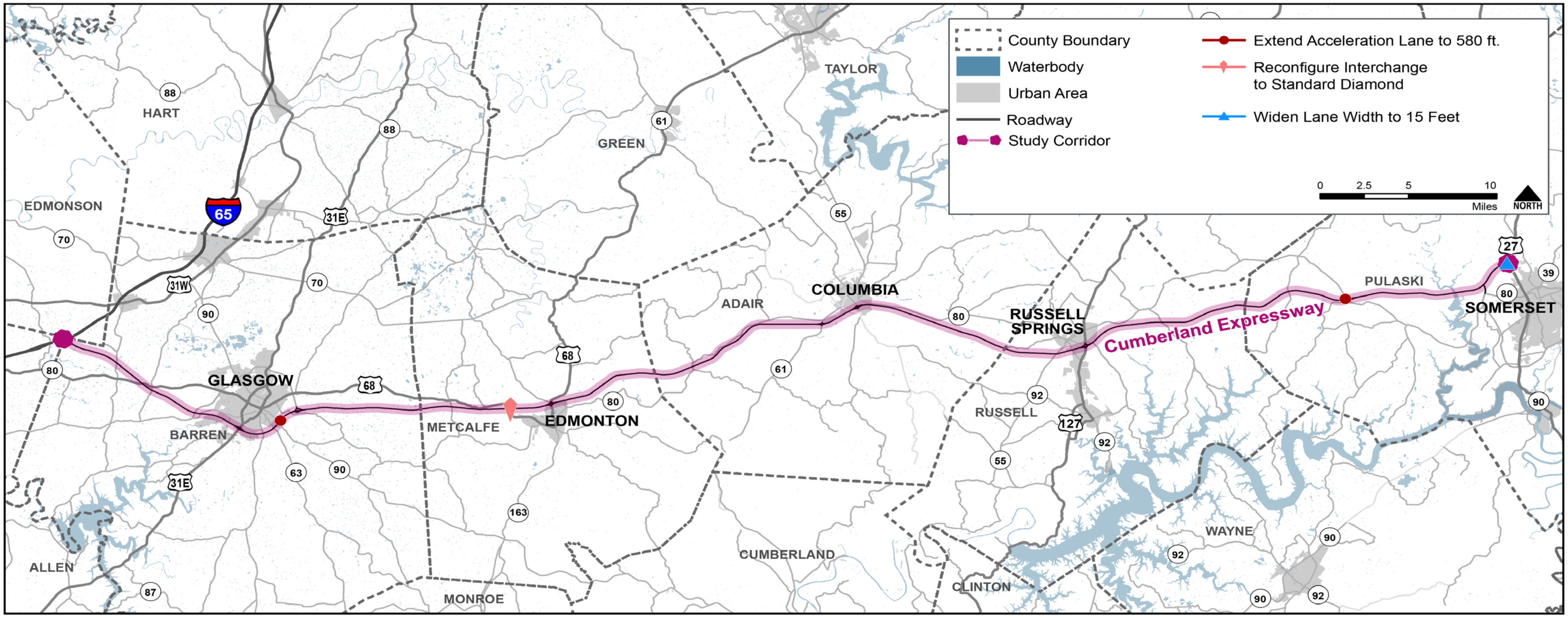
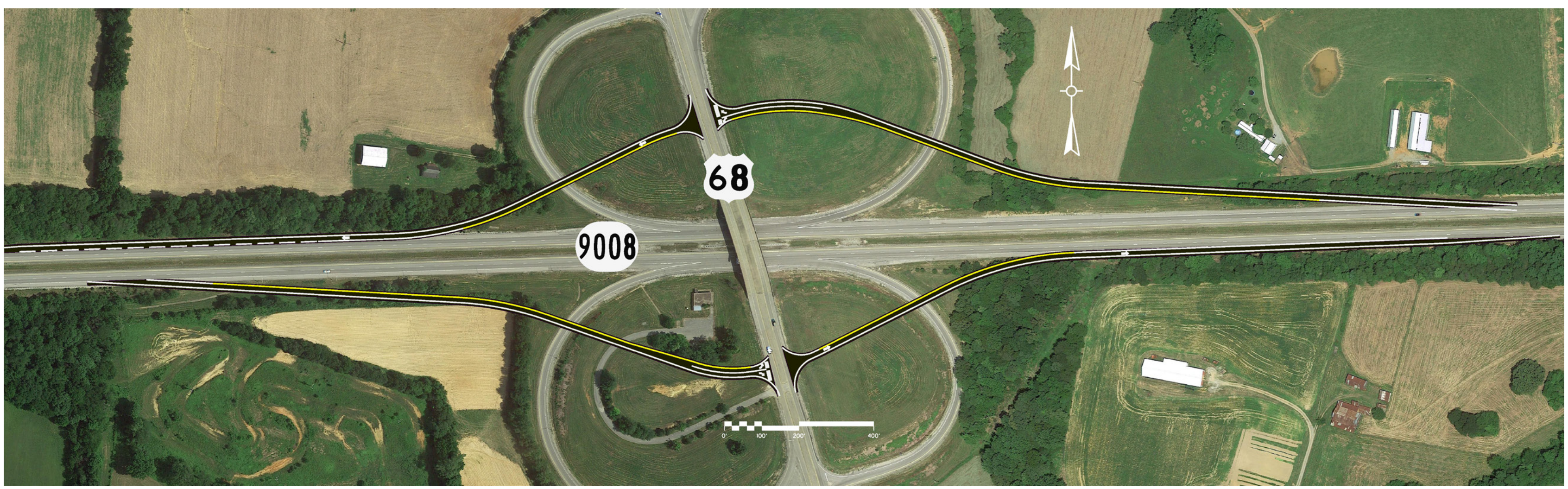


Figure 24: *Conceptual Design for Reconstruction of Exit 27 (US 68, Glasgow Road)*



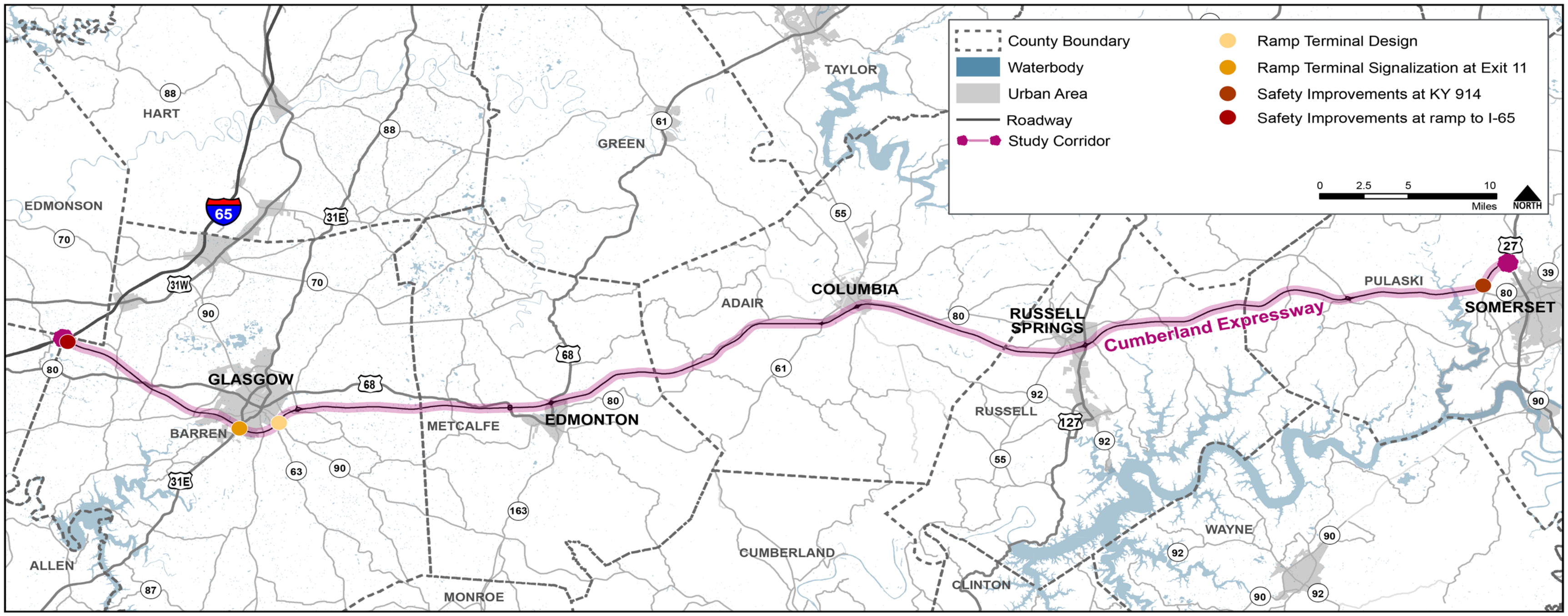
6.4 Safety and Operational Improvements

6.4.1 Additional Improvement Locations

Additional improvements that would benefit safety and operations along the Cumberland Expressway were identified while performing this study.

These improvements are not required for the Cumberland Expressway to meet Interstate standards but are included in this study for consideration by KYTC. **Figure 25** shows the locations of these improvements, and project sheets are included in **Appendix F**.

Figure 25: ***Additional Safety and Operational Improvement Locations***



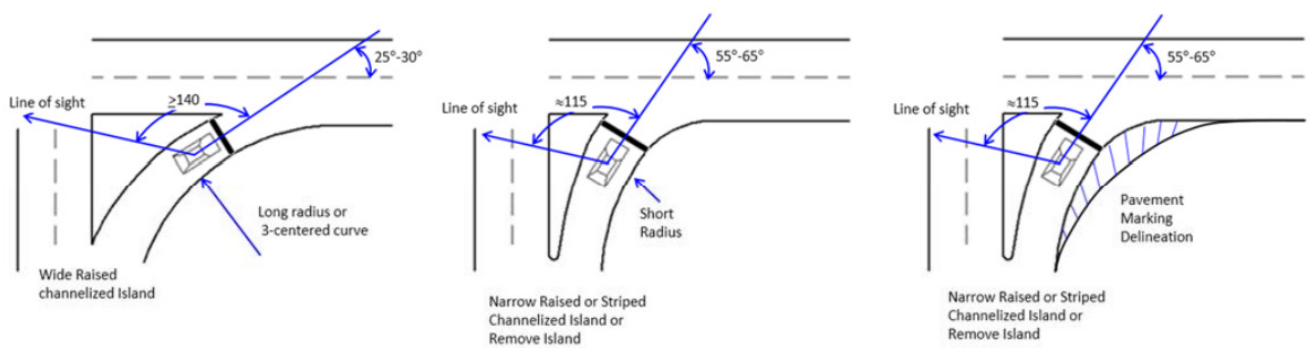
RAMP TERMINAL DESIGN

A high number of crashes were identified at the end of the eastbound off-ramp to Exit 14 (KY 90). Many of these crashes appeared to be related to the channelized right turn. **Figure 26** shows the location of crashes next to a Google Earth Street View image looking north from the channelized right turn lane. One potential improvement that could be considered for this location is to convert the channelized right turn into a "Smart Right Turn". This design approach would maintain the channelization but increase the cone of vision for right turning drivers. It would also decrease the corner radius as shown in **Figure 27**. Pavement marking delineation could be used to accommodate trucks if needed. This design approach resulted in right turn crash reductions of 47% in one recent research effort.[6] The estimated construction cost for this improvement is $30,000.

6 Barua, U. "Safety Effect of Smart Right-Turn Design at Intersections." ITE Journal, (November 2018) pp. 38-43.

Figure 26: *Exit 14 (KY 90) Eastbound Off-Ramp Crashes and Sight Distance Issues*

Figure 27: *Potential Modification to Channelized Right Turn Design*



Source: *Illinois Center for Transportation (2016)*

RAMP SIGNALIZATION

The westbound ramp terminal at Exit 11 (US 31E) currently experiences significant delays and queueing during the AM peak. Installing a traffic signal at that location and coordinating with the signals immediately adjacent can help alleviate queueing and prevent traffic from backing up onto the Expressway. The estimated construction cost of adding a traffic signal at this location is $250,000.

SAFETY IMPROVEMENTS AT KY 914

The eastbound off-ramp to KY 914 was flagged during project team discussions as a ramp where there were several truck rollover crashes in the past. In response to the truck rollover crashes, KYTC added a HFST to the ramp in 2014/15. After that application, the number of crashes on the ramp decreased. A review of the 2015 to 2019 crash data showed six crashes on the ramp: one severe injury crash, one minor injury crash, one possible injury crash, and three property damage only crashes. The severe injury crash involved a tractor trailer overturning in 2018. The minor injury crash involved a pick-up truck running off the road during wet weather conditions. Based on the number and severity of crashes on this ramp it is recommended that KYTC continue to maintain the HFST, estimated to cost $68,000. It is also recommended that the ramp continue to be monitored. If there continues to be safety issues on this ramp, it should be studied to develop additional improvement concepts to address the safety issue.

SAFETY IMPROVEMENTS AT THE WESTBOUND RAMP TO I-65

The westbound bridge over I-65 (005B00067L, MP 0.032), which is the ramp to I-65 southbound, had multiple crashes during icy roadway conditions reported. All of the crashes during icy conditions occurred on the same day within a two-hour time frame. The installation of signing, striping, and rumble strips as mitigating measures are recommended, with an estimated cost of $10,000. It is also recommended that the ramp continue to be monitored, and if safety issues persist, additional improvements should be studied.

6.4.2 Median Turnarounds

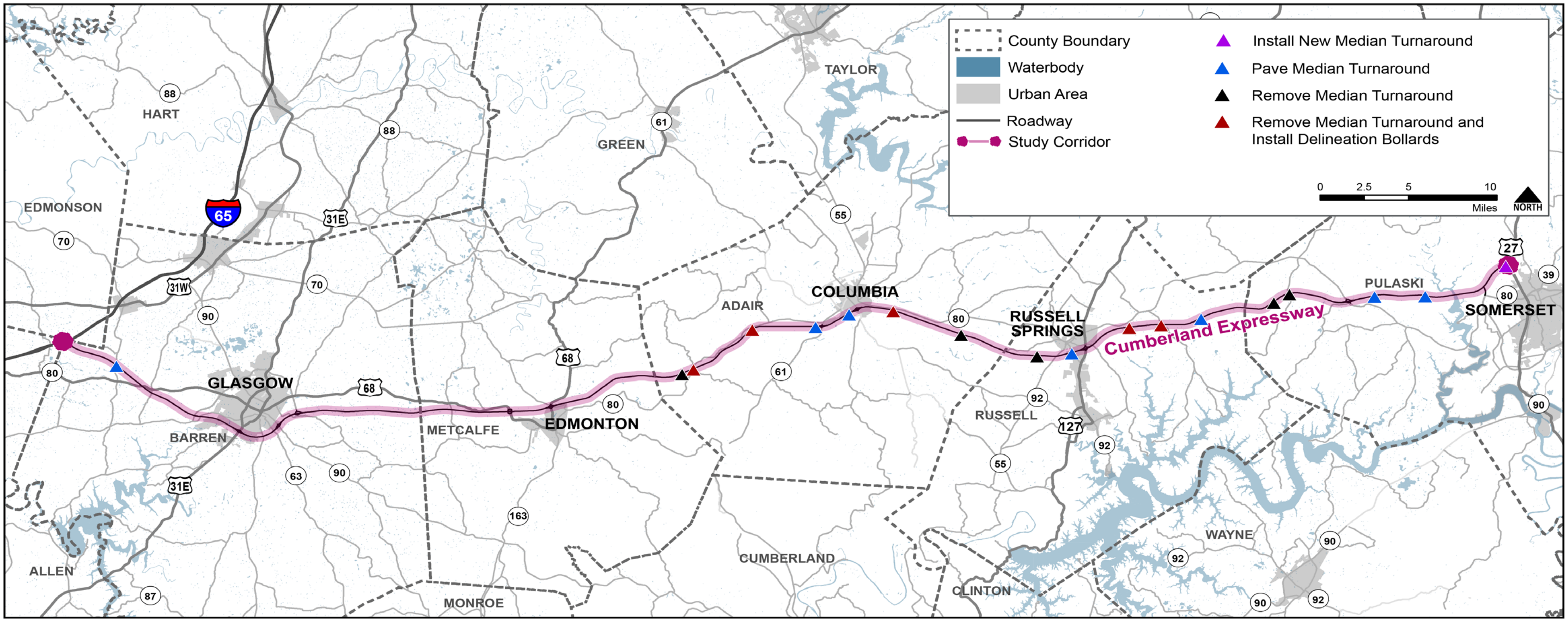
As noted in the existing conditions section, 42 median turnarounds exist along the Cumberland Expressway. Of the 42 median turnarounds, 24 are not required by Interstate standards, meaning the spacing is less than three miles from another median turnaround or interchange nor are the turnarounds located at a county line. Any changes to the median turnarounds are not required as part of upgrading the Cumberland Expressway to an interstate, therefore, the cost of these changes are not included as part of the cost to upgrade the Cumberland Expressway, and are instead included as an additional operational recommendation. The KYTC districts requested to keep 14 of the 24 median turnarounds not meeting Interstate standards, keeping the median turnarounds open for maintenance, snow and ice operations, dead animal and debris pickups, and emergency vehicle use. The total cost to remove 10 median turnarounds would be $120,000. Five of these 10 locations for removal are located at crash cushion transitions. Delineation bollards could be installed at these locations to prevent unwanted turnarounds. The cost to add delineation bollards at 5 locations is estimated to be $7,500.

Seven of the turnarounds that are remaining are unpaved turnarounds prior to crash cushions near overpasses. It is recommended to pave these median turnarounds, which would cost approximately $70,000. Additionally, the district is requesting a new median turnaround at MP 87.88 for snow and ice operations. This would cost approximately $20,000. Median turnaround locations that are recommended for removal, addition of delineation bollards, or pavement are listed in **Table 21** and shown in **Figure 28**.

Table 21: *Median Turnaround Recommendations*

Improvement	Median Mile point	Median Turnaround Needed?	Condition	Cost
Remove median turnaround	37.715	NO	Not required by district	$12,000
	55.102	NO	Not required by district	$12,000
	59.646	NO	Not required by district	$12,000
	73.854	NO	Not required by district	$12,000
	74.9	NO	Not required by district	$12,000
Remove median turnaround and install delineation bollards	38.42	NO	Crash Cushion Transition	$13,500
	42.65	NO	Crash Cushion Transition	$13,500
	51	NO	Crash Cushion Transition	$13,500
	65.333	NO	Crash Cushion Transition	$13,500
	67.1	NO	Crash Cushion Transition	$13,500
Pave median turnaround	3.216	YES	Unpaved	$10,000
	46.251	YES	Unpaved	$10,000
	48.537	YES	Unpaved	$10,000
	61.66	YES	Unpaved	$10,000
	69.5	YES	Unpaved	$10,000
	79.852	YES	Unpaved	$10,000
	82.718	YES	Unpaved	$10,000
Install new median turnaround	87.88	YES	No existing median turnaround	$20,000

Figure 28: *Median Turnaround Improvement/Removal Locations*



6.4.3 Cable Median Barrier from I-65 to Glasgow (MP 0.0 to 16.1)

According to the crash data for the corridor, there were 62 median crossover crashes during the five-year analysis period. This determination is based on the median crossover "flag field" in the CDAT crash data. The 62 crashes had a higher typical severity when compared to all crashes in the corridor, with seven (11%) of the 62 being fatal crashes as shown in **Table 22**. Most of the crossover crashes were single-vehicle crashes (46) with the 16 multi-vehicle crashes of various types. This high severity for median crossover crashes raises the question of whether a cable median barrier (or equivalent other barrier type) is warranted for portions of the corridor.

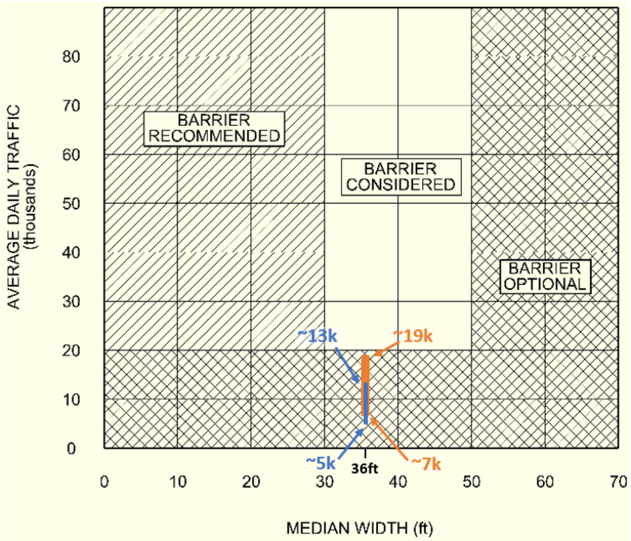
Table 22: Median Crossover Crashes on the Cumberland Expressway (2015-2019)

	Crash Severity					
Crash Type	Fatal	Serious Injury	Minor Injury	Possible Injury	Property Damage Only	Total
Single Vehicle	5		7	6	28	46
Sideswipe Same Direction			1		5	6
Angle	1				3	4
Head On			1		1	2
Rear End	1			1		2
Sideswipe Opposite Direction				1	1	2
Total	7	-	9	8	38	62

To evaluate the need for a median barrier the crashes were mapped to determine if there were clusters of crashes, especially the high severity crashes (**Figure 4**). It appears from the data that the highest density of crossover crashes is in the western portion of the corridor, where the traffic volumes is the highest. This includes three fatal crashes. There are pockets of crashes in other locations and some stretches with no median crossover crashes.

Another step in the evaluation was a review of the *Roadside Design Guide* criteria for installing median barriers on fully controlled access highways with traversable medians. The guidance is presented in **Figure 29** along with the current and projected future volume ranges and the current median width (distance between the travel lanes in the two directions). As shown, the entirety of the Cumberland Expressway falls in the "Barrier Optional" area on the figure due to the traffic volumes falling below 20,000 vehicles per day.

Figure 29: 2011 Roadside Design Guide Criteria for Median Barriers on Fully Access Controlled Highways



Given the high severity of the crossover crashes relative to all crashes, the fact that there was some observed clustering of the crashes, and that the current guidance appears to suggest a barrier is optional, it was decided that a high-level benefit cost analysis would be useful to provide direction on installing cable median barrier.

Three segments of the corridor were selected: one from I-65 to KY 1519 west of Glasgow; a second from US 68 north of Edmonton to KY 61 west of Columbia; and a third from KY 55X in Columbia to US 27. These segments included areas with a higher number of crossover crashes and/or areas that included the most severe crossover crashes. Crash modification factors (CMFs) were obtained from the CMF Clearinghouse based on recent cable median barrier research in Iowa.[7] These CMFs were applied to the observed five-year crash data. The expected future 10-year crash reduction was then monetized using USDOT guidance and compared to an estimated constriction and maintenance cost. The construction cost considered either cable median barrier or double-sided guardrail. The construction cost in 2022 dollars was assumed to be $190,000 per mile for cable-median barrier and $219,000 per mile for double-sided guardrail. The maintenance cost assumed $6,000 per mile per year to maintain the barrier (in 2019 dollars). The summary results of this high-level cost/benefit analysis are provided in **Table 23**.

Based on the cost/benefit analysis it is recommended that cable median barrier be installed from I-65 (MP 0.0) to just past Glasgow (MP 16.1) as shown on **Figure 30**, with an estimated cost of $3,059,0000. Cable median barrier will be installed in the median just off the edge of shoulder on one side and will protect cross-over crashes in both directions. This portion of the corridor has the highest density of crossover crashes and severe crossover crashes. The installation is expected to help reduce severe crashes on this highest volume portion of the Cumberland Expressway. It is also predicted to yield an overall societal benefit/cost ratio of approximately 8.1 for the cable median barrier alternative. The remainder of the Cumberland Expressway should be monitored to determine if additional median barrier would be beneficial after the installation of the initial 16 miles.

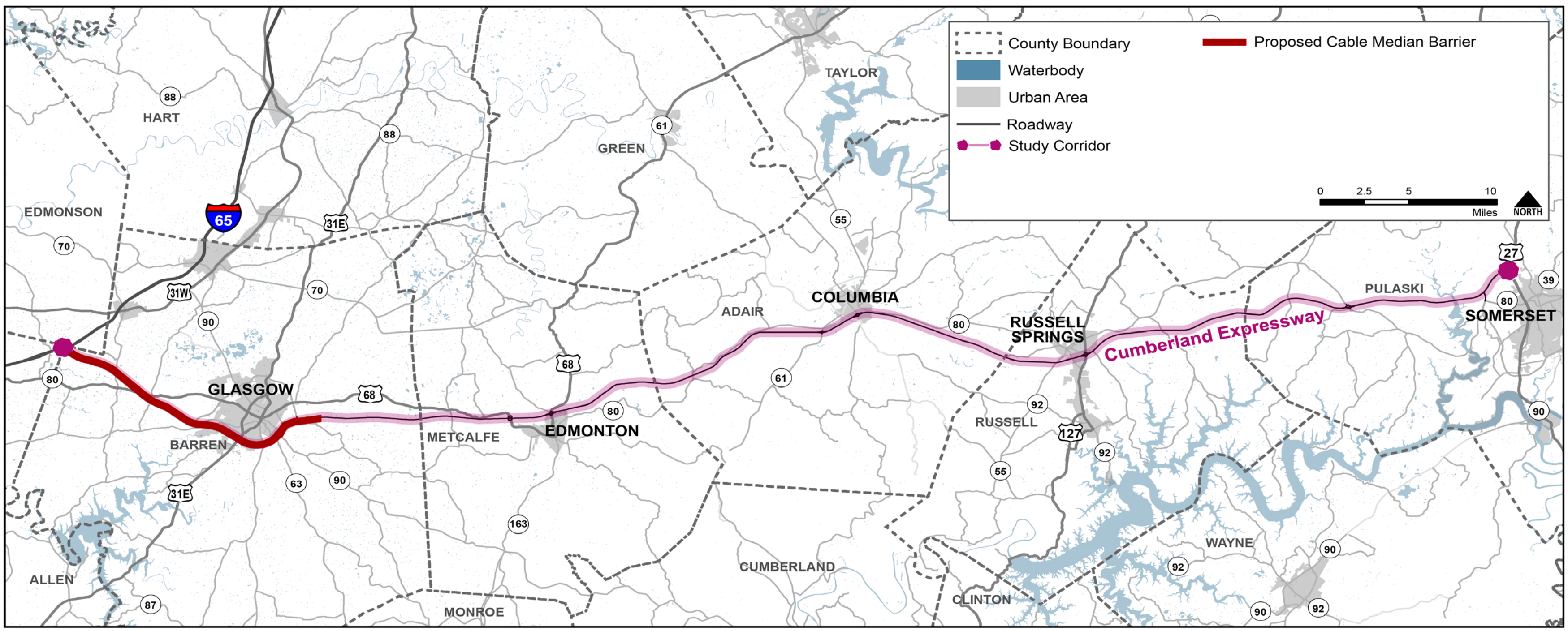
7 http://publications.iowa.gov/28699/1/Iowa_median_cable_barrier_eval_Final%20Report.pdf

Table 23: ***Cost Benefit for Median Barriers along the Cumberland Expressway***

Seg	Start	End	Length	Barrier Type	Cost (Millions)	Safety Benefit (Millions)	Benefit / Cost
1	I-65 MP 0.0	KY 1519 MP 16.1	16.1	Cable Median Barrier	$3.1	$25.0	8.1
				Double-Sided Guardrail	$3.5	$25.0	7.2
2	US 68 Greensburg Rd MP 29.8	KY 61 MP 46.6	16.8	Cable Median Barrier	$3.2	$8.4	2.6
				Double-Sided Guardrail	$3.6	$8.4	2.3
3	KY 55X MP 48.9	US 27 MP 88.2	39.3	Cable Median Barrier	$7.5	$24.8	3.3
				Double-Sided Guardrail	$8.5	$24.8	2.9

Note: Constant 2019 dollars

Figure 30: Proposed Initial Installation of Cable Median Barrier on the Cumberland Expressway



6.4.4 New Interchange at KY 249

A new interchange at KY 249 is proposed between the existing interchanges at US 31E (Scottsville Road) and KY 90 (Burkesville Road). This project is included in the *Kentucky FY 2020 – FY 2026 Highway Plan* as Item No. 3-80002.00 but is not funded. This location was not identified as an area with safety or operational issues as part of this study. A new interchange would provide additional access to Glasgow from the south as well as a connection to the schools and other development just north of the Cumberland Expressway in this area. While it appears feasible if urban interchange spacing standards are followed, it would place a new interchange just over 1 mile from KY 90 and about 1.5 miles from US 31E. A recent study completed for this interchange did not show a substantial travel time or safety benefit associated with the construction of the interchange. When upgrades to KY 249 were included with the interchange the benefit/cost ratio was just below 1.0. In summary, this interchange could potentially be constructed while meeting urban Interstate standards, but the project may not offer benefits that exceed the cost.

6.5 Cost Estimates

Planning level construction cost estimates were developed in 2021 dollars for all of the improvements listed. Costs were separated into costs for initial conversion, these being improvements that should be made before the Expressway is converted to an Interstate, and costs for full compliance. The cost estimates for additional safety and operational improvements are shown separately, as those are not required for compliance with Interstate standards but are recommended as part of this study. An additional 15% is added to the construction cost to account for design and environmental related costs, and another 15% is added to the construction cost to account for any miscellaneous construction costs. **Table 24** shows the cost estimates for all improvements likely to be required for initial conversion of the Cumberland Expressway to an interstate. **Table 25** shows the cost estimates for all improvements necessary for full compliance with Interstate design standards. **Table 26** shows the cost estimates for the recommended safety and operational improvements.

Table 24: *Cost Estimates for Initial Conversion to Interstate Design Standards*

Total Initial Conversion Cost (2021 $)	$26,351,243
Total Initial Conversion Construction Cost	$20,270,187
Design + Environmental (15%)	$3,040,528
Miscellaneous (15%)	$3,040,528

Table 25: *Cost Estimates for Full Compliance with Interstate Design Standards*

Total Full Compliance Cost (2021 $)	$41,548,347
Total Full Compliance Construction Cost	$31,960,267
Design + Environmental (15%)	$4,794,040
Miscellaneous (15%)	$4,794,040

Table 26: *Cost Estimates for Additional Safety and Operational Improvements*

Total Operational and Safety Improvement Cost (2021 $)	$4,724,850
Total Operational and Safety Improvement Construction Cost	$3,634,500
Design + Environmental (15%)	$545,175
Miscellaneous (15%)	$545,175

6.6 Recommendations

Table 27 shows a summary of all of the recommendations to upgrade the Cumberland Expressway to Interstate standards. **Table 28** shows a summary of the additional safety and operational improvements recommended as part of this study. Detailed tables are included in **Appendix F**.

Table 27: Summary of Recommended Improvements to Upgrade the Cumberland Expressway to Interstate Standards

Category	Subcategory	Miles	Cost (2021 $)	Initial Conversion	Full Compliance	Requires Design Exception	Requires Design Variance	Safety Concern
Mainline								
Shoulders	Widen inside shoulder from 3' to 4'	15.086	$2,240,000		✓	✓		YES
Superelevation	Increase superelevation (locations with safety issues)	0.354	$623,000	✓				YES
	Increase superelevation (locations without safety issues)	0.374	$55,000		✓	✓		
Headlight Sight Distance	Increase curve length	0.112	$459,000		✓		✓	
Guardrail	Replace damaged guardrail	5	$807,000	✓				YES
	Add new guardrail to address safety issues	2.433	$505,387	✓				
	Add new guardrail to address clear zone issues	2.5	$662,000	✓	✓		✓	
	Replace all guardrail less than 31"	29.2	$4,640,280		✓		✓	
Interchanges and Ramps								
Ramps - Accel/ Decel	Exit 14 (KY 90) Increase EB accel length to 580'	N/A	$163,000	✓				
	Exit 78 (KY 80) Increase WB decel length to 580'	N/A	$138,000	✓				
Lane Width	Exit 88 (US 27) Increase cloverleaf lane width to 15'	N/A	$182,000	✓				
Interchange Rebuild	Exit 27 (US 68, Glasgow Road) Reconfigure to standard diamond	1.667	$15,000,000	✓				
Bridges								
Bridge Railing	Replace metal railing (locations with safety issues)	9	$1,179,800	✓				YES
	Replace metal railing (locations without safety issues)	10	$1,170,000		✓		✓	
Bridge Width	Widen bridge 7.5 ft	2	$1,042,800		✓		✓	
Bridge over Fish-ing Creek	100B00074L/100B00074R - Bridge over Fishing Creek - Replace bridge railing + widen 1 ft	1	$2,083,000		✓	✓		YES
	100B00074L/100B00074R - Bridge over Fishing Creek - Replace bridge railing + HFST	1	$1,010,000	✓				YES

Table 28: Summary of Recommended Additional Safety and Operation Improvements

Category	Subcategory	Count	Cost (2021 $)	Safety Concern
Upgrade Ramp Terminal Design	Remove or modify channelization and modify right turn radius @ Exit 14 (KY 90) EB ramp	1	$30,000	YES
Add Traffic Signal at Interchange Ramps	Signalize the Exit 11 (US 31E) WB Ramp Terminal	1	$250,000	YES
Safety Improvements at KY 914	Continue High Friction Surface Treatment	1	$68,000	YES
Median Turnarounds	Remove median turnarounds	5	$60,000	NO
	Remove median turnarounds and install delineation bollards	5	$67,500	NO
	Pave gravel median turnarounds	7	$70,000	NO
	Install new median turnaround	1	$20,000	NO
Safety Improvements at WB On Ramp to I-65	Add signing, striping, and rumble strips	1	$10,000	YES
Cable Median Barrier	Add cable median barrier to prevent crossover crashes	16.1 (mi)	$3,059,000	YES

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7 Next Steps

Following completion of the study, KYTC will coordinate with FHWA to determine which items will be required for conversion of the Expressway to an interstate. The resulting project(s) will be considered a federal action and therefore it must adhere to the processes outlined in the National Environmental Policy Act (NEPA). This policy requires that environmental, social, and economic effects be assessed and considered in the decision-making process. The environmental process culminates in a FHWA-approved environmental document. These projects may require funding for all phases to be appropriated in future Kentucky Highway Plans.

7.1 Contacts

Written requests for additional information should be sent to the KYTC Division of Planning Director, 200 Mero Street, Frankfort, Kentucky 40622.

KENTUCKY TRANSPORTATION CABINET

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