Benefit Cost Analysis Memorandum

Fixing LOw Water Bridges for Emergency, Transportation, Technology, Equity, and Resilience (FLOW BETTER)

2022 RAISE Grant Application

Prepared for NCDOT by AECOM

April 14, 2022

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Executive Summary

A benefit cost analysis (BCA) was conducted for the Fixing LOw Water Bridges for Emergency, Transportation, Technology, Equity, and Resilience (FLOW BETTER) Project to support the grant application of the North Carolina Department of Transportation for the USDOT 2022 Rebuilding America's Infrastructure with Sustainability and Equity (RAISE) program. There are twenty-eight bridges comprising the Project as a whole, and because each bridge has independent utility, individual BCAs were estimated. This analysis was conducted in accordance with the 2022 Benefit Cost Analysis Guidance for Discretionary Grant Programs (USDOT guidance).[1] Capital outlays are scheduled to begin in 2024 for the first bridges and some bridges are scheduled to begin operations starting in 2025. The last bridge is scheduled for completion in 2028. All values are in 2020 dollars discounted at 7 percent to 2020 and cover a 20-year operations period, consistent with USDOT guidance.

Exhibit 1 presents the Impact Matrix, which describes the baseline, the Project as a whole, and the estimated results.

[1] USDOT Benefit Cost Analysis Guidance for Discretionary Grant Programs, March 18, 2022 https://www.transportation.gov/office-policy/transportation-policy/benefit-cost-analysis-guidance-discretionary-grant-programs-0

Exhibit 1 – Impact Matrix

Current Status/Baseline & Problem to be Addressed	Change to Baseline or Alternatives	Types of Impacts	Affected Population	Economic Benefit (Net Present Values, $2020 M) Discounted at 7%	Page Reference BCA
Twenty-four (24) of the 28 Project bridges are structurally deficient or functionally obsolete. Twenty-four (24) of the bridges are posted due to weight restrictions with the result that the large or heavy vehicles typically used in agriculture and shipping cannot use the route. The restrictions result in detours or partial loading; both practices raise production costs and decrease farm incomes, in an area heavily reliant on Christmas Tree farming for economic vitality. Detours also occur due to frequent flooding of the bridges and cut off populations and delay critical emergency services or eliminate the opportunity for households to participate in daily activities.	The Project would replace 28 rural bridges, bringing them up to a state of good repair and allowing for all vehicles to use them, reducing VMT and travel times in the region. In addition, adjacent farms will reduce operating expenses from improved efficiencies in the transportation network, and the bridges will be safer and allow for more reliable emergency access. Bringing the bridges up to a greater level of service reduces the frequency and duration of flooding that results in detours or leaves populations without the ability to participate in daily activities. The reduced VMT results in travel cost savings for autos, operating cost savings for trucks, emissions savings, safety improvements and crash reductions, less congestion and noise, and residual value.	**Safety**			
		Reduced Roadway Fatalities and Crashes	Drivers and passengers who reduce VMT after Project opening	$1.8	15
		Safety Improvements at Bridges	Drivers, passengers, and property owners near the Project bridges	$4.2	17
		Emergency Access Benefit	Populations relying on bridges that have reduced access when flooded	$0.3	17
		State of Good Repair			
		Roadway Maintenance Savings	NCDOT and Taxpayers	$0.001	18
		Bridge Repair Costs Avoided	NCDOT and Taxpayers	$4.5	18
		Bridge Current Maintenance Costs Avoided	NCDOT and Taxpayers	$0.1	18
		Economic Competitiveness			
		Travel Time Savings Detours	Drivers and passengers who reduce VMT after Project opening	$0.6	18
		Travel Time Savings Bridge Lanes	Drivers and passengers who use the bridges	$0.2	19
		Auto Travel Cost Savings	Drivers who reduce VMT after Project opening	$0.5	19
		Residual Savings	NCDOT and Taxpayers	$3.8	19
		Truck Operating Savings	Freight operators, Shippers, and Customers	$3.4	19
		Congestion Reduction Benefit	Populations and drivers located on detour paths	$0.03	19
		Environmental Sustainability			
		Emissions Savings	General public	$0.032	20
		Quality of Life			
		Noise Reduction Benefit	Populations and drivers located on detour paths	$0.0003	21
		Agricultural Access Improvement	Farms in the vicinity of Project bridges and tourists accessing the farms	$32.0	20
		Mobility and Connectivity Benefits			
		Trip Not Taken	Populations located on dead-ends that rely on bridges	$16.7	22

Exhibit 2 summarizes long-term outcomes of the Project. Taken in total, the Project provides $69.5 million in benefits—reduced roadway fatalities and crashes, safety improvements at the bridges, emergency access benefits, roadway maintenance savings, bridge repair costs avoided, bridge maintenance costs avoided, travel time savings, auto travel cost savings, residual savings, truck operating savings, congestion reduction, emissions savings, agricultural access improvements, noise reduction, and the value of a trip not taken —over the analysis period, using a 7 percent discount rate. Compared to a similarly discounted cost estimate, the Benefit Cost Ratio for the Project is 2.1, a solid return on this critical investment for the region. The net benefits of the Project are $36.4 million using a 7 percent discount rate.

Exhibit 2 – Costs and Benefits Delivered by Long Term Outcomes

Total Project	7% Discount Rate
Costs (2020 $M)	
Capital Cost	$33.1
Total Costs	*$33.1*
Benefits (2020 $M)	
Safety Benefits	
Reduced Roadway Fatalities and Crashes	$1.8
Safety Improvements at Bridges	$4.2
Emergency Access Benefit	$0.3
Sub-Total	$6.3
State of Good Repair Benefits	
Roadway Maintenance Savings	$0.0006
Bridge Repair Costs Avoided	$4.5
Bridge Current Maintenance Costs Avoided	$0.1
Sub-Total	$4.6
Economic Competitiveness Benefits	
Travel Time Savings Detours	$0.6
Travel Time Savings Bridge Lanes	$0.2
Auto Travel Cost Savings	$0.5
Residual Savings	$3.8
Truck Operating Savings	$3.4
Congestion Reduction Benefits	$0.030
Sub-Total	*$8.6*
Environmental Sustainability	
Emissions Savings	$0.03
Sub-Total	$0.03
Quality of Life	
Agricultural Access Improvement	$32.0
Noise Reduction Benefits	$0.0003
Sub-Total	$32.0
Mobility and Connectivity Benefits	
Trip Not Taken	$16.7
Sub-Total	$16.7
Net Operating & Maintenance Costs	$1.4
Total Benefits	*$69.5*
Outcome	
Net Benefits (2020 $M)	$36.4
Benefit-Cost Ratio	**2.10**

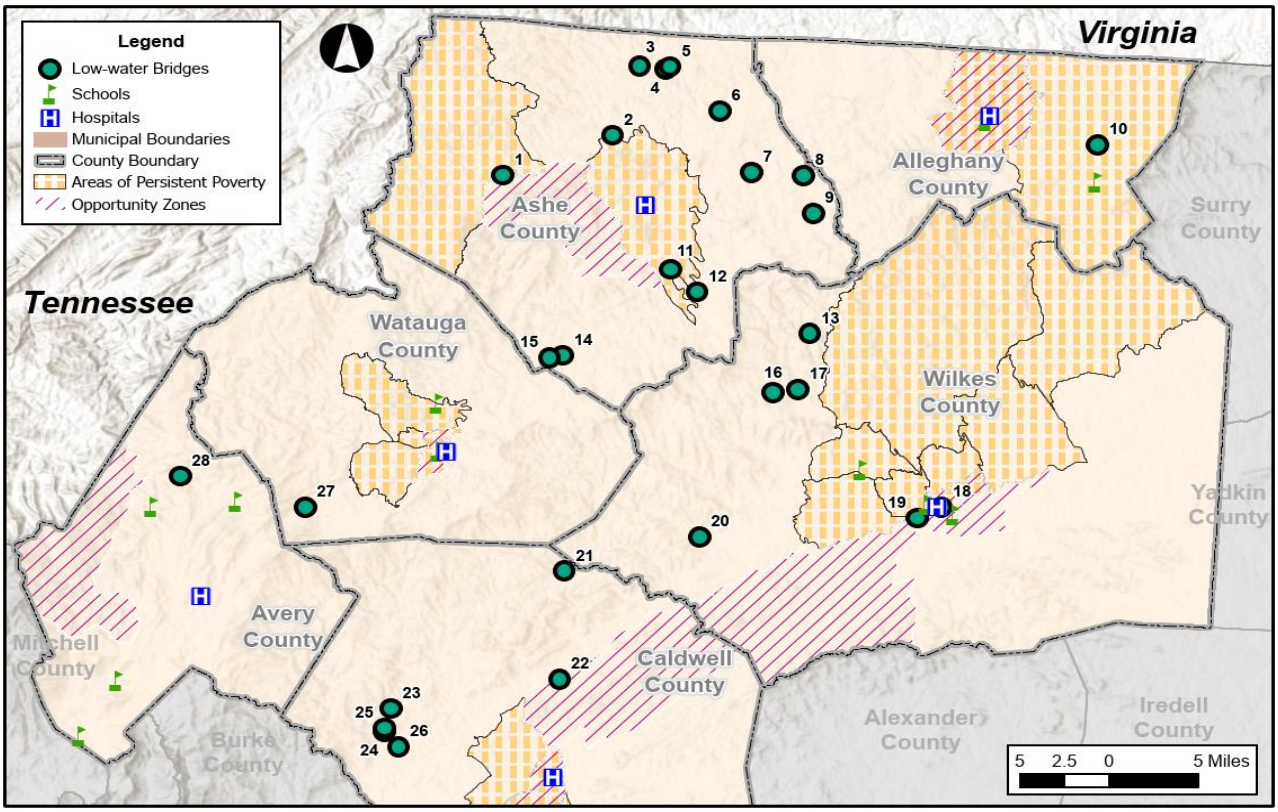
1. Introduction

FLOW BETTER (or "Project" hereafter) was developed through North Carolina's Department of Transportation ("NCDOT" hereafter). The Project will replace twenty-eight rural bridges located in six rural counties in western North Carolina.

The following North Carolina counties contain one or more of the Project bridges, as identified in parenthesis. Figure 3 illustrates the location of each Project bridge.

1. Alleghany (1)
2. Ashe (13)
3. Avery (1)
4. Caldwell (6)
5. Watauga (1)
6. Wilkes (6)

Exhibit 3 – Location of the Bridges in Western North Carolina



The Project addresses multiple criteria in the RAISE Grant program. These include: Safety, Economic Competitiveness, Quality of Life, State of Good Repair, Mobility and Connectivity, and Environmental Sustainability. In some cases, the expected Project outcomes apply to more than one of the benefit criteria identified above.

- ***Safety***: The Project improves safety in several ways.
  - First, in instances where the existing bridge was built decades ago, the new bridge and approach will be designed for modern standards and vehicles, reducing the potential for fatalities, injuries, and crashes.
  - Second, once the bridge is replaced and able to accommodate all types of vehicles, detours will be eliminated, reducing vehicle miles traveled (VMT) and the chance of a crash.
  - Third, each of the replacement bridges will be built higher and with guardrails, reducing the likelihood of being flooded, damaged by debris and unavailable for use. The BCA estimates the

value of the safer bridge design and the reduction in VMT. In order to value the improved reliability of the bridges, the Level of Service (LOS) between the No Build and Build condition was used to evaluate the change in the number and duration of flooding events.[2]

  - Finally, the improved bridges reduce the risk of delays in the event of an emergency, particularly for populations stranded by a dead-end and a washed-out bridge. An emergency access benefit is estimated for bridges based on the number of flooding events and duration avoided.

- ***Economic Competitiveness***: Six types of economic competitiveness benefits are estimated as part of the BCA. With the elimination of detours, (1) travelers save time and avoid the (2) cost and (3) congestion associated with VMT from the detour and, (4) Trucks will save operating cost as well. As these bridges have a long useful life that exceeds the 20-year analysis period applied in the BCA, (5) a residual value is estimated. Many bridges are one lane and will be upgraded to two when they are rebuilt; (6) the travel time savings for vehicles that must wait while other vehicles cross under current conditions is included as a benefit.
- ***Quality of Life***: The Project benefits Quality of Life in three primary ways. First, the low posted weight limit of the bridge causes a daily inconvenience to travelers, including school buses. Second, the ability to move large farm equipment among fields allows agricultural producers to conduct their work more efficiently. The AADT for the bridges likely omit counts of tractors and other farm machinery that must divert and find another route when moving from field to field during planting or harvest season, as well as delivery vehicles between farms and retail locations. This analysis provides a conservative estimate of the value of improved agricultural access improvements in the vicinity of the bridges. The improved efficiency allows farmers to reduce farm expenses, supporting rural incomes. Finally, the VMT avoided by detours also results in noise reduction benefits.
- ***State of Good Repair***: Once the posted bridges are replaced and able to accommodate all types and weights of typical vehicles in use, the need to detour around the bridge will be eliminated, reducing truck and auto VMT and roadway wear and tear. Avoided damages and repairs to bridges after flooding events will also keep the bridges in a state of good repair.
- ***Mobility and Connectivity***: For bridges that lead to dead-end roads, the loss of the bridge during flooding events means those populations are cut off from all trips including employment, education, and health care. Avoiding this loss to those populations is valued as a trip not taken.
- ***Environmental Sustainability***: Once the posted bridges are replaced and able to accommodate all types and weights of typical vehicles in use, and the higher bridges flood less frequently and for shorter durations, the need to detour around the bridge will be eliminated, reducing VMT and associated emissions. In addition, the bridges will no longer leach chemicals into the waterways, protecting people, animals, and plants from pollution.

Supplementary Materials can be found on the website (https://connect.ncdot.gov/resources/RAISE2022-LowWater/Pages/default.aspx).

2. Framework

The parameters of the benefits analysis follow the protocols set by the Office of Management and Budget (OMB) Circular A-94 as well as the recommended quantification methods by the USDOT and the Federal Emergency Management Agency (FEMA). Generally, standard factors and values accepted by Federal agencies were used for the benefits calculation except in cases where more project-specific values or prices were available. In all such cases, modifications are noted and references are provided for data sources. The analysis follows a conservative estimation of the benefits. By adhering to a strict standard of what could be included in the benefits analysis, actual total benefits may be greater than depicted in the results.

The No Build scenario assumes that the Project would not be built and current conditions and operations would continue in the Project area. Under the No Build, the purpose of and need for the Project would not

[2] See Analysis Assumptions for more information on how the LOS impacts the benefits

be met and would generally be limited to the operation and maintenance of existing infrastructure. The Project was compared to the No Build scenario to identify benefits and costs.

A custom model was developed to estimate the future benefits for the Project. Benefits were estimated over a 20-year period of analysis beginning when construction ends and concluding after 20 full years of operations. Each project schedule varies, but for the group of twenty-eight projects, the construction period is from 2024 through 2028, and operations begin in 2025 with partial years included as needed.

The benefits are expressed in constant 2020 dollars, which avoids forecasting future inflation and escalating future values for benefits and costs accordingly. The USDOT guidance was used to adjust past cost estimates or price values into 2020-dollar terms.

The use of constant dollar values requires the use of a real discount rate for discounting to the present value. Projects expecting to use Federal funding are required to use a 7 percent discount rate.

3. Analysis Assumptions

A list of assumptions for the Project is provided in the BCA workbook (see Inputs tab in the file BCA.xlsx) as well as in Exhibit 4.

Exhibit 4 – BCA Calculation Inputs

Input	Value	Source
General		
Discount Rate	7%	2022 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Discount Rate - CO2 Emissions	3%	2022 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Deflator	See "Deflator" Sheet	2022 BCA Guidance for Discretionary Grant Programs and https://www.whitehouse.gov/wp-content/uploads/2021/05/hist10z1_fy22.xlsx
Dollar year	2020	2022 BCA Guidance for Discretionary Grant Programs
Discount year (base year)	2020	2022 BCA Guidance for Discretionary Grant Programs
Annualization factor	365	
Vehicle occupancy - All Travel	1.67	2022 BCA Guidance for Discretionary Grant Programs
AADT annual growth	1%	NCDOT
Population annual growth	1%	Estimated
Truck share	4.0%	Estimated based on NCDOT traffic counts
Water gage installation per bridge (2022$)	$40,000	NCDOT
O&M for flood gage (2021$)	$2,500	NCDOT
O&M for flood gage (2020$)	$2,462	NCDOT
State of Good Repair		
Roadway Maintenance Cost per Mile, Rural Interstate (2000$) - Auto	$0.000	Source: FHWA Highway Cost Allocation Study, 2000 Addendum, Table 13
Roadway Maintenance Cost per Mile, Rural Interstate (2020$) - Auto	$0.000	Adjusted by GDP Deflator
Roadway Maintenance Cost per Mile, Rural Interstate (2000$) - 40 kip truck	$0.010	Source: FHWA Highway Cost Allocation Study, 2000 Addendum, Table 13
Roadway Maintenance Cost per Mile, Rural Interstate (2020$) - 40 kip truck	$0.015	Adjusted by GDP Deflator

Share of Construction costs that are for bridge structure	75%	Engineering judgement
Quality of Life		
Roadway Noise Cost per Mile, Rural Interstate (2020$) - Auto (Light Duty Vehicle)	$0.0002	2022 BCA Guidance for Discretionary Grant Programs
Roadway Noise Cost per Mile, Rural Interstate (2020$) - 40 kip truck (Buses & Trucks)	$0.0033	2022 BCA Guidance for Discretionary Grant Programs
Mobility and Connectivity		
Hours of disbenefit for Trip Not Taken; 12 hours recommended per trip, conservatively using half	6	Federal Transit Administration, How to Use the FTA HMCE Tool, 2017, https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/funding/grant-programs/emergency-relief-program/60461/fta-hmcetooluserguide-mar2017.pdf
Economic Competitiveness		
Travel time savings - share of vehicles per bridge that wait	5%	Estimated
Travel time savings per vehicle (minutes)	1	Estimated
Percent of farms affected by county	5.5%	NCDOT, https://connect.ncdot.gov/projects/research/RNAProjDocs/RP2020-20_Final%20Report.pdf
Percent of farm expenses impacted	3.5%	Estimated from USDOT data. NC Farm Services is 10.2 percent of production costs; Farm services is a summation of all crop custom work, veterinary custom services, **transportation costs,** marketing charges, insurance, leasing of machinery and equipment, utilities, general expenses, and miscellaneous business expenses. See page 17 of https://www.nass.usda.gov/Publications/Todays_Reports/reports/fpex0721.pdf
Vehicle Maintenance Cost per Mile, Auto (2020$)	$0.45	2022 BCA Guidance for Discretionary Grant Programs
Vehicle Operating Costs per Mile, Truck (2020$)	$0.94	
Value of Time (2020$), private vehicle travel time per person hour, all purposes	$17.80	
Value of Time (2020$), truck driver per hour	$32.00	
Times bridges flood in No Build, on average per year	6	Per EMS, most bridges flood 3-6 times per year
Reduction in time of bridge closure in Build due to flooding	50%	Estimated per discussion with NCDOT
Roadway Congestion Cost per Mile, Rural Interstate (2020$) - Auto (Light Duty Vehicle)	$0.026	2022 BCA Guidance for Discretionary Grant Programs
Roadway Congestion Cost per Mile, Rural Interstate (2020$) - 40 kip truck (Buses & Trucks)	$0.067	2022 BCA Guidance for Discretionary Grant Programs
Safety		
PDO Crash Modification Factor	15%	NCDOT, https://connect.ncdot.gov/resources/safety/TrafficSafetyResources/NCDOT%20CRF%20Update.pdf
Injury Modification Factor	32%	
K - Killed (2020$)	$11,600,000	
# Accidents Reported (Unknown if Injured) (2020$)	$159,800	

Emergency Response Time without flooding (minutes)	10	Estimated per discussion with local EMS responders
Emergency Response Time with flooding (minutes)	40	Estimated per discussion with local EMS responders
Emergency Response Population Impacted	100	Estimated per discussion with local EMS responders
Injury Crash (2020$)	$302,600	2022 BCA Guidance for Discretionary Grant Programs
Fatal Crash (2020$)	$12,837,400	2022 BCA Guidance for Discretionary Grant Programs
PDO Crash (2020$)	$4,600	2022 BCA Guidance for Discretionary Grant Programs
Environmental Sustainability		
Damage Costs for Emissions per metric ton (2020$)		
Factor g/MT	1,000,000	
Year	CO2	
2021	$52	2022 BCA Guidance for Discretionary Grant Programs
2022	$53	
2023	$54	
2024	$55	
2025	$56	
2026	$57	
2027	$58	
2028	$60	
2029	$61	
2030	$62	
2031	$63	
2032	$64	
2033	$65	
2034	$66	
2035	$67	
2036	$69	
2037	$70	
2038	$71	
2039	$72	
2040	$73	
2041	$74	
2042	$75	
2043	$77	
2044	$78	
2045	$79	
2046	$80	
2047	$81	
2048	$82	
2049	$83	
2050	$85	
Year	NOx	
2021	$15,545	2022 BCA Guidance for Discretionary Grant Programs
2022	$15,600	
2023	$15,800	
2024	$16,000	
2025	$16,200	
2026	$16,500	
2027	$16,800	
2028	$17,100	
2029	$17,400	
2030	$17,700	
2031	$18,100	
2032	$18,100	

2033	$18,100	
2034	$18,100	
2035	$18,100	
2036	$18,100	
2037	$18,100	
2038	$18,100	
2039	$18,100	
2040	$18,100	
2041	$18,100	
2042	$18,100	
2043	$18,100	
2044	$18,100	
2045	$18,100	
2046	$18,100	
2047	$18,100	
2048	$18,100	
2049	$18,100	
2050	$18,100	
Year	SOx	
2021	$15,545	2022 BCA Guidance for Discretionary Grant Programs
2022	$15,600	
2023	$15,800	
2024	$16,000	
2025	$16,200	
2026	$16,500	
2027	$16,800	
2028	$17,100	
2029	$17,400	
2030	$17,700	
2031	$18,100	
2032	$18,100	
2033	$18,100	
2034	$18,100	
2035	$18,100	
2036	$18,100	
2037	$18,100	
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2040	$18,100	
2041	$18,100	
2042	$18,100	
2043	$18,100	
2044	$18,100	
2045	$18,100	
2046	$18,100	
2047	$18,100	
2048	$18,100	
2049	$18,100	
2050	$18,100	
Year	PM2.5	
2021	$722,079	2022 BCA Guidance for Discretionary Grant Programs
2022	$748,600	
2023	$761,600	
2024	$774,700	
2025	$788,100	
2026	$801,700	

2027	$814,500
2028	$827,400
2029	$840,600
2030	$854,000
2031	$867,600
2032	$867,600
2033	$867,600
2034	$867,600
2035	$867,600
2036	$867,600
2037	$867,600
2038	$867,600
2039	$867,600
2040	$867,600
2041	$867,600
2042	$867,600
2043	$867,600
2044	$867,600
2045	$867,600
2046	$867,600
2047	$867,600
2048	$867,600
2049	$867,600
2050	$867,600

Flood Frequency and Duration

The low-water bridges in the Project are designed to overtop, but the rebuilt structures will include guardrails that will reduce debris and damages and the duration of bridge closure from flood events. The rebuilt bridges will still flood, but less ***frequently*** and for a shorter ***duration***. The analysis of the impacts from detours that result from flooding of the low-water bridges is based on two factors: the ***frequency*** of floods (number of flooding events per year) and the ***duration*** of bridge closure from a flood (number of days the bridge is closed per flooding event). The ***frequency*** of the flood is estimated at 6 floods per year in the No Build. The ***duration*** of bridge closure from each flood is based off of NCDOT Traveler Information Management System (TIMS) data, which is a record of flooding events that have caused the bridges to flood and close; it is bridge-specific and provided by NCDOT. The bridge's LOS relates to the frequency with which the bridges are designed to flood. For example, some of the bridges have a LOS of 0.5 in the No Build, indicating that they are designed to flood twice per year. In the Build, bridges will be improved up to at least a LOS of 2, or designed to flood once every two years. Bridges will be improved to a greater degree, as allowable by geometry and other localized considerations. Note that the LOS for design does not necessarily correlate with the ***frequency*** of floods experienced at the bridge per year.

The degree to which the LOS improves in the Build compared to the No Build, as well as a reduction in bridge flood closure duration of 50 percent, is used to estimate the days of detoured bridge traffic that would be saved in the Build. Two bridges are not considered low-water bridges and their LOS does not change between the No Build and Build, indicating that flooding does not typically impact the bridges.

4. Benefit Analysis

The method, analysis, and results for each Project benefit category are described in the following sections.

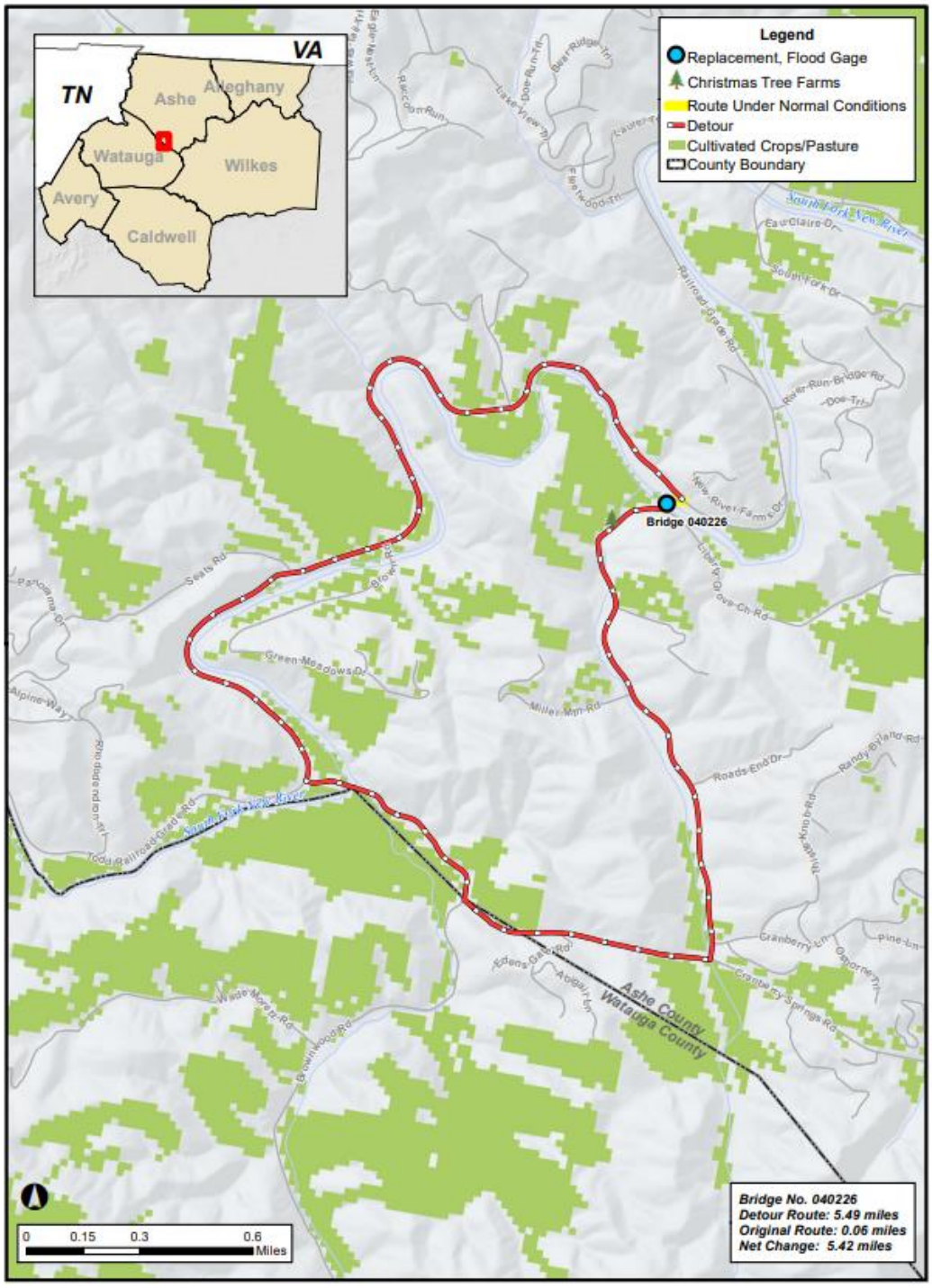
Safety

The Project would result in safety benefits by removing VMT from the region's roads, bringing the bridges up to current design standards and maintaining better emergency access in flooding events.

Reduced Roadway Fatalities and Crashes

The construction of the bridges results in temporary closure of the bridge and therefore forces all traffic to detour on a longer route. This longer route results in increased VMT for the duration of the bridge closure. The temporary increase in VMT for construction is offset with the reduction in VMT once the bridges open. Under the No Build condition, trucks that are overweight of the posted bridge weight limit must divert around the bridge and all traffic must divert when the bridge is flooded. The diversion mileage was estimated for each bridge using GIS for the shortest alternate route. The diversion is conservative, as a vehicle that originates or is destined closer to the bridge location would take a longer detour than the average through traffic. See Exhibit 5 for an example of the routes estimated for each bridge. The blue dot is the bridge, and the yellow route is the through-route that a vehicle intends to travel, but because the bridge is posted or flooded, the vehicle must take the longer red route (Detours). The difference in mileage between the red and yellow route is the net detour used in the analysis.

Exhibit 5 – Example Detour Route



Source: AECOM GIS

The annual average daily traffic (AADT) for each bridge was provided by NCDOT and the number of trucks that divert due to posted weight limits were estimated using existing AADT, truck percentages, and growth rates. Multiplying the number of trucks diverted daily by 365 to get annual traffic and by the net diversion results in the annual VMT saved under the Project.

In addition, VMT is saved during flood events. Emergency services providers in Ashe County note that the bridges flood 6 times per year for a duration of time provided in NCDOT TIMS data by bridge; therefore, the

detours due to flooding for all vehicles are factored by the LOS change from the No Build to the Build. The ***duration*** of flooding and bridge closure are assumed to decrease by 50 percent in the Build compared to the No Build, which is based on TIMS data. The product of the AADT and mileage of net detours is the VMT avoided by the Project.

Multiplying the AADT by the bridge closure time for construction (up to 7 days per bridge) provided by NCDOT and the net diversion mileage results in the additional VMT incurred during the construction period.

Net VMT is found by offsetting the additional VMT incurred during construction against the VMT avoided from reduced flooding. The rates of crashes that result in fatalities, injuries, and property damage are applied to the net annual VMT to derive the estimated crashes from the change in VMT. The crash rates for fatalities, injuries, and property damage are County-specific rates from NCDOT data.[3]

These crash rates multiplied by the VMT avoided were then valued based on USDOT guidance for injury, fatal, and PDO crashes. Exhibit 4 provides the estimated cost of different types of crashes. ***The total reduction in highway fatalities, injuries, and PDO results in $1.8 million in benefits, discounted at 7 percent.***

Safety Improvements at Bridges

In addition to the safety benefit from changes to VMT, the replacement of the bridges results in safety benefits from bringing the bridges up to current design standards. The bridges are out of date and lacking the safety features and designs of today's bridges. Three improvements will be made to the new bridges: first, guard rail will be added and replaced up to AASHTO standard; second, the bridges will be widened; and third, horizontal alignments will be altered to the degree possible.

NCDOT estimated that a 32% reduction in fatal and injury crashes and an 18% reduction in PDO crashes would occur at the bridges once replaced.[4] NCDOT provided crash data within 500 feet of the bridges over a five-year period. Data were provided for fatal and injury crashes of type A, B, and C, and PDO and unknown crashes. The reduced crashes were valued based on USDOT guidance and are listed in Exhibit 4. Only four bridges experienced crashes since 2013, including Structure 960730 where two pedestrians were struck and killed in June 2021.[5] The existing bridge does not have sidewalks, but the replacement structure will. ***The total safety improvements at bridges result in $4.2 million in benefits when discounted at 7 percent.***

In addition, the Project bridges will be replaced at higher elevations where possible, reducing the likelihood of wash-out and improving hydraulic conveyance. They are likely to reduce upstream flooding, possibly affecting open farmland and forest areas. These benefits were not quantified for this BCA.

Emergency Access Benefit

Emergency services provide vital services to communities, such as fire response and emergency medical care. The ability for emergency services to respond quickly is essential to reducing damages and decreasing injuries and fatalities. Currently, emergency response is delayed due to the flooding of the bridges.

The FEMA method for estimating the loss of emergency services was used to estimate the benefits of the Project.[6] Due to the flooding, the analysis assumes that emergency response is delayed by 30 minutes

[3] See Appendix A at the end of this document
[4] NCDOT, Crash Reduction Factor (CRF) Information, Traffic Safety Unit, July 21, 2020, https://connect.ncdot.gov/resources/safety/TrafficSafetyResources/NCDOT%20CRF%20Update.pdf
[5] McKenith, DaVonte, WXII 12, "Wilkesboro Police arrest woman in deadly hit & run case," June 10, 2021, https://www.wxii12.com/article/2-dead-hit-and-run-suspect-wanted-bodies-found-under-wilkesboro-bridge/36642386
[6] Presented in the USDOT's Benefit-Cost Analysis Guidance for Discretionary Grant Programs and described in FEMA's Benefit-Cost Analysis Re-Engineering (BCAR), Development of Standard Economic Values Version 6.0, December 2011, https://files.hudexchange.info/course-content/ndrc-nofa-benefit-cost-analysis-data-resources-and-expert-tips-webinar/FEMA-BCAR-Resource.pdf

for an average population of 100, based on conversations with Ashe County Emergency Medical Services (EMS). EMS may take the detour route or an alternate such as through the woods via all-terrain vehicle, depending on the emergency and location. The value of emergency access was factored by the frequency of floods based on each bridge's improvement in LOS from the No Build to Build and change in flooding duration per incident. The duration of flooding is based on a conservative 50 percent reduction to the TIMS data per bridge. Population growth is expected to growth at 1 percent annually for the duration of the analysis period.

With the bridges reconstructed, the net results are positive safety benefits for the Project due to the faster response time. ***The emergency access benefit totals $0.3 million discounted at 7 percent.***

State of Good Repair

The Project would result in state of good repair benefits by removing auto trips from the region's roads and saving in maintenance expenses.

Roadway Maintenance Savings

An increase in auto VMT during construction incurs additional roadway maintenance costs, such as painting and paving. The roadway maintenance cost savings is negligible per auto VMT on rural highways, as obtained from the FHWA Highway Cost Allocation Study. Like autos, trucks incur more VMT during construction but save VMT once the bridges are open. The FHWA Highway Cost Allocation Study values roadway maintenance cost per mile at $0.015 for a 40-kip truck. Multiplying the auto and truck VMT by the maintenance costs per VMT results in roadway maintenance savings. ***Roadway maintenance savings are negligible, discounted at 7 percent.***

Bridge Repair Costs Avoided

When the low-water bridges flood, the bridges incur damages. NCDOT provided estimates of the costs for debris removal, inspection, and repairs per flooding event in the No Build and Build. For each flooding event, NCDOT would save $1,500 (2020$) in repair costs, while debris removal and inspections would remain the same. Based on TIMS data on flood durations, the improvement in LOS in the Build compared to the No Build, and the costs of repairs for the floods, the ***bridge repair costs avoided amount to $4.5 million discounted at 7 percent.***

Bridge Current Maintenance Costs Avoided

The bridges are in need of maintenance investments in order to bring them into a state of good repair. NCDOT estimated the costs of these necessary repairs that would be made in the next six months. As such, the analysis assumes these costs are incurred in 2022. If the bridges are reconstructed, these costs would be avoided. ***Bridge current maintenance costs avoided amount to $0.1 million, discounted at 7 percent.***

Economic Competitiveness

The Project would produce economic competitiveness benefits by allowing vehicles to take a more direct route, resulting in travel time savings, auto travel cost savings, truck operating cost savings, and congestion reduction benefits. The remaining value of the Project is captured by the residual value. Vehicles would avoid waiting at single-lane bridges because the bridges would be upgraded to two lanes if they are not already.

Travel Time Savings Detours

Because autos must travel longer routes during the construction period, they incur travel time delays. Assuming a 55 mile per hour travel speed on both the through-route and the detour route, the average travel time loss was estimated for the annual traffic volumes. Multiplying the annual hours lost by the

average vehicle occupancy (1.67) and the personal value of time ($17.80 in 2020 dollars), as found in Exhibit 4,[7] as well as the change in frequency and duration of flooding events, yields the total travel time savings. ***The total travel time savings for the Project amounts to $0.6 million discounted at 7 percent.***

Travel Time Savings - Bridge Lanes

Travel time is saved for vehicles that utilize the one-lane bridges.[8] Assuming one minute of delay for five percent of the AADT per bridge, ***the travel time savings for bridge lanes totals $0.2 million discounted at 7 percent.*** Note that no benefit accrues for bridges 960012 and 960730 because they each already have two lanes.

Auto Travel Cost Savings

The longer auto trips during construction also result in negative travel cost savings, while reduced detours due to flooding events saves auto VMT in the Build. Travel cost savings was estimated using a cost savings of $0.45 per reduced auto VMT as recommended by USDOT guidance. ***Auto travel cost savings amount to $0.5 million discounted at 7 percent.***

Residual Value

Construction of the new bridges results in residual value after the end of the 20-year analysis period because the useful life of the bridge is 75 years.[9] The full value of the right of way acquired for the Project was also included in the residual analysis. It was assumed that 75 percent of the capital costs for construction are for bridge infrastructure. The remaining value of the bridge and right of way acquired was summed and discounted from the last year of the 20-year analysis period. ***The value of the remaining useful life for the Project discounted at 7 percent is $3.8 million.***

Truck Operating Savings

Based on the additional truck VMT incurred during construction and the long-term truck VMT savings from avoiding detours when the bridges' posted weights increase and when the bridges flood, the net truck operating savings is calculated. The savings per mile of $0.94 in 2020 dollars is recommended by USDOT guidance. ***The total truck operating savings for the Project amounts to $3.4 million discounted at 7 percent.***

Congestion Reduction Benefit

The net VMT savings due to the reduction in the number of detours results in to reduced road congestion. The value of roadway congestion per mile on rural interstates is $0.026 for autos and $0.067 per for trucks, as provided by USDOT guidance. ***The total congestion reduction benefit for the project are negligible, discounted at 7 percent.***

Environmental Sustainability

The Project would result in net environmental sustainability benefits by temporarily increasing auto and truck VMT during construction but reducing VMT in the long-term by avoiding detours during flooding events and detours due to posted bridges.

[7] USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, March 18, 2022 https://www.transportation.gov/office-policy/transportation-policy/benefit-cost-analysis-guidance-discretionary-grant-programs-0

[8] Bridges greater than or equal to 20 feet in width can accommodate two lanes. 21 bridges are one-lane.

[9] Source: USDOT Bridge Preservation guide, Maintaining a State of Good Repair Using Cost Effective Investment Strategies, August 2011, page 2, http://docplayer.net/11349542-Bridge-preservation-guide-maintaining-a-state-of-good-repair-using-cost-effective-investment-strategies.html

Additionally, the majority of the Project bridges were constructed with chemically treated timber, which leaches pollutants into the region's waterways, threatening sensitive wildlife species, such as the Eastern Hellbender salamanders, and ecosystems, such as trout watersheds. Furthermore, many existing bridges contain lead-based paint or primer, which can deteriorate over time and be introduced to the region's waterways and soils through exposure from the affected bridges. The Project will remove sources of environmental contamination to improve water quality and the replacement bridges will have concrete, rather than timber decks, which offer longer lifecycles and decrease contaminate exposure. Replacing the bridges will also ensure that lead based paint is properly removed and disposed of during construction. ***While these measures will increase sustainability by helping to mitigating public health concerns for environmental justice communities, the benefits were not quantified in this analysis.***

Emissions Savings

The increase in auto and truck VMT will result in a temporary increase in emissions during the construction period, but the reduction in VMT after the bridges open results in overall emissions savings for the long-term. The two are netted in this analysis.

The avoided VMT decreases the amount of annual nitrogen oxides (NOx), sulfur oxides (SOx), particulate matter ($PM_{2.5}$), and carbon dioxide (CO2) in the atmosphere. Auto and truck emissions rates (g/mile) are estimated based on the California Air Resources Board (CARB) On-road Emissions Rates model, which was run to estimate the long-term change in emissions rates. CARB projected annual emission rates were used to estimate emission for 2020-2050 by applying the appropriate annual rates to the annual VMT avoided.

The tons of reduced emissions were monetized using the recommended values as shown in the Environmental Sustainability section of Exhibit 4. ***In total, the Project results in $0.03 million in emissions savings, discounted at 7 percent.*** The value of CO2 avoided was discounted at 3 percent.

Quality of Life

The ability to easily move large farm equipment and trucks among fields and roadways allows agricultural producers to conduct their work more efficiently. The improved efficiency allows farmers to reduce transportation costs and be more profitable, supporting rural incomes. In addition, the reduced VMT from detours also results in noise reductions.

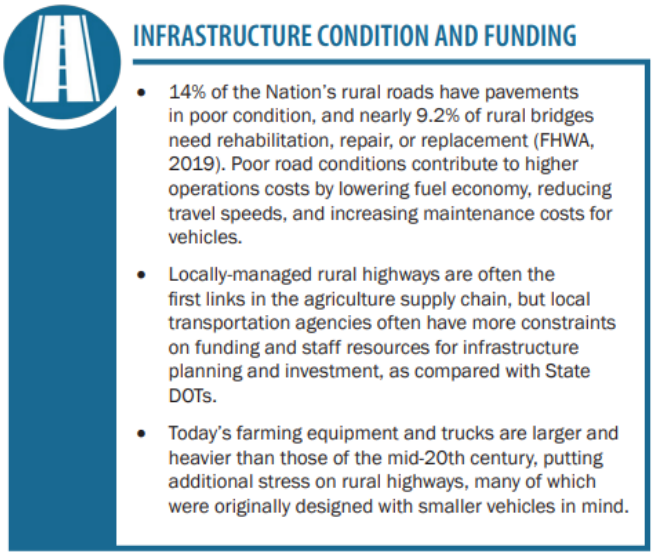
Agricultural Access

The Project benefits the farms that are nearby by allowing trucks to take more direct routes to and from markets and also allowing farm equipment and products to move around more efficiently within and between farms. The improved access during flooding also means tourists destined for the local Christmas Tree Farms, for example, can travel more easily and further support the region's agricultural interests. The agricultural access benefit quantifies the increase in farm efficiency that can be realized with an improved transportation network. Western North Carolina is well-known as a destination for tourists seeking to cut their own Christmas trees, and the state produces over 20 percent of the nation's Christmas trees. Most of the trees grown in the region are Fraser Fir and they are shipped to every state in the U.S. as well as internationally.[10] The trees are transported from farms by a variety of trucks ranging from dry van trucks, refrigerated trailers, open trailers, and flatbeds. One of the ways for producers to keep shipping costs down is to get drivers in and out quickly and by reducing stops and handling as much as possible.[11] Therefore, an efficient transportation network through reliable routes that can accommodate heavy trucks reduces the burden on growers. Transportation's importance to agriculture is show in Exhibit 6.

[10] North Carolina Christmas Tree Association, North Carolina Christmas Tree Facts, https://ncchristmastrees.com/tree-facts/

[11] ZMODAL, "Logistics of Christmas Tree Shipping," December 15, 2020, https://zmodal.com/2020/12/15/logistics-of-christmas-tree-shipping/

Exhibit 6 – Transportation Infrastructure and Agriculture



Source: USDA The Importance of Highways to U.S. Agriculture, December 2020, https://www.ams.usda.gov/sites/default/files/media/Main_Highway_Report.pdf

Despite evidence that the transportation network has an important and direct impact on the cost of transporting goods:

> "A highly competitive and efficient transportation system results in lower shipping costs, smaller market margins for middlemen, and more competitive export prices. Such efficiencies also result in lower costs for U.S. consumers and higher market prices for U.S. producers," [12]

It is difficult to quantify the cost savings that could be attributable to reconstructing the Project bridges. The United States Department of Agriculture estimates North Carolina's farm services[13] expenses make up 10.2 percent of production costs. A portion of these costs, estimated to be 3.5 percent, would be impacted by the Project. Based on 2017 county average total farm production expenses,[14] converted to 2020 dollars and estimating each bridge replacement affects 5.5 percent of the farms in the county,[15] the average expense savings considering the number of farms results in the total annual agriculture access benefits. The annual reduction in expenses was held constant throughout the analysis period by county. This improved efficiency allows farmers to be more profitable, supporting rural incomes. ***In total, the Project results in agricultural access benefits of $32 million when discounted at 7 percent.***

Noise Reduction Benefits

Vehicles saving VMT by avoiding detours during flooding periods with improved bridges will lead to a reduction in the amount of noise emitted by vehicles, which is estimated at $0.0002 per mile for autos and $.0033 per mile for trucks ($2020) per USDOT guidance. The disbenefit created by construction detours are also accounted for. ***The total noise reduction benefit for the project is negligible, discounted at 7 percent.***

[12] USDOT Federal Highway Administration, Public Roads – Summer 2019, https://highways.dot.gov/public-roads/summer-2019/farm-table
[13] Farm services is a summation of all crop custom work, veterinary custom services, transportation costs, marketing charges, insurance, leasing of machinery and equipment, utilities, general expenses, and miscellaneous business expenses.
[14] USDA County Summary, Crop and Livestock Cash Receipts by County, https://www.nass.usda.gov/Statistics_by_State/North_Carolina/Publications/Annual_Statistical_Bulletin/AgStat/Section06.pdf
[15] NCDOT, Identifying Bridges Critical to North Carolina Agriculture and Commerce, February 3rd, 2021 https://connect.ncdot.gov/projects/research/RNAProjDocs/RP2020-20_Final%20Report.pdf

Mobility and Connectivity

Many of the low-water bridges are unusable when flooded, meaning that people with no alternative routes to leave their home must forgo any trips they would make on a day with flooding. This has an economic and societal cost, which would be minimized through the improvement of said bridges. Therefore, the project would reduce the number of trips not taken due to flooding, leading to residents being better connected with the region physically and economically.

Trip Not Taken

There is value in trip-making; otherwise, trips would not be made. Likewise, there is a value for trips that are not taken, and the cost is primarily in productivity and economic activity. The value of a trip not taken is estimated using FTA guidance, which assumes a 12-hour penalty for each one-way trip lost.[16] To be conservative, this analysis uses 6 hours per one-way trip lost. The analysis estimates the value of the loss in productivity for each trip that is not made. The avoidance of this loss is a benefit for the region.

When a trip is not made, the productivity and spending impacts associated with that trip are lost to the region. It is assumed that no trips can be made when the bridges flood because there is no detour option for the populations stranded by a dead-end. Trips not taken are valued based off of the bridge AADT, auto occupancy, and frequency and duration of flood savings with the Project. ***The value of trips not taken avoided during flooding closures totals $16.7 million discounted at 7 percent.***

5. Cost Analysis

The Project has two cost components: the initial capital costs and ongoing operating and maintenance (O&M) costs.

Capital Costs

The capital costs for the Project include the costs for right of way, utilities, design, and construction. Six bridges receive conduit for future fiber installation[17] and six bridges receive flood gages.[18] [19] The capital costs are applied over the individual project construction periods, beginning in 2024 and ending in 2028. Capital costs were estimated in 2020 dollars, using the GDP deflator from USDOT guidance where necessary, resulting in a total cost of $48.3 million. The individual project costs are expended equally over the construction periods and the bridges range in cost between $773,000 and $11.6 million (2020$). ***The total capital costs for the Project discounted at 7 percent are $33.1 million.***

Annual Operating and Maintenance Costs

The Project requires annual and periodic O&M expenditures to maintain the new bridges, but the replacement bridges would result in O&M savings from the No Build. In the No Build and Build, the cost to maintain the bridges was estimated by NCDOT for each bridge, considering spending records and expected reductions in spending from the improvements. In addition, O&M costs for flood gages is $2,460 (2020$) per year for the six bridges where they will be installed. ***The net O&M savings over the analysis period and discounting at 7 percent is $1.4 million.***

[16] Federal Transit Administration, How to Use the FTA HMCE Tool, 2017, https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/funding/grant-programs/emergency-relief-program/60461/fta-hmcetooluserguide-mar2017.pdf
[17] 040047, 040093, 040480, 130130, 960012, and 960730
[18] 040047, 040226, 040509, 130275, 940319, and 960012
[19] The narrative and this memo use the U.S. Geological Survey (USGS) spelling of “gage” per the agency’s use in its standard discharge records.

6. BCA Results

The analysis results in a total Project Benefit Cost Ratio (BCR) of 2.10 when discounted at a rate of 7 percent. Exhibit 7 displays a summary of the BCA results for the total Project.

Because each rural bridge has independent utility, a separate BCA was developed for each bridge. The individual results go up to 11.79 at a 7 percent discount rate. While three of the 28 bridges do not cross a 1.0 BCR threshold at 7 percent, all but one reflect a BCR over 0.85 —a high bar for rural low-volume bridges. Importantly, the bridges surpass the 1.0 threshold as a group, indicating the Project benefits justify the cost. The reason some bridges do not result in BCRs over 1.0 is primarily due to the high cost of the bridge replacement and/or the low AADT in these rural areas (40-80 vehicles per day), resulting in lower net benefits than would be the case if there were more traffic on the bridges. Although there is low traffic on the bridges, they are still important for the populations and farming communities that rely on them for access to the regional economy. Exhibit 8 shows the BCR for each bridge individually.

Exhibit 7 - BCA Results for Total Project

Total Project	7% Discount Rate
Costs (2020 $M)	
Capital Cost	$33.1
Total Costs	*$33.1*
Benefits (2020 $M)	
Safety Benefits	
Reduced Roadway Fatalities and Crashes	$1.8
Safety Improvements at Bridges	$4.2
Emergency Access Benefit	$0.3
Sub-Total	$6.3
State of Good Repair Benefits	
Roadway Maintenance Savings	$0.0006
Bridge Repair Costs Avoided	$4.5
Bridge Current Maintenance Costs Avoided	$0.1
Sub-Total	$4.6
Economic Competitiveness Benefits	
Travel Time Savings Detours	$0.6
Travel Time Savings Bridge Lanes	$0.2
Auto Travel Cost Savings	$0.5
Residual Savings	$3.8
Truck Operating Savings	$3.4
Congestion Reduction Benefits	$0.030
Sub-Total	*$8.6*
Environmental Sustainability	
Emissions Savings	$0.03
Sub-Total	$0.03
Quality of Life	
Agricultural Access Improvement	$32.0
Noise Reduction Benefits	$0.0003
Sub-Total	$32.0
Mobility and Connectivity Benefits	
Trip Not Taken	$16.7
Sub-Total	$16.7
Net Operating & Maintenance Costs	$1.4
Total Benefits	*$69.5*
Outcome	
Net Benefits (2020 $M)	$36.4
Benefit-Cost Ratio	**2.10**

Exhibit 8 – BCA Results for Each Project

Bridge ID	BCR (7% Discount Rate)
40351	0.90
960340	6.17
960341	5.34
40048	1.63
40093	1.81
40463	0.85
20082	1.02
940319	10.15
40477	1.54
130130	1.41
50091	2.00
40343	1.62
40183	1.49
130317	2.60
130185	2.93
130186	3.31
130275	2.93
40304	2.96
40466	1.86
40509	1.15
40226	1.44
40480	2.00
960655	11.79
40047	2.59
960691	6.96
130349	5.43
960012	0.57
960730	1.58

Appendix A List of Supporting Documents

AECOM, “BCA.xls” excel workbook

FEMA Benefit-Cost Analysis Re-Engineering (BCAR), Development of Standard Economic Values Version 6.0, December 2011, https://files.hudexchange.info/course-content/ndrc-nofa-benefit-cost-analysis-data-resources-and-expert-tips-webinar/FEMA-BCAR-Resource.pdf

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USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, March 18, 2022 https://www.transportation.gov/office-policy/transportation-policy/benefit-cost-analysis-guidance-discretionary-grant-programs-0

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ZMODAL, “Logistics of Christmas Tree Shipping,” December 15, 2020, https://zmodal.com/2020/12/15/logistics-of-christmas-tree-shipping/

Crash Data by County:

NCDOT, Allegany County 2020 County Profiles https://connect.ncdot.gov/resources/safety/Documents/Crash%20Data%20and%20Information/2020%20Alleghany%20County%20Crash%20Profile.pdf

NCDOT, Ashe County 2020 County Profiles

https://connect.ncdot.gov/resources/safety/Documents/Crash%20Data%20and%20Information/2020%20Ashe%20County%20Crash%20Profile.pdf
NCDOT, Avery County 2020 County Profiles
https://connect.ncdot.gov/resources/safety/Documents/Crash%20Data%20and%20Information/2020%20Avery%20County%20Crash%20Profile.pdf
NCDOT, Caldwell County 2020 County Profiles
https://connect.ncdot.gov/resources/safety/Documents/Crash%20Data%20and%20Information/2020%20Caldwell%20County%20Crash%20Profile.pdf
NCDOT, Watauga County 2020 County Profiles
https://connect.ncdot.gov/resources/safety/Documents/Crash%20Data%20and%20Information/2020%20Watauga%20County%20Crash%20Profile.pdf
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