U.S. 70 COMBINED REPORT

THE NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

PREPARED BY

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CAMBRIDGE SYSTEMATICS

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STATE OF NORTH CAROLINA · DEPARTMENT OF TRANSPORTATION

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Definition of Terms

The following section provides definitions for key terminology used throughout the report.

Adaptive Capacity: The degree to which the system containing the asset (road, bridge, etc.) can adjust or mitigate the potential for damage or service interruption.

Climate Variable: A characteristic of the climate that affects the transportation system. The climate variables most often analyzed in a transportation vulnerability assessment are temperature, precipitation, sea level, and river discharge.

Comprehensive Transportation Plan (CTP): State mandated long-range transportation plan for municipalities, counties, and large metropolitan areas (MPOs).

Criticality: Definitions of criticality according to the FHWA are difficult to implement and depend on the lens through which they are being evaluated. NCDOT worked to develop criticality indicators specific to the assets along U.S. 70.

Exposure: The degree to which a transportation asset (roadway, bridge, etc.) experiences a hazard.

Indicator: An indicator is a representative data element that can be used as a proxy measurement of the overall exposure, sensitivity, or adaptive capacity of a specific asset.

Infrastructure Investment and Jobs Act (IIJA): IIIJA is the latest federal reauthorization bill signed into law on November 15, 2021. The bipartisan bill includes several new requirements under the PROTECT (Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation) program supportive of resiliency considerations in statewide and metropolitan planning.

Metropolitan Planning Organization (MPO): Represents the policy board of an organization designated to conduct the metropolitan transportation planning process. MPOs represent localities in all urbanized areas with populations over 50,000 as determined by the U.S. Census.

Metropolitan Transportation Plan (MTP): The MTP is a federally required long-range transportation plan overseen by MPOs that considers all transportation modes

and defines the policies, programs, and projects to be implemented over the next 20 years. By federal law, MTPs are updated every four years.

Resilience: The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions (NCDOT Resiliency Policy).

Risk: A combination of the likelihood that an asset will experience a particular climate impact, and the severity or consequence of that impact.

Sensitivity: The degree to which an asset is damaged, or service is interrupted by a climatic hazard.

Strategic Highway Network (STRAHNET): The U.S. Department of Defense's (DoD's) 62,791-mile system of roadways deemed necessary for emergency mobilization to support U.S. Military operations.

Strategic Transportation Corridors (STC): NCDOT has identified 55 highway corridors deemed to be of high priority in achieving state development goals, and in 2013 developed policy for the STC and corridor network.

Transportation Asset Management Plan (TAMP): A strategic framework for considering the full life cycle cost and performance of transportation infrastructure. The TAMP documents considerations for preserving the entire network of bridge and pavement assets.

Vulnerability: The extent to which a transportation asset or system is susceptible to sustaining damage from hazards during extreme events. Vulnerability is a function of the extent to which an asset or system is exposed to damaging forces; its sensitivity to those forces; and its adaptive capacity.

Vulnerability Assessment and Adaptation Framework (VAST): FHWA's VAST Framework provides transportation agencies with a process and tool to assess the vulnerability of transportation infrastructure and systems to extreme weather and climate effects. Link to user's guide: **https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/**

1.0 Executive Summary

The U.S. 70 Strategic Transportation Corridor (STC) is a high-priority transportation corridor in eastern North Carolina that serves as both a priority highway freight network and a hurricane evacuation route for the state. It also provides connections to critical facilities including three military bases, the Port of Morehead City, and the Coastal Carolina Airport.

In 2022, NCDOT began a pilot study of the U.S. 70 Corridor from the Wake County/Johnson County line to the community of Atlantic in Carteret County using the U.S. DOT's Vulnerability Assessment Scoring Tool (VAST). VAST was designed to help state, regional, and local transportation agencies assess the impacts of climate change and extreme weather events on their transportation systems. VAST is an indicator-based assessment of a roadway's vulnerability to extreme heat and flooding (both inland and coastal) for two scenario-year timelines (2030 and 2050).

A second phase was added called VAST+ which supplemented the results of VAST by conducting additional analysis to validate specific flood-prone locations identified by NCDOT based on historic climate events (such as Hurricane Dorian).

Along with the VAST, the U.S. 70 Vulnerability and Risk Assessment includes an assessment of asset criticality. Criticality assesses a transportation asset's importance to the functioning of the transportation system and in meeting the needs of users.

Both assessments use qualitative and quantitative methods and data, including anecdotal information from a stakeholder survey and data on metrics ranging from asset usage to surrounding demographics.

The Criticality and Vulnerability scores along the corridor were equally weighted to produce a composite score, and then grouped into high, moderate, lower, and limited criticality and vulnerability categories. The resulting scores indicated that the most vulnerable and critical segments of US 70 are near Smithfield, Goldsboro, Kinston, northwest of New Bern, and in segments along the coast east of Morehead City (see Figure 1-1). The highest scoring segments (3.26, 3.34 and 3.38) are just south of Kinston in Lenoir County, just north of Goldsboro in Wayne County, and just north of Smithfield in Johnston. While the lowest scoring segments (1.04, 1.08 and 1.11) are between Havelock and New Bern in Craven County.

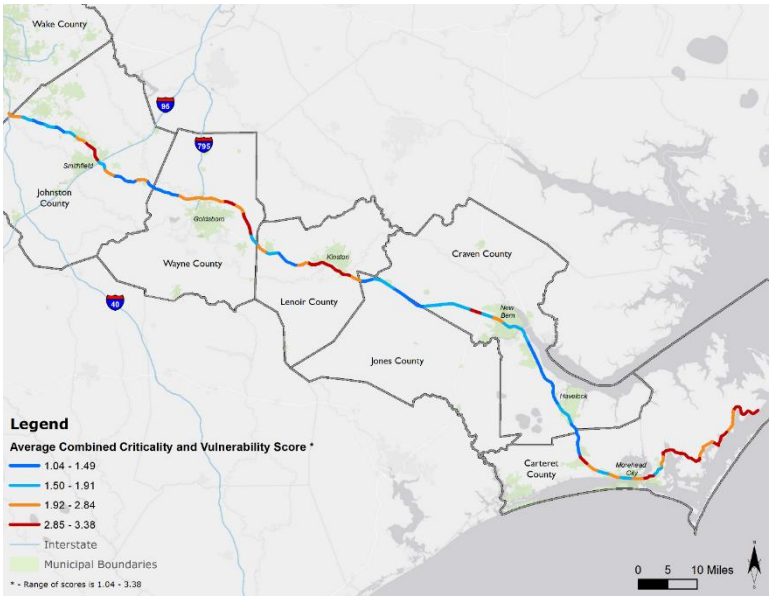

Figure 1-1. Combined Vulnerability and Criticality Score

The study outcomes and uses can inform the lifecycle of facility improvements from project conception, project development, prioritization and programming through maintenance and operations. Information provided to NCDOT in this document is not intended to be prescriptive but should serve as consideration for further study and evaluation. Instead, the results can be used as input to the traditional methods of project development and programming (such as CTP, MTP development and the SPOT Process).

2.0 Introduction

2.1 Background and Purpose

The North Carolina Department of Transportation (NCDOT) is addressing the resilience of the state's transportation network incorporating resiliency into policy development, planning and project development and academic research. NCDOT has taken steps to respond to Governor Cooper's Executive Order 80 (EO 80) Section 9 and the 2020 NC Climate Risk Assessment and Resilience Plan (2020 Plan) by addressing climate and non-climate stressors to make transportation more resilient by adapting to changing conditions, managing risk, and protect, maintain and bolster the state's multimodal transportation network.

The NCDOT adopted a Resilience Policy in 2021, as part of its broader mission to connect "people, products and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina." NCDOT applies FHWA's definition of resiliency, which is "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions." With the Resiliency Policy, NCDOT pledged to take active steps to manage risk and strengthen the transportation system against natural and manufactured hazards. Link to NCDOT Making Transportation Resilient: https://www.ncdot.gov/initiatives-policies/Transportation/transportation-resilience/Pages/default.aspx

The NCDOT has developed resilience goals and objectives to cooperatively plan, construct, operate, and maintain a safe, efficient, and resilient transportation network that is captured in its annual Resilience Strategy Reports. One of its objectives is to identify and pilot risk and vulnerability assessments to guide resilience efforts across the spectrum of NCDOT activities. NCDOT received funding from Session Law 2019-251- SB 356 to assess flood risk and conduct vulnerability assessments on the Strategic Transportation Corridor System and engaged a consulting team to conduct a Vulnerability and Risk Assessment (VRA) to evaluate the 170-mile Strategic Transportation Corridor (STC) U.S. 70.

U.S. 70 STC moves a significant amount of freight and people while linking critical centers of economic activity to international air and seaports, supporting interstate commerce. U.S. 70 functions as the Eastern spine of North Carolina by linking three military bases, the Port of Morehead City, the Global TransPark and Coastal Carolina Airport. NCDOT recently received federal approval to designate U.S. 70 bypasses in

Johnston, Wayne, and Lenoir counties as Interstate 42. The study corridor spans from the Wake County/Johnson County line to the community of Atlantic in Carteret County (see Figure 2-1). In addition to supporting the day-to-day activities of the region, U.S. 70 is a hurricane evacuation route, and part of the Strategic Highway Network (STRAHNET).

The NCDOT selected the U.S. Federal Highway Administration (FHWA) National Assessment and Adaptation Framework (the Framework) developed in 2017 to conduct a pilot vulnerability assessment of the U.S. 70 Corridor. The Framework was designed to help state, regional, and local transportation agencies and partners assess the impacts of climate change and extreme weather events on their transportation systems. The Vulnerability Assessment Scoring Tool (VAST) was developed as part of the Framework to assist users in identifying and better understanding the vulnerability of their assets based on different indicators and time scenarios. The findings are intended to help NCDOT Divisions, units MPOs and RPOs incorporate climate adaptation considerations into their decision-making and to plan for, build, and maintain more resilient transportation infrastructure and systems.

Figure 2-1 U.S. 70 Project Corridor

Along with the VAST, the U.S. 70 VRA includes an assessment of asset criticality. Criticality assesses a transportation asset's importance to the functioning of the transportation system and in meeting the needs of users. Both assessments use qualitative and quantitative methods and data, including anecdotal information from a stakeholder survey and data on metrics ranging from asset usage to surrounding demographics.

This report provides an overview of the methodology applied to the VAST and criticality assessment, and crucially, key findings and recommendations from the combined analysis for U.S. 70. The analysis utilizes past, present, and future climate variables to better understand the transportation assets along the corridor that are most important and most vulnerable to future climate events. These insights can inform strategic, timely decisions at key stages of NCDOT's preconstruction process and maintenance and restoration of operations during major events. *The Criticality Technical Memorandum* and *VAST Technical Memorandum* are available for more detailed documentation of each assessment.

3.0 Study Conclusions

This section is intended to identify and discuss opportunities and potential uses of the criticality and vulnerability and outcomes from the U.S. 70 study. There are opportunities spanning across both NCDOT responsibilities as well the work of state agencies and local partners. The study outcomes and uses can inform the lifecycle of facility improvements from project conception, project development, prioritization and programming through maintenance and operations. Information provided to NCDOT in this document should not be considered prescriptive but should serve as consideration for further study and evaluation.

3.1 Potential Impacts to NCDOT

This section discusses the findings and impacts to NCDOT associated with the vulnerability and criticality study. This includes but is not limited to, who is impacted, where the impacts are highest, and how data can be used by those responding to specific areas. It is important to note that this study includes an additional evaluation of roads from past events (referred to as VAST+) that have flooded over half a foot which has been added to the understanding of road impacts found in the Vulnerability study.

The scoring results of the study can be integrated into current and future transportation planning by NCDOT in several ways. The Identification of corridor sections that are both highly critical and highly vulnerable can help with project identification, development, and support through planning, scoping, prioritization, and programming. Comparing outputs with demographics can provide an understanding of underserved and underprivileged communities whose recovery could be impacted by a road closure either directly from the cost of rebuilding or indirectly from loss of income from inability to travel or lack of access. Criticality could be incorporated into the traditional NCDOT project development process and

expanded to coordinate with other state and local agency plans. Other coordination and uses include:

Comprehensive Transportation Plan (CTP) Development: The study limits of the U.S. 70 corridor traverse six counties from the Wake/Johnston County line to coastal Carteret County. Each county's CTP adoption predates the establishment of NCDOT's resilience practice and policy. Therefore the U.S. 70 study outcomes (along with other locally lead risk and vulnerability assessments) can serve as input into the development of future CTP updates. As noted below NCDOT's Transportation Planning Division (TPD) is preparing a Resilience Guide to introduce system risk and vulnerability reviews within CTP development including the review of corridor study outcomes which bisect the area and form the basis of early environmental data collection and review. Folding the study outcomes into CTP development will continue to provide visibility and attention to high criticality and vulnerability-scored segments as part of identifying and early scoping of future project improvements and state/local partner engagement.

Metropolitan Transportation Plan (MTP) Development: The study limits of the U.S. 70 corridor traverse three MPO areas – Capital Area MPO (CAMPO), Goldsboro MPO, and New Bern MPO. Similar to CTPs the outcomes of the U.S. 70 can serve as inputs to MTP updates in each of these areas. MTPs are updated every 4 years with minimum 20-year plan horizons and by federal law must consider strategies that "improve the resiliency and reliability of the transportation system and reduce or mitigate stormwater impacts of surface transportation" in the long-range planning process. The criticality and vulnerability scored segments are a starting point to review system risks, needs, and performance and recommend cost-feasible project priorities that address long-term mitigation strategies. The three MTP update cycles will vary so the study outcomes also provide an opportunity for information sharing and resilience-based reviews between each MPO.

TPD Resilience Guidance: TPD is undertaking a project to formalize resilience reviews within each step of the five-step CTP development process. The study will recommend resilience-based checklists, questions, data sharing, and coordination opportunities that include quantitative data and qualitative input (survey, stakeholder expertise, NCDOT Highway Division input, etc.). CTP recommendations can be screened against the results of the U.S.70 study and other county, or municipality-led risk and vulnerability assessments. The Guidance is expected to recommend the creation of a Resilience Features Map as part of "CTP Step 2 – Conduct Needs Assessment" to highlight and inventory transportation assets impacted by prior events, critical to equity communities and/or suspectable to future events and therefore flagged as a system deficiency to address. The Reliance Features Maps are anticipated to include other environmental data, folded within the CTP report where needed, and will be compared to existing environmental map requirements. This information will be shared with Project Development & Environmental Analysis (PDEA) to inform alternative analyses. This is a crucial step to

bridge resiliency-assessed outputs from long-range plans to inform NEPA, particularly the first two steps of the concurrence process.

Strategic Transportation Prioritization (SPOT): The SPOT Process is the methodology that NCDOT uses to incorporate projects developed by CTPs and MTPs into the State Transportation Improvement Program (STIP). The process involves scoring all roadway, public transportation, bicycle, pedestrian, rail, and aviation projects on several criteria. Projects that score highly are included in the STIP, which is used for project funding. Incorporating criticality and vulnerability scores from this assessment can bolster the support for future projects through data-driven identification of roadway segments that need improvements, or new location projects that could improve factors such as coastal evacuation and roadway redundancy. This topic is expected to be reviewed as part of the Prioritization 8.0 Workgroup (or P8.0) starting in the fall of 2024.

Asset Management and Maintenance: The outcomes of this study can also identify and focus maintenance and improvement efforts, as well as potentially help attract federal funding for maintenance projects. The outcomes of the criticality and vulnerability assessment can be incorporated into the annual Transportation Asset Management Plan (TAMP), a strategic framework for considering the full life cycle cost and performance of transportation infrastructure which is required as part of MAP-21. The development of a TAMP is meant to ensure that states are using a data-driven approach to expending federal funds. The data-driven nature of the criticality and vulnerability assessments can make it a logical input into the risk management analysis conducted as part of the TAMP to mitigate a high-priority risk. Sections of roadways that score high on criticality and vulnerability can help direct asset management investment in those areas to address resiliency and response issues related to natural disasters.

Division-Level Assistance: The outcomes of this study could be used to inform NCDOT Division-level activity and response. The Divisions provide on-the-ground knowledge and validation of observed events and flood records (as incorporated in the VAST+ study) and serve as liaisons to coordinate state and local efforts to review proposed solutions to flood-prone assets under the highest criticality and vulnerability-scored segments. U.S. 70 study outcomes should be shared with Division 2, 4 and 5 staff who can in turn further investigate and scope an appropriate response. The range of responses could include targeted fixes through Division-managed funds or for the longer term, large-scale solutions as noted in the STIP gap analysis section.

Local Risk and Vulnerability Assessments: Several state, regional and local initiatives are underway in eastern North Carolina to establish resilience-based plans, projects, and strategies to strengthen community response in the face of growing environmental threats and position for state and federal recovery funds. The Resilient Coastal Communities Program (RCCP) is a grant program administered by the NC Division of Coastal Management (NCDCM) which supports the preparation of Risk and Vulnerability Assessments (RVA). Craven County completed its first RVA in

2022. New Bern, in a separate but related effort, completed its augural Resiliency and Hazard Mitigation Plan in 2022 which outlines hydrologic conditions, flood risks, and mitigation strategies – including critical transportation assets for increased community resilience. The U.S. 70 study outcomes should be shared with these local partners (and other counties developing hazard mitigation plans along the corridor) to foster coordinated information and data sharing. Future updates to these local plans could also be coordinated with scoping future STIP or Division-managed multimodal transportation projects to achieve mutual resiliency goals. One of those goals could include a review of both state and local transportation investment considering underserved and socially vulnerable populations. Greater engagement and coordination opportunities across state and local agencies include:

- **NC Regional Hazard Mitigation Plan Phase –** the Division of Emergency Management (NCEM) within the Department of Public Safety (DPS) coordinates regional hazard mitigation planning which integrates strategies across several counties and municipalities. This level of coordinated planning enhances the ability of localities to qualify and secure Federal Emergency Management (FEMA) funds. These efforts help mitigate the loss of life and property from disasters but also focus on responsive actions, including critical infrastructure assets. NCDOT can share the outcomes of this study, including additional project planning and environmental analysis of gap areas highlighted in Section 4 with the State Hazard Mitigation Branch. This step would build upon coordination already taking place between NCEM and NCDOT to share hazard-related data for pre-event and post-event planning. Deeper integration of cross-agency mitigation activities can avoid future conflict with deed-restricted property and other community, or natural sensitive assets based on proposed transportation improvements in the locations of concern.
- **Regional Resiliency Project Portfolio –** the Eastern Carolina Council of Governments and NC Office of Risk and Recovery have advanced a forward-looking vulnerability assessment to strengthen regional resiliency. The Eastern Carolina Vulnerability Assessment recommends five to 10 high-priority projects across several infrastructure categories including transportation to singularly focus responsive strategies for the nine-county region. U.S. 70 runs through five of the nine counties and outcomes of this study can be cross-referenced with the regional priorities to work in lockstep towards meeting state, regional and local goals. Scoping reviews of current and future STIP projects (identified in Section 4) compared to regional priorities could further validate and refine improvements that address data-driven, and stakeholder-identified areas of concern.
- Deeper integration of cross-agency mitigation activities can avoid future conflict with deed-restricted property and other community, or natural sensitive assets based on proposed transportation improvements in the locations of concern.

- Scoping reviews of current and future STIP projects (identified in Section 4) compared to regional priorities could further validate and refine improvements that address data-driven, and stakeholder-identified areas of concern.

4.0 Assessment

The U.S. 70 study included two separate assessments. The first was a criticality assessment which scored the individual segments in the corridor based on a set of indicators that measured the importance of the segment in the transportation network. The second was a vulnerability assessment that measured the vulnerability of the segments to extreme weather and climate effects indicators. The outcomes of the two assessments can help transportation decision-makers prioritize and implement effective mitigation and adaptation strategies. The two assessments are summarized below.

4.1 Criticality Approach, Key Inputs and Findings

Key Findings

Criticality is higher around the municipal areas along the corridor including Smithfield, Goldsboro, Kinston, New Bern, and Morehead City, as seen by the orange and red coloring in **Error! Reference source not found.** This is to be expected as these areas are of high U&O, SE, and H&S importance to the corridor. This combination of high-scoring categories represents areas that would be important for NCDOT to prioritize in terms of ensuring reliability and functionality. There are additional areas of higher criticality along the eastern end of the corridor due to indicators related to proximity to coastal assets (i.e., Port), low redundancy, and high tourism spending.

The segments have been organized into Low, Medium, and High Criticality based on the spread of the data with 28 segments being considered Low, 29 segments as Medium, and 28 segments as High (Figure 4-1).

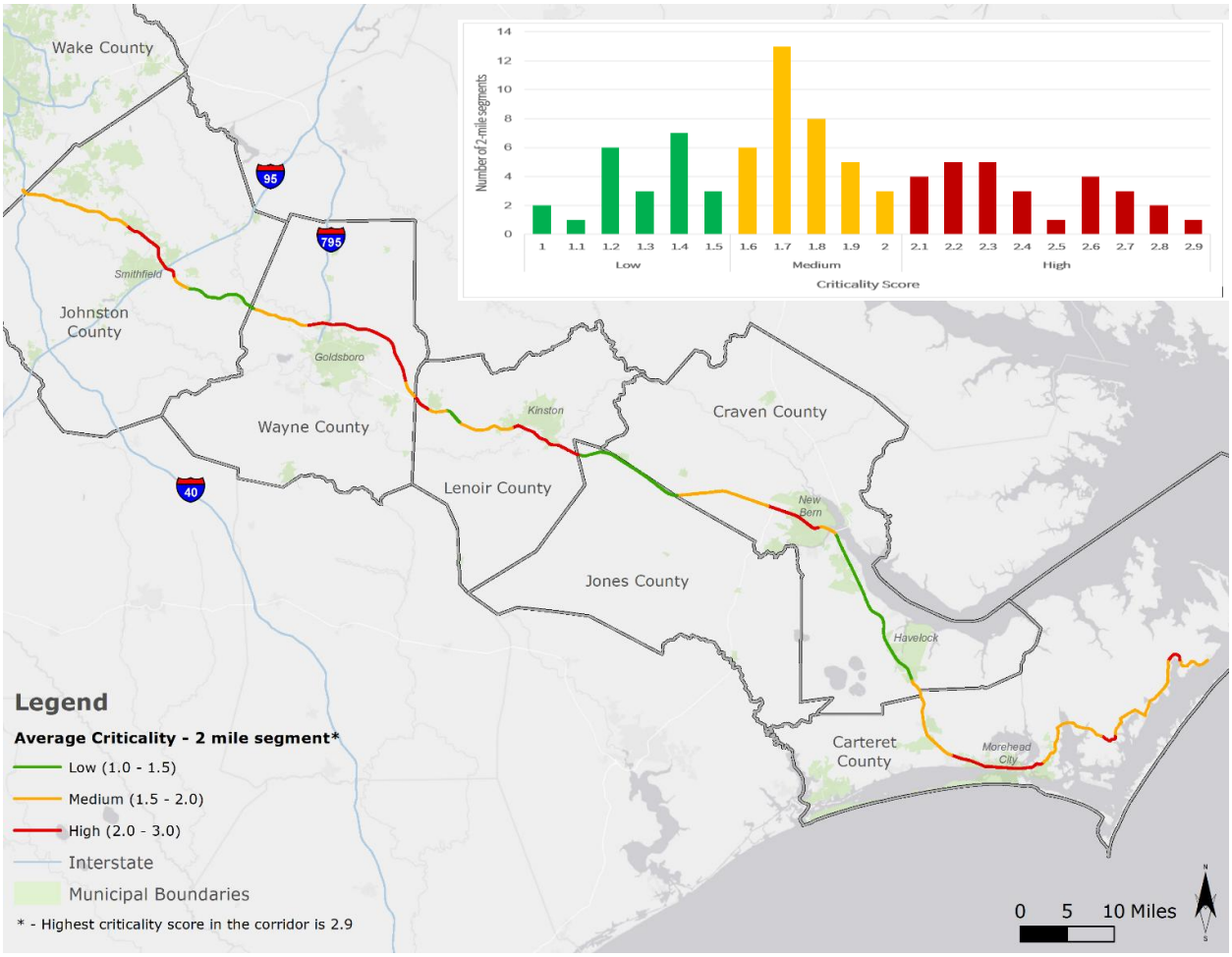

Figure 4-1. Overall Criticality of U.S. 70

Study Assets and Indicators

As a part of the Strategic Transportation Corridor (STC) U.S. 70 Vulnerability Assessment, the team reviewed the criticality of the roadway segments and access roads along this STC. The Criticality Assessment was run on the primary roadway of U.S. 70. The roadway was divided into 2-mile segments, resulting in 85 segments assessed for criticality.

Asset criticality determination provides a basis for establishing which assets are the most important for the transportation system's functioning. Assessments of criticality often reference risk, but critical assets in the context of a climate change vulnerability assessment are intended to include those assets that if disrupted, inflict some significant impact. These assets may serve as emergency evacuation routes, be of economic importance, provide access to healthcare facilities, provide equitable social connectivity, or support other local or regionally important needs.

For this assessment, indicators are grouped as per FHWA VAST guidance into Usage and Operational (U&O), Socioeconomic (SE), and Health and Safety (H&S) importance. The individual indicators used in the assessment are shown in Table 4-1.

Table 4-1. Indicators used in the Criticality Assessment

Usage and Operational Indicators	Socioeconomic Indicators	Health and Safety Indicators
• Truck Traffic (AADTT) • Redundancy Connectors	• Equity Areas • Tourism Expenditures • Employment Density • Proximity to Military Bases, GTP, and Port	• Proximity to Hospitals • Proximity to Utility Plants • Proximity to Emergency Shelters

Each indicator group has a score based on its indicators. Indicator scoring was scored on a 0 to 4 scale to align with the VAST where 4 represents the asset being more critical and 1 being less critical. The following are the calculations used for each indicator group that applies equal weighting to the indicators of that group.

Usage and Operational (U&O) Score = (Truck Traffic Score * 50%) + (Redundancy Connectors Score * 50%)

Socioeconomic Score = (Equity Areas Score * 25%) + (Tourism Score * 25%) + (Employment Density Score * 25%) + Proximity to Military Bases/GTP/Port Score * 25%)

Health and Safety (H&S) Score = (Proximity to Hospitals Score * 33%) + (Proximity to Power Plants Score * 33%) + (Proximity to Emergency Shelters * 33%)

The following is the overall criticality score calculation methodology that uses equal weighting between the indicator categories.

Criticality Score = (U&O Score * 33%) + (Socioeconomic Score * 33%) + (H&S Capacity Score * 33%)

For detailed information on the indicators and methodology, see the *U.S. 70 Criticality Memorandum* and for details on the datasets including exact names and years, please review the *U.S. 70 Existing Conditions Technical Memorandum*.

4.2 Vulnerability Assessment Scoring Tool (VAST) Approach, Key Inputs and Findings

Stressors, Assets, and Indicators for Vulnerability

The NCDOT transportation asset and NC climate data inventory (supplemented by TAC survey results) defined the assets and climate stressors needed to run VAST. The assessment includes six assets (Roads, Access Roads, Bridges, Pipes, Rail Lines, and Critical Buildings) and three climate stressors (Temperature, Coastal Flooding, and Inland Flooding) that reflect the unique conditions along the U.S. 70 corridor. The Vulnerability assessment included not only the main U.S. 70 corridor but also NCDOT pertinent assets and the access roads leading to these assets (see Figure 4-2).

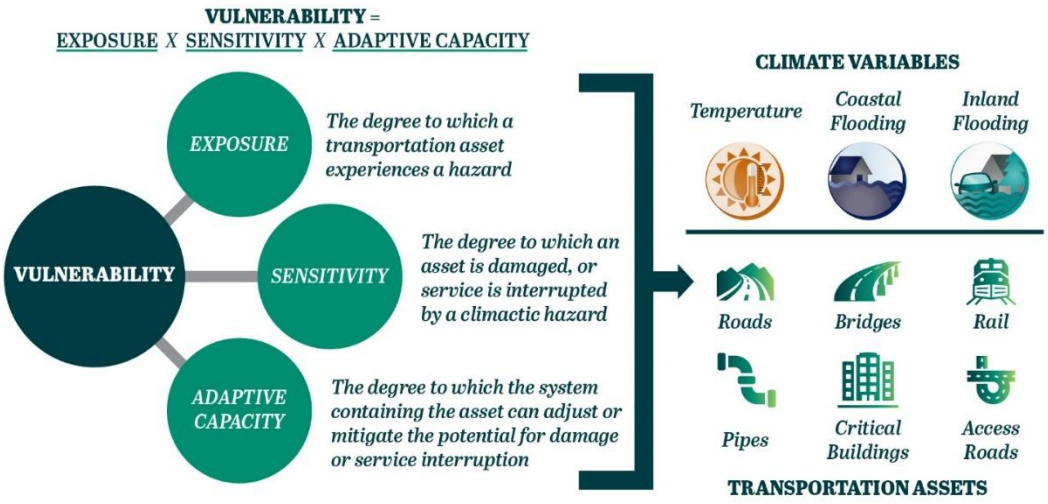

Figure 4-2 Vulnerability Assessment Approach

Selection of indicators and supporting datasets across all transportation assets and climate stressors are needed to support the Exposure, Sensitivity, and Adaptive Capacity analysis. The FHWA outlines the following definitions for Exposure, Sensitivity, and Adaptive Capacity:

- Exposure: the nature and degree to which an asset is exposed to significant climatic variations.
- Sensitivity: the degree to which an asset is affected, either adversely or beneficially, by climate-related stimuli.
- Adaptive Capacity: the ability of a system (or asset) to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

An inventory of potential indicators and supporting data for each stressor-climate pair were identified and refined using three criteria: Data Availability (related to dataset availability and robustness), VAST requirements (related to data readiness to load into VAST), and balance (related to balancing operational and scope components of running VAST).

Vulnerability Scoring

Across all climate stressors, over 95% of roads and bridges along the corridor are considered to have low-medium vulnerability risk. Table 4-2 provides the VAST composite scores across all climate stressors and assets for both the 2030 and 2050 scenarios. The tables provide further insights including vast scoring, mapping, and a set of observations presented by climate stressors across both scenarios.

Table 4-2. VAST Composite Scores Across All Climate Stressors

	Lowest Considered Scenario 2030				Highest Considered Scenario 2050			
Asset Type	Low VUL (%)	Low-Med VUL (%)	High-Med VUL (%)	High VUL (%)	Low VUL (%)	Low-Med VUL (%)	High-Med VUL (%)	High VUL (%)
Roads (miles)	151 (49%)	157 (51%)			125 (41%)	174 (56%)	9 (3%)	
Bridges (count)	90 (74%)	31 (25%)	1 (1%)		68 (56%)	53 (43%)	1 (1%)	
Access Roads (miles)	41 (63%)	24 (37%)			33 (51%)	32 (49%)		
Pipes (miles)	3.0 (74%)	1.0 (25%)	0.1 (1%)		2.8 (69%)	0.9 (23%)	0.3 (8%)	

Table Note: Buildings and Railroads are excluded from the table but included in the analysis for Exposure only. The lowest scenario considered is RCP4.5 for Coastal Flooding and Temperature, and RCP8.5 for Inland Flooding. The highest considered scenario is RCP8.5 for Coastal Flooding and Temperature, and RCP4.5 for Inland Flooding.

VAST +

The second phase of the assessment "VAST+" supplements the first phase by conducting an augmented analysis to review, process and incorporate past extreme weather events along the U.S. 70 corridor. The results of VAST+ augment the vulnerability scores produced by Phase I. This phase leveraged NCDOT's historic events data and the results of VAST to conduct sensitivity tests and incorporate indicators that amplify the importance of prior events as a contributing factor to assessing overall corridor vulnerability.

The VAST+ assessment included the flood inundation analysis of previous Historical flooding locations along or near the U.S. 70 corridor in comparison to four NCDOT datasets including:

- Coastal Roadway Inundation System (CRIS)—A planning tool for coastal road inundation based on intervals of static, level pool flooding along the NC coast.
- Roadway Inundation Tool (RIT)—A planning tool with estimated roadway inundation based on static flood recurrence intervals from FEMA studies.
- Flood Inundation Mapping Alert Network for Transportation (FIMAN-T)—A gauge-based tool providing near real-time awareness of flood impacts to roads and bridges within limited areas and around riverine and coastal gauges.

Indicators for the VAST + process and their weighting were Flood Inundation (70%), Return Period (10%), and Washout/Federal Reimbursements (20%). Based on the flood event analysis results, percent weight attributed to inundation (highest among all indicators) and the 0.5-foot threshold deemed impassable, unsafe and disruptive for system performance—the VAST+ findings recommended shifting 50 roadway miles and 36 bridges from the VAST application composite scores from low-limited-moderate to high vulnerability (Figure 4-3).

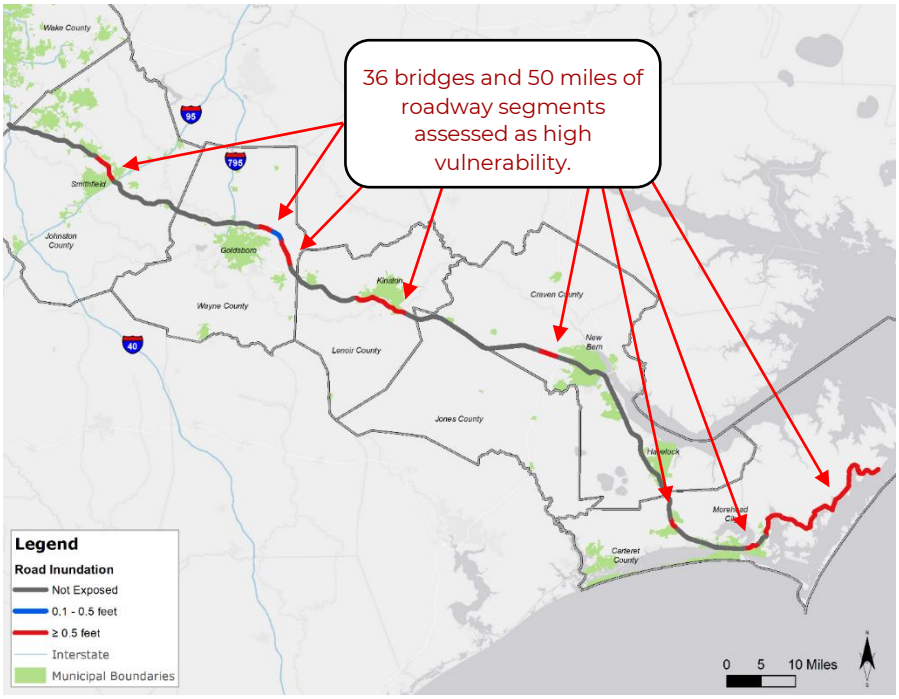

Figure 4-3 VAST+ Recommendations for High-Vulnerability Assets

Vulnerability Takeaways

A summary of top-line takeaways related to sensitivity, adaptive capacity, and exposure across all climate stressors are presented in Table 4-3 through Table 4-6. Each table highlights a set of results/observations and associated policy, program, or performance considerations.

Table 4-3. Sensitivity Top Line Takeaways

Results and Observations	Policy, Program, or Performance Considerations
The overall asset condition along the corridor is above the rest of the state.	Implement incremental responsive actions including: • Glenburnie Road Interchange Improvements (STIP, U-6102) • Radio Island Road/Newport River Bridge • Construction methods to complete Havelock Bypass (R-5777C)
Due to the current state of assets, there is a moderating impact on vulnerability - assets addressed as medium/high vulnerability are in poor condition.	• Implement proactive, scenario-based asset management. • Assess asset deterioration under variable impacts of extreme weather and frequency/magnitude of climate stressors.

Table 4-4. Adaptive Capacity Top Line Takeaways

Results and Observations	Policy, Program, or Performance Considerations
U.S. 70 network density is lower than the rest of the state and the bridge detour length is shorter than the rest of the state.	• Enhance redundancy and develop detour management plans to mitigate disruptions along critical facilities connecting to U.S. 70 • Prepare plans informed by criticality determination: Goldsboro Bypass, Jones County, Morehead City
Replacement costs: maintain native NCDOT segmentation range.	Prepare guidance for Strategic Transportation Corridors (STCs) to inform, and coordinate preliminary engineering and STIP decisions.

Table 4-5. Exposure Top Line Takeaways

Results and Observations	Policy, Program, or Performance Considerations
The change in days per year above 95°F increases by 15 in 2030 and 30 days in 2050. In addition, there is a moderating ocean effect on temperature change that contributes to the east/west divide at New Bern. **There is no overlap between Inland vs Coastal flooding**	• Evaluate aggressive extreme temperature responses west of New Bern. Institute inspection and monitoring of vulnerable sections. "Do nothing" risks exacerbate by 2050: • Infrastructure impacts - pavement softening, rutting, expansion of bridge joints, load restrictions • Maintenance/Operation impacts - limits on construction activities, worker safety • Assess evacuation planning - needs, washouts, debris removal

Table 4-6. Extended Building Analysis

Return Period (Yrs.)	Number of Buildings	Building Count Percent	Square Footage	Square Footage Percent
10	9,774	35.8%	23,832,270	33.6%
50	10,100	37.0%	26,355,138	37.1%
100	5,353	19.6%	15,191,782	21.4%
500	2,082	7.6%	5,576,972	7.9%
Total	27,309	100%	70,956,162	100%

-

5.0 Combined Scoring

The Resiliency assessment consisted of a combined scoring of Criticality and Vulnerability. The goal was to have a comprehensive understanding of the resilience of the roadway. An additional VAST+ assessment was done which included a historical evaluation of flooding extents along U.S. 70 to highlight roadway segments experiencing at least 0.5 feet of overtopping from prior storm events. The VAST+ results augment and further highlight locations of concerns vulnerable to travel disruption under future extreme events. Following the completion of the Vulnerability and Criticality Assessments (see *U.S. 70 Criticality Memorandum and U.S. 70 VAST Technical Memorandum*), the team combined the overall composite vulnerability score (across all climate stressors) with the composite criticality score per roadway segment. The combined assessment identifies segments of transportation assets most susceptible to climate stressors, but also critical to sustain reliable transportation mobility, access, and regional-based economic activity along the corridor. The roadway segments determined to be highly critical and

vulnerable should be considered high risk and require further improvement or adaptation measures to contribute to a resilient transportation corridor.

The Criticality and Vulnerability scores were equally weighted to produce a composite score, and then then grouped into high, moderate, lower, and limited criticality and vulnerability categories. This combination resulted in a composite score of between 1.04 (Limited Criticality and Vulnerability) and 3.38 (High Criticality and Vulnerability). Table 5-1 shows the combined score. These values reflect the lower values in data seen in the Vulnerability and Criticality Assessments. Information on these values is further defined in *The Criticality Technical Memorandum* and *VAST Technical Memorandum*.

Table 5-1 Vulnerability and Criticality Scoring - Roadways

Asset Type	Limited Crit. and Vuln. (%) Score: <1.49	Lower Crit and Vuln. (%) Score: 1.50 – 1.91	Moderate Crit. And Vuln. (%) Score: 1.92 – 2.84	High Crit. And Vuln. Score: 2.85 – 3.38
Roads (miles)	22 (25.8%)	21 (24.7%)	21 (24.7%)	21 (24.7%)

Criticality and Vulnerability Score = (Criticality Score * 0.5) + (Vulnerability Score * 0.5)

The results in Figure 5-1 show the higher scoring segments near Smithfield, Goldsboro, Kinston, northwest of New Bern, and in segments along the coast east of Morehead City. The highest scoring segments (3.26, 3.34 and 3.38) are just south of Kinston in Lenoir County, just north of Goldsboro in Wayne County, and just north of Smithfield in Johnston. While the lowest scoring segments (1.04, 1.08 and 1.11) are between Havelock and New Bern in Craven County.

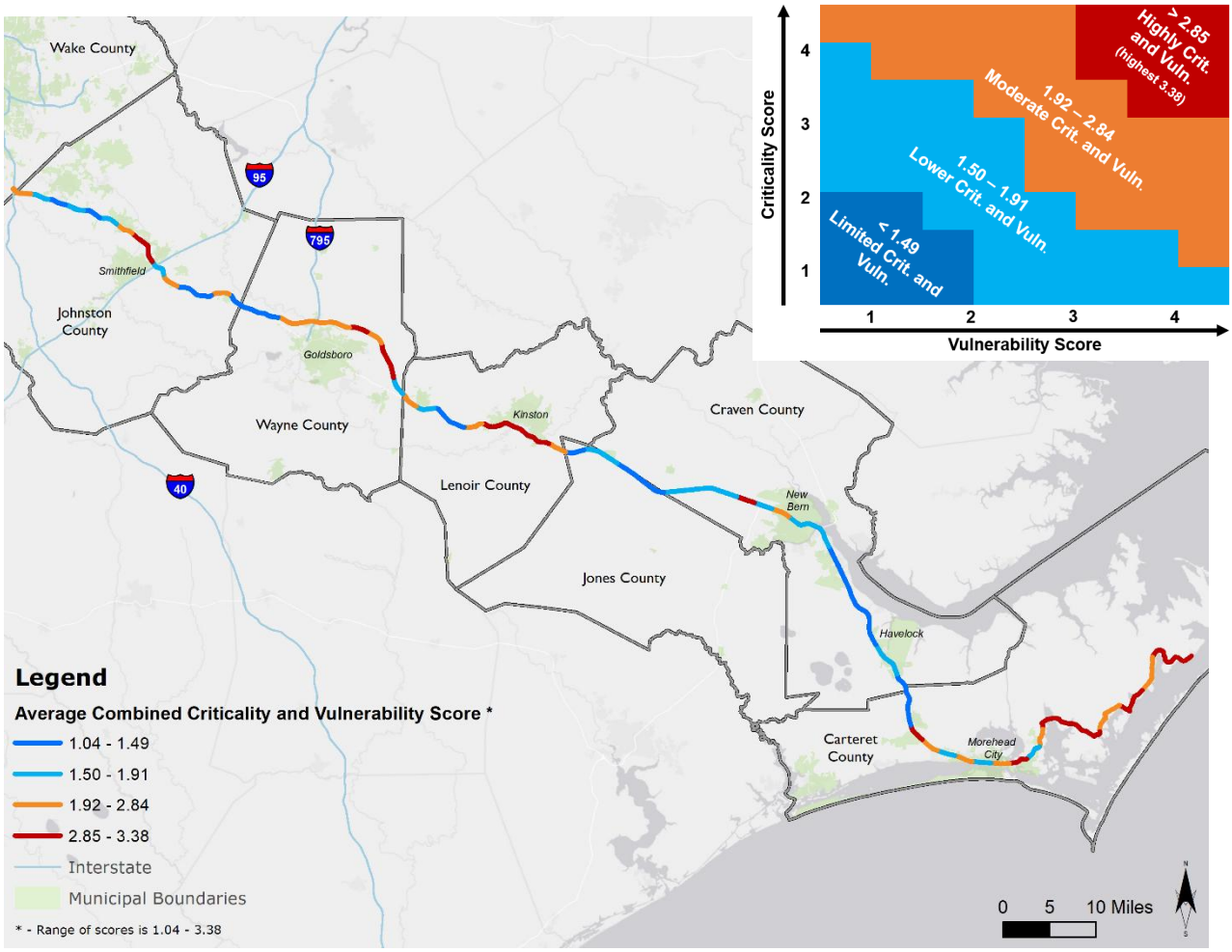

Figure 5-1 Combined Criticality and Vulnerability Score along U.S. 70

5.1 STIP gap analysis

A gap analysis was conducted to compare 2024-2029 STIP committed projects to the combined Criticality and Vulnerability results along the corridor. This step was taken to review where future capital improvements overlap locations of concern from Table 5-1 and conversely where gaps exist, i.e., where no project is programmed in a high Criticality and Vulnerability area. This exercise is independent of ongoing maintenance and Division Design Construct-funded activities advanced through NCDOT Divisions along the corridor. Obtaining details of those activities is beyond the scope of this analysis but once mapped could augment the findings. Figure 5-2 indicates three locations where STIP roadway widening, and pavement rehabilitation improvements are anticipated to address immediate high criticality and vulnerability concerns. Those locations and STIP projects are:

- East of Smithfield to the Johnston/Wayne County line (R-5718, I-6044, U-5726)
- Southwest to southeast of Kinston (R-2553B, R-2553C)
- East of Morehead City (R-4746)

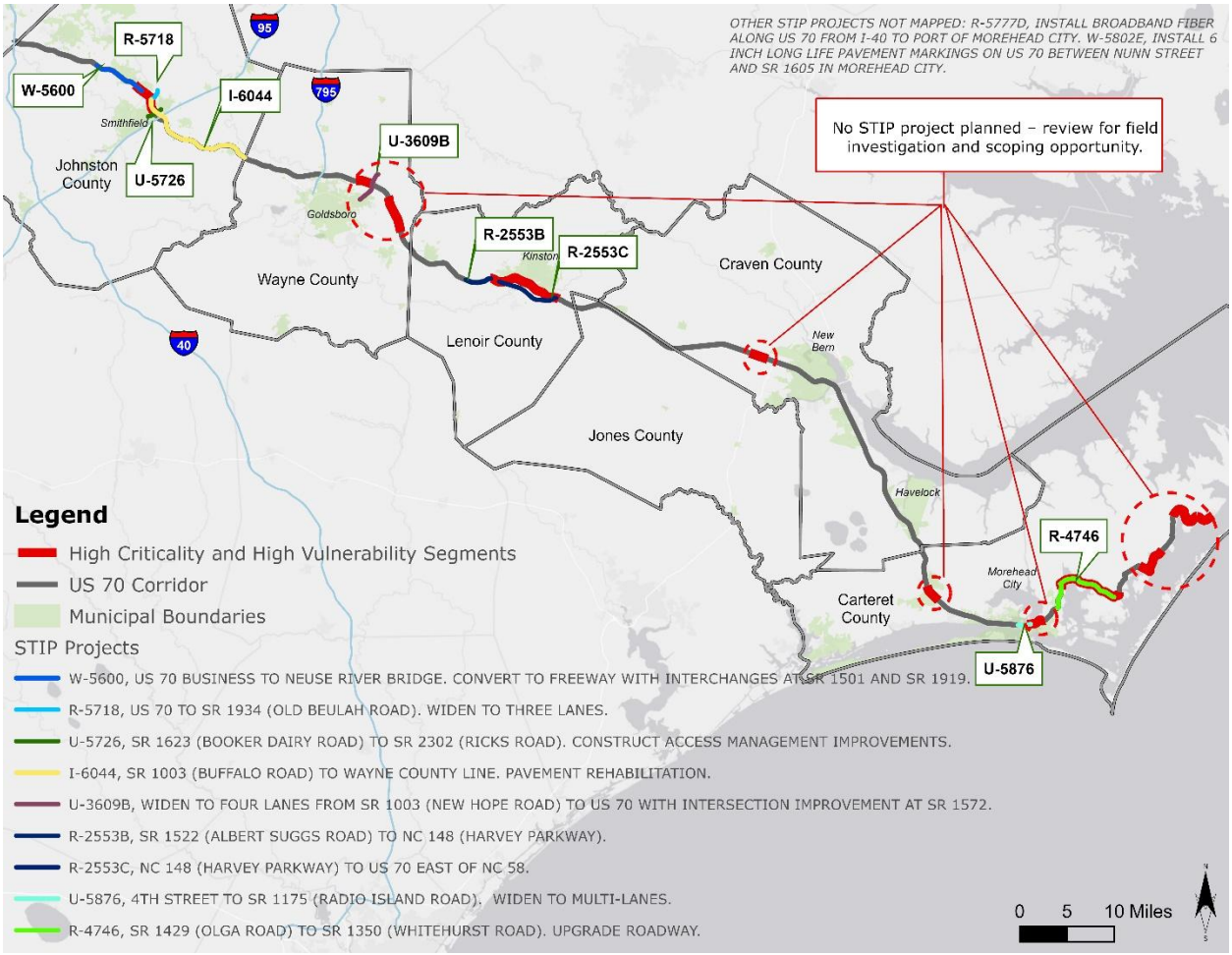

Figure 5-2 High Criticality and Vulnerability to STIP Project Gap Analysis

Table 3-2 lists five high criticality and vulnerability locations where no STIP projects are programmed. These locations offer NCDOT an opportunity for further field investigation and feasibility review to determine optimal scope activities and investment - capital, reconstruction, rehabilitation, expanded maintenance or other actions required to harden and strengthen roadway infrastructure to withstand future events. Table 5-2 also describes the risk focus and hazard exposure that could inform these decisions.

Why is this important? Mainly because the gap analysis results provide a path forward to coordinate scoping activities with federal, state, and local partners along the corridor. As noted earlier several resilience-focused plans and actions have been studied or underway in eastern NC through NC DPS, NCDEM, NCORR and counties along U.S. 70. Efficient, safe, and reliable travel along U.S. 70 during major events remains critical to the US Department of Defense and NC Ports Authority who are long-standing key stakeholders of freight movement and military mobilization in the corridor. NCDOT can share gap analysis results and coordinate scoping options with these partners to surface data-sharing, resource and potential cost-sharing opportunities not otherwise realized in isolation. The increased level of coordination

can enhance NCDOT's resiliency practice and serve as a model to follow for future studies. These efforts also help to bring together the perspectives and on-the-ground experience of partners whose insights combined with the assessment outcomes from desktop tools (such as VAST) provide a more comprehensive approach to resiliency and short- and long-term considerations for U.S. 70.

Table 5-2 STIP Gap Analysis

#	Location (Length in miles)	STIP Project in Proximity	Risk / Feasibility Review
1	East of Goldsboro to the Wayne/Lenior County line (5 miles)	U-3609B	• Vulnerable to roadway overtopping, scour risk to hydrologic structures and potential pavement integrity damage driven by heavy precipitation and inland flooding events. The New Bern and Newport segments are also vulnerable to storm surge and sea level rise.
2	West of New Bern to New Bern city limits (3 miles)	N/A	
3	Newport city limits (3 miles)	N/A	
4	East of Morehead City limits near Beaufort (3 miles)	U-5876	• Vulnerable to roadway overtopping, scour risks to hydrologic structures and potential pavement integrity damage driven by heavy precipitation, storm surge and sea level rise.
5	East of Beaufort to beyond the Marine Corps Outlying Landing Field (MCOLF) – 12 miles	R-4746	• Vulnerable to roadway overtopping, scour risks to hydrologic structures and potential pavement integrity damage driven by heavy precipitation, storm surge and sea level rise.

5.2 Conclusions Linked to RIP / PROTECT Funding

Recommendations and outcomes for this assessment were prepared for new resiliency planning requirements established under the federal Infrastructure Investment and Jobs Act (IIJA) within the Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) program guidance. Table 5-3 details how this Vulnerability/Criticality study responds to or applies to mandatory and optional requirements related to the development of Resilience Improvement Plan development under the PROTECT formula program guidance.

Table 5-3 U.S. 70 Vulnerability/Criticality Study and PROTECT Guidance Alignment

	PROTECT Guidance Contents for Resilience Improvement Plans (RIPs)	Elements Addressed by the U.S. 70 Vulnerability/Criticality Study
1	Encompass immediate and long-range planning activities and resilience investments	• Considers short and long-term planning horizons (years 2030 and 2050). • Conducted coordination with regional partners on projects and MTP projects rolled up into the State Transportation Improvement Program (STIP). • While the study's focus was on vulnerability and criticality assessments, coordination with other planning activities was incorporated through stakeholder feedback during vulnerability assessment (VA) development. This information will inform high-level NCDOT adaptation strategies and improvements.
2	Demonstrate a system-wide approach to transportation system resilience	• U.S. 70 study is a corridor assessment and within that context, a system-wide approach has been taken to address the resilience of the corridor by considering a range of assets, communities, and interconnections. • Multimodal assets were included in the assessment.
3	Consistent with and complement State and local hazard mitigation plans	• U.S. 70 study addressed high-priority hazards in the corridor that are consistent with and informed by local and State Hazard Mitigation Plans. • Study is consistent with State and local Hazard Mitigation Plans.
4	Include a risk-based assessment of vulnerability to current and future weather events and natural disasters	• VAST outputs combined with criticality determination from the VA serve as a starting point to evaluate risk implications in the future. • This assessment conducted additional modeling for projecting precipitation effects addressing the probability of hazard occurrence, along with a range of scenarios (RCPs low and high) that provide a broad framework for incorporating risk into decision-making. Past, present, and future climate variables have been considered in the study.
5	Describe ways to improve response to impacts and changes	• This Study directly incorporates sea level rise and future inland flood impacts. The VAST results, including vulnerability scores and criticality results, provide data that can be leveraged during hazard events to better inform decision-makers. VAST results can also be used to guide development of adaptation strategies.

		• Past hazard event information from BridgeWatch and Fiman-T are used to inform known areas of concern and previous locations and infrastructure that have been impacted. This has provided validation for a robust vulnerability assessment. • Criticality determination method also considered detour potential, which informs detour management plans or emergency planning purposes. Study results can help inform Continuity of Operations (COOP) plans and evacuation planning as part of how response to potential impacts can be improved.
6	Describe the codes, standards, and regulatory framework to ensure improvements	• Governor Cooper's Executive Order 80 (EO 80), EO 246, NCDOT's Resiliency Strategy Report and Resiliency Policy serve as proactive state-initiated responses to prepare for extreme natural hazards. • This state-level guidance on NC floodplain mapping was used as the input source for the VAST analysis.
7	Consider benefits of natural Infrastructure	• The NC floodplain mapping used to support the VA incorporated the impacts of flooding from both hard infrastructure and natural infrastructure features, such as wetlands impacts in flood flows. This mapping was primarily led by NC agencies in coordination with federal agencies such as FEMA and USACE. • The VAST outputs are also envisioned to be incorporated in future planning and infrastructure improvement efforts.
8	Assess community infrastructure resilience	• The VA assessed the exposure vulnerability of state-owned facilities and building footprints within a 10-mile radius of the corridor. • The NC Hazard Mitigation Plan can also be leveraged to broaden the assessment of other community assets in the future.
9	Use a long-term planning period	• The VA used planning scenarios for the years 2030 and 2050.
10	Designate evacuation routes and strategies	• The VA addressed evacuation routes, detours, and redundancy issues along the corridor. The Criticality Assessment included indicators to assess proximity to emergency services and shelters and redundancy connectors along the corridor.
11	Plan for response to anticipated emergencies	• While the VA did not directly address emergency response, the VAST output datasets can be leveraged to help inform emergency response and planning.

12	Describe the resilience improvement policies	• The VA provided vulnerability and criticality scores that can inform future decision-making on where to focus improvement strategies. • NCDOT's TAMP mentions the NCDOT Resilience Policy, project planning and selection, project examples, and flood management tools to improve resilience. • VAST output datasets can also provide supplemental information for NCDOT (HPMS) for bridges, pavements, and reliability.
13	Include investment plan & priority projects	• Investment plan is not included. However, a list of priority assets as a combination of vulnerability and criticality has been identified.
14	Use science and data	• Project relied on downscaled climate data - Localized Constructed Analogs (LOCA) from the National Climate Assessment and modeled data

5.3 Insights for future STC studies

Several state data sets, national and state DOT practice and potential for greater tool integration will shape the analytical rigor of future STC studies. The U.S. 70 study helps lay a foundation to also pilot analytical tools grounded through observed data and historical records. Insights drawn from scenario planning can also provide insights into the impact of adaptation on system performance. The following represents a few go-forward ideas for NCDOT consideration:

Tool Integration & Emerging Data: NCDOT and NCEM's resilience planning and reporting tools – referred to as Resilience Analysis Framework for Transportation (RAFT) – could be enhanced by the inclusion of the data produced by the U.S. 70 study. For example, including the criticality data in the Roadway Inundation Tool (RIT) would provide users with additional context information for the U.S. 70 corridor. Similarly, including the VAST+ assessment results would provide information on potential flooding impacts outside of the standard flood zones. Additionally, the VAST+ study used washout data from prior major hurricanes cross-linked to locations of FEMA expenditures as an indicator of system vulnerabilities and a starting point for further analysis. The VAST+ study also explored the use of bluespot modeling to map topographic depressions along and across U.S. 70 that have a higher propensity for ponding and thereby exacerbate the risk for overtopping and pavement damage. Bluespot is a widely accepted industry approach that could be added as another "tool in the NCDOT toolset." The application of this type of modeling combined with the expansion of Base Level Engineering (BLE) flood hazard data to cover two-thirds of the state in the next few years holds exciting possibilities to leverage RAFT and enhance analytical elements of STC studies and planning area RVAs. Future STC studies can also benefit from enhanced asset

information to evaluate vulnerable non-highway modes in the corridor such as passenger rail and transit.

Scenario and Event Planning – the future of scenario planning analysis could incorporate feedback loops between hydrologic models, RAFT tools and travel demand models traditionally used to develop long-range plans. Similar to economic and land use models the feedback loops allow for analysts to evaluate the change in system performance based on changes in travel demand. For resiliency, those "case studies" could include evacuation scenarios that test system redundancy and corridor performance. One example could include evaluating the vehicle miles traveled, travel time or hours of delay associated with diverting traffic off U.S. 70 and onto parallel routes to move travelers away from impending storms. Conversely, input assumptions between models could also determine what operational improvements are required to maintain a desired level of service along U.S. 70 (or other STCs) for detour planning. This could also apply to other service goals such as allowing a level of operation throughout for efficient freight travel and military mobilization during a major event or to maintain access to critical local facilities. Scenario planning that combines this type of analysis can foster even tighter integration and insights across various internal planning, project development, prioritization, and project delivery decisions.

Resilience Performance Metrics – the use of performance metrics to monitor and report transportation investment has increased rapidly over the last decade. Resiliency metrics are starting to be reviewed at several State DOTs and more national guidance to define and support the use of these metrics is forthcoming through the efforts of the Transportation Research Board (TRB) and National Cooperative Highway Research Program (NCHRP). Table 5-4 provides example performance measures for a roadway that could be incorporated into future STC studies to link resilience assessment outcomes to the effectiveness of adaptation strategies. **Proposed measures and strategies are for illustration only** and are provided here to demonstrate "next step" opportunities for NCDOT consideration. NCDOT would need to determine the level of data and policy decisions required to establish goals, objectives, and measures for each future corridor, but the outcomes could strengthen the case for strategy implementation and quantify the return on investment. Such approaches could also tie back to or seek consistency with statewide RIPs and performance measures could expand to include other assets over time such as bridges, pipes, access roads, rail/transit, and state-maintained structures.

Table 5-4 Linking Resilience Assessment to Reportable Outcomes

Roadway Asset Example for Future Corridor or Planning Area Study -- Illustration Only			
Climate Stressor	**Performance Metric Objective or Measure**	**Vulnerability/Criticality Assessment**	**Proposed Adaptation Strategy**
Extreme Heat	*"No more than __% of miles experience pavement buckling minimizing freight mobility disruption per year"*	__% of miles susceptible to pavement buckling at __ location(s) during extreme heat (>95 degrees)	Revise pavement treatment mix to withstand higher temperatures and maintain assets to a state of good repair. Update pavement maintenance and treatment cycles
Precipitation **Coastal / Inland Flooding**	*"__% of roadway miles reopen to traffic no more than __ hours after overtopping"*	__% of miles susceptible to flooding under 100/500-year events at __ location(s)	Define redundant roadways to divert traffic during events. Develop detour policies and expand incident management infrastructure to alert and reroute travelers during events

Precipitation **Coastal / Inland Flooding**	*"__number of access roads programmed in STIP to improve connectivity to equity populations and critical facilities (ports, military bases, maintenance yards)*	__% of "last mile" segments susceptible to flooding under __ event(s) at __ location(s)	Update project prioritization practice to include scoring criteria for access to underserved communities and critical localized facilities

6.0 Conclusion

The VAST findings along the US 70 corridor can be used by NCDOT to:

1. Identify Performance Level concepts assisting with asset management and maintenance to determine the areas of lowest resilience and greatest resiliency impact to improve transportation assets. This will drive future improvement determination and level of effort,
2. Agency-level concepts providing decision-level assistance for coordinated and consolidated programs and plans that work with one another for common resiliency goals, and
3. Planning /Prioritizing/Programming level concepts to assist with Local Risk and Vulnerability assessments taking into account demographics that can provide an understanding of underserved and underprivileged communities whose recovery could be impacted by a road closure either directly from cost of rebuilding or indirectly from loss of income from inability to travel or lack of access.

These concepts can lead to the ability for State and local areas to be more resilient. Providing the means to understand Who, where, and how citizens are impacted leading to results that can be used to plan, prioritize and program improvements. The methodology also presents a way to include the results of vulnerability and risk assessments into LRTP/CTP planning process and transfer lessons learned to local partners.