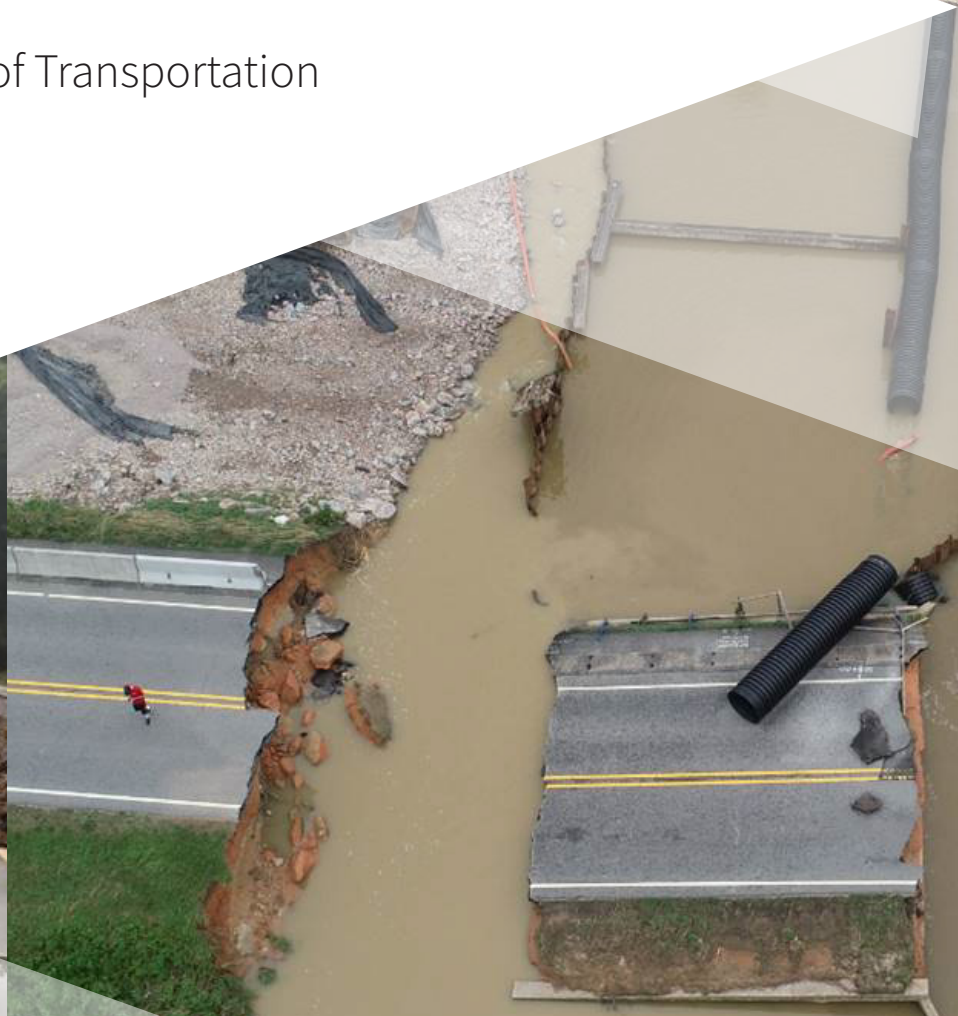
MARCH 2021
Annual Update

NCDOT Resilience Strategy Report

North Carolina Department of Transportation



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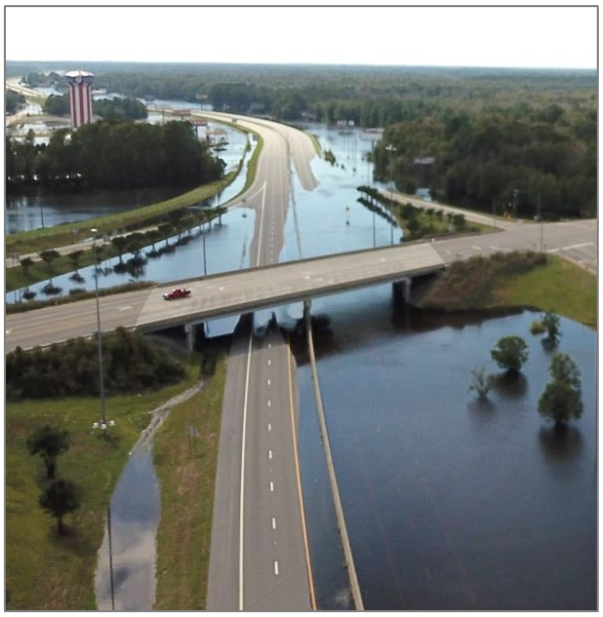
ACRONYMS

AREA	Absorptive, Restorative, Equitable access and Adaptive
ASSIST	Application for Site-Specific Information Storage and Tracking
BOT	Board of Transportation
CRC	North Carolina Coastal Resource Commission
CTP	Comprehensive Transportation Plan
DOT	Department of Transportation
EO	Executive Order
FHWA	Federal Highway Administration
FIMAN-T	Flood Inundation Mapping and Alert Network for Transportation
GCM	Global Climate Models
GIS	Geographic Information Systems
IPCC	Intergovernmental Panel on Climate Change
IPD	Integrated Project Delivery
MPO	Metropolitan Planning Organization
MTP	Metropolitan Transportation Plan
NC	North Carolina
NCEM	North Carolina Emergency Management
NCDEQ	North Carolina Department of Environmental Quality
NCDPS	North Carolina Department of Public Safety
NCDOT	North Carolina Department of Transportation
NCDWR	North Carolina Division of Wildlife Resources
NCHRP	National Cooperative Highway Research Program
NBI	National Bridge Inventory
NCORR	North Carolina Office of Recovery and Resilience
NOAA	National Oceanic and Atmospheric Administration
RP	Research Project
RPO	Rural Planning Organization
TPD	NCDOT's Transportation Planning Division
SERT	State Emergency Response Team
STC	Strategic Transportation Corridors
STIP	State Transportation Improvement Program
TIMS	Transportation Information Management System
USACE	United States Army Corps of Engineers
USDOT	U.S. Department of Transportation

1.0 Introduction



Flooding of I-95 in Robeson County

Transportation is the backbone of North Carolina's economy, connecting manufacturers with supply chains, consumers with products and tourism, and people with their workplaces, homes, and communities across urban, suburban and rural landscapes. High impact weather events and natural hazards disrupt the safety and reliability of North Carolina's multimodal transportation network. These weather events also stress resources to keep pace with the costs of infrastructure damage inflicted by intense and frequent storm and flood events.

NCDOT is responsible for the second highest number of state-owned highway miles in the country and contributes financial support to elements of non-highway improvements which can integrate resilience into transportation planning and measure resilience related outcomes across multiple modes. Recovery costs from Hurricanes Matthew, Florence and Dorian have siphoned resources from other important projects which, in turn, negatively impacts the N.C. Department of Transportation's (NCDOT's) cash balance and maintenance reserves. The COVID-19 global pandemic also introduced a new uncertainty that is altering transportation patterns and choices. Making transportation more resilient to climate and non-climate stressors will require a strategic planning approach, that adapts to changing conditions, manages risk and protects, maintains, and bolsters the state's transportation network.

The NCDOT is taking steps to incorporate Absorptive, Restorative, Equitable Access and Adaptive (AREA[1]) capacity to prepare and respond to the threat of natural hazards and extreme events by focusing more coordinated efforts on transportation resilience. These efforts – initiated through a multi-disciplinary approach and stakeholder input – are captured in NCDOT's Resilience Strategy Report (NCDOT Strategy). The NCDOT Strategy outlines existing initiatives and future short-, medium- and long-term steps to advance and deepen agency-wide resilience practice and capability. The NCDOT Strategy responds to Governor Cooper's Executive Order 80 (EO 80) Section 9 and the 2020 NC Climate Risk Assessment and Resilience Plan (2020 Plan), which calls for an annual report to communicate progress and accomplishments towards cabinet agency resilience goals and objectives.

NCDOT Resilience Strategy Report

The NCDOT Strategy is the department's inaugural resilience report and will serve as a "roadmap" to guide resilience awareness, potential policy amendments, practice enhancements, and investment decisions, using the AREA concept as a coordinating framework. It is anticipated that the NCDOT Strategy will evolve

[1] RAND report which introduces AREA concept -- https://www.researchgate.net/profile/Aaron_Strong/publication/336617146_Incorporating_Resilience_into_Transportation_Planning_and_Assessment/links/5dfa776692851c836485a91c/Incorporating-Resilience-into-Transportation-Planning-and-Assessment.pdf

over time, will be updated annually, and will be developed to advance NCDOT's multi-faceted 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." This first iteration of the NCDOT Strategy focuses on aligning goals and objectives. It looks to baseline an understanding of resilience terms and hazard types and to standardize the terminology used in activities moving forward. The NCDOT Strategy includes a review of completed and ongoing agency activities, studies, plans, as well as state and national tools for use in contextualizing the recommended strategies. A peer review of three other state departments of transportation (DOT)s has identified relevant practices that help to inform NCDOT as it pursues future resilience-related actions, such as vulnerability assessments or pilot studies.

The development of the NCDOT Strategy was heavily guided by engagement activities through online workshops, surveys and polling activities with key agency leadership, departments, units, and divisions, as well as regional planning partners. The N.C. Department of Environmental Quality (NCDEQ) and the Federal Highway Administration (FHWA) also participated in workshops to offer guidance and interagency coordination. The NCDOT Strategy proposes a high-level set of strategies to embed resiliency consideration, analysis and application through all NCDOT activities. These strategies will further catalyze multi-disciplinary efforts to incorporate resiliency awareness into key project life cycle stages.

Goals and Objectives

NCDOT's goal is to cooperatively plan, construct, operate, and maintain a safe, efficient, and resilient transportation network. The following four key objectives support this goal and guide future progress:

- **Objective 1:** Define the core components of a policy framework.
- **Objective 2:** Assess the vulnerability and risk of key infrastructure in North Carolina's multimodal transportation network.
- **Objective 3:** Identify and pilot risk profiles to guide resilience efforts across the spectrum of NCDOT activities.
- **Objective 4:** Identify current and future opportunities to coordinate with federal and state agencies and local planning partners.

The NCDOT Strategy establishes a three-step framework building from the 2020 Plan to achieve NCDOT's resilience goal and objectives. Each step of the framework – policy, program and practice – catalyzes the AREA concept leading to the ultimate outcome of "resilience incorporated within each phase of transportation – from long range planning to operations and maintenance."

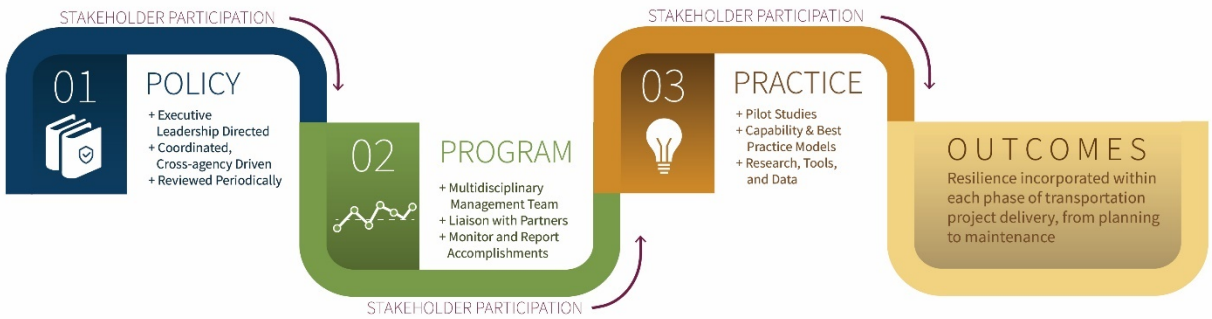


Figure 1-1: NCDOT Strategy Framework

Policy – Step 1 guides the research into the components and benefits of an NCDOT resilience policy to unify, guide and direct agency-wide resources and efforts. Policies help bring visibility and attention to resilience considerations across transportation disciplines and foster collaboration and coordination among professional staff and programs and the Department's federal, state and local partners. Any resilience policy would be reviewed as part of the annual NCDOT Strategy update or on an established cycle to adapt to updated science, changing industry trends and other data and technology driven applications.

Program – Step 2 will include efforts to formalize the arrangement of a multidisciplinary team to implement the resilience policy. This step would leverage the coordination and collaboration already in place between respective NCDOT units (Technical Services Division and Transportation Planning Division), which supported the development of the NCDOT Strategy. Moving forward, the team could expand to include experts from operations and maintenance, transportation mobility and safety, and project development units as needed. Functionally, this will not be a dedicated resilience office. This multidisciplinary team assumes a core group of staff will organize and assist NCDOT's resilience efforts by sharing, resources and analytical support to monitor, report and communicate the progress of NCDOT's resilience activities. The team would oversee the growth of practice and strategies to equip and train staff in resilience planning skills and the implementation of both short- and long-term strategies.

Practice – Step 3 will include efforts to initiate a broader and more multimodal approach to apply, integrate and advance resilience-based analyses and recommendations across agency activities. Section 3.0 outlines these activities, including planning studies, design consideration changes, select multimodal vulnerability assessments and other short-, medium- and long-term strategies. Pilot projects could serve to expose a larger cross section of internal and external NCDOT stakeholders to resilience-related data, tools and applications, which support capacity building. Increased engagement with stakeholders can lead to shared assessment opportunities to incorporate resilience within agency performance measures, equity and environmental justice-based assessments, and economic and land use considerations. The net result will work to strengthen the department's resilience practice and grow professional staff capabilities, leading to additional training, peer exchanges and workshops that distinguish NCDOT as a leader among state DOTs.

Polk County Howard Gap Road

2.0 Resilience Definitions and Standardization

In the transportation sector, the term "resilience" has a range of definitions across national guidance documents and by state DOTs. Common among the definition of resilience is how the practice area supports the fundamental goals of the transportation agency, particularly to maintain the safety of the system in response to natural and manmade threats. Many peer states use aspects of the sustainability definition, which is both a more widely accepted and understood term and frequently interchanged with resilience.

FHWA defines resilience as the "ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions."

In addition to baselining a common understanding of how to define resilience itself, related and frequently used terms help standardize NCDOT's approach when describing resilience. A glossary of resilience related terms supports consistent communication both within and outside the agency. This glossary is available in the Glossary of Resilience Terms on the NCDOT Transportation Resilience webpage. This includes commonly used terms and will continue to evolve and expand in accordance with federal and industry accepted terminology.

Interpreting Risk and Hazards

Hazard event types may be categorized based on shocks or stressors in differing regions across the state of North Carolina. Based on meetings with various business units and divisions, and according to the State Hazard Mitigation Plan (2018), the western region of the state has identified rockslides, mudslides and unstable slopes as hazards. The Piedmont and coastal plain areas identify riverine flooding as a major hazard, while hurricanes and storm surges are hazards to coastal areas. Main hazard types found in North Carolina are included below (see It is important to note the regional variation in how hazards are viewed and referenced in North Carolina, as some hazard types have consequences that maybe different or have similarities, such as flood inundation or rockslides which cause route detours due to access restrictions.

Swain County Nantahala Gorge Rockslide

Table 2-1). This table reflects and expands upon the severe climate hazards identified in the 2020 Plan. It is important to note the regional variation in how hazards are viewed and referenced in North Carolina, as different hazard types have consequences that may be similar, such as flood inundation and rockslides which differ as hazards but have a similar consequence - cause route detours.

Table 2-1: Hazard Types[2]

Hazard Type	Hazard Condition	Region
Meteorological	Temperature (hot or cold)	N.C. Statewide
	Fog	N.C. Statewide
	Precipitation	N.C. Statewide
	Storms (thunder, snow, winter, ice)	N.C. Statewide
	Hurricane	N.C. East
	Tornado	N.C. East
	Severe wind	N.C. Statewide
Climatological	Drought	N.C. East / N.C. Central
	Wildfire	N.C. West
	Sea level rise	N.C. East
Hydrological	Coastal storm/flood	N.C. East
	Inland flood	N.C. East
	Storm surge	N.C. East
	Saltwater intrusion	N.C. East
	Riverine flood	N.C. Statewide
Geophysical	Landslide	N.C. West
	Rockslides/mudslides	N.C. West
	Sinkholes	N.C. East

The FHWA describes the purpose of a climate change risk assessment as the identification of hazards that may be caused or exacerbated by climate change, and to assess the likelihood and relative consequence of these hazards in order to prioritize responses and mitigate risks, where the term "hazards" refers to disruptions and stresses. A climate change risk assessment can be used as a tool to identify climate change adaptation options, to enhance the resilience of the transportation network.[3] The key to defining hazards is identifying the threat, or condition, and the anticipated impacts to assets. This is frequently an important part of a vulnerability assessment and a determination of criticality.

Risk is the positive or negative effect of uncertainty or variability on agency objectives. Managing risk is about managing uncertainty, variability, threats, hazards, and even opportunities. A negative risk could be a flood, and a positive one a new technology. Risk management is about managing performance and identifying and mitigating risks.[4]

[2] This table reflects and expands upon the severe climate hazards observed in the North Carolina Climate Risk Assessment and Resilience Plan (2020).
[3] FHWA, Literature Review: Climate Change Vulnerability Assessment, Risk Assessment and Adaptation Approaches, July 24, 2009
[4] State of North Carolina Hazard Mitigation Plan, February 2018, page 3-2.

Sea Level Rise Projections in North Carolina

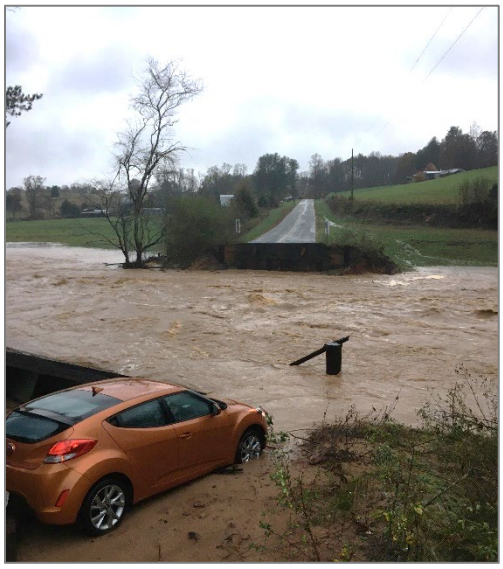
Roadway flooding after tropical storm Nicole

The Coastal Area Management Act of 1974 (§ 113A-100) establishes regulations regarding coastal resources and determines the North Carolina Coastal Resource Commission (CRC) as the agency responsible for sea level rise projects, among other coastal area management actions between local and state governments. Projections for sea level rise in North Carolina derive from the Intergovernmental Panel on Climate Change (IPCC) and National Oceanic and Atmospheric Administration (NOAA) using tide gauges which measure the daily high and low tides. The North Carolina Legislature allows the CRC to look out only 30 years with projections under Session Law 2013-202 to accommodate planning for infrastructure life cycles. Extreme, high, intermediate and median projections are based on global NOAA/IPCC curves used to predict scenarios of sea level rise before 2120. The rate of sea level rise at specific locations may be more or less than the global average depending on specific location and the time frame of analysis. Two main factors affect spatial variation of rates of seas level rise along the North Carolina coast: the vertical movement of the Earth's surface; and the effects of water movement in the oceans (including thermal expansion and shifting position and changing speed of the gulf stream). The Coastal Resource Commission (CRC) Science Panel produced the North Carolina 2015 Sea Level Rise Assessment Report that describes the 30-year sea level rise projections for the state. The report is currently being updated.

3.0 Background Analysis

NCDOT has undertaken several studies and steps in response to severe weather events over the past 5 years. These steps include both short-term assessments conducted after major events – such as I-40 and I-95 Feasibility Studies after Hurricanes Florence and Matthew – and the development of long-term initiatives to better share and communicate resilience related data and storm impact and system vulnerability analyses both within NCDOT units and to external partners. This section provides a brief overview of those activities organized by the cross section of NCDOT units overseeing resilience considerations in their areas of practice at a network, corridor and project-based level.

This section also updates the summary of activities outlined in NCDOT's Transportation chapter response to the 2020 Climate Risk Assessment Resilience Plan (2020 Plan). The short- and long-term actions are found in Section 5.0: Strategy Development.



Bridge washout at Cattlemans Rd in Iredell County

National Guidance

The USDOT's national policy goals and strategies for risk and resilience direct federal agencies, including FHWA, to address preparedness and resilience to climate change and extreme weather events, which present growing risks to the safety, reliability, effectiveness and sustainability of the nation's transportation infrastructure and operations.

Additionally, the 2015 FAST Act introduced new planning factors and requirements for states and MPOs to consider and implement, improving the resiliency and reliability of the transportation system (23 CFR 450.206(a)(9) and 23 CFR 450.306(b)(9)). MPOs are to consult with agencies and officials responsible for natural disaster risk reduction when updating their Metropolitan Transportation Plan (MTP) and Transportation Improvement Program (TIP) (23 CFR 450.316(b)) and to assess capital investment and other strategies that reduce the vulnerability of the existing transportation infrastructure to natural disasters (23 CFR 450.324(g)(7)).

The USDOT Strategic Plan (2018-2022) – USDOT's Strategic Plan for FY 2018-2022 – establishes long-term goals and objectives the agency seeks to accomplish, including strategies that describe how the USDOT plans to make progress toward its objectives. The development of innovation is a priority area and strategic objective for USDOT, which also includes development of new tools to improve transportation infrastructure durability and resilience.

Agency Activities, Studies, Plans, Tools and Resources

Long Range Planning

NCDOT's Transportation Planning Division (TPD) prepares long range transportation plans responsive to federal and state requirements and future travel demand, which in turn support traffic and design decisions in preconstruction. TPD also interfaces with local communities and agencies across the state to assess land use and travel unique to specific areas. Recently, TPD updated and incorporated new geographic information system (GIS) layers as part of its Comprehensive Transportation Planning (CTP) process to support up-to-date reviews of environmental and transportation data which enhance planning decisions. TPD's role and approach provides multiple opportunities to incorporate resilience through vulnerability assessments and modeling scenarios at network and corridor-based levels. This section outlines recent efforts to advance and emphasize resilience planning from state, regional, and local perspectives.

- NC Moves 2050 Plan (adopted February 4, 2021) - The NC Moves 2050[5] is North Carolina's latest strategic, long-range statewide multimodal transportation plan. The NC Moves 2050 Plan defines how NCDOT and its partners can better prepare for future transportation changes due to economic, demographic, environmental and technological forces.

  The plan recommendations were developed through transportation implications associated with four alternative futures: innovative; globally connected; renewed; and unstable. The unstable future scenario assumes more frequent and intense environmental threats, which displace N.C.'s coastal population, alter travel patterns, and shift the focus to managing and strengthening assets and building broader system redundancy.

[5] https://www.ncdot.gov/initiatives-policies/Transportation/nc-2050-plan/Pages/default.aspx

Maintaining a resilient, high-quality system is one of five core objectives of NC Moves 2050. Implementing the plan will operationalize strategies and actions which "develop and mainstream risk/resiliency practices" throughout the agency.

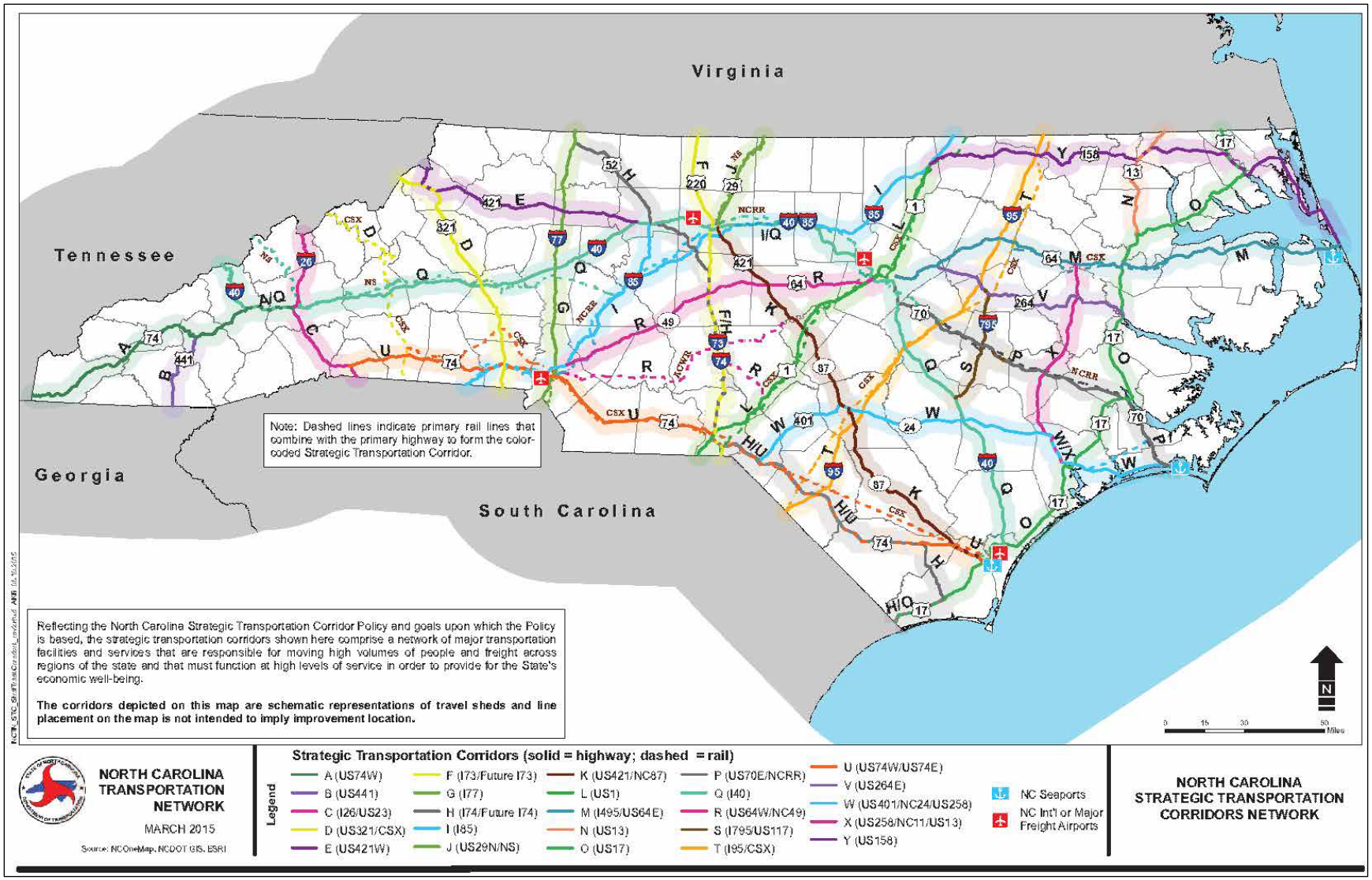
Table 3-1: Actions to Mainstream Resilience in NCDOT (NC Moves 2050)

Action 1	Incorporate and integrate risk and resilience considerations across transportation activities – from long-range planning through operations.
Action 2	Identify and prioritize multimodal transportation improvements that enhance system performance and reliability.
Action 3	Standardize, measure, and report asset management practices that advance transportation infrastructure resilience.
Action 4	Support community-based resilience approaches that inform NCDOT practices.

- Flood Risk Vulnerability Assessment of Strategic Transportation Corridor (Session Law 2019) - Figure 3-1 displays the Strategic Transportation Corridors (STC). These corridors form a network of 25 critical multimodal transportation corridors which are considered the backbone of the state's transportation system. These 25 corridors move most of the state's freight and people, link critical centers of economic activity to international air and seaports and support interstate commerce. They must operate well to help North Carolina attract new businesses, grow jobs and catalyze economic development.

  In response to Session Law 2019-251, Senate Bill 356, Section 1.7 (4) NCDOT's Transportation Planning Division and Technical Services Division units started a process to evaluate the STC network for flood inundation and potential hazard vulnerability. Flood mapping is being finalized to pinpoint vulnerable locations and assets to identify resilience and environmental considerations of proposed capacity and safety improvements in local long-range plans in affected areas.

I-95 Flooding at MM 18 in Robeson County after Hurricane Matthew



Source: https://connect.ncdot.gov/projects/planning/STC%20Documents/STC%20Map.pdf

Figure 3-1: NCDOT Strategic Transportation Corridors

Project Development and Design Tools

Ice damage in Granville County

The Technical Services Division provides project and program management, planning, design and other preliminary engineering services to advance projects to construction in response to state and federal requirements. This group oversees hydrological design considerations and flood risk and assessment tools to enhance decision making and preparation for future events. It also interfaces with state and federal agencies to minimize and mitigate transportation impact on built and natural environments. The Technical Services Division works closely with the North Carolina Department of Emergency Management (NCEM) and NCDOT's 14 Highway Divisions to provide riverine and flood mapping data and analysis in preparation for, and response and recovery from, storm events. The role of the Technical Services Division will be to lead NCDOT's response to EO80 requirements and positions staff to coordinate resilience activities which will increasingly include other NCDOT units, tools and data. This section outlines recent efforts to advance and emphasize resilience through corridor and project-based studies, research and design adaption.

Project Development

- I-95/I-40 Flood Resilience Feasibility Study[6] – This 2019 study addresses the vulnerability of two major Interstate corridors – I-40 and I-95 – to natural flooding disasters and develops adaptation measures to mitigate against future flooding disasters. It was conducted in response to a directive from the NCDOT Secretary of Transportation to identify improvement options and estimate costs to make sections of I-95 and I-40 more resilient to future storm events. The improvement options span from south of the I-40/I-95 interchange in central N.C. to Wilmington. Each improvement option is intended "to decrease the potential for flooding of the Interstate segments and minimize disruption to transportation during extreme weather events" and the study methodologies could be used to inform flood resilient design considerations for projects in the State Transportation Improvement Program (STIP).
- Research Project (RP) (2018-32) Flood Abatement Assessment for Neuse River Basin[7] – The objectives of this 2019 research were to better understand the source(s) and nature of flooding in the Neuse River Basin and to identify and evaluate potential flood mitigation measures with a special focus on maintaining critical transportation services to eastern N.C. communities – such as Smithfield, Goldsboro and Kinston. Hydrological modeling and community input revealed that a

[6] https://www.ncdot.gov/projects/i-95-corridor-improvements/Documents/i-95-i-40-flood-resilience-study.pdf

[7] https://ncseagrant.ncsu.edu/coastwatch/current-issue/summer-2020/road-to-resilience-2/; https://ncseagrant.ncsu.edu/program-areas/coastal-hazards/n-c-coastal-rivers-flood-mitigation/; Principal Investigator: Barbara Doll NC Sea Grant, Box 8605, NCSU Raleigh, NC 27695-8605 Email: bdoll@ncsu.edu Phone: 919-515-5287; Fax: 919-515-6772

series of strategic transportation improvements (such as raising roadway elevations) may have a greater effect on reducing future flooding risks than simply widening bridge spans across the river basin. The NC Sea Grant and NC State University collaborated with NCDOT, NCDEM and local governments to conduct the research, which concluded in 2020.

Flood damage along Bethlehem Church Road in Stanly County

- United States Army Corps of Engineers Disaster Recovery 19 Flood Mitigation Studies – Tar, Neuse and Lumber River Basins – Under the Federal Disaster Relief Act of 2019, the United States Army Corps of Engineers (USACE) initiated three flood risk management studies for the Tar-Pamlico, Neuse, and Lumber River Basins through a cost-sharing agreement with the NCDEQ in April 2020. The purpose of these feasibility-level studies is to reduce flood risks by evaluating and recommending a potential range of structural, nonstructural and natural/nature-based mitigation measures that could minimize or even avoid future impacts of significant and extreme weather events within the river basins. The USACE is using existing floodplain and technical data from multiple sources, including state, local (counties, cities, towns) and communities impacted by prior events. The USACE has further engaged the involvement of subject matter experts from multiple state agencies including the NCDEQ, North Carolina Division of Wildlife Resources (NCDWR), NCDEM, North Carolina Office of Recovery and Resilience (NCORR) and NCDOT in multiple information gathering meetings with and without potential stakeholders. There will be opportunities to engage the public through public scoping and information meetings as these studies progress. These feasibility-level studies are scheduled to be completed by April 2023.

Project Design

- I-95 Flood Resiliency Design and Innovation through USDOT BUILD Grant – During Hurricane Matthew and Hurricane Florence I-95 was flooded in 10 locations between Exit 13 and Exit 76. In Lumberton, I-95 was flooded for more than seven days due to the flood waters of the Lumber River. The NCDOT was awarded a USDOT BUILD Grant for Transportation Improvement Projects I-6064 and I-5987 to incorporate flood resilience, a flood alert network and flood vulnerability stress test. Through the use of complex hydrological modeling, the Department will build a new highway that will withstand future extreme events and provide flood alert information that will improve safety, performance (to freight hubs, military bases, and rural access to major urban markets) and provide greater resilience to maintain the use of transportation lifelines.
- North Carolina Future Precipitation for Resilient Design – The frequency and intensity of both floods and droughts are expected to increase in response to a warming climate; however, significant uncertainties remain regarding regional changes, especially for extreme rainfall. Traditional design has been based on long-term historical data that assumed that the past conditions would represent future conditions. Since this is not the case, Global Climate Models (GCM) are helping engineers and scientists predict future climate conditions. NCDOT, NCEM, the North Carolina State Climate Office and researchers will be using GCMs in this three-year study to (1) assist NCDOT with climate adaptation and resilience planning and (2) improve confidence in

future flood risk using existing downscaling data/methodologies and tailored high-resolution climate model projections. The study is scheduled to be completed in 2023.

- NCHRP 20-44(23) – Pilot Test of Climate Change Design Practices Guide for Hydrology and Hydraulics – NCDOT staff are participating in the study with the possibility that N.C. will be one of the pilot project sites. The objective of National Cooperative Highway Research Program (NCHRP) 20-44(23) project is to conduct pilot tests in concert with several state DOTs to determine the effectiveness and ease of implementation of the Design Practices Guide produced in NCHRP Project 15-61 (Applying Climate Change Information to Hydrologic and Coastal Design of Transportation Infrastructure)[8]. The research is expected to conclude in 2022.
- FHWA – Pooled Fund Study – Intensity-Duration-Frequency / Depth-Duration-Frequency Atlas 14 Rainfall Update - Rainfall data for design has not been updated in N.C. since 2004. The purpose of this study is to update precipitation frequency estimates first published in NOAA Atlas 14 Volume 2 for D.E., M.D., N.C. and V.A. The estimates and bounds of 90 percent confidence intervals will be provided at 30 arc-second durations of 5-minute through 60-day average recurrence intervals of 1-year through 1000 years. The study results will be published on the web as NOAA Atlas 14 Volume 13 through the Precipitation Frequency Data Server. The two-year study is planned to start in the summer of 2021.
- Predicting Roadway Washout Locations During Extreme Events RP 2021-03 – Recent extreme rainfall events have revealed the transportation network's vulnerabilities to road washouts. Currently, NCDOT reacts to these problems as they are reported from the field. Knowing where washouts are likely to occur will lead to identifying locations for countermeasures to protect the roadway and assist with positioning of resources more efficiently. The purpose of this research project is to develop models and test several approaches for predicting crossing washouts based on forecasted rainfall. Washouts and the model predictions will be used to develop a network of "safe" routes for each watershed. The research will be completed in 2023.

Operations and Maintenance

The Division of Highway's 14 Highway Divisions interface directly with citizens, contractors, local governments and state/federal agencies to oversee the operation of the 2nd largest state maintained system in the nation. The Highway Divisions are responsible for safe, adequate access and passage for motorists and freight movement through major events and lead post event recovery efforts. This section outlines recent efforts to incorporate resilience within infrastructure assets and project specific retrofits and details recently completed or upcoming highway projects. These efforts are using infrastructue hardening and nature-based strategies to prepare for future risks and flooding events.

- Transportation Asset Management Program – Pipe Inventory Program – NCDOT's asset management practice is shifting towards a forward-looking approach to identify at-risk culverts and pipes that often meet criteria for federal funds. Knowing the location and condition of the department's drainage structures is an important component of building resilience into the state's

[8] See this link: https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4858

network. Recently, NCDOT undertook a statewide inventory and condition assessment of culverts and crossline pipes that are not part of the National Bridge Inventory (NBI), coordinated closely through the Chief Engineer's office in the Division of Highways. The effort creates the first statewide comprehensive geospatial record of approximately 26,000 non-NBI structures (culverts and pipes over 48 inches) and approximately 350,000 crossline pipes (48 inches and below). The data collected as part of the pipe inventory program supports the department's lifecycle approach to asset management. The next phase of the program is to re-evaluate each asset on a cyclical basis, and to incorporate ongoing changes to the inventory.

Roadway closures after tropical storm Nicole

Maintenance: Resilience Retrofits

- N.C. 24 Causeway – White Oak River – N.C. 24 is a key route for community members in Cedar Point and Swansboro, providing important connectivity between Marine Corps Base Camp Lejeune, Marine Corps Auxiliary Landing Field Bogue, the Morehead City State Port and Marine Corps Air Station Cherry Point. The highway also serves as a vital evacuation route for hurricanes and a commuter road with approximately 26,000 vehicles traveling through per day. The priority sites along N.C. 24 proposed sustained damages from hurricanes Florence, Irene and Ophelia, and are particularly vulnerable to future storm degradation. In partnership with the North Carolina Coastal Federation, the Department procured a National Fish and Wildlife Fund grant to build living shorelines and surge and wave-energy countermeasures adjacent to N.C. 24 that will have transferability for future projects. NCDOT plans to use this project to support its strategy to increase infrastructure resilience along NCDOT coastal highways.
- N.C. 12 is a critical route linking barrier islands along N.C.'s coast with resilience related improvements occurring through multiple STIP projects. The new Herbert C. Bonner bridge connecting Oregon inlet to Pea Island included design elements in its span to adapt to changing oceanic and sound tidal conditions. Specifically, four channel spans allow wave action and natural channel flow beneath the structure to migrate while simultaneously maintaining adequate access for vessels. Further south in Rodanthe the "jughandle" bridge (B-2500B) has been built on the backside of the island to provide redundant and accessible travel access if N.C. 12 is overtopped or washed out in a major event.

Traffic System Management and Operations

NCDOT's Mobility and Safety Division is responsible for maintaining a safe and reliable roadway network across N.C. They support operational resilience through major disruptions and emergencies using strategies to manage traffic and relay traffic conditions for travelers. This situational awareness is critical during extreme natural hazards warning motorists of inundated road conditions or ensuring supplies are directed along passable routes. Communication with N.C. neighbor states – T.N., V.A., S.C., G.A. helps N.C. to coordinate and align evacuation strategies for increasingly intense storms with wider swathes of impact which extend beyond one state's boundary.

- Traveler Information Systems – NCDOT provides real time traffic conditions and incident information through DriveNC.gov which feeds updates to navigation companies, digital message boards, 511 and the customer service center. This interconnected system alerts motorists to upcoming closed or partially closed roads due to storm events, crashes or construction zones and is linked to 511 and national traffic and road closure conditions. These systems can also direct motorists and freight operators to use coastal evacuation routes or avoid storm damaged facilities in advance of or during major storm events.
- Active Traffic Management and Incident Management – NCDOT employs several strategies – working with state, local law enforcement and tow companies on a daily basis to clear disabled vehicles or efficiently address incidents. These measures take on increased significance during major weather events when increased crash potential further exacerbates critical roadway capacity. Active traffic management includes a series of emergency operational strategies at a corridor or regional network level, such as signal system synchronization or use of shoulders (and reversible lanes in extreme cases) to move large volumes of traffic from storm impact areas.

Emergency Management Coordination

Chapter 166A of the North Carolina General Statutes (NCGS) establishes the authority and responsibilities of the Governor, state agencies and local government for the preparation, response, recovery and mitigation of disasters. The principal department tasked with oversight and control of emergency management in North Carolina is the Department of Public Safety (NCDPS). The Secretary of NCDPS is responsible to the Governor for all state emergency management activities. The Director of Emergency Management also has the role of State Emergency Response Team (SERT) leader.

The NCDOT is a key SERT partner managing transportation infrastructure. NCDOT's infrastructure plays a critical role in safe and expeditious transport of supplies, commodities, equipment, personnel and survivors. In addition to the traditional role of maintaining and repairing roads, bridges, airports, ferries, waterways and rail impacted by hazards, NCDOT is now being expected by SERT partners to provide real-time and forecasted multi-modal situational intelligence. With this new added role, NCDOT must provide the defined information to the appropriate stakeholders at key points of planning and decision-making.

An increased level of coordination is occuring across the Division of Highways to communicate and share data to inform storm prepardness decisions. The Division of Highway's Transportation Mobility and Safety Unit oversees statewide traffic operations and interfaces with state/local law enforcement to provide real time traffic data for emergency response. The Technical Services Division provides staff expertise and resources to disseminate storm response prepardness and recovery information. The State Maintenance Operations Unit supports a storm prepardness program that oversees optimal use of emergency relief funds. The Global TransPark and local airports serve as staging areas for recovery efforts, providing warehousing and access to points of distribution (e.g. water distribution, vaccination sites, military bases, stadiums). This section provides an overview of these coordinated activities and the role of the units which oversee these efforts.

- Storm Emergency Response Page – An internal NCDOT SharePoint site serves as a clearinghouse of NCDOT's storm coordination information and agency responses to extreme weather events for units within the Division, the Chief Engineer's Office, the Secretary's Office, Communications Office and the Information Technology Office. This site helps to facilitate the following:

  - Share information with Senior Leadership such as anticipated impacts to the transportation infrastructure to assist with making decisions.
  - Increase knowledge between staff and senior leadership to allow for immediate situational awareness in both directions.
  - Identify and develop IT consistent solutions to assist with data collection, data sharing and data analytics.
  - Ensure communication and collaboration occurs across multiple disciplines and organizations.
  - Develop in-house strike teams to quickly produce plans of action, scope, schedule, preliminary construction plans and costs for recovery from major infrastructure damage.
  - Prepare a storm webpage for sharing relevant information including reports from the National Weather Service, traffic information, links to resources and the latest available storm response tools.

- Application for Site-Specific Information Storage and Tracking (ASSIST) – ASSIST was developed by State Maintenance Operations because of needs identified during the department's financial recovery efforts of Hurricane Matthew in 2016. Using the Survey123 platform within ArcGIS, the survey was designed for mobile, offline, field data collection, and has been continuously updated to coincide with, and better fulfill, federal agencies' (Federal Emergency Management Agency and FHWA) data requirements for reimbursement. First employed during Hurricane Florence recovery efforts in 2018, ASSIST collects data points such as geo-locations, pictures, damage dimensions and initial preliminary estimates. The collected information can be displayed as a searchable and filterable data layer within ArcGIS and can be used by field, central or management personnel to make real-time, data driven decisions to support the department's physical efforts throughout an event. Preliminary information is used to support event declarations by state and federal agencies and once reviewed, confirmed and additional data added, the gathered information is submitted to federal agencies for reimbursement.
- BridgeWatch Pilot Project – The NCDOT implemented a 3-year pilot using the BridgeWatch solution by U.S. Engineering Solutions. BridgeWatch is an online bridge-monitoring application service that enables transportation professionals to proactively monitor, in real-time, bridges and culverts to alert of potential and active flooding conditions. BridgeWatch will actively monitor over 1,500 structures statewide and will send out alerts when monitoring thresholds are exceeded. BridgeWatch can also be used as a hands-on training and scenario tool for emergency evacuation or security drills with event simulation capabilities.
- Flood Inundation Mapping and Alert Network for Transportation (FIMAN-T) – In 2020, NCDOT and NCDEM partnered to develop FIMAN-T, a web-based tool used to provide NCDOT officials and emergency management stakeholders with real-time and forecasted flood inundation depths along roads, bridges and other NCDOT assets in support of risk-based decision-making during flooding events. The goal of FIMAN-T is to provide visualizations and metrics for roadway inundation and bridge hydraulic performance and identify potentially impacted NCDOT assets. This will enhance NCDOT's responsiveness during flooding events by generating data and reports for use in disaster response and planning. A pilot was completed for the Neuse River Basin for use during the 2019 hurricane season. NCDOT and North Carolina Emergency Management are working together to expand FIMAN-T sites to include high risk transportation corridors such as I-40, I-95, N.C. 24, U.S. 74. In addition, new functionality is being added to FIMAN-T to include forecasted hurricane and tropical storm surge inundation and roadway impacts for the entire N.C.

coastline allowing emergency managers and first responders to have awareness of potential roadway and evacuation impacts from an approaching storm.

4.0 Engagement

NCDOT engaged both leadership and a broad group of stakeholders from across the department, metropolitan planning organizations (MPOs) and rural planning organizations (RPOs) and state partners to gather input and define the range of strategies and actions to inform and guide NCDOT resilience efforts (Table 4-1). Three virtual workshops and an online survey were held that engaged NCDOT units/divisions or authorities to participate and provide feedback on the development of a resilience vision, goals, objectives and strategies for action over the next year. In addition, a survey and interviews with staff from the ports, ferry, rail, aviation and freight divisions were conducted to gain additional input. The matrix below summarizes the three workshops, focus areas and themes.

Table 4-1: Stakeholder Engagement

Workshops	Attendees	Focus Areas	Themes
Virtual Meeting #1 Leadership Meeting December 17, 2020	Project Management Team and NCDOT Leadership	• Unified, coordinated vision for the department • Definitions for resilience and terminology	• Embed resilience into DOT practices • Multimodal approach including all modes/divisions/units • Framework for resilience best practices and prioritization process
Virtual Meeting #2 Workgroup Meeting January 8, 2021	Project Management Team, representatives from across the department - divisions, aviation, ferries, integrated mobility, rail, planning, maintenance, asset management, ports, Turnpike, Global TransPark, freight, and MPOs/RPOs,	• Historic background over last decade • Need to produce a strategy document • A survey and interviews to follow up the discussion and obtain more input • Input on risk and resilience state of practice in North Carolina using real-time polling	• Resources for pilots and studies • Local/regional vulnerability assessments needed • Leverage stakeholders / agency tools/data for resilience • Incorporate resilience in prioritization
Virtual Meeting #3 Workgroup Meeting February 3, 2021	Project Management Team, representatives from across Department - Divisions, Aviation,	• Discussion of “why resilience” and department-wide goal from Governor’s EO 80	• Strategies included technical assistance, vulnerability assessments, central

Workshops	Attendees	Focus Areas	Themes
	Ferries, Integrated Mobility, Rail, Planning, Maintenance, Asset Management, Ports, Turnpike, Global TransPark, Freight, and MPOs/RPOs, NCDEQ	• Strategy report will include glossary, peer research, vision, goals and objectives and short/long term actions • Cross disciplinary approach • Review and input of draft strategies using real-time polling	data hub, asset management, and planning needs • Longer term strategies: expand and deepen capacity, investigate resilience in strategic prioritization, additional STC vulnerability studies and resilience scenario planning

5.0 Strategy Development

As introduced earlier, the NCDOT Strategy establishes a three-step framework to achieve the department's goals and objectives, beginning with an overarching departmental policy to unify and direct agency wide efforts. Step two formalizes a multidisciplinary team that will help implement the policy. Step three leads to coordination and collaboration within NCDOT units that will establish pilot studies, capabilities and best practices, develop tools, and identify data and research needs. Resilience actions will be incorporated into practice areas that align with NCDOT's Integrated Project Delivery (IPD): Planning, Design, Maintenance, Operations and Construction and includes TSMO. In addition, several strategies are cross-cutting that affect all practice areas, such as branding, funding and communications.

US 401 washout, Franklin County

Table 5-1 provides an overview of short, mid-and long-term strategies organized by practice areas. A short-term implementation horizon is defined as the next 6–12 months. Mid-and long-term horizons are defined as the next 2-5 years or longer.

Table 5-1: NCDOT Resilience Strategies

SHORT-TERM STRATEGIES	
Strategy	Description
Cross-cutting	
Awareness and Branding	
Raise Resilience Visibility and Awareness Build an Agency Resilience Brand	Build agency awareness of resilience Develop webpage for NCDOT resilience related activities and information and promote through collaboration, presentation and partnerships
Funding	
Explore Funding Opportunities	Explore resources needed to increase resilience of critical infrastructure throughout the state, and especially in rural areas
Research Participation	
Participate in National, State Research	Maintain participation in state and national research activities.
Scoping	
Continue facilitating Resilience Scoping Guidance	Explore opportunities in express design (conceptual design) and project scoping guidance
Planning	
Conduct Multimodal Vulnerability Assessment in Strategic Transportation Corridor	Identify and Pilot a project to evaluate transportation vulnerability, risk and environmental stressors within a long-distance corridor
Incorporate Resilience Assessments in Long Range Plans	Determine how best to incorporate resilience in the MPO/RPO MTP and CTP updates to assess vulnerability and risk of local projects and communities

SHORT-TERM STRATEGIES	
Strategy	**Description**
HIGHWAYS: Incorporate Resilience within Integrated Project Delivery (IPD) Update	Identify and pilot resilience screening review (climate risk assessment and benefit cost analysis) for major projects and key transportation assets. Incorporate traffic operational strategies into project scoping and advance integrated roadway management (ramp meters, managed motorways). Capture within Integrated Project Delivery (IPD) process and Project Delivery Networks (PDN).
AVIATION: Address Gaps in Resilience Planning and Standards	Investigate and pilot resilience-based guidelines, protocols and strategic opportunities for use in guiding multimodal resilience evaluations and vulnerability assessments (as part of criticality index) with diverse regulatory bodies.
FERRY: Address Gaps in Resilience Planning and Standards for Ferry	Assess ferry channels and conduct vulnerability and criticality assessments to address future impacts
FREIGHT: Address Gaps in Resilience Planning and Standards	Investigate and pilot resilience-based guidelines, framework, protocols, strategic opportunities, and communications plan focused on redundancy, supply chain, data and risk analysis.
PORTS: Address Gaps in Resilience Planning and Standards	Outline framework with strategic opportunities, including design protocols.
RAIL: Address Gaps in Resilience Planning and Standards	Incorporate resilience evaluations in multimodal plans and designs and with other federal and state agencies and regulatory parties as needed
Design	
Investigate incorporating Resilience into Design Guidance	Investigate and pilot context sensitive resilience-based design standards and guidelines based on higher risk, hazard prone infrastructure and life-cycle durability

SHORT-TERM STRATEGIES	
Strategy	Description
 **Operations**	
Continue to incorporate Resilience Analysis for Asset Management	Identify and pilot risk and resilience analysis and explore implications in Transportation Asset Management Plan updates
 **Maintenance**	
Continue Resilient Infrastructure Treatments in Maintenance/Operations	Explore retrofit and ongoing treatments to withstand future high impact events
 **Construction**	
Apply Adaptive Methods for Construction Processes	Identify and Pilot construction methods and techniques to withstand extreme events

MID- TO LONG- TERM STRATEGIES	
Strategy	Description
Planning	
Incorporate Resilience Analysis into Freight Planning Conduct Additional Multimodal Vulnerability Studies in STCs	Investigate and Pilot, corridor and network specific freight resilience planning methodology Evaluate vulnerability, risk and environmental stressors within infrastructure components of high priority multimodal transportation corridors
Operations	
Incorporate Resiliency Analysis into Traffic System Management and Operations (TSMO) planning	Investigate and Pilot corridor and network specific TSMO resiliency planning methodologies
Cross-cutting	
Investigate Resilience Criteria for Funding Opportunities	Investigate resilience related criteria for use in determining funding opportunities at the state and federal level